DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS ON THE MAHI-KADANA IRRIGATION PROJECT GUJARAT, INDIA

WATER MANAGEMENT SYNTHESIS PROJECT

WMS REPORT 18

DIAGNOSTIC ANALYSIS OF FARM IRRIGATION SYSTEMS IN THE MAHI-KADANA IRRIGATION PROJECT, GUJARAT, INDIA

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EXECUTIVE SUMMARY

Workshop Objectives

An understanding of how and why a system operates is the best basis for designing improvements. Selected improvements can solve priority problems, benefit the farmer, and make the irrigation system more effective. Solutions to irrigation system problems not based on knowledge of the system frequently create more problems.

The objectives for the professional development workshop on Diagnostic Analysis held in Gujarat State, India in February and March of 1981 were to:

(1) teach discipline knowledge and skills for Diagnostic Analysis;

(2) teach teamwork principles and provide team experiences in Diagnostic Analysis;

(3) teach the interdisciplinary and disciplinary concepts, principles, and procedures used in Diagnostic Analysis; and

(4) understand the operation of an irrigation system from Diagnostic Analysis studies.

The primary purpose of the course was to train several interdisciplinary teams in the process of Diagnostic Analysis. To gain experience in conducting a Diagnostic Analysis study, three interdisciplinary teams collected data on the operation of two systems (unimproved traditional and improved rotational) in the Mahi-Kadana Irrigation Project. In the unimproved traditional system, the minor (or subminor) runs 10-days-on and 5-days-off and the outlets below the minor are left open; in the improved rotational system, the minor (or subminor) runs continuously and the outlets are opened in rotation.

"Diagnostic Analysis of Irrigation Systems" is a workshop that evolved through experiences in water management in Pakistan, Egypt, and other countries. The workshop, developed by the Water Management Synthesis Project, was part of the activities of the Consortium for International Development and funded by the Agency for International Development, with Colorado State and Utah State as lead universities. The course was organized and presented in cooperation with the Command Area Development Authority in the Mahi-Kadana Irrigation Project in Gujarat, India.

Workshop Activities

During the workshop, guest lecturers provided background information on the project. Among the workshop leaders were an agronomist, an economist with an emphasis in farm management, both irrigation and on-farm engineers, and water management extension workers. The three participant teams involved in the workshop each had an agronomist, an economist, irrigation and on-farm engineers, and extension workers. Two of the teams. Jaismand and Chambal, were from Rajasthan State. The third team, Anand, was from the Mahi-Kadana Irrigation Project in Gujarat.

The first week's lectures explained the concept and procedures of Diagnostic Analysis. Guest lecturers provided background information in agronomy, soils, irrigation, and the socio-economic conditions of the project. Workshop leaders then lectured on subjects needed to conduct both a Diagnostic Analysis study and a reconnaissance study of the project. During the first week's reconnaissance studies, the teams visited the project's field locations.

During the second week, activities prepared teams to study an outlet in detail, and the teams then began the study. Reconnaissance findings were used to develop specific questions for detailed studies of sample outlets on a representative minor. Sample farmers were also selected. Emphasis was placed on learning relevant principles and skills through field experience.

An analysis and synthesis of the results of the initial detailed study occurred during the third week. After analyzing the results of the first study, a second detailed study was planned. Additional emphases were on discipline training, team training, and principles for planning and executing such a study.

The execution of the second detailed study was the focus of the fourth week. While data were analyzed and the results synthesized, additional teamwork training was provided.

During the fifth week, the teams analyzed data and reported on the Diagnostic Analysis of the Mahi-Kadana Irrigation Project. Each team prepared a disciplinary report. Team members also prepared a team report. They formally evaluated the course and discussed their impressions. Each participant received a certificate during closing ceremonies acknowledging his successful completion of the workshop.

Major Findings

The discussion presented here summarizes the workshop's major findings and their implications.

The irrigation engineers discovered that the canal system below the minor gate was often operated by farmers. Farmers' responsibilities included opening and closing outlets and raising and lowering gates at cross-regulators to arbitrarily increase the water supply for sections along the canal. The Irrigation Department did not have the staff or the means for communicating with farmers to appropriately regulate the distribution of water. The daytime rather than 24-hour operation of the canal system also increased water supply variability at the outlet.

Field channel design and installation of control structures at an outlet prevented many areas on the outlet command from receiving water. In some instances this problem resulted in more than 50 percent of the outlet area being uncommanded. These farmers received either no irrigation water or water only with large investments of time and resources. These farmers sometimes took tubewell water instead.

Subsequent operation of the field channels revealed that many areas were uncommanded because of poor design, poor maintenance, or social conflicts among farmers on the outlet. Poor design and lack of control structures caused field-channel erosion below the ground level. As a result farmers could not apply water to their fields or could only apply water by blocking the field channel to raise the water level to the top of the field channel banks. This ponding caused large water losses due to overtopping and seepage. Control structures that had either deteriorated or were improperly designed caused major areas on the outlet to be uncommanded.

Fields were improperly graded in both study areas. However, farmers believed their fields were adequately graded and that the cost of grading estimated by the project was excessive. Associated with these low and high areas were poor crop stands, no stands, or poor crop conditions. In addition, farmers used wild flooding to pre-irrigate some fields, which resulted in over-irrigation.

Few differences in cropping intensities, services available, technologies used, and crop yields existed between the farms of the improved versus unimproved systems. In addition, on both systems neither soil salinity nor sodicity problems were significant.

With canal irrigation, the potential for salinity problems in well-drained light-textured soils was low. However, large portions of each outlet were irrigated by private tubewells, and the higher salinity of these well waters increased the potential for future salinity problems. These problems were further aggravated by growing rice during the monsoon season.

Nutrient imbalances and inadequate irrigation appeared to be the major causes of the poor performance of Sonalika wheat in almost all the fields studied. Fields of tobacco, the most widely grown commercial crop observed in the project area, were seriously infested with the parasite Orobanche.

Social conflicts among farmers and conflicts between farmers and the Irrigation Department resulted in unmaintained field channels and destruction and removal of the constructed field channels. Consequently, the canal water available to farmers on major areas of each outlet was unreliable.

Farmers believed the field channels constructed by the government were government property and the responsibility of the government to maintain. Irrigation and On-Farm Development Works officials believed the field channels were the farmers' property and their responsibility to maintain. Thus, a conflicting viewpoint existed.

Farmers consistently used private tubewell water instead of canal water, even though the tubewell water cost seven to nine times more. Farmers' dissatisfaction with the dependability of the canal water supply, lack of control over water from the field channels (versus pipelines from the tubewells), and the conflicts in delivery of canal water caused farmers to invest in the expensive tubewell water.

The primary source of information for farmers was other farmers. The current Training and Visitation system of extension in the area reached only a small percentage of the local farmers. Thus, few farmers received information concerning proper water management.

Although farmers used high-yielding crop varieties, the purity of their seed was doubtful. Also, the farmers' knowledge and practices related to proper crop production were inadequate, and in some cases information provided by extension workers constrained yields. Of the many practices recommended for improving crop production, the only widely adopted practice was using high-yielding variety seed. The major practices needed for improved crop production and the information about using these practices were lacking.

Evaluation

Participants formally evaluated the workshop using a self-evaluation form. India and USAID evaluated the workshop informally in discussions with both participants and leaders; their evaluation consisted of informal statements, a review of the workshop's goals, and written commentary at the end. Leaders evaluated the workshop during a three-day review held at the end of the course.

Most participants considered working as an interdisciplinary team and learning discipline skills highly beneficial. They believed a key benefit of the workshop was learning the value of Diagnostic Analysis. Other benefits were learning new skills, such as on-field irrigation evaluation, and developing an understanding of the farmers' viewpoints.

Some participants suggested that certain additional equipment should have been available. Some commented on the difficulties they would encounter implementing such Diagnostic Analyses in their own organizations. They suggested that a one-week workshop for senior personnel within their organization would be beneficial. The workshop leaders and participants considered the difficulties of implementing Diagnostic Analysis outside of a central group. Only the Chambal team was part of a central group; while this was considered an advantage, resistance from its senior personnel was considered a disadvantage.

When asked what this workshop meant to them, participants rated their feelings in order of importance: (1) learning interdisciplinary team and team management approaches, (2) understanding real farm-level problems, (3) gaining knowledge of water management, (4) learning with and from other disciplines, and (5) learning Diagnostic Analysis processes and procedures.

Finally, the 16 participants suggested that future training programs could be improved by selecting participants more carefully; providing ample time to prepare participants; focusing more on field site selection and preplanning; acquiring more information about field sites for planning field exercises; and providing more time for field exercises, data analysis and interpretation, and team report preparation. Participants also noted the need for more information about water management in other countries through films and slide shows, especially for evening sessions. Participants needed more literature before and during the training sessions, as well as a system to keep participants supplied with relevant literature after the program ended. Clearly a definite need for relevant information for professionals in water management exists.

The government of India and USAID also observed field workshop activities and wrote a report presenting an overview of the workshop, its activities, and some of the findings. They noted that, although the studies provided less data than desired, the workshop's emphasis was primarily on training. One observer noted that the Diagnostic Analysis training should be planned for the new training centers being established in many states in India. Following the workshop, a training program related to Diagnostic Analysis was suggested as one of the major activities of a Rajasthan Irrigation Improvement Program. The Gujarat Mahi-Kadana Irrigation Project is considering repeating the course to improve skills and expertise of personnel closely related to the new training center.

The workshop leader evaluations suggested the following improvements: (1) a more carefully planned syllabus and schedule for the course; (2) better facilities and support by having more time; (3) advance selection of the training sites; (4) developing more materials in advance of the presentation of the course, including preparing videotapes of discipline lectures, overviews of reconnaissance and detailed studies, and certain team exercises; and (5) careful planning before the course begins.

Recommendations

(1) Soils in the area are good for most irrigated crops except rice. A positive policy is needed to provide product prices, markets, inputs, and service incentives to encourage production of other crops. A water pricing policy that discourages rice production is also needed.

(2) An effective extension service program has the potential to increase average project yields by 50 percent and should be initiated immediately. Education about improved production practices and skills is needed.

(3) Moderate groundwater salinities, rising water tables, and extensive irrigation of rice suggest potential waterlogging and salinity problems will occur in the future. These problems should be examined more closely.

(4) Orabanche, a serious parasite, may become worse in the future and must be treated.

(5) The system of canal management needs further study and immediate improvement to ensure predictable, controlled water supplies.

(6) Field channel improvements need more careful study:

(a) A design procedure is needed to maximize the area commanded, provide stable channels and effective control structures, and supply water in a predictable, controlled manner.

(b) People designing and constructing field channels urgently need training to provide acceptable designs.

(c) Farmer water user associations should be started for operation, maintenance, planning, and construction of on-farm development works.

(7) Technical assistance should be provided to farmers to improve field irrigation systems and provide precision land leveling. Knowledge about the importance of land leveling and improved irrigation practices should be provided.

(8) A carefully planned, complete Diagnostic Analysis study of the project should be done immediately.

(9) Organizational arrangements for testing the recommended solutions to major problems need to be provided.

(10) Training and organizational improvement are needed before solutions can be implemented.

SECTION I - INTRODUCTION

A. Irrigated Agriculture in Gujarat

The past performance of the major irrigation projects in India has been poor (Jayaraman and Jayaraman, 1981). A principal cause of this problem appears to be inadequate discharge of water from dams; reservoirs; networks of canals, branches, and distributaries leading up to the government outlet; and the distribution system below the outlet (which sometimes has no field channels and field drains serving individual farmer's fields). Other contributors to this problem include management functions, such as rotation of canals and distributaries depending on farmers' irrigation needs, delivery of water to farms according to crops' water requirements, and settlement of disputes among the farmers.

Over the past decade, Gujarat State in India has experienced a serious underutilization of irrigation investments and unexpectedly low crop yields (World Bank, 1980). Agriculture normally contributes 30 to 40 percent of the state's income and employs about 65 percent of the labor force. The state is particularly susceptible to droughts and famine due to its low and uncertain rainfall and limited irrigation facilities. Largely as a result of favorable weather, agricultural production peaked in the early 1970's; it has since stagnated. Today the Government of Gujarat is trying to regain this momentum through plans that emphasize irrigation, promote soil conservation programs to improve soil moisture retention in rainfed areas, and strengthen extension and research activities focusing on drought and pest-resistant varieties.

In 1979, only about 18 percent of Gujarat's cropped area was irrigated, a figure less than two-thirds of the national average (World Bank, 1980). Water resources are heavily concentrated in the southern and central parts of the mainland where three major rivers flow and rainfall is relatively high. Statewide, the potential for the development of surface water resources is limited by seasonal river flows, high costs to build dams in flat areas where river flows are less seasonal, and water use agreements with upper riparian states. With the exception of the Narmada River, most river flows are already being used or are scheduled for development. In addition, half or more of the potential for well irrigation in most rainfed areas has been developed.

Project design, water allocation, and canal operation have changed little since the nineteenth century when the primary irrigation objective was to "insure" farmers against drought and famine. Thus, design and management deficiencies make it difficult to ensure the timely and reliable water deliveries needed for production agriculture. Given an unreliable water supply, farmers have little incentive to carry out the government's On-Farm Development Works programs. For any programs to be successful, improvements in the irrigation system, water allocation procedures, system operation practices, and on-farm development must be complementary.

B. Purpose and Objectives of the Diagnostic Analysis Workshop

Experiences in both the United States and other countries have repeatedly shown that an interdisciplinary on-farm Diagnostic Analysis and study of irrigated farming systems is an effective way to evaluate the operation and performance of a given irrigation project. To train its own staff to do such analyses, the Government of India requested that the Water Management Synthesis Project at Colorado State University conduct a professional development workshop on Diagnostic Analysis of Irrigation Systems in Gujarat State.

This professional development workshop occurred during the five weeks from February 17 to March 19, 1981. Briefly, the objectives of the Diagnostic Analysis Workshop were:

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

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

In realizing the above objectives, the participants were expected to benefit by learning to work in a team within an interdisciplinary setting, understanding the complexities of the farm and the farmer's role in managing the farm and the irrigation systems, and expanding their discipline knowledge and field study skills.

The workshop was conducted in cooperation with the Command Area Development Authority (CADA) in the Mahi-Kadana Irrigation Project, Anand, Gujarat. During the first week, lectures, discussions, and teambuilding exercises were used to familiarize the participants with the concepts and procedures used in the Diagnostic Analysis. The balance of the workshop involved field studies and report preparation and presentation (Appendix C).

C. Study Area

1. Location and General Description

Study sites for the workshop were selected in the Mahi-Kadana Irrigation Project, located on the Mahi River in Gujarat's central mainland (Figure 1). The cultivable command area served by the project is about 224,000 ha. The project includes a dam across the Mahi River mainly to provide storage for the right-bank canal; construction of a left-bank canal to serve 11,000 cultivable ha; extension of the right-bank canal; construction of field channels, drains and landshaping and financing of these works through institutional credit; construction of market roads; and an agricultural support program (World Bank, 1980).

2. Climate, Soils, and Topography

Gujarat has a tropical monsoon climate with temperatures ranging from 13 to 27 C in January and 27 to 41 C in May. The central mainland of Gujarat receives about 500 to 800 mm of rainfall annually, with about 95 percent of it falling during June to September.

The central mainland is one of Gujarat's three geographic areas, consisting of extensive alluvial plains flanked by hilly terrain to the east. The land slopes gently towards the west and southwest. Frequently, the Mahi River floods the coastal areas; the poor drainage that results often causes salinity and waterlogging problems.

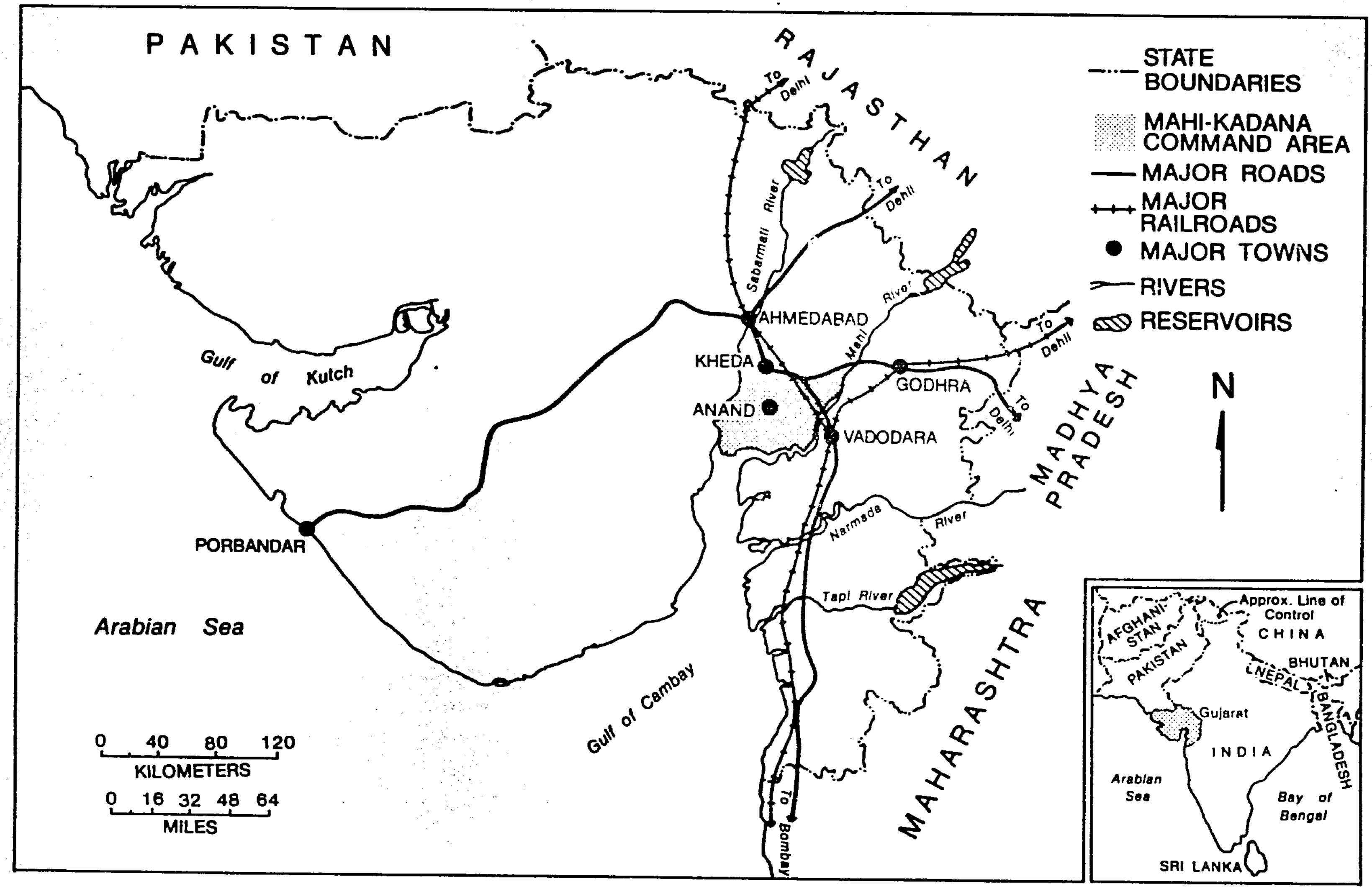

Figure 1. Map of Study Area in Gujarat State, India

Soils in the central mainland are primarily sandy loams. Coastal alluvium dominates along the Gulf of Cambay.

3. Design and Operation of the System

The development of irrigation facilities on the Mahi River involved two stages. The first stage, constructing a pick-up weir an Wanakbori, was completed in 1958; irrigation started during the 1958/59 Rabi season in the initial reaches. The work of extending canals in the command area is now nearing completion. The second stage, building a storage dam at Kadana, began in 1968 and recently was completed.

Before the storage dam was constructed, irrigation was supplemental during the Kharif season. Now the Kadana dam potentially can irrigate 224,800 ha. Rabi crops account for 68,550 ha, and two-seasonal, perennial, and follow-on crops account for 61,600 ha. Thus, the project is Rabi-oriented.

The storage water from the reservoir is distributed to the fields by a network of canals—main, branch, distributary, minors and watercourses (Figure 2). The command area of the right-bank main canal is 213,000 ha and of the left-bank main canal is 11,000 ha. Because irrigation on the left-bank canal is very recent, this study was conducted on the right-bank canal system. The right-bank canal system consists of a main canal, which supplies water to several branch canals and distributaries. Some of the branches taking off from the main canal are Nadiad, Petlad, and Borsad.

Sihol Minor takes off from the Petland Branch. The total command area under this minor is 2,138 ha (5,280 acres). The length of the minor is 11,433 m (37,500 feet). This minor was formerly designed to carry a discharge of 1,133 lps (40 cusecs). Later, it was modified to carry more discharge. The minor was designed to operate on a 10-days-on and 5-days-off rotation. Because no improvements have been made on this minor, it is classified as a traditional system.

Outlet 12/L takes off on the left side of the minor and commands an area of 20 ha (50 acres). The design discharge of the outlet is 22.6 lps (0.80 cfs). The discharge through the outlet is regulated by a gate provided at the taking-off point.

Outlet 10/LA takes off on the left side of the minor. The design discharge of the outlet is 35 lps (1.23 cfs) and is regulated by a 23-cm (9-inch) screwtype gate. The cultivable command area under the outlet is 18 ha (45 acres). At the take-off point of the outlet, no cross regulating device exists to regulate the flow rate and depth of flow.

Outlet 02/L takes off on the left side of the minor. The design discharge of the outlet is 52.7 lps (1.86 cfs), and the cultivable command area is 93 ha (230 acres).

Subminor 10R takes off from Chikhodara Distributary, which takes off from Petland Branch. The official discharge into the subminor is 207 lps (7.30 cfs), and the cultivable command area is 174 ha (430 acres). The official number of outlets on this subminor is 10: 8 on the right side and 2 on the left side. The outlets have been provided with screw gates to regulate the required discharge. Trapezoidal flumes to measure the flow rate have been

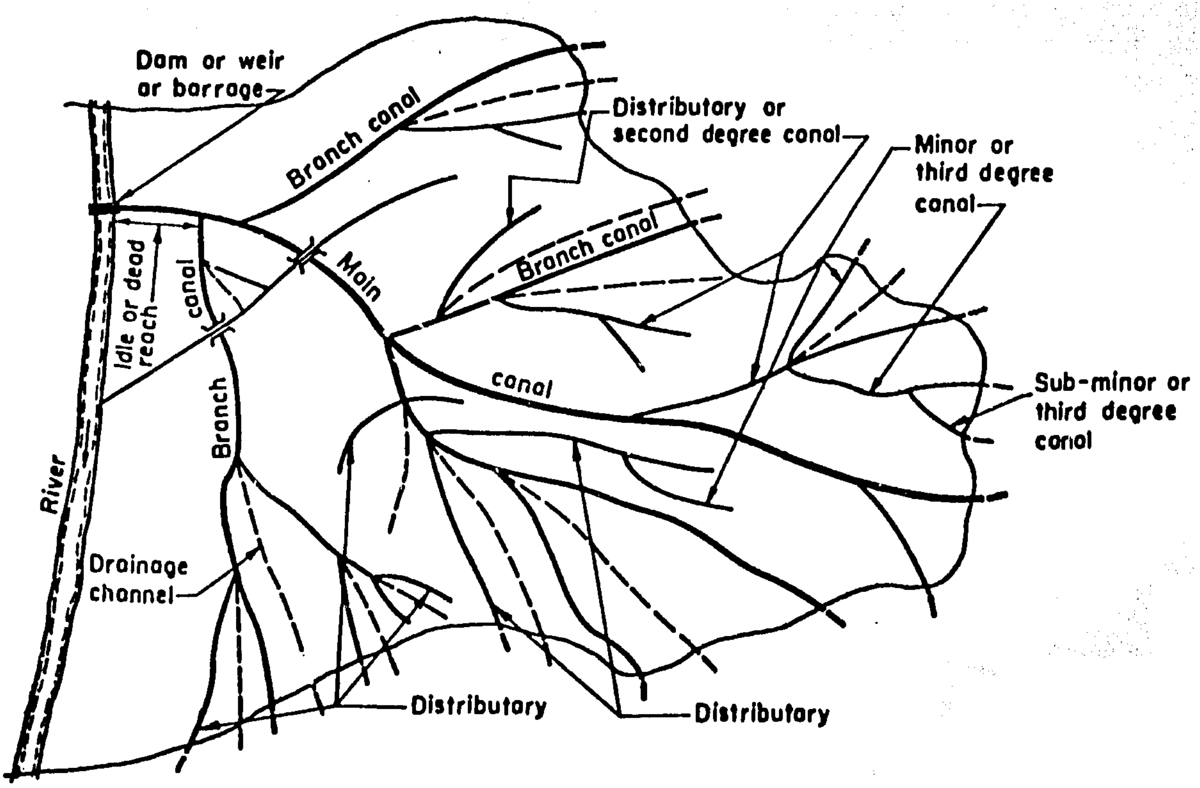

Figure 2. Sketch of a Typical Irrigation System (Punja
(Kraatz and Mahajan, 1975).

installed as part of the improvements associated with the rotational water distribution (RWD) system.

Outlet 01/R takes off on the right side of Subminor 10R, and has been provided with a screw gate. The official command area under this outlet is 12 ha (30 acres). The design discharge of the outlet is 36 lps (1.27 cfs).

Outlet 05/L of Subminor 10R takes off on the left side of the subminor. The design discharge of 36 lps (1.27) is regulated with a screw gate. The cultivable command area of the outlet is 25 ha (62 acres).

Rawalapura Subminor takes off from Petlad Branch on the left. The cultivable area under the subminor is 220 ha (544 acres). The minor has 21 outlets including 2 additional outlets provided under the RWD system. The area under the outlet blocks varies from 2.4 ha (6 acres) to 30 ha (75 acres). A schematic of the Rawalapura Subminor is presented in Figure 3.

4. Cropping Pattern

Gujarat's three cropping seasons are *Kharif* (June to October), *Rabi* October to February), and hot weather (March to June). Most cropping occurs during *Kharif* when farmers can use monsoon rainfall. However, some crops are grown in *Rabi* with irrigation.

Gujarat's agriculture is oriented towards cash crops, especially cotton and groundnuts. The state produces about one-fourth of India's cotton and groundnuts and one-third of its tobacco. In recent years there has been a rapid increase in the production of high-value fruit, vegetables, and spices demanded by the growing urban population of neighboring states.

Food grains, such as pearl millet, sorghum, wheat, paddy, and maize, account for less than half the cropped area. As a result, Gujarat is seriously deficient in food grains.

5. Socio-economic Conditions

Gujarat is the third most urbanized state in India, with one of the highest birthrates and a 1980 estimated population of 32 million people increasing at about 2.6 percent per year (World Bank, 1980). About 21 percent of the population belongs to traditionally disadvantaged groups, like scheduled castes and tribes. Typically, about 40 percent of the rural population has incomes below the poverty line.

With relatively high rainfall and fertile soils, the central mainland is densely populated with small farms. Tenancy legislation, which gives tenants ownership rights to land they previously rented, is strictly enforced in Gujarat. According to the 1970 Agricultural Census, 97 percent of all holdings were fully owned.

D. Contents of this Report

The remaining sections of this report present the observations of the participants who conducted the Diagnostic Analysis. Sections II, III, IV, and V describe the findings in Extension, Economics, Engineering, and Agronomy, respectively. The Participants' Evaluation of the Diagnostic Analysis Training Workshop appears in Appendix A. Additional information on

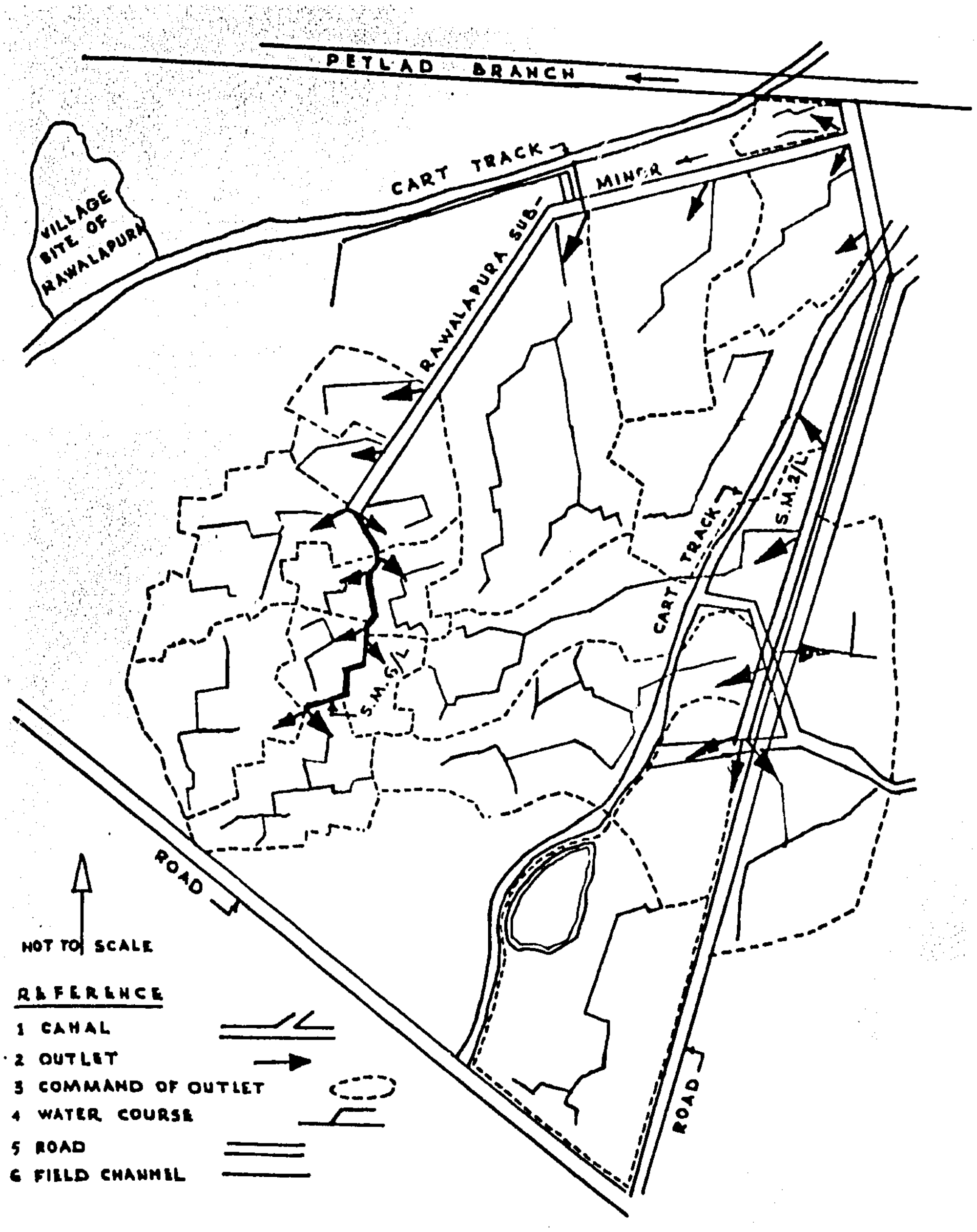

Figure 3. Command Area Under Rawalapura Subminor, Mahi-Kadana Irrigation Project, Gujarat State, India (Jayaraman, 1982).

Engineering is in Appendix B. A List of Participants and Workshop Schedule appears in Appendix C, and a Glossary is in Appendix D.

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

SECTION II - EXTENSION

A. Diagnostic Analysis of Factors Influencing Farmer Irrigation and Adoption Behavior

1. Introduction

As a part of the Diagnostic Analysis Training Workshop conducted at Anand, Gujarat State, India, from February 16 to March 19, 1981, three extension participants collected field data from 57 farmers. Each extension trainee was a member of the three interdisciplinary teams that investigated three improved and four unimproved on-farm irrigation systems. The teams' purpose was to observe farm field activities and to interview farmers to identify those factors influencing farmer behavior. In addition, the teams studied farmers' perceptions of how the system operates and their present irrigation behavior.

2. Methods

Following a training workshop on data collection, the extension personnel and the training team conducted open-ended interviews with local farmers. Information obtained from the field interviews and from relevant literature guided the development of a detailed questionnaire, which was subsequently pretested using a 10 percent sample of interviewees. The interviews focused on major factors influencing farmers' irrigation and adoption behaviors.

Interviewers selected a stratified, proportional, random sample of farmers on the seven systems (10 percent of total population) (Table 1). However, the numbers of farmers selected from each farm size class (marginal, small, medium to large) in each of the seven systems did not accurately represent the farm population of Gujarat State. For example, medium-large farms formed 50 percent of the sample but actually constituted only 23 percent of the population. The sample sites were selected near the Training Center due to time and logistics constraints. In the Mahi-Kadana project study area, farm holdings averaged only 2.5 hectares on the specific command areas studied.

Since farmers owned and operated fields on other watercourses outside the study area, the average farm size for all systems was about 5.3 hectares (Table 2). Table 2 shows that 33 of the 57 sample farms were near heads of watercourses. This was primarily because the conveyance channels were not fully developed to service the total area, even on "improved" systems. Only two large farms exceeded 5.0 hectares.

Table 1. Sample farm size and type of irrigation system

Farm Size Classes	Improved System (Number)	Unimproved System (Number)	Total (Number)	Proportions: Percent in Population	Proportions: Percent in Sample
Marginal (Less than 1 ha)	4	10	14	43	25
Small (1 ha to 2.5 ha)	3	11	14	34	25
Medium to Large (2.5 ha and above)	17	12	29	23	50
TOTALS	24	33	57	100	100

To check reliability, some questions were designed to solicit the same data twice. Open-ended interviews with members of three village Panchayat (local government bodies) and information from other outside sources, including major and minor irrigation officials, provided additional external checks on farmers' responses. Interviewers also used physical observations to confirm the existence of reported farm implements, crops, cropping patterns, tubewells, and other physical objects or materials.

The major criteria guiding the overall Diagnostic Analysis study included:

(1) controlling water by predicting supplies at the farm level,

(2) maintaining productivity of water to farms,

(3) distributing water equitably among farmers,

(4) maintaining soil and water resources,

(5) making investments in the system cost-effective, and

(6) involving farmers in the farm system operations.

The primary focus of this part of the study was on those institutional factors thought to influence farmer irrigation behavior (Figure 4). Irrigation behavior, like all human behavior, takes place in a definite situation, and is goal oriented, motivated, and regulated by norms established over time. A norm refers to any "rule of the game" that strongly influences human behavior.

Table 2. Description of sample farms

Type of System and Outlet Number	No. of Sample Farms	Percent of Total Farms Selected	Number of Sample Farms: Farm Size Classes: Marginal (No.)	Small (No.)	Medium-Large (No.)	Number of Sample Farms: Distance from Water Source: Head (No.)	Middle (No.)	Tail (No.)	Average Farm Size (hectares): Total	Study Water Course
Improved										
01/R	8	53	–	–	7	3	2	3	7.71	3.76
04/RA	8	24	3	3	2	–	3	5	3.86	0.78
05/L	8	28	2	4	2	4	3	1	4.33	1.43
SUBTOTAL	24	31*	5	7	11	7	8	9	5.30*	2.00*
Unimproved										
02/L	12	25	1	3	9	6	7	–	7.41	1.45
10/AL	9	89	5	–	4	9	–	–	3.27	3.00
11/L	8	25	2	4	2	2	3	2	3.97	3.41
12/L	4	18	1	–	3	2	–	2	7.16	7.16
SUBTOTAL	33	46*	9	7	18	19	10	4	5.31*	2.81*
TOTAL	57	37**	14	14	29	26	18	13	5.30**	2.55**

*Percent of total or average size for improved or unimproved.
**Percent of total or average size for improved and unimproved.

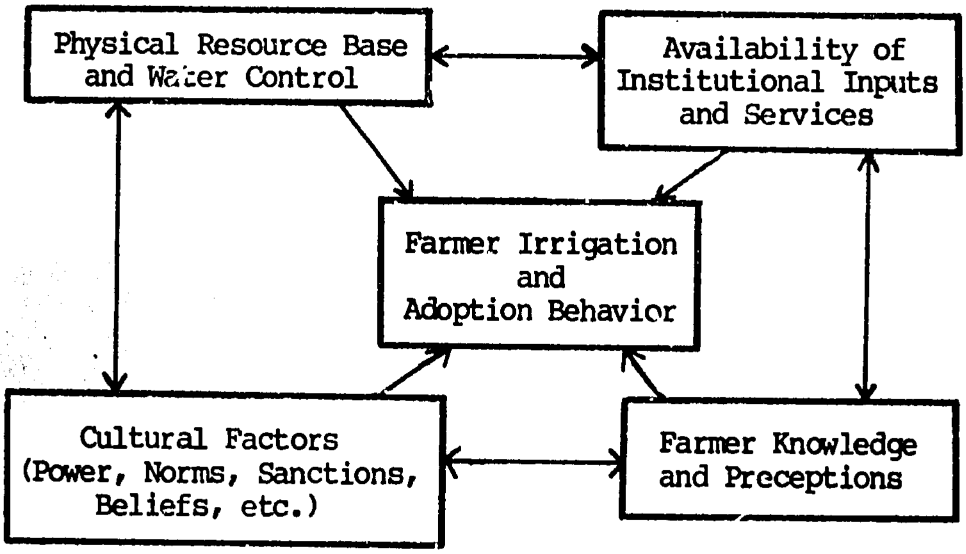

Figure 4. Factors influencing farmer irrigation and adoption behavior.

3. Adoption of Recommended Practices and Selected Technology and the Availability of Institutional Inputs and Services

The Agriculture Department in Mahi-Kadana recommended practices for three major crops (Table 3). Table 4 shows the percentage of farmers by four size classes and type of system using the recommended practices. From 75 to 100 percent of the 24 farmers on improved systems used high-yielding-varieties (HYVs) of wheat, whereas 62 to 100 percent of the 33 farmers on unimproved systems used them. Farmers on both systems differed only slightly in seedbed preparation, the range of sowing dates used, and the seed rates used. While nitrogen use varied, farmers were not applying adequate levels of inorganic N, P, and K fertilizers. Only a few farmers used any P and K. Although only about half the sample farmers reported weeding their wheat crops, all sample farmers used the recommended number of irrigations.*

Most sample farmers grew "calcuti" tobacco and prepared their seedbeds with two or more deep plowings. Many farmers could not follow recommendations about planting dates and levels of fertilizer due to unpredictable irrigation supplies and water control. Although many farmers on the improved systems cultivated their tobacco crops five or more times, only half of the marginal farmers, none of the small farmers, and 45 percent of the medium-to-large farmers on unimproved systems followed this practice. With one exception, all farmers weeded the "calcuti" tobacco crop at least twice. In contrast to wheat farmers, almost all tobacco farmers could not apply the 10 to 12 irrigations recommended by the Agriculture Department.

Most farmers on the unimproved system waited until the last possible date to plant HYVs of paddy in order to take advantage of monsoon rains.

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* The recommended number of irrigations used by the Agricultural Department for years does not provide information on amount of water applied, timing of irrigations, or the quality of irrigation. In terms of irrigation water management, the number of irrigations is frought with many problems.

Table 3. Recommended practices for three major crops

Recommended Practices	HYVs* Wheat	HYVs Rice	Calcuti Tobacco
1. Number of deep plowing for seed-bed preparation	2	1	2
2. Range of sowing dates	Nov. 15-Dec. 15	July-August	Oct.-Nov.
3. Seed rate or plants per hectare (kg/ha)	100-125	--	--
4. Sowing or planting method	Drill	Transplant	Transplant
5. Times cultivated	--	--	--
6. Times weeded	2	2	2-3
7. Range of Irrigation	6-8	3-4(if needed)	10-12
8. Nutrient inorganic fertilizer (kg/ha)			
a) N	120	100	200
b) P	60	50	0
c) K	40	50	0
9. Organic farm yard manure (tons/ha)	10	12	10

*HYV = High Yielding Varieties.

Table 4. Farmers' use of recommended practices for three major crops

Crops and Recommended Practices for High Yielding Varieties (HYVs)	Percent of Farmers Using Practices					
	Marginal Farms		Small Farms		Medium Farms*	
	Improved System (n=8)	Unimproved System (n=8)	Improved System (n=3)	Unimproved System (n=5)	Improved System (n=16)	Unimproved System (n=20)
A. Wheat						
1. use of HYVs	80(4)**	62(5)	100(3)	60(3)	75(12)	100(20)
2. seedbed preparation	100	60	67	100	100	60
3. sowing date range	75	60	67	33	25	60
4. seedrate range	100	0	100	100	50	50
5. method of sowing	100	60	100	67	100	
6. fertilizer						
a) N	50	60	0	0	17	50
b) P	0	0	0	33	17	25
c) K	0	0	0	0	17	5
7. times weeded	75	40	33	67	42	40
8. range of irrigations	100	100	100	100	100	100
B. Tobacco (Calcuti)						
1. use of improved variety	60(3)	75(6)	100(3)	80(4)	81(13)	100(20)
2. seedbed preparation	100	83	67	100	100	100
3. planting date range	0	17	67	20	23	0
4. plant rate		?				
5. fertilizer (N)	0	17	67	0	69	50
6. times cultivated	100	50	100	0	42	45
7. times weeded	100	100	100	50	100	100
8. range of irrigations	0	17	0	0	0	10
Paddy						
1. use of HYVs		100(8)		40(2)		90(18)
2. seedbed preparation		50		100		100
3. range of sowing date		37		0		17
4. method of planting		100		100		100
5. fertilizer						
a) N		25		0		22
b) P		0		0		17
c) K		0		0		11
6. times weeded		50		100		61
7. times irrigated		50		100		100

*Includes 2 large farms with 5 and 6 hectares each.

**Denotes the number and percentages of farms using the improved varieties. Other percentages are based on this number.

Nitrogen levels were low, and few farmers used any P or K fertilizers. Farmers usually weeded and applied three or four irrigations in addition to monsoon rains if needed. On the improved system paddy, many farmers used the recommended levels of N; several farmers also used P and K. On medium-sized farms, farmers planted their seedlings on the July-to-August recommended date.

a. Use of Selected Farm Technologies

Table 5 shows farmers' ownership and use of selected improved technologies. Only a few medium-size farmers owned an improved bullock-powered cultivator and mouldboard plow; no farmers used a bullock-powered automatic seed drill. Some used a small drill or a funnel attached to a small plow. While most farmers used tractors for plowing, only six farmers used tractors for land leveling. Only two farmers owned and used an improved rubber-tired bullock cart. Over half of the 57 farmers reported some use of a tractor trolley for farm work, especially for hauling produce to market. Three farmers owned private tubewells; over a third purchased tubewell water from owners, at an average cost of RS 12 per hour.

b. Sources and Adequacy of Farm Information

Tables 6 and 7 show farmers' primary sources of farm information and their views on the adequacy of the source. A major source of information about market news such as farm produce prices was private business, which includes middlemen, shopkeepers, and the village cooperative. About 87 and 55 percent, respectively, of the farmers on improved and unimproved systems used these sources. Forty-two percent of the farmers on the unimproved systems used other farmers as sources of information, but few thought that these sources were adequate. For information about input prices. 92 and 96 percent of the farmers of improved and unimproved systems used private business sources; more than half of the farmers felt these sources were "usually adequate." For information on market places for selling farm products, most farmers relied on local business sources and other farmers; about half of these farmers said these sources were "usually adequate." Few farmers used either mass media or extension sources of information for market news.

Only about half the farmers on the improved system and one-third on the unimproved system learned about new crop varieties from extension sources. Only six farmers believed this source was "usually adequate." The remainder of the farmers primarily relied on private business and other farmers for information, but few farmers said these sources were "usually adequate."

For fertilizer and insecticide use, the major sources for the improved-system farmers were, in order, extension, private business, other farmers, and mass media. Major sources for the farmers on unimproved systems were private business, other farmers, mass media, and extension. Extension programs were well organized for the improved system, while private businesses run by the strong Patel family in the area were more active for the unimproved system. For fertilizer and insecticide information, all farmers thought private business sources were "usually adequate."

For irrigation information, farmers exclusively used irrigation authorities, with the exception of three farmers who used "other farmers." Farmers rated information about irrigation revenue rates from the chowkidar, talati, or karkoon as "somewhat" to "usually adequate." Only about half of the farmers felt information about expected seasonal irrigation supplies was

Table 5. Farmers' use of improved farm technologies

Improved Technologies	Percent of Farmers Using Technologies					
	Marginal Farms		Small Farms		Medium Farms*	
	Improved System (n=8)	Unimproved System (n=5)	Improved System (n=3)	Unimproved System (n=4)	Improved System (n=16)	Unimproved System (n=21)
A. Bullock cultivation						
1. owns	0	0	0	0	19	5
2. borrow/rent	0	0	0	0	0	0
3. no use	100	100	100	100	81	95
B. Bullock mouldboard plow						
1. owns	0	0	33	25	6	5
2. borrow/rent	0	0	0	0	0	0
3. no use	100	100	67	75	94	95
C. Bullock powered automatic seed drill						
1. owns	0	0	0	0	0	0
2. borrow/rent	0	0	0	0	0	0
3. no use	100	100	100	100	100	100
D. Tractor plowing						
1. owns	0	0	0	0	6	14
2. borrow/rent	60	87	67	50	56	81
3. no use	40	13	33	50	38	5
E. Tractor land leveling						
1. owns	0	0	0	0	0	14
2. borrow/rent	0	40	0	50	19	10
3. no use	100	60	100	50	81	76
F. Rubber tired bullock cart						
1. owns	0	0	0	0	0	10
2. borrow/rent	0	0	0	0	0	0
3. no use	100	100	100	100	100	90
G. Tractor trolley						
1. owns	0	0	0	0	6	14
2. borrow/rent	88	40	100	50	62	66
3. no use	12	60	0	50	32	20
H. Tubewell						
1. owns	0	0	0	0	0	14
2. borrow/rent	12	40	67	25	37	33
3. no use	88	60	33	75	63	53

*Includes two large farms with 5 and 6 hectares.

Table 6. Farmers' sources of farm information

Types of Farm Information	Percent of Farmers Using Sources									
	Media		Extension		Irrigation Authorities		Private Business and Coop		Other Farmers	
	Improved System (n = 24)	Unimproved System (n = 33)	Improved System (n = 24)	Unimproved System (n = 33)	Improved System (n = 24)	Unimproved System (n = 33)	Improved System (n = 24)	Unimproved System (n = 33)	Improved System (n = 24)	Unimproved System (n = 33)
A. Market News										
1. Farm Products Prices	4	0	0	3	0	0	87	55	8	42
2. Input Prices	0	0	4	0	0	0	92	96	4	9
3. Market Place	8	3[a]	0	0	0	0	87	55[b]	4	42[b]
B. New Crop Varieties[c]	8	11	54	32	0	0	21	17	17	0
C. Fertilizer Use[d]	8	21	50	7	0	0	33	53	8	18
D. Insecticides	8	26	42	4	0	0	21	39	29	30
E. Irrigation Matters[e]										
1. Revenue Rates	0	0	0	0	100	100	0	0	0	10
2. Seasonal Supplies	0	0	0	0	60	NA	0	0	0	0
3. Canal Closures	0	0	0	0	100	100	0	0	0	0
4. Warabundi Sytem	0	0	0	0	100	NA	0	0	0	0
5. Watercourse Improvements	0	NA	0	NA	4	20	0	0	0	13
6. General Farm Water Use	0	3	0	0	0	10	0	0	0	3

[a] n = 19.
[b] n = 29.
[c] n = 28 for unimproved systems.
[d] n = 23 for unimproved systems.
[e] For improved systems, n = 23; for unimproved systems, n = 30.

Table 7. Farmers' views of the adequacy of farm information sources

Types of Farm Information	Percent of Farmers Responding About Source Adequacy																													
	Media						Extension						Irrigation Authorities						Private Business and Coop						Other Farmers					
	Improved System (n = 24)			Unimproved System (n = 33)			Improved System (n = 24)			Unimproved System (n = 33)			Improved System (n = 24)			Unimproved System (n = 33)			Improved System (n = 24)			Unimproved System (n = 33)			Improved System (n = 24)			Unimproved System (n = 33)		
	0	1	2*	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2	0	1	2
A. Market News																														
1. Farm Products Prices	96	-	4	100	-	-	-	-	-	97	-	3							17	8	75	16	15	39	92	-	8	58	15	27
2. Input Prices	100	-	-	-	-	-	92	4	-	100	-	-							13	8	79	12	30	58	96	-	4	91	6	3
3. Market Place	92	-	8	97[a]	3[a]	-	-	-	-	100[a]	-	-							21	21	58	55[b]	6[b]	39[b]	96	-	4	70[b]	21[b]	9[b]
B. New Crop Varieties[c]	92	4	4	90	5	5	54	21	25	79	21	-							79	-	21	83	10	7	88	4	8	100	-	-
C. Fertilizer Use[d]	92	8	-	29	14	7	54	29	17	93	7	-							67	-	33	50	11	39	96	4	-	82	18	0
D. Insecticides	92	8	-	73	9	18	58	25	17	96	4	-							79	11	8	61	13	26	71	8	21	74	17	9
E. Irrigation Matters[e]																														
1. Revenue Rates	100	-	-	100	-	-	100			100			18	39	43	-	13	87	100	-	-	100	-	-	-	-	-	90	-	10
2. Seasonal Supplies	100	-	-	100	-	-	100			100			13	22	65		NA		100	-	-	100	-	-	-	-	-			
3. Canal Closures	100	-	-	100	-	-	100			100			13	9	78	-	10	90	100	-	-	100	-	-	-	-	-			
4. Warabundi Sytem	100	-	-	100	-	-	100			100			13	22	65		NA		100	-	-	100	-	-	-	-	-			
5. Watercourse Improvements	100	-	-	-	NA	-	100			NA			96	4	-	80	13	7	100	-	-	100	-	-				86	7	7
6. General Farm Water Use	100	-	-	100	-	-	100			100			100	-	-	90	7	3	100	-	-	100	-	-				97	3	0

*Adequacy code: 0 = not; 1 = somewhat; 2 = usually.
[a] n = 19.
[b] n = 29.
[c] n = 28 for unimproved systems.
[d] n = 23 for unimproved systems.
[e] For improved systems, n = 23; for unimproved systems, n = 30.

"adequate." Information about canal closures was "usually adequate." On the improved system using a warabundi or regulated turn system for water delivery, most farmers viewed the information provided as "usually adequate." Farmers primarily depended on irrigation authorities and other farmers for information about watercourse improvements.

Surprisingly few farmers received information on general farm water use from any source other than a few fellow farmers. When asked if they receive information on how, when, and how much to irrigate crops, only 4 of the 57 farmers reported they "usually" receive information from the VLW Extension worker on the improved system (Table 8). Farmers using both systems seldom received help from the so-called Training and Visitation system contact farmer or information from the canal chowkidar or media sources. Only one farmer received information from seed or fertilizer agents. About half of the farmers on the improved system and about 85 percent of those on the unimproved system received some of their information from other farmers. This poor extension involvement exists because extension staff, contact farmers, and canal authorities have not received training to provide adequate information to farmers about irrigation, particularly in the area of on-farm water management.

Farmers on the improved system said they first learned about the Command Area Development project from "other farmers," the "canal chowkidar," and the "Command Area Development Authority (CADA) notice board." Though farmers on the unimproved system are located close to the improved system, 91 percent of those interviewed reported never hearing about the program. Only 3 of 33 farmers said they heard about the improvement activities through the newspaper, extension personnel, or the canal chowkidar (Table 9).

Only farmers on the improved systems evaluated the specific improvement activities implemented and stated their levels of satisfaction (Tables 9 and 10). Half of the sample farmers rated the warabundi system as "good," and only a startling 21 percent rated the improved canals and 25 percent rated the land leveling as "good." A little over one-third rated the watercourse structures as "good." Since less than half of the farmers rated the behavior of government workers as "good," a considerable credibility gap between farmers and government staff must exist. Only about 29 percent of the sample farmers rated the cost recovery program as "good," 29 percent "fair," and 34 percent "no comment." The rather high percentages of farmers reporting "no comment" about their levels of satisfaction with CADA activities may reflect their hesitancy or fear of being too open or candid with the field investigators who were government employees.

c. Conclusions

(1) Most farmers did not know the local extension worker and received little or no assistance from him or the contact farmers.

(2) The major source of information about marketing of farm products and prices was local shopkeepers and market middlemen.

(3) Farmers received virtually no assistance from anyone, except other farmers, about how, when and how much to irrigate.

(4) Most farmers thought agricultural information received was either "sometimes adequate" or "not adequate."

Table 8. Farmers' information sources on how, when and how much to irrigate crops

Sources and Uses of Information on Crop Irrigation	Percent of Farmers Using Sources	
	Improved System (n=24)	Unimproved System (n=33)
VLW (Extension)		
Never	50	70
Sometimes	33	30
Usually	17	-
Contact Farmer		
Never	83	91
Sometimes	12	6
Usually*	5	3
Canal Chowkidar		
Never	75	52
Sometimes	8	21
Usually	17	27
Radio/Newspaper/TV		
Never	46	45
Sometimes	54	39
Usually	0	16
Seed/Fertilizer Agents		
Never	96	00
Sometimes	4	0
Usually	0	0
Other Farmers		
Never	54	15
Sometimes	17	36
Usually	29	49

*In both cases this farmer is the contact farmer under the Training and Visitation Extension system.

Table 9. Farmers' sources of knowledge about Command Area Development activities

Sources of Knowledge	Percent of Farmers Using Sources Improved System (n = 24)	Unimproved System (n = 33)
Newspaper	0	3
Chowkidar	17	3
Extension	4	3
CADA Notice Board	12	--
Karkoon	4	--
Other farmers	29	--
No report or not heard	33	91

Table 10. Farmers' satisfaction with Command Area Development Authority activities

CADA Activities	Levels of Satisfaction of Improved System Farmers (percent responding)			
	Good	Fair	Poor	No Comment
Warabundi System	50	29	8	13
Improved channels	21	12	46	21
Land leveling*	25	33	25	17
New watercourse structures	37	21	8	34
Government workers' behavior	42	25	--	33
Cost recovery program from farmers for improvements	29	29	8	34

*Eight farmers report not using land leveling, and one states the cost is high.

(5) Farmers considered both the source of information about and their satisfaction with most Command Area Development activities fair to poor in quality.

4. Farmers Knowledge and Views about When and How Much to Irrigate, Water Movement in Soils, and Sources of Water Losses

A survey of farmers determined how they decide to start or stop irrigating particular field crops (Table 11). Most farmers said they decide to irrigate one crop rather than another by observing the appearance of plants in the fields and the soil surface. No farmers reported making decisions by examining the subsurface soil, and only three used the method of recalling the last date a crop or field was irrigated. Likewise, only three farmers observed the stage of plant growth, while four farmers used "guesswork," "God's will," or "when the water comes." In sandy to sandy-loam soils where traditional methods of irrigating are inadequate, visually observing the soil or plants is tricky.

When asked how they decide to stop an irrigation, farmers preferred, in order of rank, to stop the advancing water just before it reached the far border. after the water reached the far border, and when the application of water covered all the high spots in the field being irrigated. Only three farmers reported "guesswork" or "don't know." Farmers have learned by trial and error how to irrigate their fields, and they try to cover the high spots in fields which are not level. As a result, the high spots in fields typically receive inadequate moisture, and the low spots are usually over-irrigated.

Farmers also compared their usual irrigation practices to the "optimum" irrigations they would provide if water were more freely available. Farmers' reports for irrigations of the same crops on the same system, with similar physical soil types and water availability, varied widely (Table 12). For example, for HYVs of paddy, values for the optimum irrigation ranged from 3 to more than 15 irrigations for improved-system farmers, and 5 to 10 irrigations for those on the unimproved system.

The modal number of optimum irrigations for both the improved and unimproved systems was similar for paddy and wheat but varied greatly for the two crops of tobacco (Table 13). Likewise, modal numbers of "usual" irrigations differed substantially between the two types of systems for wheat, paddy, and calcuti tobacco.

The wide range in reported irrigations probably occurs because farmers received little help in applying irrigation water and because their trial and error methods varied. In addition, field levelness and water control may have differed between farms. If farmers had had similar water control on similar soils for the same crops plus a knowledge of <u>when</u> and <u>how much</u> and <u>how</u> to irrigate, less variation in both "usual" and "optimum" irrigations should have appeared.

Table 11. Farmers' methods for deciding when to irrigate crops

Methods for Deciding When to Irrigate Crops	Percent of Farmers Using Each Method: Improved System (n = 24)	Percent of Farmers Using Each Method: Unimproved System (n = 33)
1. Major decision method for irrigating a crop		
a) Remember date of last irrigation	0	9
b) By appearance of soil surface	33	45
c) By appearance of plants (leaves)	58	30
d) By stage of growth of plants	4	6
e) By examining subsurface soil for moisture	0	0
f) Guess work, God's will, or when water comes	4	9
2. Major decision method for stopping an irrigation		
a) When water reaches border at end of field	17	39
b) Before water reaches border at end of field	50	46
c) When water covers all high spots in the field	29	9
d) When water reaches a certain depth	0	0
e) When have applied water for a certain known period	0	0
f) Guess work or don't know	4	6

Table 12. Farmers' estimated number of optimum versus usual irrigations for selected crops

Type of Crop and System	Number of Farmers Applying Given Numbers of Irrigations													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HYVs of Paddy														
Optimum Irrigation														
Improved System (n = 19)		1	2	1	5*	2	3		4					
Unimproved System (n = 23)				1	9	2	5	2	4					
Usual Irrigation														
Improved System (n = 19)														
Unimproved System (n = 23)	2	3	8	6	3		1							
Local Bidi Tobacco														
Optimum Irrigation														
Improved System (n = 22)			1	5	5	7	3	1						
Unimproved System (n = 31)		2	5	7	11	5		1						
Usual Irrigation														
Improved System (n = 22)		1	7	6	6	2								
Unimproved System (n = 31)	4	8	9	9	1									
Improved Calcuti Tobacco														
Optimum Irrigation														
Improved System (n = 13)						1	1	4	1	5				1
Unimproved System (n = 20)										5	1	7	4	3
Usual Irrigation														
Improved System (n = 13)														
Unimproved System (n = 20)	3	9		6			2							
HYVs of Wheat														
Optimum Irrigation														
Improved System (n = 20)				5	7	8								
Unimproved System (n = 28)					5	12	10	1						
Usual Irrigation														
Improved System (n = 20)			9	5	5	1								
Unimproved System (n = 28)			3	6	13	3	2	2						

*Underlined digits indicate modes.

Table 13. Range and modal irrigations for four crops

Crops and Irrigation System	Improved System		Unimproved System	
	Range	Mode	Range	Mode
Paddy (HYVs)				
Optimum Irrigation	3-15	6	5-10	6
Usual Irrigation			2-8	4
Local Tobacco				
Optimum Irrigation	4-9	7	3-9	5
Usual Irrigation	3-7	5	2-6	5
Calcuti Tobacco				
Optimum Irrigation	7-15	11	11-15	13
Usual Irrigation			2-8	5
Wheat (HYVs)				
Optimum Irrigation	5-7	7	6-9	7
Usual Irrigation	4-7	4	4-9	6

Farmers lack a considerable knowledge of basic soil and water relationships (Table 14). When asked to estimate the depth of infiltration of 3 inches of water ponded on a sandy-loam soil, 14 farmers reported that they did not know, 12 reported less than 6 inches, and 30 reported 6 to 12 inches. Actual infiltration is 37 or more inches. Estimates of root penetration depth for three crops in sandy-loam soils ranged from "don't know" to "less than 6 inches" and "up to 13 to 24 inches." Likewise for wheat, most farmers reported "don't know" or believed in short root penetration. Actual root penetration for all three crops is 25 to 36 inches. Farmers also believed that trees have deep root systems (6 to 24 feet), while crops have shallow roots in soils with minimal water infiltration. Most trees' roots extend even deeper than farmers thought, about 37 or more feet.

Questions about which crops (including improved paddy, hybrid maize, and improved tobacco) used more total water from pre-irrigation through the crop harvest revealed that 47 of the 57 farmers correctly reported paddy. 5 reported tobacco, and 5 reported "do not know" (Table 15). Farmers generally knew how plants uptake water.

Table 14. Farmers' responses to questions about plant-water-soil relationships

Questions	Number of Farmers Responding (n = 57)
1. Root depth of crops in sandy-loam soil:	
<u>Tobacco</u>	
a) Don't know	6
b) <6"	7
c) 6-12"	26
d) 13-24"	18
e) 25-36"	-
f) 37+"	-
<u>Wheat</u>	
a) Don't know	10
b) < 6"	19
c) 6-12"	28
d) 13-24"	-
e) 25-36"	-
f) 37+"	-
<u>Groundnuts</u>	
a) Don't know	43
b) < 6"	4
c) 6-12"	9
d) 13-24"	1
e) 25-36"	-
f) 37+"	-
2. Depth of infiltration of 3" of water ponded on a sandy-loam soil:	
a) Don't know	14
b) < 6"	12
c) 6-12"	30
d) 13-24"	1
e) 25-36"	-
f) 37+"	-
3. Root depth for tree of 24" girth:	
a) Don't know	8
b) < 6'	-
c) 6-12'	19
d) 13-24'	19
e) 25-36'	5
f) 37+'	6

Table 15. Farmers reports of how plants uptake water and which crops use more total water from pre-irrigation to harvest

Questions	Number of Farmers Responding (n = 57)
1. Crops which use most water:	
a) Improved Paddy	47
b) Hybrid Maize	0
c) Improved Tobacco	5
d) Don't Know	5
2. How plants uptake water:	
a) By Root Systems	50
b) Don't Know	7

This preliminary information suggests that farmers need extension and other help in better understanding soil-plant-water relationships. Such knowledge affects understanding of <u>how</u>. <u>when</u>, and <u>how much</u> to irrigate crops effectively. Other studies have found that farmers' beliefs about these plant-soil-water relationships influence how they irrigate crops.

Table 16 illustrates major sources of water losses from the outlets to farmers fields. On both the improved and unimproved systems, respectively, 74 and 68 percent of the farmers reported the most important sources as leaks in channel banks and seepage through watercourse bottoms. Only a few farmers reported such problems as dead storage, vegetative growth along conveyance channels, breaks in watercourse junctions, nonalignment of channels, and unlevel fields. Interestingly, visual observations indicated considerable water losses from channels overtopping due to lack of a free board, vegetative growth within and along channels, dead storage, and substantial breaks at watercourse junctions. Engineers measured substantial losses of 50 percent or more on some 1000-foot sections of conveyance channels. mostly from inadequate freeboards, poor alignment of channels, and improper channel depths relative to the field elevation. In general, farmers were aware of some of the sources of losses but were unaware of the magnitude of these losses.

5. <u>The Physical Resource Base and the Water Control Situation</u>

Physical resources such as soils, topography, and climate and control over water influence farmer behavior significantly. A farmer's control over water strongly determines his decisions and outcomes about which area is irrigated, source and method of irrigation, cropping intensities, quality of crop, collective action, and crop results or yields. These factors in turn influence farm income and levels of living for all classes of farmers.

The Mahi-Kadana Project area has good to very good sandy-loam soils and a seasonal rainfall ranging from 14-31 inches per year. The monsoon rains alone produce about 10-15 inches in the <u>Kharif</u> season (summer months of June to October). The summer and winter seasons have mean maximum temperatures of 100 and 67°F, and provide a year-around climate for a mixture of crops includ-

Table 16. Farmers' reports of two major sources of water losses on their fields

Major Sources of Water Losses	Percent of Farmers Responding			
	Improved System (n = 23)		Unimproved System (n = 31)	
	Most Important	Next Most Important	Most Important	Next Most Important
1. Spills and overtopping	0	0	0	0
2. Leaks in channel banks	39	30	55	19
3. Seepage at watercourse bottom	35	26	13	10
4. Water standing in channels	0	13	3	26
5. Vegetative growth along channels and trees	4	9	0	3
6. Breaks at junctions of watercourse	0	0	3	3
7. Nonalignment of channels	9	13	10	10
8. Unlevel fields	4	9	3	19
9. Farmers carelessness in not maintaining channels	9	--	10	0
10. No report of losses	0	0	0	0

ing paddy, maize. pearl millet, wheat, bananas, papaya. tobacco, groundnuts, and vegetables. The soils are deep with good to excellent texture providing good infiltration rates for water. Good farming practices include the use of inorganic fertilizers, proper irrigation, and plant protection. The soils and climate of the area have a potential for double or triple the current average crop yields.

Table 17 shows the total land area owned by the 57 sample farmers, the area cultivated, and the area irrigated by source of water for the two cropping seasons for both improved and unimproved systems. The areas irrigated by canal for both seasons were greater for the improved system, which had a more extensive conveyance and a warabundi-regulated turn system for irrigations. The area irrigated by canal and private tubewell was greater for the Rabi season because many farmers relied on the variable monsoon rainfall for Kharif crops. The area irrigated by tubewell was much greater for the unimproved system due to an extensive network of underground conveyance systems supplied by private tubewell owners who sell irrigation water.

For both seasons the area irrigated by the canal system on the improved system was about twice that of the unimproved system. A large percentage of cultivated area was irrigated by tubewell for the 33 farms on the unimproved system. About 142 percent of the cultivated area was irrigated by both methods during Rabi, suggesting that both canal and tubewell water were used on the same areas to increase the cropping intensities. In the field, more area was in bananas, papaya. and other high quality crops on the unimproved than improved systems.

Farmers said they were not using more water from the canal gravity flow system for a variety of reasons (Table 18). About one-quarter of the farmers of both systems reported that there was no watercourse conveyance channel to their fields, making it impossible to utilize the gravity system. Another one-quarter stated that their land was too high to irrigate with canal water. Physical observations indicated that, due to inadequate design of the slope and subsequent erosion, conveyance channel beds were too deep to irrigate some fields. About 20 percent of the farmers felt the canal gravity system was not dependable, and several farmers reported that tubewells provided better water control. Interestingly, about 20 percent of the farmers reported that tubewell water is better because it is warmer, less saline, and more fertile (due to an assumed mineral content) than canal water. Such a belief works as an advantage for the tubewell owners who profit from selling water at a rate about seven to nine times higher than canal water rates. Selected physical measurements and observations confirmed the lack of water control and the inability of the canal system to provide predictable supplies of water.

About one-third to one-half the farmers have used tubewell water from time to time. The mean and median distance to deliver tubewell water by underground pipelines was 1388 and 1200 feet, however, the longest distance was 3000 feet. The cost per hour to farmers who purchased tubewell water averaged Rs 12 per hour, but ranged between Rs 10 to 18 depending on the competition among well owners to sell water. The major crops for which farmers purchased tubewell water were tobacco and bananas; where fields could not be serviced by the canal gravity system, farmers purchased tubewell water for fodder, wheat, vegetables, and other crops.

Table 17. Total land area, area cultivated, and area irrigated by surface and groundwater for *Kharif* and *Rabi* crop seasons[1]

Farm Area	Improved System (n = 24)				Unimproved System (n = 33)			
	Kharif		Rabi		Kharif		Rabi	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Cultivated area	108.10	85.0	112.40	88.4	170.33	97.2	171.48	98.0
Area irrigated by canal	51.88	48.0	91.82	81.7	34.41	20.2	78.59	46.0
Area irrigated by tubewell	26.40	24.4	30.60*	27.3	22.48	13.2	164.57	96.0
Area irrigated by tubewell and canal	78.28	72.4	122.42	109.0	56.89	33.4	243.16	142.0
Total land area	127.12	100.0	127.12	100.0	175.27	100.0	175.27	100.0

* Only 4.2 acres were reported to be irrigated by the public tubewell.

1 Note that this is the area on the 7 systems studied and not the total area owned and cultivated which includes land on other systems.

Table 18. Major reasons farmers report for not using <u>more</u> canal water

Major Reasons for Not Using More Canal Water	Percent of Farmers Responding	
	Improved System (n = 22)	Unimproved System (n = 30)
1. No watercourse system to farm	27	23
2. Canal water not dependable supply	18	23
3. More water control with tubewells	5	10
4. Land too high to irrigate from canal outlet	23	23
5. Tubewell water is better*	23	20
6. Own private tubewell	4	—
	100	100

*Improved Systems: 5 farmers report the water is less salty, warmer, and more fertile.
Unimproved Systems: 6 farmers report water is less salty, warmer, and more fertile.

a. Land Leveling and Water Control

Farmers also had problems controlling water once it was delivered to their fields. Topographical surveys indicated that fields were not adequately leveled. To overcome unlevel fields, farmers often made field basins small, from less than 0.01 ha to about 0.025 ha. Only 6 and 9 percent of the farmers on the improved and unimproved systems, respectively, reported that their fields were currently in a poor state of levelness (Table 19). Evidently farmers were not aware of the need for precision land leveling because they had not seen or understood its benefits. About one-quarter of the farmers on the improved system had not had leveling of any type done as compared to 40 percent of the farmers on the unimproved system.

Most farmers did rough leveling using bullock equipment and tractors with back blades, usually after growing two crops. They preferred to use private tractors and human labor with baskets. Even on the improved system where land leveling assistance was available, only a few farmers preferred the government land leveling program. Farmers on the improved system generally were not satisfied with the work done by the government program. Field investigations observed no precision land leveling work by the government; the leveling completed to date is only rough leveling which is not of much use to farmers in helping them improve the control of water on fields.

b. Water Control and Minor System Operation

Water control at the farm level refers not only to physical problems such as conveyance losses, alignment of channels, and topographic level of fields, but also to organizational procedures used in the operation of the system.

On the improved system 50 percent of the farmers reported that the daytime flow levels of the minor canal which delivers water to the command outlets were only "partial" instead of "full" during the Kharif season (Table 20). For the Rabi season, only 35 percent reported that the flow levels during the day were at the "full" level. For the unimproved system, 81 percent reported that the day and night flow levels during Kharif season were only "partial." For the Rabi season, 92 percent reported "partial" flow levels during the day. Especially on the unimproved system, minor flow levels seemed to vary substantially during the day. At three points on the unimproved minor system, farmers were using boards, banana stalks, and other debris to check up the water to create higher rates of discharge from outlet gates.

Table 20. Farmers' estimates of flow levels of minor canals by season and by time of day

Season and Time of Day	Percent of Farmers Responding							
	Improved System (n = 20)				Unimproved System (n = 31)[1]			
	Full Flow	Partial Flow	Low Flow	Closed	Full Flow	Partial Flow	Low Flow	Closed
Kharif Season								
Day	50	50			19	81	--	--
Night	NA*	NA*			NA+	NA+		
Rabi Season								
Day	35	65	—	—	4	92		4
Night	NA**	NA**			NA++	NA++		

*Only 2 farmers reported full level and 4 reported partial.
**Only 2 farmers reported full level.

+Denotes only 6 farmers reported full level and 2 reported partial.

++Denotes only 5 farmers reported full level.

[1]For the Rabi season, n = 25.

Farmers must obtain a pass from the Irrigation Department each season for water allocation. Evidently the procedure works fairly well because most farmers reported acquiring passes from irrigation authorities without much delay (Table 21). The forms used, however, were large sheets of paper which the farmers could not easily carry. One counterfoil was kept by the executive engineer's office, one was retained by the canal chowkidar, and one remained with the farmer. Farmers usually did not produce the pass when requesting water from the gatekeepers or chowkidars.

Farmers reported delays in getting the outlets opened by the gatekeepers for given irrigation turns (Table 22). For most farmers the time required was about one to two hours; 25 percent of the farmers on the

Table 21. Farmers' estimates of time to acquire an irrigation pass after application is made

Estimated Time to Acquire Irrigation Pass	Percent of Farmers Responding: Improved System (n = 21)	Percent of Farmers Responding: Unimproved System (n = 30)
Immediately	19	7
1-2 days	24	27
3-4 days	24	34
5-7 days	14	13
8-10 days	5	13
11-13 days	5	--
14-17 days	10	3
Over 17 days	--	7

Table 22. Farmers' estimates of time required to get outlets open for irrigation for Kharif and Rabi seasons

Estimated Time Required to Get Outlets Open	Percent of Farmers Responding			
	Improved Warabundi System (n = 21)		Unimproved Demand System (n = 31)	
	Kharif	Rabi	Kharif	Rabi
Immediately	0	0	6	3
"Few minutes"	29	29	10	16
1 to 2 hours	62	52	23	35
3 to 4 hours	9	19	0	16
1 to 2 days	--	--	6	6
2 to 3 days	--	--	13	10
More than 3 days	--	--	6	0
Varies greatly and don't know	--	--	32	13

unimproved system reported that it often took from one to two or even up to three days or more to get gates opened. Others reported that there was great variation. Field investigations revealed that the gatekeepers were often not at their posts where the farmers could contact them. When such a problem exists, farmers usually open and close the gates themselves. Two farmers showed investigators a crude key or lever they had made to open and close the outlet at will at gates. Farmers reported that less time was required to get the gates open for water deliveries on the improved system than on the unimproved system.

Farmers also estimated the time usually required for water to reach their fields after their demand for water or _warabundi_ turns, and the time it took water to reach their fields once the outlets were opened (Table 23). About 40 percent of the farmers reported that after their initial demand for water (on the unimproved system) or their turn on the _warabundi_ system (improved system), water was provided quickly. Because a large percentage of farmers for both systems reported a delay of one to several days, some serious procedural problems existed. Further investigations are needed to evaluate this problem in detail. Field investigators did find some cases where powerful farmers were destroying conveyance channels or inhibiting smaller farmers from receiving water, possibly due to land and water disputes or for other reasons.

Most farmers received water on their fields within about one hour after the outlets were opened (Table 23). A major exception to this included about 60 percent of the farmers on the unimproved system where the conveyance channels were in a poor state of repair or maintenance.

The estimated median time for farmers to irrigate a _bigha_ of land (0.2 ha) from the canal system for farms on the improved system was 3 and 2-1/2 hours for _Kharif_ and _Rabi_ seasons, respectively. The range for the _Kharif_ season was 1 to 4 hours and for the _Rabi_ season 1/2 to 4 hours. The time to irrigate a field depends on many factors such as the levelness of the field, the care of the irrigation, and the available head of water, which varies with distance from the source and conveyance losses. The median time for head farmers to irrigate a _bigha_ from the canal system was 2 hours for both _Rabi_ and _Kharif_ seasons; for middle and tail farms on the improved system the median times were 1-1/2 hours for the _Kharif_ season and 3-1/2 hours for _Rabi_ season. The range in time required was 1-1/2 to 3 and 1-1/2 to 4 hours for head farms in _Kharif_ and _Rabi_ seasons, and 1 to 20 hours for middle and tail farms for both seasons.

Field observations suggested that it took longer for a typical irrigation on most tail farms on the unimproved systems than on the improved systems. For example, the reported time to irrigate a _bigha_ on the unimproved system averaged 5-1/2 hours with a median of 2 hours and a range of 1 to 38 hours. Three farms located at the tails of the system averaged 24 hours and one averaged 48 hours.

After an irrigation was completed, farmers reported that the gate was usually closed in less than 30 minutes. However, the common practice was for the irrigator rather than the gatekeeper to close the gate, and in a few instances much water was wasted due to lack of prompt closing of the outlet gate.

Table 23. Farmers' reports of the water control situation for improved and unimproved systems by *Kharif* and *Rabi* cropping seasons

Question	Improved *Warabundi* System (n = 21) Kharif	Improved *Warabundi* System (n = 21) Rabi	Unimproved Demand System (n = 25)[1] Kharif	Unimproved Demand System (n = 25)[1] Rabi
1. Time required for water to reach farm after initial demand for water or Warabundi turn begins				
a) Immediately	38	38	44	44
b) Less 1 hour	5	5	--	--
c) 1-2 hours	5	5	--	--
d) 2-3 hours	5	5	--	--
e) 1 day	24	29	12	20
f) 2 days	24	19	24	15
g) 3 days	--	--	12	12
h) 4 days	--	--	--	4
i) 5 days	--	--	8	4
2. Time required for water to reach field after outlet is opened				
a) Few minutes (less than 30 min.)	10	5	26	10
b) 30 min. to less than 1 hour	62	67	16	23
c) 1 to 2 hours	18	18	48	61
d) More than 2 hours	10	10	10	6*
3. Estimated time to close outlet after irrigation turn is completed				
a) Immediately	71	71	35	48
b) Less than 30 min.	19	19	10	20
c) Varies on who closes outlet, chowkidor or farmer			42	9
4. Times take irrigation water at night (*Kharif* and *Rabi*)				
a) Never	57		68	
b) Sometimes**	33		26	
c) No report	10		6	

*2 farmers reported 24 or more hours.
**Usually *Rabi* season--those who report state 2-3 times per season.
[1] For Question 4, n = 31 on the unimproved system.

When asked if they take extralegal water at night when the gatekeepers are off duty, more than 25 percent of the farmers said they open the gates and take water "sometimes" at night, which is to be expected on a system with loose discipline (Table 24). More than 60 percent of the farmers reported that they "sometimes" or "often" take water on unauthorized turns and that stealing of water occurs. Farmers of both systems reported opening the outlet gates because the gatekeepers were often not available at the time required. They also noted that powerful farmers used their influence on gatekeepers to get extra water. Only on the unimproved system did farmers report illegal outlets, which field investigations later confirmed.

From 20 to 30 percent of the farmers reported that some farmers pay low water rates for high-rate crops. For example, a farmer could pay the low irrigation rates for wheat and actually use the water for tobacco, a high-rate crop.

Taking water out of turn appeared to be a bigger problem on the improved system than the unimproved system. Also, about 30 percent of the farmers on the improved system and 60 percent of the farmers of the unimproved system reported destruction of watercourse structures. Some cases reported large farmers destroying structures and conveyance channels so that small farmers could not receive canal water. Likewise, farmers of both systems reported some destruction of minor canal structures. One irrigation official cited several accounts over the last five years where check structures were damaged as well as outlet gates. The iron gates and checks often were stolen to sell for scrap iron and metal.

In summary, extralegal activities between the improved and unimproved systems differed very little. The enforcement of water control regulations on both systems needs to be greatly improved; when a system was not functioning well to provide water control, farmers used almost any means to get water even if it could hurt them in the long run. Because many farmers reported "not known" to many types of extralegal activities, they probably did not feel free to respond otherwise.

c. Water Control Problem Situations

Farmers confronted by a system which does not provide adequate water control indicated they would find ways to manipulate the system to get needed water (Table 25). When asked what they would do if someone took part of their water on a given irrigation turn, some farmers said they would inform the chowkidar, others would quarrel or get into conflicts with other farmers, and about 30 percent would simply do nothing or go without water. On improved and unimproved systems, 30 and 49 percent of the farmers reported that when a powerful farmer takes their turn, they "do nothing" or "let him take the water." Marginal and small farmers on both systems reported that due to the power of some larger farmers, they simply go without water for that particular turn.

If the outlet were not opened or needed to be closed after an irrigation, most farmers said they would either do the job themselves or inform the chowkidar. Evidently this is a bigger problem on the improved system; farmers said their usual practice would be to close the outlet gates themselves if the chowkidar had not closed the gate after an irrigation.

Table 24. Farmers' reports of unauthorized irrigations and other extralegal activities

	Percent of Farmers Responding				
Type of Activity	Never	Sometimes	Often	No problem	Not Known
Improved Systems (n = 23)					
1. Taking unauthorized turns	4	52	8	26	10
2. Stealing water	9	48	9	9	26
3. Farmer opening of gates	0	43	22	9	26
4. Using influence on gatekeepers	17	35	0	9	39
5. Installing illegal outlets					
6. Paying lower crop units while receiving water for higher rate crops	4	30	0	9	56
7. Taking water out of turn	9	30	0	4	57.
8. Destroying watercourse structures	13	26	4	0	57
9. Destroying structures on minor	13	26	4	0	57
Jnimproved Systems (n = 29)					
1. Taking unauthorized turns	28	59	14	-	-
2. Stealing water	34	52	14	-	-
3. Farmer opening of gates	48	24	28	-	-
4. Using influence on gatekeepers	55	38	7	-	-
5. Installing illegal outlets	69	31	-	-	-
6. Paying lower crop rates while receiving water for higher cost crops	79	21	-	-	-
7. Taking water out of turn	86	10	4	-	-
8. Destroying watercourse structures	41	55	4	-	-
9. Destroying structures on minor	97	3	-	-	-

Table 25. Farmers' responses to specific water problem situations on improved and unimproved farm systems

Water Problem Situation and Farmers' Responses	Percent of Farmers Responding: Improved System (n = 21)	Percent of Farmers Responding: Unimproved System (n = 29)*
1. If someone takes part of your water on a given irrigation turn?		
a) Inform chowkidar	--	24
b) Quarrel or conflict	14	17
c) Take his water	--	3
d) Settle by discussion	--	3
e) Do nothing or go without water	29	34
f) "Happened often"	17	--
g) No problem	40	19**
2. If outlet not fully opened?		
a) Inform chowkidar	43	58
b) Open outlet myself	48	38
c) Do nothing	--	4**
d) No problem	9	--
3. If outlet not opened by chowkidor as often as requested?		
a) Report to chowkidar or his superior (karkoon)	29	24
b) Open outlet myself	29	14
c) Do nothing	--	17**
d) No problem	19	45
e) No report	23	--
4. If many farmers demand water at the same time?		
a) By turn or by warabundi fixed for improved system	48	31
b) Group discussion		24
c) Powerful decides	5	3
d) Group conflict occurs		10
e) Chowkidar decides	14	21
f) Do nothing, take water lost, or take tubewellwater		7
g) No problem	33	3
5. If outlet not closed after requesting chowkidor to close it?		
a) Close outlet self	67	79
b) Inform chowkidar	5	0
c) Do nothing	0	3
	10	18
	18	

Table 25. (Continued)

Water Problem Situation and Farmers' Responses	Percent of Farmers Responding: Improved System (n = 21)	Percent of Farmers Responding: Unimproved System (n = 29)*
6. When a powerful' farmer takes your turn?		
a) Fight/conflict	--	7
b) Take his water	--	10
c) Do nothing, let him take it	30	49
d) Inform chowkidar	14	3
e) No problem	23	31
f) No report	33	--
7. If distributory level not running full for your turn?		
a) Inform chowkidar	29	59
b) Wait until it is full	29	21
c) Take tubewell water		7
d) Take what water is available		7
e) No problem	23	7
f) No report	19	--
8. When your turn runs dry due to closures?		
a) Inform section officer	--	14
b) Inform chowkidar	29	3
c) Take tubewell water	10	24
d) Wait and take canal water	10	14
e) No problem	24	41
f) No report	17	4
9. If irrigation application not processed quickly or sanctioned?		
a) Inform irrigation officials	19	10
b) Do nothing or wait	10	7
c) No problem	19	83
d) No report	52	--
10. If you need extra irrigation water and due to arrears in revenue have no pass?		
a) Request chowkidar for extra water	14	14
b) Take Tubewell water	81	38
c) No problem	5	48
11. If minor irrigation official requests a free gift of cash or kind?		
a) Pay	--	3
b) No problem or not known	38	97
c) No report	62	--
12. If water revenue charge not correct?		
a) Inform Talati for correction	33	31
b) Inform Deputy Engineer for correction	--	28
c) Wait and it will be adjusted	14	3
d) Do nothing	5	3
e) No problem	19	3
f) No report	29	32

*One marginal farmer reported his watercourse was destroyed by a powerful farmer in 1979; two marginal farmers got to canal water and one marginal farmer gave no report.

**Those reporting "do nothing" were marginal farmers on watercourses dominated by powerful farmers.

If several farmers demanded water at the same time, farmers would decide who goes first in several ways. Most farmers would use the warabundi turn system in which the chowkidar decides. This response was less common on the improved than the unimproved system.

If the distributary or minor were not running full for their turn, farmers said they would either inform the chowkidar or wait until the level was adequate. Field studies noted that, to check up the water level for a given outlet, the chowkidar released more water or the farmers operated the cross regulators or placed debris in culverts or siphons on the minor. Again, the problem seemed more common on the unimproved than the improved system.

If a turn ran dry due to a closure of the canal and minor, farmers said they would inform the irrigation authorities and take private tubewell water until canal water was available. The tubewells provide a type of insurance or backup system to farmers though the cost of tubewell water is high.

If irrigation applications were not processed quickly, farmers would either inform the irrigation authorities or wait. This problem was minor for most farmers, with over 50 percent of the farmers on the improved system giving "no report" of the problem.

Farmers do not get a new seasonal pass for canal water if their accounts are in arrears. Nevertheless, if denied passes, a few farmers said they would pressure or influence the chowkidar to provide extralegal water. Most would rely on the private tubewell water to meet their needs.

Farmers had ways of influencing minor irrigation officials, even though some farmers did not respond to this question or simply reported "no problem" or "not known." Several major irrigation officials indicated that farmers offer bribes and tips to gatekeepers, chowkidars, and karkoons to receive extralegal water and to get their pass applications sanctioned judiciously. Again 62 percent of the respondents for the improved system chose to not answer this question.

If there were an error in the water revenue charges, most farmers would inform the irrigation authorities and correct the error. Evidently this was not a serious problem for most farmers.

In conclusion, farmers, when confronted by problems, would attempt to solve them through either legal or extralegal means. If the system were not providing adequate water control, farmers would seek and find ways to get the required water. Usually the larger and more powerful farmers could solve these problems, while the marginal and smaller farmers would suffer.

Designing a system which in practice provides water on an equitable basis to all farmers is difficult. Adequately implementing the warabundi mechanism used on the improved system would resolve most of the problems discussed for all classes of farmers. However, the warabundi as an organization must also be supported by a technical system which provides more water control than the one in place on the Mahi-Kadana improved farm system.

d. Water Control and Regular Maintenance

Efficiently delivering water also requires regular maintenance of the main watercourse conveyance system. On both systems farmers indicated that, since the government had built the system, it should maintain the system on a regular basis. Field investigations revealed that the main watercourse system was poorly maintained, and that in some cases powerful farmers had destroyed sections of the watercourse. On the 02/L system a section of roughly 200 feet was no longer in use.

Table 26 shows that no formal association existed on either farm system, indicating a major problem. Irrigation and CADA personnel thought regular maintenance should be the farmers' responsibility. On the other hand, farmers thought maintenance should be the Irrigation Department's responsibility. To date this situation has not been resolved, and regular and adequate maintenance is almost nonexistent.

Farmers on the unimproved system cleaned their own sections of the main watercourse collectively. Cleaning took place about once each season on both systems. About 35 percent of the farmers on the improved system and 15 percent on the unimproved system reported hiring labor at an average cost per cleaning of about Rs 200. The average man-days for cleaning was about 7 to 10 man-days. Evidently most farmers were not satisfied with the frequency of cleaning, but when the watercourse was cleaned on a seasonal basis, most farmers were satisfied with the quality of work. Field investigators judged the quality of cleaning and maintenance as poor to very poor.

Discussions with three village Panchayat indicated the need for formal, legally authorized associations for farm water users to handle regular maintenance, water disputes, and improvements. The village council (Panchayat) members agreed that the organizations should be legal, provided with incentives for the operation and maintenance of the farm system, and possibly run by a committee representing local watercourse groups. To date farmers are not being given adequate incentives to become involved in the operation of the farm system. Farmers usually will not organize until there are substantial benefits, such as improved water control, and incentives and technical assistance. One possible approach, initiated in Thailand, returns a percentage of water revenue to water user associations for installing watercourse structures and providing for regular maintenance. Of course, no solution to this problem can be reached if the irrigation authorities and the farmers simply continue to blame each other and assume that the other party is responsible for cleaning and maintenance.

e. Irrigation Behavior and Cultural Factors

The major cultural factors influencing a farmer's irrigation behavior are power, norms or "rules of the game," rewards and sanctions, and beliefs or knowledge. In terms of beliefs, farmers believed that the optimum number of irrigations for the following crops is (Table 12):

Table 26. Farmers' reports about main watercourse cleaning[1]

Item	Percent of Farmers Responding: Improved System (n = 20)	Percent of Farmers Responding: Unimproved System (n = 29)
1. Existence of Watercourse Committee		
a. Formal	0	0
b. Informal	90	93
c. None or don't know	10	7
2. Method of Cleaning/ Maintenance		
a. Each farmer cleans a section in proportion to irrigated area		85
b. Collective cleaning by farmers on given days	60	
c. Collective cleaning by farmers when asked by irrigation officials	5	
d. Farmers collect funds to pay labor for cleaning	35	15
3. Regularity of Cleaning Each Season		
Kharif		
a. None	0	3
b. Once	70	90
c. Twice	25	7
d. More than twice	5	-
Rabi		
a. None	20	45
b. Once	75	41
c. Twice	5	11
d. More than twice	-	-
4. Satisfaction with Frequency of Cleaning		
a. Yes	20	41
b. No	80	52
c. Not sure	0	7
5. Satisfaction with Quality of Cleaning		
a. Yes	100	93
b. No	0	0
c. Not sure	0	7

[1] The costs of cleaning were a mean of Rs 199, a median of Rs 200, and a range of Rs 64-400. The number of man-days per cleaning for the unimproved system was a mean of 9.5, a median of 7,and a range of 4-30.

Paddy	- 6	irrigations,
Local Tobacco	- 4-5	irrigations,
Improved Tobacco	- 5-8	irrigations, and
HYV sow wheat	- 7	irrigations.

Agreement of these beliefs with actual practice or scientific findings is questionable. Second, farmers also believed that tubewell water, in terms of temperature, salinity levels, and fertility, was better quality than canal water (Table 18). Third, farmers believed that the CADA improvement activities were poor and they lacked confidence in government works (Table 18).

Fourth, another important set of beliefs was that crops' roots are shallow and that water shallowly infiltrates soils. Farmers knew little about deep rooting systems of crops or return flow of water to the ground sources. Yet, most farmers knew that plants get water from their root systems. A few (7 of 57) farmers said they did not know how plants uptake water. Fifth, when asked about the major sources of losses of water from the outlets to final application to their fields, farmers could not estimate the magnitudes of these losses.

Sixth, farmers also believed strongly in the local proverb that "right is might." Less powerful farmers reported doing nothing if powerful farmers took their water (Table 25). Powerful farmers reported they would fight or take other farmers' water when they try to go ahead in a turn. In one incident in a village where watercourse command areas were dominated by a high-caste Patel family, a scheduled caste farmer stole water from another farmer during a night irrigation. About 50 Patel farmers with lathis went to the violator and threatened to beat him to death if there was ever another offense against a fellow Patel. Such norms strongly influence a farmer's actions, but the powerful can often ignore local values at will.

Seventh, farmers falsely believed that their fields were level enough for adequate irrigation and would change their view only by seeing the visible benefits of precision leveled fields. All fields surveyed by the engineers exceeded by several magnitudes the specifications for acceptable leveling for good water management.

In terms of rewards and sanctions. incentives for improving farmers' irrigation behavior and adequate enforceable laws and codes for more efficient operation of the system were lacking. The investigation of complaints about a particular canal chowkidar found that his low caste position was the major reason he was not liked by higher caste groups of farmers.

Cultural variables also include power and influence of other farmers on a given system or in a village. Those who have power either through status from a large powerful family or a high caste position can violate local norms almost at will and use their position with government authorities. Major and minor irrigation officials reported that the elite used politicians to influence decisions. This practice is common in most irrigation systems around the world.

Farmers were asked to rank the power and influence of each member on the sample watercourses in relation to operation of the farm irrigation system. Operation of the system referred to cleaning and maintenance, settling disputes, and organizing farmers for collective action such as improvements. Since cleaning and maintenance activities were generally poor, farmers could potentially engage in collective action. However, until irrigation authorities provide more technical assistance to improve water control and officially encourage farmers to develop viable water users associations, such organizations probably will not emerge.

Table 27 shows how farmers rated the relative power of all the farmers in the command studies and the relative power of themselves. Each farmer assigned a rank to all other farmers on a given watercourse: 0 = no influence; 1 = little influence; 2 = some influence; and 4 = very much influence. The actual influence score obtained by a given farmer was computed by summing the scores judges gave to each farmer. Each farmer influence score was then "normed" relative to all other scores by calculating its percentage of the potential score (highest possible score is achieved when all judges award the value of 4 to a given farmer). Table 27 shows that the distribution of scores was fairly normal, and sample farmers did not attribute high scores to themselves.

Power/influence is usually related to the size of land holdings and religious caste position. Table 28 shows the relative power that sample farmers attributed to all farmers on the study watercourses according to farm size and caste. The medium-large size farmers had average and median power/influence scores only slightly higher than the other size classes. In terms of caste position, the number of Brahmins, Kristis, Valands, and Dixits on the watercourses was small. Farmers felt the Brahmins had the most power. The Valands, Kristis, Dixits, and Jadavs represented the lower castes. In some cases, Patels and Ghahils had much more power than Brahmins.

To intervene and gain cooperation from farmers on a particular watercourse, one should know if power/influence is centralized in a few individuals or fairly equally distributed. Centrality of power is one measure that tells what percentage of farmers on a given watercourse scores some specified amount (i.e., 80% or 50%+) of the potentially highest influence score. Obviously, farmers who score 80%+ of the potential score are more "central" in the watercourse decision network than are farmers who score 30%+ of the potential. Table 29 shows the percent of farmers on the watercourses who received 80%+ and 50%+ of the highest possible score.*

* To compute centrality scores, refer to D.M. Freeman, M.K. Lowdermilk, and A.C. Early. 1978. Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan, Vol. VI, Appendix 2. Water Management Technical Report No. 48. Colorado State University, Fort Collins. 319 pp.

Table 27. Farmers' power/influence scores for all farmers on all sample watercourses

Power/Influence Level Categories	Percent of Farmers Responding			
	Score for all Farmers from Sample Watercourses		Score for Sample Farmers	
	Number	Percent	Number	Percent
0-5*	7	3.3	0	0
6-10	5	2.4	5	13.2
11-15	14	6.7	3	7.9
16-20	44	21.1	10	26.3
21-25	54	25.8	11	29.0
26-30	17	8.1	4	10.5
31-35	34	16.3	3	7.9
36-40	2	1.0	0	0
41-45	9	4.3	0	0
46-50	3	1.4	0	0
51-55	5	2.4	0	0
56-60	2	1.0	0	0
61-65	7	3.3	0	0
66-70	0	0	0	0
71-75	3	1.4	1	2.6
76-80	0	0	0	0
81-85	2	1.0	0	0
86-90	0	0	0	0
91-95	1	.5	1	2.6
96-100	0	0	0	0
	209	100.0	38	100.0

* Seven farmers (3.3%) were judged to have an influence score between 0 and 5% of the highest score possible.

Table 28. Sample farmers' power/influence scores according to farm size and caste position

Farm Size and Caste	N	Sample Farmer Power/Influence Scores		
		Average	Median	Range
Farm Size (hectares)				
Marginal (< 1 ha)	33	24.5	25	8-53
Small (1-2 ha)	4	20.5	17	16-25
Medium-Large* (2-5 ha)	90	26.1	27	0-92
Caste Position and Rank				
1. Brahmin	2	40.5	—	28-53
2. Ghahil	10	32.6	25	17-70
3. Parmar	20	28.2	25	13-63
4. Patel	72	27.3	25	0-92
5. Jadav	13	22.7	25	8-33
6. Dixit	5	18.0	13	13-38
7. Kristi	1	13.0	13	—
8. Valand	4	11.7	11	0-25

* Only two farmers had holdings over 5 hectares.

Survey results indicated that a few farmers have a lot of power/influence (watercourses 5/L, 02/L, and 11/L), but that the majority have much less. Most farmers received 50%+ of the highest potential score, particularly those in the unimproved systems. On watercourses 02/L, slightly more than one-third of the farmers scored higher than 50%+. The centrality scores indicate that power/influence was fairly equally distributed along each sample watercourse.

Equality (concentration) of power/influence is a measure that defines the extent to which power/influence is distributed equally among farmers in the watercourse network. This score answers the following questions: if one proceeds downward from the top of a ranked frequency distribution of farmer power/influence scores, how many farmer scores does it take, when summed, to equal or exceed 50 percent of the sum of all scores?*

Table 29 shows that power was least equally distributed on watercourses 10/LA and 12/L, where only 22 and 20 percent of the scores made up 50 percent of the total power/influence scores. On these watercourses, one

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* To compute equality scores, refer to D.M. Freeman, M.K. Lowdermilk, and A.C. Early. 1978. Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan, Vol. VI, Appendix 2. Water Management Technical Report No. 48. Colorado State University, Fort Collins. 319 pp.

Table 29. Power/influence centrality and equality scores by sample watercourses

Type of System and Outlet Number	No. of Total Farms	No. of Sample Farms	Percent of Farmers: Centrality Score* 80%	Centrality Score* 50%+	Equality Score**
Improved Systems					
5/L	29	8	3	10	38
4/RA	34	8	0	9	44
11/RA	15	8	0	13	40
	78	24	1***	9	41
Unimproved Systems					
02/L	29	10	7	34	24
11/L	24	6	4	8	37
10/LA	9	6	0	22	22
12 L	15	2	0	15	20
	77	24	4	20	29
TOTALS	155	48	3	14	36

* Centrality score is percent of all farmers who receive 80%+ and 50%+ of the potential highest score.

**Equality scores equal the number or percent of ranked top scores which are required to account for 50% of the sum of all scores attributed by sample farmers.

***1% of 78 farms on improved systems had centrality scores of 80%+.

should approach such individuals to organize collective improvement activities.

Table 30 shows the relative power of caste groups on the sample watercourses. On 5/L the *Parmars* had high power/influence scores, but the *Patels* had more total power due to a larger number of farmers. Because total power of a group (power scores plus frequency of caste membership) is important, anyone working with farmers should assess the distribution of caste membership as well as the power index score mentioned here. The *Patels* had the most power, relatively, on 4/RA, 11/L, 02/L, and 12/L, because of both their caste position and total holdings. On 11/RA, however, the *Parmars* had more relative power and influence.

Table 30. Average power/influence scores of caste groups of farmers on each sample watercourse command area

Caste Groups	Farmer's Power/Influence Scores by Outlet Number													
	5/L		4 R/A		11/RA		11/L		02/L		10/AL		12/L	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Brahmin	--	--	2	40	--	--	--	--	5	13	--	--	--	--
Ghahil	--	--	--	--	--	--	2	25	--	--	8	34	--	--
Parmar	3	35	11	25	7	30	--	--	--	--	--	--		
Patel	24	23	23	28	6	23	9	38	24	46	--	--	7	34
Jadav	--	--	--	--	--	--	12	24	--	--	1	4	--	--
Dixit	--	--	--	--	--	--	--	--	--	--	--	--	4	15
Kristi	1	13	--	--	--	--	--	--	--	--	--	--	--	--
Valand	1	9	--	--	--	--	1	25	--	--	--	--	2	6
Total	29		34		15		24		29		9		13	

6. Conclusions and Recommendations About Factors Influencing Farmer Behavior

A major benefit of the Diagnostic Analysis model of training is the trainees' collection of empirical field data on systems operation. These data have several important uses. First, the data provide an understanding of how the system operates and the key constraints on improving it. Second, they facilitate understanding of the problems and their causes, which is the first step in finding solutions. Third, they serve as the basis for a number of direct solutions that evolve from the diagnostic analysis process itself. Fourth, they can be used as benchmarks to evaluate improvement programs. Fifth, they can be used by policy-makers and project managers for planning purposes.

The major conclusions and recommendations from the extension data are:

(1) Currently farmers on both improved and unimproved systems are not receiving help on how, when, and how much to irrigate crops.

(2) Extension activities are weak on both systems. The Training and Visitation system of extension needs to include water management as part of its program to improve crop production.

(3) Farmers on both systems using gravity irrigation have water control problems associated with operational procedures, design and construction, position of conveyance channels, and levelness of fields. Improved location and elevation of channels, precision land leveling, and watercourse structures are needed to solve these problems.

(4) Farmers need technical help, services, or incentives to organize water user associations for regular maintenance of the farm system. Farmers will organize only if they receive assistance and legalized incentives, and if they perceive the benefits of improved water control. The Panchayat indicated interest in playing a role in water management improvement, but the Panchayat and the irrigation authorities do not communicate with each other.

(5) Farmers feel that the irrigation authorities and CADA programs are too authoritative and paternalistic. Present levels of satisfaction with CADA activities and the credibility of the government staff are low and need improvement.

(6) Farmers realize the value of water. Most are willing to pay seven to nine times more for private tubewell water than for the public canal water because they receive predictable supplies and can control the water.

(7) Few differences in cropping intensities, services available, technologies used, and crop yields exist between the farms of the improved versus the unimproved systems. Thus, the CADA should both intensify and improve the quality of improvement activities, with a focus on improved water control.

(8) Both systems currently operate with a low level of discipline. In such environments, farmers with power and influence most often gain at the expense of the small and weak farmer.

B. Major and Minor Irrigation Official's Perceptions of Operation of the Irrigation System in the Mahi-Kadana Project of Gujarat State, India

1. Introduction

As part of the analysis of the irrigation system below the government outlet, diagnostic analysis exercises included structural interviews with five minor irrigation officials and six major officials. The purpose was to document their perceptions of system operation and their views of how the management of the system could be improved.

2. Methods

After reviewing available literature, hearing overview lectures by officials working in the area, and conducting informal interviews with farmers and officials in a five-day reconnaissance exercise, the teams developed interview schedules dealing with key operational issues. The reconnaissance findings guided the development of questions and pre-testing of schedules. Six major officials received the questionnaires in English 7 to 10 days prior to the personal interviews. Five minor officials were interviewed in Hindi by two of the workshop staff; information was cross-checked and compared for accuracy with other data available through field observations and interviews with 33 randomly selected farmers, conversations with other officials, and outside sources of information. The sample of all the minor officials on three watercourse command areas included 25 percent of the chowkidars, 50 percent of the karkoons, and the only section officer on the one minor system.* Since the total number of respondents was only 11, a simple, descriptive analysis is provided here.

3. Minor Irrigation Officials and Operation of the Irrigation System

a. Profile of the Minor Officials

The minor officials included two chowkidars, two karkoons, and one section officer. The duties of the chowkidars include receiving farmers' daily demands for water and reporting to the karkoons, opening and closing four to five outlets along the distributory, and helping farmers submit applications for water every season. The karkoons supervise the chowkidars, raise and lower the check structures, grant irrigation passes, detect damages to structures and unauthorized irrigations, recommend to the section officer fines and other sanctions for farmer infractions of rules, prepare water demand accounts every 15 days, and check structures and distributary banks.

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* All of the minor officials located on the three improved systems were not interviewed because time did not permit during the intensive training program.

b. Duties of Section Officer

The duties of the section officer include: collecting demand notices and providing deputy engineers with the water demand accounts, monitoring canals and distributing water, inspecting major structures, supervising karkoons, and evaluating the work performance of other minor officers.

Due to a shortage of full-time chowkidars, only 5 of 10 on one distributory investigated were permanent staff. Of the two interviewed, one was a farmer hired on a monthly basis during the non-monsoon period, and the other was hired on a work charge or year-to-year basis without pension or other compensation.

c. Years of Service, Family Size, and Education

The two chowkidars had an average of 12.5 years of service. The two karkoons had an average of 9.5 years of service, while the section officer had 25 years of service coming up through the ranks.

The average family size of the five minor officials was five persons, and the average amount of formal education was about 10th grade. The two chowkidars averaged 7th grade education, the karkoons 12th grade, and the section officer 13th grade.

d. In-service/On-the-job Training and Promotions

Only the section officer had received training which included four months of theory and nine months of practical training on the job.

The only promotions from lower positions were of one karkoon from the position of chowkidar in 1975, and of the section officer from a technical assistant position in 1965.

e. Special Facilities, Incentives, and Salary

While no facilities were provided for the temporary chowkidars, the karkoons had a house, medical coverage, and a travel allowance.

Table 31 shows the salary levels per month reported by each minor official. In terms of inflation over a 10- to 15-year period and the job responsibilities, these salaries appeared low; however, compared to the salary levels of agricultural extension workers with a Bachelor of Science degree (about Rs 500-650), these salary levels seemed adequate. The highest salary possible under current (1981) scales for the work charge chowkidar was Rs 450/month. The highest salary available for karkoons was Rs 705/month, and for the section officer Rs 976/month.

Table 31. Salary levels per month reported by each minor official

Position	Monthly Salary (Rs) Starting	(Year)	Present	(Year)
A. Work Charge *chowkidar*	90	(1973)	402	(1981)
B. Monthly *chowkidar*	90	(1968)	195	(1981)
C. *Karkoon* I	147	(1967)	607	(1981)
D. *Karkoon* II	563	(1976)	650	(1981)
E. Section Officer	225	(1956)	976	(1981)

Although the two *chowkidars* interviewed did not want to sound negative about their performance of duties, all minor officials agreed that farmers used pressure and threats to get more water either legally or illegally, that farmers took water illegally, and that allocation problems existed when two or more farmers demanded it simultaneously (Table 32). These perceived problems also appeared to be constraints in farmers' and major officials' interviews. Two of the five minor officers said large landlord politicians often threatened to report them to higher offices or use their connections with other politicians to get water.

f. Information flows and decision-making process from the farmer to the release of water from the reservoir

In theory the farmers with irrigation passes report the water demanded to the gatekeeper *chowkidar* who is to be at a stipulated place on the distributory on a daily basis. This information is then relayed to the gatekeeper/*karkoon* at the distributory gate on scraps of paper or verbally. The *karkoon* rides a cycle 10,000 feet to a canal department phone and reports to the canal office; daily estimates are made and communicated by phone each day at 6 p.m. to 8 p.m. to the gatekeeper on the main canal system. The section officer receives the daily demands from the *karkoon*, prepares a demand schedule, and reports the demands for the next day to the deputy engineer. The methods of communication are verbal with scraps of paper provided to the distributory gatekeeper. The gatekeeper/*karkoon* enters the demands in a register, and he or the section officer reports to the deputy engineer or to the executive engineer by phone.

In practice, however, farmers often go directly to either the distributory gatekeeper or the section officer who reports to the canal office. Canal Department phones are usually out of order for periods during the monsoon rains, at which time the public phone system is used. When both fail, someone must walk or find a ridge next to the reporting center. In discussions, the section officer stressed the need for a reliable, portable, communication system to improve communications for better operation of the system.

Five minor officers reported specific ways certain types of information are communicated from the Department to farmers (Table 33). Both major officials and farmers indicated that the current systems of communication to the farmers were greatly inadequate. Word-of-mouth was often used, and the few notices in the press were seldom read. Panchayat leaders and farmers reported that the notices, supposed to be placed on the village Panchayat bulletin board, often were not there. Obviously there was considerable disagreement between minor officials about the information methods or channels used to provide information to farmer users.

Table 32. Major problems perceived in the performance of minor officials duties

Type of Problem	Minor Officials Reporting Problems*	Number of times Reported
A. Departmental Problems		
1. Salary not adequate	A,B,C,D,E	5
2. Work load heavy	A.B,C,D,E	5
3. Better facilities	A,C,D	3
4. Training needed	C,D,E	3
5. Better phone system	D,E	2
B. Local Problems (Large Landlords and Farmers)		
1. Pressure and threats on chowkidars	A,B,C,D,E	5
2. Beating of chowkidars	C,D,E	3
3. Taking water illegally by farmers	A.B,C,D,E	5
4. Large landlord threats	C,D,E	3
5. Destruction of structures	C,D,E	3
6. Stealing metal gates by outsiders	C,D,E	3
7. Who gets water first among farmers	A.B,C,D.E	5
8. Opening gates at night by farmers	C,D,E	3
9. Farmers who won't file water applications	D,E	2

* A = Work charge chowkidar.
B = Monthly chowkidar.
C = Karkoon I.
D = Karkoon II.
E = Section Officer.

Table 33. Canal Department-to-farmer communication methods

Type of Information	Frequency of communication method used: Verbal by Chowkidar when they get an application for water	Written Notice on Bulletin Board at Village Office	Media	Word of Mouth by Farmers	No Fixed Procedure
Closure of system for cleaning, maintenance, etc.	2	4	-	1	
Rationing of supplies	-	1	-	1	4
Advance notice of expected seasonal supplies	-	2	1	-	4
Policy or rule changes by Department	1	2	2	1	2
Rotation schedule	2	2	1	-	3
When farmers need water above scheduled demand	2	-	-	-	6

The minor officials were asked to state the frequency of selected types of unauthorized practices by the farmers (Table 34). They estimated that farmer opening of outlet gates to acquire unauthorized water occurred about 10 percent of the time; observations indicated that this was a conservative estimate. Minor officials also reported that farmers using pumps or siphons also stole water from the minor about 10 percent of the time. In addition, they said 10 percent or more of the farmers took water beyond their allotted turn time and that at least 20 percent paid lower crop irrigation fees but used water for high-rate crops. The investigators observed that at every culvert or siphon on one distributary farmers were checking-up water by throwing in wood and banana stalks for greater discharge at outlet gates.

Table 34. Reports of five minor officials about the major types of unauthorized ways farmers attempt to take water

Unauthorized Ways Farmers Take Water	Frequency Much	Sometimes	None
1. Farmers open gates			
Night		5	
Day		5	
2. Farmers steal water from minors or canals		3	2
3. Farmers take water beyond turn time		5	
4. Farmers trade canal water for tubewell water or vice versa		1	4
5. Farmers operate cross regulators or block distributory to check-up water		4	
6. Water allowed to flow from unclosed outlets when no one is using water		4	1

Minor officials also were asked to report the usual action taken regarding several problem situations (Table 35). This information suggests that the system of operation and maintenance was quite loose. To implement the panchnama or fine, two witnesses must be found, which is often difficult. In terms of damage to gates and structures in the last three years, the iron gates at the Branch Canal were stolen five times. In 1980, one minor check structure was taken, but over the last 12 years 18 or more structures have been stolen and sold as scrap metal. All the brass nuts on earlier outlet gates were stolen due to the high value of brass. Some illegal pipes had also been placed in the minor banks, and two minor officials confirmed that two or more such cases occur each year.

Other damages to the system resulted from cattle, carts, and tractors damaging minor canal banks and roads especially during the monsoon season when roads and canal banks are in a moist, fragile condition.

Table 35. Water problem analysis and usual action taken

Problem Situation	Usual Action	Times Reported
1. When several farmers demand water at the same time	Tell supervisor	1
	Close gates until they cooperate	1
	Section officer intervenes	1
	Try to explain and get cooperation	4
2. When powerful farmers demand special privileges	Supply water	3
	Make them understand	1
	Call in higher official	1
3. When farmers open gates at outlet	Nothing/overlook	3
	Issue panchnama for fine if possible	2
4. When farmers do not close gate at outlet at proper time	Detect and close	1
5. When farmers damage outlets or structure	Karkoon gives panchnama	1
	Inform higher official/police	
	Nothing	1
6. When minor level of water drops	Raise level	2
	Karkoon regulates	1
	Informs supervisor	1
7. When farmers raise minor water level	Overlooks	2
	Report to officer or police	3
8. When farmers take unauthorized water	Nothing	1
	Karkoon gives panchnama	3
	Warning	1

g. Farmers Cleaning and Maintenance of the On-Farm Main Watercourses

Farmers' reasons for not regularly cleaning and maintaining the common or main watercourses included the following: Field channels were originally built by the government and the farmers felt that regular cleaning and maintenance was not their responsibility; the Department did not pressure farmers about cleaning; some farmers kept others from cleaning; farmers lacked cooperation and knowledge or were lazy, and no formal farmer organizations existed for this task. Minor officials reported no official efforts to organize farmers.

Minor officials' explanations of why farmers preferred expensive, private tubewell water to canal water included: More water control was possible from private tubewells; field watercourse channels were lacking in much of the command area; some areas on the command were too high relative to level of field channels; and private well owners extended credit to farmers who purchased water. While these reasons may be valid, the major factor was probably the lack of water control in the canal gravity system and the current inability of the system to serve considerable areas of the command area.

When asked what should be done to improve water control at the farm level, the minor officials suggested: Government should improve and maintain all farm-level main watercourses; farmers should level fields not presently served by the canal system; the Department should build better watercourses; and farmers should be formally organized for regular cleaning and maintenance of the farm system.

4. The Major Officials and Operation of the Irrigation System.

Six major irrigation officials, including the two deputy engineers, the two executive engineers, the superintendent engineer, and the chief engineer, responded to structured interviews and open-ended questions. The questions asked about their major duties, acres of irrigated area supervised, average formal education, special job training, and the selection process used to fill these important higher positions in the irrigation organization.

a. Deputy Engineers

The major duties of the deputy engineers* included operating and maintaining canals, guiding the minor office, providing on-the-job training of staff, and supervising section officers. The deputy engineer was also responsible for providing publicity and disseminating information to staff and farmers; deciding about fines and sanctions for illegal behavior of farmers; getting timely applications for water from farmers; and keeping day-to-day accounts of the water regime and demands for the subdivision under his control. Each deputy engineer had an area of about 43,000 acres in his subdivision with five section officers in charge of about 10,000 acres of irrigated land each. One deputy engineer reported that he was in charge of 39,000 acres of irrigated land and had a staff of four section officers, 39 karkoons, and 156 chowkidars who handled about 860 outlets on a warabundi or improved system. The other deputy engineer was in charge of an unimproved system.

Both deputy engineers had degrees in civil engineering, requiring a total of about 16 years of formal education. Neither of the two had received special job training since 1978. Both were selected for their present positions on the basis of seniority and merit. Both had successfully passed a special departmental examination for professional engineer, which included questions about operation and maintenance, accounts, measurements, and the Bombay Canal and Drainage Law.

* One deputy engineer was in charge of a subdivision that had an unimproved farm system, and the other was in charge of a subdivision that had some improved systems.

b. The Executive Engineers

The executive engineers supervised about 15 deputy engineers and were responsible for operating and maintaining a system of about 150,000 irrigated acres. Both executive engineers were Bachelor of Science graduates in civil engineering and had special job training through some workshops and seminars. One executive engineer said he had taken a six-week course at the Water Technology Center in New Delhi consisting solely of lectures. Both senior officials said they attend regular monthly meetings with the superintendent engineer to keep up on new developments and make decisions on problems and policies.

The method of selection of these officials was based primarily on past performance, seniority, and merit. No examination or interviews were used in the selection process for promotions.

c. The Superintendent Engineer

The superintendent engineer's duties involved planning and administering the budget, administering the irrigation system, and selecting officers. The superintendent engineer reported that, of the total operation and maintenance budget, about 70 percent was allocated for salaries alone, leaving little else to cover the costs of operation and maintenance. The superintendent engineer had a Bachelor of Science degree in civil engineering and had attended several professional development training programs. He also participated in many tours inside India and two special tours to study irrigation systems in the USA and Spain. He held regular monthly planning meetings with his executive engineers to discuss problems and policies. Selection for this important position was usually based on one's past job performance record in the department, merit, and seniority. The superintendent engineer stated that he usually prefers to select other officials who have come up through the ranks rather than outsiders because he knows them better.

d. Chief Engineer

The chief engineer, as the top most technical official in the irrigation organization, was in charge of the administration of the State Irrigation Department. He worked closely with planners and policy makers and was in charge of all irrigation in the state of Gujarat, India. As the highest official he was involved with the central water commission in improving the system and spent considerable time conceptualizing and developing projects with his staff. He traveled often within India and had traveled overseas. Like the other high officials, he was selected on the basis of merit, seniority, and his ability to communicate, plan, and implement policy.

e. Facilities Provided for Major Officials

Table 36 shows the special facilities provided for major officials. The Irrigation Department usually provided housing, transportation, and medical facilities. Incentives for training for lower-level high officials existed more in theory than practice.

After observing part of the Diagnostic Analysis hands-on training program, both the deputy engineers and the executive engineers expressed the desire to participate in such training. They and the deputy engineers noted the value of tours to other projects in India to learn about different approaches to system operation and management and other developments in system improvements.

Table 36. Special facilities provided for major officials

Facilities	Deputy (2)	Exec. (2)	Supt. (1)	Chief (1)
1. Housing or House Rent	X	X	X	X
2. Vehicle	X	X	X	X
3. Special Training Shortcourses, workshops	-	-	X	X
4. Study Tours Local	-	Occasional	X	X
5. Higher Education For Professional Development	In theory at Water Technology Center, Delhi		At own expense	
6. Allowances				
Medical	X	X	X	X
Educational	-	-	Short Course	X

f. Ways to Provide More Status and Prestige for Involvement in Operation and Maintenance

A critical issue under current policy debate in India is that, with an expenditure of about $3 billion per year for irrigation projects and improvement schemes, operation and maintenance (O&M) must be highlighted more than in the past. Traditionally in India as elsewhere, design and construction has been both more prosperous and more prestigious for engineers.

The ways the six major officials believed that O&M could be improved as a career choice included the following:

- Establish a separate career structure for O&M.

- Provide more incentives in terms of salary and other benefits for O&M.

- Provide special O&M training with a focus on water management.

- Increase O&M budgets in projects.

- Provide improved facilities for minor officials and increase quantity and quality of these key people.

- Provide more recognition by government for O&M.

- Provide executive engineers with magisterial powers such as a forestry and railway officials have.

- Provide guards for key canals and structures.

- Provide special uniforms for chowkidars, like those for the police department.

This was a real issue with those officials concerned with the growing responsibilities in O&M and the present lack of policy and budgetary focus provided for O&M activities. These major officials liked the Central Government's current thinking about establishing a career structure for O&M separate from design and construction. They also expressed the need to require that present irrigation department employees and all future new employees acquire special training in water management. One member of the National Planning Commission in Delhi also stated that all engineers need special training in water management. His concern was that, unless the large government expenditures in irrigation improvement produce better quality work, there may be political opposition to the Command Area Development Program, which might impede its progress.

g. Political Problems and Externalities of Irrigation Projects

Since water is not only a technical problem but also has social, economic, and political ramifications, the six major officials were asked about their views of some of these impacts or externalities (Table 37). They were aware of the negative impacts but desired more data and understanding of how these impacts might be mitigated in actual project areas.

h. Professional Development Needs for Irrigation and Other Officials Involved in Irrigation

Major officials perceived a definite need for intensive training for technicians and extension workers who work with farmers. For civil engineers they suggested special training in precision land leveling and improvement of the canals and distributories. For agricultural engineers they recommended special training in precision land leveling, watercourse rehabilitation, improved irrigation practices, and water requirements of crops. For agronomists they recommended training in aspects of precision land leveling, improved cropping practices, and economics of various crops. For extension personnel the training needed included improved crop management practices, utilization of inputs, and methods on how to organize and train farmers effectively. Finally, they perceived the need to train farmers in improved cropping and irrigation practices as well as how to maintain improved systems. All the major officials interviewed felt that the required training should be done in short hands-on intensive courses that teach by experience rather than simply by lectures.

Table 37. Major Official's Views about Various Types of Impacts of Irrigation Projects

Type of Problem	Synthesis of Views Reported
1. Interstate Problems	Submergence of land in states of Rajasthan and Maharastra due to reservoirs
	Sharing of water between states from same watershed
2. State Problems	Political influence in location and operation of projects
	Submergence of Okahi lands within Gujarat State
	Civil court cases versus the Irrigation Department
	Different water requirements and politics of distribution between areas in the state
3. Extension of Projects	
a) Submergence of land by reservoir	Submergence of land in states of Rajasthan and Maharastra due to reservoirs
	Sharing of water between states from same watershed
b) Emergency flooding	Two escapes built into Mahi-Kadana System used in 1973 but often have to flood crop lands
c) Waterlogging/ salinity	Due to heavy clay pockets in some areas, lack of lined canals, and the lack of a conjunctive use program
d) Health hazards	Rises in incidence of malaria (need studies of waterborne diseases, etc.)
e) Other hazards/ impacts	Need studies about environmental impacts; how to irrigate lands above canal command; and the degree of damage to transportation system; need to make water more equitable in supplies between head and tail enders.

The major officials recommended the following specific training for minor officials and deputy engineers:

(1) Canal chowkidar - Specific training related to job function and water accounting, settlement of conflicts/ warabundi system.

(2) Canal inspectors/ karkoons - Canal maintenance, methods for water allocation, communications with farmers and supervision of gatekeepers (chowkidars).

(3) Section officers - Distribution of water, supervision of Staff, Water Management demonstration and extension methods.

Not only was a need for training felt, but there was also some understanding of the types of training required. The major officials ranked the training needs first for the deputy engineers, second for the section officers, third for the karkoons, and fourth for the chowkidars.

The major officials suggested ways to strengthen the present legal authorities of irrigation staff, and suggested specific new or improved legal authorities to ensure more discipline in the operation and maintenance of the entire irrigation system. Both minor and major officials reported that inadequate discipline existed in the present operation of the system.

At the farm level, these officials felt that farmers should be organize at the watercourse level and be given specific responsibilities for regular cleaning and maintenance. They suggested that on end watercourses, small groups of farmers should be united at the village Panchayat level to involve the local government council in improved maintenance and improvement programs. One major official noted that outlets should be closed when farmers do not adequately maintain and clean the main watercourse or cannot decide on whose turn is next.

At the outlet level, the officials' suggestions ranged from taking drastic police action to establishing a flat rate for irrigation water to reduce current administrative costs. One official suggested selling the water to farmers at wholesale rates and allowing them to operate both the distributaries and the farm system. Some felt that at the minor level certain irrigation officials should be given magisterial powers to level sanctions on the spot. This method would circumvent having to find two witnesses for any infraction of the rules prior to issuing a panchnama (fine). Such mobile magistrates could also work along the main canal and handle cases which often require up to four years to resolve through the civil court system.

Most officials agreed that the old Bombay Irrigation Act needs much revision in light of current irrigation needs.

These and other measures could resolve some of the following conflicts presently faced in the operation and maintenance of the Mahi-Kadana system:

(1) Farm System Level: Conflicts exist over who maintains watercourses; between farmers over cleaning; and between farmers over whose turn is first when two or more demand water.

(2) Outlet Level: The chowkidar's job and farmers' wishes sometimes conflict; conflicts exist over damage to outlets and who is guilty.

(3) Minor System Level: Obstructions by farmers, damage to the system, stealing of water, and local pressures on minor staff exist.

(4) Main System Level: Problems include release of water downstream, lack of budget for O&M; encroachments by tubewells as they place pipes under canals; and conflicts within the Department over the level of staff needed.

i. DeJure and DeFacto Operation of the System at the Outlet and Farm Levels

The major officials interviewed evaluated how the system presently works at the farm level, by comparing the operational rules with actual practices observed in the field (Table 38).

j. Essential Technologies and Management Procedures to Improve Systems Operation and Maintenance

The six major officials ranked selected technologies and management procedures which they perceived as essential to improve the O&M of the major system to the farm system. Table 39 shows these rankings, with (1) as highest priority. Despite the small number of respondents, this ranking reveals some general agreement on a few technologies but much disagreement on others. For the major system, most concerns focused on the need for improved information systems, improved monitoring and maintenance, and training. Needs identified for the minor system included improved maintenance, staff training, and monitoring. At the outlet level, the top priority was training. At the farm level, the two top priorities were land leveling and the lining of channels.

k. Procedures for Achieving Improved Farmer Cooperation in Regular Cleaning and Maintenance of Main Watercourses

The five major officials interviewed also ranked six ways or means to achieve greater farmer cooperation in watercourse cleaning and maintenance (Table 40). The best perceived method to gain more farmer cooperation was the formation of legal water user associations, followed by improving and enforcing laws to gain compliance. The third-ranked method was improving water control at the farm level. Probably one method alone would not be adequate; a combination of incentives, such as better water control with a strong association and laws which could be enforced, could be packaged to gain more farmer involvement in maintenance. Such a combination is needed to bring more discipline to this loosely operated system.

Table 38. DeJure Rules and Regulations of System Operation Versus the DeFacto Operation

DeJure Rules and Regulations	Practice
1. Water applications require 15 days to process for farmers.	Four officials reported that it takes about 20-25 days.
2. Outlets are to be operated only by authorized personnel.	Two officials reported that farmers opened and closed the outlets about 75% of the time.
3. Officials regulate outlet discharge.	One reported there is little or no variation while two officials reported variations from 1.0 to 2.5 CFS at times.
4. Requlated and fixed turns on *warabundi* system cannot be changed unilaterally by farmers.	On the *warabundi* watercourses it seems to be working.
a) Trading of turns not permissible.	Trading takes place and is allowed.
b) Trading canal water for tubewell water and vice versa is not allowed.	Trading does take place but not much due to the higher price of tubewell water.
5. Illegal to use water from one outlet for an area on another outlet command.	Such use takes place because of the unlevel topography and lack of good watercourses in some areas.
6. Illegal to make unauthorized cuts in distributory or main watercourses.	This practice does take place at times.
7. Illegal to steal water from unauthorized turn.	Stealing sometimes takes place.
8. Unauthorized remission of water rates not permissible.	This practice probably happens, but it should not.
9. Farmers must do regular maintenance of main water-courses and protect structures.	Farmers usually do not.
10. Illegal to give gifts to minor irrigation authorities.	A bonus is given to *chowkidars*.
11. Irrigation authorities provide farmers ample advance notice of all canal closures.	Authorities need to improve on this.
12. Irrigation authorities provide information to farmers about rotation of minors.	Farmers use the *Panchayat* Board.

Table 39. Major Officials' Rankings of Priorities in Improving Operation of the Irrigation System

Irrigation System Improvements	Individuals' Rankings					
	DE1	DE2	EE1	EE2	SE	Total
A. Major System Level						
1. Improved Information System	5	2	2	4	2	15
2. Improved Monitoring	3	1	4	2	4	14
3. Improved Maintenance	1	3	3	3	1	11
4. Implementation of Codes	2	5	5	5	5	22
5. More Trained Staff	4	4	1	1	3	13
B. Minor System Level						
1. Improved Information System	5	4	5	6	2	22
2. Improved Maintenance	7	1	3	3	1	16
3. Improved Lining	3	2	7	7	4	23
4. Improved Monitoring	2	3	4	2	7	18
5. More Trained Staff	6	5	2	1	3	17
6. Better Structures	1	7	6	4	5	19
7. Improved Rotation System	4	6	1	5	6	22
8. Additional Regulation	-	-	8	8	-	16
C. Outlet Level						
1. Improved Rotation System	7	4	2	3	2	18
2. Improved Information System	1	7	5	5	5	23
3. Improved Gates	5	2	3	7	6	23
4. Improved Monitoring	3	3	7	4	3	20
5. More Trained Staff	2	1	4	1	1	9
6. Improved Pass System	4	5	6	6	7	28
7. *Warabundi*	6	6	1	2	4	19
D. Farm Level						
1. Lined Channels	4	5	1	1	6	17
2. Improved Channels with Structures	1	4	2	4	2	13
3. Land Leveling	2	1	5	2	1	11
4. *Warabundi*	5	2	3	3	4	17
5. Maintenance	3	3	4	6	3	19
6. Local Farmers Organizations	6	6	6	5	5	28

DE = Deputy Engineer.
EE = Executive Engineer.
SE = Superintendent Engineer.

Table 40. Ways to Achieve Greater Involvement in Regular Cleaning and Maintenance of Main Watercourses

Procedure	Individuals' Rankings					
	DE1	DE2	EE1	EE2	SE	Total
1. Improved control of water for farmers such as delivery on demand.	3	3	2	5	2	15
2. Improved and enforced laws to gain compliance.	2	2	1	2	6	13
3. Formation of legal water user associations.	1	1	4	1	1	8
4. Closure of outlets when watercourses not adequately cleaned.	4	4	3	4	3	18
5. Reduced water rate incentive to farmers who regularly clean and increased rates for not cleaning.	5	5	5	6	4	25
6. Charge supplementary water rates and return this to a formal WUA to utilize for cleaning and maintenance.	6	6	6	3	5	26

DE = Deputy Engineer.
EE = Executive Engineer.
SE = Superintendent Engineer.

1. Irrigation Authorities' and Farmers' Suggested Solutions to Selected Watercourse Problems

Both the officials and the 33 farmers interviewed on the unimproved system suggested solutions to specific problems, although some evidently did not perceive all the matters raised to be major problems (Table 41). Though the number of respondents was small, several useful conclusions emerged. First, both farmers and officials often agreed on the way to solve specific problems. Second, due to lack of farmer involvement when the first channels were designed and built, farmers thought that it was the government's job to repair, improve, and maintain the watercourses. Third, farmers often spoke of never being able to talk with irrigation officials or never being heard when new outlets were designed and located. Fourth, a serious problem of communication seemed to exist between irrigation authorities and farmers. Both parties appeared to agree both on the nature of many problems and their solutions but they did not communicate adequately with each other. To date on the unimproved system studied, no mechanism has been established to either improve communications with farmers or to involve farmers in important programs. Five of the farmers interviewed said they would even pay for

Table 41. Officials' and Farmers' Suggested Solutions to Problems

Perceived Problem	Suggested Solution (No. of Persons Reporting) Officials	Farmers
1. Spills or overtopping of watercourse channels	Improved design (4) Govt. repairs (2)	Govt. repairs (1)
2. Leaks in channel banks	Lined channels (2) Farmers repair (1)	Govt. repairs (10) Lining (5) Farmers repair (2) Pipe turnouts (1)
3. Seepage at the bottom of channels	(No problem)	Lining (1) Bottom design and cleaning (1)
4. Dead storage in channels	Better design (1) Better maintenance (1)	Better design (4) Better Maintenance(1)
5. Vegetative growth along channels	Farmers clean (7) Govt. clean (2)	Farmers clean (1)
6. Nonaligned channels	Better design (3)	Better design (9)
7. Breaks at junctions	<u>Pucca nakkas</u> (7) (improved outlets)	<u>Pucca nakkas</u> (3) (improved outlets)
8. Silt in channels	Farmers cleaning (9)	Govt. land leveling (7) Private land leveling (4)
9. Unlevel fields	Land leveling (7)	Govt. land leveling (7) Private land leveling (4)
10. Lack of farmer organization and	Legal WUAs* (7) <u>Warabundi</u> (7) More legal (6) Authority of Department	WUAs* (5) <u>Warabundi</u> (4) Enforce rules (4) <u>Panchayat</u> involvement (4)**
11. Irregular distribution of water by canal <u>chowkidar</u>	Establish <u>warabundi</u> (7) Add more staff (7)	<u>Warabundi</u> (1)

*Refers to farmer water user associations which are formal with legal backing.

**Key informants in three Panchayats suggested that irrigation officials should meet with Panchayat and discuss their problems. Officials should involve farmers in decisions about outlets; an arbitrator should represent WUA's at the Panchayat level; and consideration should be given to providing a part of the water revenue to the members of WUAs for regular maintenance and farm-level structures.

watercourse improvement activities such as structures and lining if they could be adequately involved in the planning and implementation.

In conclusion, the information provided by minor officials, major officials, and farmers suggested that there is a definite perceived need for change and improvement. Greater focus beyond that in the training situation is needed to get appropriate information from both irrigation authorities and farmers on how the system can be improved. Neither party can accomplish this alone.

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SECTION III - ECONOMICS

A. Introduction

The economic analysis of system operation consisted of an economic survey of farm enterprise budgets for the major crops grown in the area, of farmer use of inputs and services, of economic factors influencing farmer decision-making, and of factors affecting crop yields. The preparation of the questionnaire was the primary responsibility of the economists, but the extension personnel were also involved. The agronomists and engineers were also involved in reviewing and discussing the survey.

Results presented here discuss the factors that affected crop yield and farmer's choices of crop and production practices. Uses of inputs in major crops on improved and unimproved watercourses were estimated and compared.

B. Methods

During the first week of the training program, the members of economic and statistics disciplines had a quick refresher course in production economics. They also had opportunities to exchange notes on their experiences in data collection and farm survey methods during the discipline group meetings. These meetings stressed the following:

- The farmers do not usually maintain accounts relating to output or input applications; therefore, the data recorded through a recall method would have a fairly high degree of error.

- The data on *Rabi* production would not really pertain to the current crop and would probably refer to the past *Rabi*.

- The farmers usually have lands both within the area commanded and in the area uncommanded by the project; therefore, the data collected on output and input cannot be effectively separated. Fortunately, because the farmers have access to well or tubewell water supplies in the areas outside the command of the project, these input and output data relate more to irrigated agriculture than to unirrigated or rainfed agriculture.

- Though these farmers are separated within the command of an outlet, some farmers do not take irrigation supplies in the *Kharif* season, especially if they raise coarse grains such as pearl millet. This assumes that rainfall is adequate and normally distributed during the crop season. Thus, there is no need for supplemental irrigation during the season.

The group also considered that the time available for contacting the farmers and for collecting information was extremely limited: six days for both unimproved and improved watercourses. Therefore, a questionnaire was carefully prepared and pre-tested among the farmers in the outlet command of an unimproved watercourse. Questions pertaining to input-output relationships involved only four major crops within the area: paddy and pearl millet, grown during the *Kharif* season; wheat, a *Rabi* crop; and tobacco, a two-season crop planted in the late *Kharif* season and maturing in the mid-*Rabi* season. The data collected in regard to input-output relationships for each of the four major crops were then analyzed using the Cobb-Douglas production function.

In the sample selected, 31 farmers in the unimproved watercourses and 24 farmers in the improved watercourses were interviewed. Among the 31 farmers in the unimproved watercourse, 9 were marginal farmers, 8 were small farmers, and 14 were large farmers. Among the 24 farmers in the improved watercourses, 5 were marginal farmers, 8 were small farmers, and 11 were large farmers.

Data collected from the sample farmers for each of the four major crops represented inputs used such as chemical fertilizers (in rupees), farmyard manure (FYM), labor days other than family labor, hire charges on tractors, land preparation, and the yields obtained. Further details about land holding size, the farm's distance from the outlet, and availability of an alternate source of irrigation were also gathered.

Because the farms surveyed were located in the command area of the irrigation project, water was obviously an input to the farm operations. The limited possibility of increasing the size of the land of each farmer in the command was critical. Hence, land productivity was also an important factor.

C. Results and Discussion

1. Input Applications and Cropping Intensities

Table 42 presents the selected characteristics of the farmers surveyed. Because the number of observations was extremely small for marginal and small farms, analyses were done on an aggregate basis between the unimproved and improved watercourses.

For input applications to paddy and pearl millet, there was no significant difference between sample means of inputs per unit area. For pearl millet and tobacco, sample means relating to seeds and farmyard manure, respectively, were significantly different from each other. With these two exceptions, the general trend was that farmers had not significantly changed their traditional practices, even where rotational water distribution was introduced. The variance in inputs in improved watercourses was generally much less than in unimproved watercourses. The exceptions were in the case of farmyard manure used on wheat and tobacco. In addition, no significant difference existed between the means with respect to farmers' distance from the outlet in the unimproved and improved watercourses.

Table 43 relates the data on alternate sources of irrigation supplies to the crops cultivated. The proportion of farmers both in the improved and unimproved watercourses having either their own wells or access to tubewell supplies was largest in case of tobacco, followed by wheat, paddy, and pearl millet.

Though one would visualize a higher cropping intensity in the improved watercourses than in the unimproved watercourses, the actual figures obtained present a different picture. The mean cropping intensity in the unimproved watercourse was apparently higher, but no significant difference existed between the mean cropping intensities in the two watercourses (Table 43).

Table 42. Sample means of selected characteristics of farms surveyed

	Unimproved Watercourses			Improved Watercourses		
	Marginal Farmers	Small Farmers	Large Farmers	Marginal Farmers	Small Farmers	Large Farmers
Total number of observations	9	8	14	5	8	11
Land in watercourse (acre)	1.03	1.24	1.37	0.61	1.49	1.91
Cropping intensity	193.33	210.88	204.71	185.40	186.75	201.79
Paddy:						
Number of observations	2	3	7	4	5	8
Yield/Acre (Kg)	1142.86	886.29	880.63	761.99	969.22	1400.50
Chemical fertilizer/Acre (Rs)	443.41	276.55	298.11	283.56	242.97	225.72
FYM/Acre (Rs)	79.37	90.31	194.38	105.29	37.97	69.07
Seeds/Acre (Rs)	125.40	21.97	35.42	37.47	50.61	38.21
Labor days/Acre	73.41	41.40	47.95	58.80	34.20	47.98
Custom hire charges/Acre (Rs)	174.21	123.86	110.07	90.64	132.57	93.54
Nitrogen/Acre (Kg)	92.42	50.90	57.69	58.39	60.35	42.19
Bajra:						
Number of observations	7	5	12	1	4	6
Yield/Acre (Kg)	620.29	621.28	574.23	434.78	467.08	729.17
Chemical fertilizer/Acre (Rs)	101.00	128.71	291.26	89.57	144.02	107.58
FYM/Acre (Rs)	64.58	29.62	17.78	86.96	138.16	28.38
Seeds/Acre (Rs)	17.43	30.25	19.45	8.70	17.01	10.53
Labor days/Acre	26.19	33.12	39.37	13.04	22.93	37.01
Custom hire charges/Acre (Rs)	101.13	149.93	125.01	86.96	57.50	113.99
Nitrogen/Acre (Kg)	17.39	27.09	34.48	20.00	27.75	18.95

Table 42. (continued)

	Unimproved Watercourses			Improved Watercourses		
	Marginal Farmers	Small Farmers	Large Farmers	Marginal Farmers	Small Farmers	Large Farmers
Wheat:						
Number of observations	1	3	6	4	4	5
Yield/Acre (Kg)	461.54	783.73	920.01	1010.79	890.95	934.17
Chemical fertilizer/Acre (Rs)	429.54	216.56	214.42	364.82	251.12	207.55
FYM/Acre (Rs)	295.38	0.0	47.06	328.10	81.17	0.0
Seeds/Acre (Rs)	67.69	87.58	76.41	73.98	69.56	94.53
Labor days/acre	30.77	119.21	63.44	49.67	45.70	45.39
Custom hire charges/Acre (Rs)	230.77	167.86	106.49	176.32	74.27	150.80
Nitrogen/Acre (Kg)	43.08	46.80	55.05	82.10	59.64	34.72
Tobacco:						
Number of observations	5	7	12	3	7	11
Yield/Acre (Kg)	631.11	574.40	640.61	442.23	688.00	634.44
Chemical fertilizer/Acre (Rs)	464.03	163.94	320.27	306.26	282.82	329.33
FYM/Acre (Rs)	114.86	96.04	67.54	157.25	161.85	176.51
Seeds/Acre (Rs)	71.21	53.83	142.98	58.80	41.36	56.80
Labor days/acre	74.43	80.12	93.05	54.13	67.53	82.62
Custom hire charges/Acre (Rs)	324.44	461.86	214.02	161.37	244.32	172.07
Nitrogen/Acre (Kg)	96.11	32.12	73.66	62.23	57.66	57.24

Table 43. Distribution of sample farmers in watercourses with reference to canal and alternate sources of irrigation supplies

	Unimproved Watercourses			Improved Watercourses		
Crops	Dependent on Canal Only	Having an Alternate Source	Total	Dependent on Canal Only	Having an Alternate Source	Total
Paddy	10	2	12	1	16	17
Pearl Millet	7	17	24	3	8	11
Wheat	2	8	10	5	8	13
Tobacco	4	20	24	5	16	21

Though the mean cropping intensity in the improved watercourses was less than in unimproved watercourses, the tobacco area irrigated by canal in the improved watercourses was higher than the one obtained in the unimproved watercourses. The percentages of area irrigated by canal in _Kharif_ and _Rabi_ seasons in the improved watercourses were much higher than those in the unimproved watercourses (see Table 17).

2. Factors Influencing the Choice of Crops

The farmers were asked to rank those factors likely to influence the choice of crops over time. Because the farmers are not often articulate, and because they tend to get impatient with investigators, interviewers asked farmers to select only three among the set and rank them according to their importance.

The factors that the sample farmers evaluated were:

- price of the crop,
- water availability,
- rain,
- tradition,
- availability of market facilities, and
- home consumption.

Table 44 presents the farmers' rankings and frequencies of mention for each major crop in each of the two minors studied. To obtain the final ranks of the factors for each crop, the first rank was given a score of three, the second a score of two, and the last a score of one. For each factor an aggregate of scores was obtained by summing the scores associated with each ranking and multiplying them by the frequency of their mention. Aggregate scores for each factor were then ranked in descending order.

For paddy, the farmers on both unimproved and improved watercourses assigned first rank to home consumption and second and third rank to tradition and water availability. While price and rain were of no importance in the improved watercourses, they were ranked fourth and fifth in the unimproved watercourses; in unimproved watercourses rain would naturally be of some importance for choosing paddy, which is a monsoon-season crop. Price was important in unimproved watercourse but not in improved watercourses. This

Table 44. Farmers' rankings of factors influencing the choice of crops for cultivation

Influence on Choice of Crop	Rank
Unimproved Systems	
Paddy:	
Home Consumption	1
Tradition	2
Water Availability	3
Price	4
Rain	5
Market Facilities	NA
Pearl Millet:	
Home Consumption	1
Tradition	2
Water Availability	3
Price	4
Rain	5
Market Facilities	6
Wheat:	
Home Consumption	1
Tradition	2
Water Availability	3
Price	4
Market Facilities	5
Rain	NA
Tobacco:	
Price	1
Market Facilities	2
Tradition	3
Water Availability	4
Rain	NA
Home Consumption	NA

Table 44. (continued)

Influence on Choice of Crop	Rank
Improved Systems	
Paddy:	
Home Consumption	1
Water Availability	2
Tradition	3
Price	NA
Rain	NA
Market Facilities	NA
Pearl Millet:	
Home Consumption	1
Tradition	2
Water Availability	3
Rain	4
Market Facilities	5
Price	NA
Wheat:	
Home Consumption	1
Water Availability	2
Tradition	3
Price	4
Rain	NA
Market Facilities	NA
Tobacco:	
Price	1
Market Facilities	2
Water Availability	3
Tradition	4
Rain	NA
Home Consumption	NA

NA = not applicable because no farmers selected this factor.

lack of importance occurred because little paddy was left for disposal at the market due to the large home consumption.

For pearl millet, both in the unimproved and improved watercourses, farmers ranked home consumption, tradition, and water availability as the top three factors influencing their choice of crop. While price was not important among the sample farmers in the improved watercourses, as in the case of paddy, it placed fourth in the unimproved watercourses. Rain ranked fourth in the improved watercourses and fifth in the unimproved watercourses. Market facilities received the fifth and sixth ranks in improved and unimproved watercourses, respectively. Pearl millet is usually a Kharif crop, but it can be grown in summer if irrigation water is available. Pearl millet is primarily grown for home consumption, but recently improved varieties have enabled farmers to grow it to market as well.

For wheat, both in the unimproved and improved watercourses, the farmers said home consumption was the major reason for its production. Water availability and tradition were ranked second and third in both watercourses. Price ranked fourth in both cases. Although surplus wheat was sold in the market, only in the unimproved watercourses were market facilities important.

For tobacco, price and market facilities ranked first and second both in the unimproved and improved watercourses. While rain and home consumption did not figure in both cases, water availability and tradition ranked third and fourth.

3. Factors Affecting Crop Yields

Table 45 shows that in the case of pearl millet (bajra), seeds were a highly significant variable influencing crop yields. Two other variables, nitrogen and watercourse improvements, were also significant. Interestingly, the improvements in watercourses following the introduction of a rotational water supply caused a rise in production level.

For paddy cultivation, the size of the farmers' holdings also appeared to be significant (Table 45). Thus, the larger the size of the holdings, the greater was the ability of the farmer to invest in inputs through appropriate access to credit and other means, with a subsequent increase in the yield per acre. More important in this relationship was distance. Yields of paddy, a crop which is highly water intensive, were higher when a farm was nearer to the outlet. The conveyance losses and other inefficiencies associated with earthen field channels affected the paddy yields adversely. Areas of the project where field channels were not maintained may have shown much of this effect.

For wheat, the assurance of irrigation supplies either because of improvements following introduction of rotational water supply or because of the availability of alternate sources was an important factor (Table 45). Wheat cultivation during the Rabi season was affected by the water supply. Farmers must depend on irrigation water during the Rabi season because there is no precipitation.

Table 45. Regression results relating output/acre to selected factor inputs/acre in Cobb-Douglas Production Function ('t' ratios in parentheses)

Crops	Intercept	Seeds in Rupees	Labor Days	Custom Hire Charges in Rupees	Nitrogen in Kilograms	Distance in feet	D_1 (Dummy for Size)	D_2 (Dummy Allenuate Source of Water)	D_3 (Dummy for Improved Watercourse)	R^2	Number of Observations
Bajra	2.[illegible]0	0.419* (2.279)	−0.005 (−0.092)	0.013 (0.478)	0.031*** (1.278)	−0.003 (−0.069)	−0.040 (−0.350)	−0.040 (−0.350)	0.114*** (1.058)	0.2573	35
Paddy	21.842	−0.074 (0.416)	0.016 (0.072)	0.262 (0.624)	0.270**** (1.009)	−0.133* (−2.194)	0.742*** (1.068)	−0.101 (0.489)	0.108 (1.135)	0.3452	29
Wheat	21.398	−0.125 (−0.305)	−0.103 (0.753)	−0.007 (0.406	0.108 (0.684)	0.030 (0.538)	0.043 (0.808)	0.007**** (0.884)	0.107** (1.357)	0.2300	21
Tobacco	21.166	0.649** (1.544)	0.124** (1.400)	0.008 (1.049)	0.199** (2.252)	0.032 (0.306)	0.017 (0.600)	0.28 (0.477)	0.008 (0.578)	0.3228	45

*Coefficient significantly greater than zero (one-tailed t-test) at 0.05 level of probability.
**Coefficient significantly greater than zero (one-tailed t-test) at 0.10 level of probability.
***Coefficient significantly greater than zero (one-tailed t-test) at 0.15 level of probability.
****Coefficient significantly greater than zero (one-tailed t-test) at 0.20 level of probability.

For tobacco, nitrogen was the most significant variable, while both labor and expenditures on seeds or seedlings were less significant (Table 45). Tobacco production depends upon quality of seeds and transplanting practices and requires substantial labor for picking the leaves.

D. Summary of Findings

(1) Canal irrigation intensity increased with the improved system.

(2) Yields did not differ between improved and unimproved systems, and the yields within the improved system varied the least.

(3) The only difference in input levels' effects on crop yields was for seeds and farmyard manure for pearl millet on the improved system; there was less variance from the other inputs.

(4) For food grains (paddy, wheat, and pearl millet), consumption and tradition strongly influenced where they were grown.

(5) For tobacco, price and market facilities strongly influenced where it was grown.

(6) Improving the system made water availability a more important factor in determining where to grow paddy, wheat, and tobacco.

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SECTION IV - ENGINEERING

A. Introduction

Two teams of engineers participated in the Diagnostic Analysis of selected areas within the Mahi-Kadana Irrigation Project, located in the Kheda District, Gujarat. Irrigation engineers, who were on one team, were responsible for defining the original design, the present operational design, and the actual operating procedures of distributaries and minors under investigation. The other team, consisting of on-farm engineers, addressed similar concerns in relation to the water control system at the farm level. This system included four subsystems: water delivery (watercourses), water application, water use, and water removal.

Two areas within the Mahi-Kadana Project were selected for investigation: the Sihol Minor and the Chikhodara Distributary, particularly Subminor 10R within the latter area (Figure 5). Attention was focused on the unimproved traditional water supply and the improved rotational water supply. In the unimproved traditional system, the minor (or subminor) runs 10-days-on and 5-days-off and the outlets below the minor are left open; in the improved rotational system, the minor (or subminor) runs continuously and the outlets are opened in rotation. Sihol Minor was selected as a general example of an unimproved traditional water supply system. One of its subminors, Rawalapura, was examined as an example of the improved rotational water supply system. The engineers also surveyed Subminor 10R on the Chikhodara Distributary. This was another example of the improved rotational system.

Diagnostic Analysis is a two-phase, interdisciplinary investigation. The engineers, both irrigation and on-farm, served on the investigating team, along with economists, agronomists, and sociologists/extension personnel. The investigation itself consisted of a reconnaissance survey (an initial overview of the area to identify primary constraints or problems) followed by the detailed studies (more specific and in-depth studies of the area). The procedures and results of both phases are included in this section. A general summary then reviews the positive aspects of the system operation at the Mahi-Kadana Project as well as specific constraints and recommendations.

B. Reconnaissance Studies

Two traditional water supply minors and two rotational water supply minors were scheduled for the reconnaissance studies. After viewing the two rotational water supply minors, a third minor was visited and selected for detailed studies.

1. Procedure

The reconnaissance study of the minors included field trips by the engineers. Their objective was to answer the following specific questions: How was the system designed to operate originally? What are the present operational design procedures? What are the actual operating procedures? What are the decisions to be made? What are the criteria for the decisions? These questions were applied to both the operation of the canal system and the on-farm systems, including the watercourses and the application of water to fields.

Similar questions were asked of officials. Operating personnel were asked to describe operating procedures and the criteria used in making impor-

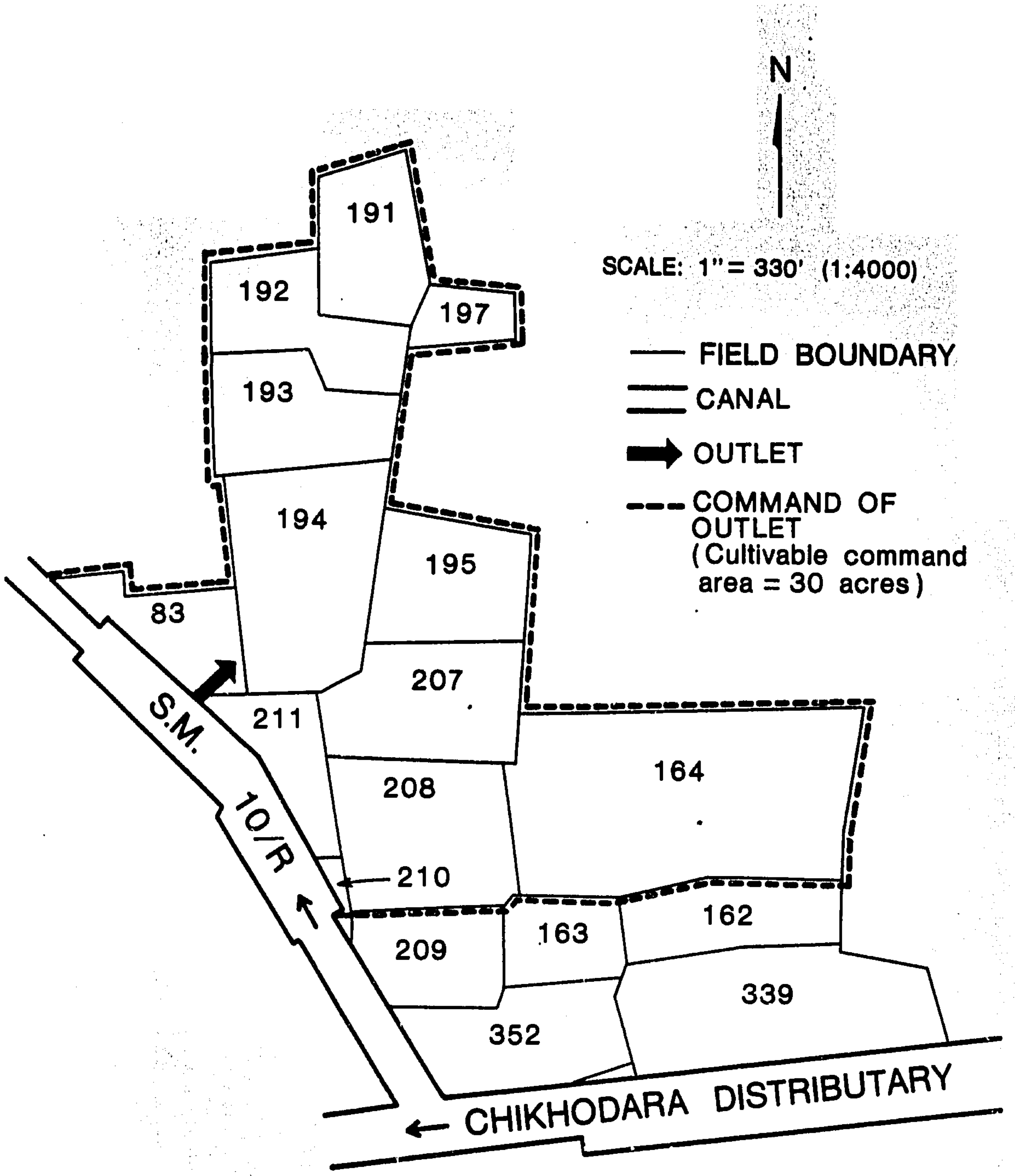

Figure 5. Field Layout Under Outlet 01/R of Subminor 10R, Chikhodara Distributary

tant decisions. The operation of each subsystem was observed for control and regulation of the water. For example, a minor must be operated to supply a regulated water level if flow at an outlet is to be dependable. To allocate water effectively, precise division and measurement of the flow must occur at each diversion point. The appropriateness of variables affecting flow also can be judged. Are the capacity, discharge, slope, roughness, and/or loss rates appropriate? The same criteria were applied when evaluating the on-farm distribution system.

Field application of water was evaluated by visual observations of performance, and the appropriateness of the variables such as flow rate, field geometry, slope (and levelness), infiltration, and the management decisions of the farmer. The farmer must decide when to irrigate (is the frequency of irrigation appropriate?); how to irrigate (is the flow rate reasonable considering other appropriate variables?); and how much water to apply (is it the right amount?). The results of each decision determine the system's performance. For example, crop symptoms indicate the performance of the water use subsystem.

During these initial studies, evidence of waterlogging, salinity, and/or poor surface drainage also was sought.

2. The Canal System

The canal system, as designed, distributed an inadequate amount of water to a large area in the project. The actual water supply distributed resulted in a 25 to 75 percent cropping intensity in any given season. Even during a short monsoon season the water supply would be inadequate to irrigate all the area.

The actual operation of the system was to distribute a projected water supply based on anticipated consumption and losses. Water was provided to farmers largely on-demand, meaning that when a farmer on an outlet needed water for irrigation, he requested the canal chowkidar (gatekeeper) to supply it. The water was supplied on a rotation basis to all farmers below the outlet. Because the demand for irrigation was much less than the system's capacity, there was a surplus of water.

The chowkidar on a canal set the gate at a predetermined level for a specific flow rate. This setting remained the same from early in the morning until late in the evening. The flow through the gate fluctuated depending upon the water level in the canal. It could vary approximately ±15 percent around the expected flow rate. It was the chowkidar's decision as to when to open the gate in the morning and when to close it in the evening. However, the specific setting of the gate was based on instructions from the karkoon, or the canal supervisor.

The traditional rotation of the canal is approximately 10-days-on and 5-days-off. The specific rotation may be extended if the demand for water is high; or it may be terminated as scheduled. Thus, the actual operation of a given minor appears to be flexible.

To maintain a constant water level, the cross regulators were adjusted according to the actual flow in the canal. These were operated by the canal chowkidar and the farmers. During the reconnaissance study, these regulators were closed early in the morning to maintain as high a water level as the

Irrigation Department would permit. In addition, siphons and road culverts were adjusted by plugging. Such efforts apparently were attempts to maintain a high water level at each outlet for a maximum outlet flow at all times. In other words, farmers operated the system to increase their water supply.

3. The On-Farm System

The farm field channels were designed according to a standard section and grade. Based on the observations of a number of outlets, the field channel elevations were not tied specifically to the elevation of the full supply level in canal. The design grade and cross-section were the same for each site. The design slopes did not change as a function of the soils and/or the topography. Division boxes were provided at each branch in the field channel system, and drop structures were provided, usually as a culvert siphon. Check structures associated with the drops were not provided to maintain the designed water surface level for the channel. Maintaining a non-erosive gradient was not considered part of the watercourse design.

In principle, the canal outlet was operated by the canal chowkidar. In practice, however, farmers advised the canal chowkidar to open the gate only to the level that gave a flow the watercourse could carry, if the capacity of the field channel was inadequate for the normal operating flow of the outlet. In some instances, the water levels were maintained at a high level in the canal, generally above the design for the watercourse. Farmers opened, closed, or partially opened the gate depending upon their particular need for a flow rate.

The actual flow rate available at the outlet also varied because of the varying water levels in the canal. Levels varied due to the high discharge during the day and the low or zero discharge during the night, as well as the adjustment of the cross regulators.

Fields became uncommanded as a result of erosion, or the eroding of the field channels below the design grades. The erosion itself was due to nonfunctioning control structures such as the drops and divisions. Farmers did not understand the cause/effect relationship of this particular problem. Their criteria for operation was not related to the system's design, nor was the design related to the needs of proper operation.

Fields were designed to operate as graded borders or level basins. The graded borders accepted the available flow in the first border and allowed it to travel to the end of the border. The farmers stopped the water when it reached the end of the border. Frequently a cut was made in the ridge separating the first border from the second border, and the second border to subsequent borders. The water ponded on the lower end of the field and then flowed to the subsequent borders as cross border flow. Thus, the opportunity time* to apply the desired amount of water was approximately the time of advance to the end of the border. Since the borders were not operated as separate hydraulic units, but water flowed from border to border, the last border and the lower end of the field tended to accumulate large amounts of

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* Opportunity time = recession time - advance time. An inadequate opportunity time would result in an inadequate depth of infiltration.

water. Farmers occasionally drained the water from the field, but this was not a normal operational procedure.

For level basins, farmers applied water until it reached the end of the field, or until a specific depth was achieved in the basin. There was no design assistance for precision leveling which is so necessary with level basins. In fact, the farmers and/or the operating engineers, were unfamiliar with the concept of precision leveling as a part of the design of level basins. Fields generally were assumed to be the sole responsibility of farmers. Engineers did not perceive that the engineering design of a field was an appropriate emphasis.

The decision on when to irrigate a field appeared to depend on the farmer's ability to access the water supply and his distance from the outlet. In a number of instances, the farmers desired to use canal water for irrigation, but the field channels were not available. On other farms, water was made available only through excessive effort on the part of the farmer. At other times, the operation of the canal system and of the field channel system resulted in the field no longer being commanded. No consistent criteria were available, from either the farmer or the engineer who designed the field channels, to evaluate the performance of the field channels in terms of supplying water to the entire command area of an outlet. Detailed discussion of how the system operates according to design, operation, and criteria for decision-making follows and is based on reconnaissance data.

4. Traditional Water Supply: Sihol Minor

The investigating teams visited two different minors that operated as a traditional water supply. The traditional water supply minor operates with a 10-days-on and 5-days-off rotation. Below the outlet water is supplied, in principle, by rotation according to the sequence of requests by farmers. The peak design discharge should be computed based on the crops and area. The discharge on a given day is calculated from the expected discharges of the sum of all outlets. Farmers request the time of operation of an outlet and, where the watercourse is not of adequate capacity, the discharge of the outlet. At the time of the investigation, the canal had algae, but it apparently disappears during the monsoon season. The canal seemed to operate at less than the full supply level. Supposedly, added capacity is provided during the Kharif season. Each outlet had a screw-type gate. A low percentage of the area (about 20 percent) was under canal water.

The discharge of one outlet was estimated to be more than 1 cfs. Near the outlet an apparently illegal siphon took water across the road or drain to another command. A siphon near the outlet on the main watercourse was used to cross an access road. When the discharge of the watercourse was estimated, the channel had considerable seepage losses. Water was in the road; the adjacent tobacco field had a small ditch to collect seepage before it reached the field; 20 to 30 feet into the field the plants were damaged or destroyed by seepage.

One section of the watercourse for several hundred feet had been converted to an underground pipeline. No apparent operational difficulties were observed; however, one joint of the pipe had developed a leak.

The condition of the watercourse suggests that (1) seepage losses were high for the sandy loam soil; (2) the flow at the outlet was sometimes reduced by increased resistance in the channel and backwater; and (3) operational losses may be significant, between 25 and 50 percent, as indicated by water standing in the road.

Fields were relatively unlevel. Small, almost rectangular basins were used for crops like wheat and fodder, and long, narrow graded borders were used for tobacco.

During the reconnaissance study, a wheat field was being irrigated. An estimate of the amount of water being applied suggested a low application depth. The wheat was under stress with an inadequate plant stand.

The Sihol Minor on the Petlad Branch, a traditional distribution system, was visited. The karkoon (canal supervisor) instructed the chowkidar to open the gate settings a certain amount at the beginning of each season. Fluctuations from 30 to 53 cusecs were observed in the discharge during the daytime. At night the flow was reduced to approximately 15 cusecs. This flow was used for irrigation by the farmers at the tail end of the minor. However, one farmer near the head of the watercourse reportedly irrigated regularly at night as well.

Fluctuations in daytime flow were related to the canal level set by the chowkidar each day. Changes in this setting are made only on the specific instructions of the karkoon who communicates such orders two or three times a season. At the time of the study, the gate setting had been established based on requests for water from the chowkidar for all outlets on the system.

Farmers, and/or the outlet chowkidar, opened or closed an outlet according to the demand. No information about procedures for adjustment of cross regulators on the minor was obtained. One implied statement was that at reduced flows, regulators were used to raise the depth of water in the minor; how the outlets were subsequently regulated could not be determined.

Conversations with three farmers revealed the following rotations:

Farmer	Rotation (Days) On/Off
#1	10/5
#2	20/7
#3	7/0

However, the official rotation for the minor and its outlets was 10-days-on and 5-days-off.

One farmer reported being charged a levy of Rs 5 at the beginning of each season for watercourse maintenance. Farmers participated in maintenance along with hired labor.

On Outlet 02/L of the Sihol Minor the estimated discharge was 2.4 cusecs. The initial sections of the watercourse appeared in good repair. At some short sections, damage due to seepage was evident. At later sections, the channel was in poorer condition. In addition, one section was on a steep slope and the channel had eroded 3 or 4 ft below the ground surface;

therefore, the channel could not command the adjacent area. A portable pump was present in the area, but time did not permit determining its exact use.

The minor's cultivated command area was 5,280 acres. The actual area irrigated was 1,100 acres, or about 20 percent of the irrigation potential. The water supply rate was approximately 0.021 cfs/acre during the Rabi season.

In two adjacent tobacco fields, one farmer irrigated on a weekly interval while the other irrigated on a monthly interval. When the teams examined soil water depth in the latter field, the probe (3 ft long) penetrated only 6 inches. The soil was dry enough to be cohesionless.

Soil from the middle border of the field, irrigated on a weekly basis, was sampled. After 2.5 ft, the soil became drier (75 percent of the total available water was depleted), but the top portion was essentially at field capacity from an irrigation two days before. The last border within the field also was checked. The soil was at field capacity the full length of the probe. These observations suggested that the farmer under-irrigated some portions of his graded borders, but usually over-irrigated the last border(s) on the lower end. This was because in every field observed using graded borders, the farmer cut the dike separating a given border from an adjacent border.

5. Rotational Water Supply

The rotational water supply consisted of the following improvements:

(1) establishment of an official rotational schedule, warabundi, for each outlet and allocation of a designed water supply, where the minor runs continuously;

(2) reduction of the area served by each outlet, installation of a screw-type gate, a trapezoidal flume, and a short, lined channel section;

(3) improvement of field channels through design, construction, and installation of control structures; and

(4) provision of inputs and services including improved extension.

a. Rawalapura Subminor

At the Rawalapura Subminor taking off from the Petlad Branch canal, farmers achieved a cropping intensity of 90 percent during the Rabi season. A discharge of 15.9 cfs supplied 486 acres, a supply rate of 0.033 cfs/acre. Flow to each outlet was regulated by the canal chowkidar who opened and closed each outlet according to the scheduled rotation. He also reduced the flow or extend the rotation under special circumstances. For example, at the time of the study, the canals were closed at night to prevent accidental flooding of tobacco for which the Irrigation Department would be required to pay damages. Elevations were regulated at two regulators with flow measurement for each subminor.

A trapezoidal flume was installed approximately 50 ft from the outlet; the discharge was 0.83 cfs. The farmer's delivery system was in adequate repair and reasonably clean. Most fields had a subsidiary field distribution system for applying water to the field. Freeboard appeared to be adequate, and junctions had not appreciably deteriorated.

One tobacco field had just been irrigated. A pre-irrigation was in progress on another field where tobacco was grown. The borders were approximately 12 by 350 ft (Figure 6). The farmer added water to the first border at the top allowing it to advance to the end of the border. The water then was stopped in the first border and started in the second border. Holes were cut in the ridge separating border number 1 from number 2; the slope from these borders transferred the water from number 1 to number 2. Water was drained from the end of each border. Water also accumulated in the last border on the lower end of the field.

Changes in elevation within each field appeared to be substantial. Both graded borders and level basins had significant variations in field surface elevations. The farmer applied an estimated 3.2 inches of water over 0.88 acres.

Appropriate distribution of water in a sandy loam soil in a graded border was not determined. This may be an important aspect of irrigation in the project area.

b. Chikhodara Distributary

The investigating team also visited the lower end of the Chikhodara Distributary where rotational water supply improvements were being implemented. Conversations with several farmers indicated that the conversion from the traditional approach to the improved rotational water supply was in a transition and knowledge about the availability of water at a given outlet was not generally available. For example, near the area we visited, one field channel had been improved and a new outlet constructed; however, the adjacent outlets had unimproved traditional outlets. Also, the weekly rotation of each outlet had not been consistently implemented. Because of this transitional status, further studies were not pursued at this point on the distributary. However, several appropriate observations were made on the one improved outlet.

Figure 7 illustrates the design and construction of the improved outlet. A screw-type gate was installed at the inlet to a siphon which carried the water under an access road to an outlet into a short, lined section of channel. A short distance after the outlet, a trapezoidal flume had been installed in the lined section of the channel. The lining terminated and the improved earthen watercourse began about 10 to 20 ft after the flume.

A cursory examination of the field channel suggested that severe erosion had occurred with subsequent deterioration of the earthen banks and sloughing. Without adequate elevation data and a design discharge, precise cause-effect relationships were not apparent. However, the relatively small drop between the short section of lined channel and the bottom of the earthen channel apparently introduced sufficient gradient to result in an erosive velocity. As a result, the improved earthen channel was severely eroded and its banks were deteriorating. It was not possible to establish whether the watercourse had been constructed before the outlet, or whether the outlet had been built at a higher elevation. Conversations with the On-Farm Development Works people indicated that the field channels were constructed both before and after the installation of the improved outlet without regard to the eleva-

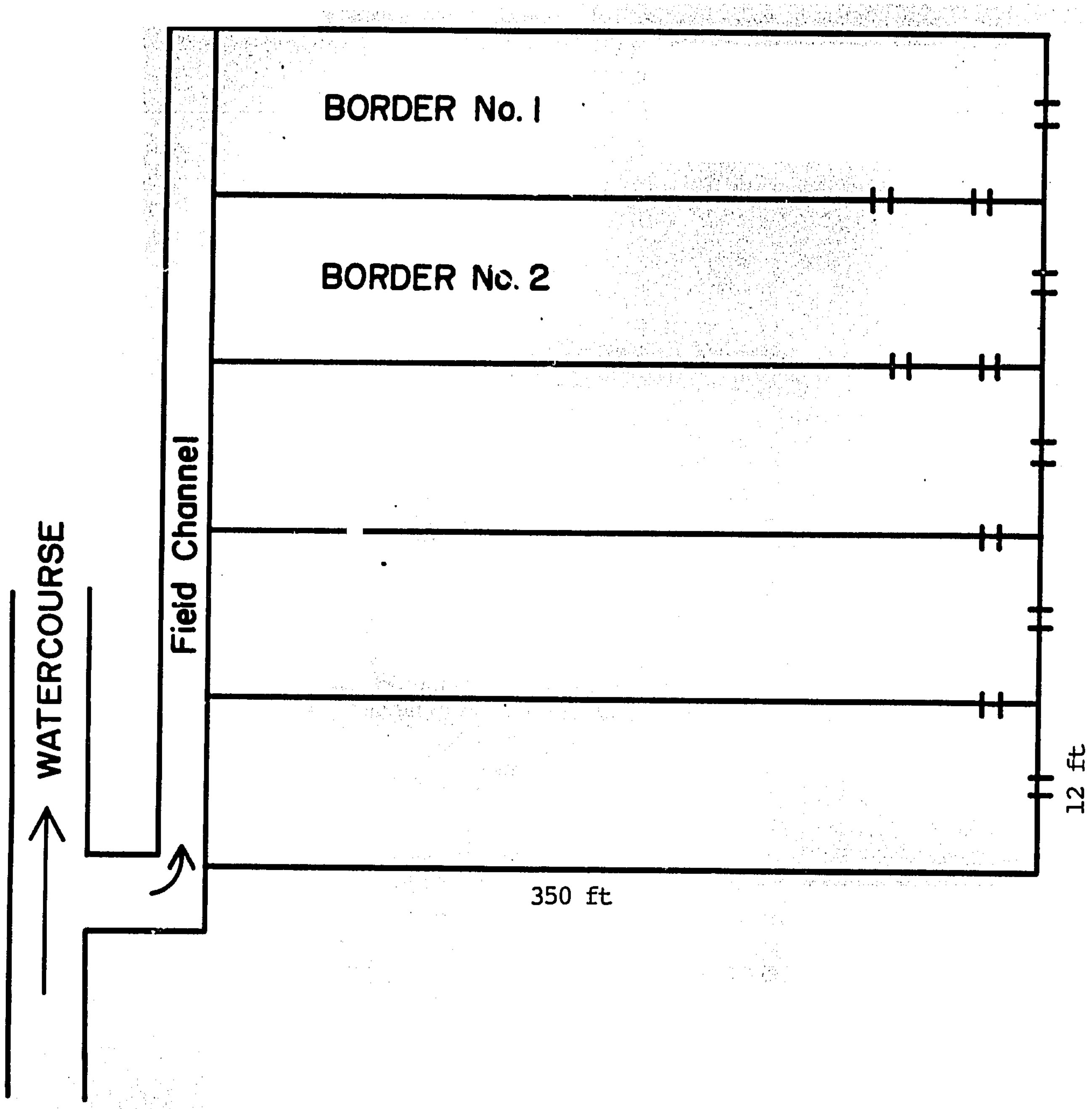

Figure 6. Schematic Diagram for Field Layout of Borders for Tobacco

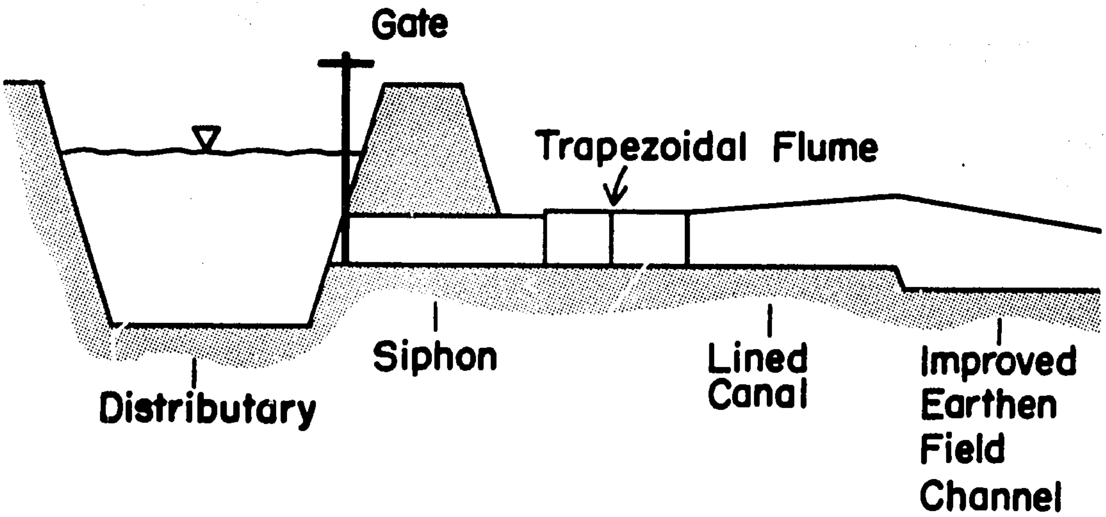

Figure 7. Improved Outlet for the Rotational Water Supply

tion of the bottom of the lined channel of the newly constructed outlet. This type of construction was observed on several outlets on the rotational water supply minors; the resulting erosion had severely damaged the channel.

The cause of such improper design, connecting the unlined field channel to the short, lined section, is related to one or the other of two factors: (1) the lack of understanding of the effect of the drop on subsequent channel erosion; or (2) the On-Farm Development Works Department and the Irrigation Department did not coordinate design elevations for the sections of channel that they built. Both causes may be relevant to a given outlet design.

c. Subminor 10R

Discussions with the other trainers indicated that the two different rotational water supply systems visited on the reconnaissance survey were not appropriate for subsequent study. The first one was an intensive development, potentially unrepresentative of the effect of the rotational water supply. The second was too transitional in nature, and the full effects of the rotational water supply had not developed. Another visit was made to Subminor 10R on the Chikhodara Distributary for the purpose of identifying the appropriateness of the subminor for a study of the rotational water supply.

The cursory visit was made by the engineering trainer accompanied by the executive engineer for the Anand division of the Mahi-Kadana Project. Improvements had been in place on the subminor for approximately one year. Observations and subsequent data verified that cropping intensities had increased on Subminor 10R more than 50 percent compared to other outlets.

The command area of most improved outlets had been reduced by the addition of a number of outlets. Each outlet consisted of a short section of lined channels and a trapezoidal flume for measurement. In addition, the screw-type gate had been installed. Each outlet also had posted, near the end of the last Rabi season, a warabundi (fixed schedule) for use by subgroups and individual farmers. Several outlets had not yet had the field channels completed; thus, some unauthorized outlets were operating because of a lack of an adequate field channel distribution system. Three or four such unauthorized outlets were observed; at one point on the Subminor 10R, farmers had constructed an unauthorized cross regulator out of brush and trash.

After a review of the data on the cropping intensity and the cursory review of the site, the Subminor 10R was selected for an evaluation of the rotational water supply.

6. Results of the Reconnaissance Survey

The purpose of the reconnaissance survey was to identify key benefits and constraints of the operating systems within the Mahi-Kadana Project. Two different approaches to water supply were noted: the unimproved traditional and the improved rotational. The command area of an outlet, whether traditional or rotational, usually was not large. The soils of the area were predominately a sandy loam. Representative cropping patterns and farm sizes were distributed throughout the area under investigation. As expected, some difference was noted between farmers at the head of an outlet and those located at the tail end.

As a result of the team's study of the traditional and rotational water supply systems, the following specific questions were developed to be answered during the detailed studies:

(1) How does the actual operation of a minor compare to the described operating procedure?

(2) What are the conflicts and constraints imposed on farmers by this operating procedure for the canal?

(3) What are the major factors constraining yield of tobacco, wheat, and pearl millet?

(4) What are the losses in the watercourses under traditional versus rotational water supply canals?

(5) What are the chief benefits of the rotational water supply? Improved field channels? Dependable timing? Dependable flow rate? Yields? Income?

(6) What are the effects of unlevel fields and variable slopes on distribution of irrigation water in a field, and subsequently on crop growth?

(7) What is the cost effectiveness of farming under various conditions of traditional water supply versus rotational water supply? Are higher or lower amounts of inputs used? Is the irrigation practice better or worse? Are yields higher or lower?

(8) What are the quality and quantity of institutional services in the two different water supplies?

(9) What are the incentives and disincentives of government staff in terms of performance?

(10) What are the factors that influence farmer decisions on how much and which crop to grow?

C. Detailed Studies

Detailed studies were conducted on four outlets with traditional water supply (Sihol Minor) and three outlets with a rotational water supply (Sub-minor 10R). The purpose was to collect data answering the specific questions stated above. This section presents the procedures by which the studies were conducted and the analysis and interpretation of data. The farm water control system includes water delivery, water application, water use, and water removal subsystems.

Major differences in system operation were assumed to exist between the traditional water supply and the rotational water supply, including the provision of the On-Farm Development Works and the location of outlets on a minor. Outlets were selected near the head, middle, and tail portions on each of the two types of water supply systems because of the expected difference in water supply along a minor. Additional outlets had been provided on both minors; therefore, the area commanded by an outlet was small. Large differences between the head and tail on an outlet were not expected; however, farms were selected on both the head and tail. The investigation on an outlet was then structured primarily around the random sampling of marginal, small, and large farmers. These were the major factors for which differences were expected to exist.

1. Procedure

Investigation of the operation of the systems was confined primarily to observation of the regulation of outlets and cross regulators. The irrigation engineers assisted the on-farm engineers in the measurement of discharge at an outlet. Cooperative activities of the canal officials and the farmers also were noted.

The procedures used for studying an on-farm delivery system appear in Trout and Kemper (1980). Primary efforts involved measuring discharge at the outlet and the field to determine losses in the field channels and amounts of water applied to fields. The elevation and cross section of the field channels and fields were surveyed to determine the effectiveness of channels for delivering water. Procedures suggested by Trout and Kemper (1980) for identifying the cause of losses and ineffective operation of the field channels also were used.

Field application of water was studied according to procedures detailed by Ley and Clyma (1980) and Gates and Clyma (1980) for the evaluation of graded border and level basin irrigation systems.

Field studies were planned by the interdisciplinary team, developed further by disciplines, and executed by various combinations of disciplines (Lowdermilk et al., 1981). An initial time frame of three days for field activities was extended to four days. Trainers and participants worked on the same outlet initially. Then one team was assigned to each of the three outlets for subsequent detailed studies on the Sihol Minor.

2. The Canal System

a. Traditional Water Supply

From the viewpoint of the Irrigation Department, maximum flexibility and reliability of water supply comes from operating a demand system in which many improvements and facilities have been provided. The traditional operation of the Sihol Minor provides a mean daily flow or design discharge for the Rabi season based on the crop consumptive use and system losses. This design discharge is obtained by averaging the discharge for the 12 hours in the day with the discharge for 12 hours at night.

The actual operation resulted in a discharge near 55 cfs during the day and 10 to 15 cfs at night. This was illustrated by the daily fluctuations in discharge, particularly in the January and February sequence (Figure 8). This daily fluctuation in discharge occurs because most farmers do not irrigate at night unless a shortage of water exists. Such shortages would occur primarily on the tail of the minor. The nighttime discharge is directed primarily to the farmers at the tail of the system so they can irrigate at night.

Figure 9 gives the variation in discharge for Outlet 02/L, Sihol Minor, on three different dates. February 26 had an increase to a maximum

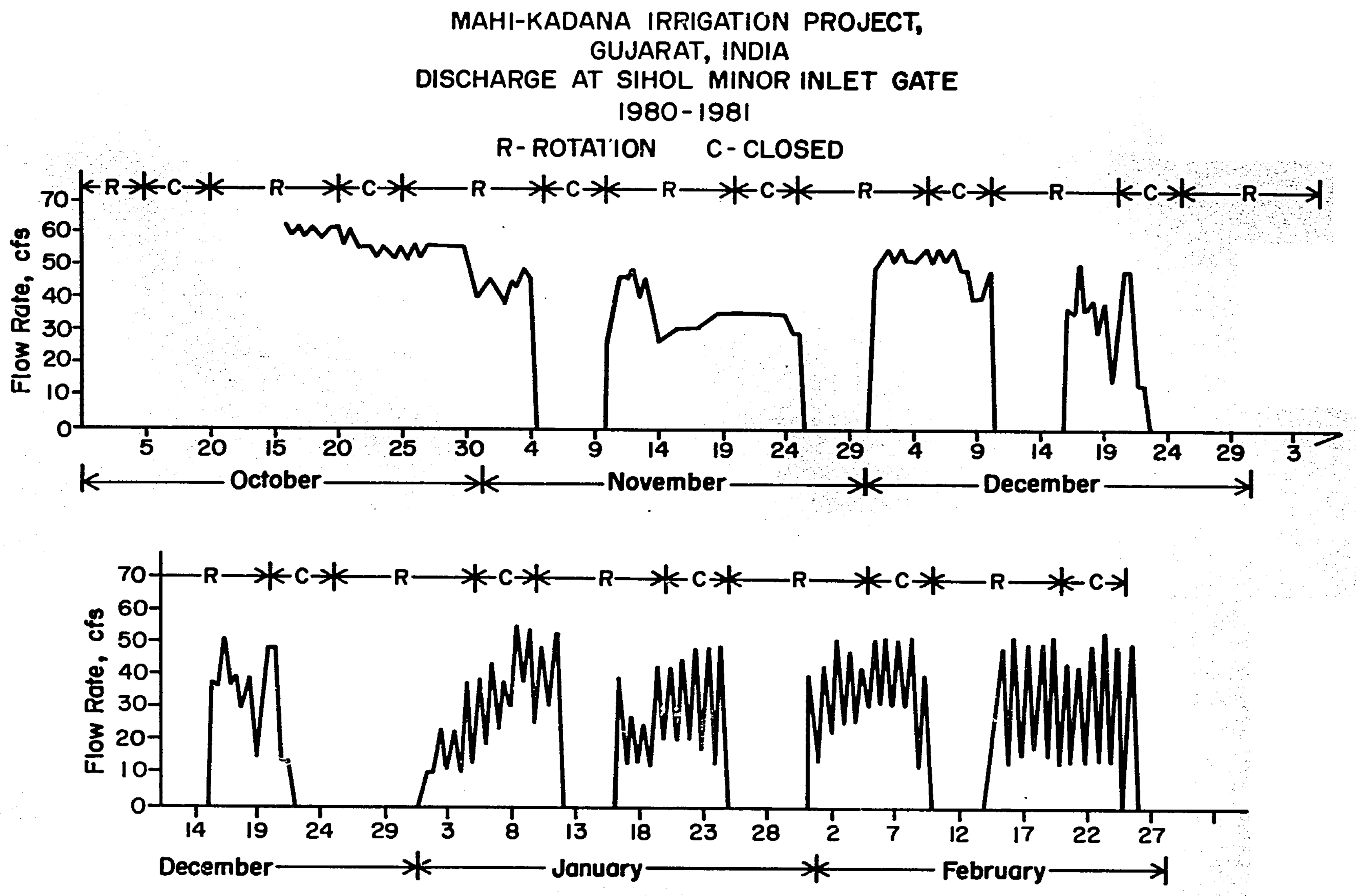

Figure 8. Variation in Daily Discharge for the Sihol Minor

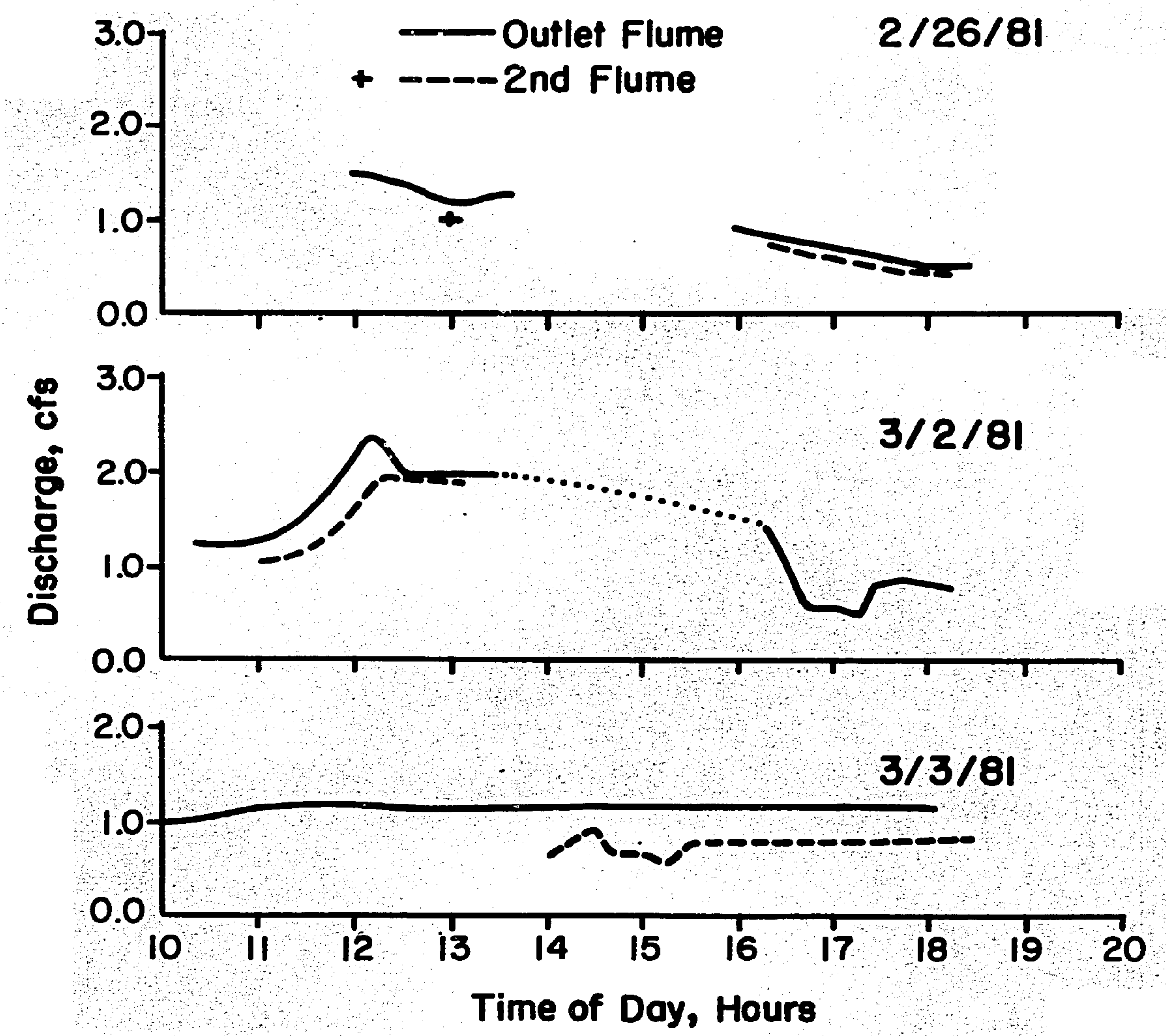

Figure 9. Variation in Discharge at Outlet 02/L, Sihol Minor

discharge (not measured) and a continuous decrease during the day. On March 2, the farmer irrigated a higher field. The lower discharge was the capacity of the field channel. Spillage and seepage exceeded an estimated 50 percent of the flow during this time. The lower flow produced a more constant discharge. On March 3, more variation in discharge was observed. These fluctuations were a function of the operation of cross regulators and the plugging of siphons by farmers. No immediately adjacent cross regulator maintained a relatively constant depth at Outlet 02/L. All three of the other outlets studied on the Sihol Minor were near siphons that had been partially plugged to maintain a more constant, but still fluctuating, water level.

The variation in discharges and water levels at the minor inlet and at Outlet 10/LA are given in Figure 10. At Outlet 10/LA, which is adjacent to a culvert, farmers used banana stalks and trash to constrict the flow through the culvert pipes. The farmers maintained a higher than design water level most of the time at the outlet. The outlet dicharge was limited by the capacity of a nearly level, poorly maintained field channel. The result was a nearly constant discharge at the outlet.

In addition to the daily fluctuation in discharge and water levels, an official rotation of 10-days-on and 5-days-off existed (Figure 8). These rotations also were established for specific intervals during the month because of the need to rotate minors and thus reduce total system capacity. In addition to the plot of daily discharges, Figure 8 gives the actual and the official on (R) and off (C) periods for the rotation. At the end of the Kharif season, while rice was still being grown, fewer daily fluctuations in discharge were observed because farmers apparently continued to use water at night. The formal rotation for the minor was not initiated until late December or January. During the 1980-81 season, the closure during December resulted from unusual widespread rainfall in the project area.

The gradual buildup of daily discharges indicated in January reflected the increasing daily requests by the farmers to open gates for irrigation. Periods of closure also were adjusted because of farmer demand. The result was a widely fluctuating on-off period that did not correspond to the official rotation communicated to the farmers. When several farmers on an outlet were asked what the official rotation of the canal was, they responded variously from a weekly rotation to 1-week-on and 1-week-off, and up to 3-weeks-on and 1-week-off. The farmers also had limited knowledge of the official rotation of the minor. In other words, the frequency with which farmers took water varied from 1 to 4 weeks and barely resembled the official rotation.

The gate outlets for the watercourses on the Sihol Minor operate as an orifice. Placing an orifice on the minor causes the outlet discharge to be approximately constant for a wide range in operational levels. Thus, the gate-type orifice is appropriate for the fluctuating levels in the minor. The gate, however, has continuously varying settings. In this study, both the canal chowkidar and the farmers attempted to raise the gate to the maximum level to attain the maximum discharge from the outlet. Therefore, the water level for outlets located some distance from a cross regulator fluctuated widely.

The reconnaissance study had noted farmer involvement in the operation of the cross regulators, associated control structures, and the outlet gates. During the detailed study, numerous instances of farmer involvement were confirmed. These included a range of unsanctioned outlets, transfer of water

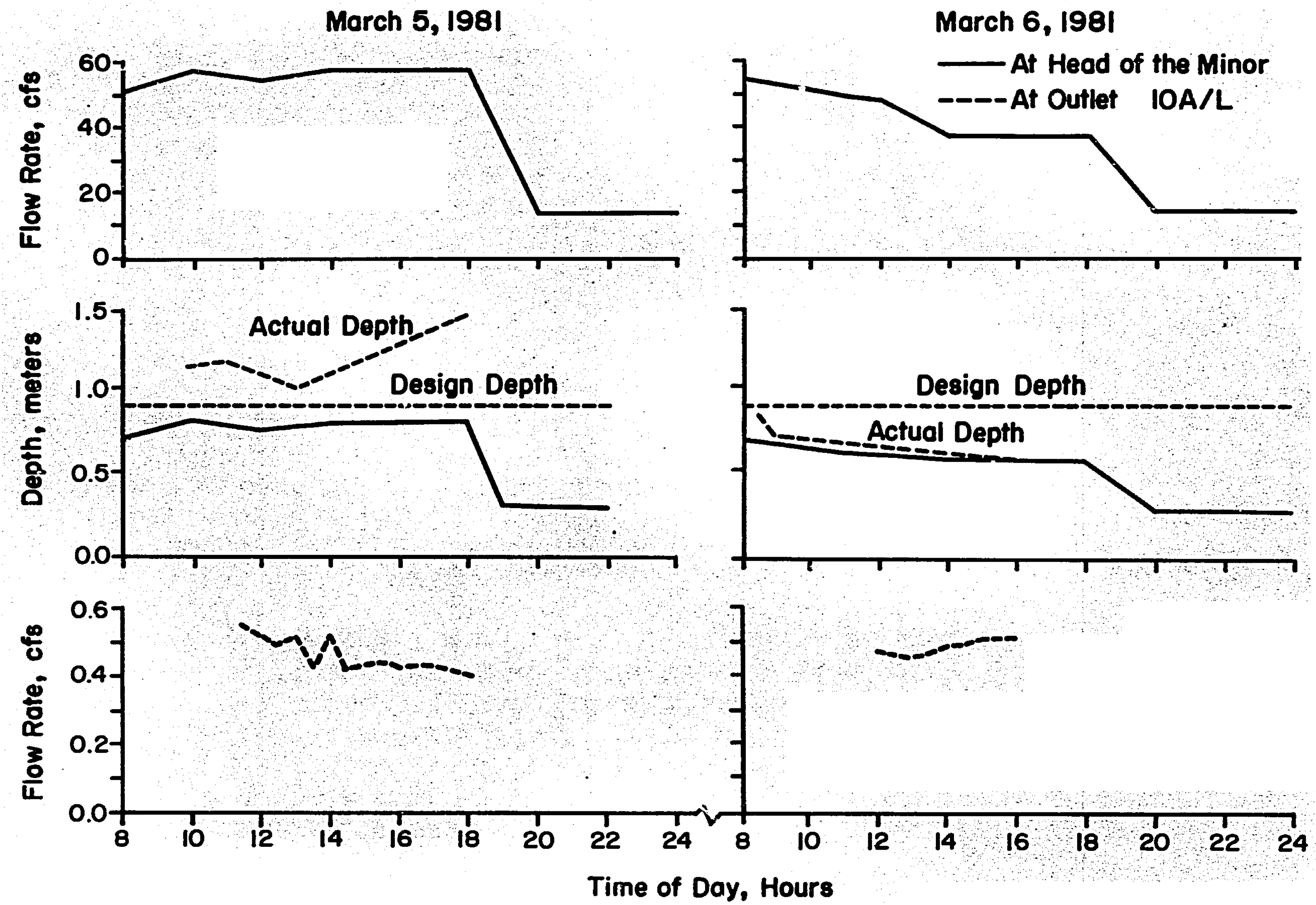

Figure 10. Discharge and Water Levels at the Minor Inlet and at Outlet 10/IA

to fields outside the listed outlet command, and outlet command areas considerably larger than designated.

Another aspect indicative of involvement was the outlet gate *chowkidar*'s interactions with the farmers. In some instances, farmers requested that the gate be raised or lowered to regulate the flow according to their needs at that time. In other instances, conflicts arose over turns of the rotation. The disputes, however, were resolved among the farmers themselves rather than by the Irrigation Department official. As a result, the more powerful farmers had undue influence over the availability of the water, and the canal water supply was undependable.

b. Rotational Water Supply

In the 1978-79 *Rabi* season, the rotational water supply system was introduced into the Mahi-Kadana Project on an experimental basis. The purpose was to improve the reliability, equity, and timeliness of water delivery and to involve the farmer in the management of the system. The rotational system was operational only during the *Rabi* season. In the improved rotational system, a minor operates continuously while an outlet operates for a time in proportion to the area commanded. Two or more outlets are operated in sequence to use a given discharge from the minor for a week. Farmers below the outlet received water by subgroups consisting of 6 to 10 irrigators each; the subgroups made up the total rotation time for an outlet. The rotation was discussed with the farmers before implementation, and the schedule for the rotation was placed on a sign board near the outlet.

The discharge at the outlet was approximately 1 cusec. The duration of the flow was a function of the area to be irrigated, the consumptive use of the particular crop, and the losses in the system (assumed to be 25 percent for field channels and 10 percent for fields).

The minor operated essentially like the traditional water supply. The 10R Subminor did not have provisions for measuring water allocation to the outlets. During the studies, the outlets were closed when they were scheduled to be opened, and opened when scheduled to be closed. The closed outlets were explained by the lower demand for water at the end of the *Rabi* season.

Several unauthorized outlets, observed during the reconnaissance, had been removed by the time of the detailed study. The justification for their initial existence was that some sections of the field channel construction had not been completed. An unauthorized cross regulator, constructed of brush and debris, also was observed. One group of farmers used a large flexible siphon to obtain water from the subminor because their land was no longer commanded by the field channel of Outlet 01/R. The branch field channels to their field could not deliver water because erosion at and around a junction had lowered the level of the field channel below their branch channel. Outlets appeared to operate on demand.

Water levels in the Rawalapura Subminor and discharges at each outlet were not obtained because most outlets were closed during the time of the detailed study.

c. Summary

Few differences between the rotational water supply and traditional water supply minors were observed. The rotational system provides water on a weekly rotation to outlets but the minor operates continuously. The traditional water supply uses a 10-days-on and 5-days-off rotation for the minor. However, outlets on both systems appeared to operate according to demand. Night irrigation was not a practice even though according to the *warabundi* it was scheduled. Daily fluctuations in flow due to farmer operation of cross regulators and outlets were prevalent.

3. The On-Farm System

The water control system at the farm level has several subsystems; water delivery, water application, water use, and water removal.

a. Water Delivery Subsystem

Figure 9 shows discharge fluctuations for Outlet 02/L, Sihol Minor, and Figure 10 gives discharges for Outlet 10/LA of the same minor. The other two outlets investigated were close to control structures; because the outlets operated as an orifice, the discharge did not vary appreciably. The dominant fluctuations for Outlet 02/L resulted from changes in the setting of the gate by the farmer and/or the canal *chowkidar*. Outlet 02/L was located a considerable distance from a cross regulator.

On the first day, February 26, the continuous decline in discharge from near 1.5 cfs to nearly 0.5 cfs reflected the continuous decline in water level in the channel during the day when other outlets were operating and the cross regulator had been adjusted (Figure 9). The second day, on March 2 before 11:00 a.m. when the flow was approximately 1.0 cfs, reflected the period when a farmer was irrigating a high field. Backwater in the field channel from a field over 2,000 feet away had reduced the capacity of the channel to 1.0 cusec. There was considerable leakage and spillage at this flow rate with a loss rate estimated at over 50 percent. The rise in discharge after that time reflected the changing of the field to one near the tail of the watercourse. The resulting increase in gradient increased the capacity of the field channel, and the flow increased from the minor. The farmer on an adjacent field requested that the discharge of the outlet be reduced in order to prevent overtopping and spillage at the higher flow rate. The continuous decline after that period again reflected the daily decline in discharge.

On March 3 the discharge from Outlet 02/L was approximately constant, but at a low level. Thus, the variation in discharge was not as significant as the discharge at a higher level. The flow rate at the field was several thousand feet away, and this represented a good measure of steady state losses in the field channel. Table 46 presents an analysis of loss rates for the different outlet commands for the unimproved traditional and improved rotational systems. Based on detailed studies on similar systems (Trout and Bowers, 1979), the average delivery efficiencies for the unimproved systems are: Outlet 02/L, 65 percent; Outlet 10/LA, 40 percent; and Outlet 12/L, 50 percent or less.

Table 46. Loss rates of watercourses on the unimproved and improved system

Outlet No.	Loss Rate, lps/100m	Percent Loss per 100 m
Unimproved System/Sihol Minor		
02/L	0.78 0.97	1.5 3.0
10/LA	1.869	15.2
12/L	No evaluations were made, but significant losses due to leakage and overtopping were observed.	
Improved System/Chikhojara Distributary		
01/R	0.91 (Site 1) 0.49 (Site 2)	— —
05/L	1.18	4.8

The loss rates were compared to those measured on the other rotational systems for which the average delivery efficiencies had been measured. This loss rate, however, did not represent the average delivery efficiency for a significant number of fields. Loss rates from channels where the fields were high and the water level in the watercourse was at a greater depth resulted in significantly greater losses. For example, studies in Pakistan showed that raising the water level in the watercourse by 1 inch doubled the loss rate. High loss rates also occurred when fields that were marginally commanded by the field channel were irrigated. The result was overtopping and breaching of the banks of the watercourse. A number of these instances were evident in irrigated fields observed as part of this study.

The elevation control of the field channels was studied. As originally designed by the On-Farm Development Works, the watercourse was to be constructed to a constant grade. However, the grade of the bottom of the watercourse was variable (Figure 11). Some sections had erosive slopes, were almost flat, or had negative slopes in the length of channel surveyed. The tops of the banks were lower than the level of the field, or the fields were uncommanded. One field on Outlet 02/L had approximately 20 cm of soil removed by the farmer in a land leveling operation to allow his field to be commanded by the watercourse.

Erosion occurred in sections that lacked control structures to maintain a non-erosive slope on the water surface during operation of the watercourse. In other instances, proper control structures were lacking where drops in elevation in the field channel were excessive. The result in each case was that farmers had difficulty irrigating significant areas in the outlet command. For example, in Outlet 02/L command, as much as 50 percent of the area was uncommanded by canal water because of the elevation of the field channel. Specific sections of the field channel varied in slope from

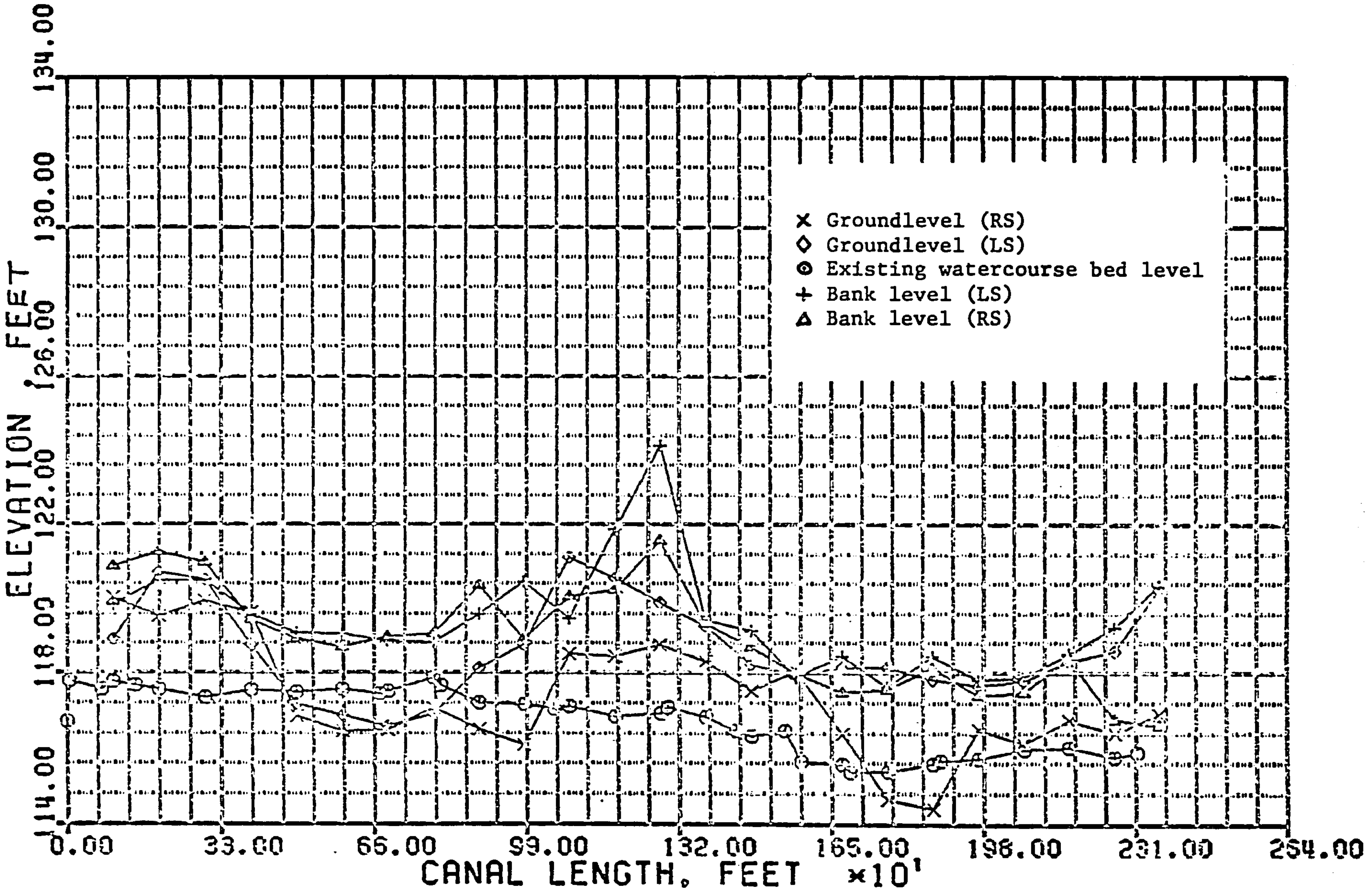

Figure 11. Sample Profile of Bed of Field Channel Outlet, 02/L

0.2 to 2.4 percent. Erosion occurred in several lengths of the channel when the flow rate and slope created an erosive velocity.

Significant erosion below the ground surface also appeared in one section of the channel. Farmers had to go several hundred feet upstream for the outlet to command the area near the watercourse. The problem was due to a significant fall in the watercourse where the watercourse had a 90 degree bend. Without a proper drop structure, severe erosion had started at this fall and had proceeded up the channel. Fields adjacent to the watercourse could not be commanded. Subsequent conversations with farmers indicated that originally the watercourse remained on the terrace and commanded the fields. Because of a conflict with the farmers in whose fields the watercourse had been located, the watercourse location was changed. Without a proper drop structure, erosion had resulted.

Table 47 presents watercourse slopes for the unimproved and improved outlets and comments about the conditions of the field channels.

Table 47. Average bed slopes of unimproved and improved watercourses

Outlet No.	Average Slope	Remarks
Unimproved System/Sihol Minor		
02/L	0.00081	Has several negative slopes, and several steep slopes even up to 0.0242 m/m
10/LA	0.00482	No steep slopes, has several negative slopes
11/L	*	Below ground-level with large areas uncommanded
12/L	0.0011	No erosion, poor maintenance including abandoned and destroyed sections. Large areas uncommanded
Improved System/Chikhodara Distributary		
01/R	0.006	Severe erosion of the bed
05/L	0.0042	No negative slopes except in the first 30 m of the watercourse

* Data unavailable.

b. Water Application Subsystem

The water application system was studied from three different viewpoints:

(1) The engineers and agronomists related crop stands and crop conditions to elevations of the field surface.

(2) Observations were made on the amount and frequency of water applied to fields based on flume measurements and estimates of discharge.

(3) Detailed evaluations were conducted on three different fields: a level-basin banana field, a graded-border tobacco field, and a graded-border, pre-irrigation fodder field.

Based on the general observations of the engineers and agronomists, and on the elevation variations within graded and level borders, a major problem existed in poor levelness of fields. According to the United States Department of Agriculture (USDA) standards for land leveling, graded borders should have a grade ±3 cm with no reverse grades. The level border should be ±1.5 cm. No field within the study met these standards (Table 48).

The ranges in elevation shown in Table 48 should be compared to a maximum allowable 6.0 cm for graded borders and 3.0 cm for level basins. All ranges exceeded these values by five times or more for level basins and from one-and-a-half to six times for graded borders. Graded borders are also unacceptable if reverse gradients are present. Several of those measured had reverse gradients and were unacceptable as field systems.

Agronomists and engineers repeatedly observed the relationship between poor stand, no stand, or poor crop conditions, and low and high areas in the field. However, approximately 70 percent of the farmers believed their fields were level, according to extension personnel.

Farmers frequently did not level their fields; if they did so, they used hand labor methods. They considered the service available from the government, which uses bulldozers, acceptable in quality but costly.

The need for technical assistance in the area of precision leveling of fields was not expressed either by officials or farmers. The attitudes of the engineers at the beginning of the training course was that water was to be delivered to the outlet. Field channels could have been constructed according to design, but they felt operation and maintenance was the sole responsibility of the farmers.

A range of general problems affected the various systems of irrigation. One major problem was the fluctuating flow rate that occurred due to the improper delivery of water by the field channels. For some fields, low flow rates occurred because of the necessity to store water in the channel, thereby raising the level in the fields sufficiently to irrigate the field. Large losses resulted and the flow rate at the field was low and varied. This was further accentuated by the variability of the discharge at the outlet. In those fields where a buildup in the water level in the field channel occurred, periodic breaks in the channel or overtopping caused further fluctuation in flow rates. These fluctuating flow rates had affected how farmers decided how much water to apply.

Farmers used wild flooding to pre-irrigate in some fields. Wild flooding delivers water to a field through a small channel constructed across the field. The water spills from this channel to the total area of the field. The sequence of spilling depends upon the topography and the small bunds built at the channel to direct the water. Observations of this practice in a number

Table 48. Range of elevations in graded borders and level basins in selected fields on the unimproved and improved systems

Outlet No.	Field No.	Border/Basin No.	Max (m)	Min (m)	Range (cm)	Mean (m)	Standard Deviation (cm)
<u>Unimproved System</u>							
02/L	647	Basin 3	99.985	99.815	17	99.932	5.5
		Basin 4	100.075	99.855	22	99.933	6.2
10/LA	673/674	Border 1	34.73	34.52	21	34.613	6.1
		Border 2	34.70	34.50	20	34.608	6.7
<u>Improved System</u>							
05/L	275	Border 7	40.94	40.79	15	40.855	5.3
		Border 8	40.96	40.77	19	40.853	5.2
12/L	678/1	Border 1	33.75	33.380	37	33.551	7.7
		Border 2	33.58	33.375	20.5	33.493	3.6
		Border 3	33.57	33.425	14.5	33.499	3.2
		Border 4	33.58	33.425	15.5	33.508	3.8
		Border 5	33.55	33.460	9	33.499	2.7
	686/1	Basin	33.84	33.695	14.5	-	-

of countries suggest that from 20 to 60 cm of water, or more, are applied in these types of irrigations resulting in over-irrigation.

The two predominant methods of irrigation used in the Mahi-Kadana project were level basins and graded borders. Level basins were used for bananas, wheat, millet, a limited amount of tobacco, and some other crops where surface topography permitted. Farmers applied water to level basins, commonly one-tenth acre or less, until the water reached the end of the field, or reached a certain depth in the field.

Only one detailed evaluation of a level basin was conducted during this study. Thus, conclusions cannot be made based on the data collected. However, experiences in a number of countries suggest that precision leveling for this method of irrigation is necessary for it to be effective.

Graded borders were used on a number of crops, predominantly tobacco. Borders ranged from a few meters to not more than 7-m wide, and from 75 to 125 m long. Most tobacco plants were inundated when irrigated by the graded border method.

Most farmers stopped applying water when it reached the end of the field. This procedure was repeatedly observed during the detailed study. However, the two detailed irrigations observed did not provide sufficient data to reach conclusions. A more detailed study of the range in levels of performance of graded borders is a high priority need. Based on experience with these types of irrigation systems and the general observations, a number of the problems with graded border irrigation exist.

Reverse grades often are observed with this method and are considered an unacceptable condition. Another problem relates to the inadequate opportunity times at the upper and middle portions of the border. This results from farmers applying water until it reaches the end of the border. Water also can pond on the lower end of the border, or the lower end of the field, due to the lack of water control and the selection of the improper flow rate.

To irrigate graded borders uniformly, the farmer must select an appropriate flow rate such that the advance and recession times result in a uniform distribution of water. The opportunity time must equal the time necessary to infiltrate the desired depth. The wide variation in flow rate at the field level, as observed by the operation of the outlet and the operation of the field channels, make it essentially impossible for farmers to control the application of water to a graded border. In general, the result over-irrigation for some fields and under-irrigation for others due to the combination of intake, slope, and flow rate. Therefore, effective water management under these conditions is extremely difficult, if not impossible. An analysis and discussion of the results of each detailed irrigation evaluation are presented in Appendix B.

c. Water Use Subsystem

A wide variation in irrigation frequency existed. Some crops were severely stressed and had yield reductions, and others were over-irrigated because of frequent applications. Therefore, within a field over- and under-irrigation is widely variable because of the nonuniformity of the surface levelness and the farmer's criteria for irrigating graded borders.

According to the extension data, farmers were not able to irrigate as frequently as they desired. However, the observed banana field was over-irrigated primarily because of too high an irrigation frequency. Tobacco fields were frequently severely stressed. Of two farmers with side-by-side fields, one irrigated every 7 days and the other every 28 days. Therefore, a more careful determination of the proper frequency of irrigation for the type of system, soils, crop, and season, is an important need. This determination should then be communicated to farmers as a general recommendation.

d. Water Removal Subsystem

Surface drainage throughout the area appeared to be good due to the light textured soils and the adequate grades on many fields. However, there may be erosion problems during the monsoon season due to rainfall and rainfall runoff from the fields. Ponding of water in flat areas with the tight soils may occur because of the lack of any surface drainage system to dispose of the excess surface water.

Subsurface drainage throughout much of the project area is presently adequate. Some areas have begun to experience waterlogging with the water-table within 1 m of the ground surface. This is in the areas where adequate water had been made available since the completion of the dam and improvement of the canal system. However, the project should place a high priority on water control in an effort to reduce the rate of rise of the water table. A number of areas in the project experienced water levels rising at a rate approaching 1 m per year. This was evident because of excess use of water from the canal, watercourse seepage, and over-irrigation of fields. This recommendation is based also on data from farmers' observations, a soil survey report on groundwater conditions, and observations of some tubewell operators in the area.

The high priority is recommended for subsurface drainage because in many areas groundwater is saline. Unless immediate measures are developed to more effectively control the excess water, the lower areas of the project will become waterlogged. The primary causes of the excess use of water are not understood quantitatively at present. However, losses in field channels and over-irrigation of fields are likely to be the dominant causes. If waterlogging and salinity are to be avoided, they must be assigned highest priority.

D. Summary

1. Positive Aspects of System Operation at Mahi-Kadana

In any Diagnostic Analysis study a major focus is the identification of constraints to the improvement of the system. In the process of studying the system, the focus tends to be on quantifiable deficiencies of operation. It is also appropriate to note the following positive aspects evident at Mahi-Kadana which have not been quantified, but which nevertheless represent major benefits:

(1) The cooperation of farmers; panchayat members; irrigation officials such as chowkidars, karkoons, section officers, and deputy and executive engineers; and the Command Area Development Authority (CADA), especially the On-Farm Development Works officials, was indicative of a high level of interest in improving

the operation of the system. Their assistance was and is essential in understanding how the system operated.

(2) The innovative approach to integrated project administration through CADA is an important emphasis for improvement of projects.

(3) The introduction of a program of rotational water supply (warabundi), including field channel improvements and a water measurement structure at each outlet, should provide improved water control.

(4) The field channel improvements are valid attempts to provide more dependable delivery of water to each farm.

(5) Cooperative approaches in villages to rural development and milk marketing are positive activities.

(6) Innovative and widespread adoption of private tubewells and underground concrete pipelines are a measure of farmer acceptance of new but beneficial technologies.

(7) Distributing water, when canal capacity is not fully utilized, with elevation control and water measurement to each minor is an innovative approach to canal system water control.

2. Recommendations

Specific constraints and recommendations related to the project include the following.

--Fluctuations in flow rate at the outlet and field were significant because of (1) fluctuations in the flow rate in the minors, and (2) the arbitrary setting of the outlet gate by the farmer.

--Watercourses were not properly designed. Even though the average gradient of the channel bottom was acceptable, in several places the channels had negative slopes. In other instances, the bottom slopes were steep, and the lack of proper control structures resulted in significant erosion of the channel bottom.

--Because of this improper alignment of the channels and resultant erosion, many of the fields in the command area became uncommanded. Frequently, only 50 percent of the total area was commanded by the field channels. Sometimes, the channel banks were at a lower elevation than the field surface. Farmers raised the water level in the field channels to irrigate fields at a higher level. Therefore, increased seepage and overtopping resulted in significant increases in losses. Conveyance losses were estimated to be 50 percent based upon the limited data available.

--Level basins and graded borders were the two irrigation methods used in the project area. However, the fields had unlevel topography; the difference between the minimum and the maximum levels exceeded the standard by several magnitudes. Fields with negative gradients also were found.

--Neither farmers nor officials perceived the need for land leveling; they considered it very expensive.

--Farmers irrigated their fields at different frequencies and were unaware of the actual or official rotation of water deliveries.

All the above factors--variable flow rate, improper design, uneven field topography, and inadequate operation of the system--have resulted in significant under- and over-irrigation within a field. This was evidenced by poor crop stands and yields in the area under investigation.

Over-irrigation, in turn, has contributed to raising the watertable at an estimated rate of 1 m per year. Eventual waterlogging and saline groundwater makes this expected problem a high priority. Therefore, water control to reduce the excessive use of water and subsurface drainage is urgently needed.

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SECTION V - AGRONOMY

A. Introduction

Three interdisciplinary teams conducted Diagnostic Analysis surveys of four outlets on the Sihol Minor and three outlets on Subminor 10R of the Chikhodara Distributary during February and March of 1981. This report presents agronomic data collected on both systems.

Prior to the diagnostic survey, the team conducted a reconnaissance survey of three outlets located on the Sihol, Rawalapura, and lower Chikhodara watercourses. The reconnaissance survey acquainted each team member with the irrigation project and provided direction for subsequent detailed studies of the system. During this survey, the agronomist on each team concentrated on visual diagnosis of the irrigated crops and soils with occasional checks of soil texture and soil pH.

B. Reconnaissance Studies

Observations made on the reconnaissance survey are listed below.

1. Crops

- Tobacco (*Nicotiana rustica* and *Nicotiana tobacum*) and wheat (*Triticum aestivum*) (var. Sonalika 1583) were the predominant *Rabi* season field crops. Other field crops observed were bananas, citrus, chickpeas, potatoes, field corn, and Egyptian clover. Some fallow fields and those in which tobacco had been harvested early were being prepared for sowing pearl millet (*Pennisetum typhoideum*).
- Wheat fields were sown in October through November and were observed in the milking to soft-dough stage.
- Wheat had been drilled by *pora hals* in most fields but most farmers drilled the wheat in two directions to improve overall emergence.
- Where wheat followed rice, seedbed preparation for wheat was very poor.
- Wheat stands varied from poor to good.
- Poor wheat stands probably resulted from low seeding rates, poor seedbed preparation, insect infestations, improper irrigation or possible salinity problems.
- The wheat seed used by most farmers was highly contaminated with other varieties of wheat.
- Stands of wheat in some fields were nonuniform suggesting improper irrigation and/or fertility problems.
- All wheat fields were nitrogen deficient.
- White ant infestations were common.

- Weeds infested many wheat fields.

- Disease problems in wheat were insignificant.

- Trees planted around the borders of most fields reduced wheat yields by shading and provided a roosting and nesting site for birds.

- Tobacco fields were ready or nearly ready for harvesting when observed.

- Tobacco fields were transplanted with approximately 90 cm by 60 cm spacing in most fields.

- Tobacco stands ranged from poor to excellent.

- Tobacco stands were highly nonuniform due to disease and insect infestations, nutrient deficiencies, improper irrigation or salinity problems.

- The major insect pests were aphids and stemborers.

- Tobacco mozaic infested every field.

- Weeds infested many tobacco fields.

- Most tobacco fields exhibited potential potassium deficiency although symptoms were masked by disease and insect problems.

- Most farmers used seed from the previous year's tobacco crop.

- Of the remaining crops, banana, a high-value cash crop, appeared to receive the best care.

- Only one field of ridged potatoes was observed, and a late irrigation increased fungal damage to the tubers.

2. <u>Soils</u>

- Surface soil samples were predominantly sandy loam.

- Surface soil samples ranged from pH 7.6 to 8.0.

- A number of fields had salt crusts.

- Organic matter content of surface soils appeared to be less than 1 percent.

- Land preparation with bullock-drawn implements appeared to be fairly easy in the light textured soils.

- Subsurface soil samples varied from sandy loam to sandy clay loam.

- Subsurface soils ranged from pH 7.4 to 7.6.

- Nutrient deficiency symptoms observed visually suggested that soil levels of potassium were inadequate for tobacco.

3. <u>Irrigation</u>

- Most fields were graded borders. Only a few level basins were observed in the lower portions of the command areas. Ridge furrow irrigation was observed in only one field of potatoes.

- Variations in grades between the head and tail end of the field and high and low spots were common in graded borders.

- Graded borders and level basins were commonly divided into strips 3- to 4-m wide. The farmers used cross bunds to improve irrigation applications over high spots and in areas with steeper grades.

- Farmers irrigated their fields through cuts in the irrigation channel because field outlets were nonexistent.

- From 20 to 50 percent of the designed command area of an outlet was not commanded.

- Private tubewells, many with sophisticated underground delivery systems, provided an alternative source of water to farmers with the means to pay for water.

- Where irrigation water was readily available, farmers appeared to over-irrigate. Excessive applications of water and short intervals between irrigations suggested that farmers had little understanding of rooting depth and soil moisture holding capacities.

Observations made during the reconnaissance indicated that detailed studies of the Mahi-Kadana irrigation project should concentrate on the condition of the two major crops, wheat and tobacco, with respect to plant populations, potential yields, insects and diseases, and nutritional disorders. Similarly, detailed characterization of the soils with respect to texture, pH and salinity seemed important. Detailed evaluations of field irrigations by agricultural engineers also seemed important to better understand the irrigation practices of the farmers.

C. <u>Detailed Studies</u>

Because data needed by each discipline overlapped, sampling procedures were coordinated among the disciplines; a stratified, random sample of farmers was studied at each outlet. With the exception of field crop data, which were restricted to wheat and tobacco crops, agronomic data were collected only on fields belonging to farmers interviewed by the sociologists and economists.

A preliminary detailed diagnostic survey of Outlet 02/L of the Sihol Minor was conducted to refine and standardize procedures for collecting data. After this preliminary analysis, the interdisciplinary teams studied selected outlets on the Sihol Minor and Subminor 10R.

The laboratory and field methods used provided specific information about the physical, chemical, and biological environment of the crops. The study period was short and permanent laboratory facilities were lacking. Detailed descriptions of the methods for determining soil texture, bulk density, pH, soil moisture and salinity hazards of soil and water are presented in Lowdermilk et al. (1981). Methods used to evaluate surface irrigation in farmers' fields are presented in the workshop manual (Gates and Clyma, 1980).

Other field data collected included stand counts of tobacco (plants per 10-m row and number of rows per 10 m, replicated 3 times) and wheat (productive tillers per m , replicated 3 times); average number of leaves per plant (10 plants, replicated 3 times); average leaf dry weight (average of 10 leaves); and the average number of grains per wheat head (average of 10 wheat heads). An average seed test weight of 40 g per 1,000 seeds was determined from seed samples obtained from the market in Anand. Estimates of the potential tobacco and wheat yields were calculated from the average stand and leaf or grain data. Estimates of insect, disease, parasite, and other pest infestations were based on the relative degree of the infestation. Low, medium, and high ratings indicated few pests and no crop damage, pests present with slight to moderate crop damage, and heavy pest infestations with severe crop damage, respectively. Visual observations of the condition of the fields and surrounding area were also made. Particular interest was paid to seedbed preparation, the levelness of fields, and trees surrounding fields.

Data collected on plant height, stands, and either leaves per plant (for tobacco) or grains per head (for wheat) were averaged for each field. In addition, average potential tobacco and wheat yields (kg/ha) for each field were calculated. Plant nutrient status was also evaluated for fields within each outlet. A summary of data collected on soils, irrigation, cropping patterns, and intensities for fields within each outlet follows.

1. Soils

Soils observed on outlets of the Sihol Minor and Subminor 10R of the Chikhodara Distributary showed little variation, ranging from uniform sandy loam at the higher elevations to uniform sandy clay loam at the lower elevations. Between these elevations was sandy loam at 0-30 cm or 0-60 cm depths, with sandy clay loam at lower depths. Only one or two low lying fields had clay loam textures. Organic contents of the soils were very low, probably less than 0.5 percent. Soil structure was absent throughout soil profiles, and surface bulk densities averaged 1.5.

According to the FAO-UNESCO soil maps of the world (1974), soils within the study area are dominated by Eutric Cambisols. Calcic Cambisols and Eutric Fluvisols comprised 20 percent and less than 20 percent of the area, respectively. Only Eutric Cambisols were observed on the outlets studied.

Preparing seedbeds in the light textured soils appeared to be relatively easy using stick plows and other bullock-powered instruments. Seedbed preparation was poorly done only when there was insufficient time between crops, such as in the rice-wheat rotation.

Colorimetric pH measurements of soils ranged from 7.8 for surface samples to 7.4 for samples at lower depths. Saturated paste pH values of soil samples taken at depths of 0-15, 15-30, 30-45, 45-60, 60-75, and 75-90 cms averaged 6.8, 6.8, 7.0, 7.0, 7.0, and 7.0, respectively. Evidence of free calcium carbonates was lacking in samples tested with diluted hydrochloric acid.

Although pH ranges of the soils indicated the maximum availability of major nutrients, observed nutrient deficiency symptoms and tissue tests performed on tobacco and wheat suggested that levels of nitrogen, phosphorus, and potassium were low. Interviews with farmers indicated that increased fertilizer costs had significantly reduced the use of inorganic fertilizers. Thus, nitrogen deficiencies would be expected throughout the project area. Unfortunately, the tissue testing methods used here to evaluate nutrient deficiencies were unreliable and therefore levels of available soil phosphorus and potassium could be suspect. Confirming low levels of available soil potassium and phosphorus would only be possible with more precise laboratory analysis and fertility trials.

Neither salinity nor sodicity problems were significant on either of the systems studied. Saturated paste extracts of soil samples taken at 0-15 cms depth had electrical conductivities ranging from .4 to 1.4 mmhos per cm. The electrical conductivities of subsurface soil samples steadily decreased to sampling depths of 90 cm, where average electrical conductivity was about half of those measured on surface samples. Although levels of sodium in soils were not measured, average pH values of 6.8 to 7.0 suggested that exchangeable sodium levels were less than 15 percent.

2. <u>Crops</u>

a. Wheat

All of the wheat fields surveyed on both irrigation systems were sown with a high yielding dwarf variety, Sonalika 1583. According to the Indian Agricultural Research Institute in 1978, Sonalika was developed for the northern zone of India and has become increasingly popular due to its tolerance to rusts. The reported average grain yield for Sonalika was 3500 kg/ha, with the highest recorded yield being 6100 kg/ha. Like other high yielding wheat varieties, yields of Sonalika depended on levels of technology used by farmers. Consistently high grain yields (greater than 3500 kg/ha) were associated with good stand establishment, high fertility, proper pest and weed control, and timely irrigations.

Average potential grain yields of wheat fields in the Sihol Minor ranged from 2150 to 4545 kg/ha with an overall average of 3429 kg/ha (Table 49). Similarly, average potential grain yields of wheat fields on Subminor 10R ranged from 1368 to 5688 kg/ha with an overall average of 3168 kg/ha (Table 50). Although the data on potential grain yields of fields on Subminor 10R showed a wider range of yields and a slightly lower overall average yield for the minor, there was little difference between the wheat yields on the two systems.

The average potential grain yields were not expected to produce the actual yields attained by farmers. Even so, 50 percent of the fields on the Sihol Minor and 60 percent of the fields on Subminor 10R were below reported

Table 49. Tabulated data collected on eight wheat fields located on four outlets of the Sihol Minor

Outlet No.	Serial No.	Plant Nutrient Status*			Relative Intensity of Pest Infestations**		Relative Weed Infestation**	Average Plant Height (cm)	Average No. Productive Tillers/m^2	Average No. Grain/Head	Average Potential Yield (kg/ha)
		N	P	K	Termite	Leaf Spot					
02/L	691	low	med	low	low	medium	medium	84.2	178.0	38.8	2770
10A/L	848/1	med	med	low	low	none	very high	74.4	196.0	35.0	2744
10A/L	848/3	med	med	med	low	none	high	77.8	299.0	38.0	4545
011/L	811	med	low	low	low	low	low	70.6	283.5	34.7	3935
011/L	813	low	med	low	low	low	high	67.3	234.0	27.2	2546
011/L	814	med	med	med	low	low	low	78.7	249.0	44.3	4423
011/L	789	low	low	low	low	low	high	62.5	205.2	26.2	2150
012/L	673	low	low	low	low	medium	low	76.8	277.5	38.9	4318
Average								74.0	240.4	35.4	3429
Standard Deviation								6.9	44.6	6.1	971

*Tissue test index of low, medium, and high levels for N, P and K.

**Relative scales were very low, low, medium, high, and very high.

Table 50. Tabulated data collected on 10 wheat fields located on three outlets of the Subminor 10R of the Chikhodara Distributary

Outlet No.	Serial No.	Plant Nutrient Status*			Relative Intensity of Pest Infestations**		Relative Weed Infestation**	Average Plant Height (cm)	Average No. Productive Tillers/m^2	Average No. Grain/Head	Average Potential Yield (kg/ha)
		N	P	K	Termite	Leaf Spot					
01/R	191/1	low	med	low	medium	medium	medium	60.3	199.0	35.1	2794
01/R	192	low	med	low	medium	medium	high	67.6	174.0	36.8	2561
04R/A	1560	med	low	low	medium	very low	medium	69.9	280.0	19.2	2150
04R/A	1564	–	–	–	medium	very low	medium	66.1	330.0	28.0	3696
04R/A	1562	med	low	low	low	very low	medium	77.2	331.0	30.0	3972
04R/A	1707/1	–	–	–	low	very low	medium	50.3	180.0	19.0	1368
04R/A	1707/3	–	–	–	low	very low	medium	72.3	287.0	25.0	2870
05/L	275	low	low	low	low	low	low	77.9	359.1	39.6	5688
05/L	281/2A	low	med	low	high	low	very high	60.0	189.8	31.3	2376
05/L	283/4	low	low	low	low	low	very high	64.3	295.0	35.6	4200
Average								66.6	262.5	30.0	3168
Standard Deviation								8.4	70.3	7.2	1240

*Tissue test index of low, medium, and high levels for N, P and K.
**Relative scales were very low, low, medium, high, and very high.

average grain yields for Sonalika. Other data in Tables 49 and 50, conversations with farmers in the field, and general observations indicated that farmers, regardless of the irrigation system, were not following the recommended cultural practices for the new high-yielding varieties of wheat.

Stands of wheat as reflected by productive tillers were 40 to 90 percent of those reported for Sonalika (Tables 49 and 50). Field observations indicated that low seeding rates, wide row spacings (25 to 30 cm), poor emergence of wheat seedlings sown on high spots, and inadequate seedbed preparation were the major contributors to low plant populations in most fields. In addition, farmers on both irrigation systems had used their own seed stock for a long time. As a result, varietal contamination was common in all fields surveyed.

Although all of the fields surveyed were sown with Sonalika wheat, plant height within fields and between fields varied considerably. Overall average plant heights in fields on the Sihol Minor and Subminor 10R were 74.0 cm and 66.6 cm, respectively (Tables 49 and 50). According to the Indian Agricultural Research Institute average heights for Sonalika should range from 105 to 110 cm. The nonuniform squat appearance of Sonalika wheat fields characterized vegetative growth on all the fields surveyed. Similarly, average number of grains per wheat head was less than reported for Sonalika (Tables 49 and 50).

While it was impossible to determine all of the causes for the poor performance of Sonalika, nutrient imbalances and inadequate irrigation appeared to be the major constraints common to all fields studied. Even then, direct evidence of inadequate irrigation was impossible to collect due to the growth stage of the wheat fields studied. However, noticeably inferior plant heights and stands of wheat on high portions of unlevel fields indicated nonuniform water distribution. In addition, conversations with a few farmers revealed that they were often unable to obtain irrigation water during critical stages of plant growth. This information along with engineering data concerning the irrigation system operation strongly suggested that irrigation deficiencies contributed to the poor performance of Sonalika wheat.

Nutrient imbalances appeared to be the single most important factor affecting the growth and yields of wheat on almost all of the fields surveyed. Although tissue tests of the upper leaves of wheat plants indicated low levels of nitrogen, phosphorus, and potassium in most of the fields (Tables 49 and 50), only nitrogen deficiencies were easily confirmed visually. Since easily recognizable deficiency symptoms of phosphorus and potassium were not observed, the results of tissue tests for these two elements were questionable.

Conversations with a few farmers indicated that the use of commercial fertilizers had declined with rising fertilizer costs. Apparently, farmers were reluctant to invest the higher input cost necessary for the successful commercial production of wheat. However, it was also apparent that little was understood about the proper use of commercial fertilizers. Broadcast ammonium sulfate on the soil surface was left for two or three days in at least two orchards before being incorporated with an irrigation; commercial fertilizer was also applied to one field of tobacco nearly ready for harvesting.

Little evidence of serious disease problems appeared in any of the fields surveyed. However, observations of insects and weed infestations indicated that farmers placed little emphasis on weed control. Almost every wheat field surveyed had some termite damage, and potential grain yields on five fields of Subminor 10R were decreased significantly due to termite infestations. Similarly, serious weed infestations occurred in a number of fields. Farmers did weed their fields, but they preferred to wait until the weeds were large enough to feed to their animals. This practice lead to lowered grain yields, but it was impossible to determine the amount of damage weed infestations had on the wheat crops.

b. Tobacco

Tobacco was the most widely grown commercial crop observed in the irrigation project area. Two species of tobacco, Nicotiana tobacum and Nicotiana rustica, were cultivated in the area. Of the two, Nicotiana rustica, a Virginia-type tobacco, commanded better prices. However, farmers preferred to grow bidi tobacco, Nicotiana tobacum, because of its greater tolerance of soil moisture stress. Although farmers on both irrigation systems grew improved tobacco varieties, varietal determinations were impossible without the farmers' input. Only on Outlet 01/R of Subminor 10R was Anand-2 confirmed as the variety of bidi tobacco grown by farmers.

Initial observations indicated that farmers on both irrigation systems seemed to take better care of their tobacco fields than their wheat fields. However, detailed studies on individual fields indicated production constraints associated with tobacco were just as severe as those associated with wheat. Furthermore, relatively few differences were observed between tobacco fields located on the Sihol Minor and those on Subminor 10R. As with wheat, suitable technologies for improved varieties were not being adopted by the farmers on either irrigation system.

Tables 51 and 52 include the field parameters measured and average potential tobacco yields for 21 fields on the Sihol Minor and 9 fields on Subminor 10R. The average potential yields of Nicotiana rustica were not included in either table because many of the fields were approximately one month away from harvesting when the survey was conducted. Only one field of Nicotiana rustica on the Sihol Minor and two fields on Subminor 10R fell within the sampling distribution. Therefore, the teams decided to limit discussions to Nicotiana tobacum.

The average potential yield of 18 fields of bidi tobacco on the Sihol Minor ranged from 1130 to 2162 kg/ha, with an overall average of 1625 kg/ha. Average potential yields for eight fields on Subminor 10R ranged from 1228 to 2488 kg/ha, with an overall average of 1955 kg/ha. Although these data suggested that potential yields of tobacco were higher on Subminor 10R, there was considerable error associated with the methods used to develop potential yields. As a result, potential yields of tobacco, which mostly likely overestimated actual yields by a considerable margin, were only useful for comparison with actual yields reported by research stations. Personal conversations with researchers at the Gujarat Agricultural University suggested that yields of improved varieties of Nicotiana tobacum should range from 3500 to 4000 kg/ha. Thus, the estimated potential yields of tobacco, regardless of the irrigation system, were well below those associated with good management practices.

Table 51. Tabulated data collected on 21 tobacco fields located on four outlets of the Sihol Minor

Outlet No.	Serial No.	Tobacco Species*	Plant Nutrient Status**			Relative Intensity of the Infestations***						Average Plant Height (cm)	Average Plant Pop. (ha)	Average No. Leaves Per Plant	Average Potential Yield (kg/ha)
			N	P	K	Root Rot	Tobacco Mosaic	Aphids	Stem-borers	Orobanche	Weeds				
02L	672	NT	low	medium	low	low	medium	low	low	high	low	69	10462	14.4	1130
02L	671	NT	low	medium	low	low	medium	low	low	low	low	52	15700	13.1	1543
02L	663	NT	low	low	low	low	medium	low	low	very high	low	46	16800	11.1	1399
02L	685/3	NT	low	low	low	low	medium	low	low	low	low	56	19500	13.2	1931
02L	680/1	NT	-	-	-	low	medium	low	low	medium	low	66	13390	14.7	1476
02L	676/2	NT	low	low	low	-	-	-	-	-	-	71	19575	14.2	2084
10A/L	843	NT	low	low	low	-	-	low	low	-	low	-	25896	10.3	2000
10A/L	674	NR	low	low	low	low	medium	low	medium	low	low	-	-	-	-
10A/L	841	NR	low	low	low	low	low	low	medium	low	high	-	-	-	-
011/L	812	NT	medium	medium	low	low	low	low	low	low	high	54	18200	13.2	1800
011/L	813	NR	-	-	-	low	low	medium	medium	low	high	39	21760	13.2	-
011/L	815	NT	medium	medium	low	low	low	low	low	low	high	56	19040	13.1	1870
011/L	816	NT	low	low	low	low	low	low	low	low	high	64	21840	13.2	2162
011/L	789	NT	low	low	low	low	low	low	low	low	high	33	14000	9.6	1008
011/L	811	NT	low	low	low	low	low	low	low	low	high	-	19600	12.3	1808
012/L	668	NT	medium	low	low	low	low	low	low	low	low	37.2	17550	10.3	1356
012/L	496	NT	low	medium	low	low	low	low	low	low	low	40.8	24000	9.6	1728
012/L	501	NT	-	-	-	low	low	low	low	low	low	57.7	18850	10.1	1428
012/L	678	NT	low	low	low	low	low	low	low	high	low	42.2	22500	8.8	1485
012/L	676	NT	low	low	low	low	low	low	low	low	low	43.2	23100	9.5	1646
012/L	686/2	NT	low	medium	low	low	low	low	low	low	low	54.0	19500	9.5	1389

*NT = Nicotiana tobacum, NR = Nicotiana rustica
**Tissue test indexes of low, medium and high levels of N, P, K.
***Relative scales were very low, low, medium, high and very high.

Table 52. Tabulated data collected on nine tobacco fields located on three outlets of the Subminor 10R Chikhodara Distributary

Outlet No.	Serial No.	Tobacco Species*	Plant Nutrient Status**			Relative Intensity of the Infestations***						Average Plant Height (cm)	Average Plant Pop. (ha)	Average No. Leaves Per Plant	Average Potential Yield (kg/ha)
			N	P	K	Root Rot	Tobacco Mosaic	Aphids	Stem-borers	Orobanche	Weeds				
01/R	83	NT	medium	medium	low	medium	medium	low	low	low	high	46.1	12825	13.3	1748
01/R	193	NT	medium	low	low	medium	medium	low	low	low	high	54.7	19575	12.4	2488
01/R	207	NT	medium	low	low	medium	medium	low	low	low	high	65.2	16675	11.1	1898
04R/A	1557	NT	low	low	low	low	low	medium	low	low	medium	-	19600	11.6	1228
04R/A	1553	NT	medium	low	low	medium	low	medium	low	low	medium	-	18200	12.2	1554
04R/A	1563	NT	medium	low	low	medium	low	low	low	low	medium	-	18200	13.7	1879
04R/A	1707/3b	NR	low	low	low	medium	medium	medium	medium	low	medium	-	22500	13.8	-
05/L	275	NT	low	low	low	low	low	medium	low	low	high	37.5	31500	11.9	2473
05/L	281/1A	NT	low	low	low	low	low	low	low	low	high	40.3	33600	10.7	2372
Average (for *Nicotiana tobacum*)												49.8	21272	12.1	1955
Standard Deviation												11.3	7306	1.0	458

*NT = *Nicotiana tobacum*, NR = *Nicotiana rustica*
**Tissue test indexes of low, medium and high levels of N, P, K.
***Relative scales were very low, low, medium, high and very high.

Plant height measurements indicated tobacco plants were moderately to severely stunted in most fields studied (Tables 51 and 52). Severely stunted plants had shortened internodes and thick stems. The average number of leaves per plant ranged from a low of 8 to a high of 16. Because stunted plants had fewer leaves per plant, average leaf counts in most fields were lower than expected. In addition, the leaves of stunted plants were often cupped under from the margins. Closer inspection revealed that most plants exhibited multiple disorders associated with disease, pests, and nutritional imbalances. Other field measurements supported the multiplicity of symptoms observed.

Tissue tests of the upper leaves of tobacco plants indicated that most of the tobacco fields surveyed were low in nitrogen and phosphorus, and that all fields were low in potassium. Farmers appeared to be unwilling to invest in fertilizers for a strictly commercial crop.

The intensity of root rot infestations seemed to be higher on Subminor 10R than on the Sihol Minor (Tables 51 and 52). Heavier infestations of root rot may have developed from over-irrigation and poor drainage. Standing water was observed in the lower portions of a few fields on the Outlet 04R/A. The multiple disorders in most tobacco plants made it difficult to evaluate the relative intensities of tobacco mosaic (Tables 51 and 52).

Although aphid infestations were fairly high in a few fields, stemborer attacks appeared to be more serious (Tables 51 and 52). Even low infestations of stemborers would probably have resulted in a 10 to 15 percent crop loss.

Orobanche, a phanerogamic parasite, was found in all of the fields surveyed (Tables 51 and 52). Although it was serious on only a few fields on Sihol Minor, infestations of this parasite would be expected to increase unless control measures involving long rotations of resistant crops are used.

Weed control measures in tobacco seemed similar to those used in wheat. Although weed infestations were much lower in tobacco fields on Sihol Minor than on Subminor 10R, many fields on both minors were heavily infested with weeds (Tables 51 and 52).

3. Irrigation Water

Electrical conductivity measurements of canal water averaged 225 µmhos per cm, indicating a high quality water suitable for use on all agricultural crops. Thus, with canal irrigation there was low potential for salinity problems in the well-drained light-textured soils. However, the poorly designed field channels on the Sihol Minor commanded less than 50 percent of the designed area. As a result, large portions of each outlet were irrigated by private tubewells. Water samples removed from three of these wells had electrical conductivity values of 630, 750, and 810 µmhos per cm, respectively. The higher salinity of these well waters may increase the potential for future salinity problems.

SECTION VI - APPENDICES

A. Participants' Evaluation of Diagnostic Analysis Training Workshop at Anand, Gujarat, India

1. Introduction

The WMSP Diagnostic Analysis Model is being used in two countries to test its relevance and to refine training course content and procedures. Trainees evaluated the Gujarat workshop twice to give their views of this model and to suggest ways to improve the training. This type of evaluation took place the second week of training and at the conclusion of the course. Other forms of evaluation used included: evaluation by trainees upon entry into the course; daily evaluative observations by the training team, discussed in regular staff meetings; evaluations by outsiders who observed the training for two to three days; a structured final evaluation by participants themselves; and a final two-day training team review session. Combined, all of these evaluations provided useful information to refine the training model. The self-evaluation results (Tables A-1 and A-2) show that participants considered acquisition of specific skills, knowledge, and attitudes essential for professional development in water management improvement. The course was of a hands-on nature and involved special discipline sessions, team sessions, and specific field exercises conducted by interdisciplinary teams. Actual watercourse commands were used for all field exercises, with the estimated time in the field ranging from 60 to 70 percent of the total training time.

The training materials used included: two training manuals, one which covered the key concepts and described the subsystems of a farm-level command area, and another which described diagnostic analysis field methods; handouts for lectures; and audio visual materials.

The primary methods used in the training included: intensive field exercises, team work and team exercises, team and group discussions, panel discussions, demonstration, and lectures.

2. Participants' Pre- and Post-Self-Evaluations

The participants completed the first self-evaluation three weeks after the training program began (Table A-1). At this point the participants should have understood the basic concepts used in the training; the expectations of the trainers and themselves, and the basis of the course. Because the program was designed with adequate flexibility, trainers were able to make changes to meet the individual needs of the trainees. Individuals or teams then received additional exposure to a subject, skill, or specific procedure if needed.

The second and final self-evaluation results provided an estimate of the progress achieved (Table A-1). Some skills listed pertained only to members of one discipline, while other skills, knowledge areas, and attitudes applied to all the participants involved in the training program.

Table A-1. Trainee evaluations of skills acquired in DA workshop

Skill		Scale of Skill Acquisition (Percent Responding)			
		Very Good	Good	Fair	Poor
1. Skills Performance for Engineers (Engineers only n=6)					
a. Installation of flumes	Pre	33	33	33	-
	Post	50	33	17	-
b. Reading flumes	Pre	50	33	17	-
	Post	67	33	-	-
c. Checking flumes for accuracy	Pre	33	50	17	-
	Post	33	67	-	-
d. Evaluation of ditch losses					
1) correct location of flumes	pre	33	17	50	-
2) correct length of time for measurements	pre	33	17	50	-
	post	50	17	17	17
e. Estimate of field application efficiencies determination					
1) field area	pre	17	33	50	-
	post	50	33	17	-
2) average flow rate	pre	33	33	33	-
	post	50	17	33	-
3) average estimated efficiency	pre	-	67	33	-
	post	33	33	33	-
4) profile of field (n=5)	pre	40	40	20	-
(n=6)	post	50	33	17	-
5) advance and recession (n=5)	pre	20	40	40	-
(n=5)	post	20	40	20	20
6) infiltration rates (n=5)	pre	20	20	60	-
	post	20	40	40	-
7) understanding results (n=5)	pre	20	20	60	-
	post	20	40	40	-
8) channel elevation control (n=5)	pre	40	20	40	-
(n=6)	post	33	50	17	-
9) field levelness (n=5)	pre	40	40	20	-
(n=6)	post	50	33	17	-
2. Skills Performance for Agronomists (n=3)					
a. Reading flumes	pre	33	67	-	-
	post	67	33	-	-
b. Crop stands	pre	100	-	-	-
	post	100	-	-	-
c. Soil moisture	pre	67	33	-	-
	post	100	-	-	-
d. Potential stands	pre	67	33	-	-
	post	100	-	-	-
e. Soil moisture	pre	67	33	-	-
	post	100	-	-	-
f. Nutrient status of plants	pre	33	33	33	-
	post	100	-	-	-

Table A-1. (continued)

Skill		Scale of Skill Acquisition (Percent Responding)			
		Very Good	Good	Fair	Poor
g. Soil salinity	pre	33	67	-	-
	post	67	33	-	-
h. Soil texture	pre	33	67	-	-
	post	100	-	-	-
3. Skills Performance for Extension and Economics Personnel					
a. Recording data on farmer behavior (n=3)	pre	-	33	67	-
	post	67	33	-	-
b. Design of data schedules (n=6)	pre	17	50	33	-
(n=7)	post	29	57	14	-
c. Interviewing techniques (n=8)	pre	12	25	63	-
	post	62	12	26	-
4. General Skills for All Participants					
a. Approval to farmers (n=9)	pre	33	67	-	-
(n=14)	post	28	43	21	7
b. Data collection methods (n=9)	pre	22	56	22	-
(n=15)	post	43	57	7	-
c. Case in data recording and pointness (n=9)	pre	44	44	11	-
(n=15)	post	53	33	13	-
d. Writing data legibly (n=9)	pre	11	33	33	22
(n=15)	post	47	33	20	-
e. Organizes work daily (n=9)	pre	22	44	22	-
(n=15)	post	20	60	20	-
f. Data reduction (n=9)	pre	-	44	56	-
(n=14)	post	7	79	14	-
g. Data management (n=8)	pre	12	12	76	-
(n=15)	post	40	53	7	-
h. Report preparation (n=9)	pre	-	44	56	-
(n=15)	post	27	67	6	-
i. Report presentation (n=8)	pre	11	11	78	-
(n=15)	post	13	80	7	-
j. Interviewing techniques (n=9)	pre	11	67	22	-
(n=15)	post	27	60	7	7
k. Developing creditability with farmers (n=9)	pre	-	56	44	-
(n=14)	post	14	64	14	7
l. Working overtime to finish a job (n=9)	pre	-	67	33	-
(n=15)	post	60	20	20	-
m. Makes special notes in field books about problems (n=9)	pre	11	44	44	-
(n=15)	post	20	67	13	-
n. Observation of farmer irrigation behavior (n=10)	pre	10	50	40	-
(n=15)	post	27	40	27	6

Table A-1. (continued)

Skill		Scale of Skill Acquisition (Percent Responding) Very Good	Good	Fair	Poor
o. Speed in work (n=9)	pre	11	56	33	-
(n=15)	post	40	47	13	-
p. Arrival at work location on time to set up instruments (n=8)	pre	12	88	-	-
(n=13)	post	38	46	15	-
5. Team Member Relationship					
a. Sharing work-helpfulness (n=14)	pre	50	50	-	-
(n=15)	post	60	40	-	-
b. Cooperation (n=14)	pre	64	36	-	-
(n=15)	post	60	40	-	-
c. Participation in team decisions (n=13)	pre	16	77	7	-
(n=15)	post	40	53	7	-
d. Sharing of leadership (n=13)	pre	8	85	7	-
(n=15)	post	40	60	-	-
e. Follows team leaders instructions (n=13)	pre	62	38	-	-
(n=15)	post	67	33	-	-
f. Role in solving team problems (n=14)	pre	14	86	-	-
(n=15)	post	60	33	7	-
g. Management of team when in leadership role (n=13)	pre	15	62	23	-
(n=14)	post	50	36	14	-
6. General Attitudes about Work and Personnel Relationships					
a. Extra hours (n=14)	pre	36	50	7	7
(n=15)	post	60	33	7	-
b. Professional pride in work (n=14)	pre	36	43	21	-
(n=15)	post	67	27	6	-
c. Modesty about oneself and discipline (n=14)	pre	29	71	-	-
(n=15)	post	73	20	7	-
d. Frankness and honesty (n=14)	pre	64	21	14	-
(n=15)	post	73	27	-	-
e. Positive attitudes about farmers (n=14)	pre	21	57	21	-
(n=15)	post	67	33	-	-
f. Positive attitudes about field hardships (n=14)	pre	29	21	36	14
(n=15)	post	47	40	13	-
g. Openness in communication (n=13)	pre	80	85	8	-
(n=15)	post	47	53	-	-
h. Cooperativeness (n=13)	pre	46	46	8	-
(n=15)	post	87	13	-	-
i. Not showing deference to trainers (n=14)	pre	79	14	7	-
(n=15)	post	73	27	-	-

Table A-2. Participants' final evaluation of key aspects related to the Diagnostic Training Workshop

Item Evaluated	Percent of Participants Responding: Very Good	Good	Needs Improvement
A. Physical facilities for training program			
1. classrooms	50	38	12
2. housing	12	62	26
3. food arrangements	12	62	26
4. transportation	87	13	-
5. lab equipment	19	31	50
B. Training equipment/supplies			
1. classroom teaching equipment (black boards) projectors	37	44	20
2. field equipment (flumes, instruments, etc.)	44	44	12
3. typing/duplication	31	56	13
4. manuals provided			
a. Volume I	87	13	-
b. Volume II	87	6	7
5. handouts provided	50	31	19
C. Training/teaching methods			
1. lectures	37	50	13
2. discussions	62	38	-
3. team reports	25	56	19
4. team planning	31	50	19
5. schedule of events	12	56	32
6. objectives of trainers	56	37	7
7. objectives of trainees	56	31	13
8. participation by trainees in discussions	44	37	19
9. reconnaissance field, exercise	56	19	25
10. detailed team field exercises	50	25	25
D. Quality of discipline training			
1. on-farm engineering (n=12)	33	50	17
2. irrigation engineering (n=13)	38	62	-
3. agronomy soil-plant-water relationships (n=13)	31	62	7
4. economics of farm operation (n=14)	29	57	14
5. extension and farmer irrigation behavior (n=15)	40	47	13
E. Quality of training			
1. learning field methods	40	60	-
2. focus on understanding of other disciplines	20	50	30
3. team building	56	44	-
4. lectures	31	56	13
5. reconnaissance field (n=13)	38	46	16

Table A-2. (continued)

Item Evaluated	Percent of Participants Responding		
	Very Good	Good	Needs Improvement
6. detailed field studies	24	47	29
7. developing work activities	18	53	29
8. developing reports	12	50	38
F. Attitudes of trainers			
1. towards trainees	81	19	-
2. towards other disciplines	81	19	-
3. participation trainees in discussion	69	31	-
4. listening to views of trainees	81	19	-
5. compromises in changing training format and activities	50	50	-
6. understanding of trainees' needs	50	31	19
7. understanding of on-farm water management (n=15)	40	47	13
8. ability to communicate	37	50	17
9. flexibility	37	63	-
10. interest in subject matter	75	25	-
G. Relevance of training			
1. to present job (n=15)	27	53	20
2. to professional development	37	37	26
3. to CADA programs	69	19	12
4. to interests and felt needs	37	44	19
5. to evaluating value of system improvements (n=15)	33	47	20
6. to understanding how the farm system works	31	50	19
7. to identify priority problems of on-farm system	37	44	19
8. to understanding farmers' attitudes	44	50	6
9. to understanding farmers' problems	31	62	7
10. to understanding field research methods	19	44	37
11. to understanding field research problems	31	25	44
12. to future training programs you may develop or take part in as a trainer	31	13	56

H. Would you recommend such training for:	Yes	Perhaps	No	Don't Know
1. other officers with similar position as yours? (n=15)	60	13	27	-
2. CADA field staff?	94	-	-	6
3. all irrigation department engineers?	56	19	19	6
4. all new irrigation engineering graduates? (n=15)	73	20	-	7
5. extension staff involved in CADA's?	87	13	-	-
6. agronomists working in CADA's? (n=15)	87	7	6	-
7. economists working in CADA's?	75	19	6	-

The results reflected several group characteristics. First, the participants were mostly senior staff with much experience. For example, the three agronomists knew most of the basic skills required, but they as well as other participants had little or no previous team work experience of the type taught. Second, the first self-evaluation took place in the third week of the five week workshop, reducing the expected differences between the first and second self-evaluations. Third, the course was designed for six full weeks but was shortened due to civil disturbances in the town of Anand, Gujarat which increased greatly by the week of March 19th. Workshop leaders then decided to end the course after five weeks of training. Fourth, since there were only seven engineers, three agronomists, three extension specialists, and three economists, sample sizes for the evaluations were small. Two of the economists also joined the training program late. Percentages are reported because the sample size changed between the pre- and post-self evaluation.

The following lists those areas that noticeably changed between the two evaluation periods:

(1) Skill Performance for Engineers

a) installation of flumes
b) evaluation of ditch losses
c) estimation of field application efficiencies

(2) Skill Performance for Agronomists

a) reading flumes
b) estimation of potential cropstands
c) estimation of nutrient status of plants
d) analysis of soil texture and salinity

(3) Skill Performance for Extension Staff and Economists

a) recording data on farmer behavior
b) interviewing techniques

(4) General Skills and Abilities for all Participants

a) approaches in working with farmers
b) data collection
c) data reduction
d) data management
e) report preparation
f) report presentation
g) speed in work
h) ability to work overtime

(5) Team Member Relationships (team building)

a) participation in team decision making
b) sharing of team leadership
c) role in solving team problems
d) management of team when in team leader role

(6) General Attitudes about Work and Personnel

a) professional pride in work
b) modesty about self and one's discipline
c) positive attitudes about farmers
d) positive attitudes about field hardships
e) cooperativeness

This summary indicates where participants felt they made the most progress. While it is difficult to measure changes over a short period of time, Table A-1 indicates that the participants did feel they gained from the training experience. Daily observations by the trainers and comments of the participants indicate that the training was both useful and effective. The trainees also had a professional view of themselves. Where they felt that they needed more help, they made this known in a frank and candid manner. Also, they felt that the self evaluation exercise was useful as a learning and self-diagnosis tool. Several plan to use this in the future training and evaluation of their staffs. Overall the training staff thought the participants were eager for this opportunity to learn new approaches to diagnosis of irrigation problems in the field. The majority requested more time in the field than was possible in a short five-week period. Of the 16 participants, 9 reported that they would like more time in the field learning by doing.

When asked about the importance of the diagnostic training course for their current job assignments, the participants viewed the following activities as important:

(1) "Learning specific skills of flow measurements, measurements of irrigation efficiency, data collection, irrigation practices for helping farmers improve their crop production" (six participants).

(2) "Learning diagnostic analysis skills to identify and solve water management problems to improve system performance" (three participants).

(3) "Understanding more about complete farming systems, crop practices, and basic agriculture in order to improve technologies for crop producton" (three participants).

(4) "Helps me improve my work in the Command Area Development program and the management of staff" (three participants).

(5) "Provides me an opportunity to improve my professional capabilities in irrigation improvement" (one participant).

3. Participants' Final Evaluation

The final overall evaluation was conducted on the last day of the training program (Table A-2). Participants' comments were useful for improving the training program for later use elsewhere. The items rated as "very good" by 50 percent or more of the participants included the following:

Transportation Facilities
Training Manuals
Discussion Methods
Objectives of Trainers and Trainees
Reconnaissance Field Exercises
Team Building Exercises
Attitudes of Trainers Toward Trainees
Attitudes of Trainees Toward Others
Participation of Trainees
(each discipline in discussion sessions)
Listening of Trainers to Trainees
Flexibility of Trainers
Understanding of Trainees Needs
Interest in Subject Matter
Relevance of Training to Command Area Development Program

Participants' views about areas needing more improvement included the following: lab facilities, scheduling of events, and developing reports. These and other items which need improvement agreed with the views of the four trainers who held their own two-day evaluation after the course was completed.

The participants were asked to provide their views of the need for this type of training for others (Table A-2). Most participants felt that similar training is needed for all CADA staff especially extension, agronomy, engineering, and economics personnel. Most participants also reported that similar training is needed for officers in similar positions as their own and for all new irrigation engineering graduates. About 56 percent of the respondents felt that all Irrigation Departments need this training. While 94 percent thought that all CADA staff should be trained, 13 of the 16 participants stated in an open-ended question that there was also a critical need to train or convince the top officials as well; these officials control the budgets, make the plans, and finally have to respond to training needs and assure that new skills gained will be properly utilized in action programs. Before such training can produce substantial program results, short and well-focused training seminars are needed for high-level policy makers and administrators. Participants also suggested that top officials should receive a "stream" of good literature which can help change some of their attitudes and behaviors toward new approaches of improving water management and training professional staff. Unless this important audience of officials is effectively reached, those trained may not be able to implement their new skills and knowledge.

Table A-3 summarizes participants comments about what this training program meant to them. In ranked order, participants thought learning interdisciplinary team and team management approaches, understanding of real farm level problems, gaining a knowledge of the meaning of water management, learning with and from other disciplines, and learning diagnostic analysis processes and procedures were most important.

Table A-3. Summary of participants views of what training program meant to them

Responses	No. of Responses	Percent of Total Responses
1. Field study was a new experience	1	3
2. Learned to evaluate a real system	1	3
3. Understanding of farm irrigation behavior	2	5
4. Learned about importance of water control	2	5
5. Learned diagnostic analysis process and procedures	3	8
6. Understanding of real farmer problems	4	10
7. Learned from working with other discipline members of team and staff	4	10
8. Learned what water management is	5	13
9. Learned interdisciplinary team work	8	20
10. Good training program	9	23

Finally, the 16 participants suggested ways future training programs can be improved. Key points stressed were:

- Improve selection of participants to provide ample time and preparation for the trainees.

- Focus more on field site selection and pre-planning to acquire advance information about field sites for planning field exercises.

- Provide more time for field exercises, data analysis, interpretation, and team report preparation.

- Design into the course more information about water management in other countries through films and slide shows, especially for evening sessions.

- Provide participants with more literature before and during the training sessions and develop a system to keep participants supplied with relevant literature after the training is completed. There is a definite need for an information network for professionals in water management.

These and other insights provided by the participants are being carefully considered as the Water Management Synthesis Project continues to test, demonstrate, and refine the Diagnostic Analysis model and training program in other countries.

B. Engineering

1. Evaluation of Outlet 02/L of the Sihol Minor

Field evaluations were done both on the application and the distribution systems. The actual operating conditions of the existing systems are discussed below.

a. Conveyance System

The conveyance system consisted of an earthen watercourse with a trapezoidal section having the dimensions shown in Figure B-1. The canal was supposed to carry an official flow rate of 1.86 cfs, but the fluctuations in flow rate were significant (Figure B-2). According to the topographic profile of the canal, the watercourse has negative gradients (slopes) at several points. The length of the canal up to the division box was approximately 2,362 ft (720 m). The elevation at the beginning of the canal was 117.79 ft (35.9 m) and at the end 115.49 ft (35.2 m). Therefore, the average slope of the canal was 0.00081 ft/ft or 1:1235.

To evaluate the conveyance efficiency of the channel, flow rates were measured at two different sections of the canal (Figure B-2):

1) On March 2, 1981

$$Q_L = \frac{(1.80 \text{ cfs} - 1.613 \text{ cfs})}{2218 \text{ ft}} \times 100 \text{ ft}$$

$$= .0084 \text{ cfs}/100 \text{ ft}$$

$$= \frac{(50.98 - 45.68) \text{ lps}}{(676.21) \text{m}} \times 100 \text{ m}$$

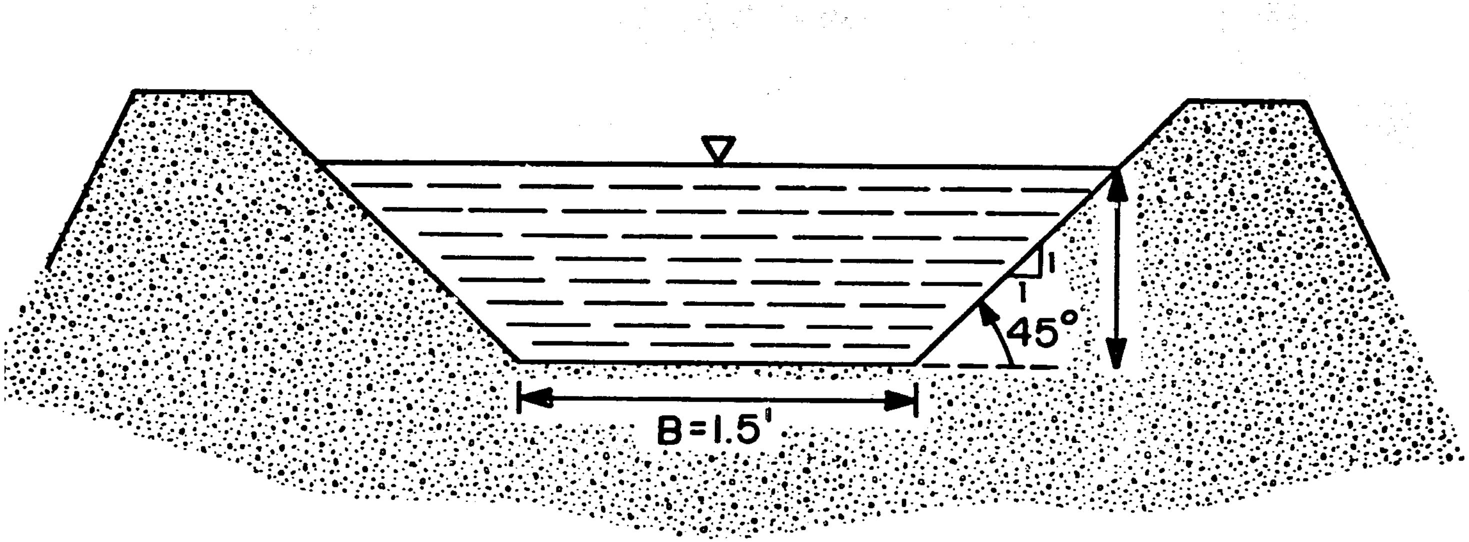
$$= 0.784 \text{ lps}/100 \text{ m}$$

$$Q_L(\%) = \frac{(0.0084) \text{ cfs}}{(1.80) \text{ cfs}} \times 100 \text{ ft}$$

$$= 0.4684\%/100 \text{ ft}$$

$$= \frac{(0.784) \text{ lps}}{(50.98) \text{ lps}} \times 100 \text{ m}$$

$$= 1.537\%/100 \text{ m}$$



.gure B-1. Cross-section of the Watercourse, Outlet 02/L, Sihol Minor

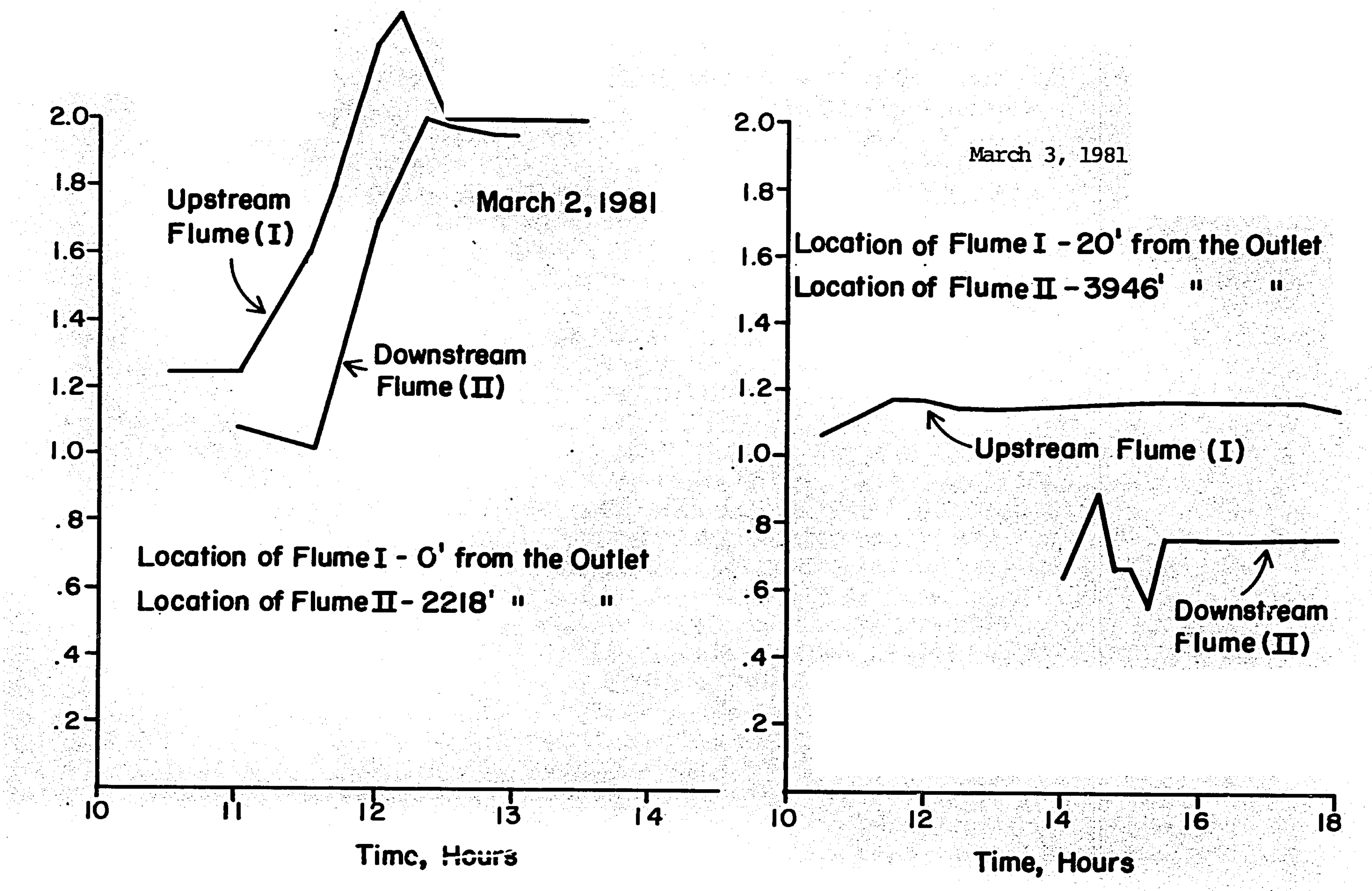


Figure B-2. Flow Rate Measurements, Outlet 02/L, Sihol Minor

2) On March 3, 1981

$$Q_L = \frac{(1.15 \text{ cfs} - 0.74 \text{ cfs})}{(3950 \text{ ft})} \times 100 \text{ ft}$$

$$= 0.0104 \text{ cfs/100 ft}$$

$$Q_L(\%) = \frac{(0.0104) \text{ cfs}}{(1.15) \text{ cfs}} \times 100 \text{ ft}$$

$$= 0.9026\%/100 \text{ ft}$$

From the above, it is clear that the loss rates on March 3 were almost double the loss rate on March 2.

For the design flow rate of 1.85 cfs, the area and the velocity were estimated using Manning's equation. The depth of flow in the channel was found to be 0.781 ft (0.238 m). This value was calculated using the design flow rate of 1.85 cfs, channel slope of 0.00081 ft/ft, and the bottom width of 1.5 ft. Assuming n to be 0.025, the velocity of flow was calculated to be 1.0 ft/sec.

The soils at this particular site were of silty loam type. The maximum permissible velocity for these soil conditions is 1.84 ft/sec (Kruse et al., 1980). Therefore, the average velocity in the channel was within the range of permissible velocities. The above authors also recommend that a minimum slope of 0.0004 m/m should be provided to discourage weed growth and siltation. Even though the average slope of the channel was 0.00081 m/m, there are several sections along the channel that had steeper gradients. They are:

Section	Slope (m/m)
1	0.0020
2	0.0064
3	0.0038
4	0.0242

These slopes were significantly higher resulting in severe erosion. Design of drop structures might be considered to prevent erosion of the channel.

b. Application System

Basin irrigation was the most common method of irrigation. The basins were uneven in topography, but were operated as if they were level. A banana field was evaluated under this outlet. The soil-moisture characteristics of the field were determined (Table B-1) and the infiltration parameters were

Table B-1. Soil-Moisture Characteristics

FORM 6 - SOIL WATER CONTENT DATA AT FIELD CAPACITY

IDENTIFICATION Survey #647, Bananas OBSERVERS Agronomist Team

DATE March 3, 1981

REMAKS:

Station	Depth cm	Can No.	Wt. Can Tare g	Wt. Can & Soil Wet g	Wt. Can & Soil Dry g	Wt. Soil Dry g	Wt Water g	Water Content % by Weight	Bulk Density γ_b	Water Content % by Volume	Water Depth d mm
	0-30	1	48.0	210.6	190.3	142.3	20.3	14.3		21.0	
I	30-60	2	47.6	178.3	160.0	112.4	18.3	16.3	1.47	24.0	
	60-90	3	47.9	166.7	149.1	101.2	17.6	17.4		25.6	
	0-30	4	47.4	149.4	137.8	90.4	11.6	12.8		18.8	
II	30-60	5	47.5	141.8	129.0	81.5	12.8	15.7	1.47	23.1	
	60-90	9	47.6	146.3	132.4	84.8	13.9	16.4		24.1	
	0-30	6	47.4	224.6	204.1	156.7	20.5	13.1		19.3	
III	30-60	7	47.7	238.9	213.8	166.1	25.1	15.1	1.47	22.2	
	60-90	8	47.8	214.4	191.9	144.1	22.5	15.6		22.9	
	0-30	10	47.0	236.3	213.2	166.2	23.1	13.9		20.4	
IV	30-60	11	47.3	182.9	163.7	116.9	19.2	16.4	1.47	22.2	
	60-90	12	47.3	202.1	180.2	132.9	21.9	16.5		24.3	
	0-30	13	47.2	257.5	227.6	180.4	29.9	16.6		24.4	
V	30-60	14	47.4	217.7	193.4	146.0	24.3	16.6	1.47	24.4	
	60-90	15	47.7	196.3	174.9	127.2	21.4	16.8		24.7	
	0-30	16	47.2	258.2	231.9	184.7	26.3	14.2		20.9	
VI	30-60	17	47.2	196.1	174.5	127.3	21.6	17.0	1.47	25.0	
	60-90	18	47.2	263.7	231.2	184.0	32.5	17.7		26.0	

estimated using cylinder infiltrometer data (Figure B-3). An infiltration function of the following form was obtained for Basins 3 and 4:

$$z = 1.5t^{0.22} \quad (1)$$

in which z = cumulative infiltration (cm); and t = infiltration opportunity time (min). The inflow rate into the field was measured. The average depth applied to the fields was 6.2 and 6.7 cm, for Basins 3 and 4, respectively. Since there was no runoff, the average depth applied also was equal to the average depth infiltrated. The field slopes, advance and recession times are presented in Figures B-4 and B-5. The infiltration opportunity time in each section of the field was obtained from the advance and recession data

The average depth infiltrated in the fields was 3.14 cm for Basins 3 and 3.06 cm for Basin 4. The actual depth of water infiltrated into the basins was significantly different from the estimated depth of infiltration. Therefore, the infiltration function needed to be estimated again. The exponent was kept constant and only the proportionality constant was changed. For Basin 3, the proportionality constant was adjusted to be 1.97 and for Basin 4, it was adjusted to be 2.19. Therefore, the infiltration functions were given by

$$z = 1.97t^{0.22} \quad (2)$$

$$z = 2.19t^{0.22} \quad (3)$$

The depths of water infiltrated in different sections of the fields were calculated using Equations 2 and 3, and are presented in Figures B-4 and B-5. The distribution uniformity, calculated using the Christiansen's uniformity coefficient, was 0.94 for Basin 3, and 0.93 for Basin 4. This is a significantly high distribution uniformity for surface irrigation with nonuniform field slopes. However, when the depth of application increased, the uniformity tended to be higher. No data was collected on soil-moisture deficiency before irrigation. Therefore, the application efficiency could not be estimated.

2. Evaluation of Outlet 02/L of Sihol Minor

The outlet 10/LA takes off on the left at RD 8600' of Sihol Minor which in turn takes off at RD 1,02,4000' of Petlad Branch. The application and conveyance systems performance under this outlet was evaluated.

a. Conveyance System

The channel was 415 m in length. The bottom elevations of the channel are presented in Figure B-6. The elevation at the beginning of the channel was 35.11 m and at the end, 34.91 m. Therefore, the average slope of the channel is 0.000482, which is very flat. The channel bottom did not have any steep slopes but it did have several negative slopes (Figure B-6).

In order to estimate the loss rates in the channel, measurements were made at two locations in the channel, located 197 m apart. The flow rates at the two sections are presented in Figure B-7. The average loss of water was 30 percent. This amounted to a loss rate of 1.87 lps/100 m and a percent loss rate of 15.2/100 m.

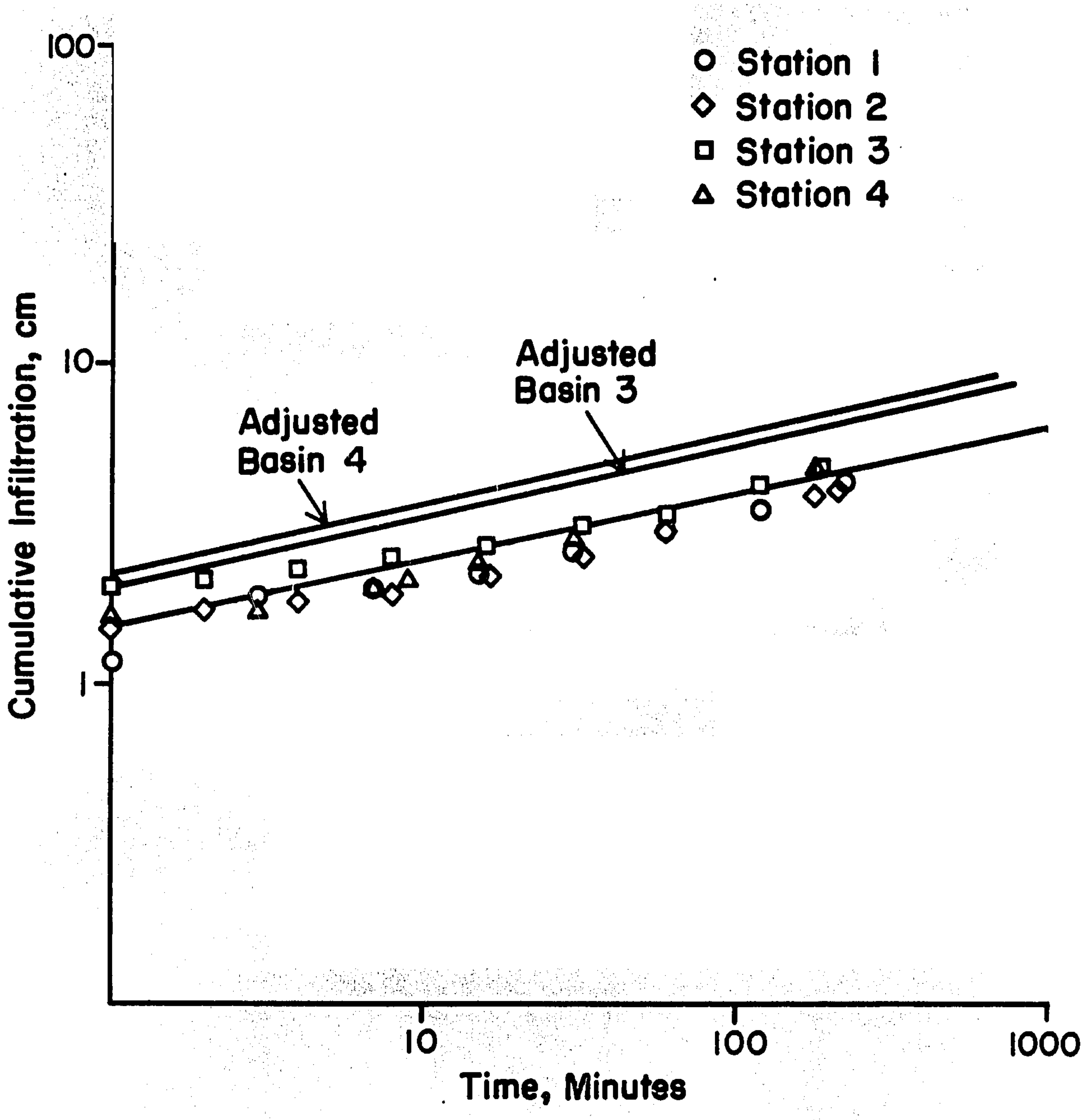


Figure B-3. Infiltration Characteristics of Basins 3 and 4, Outlet 02/L, Sihol Minor

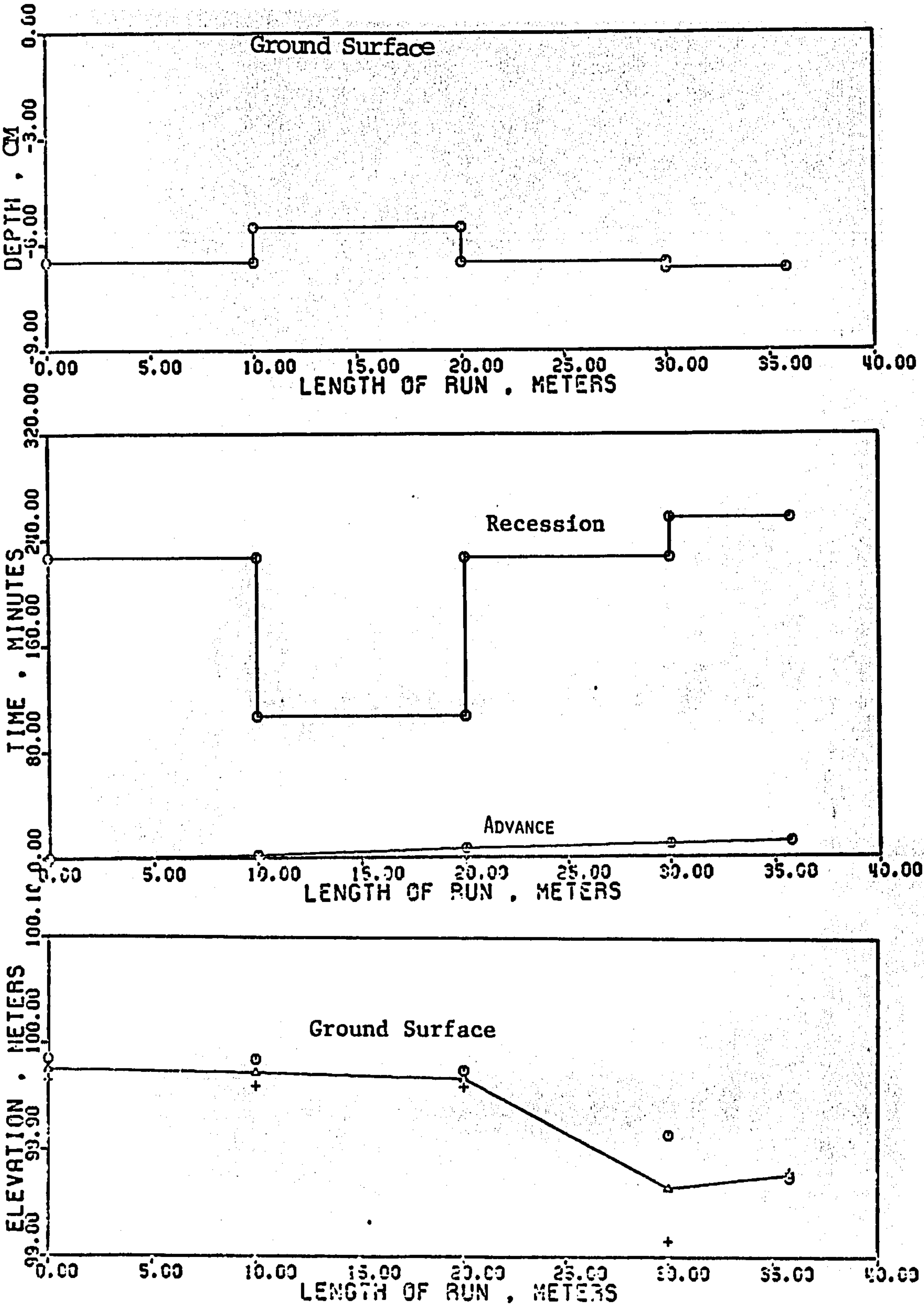


Figure B-4. Field Slope, Advance and Recession, and Depth Infiltrated in Basin 3

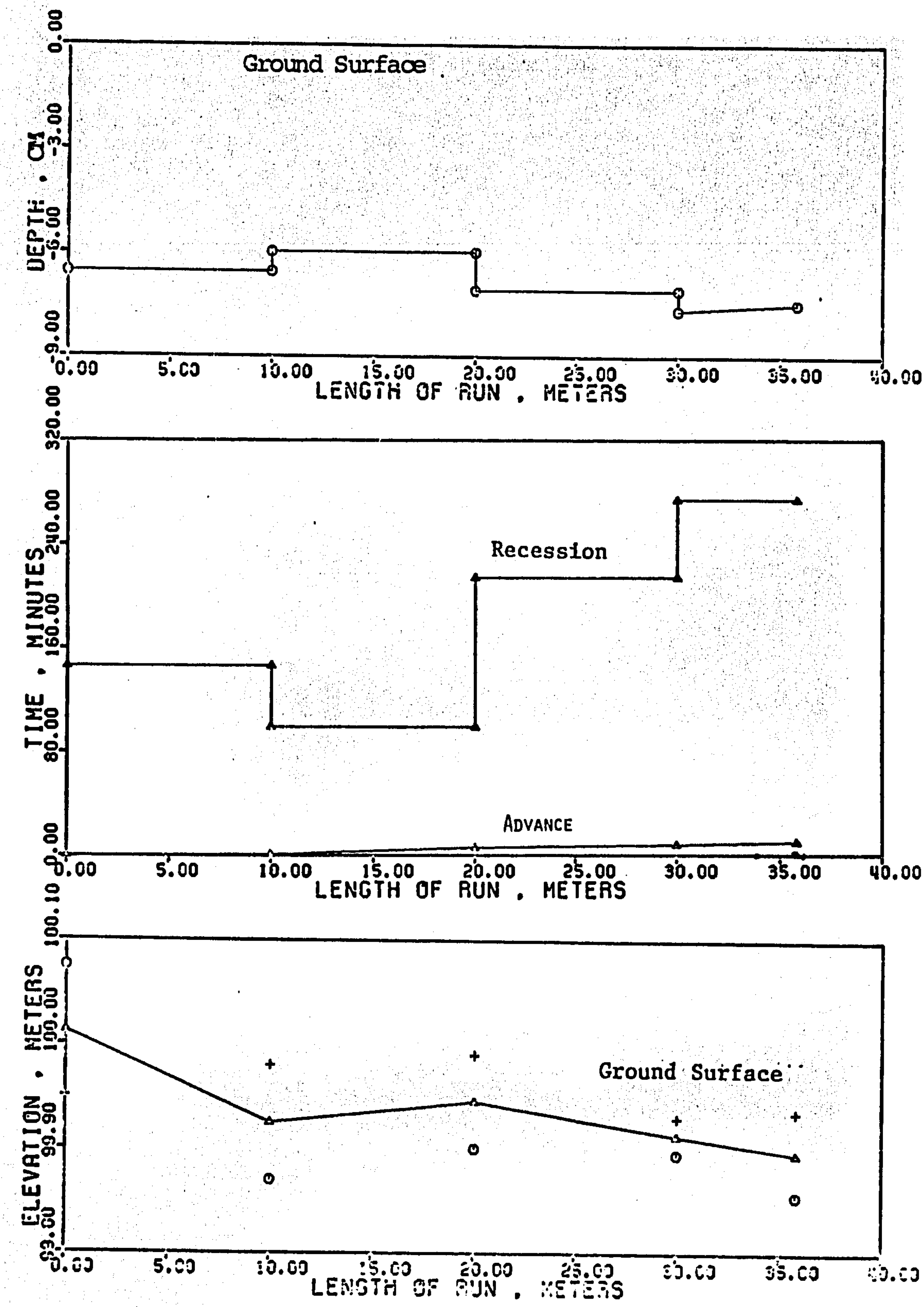


Figure B-5. Field Slope, Advance and Recession, and Depth Infiltrated in Basin 4

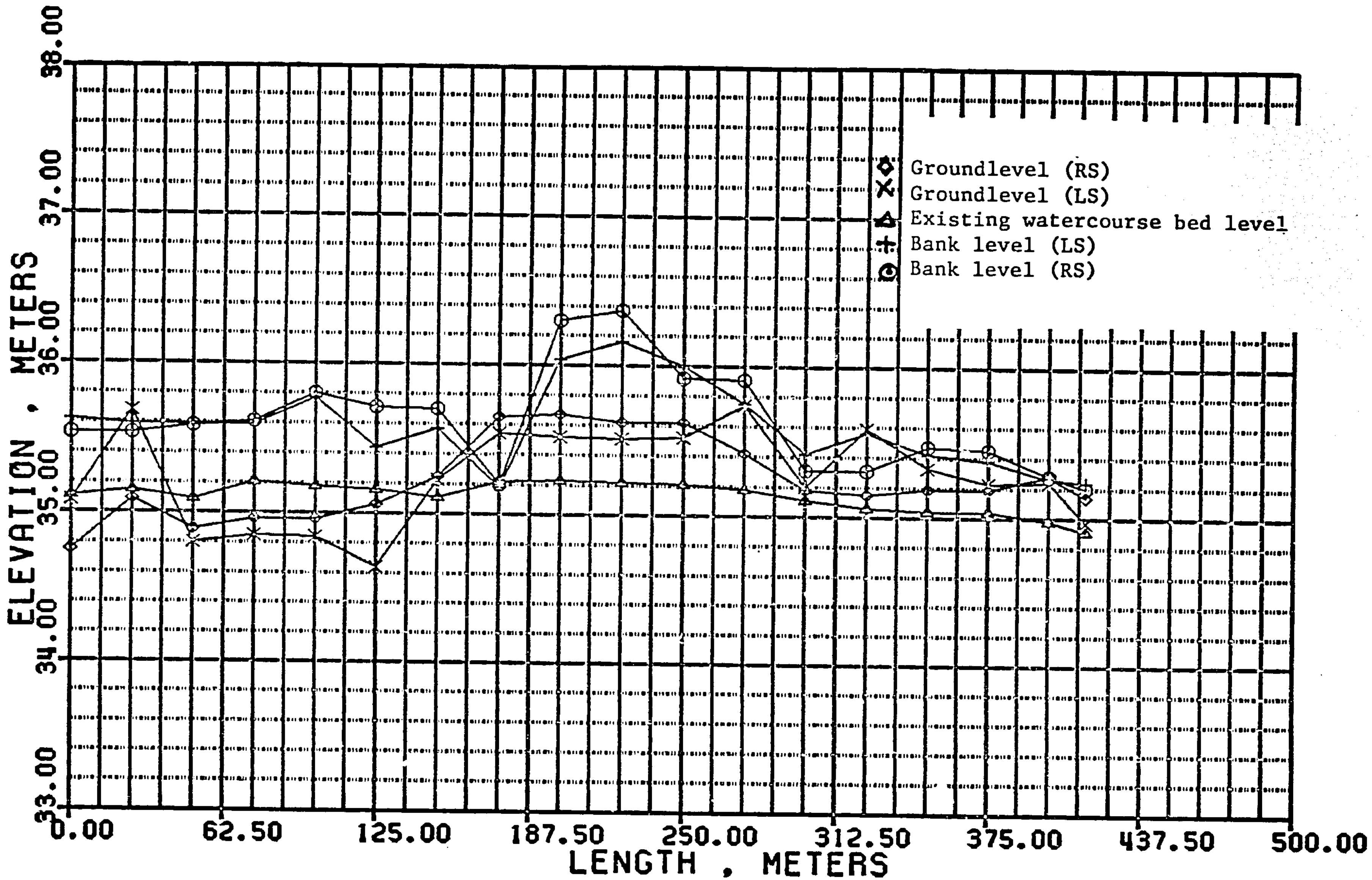


Figure B-6. Longitudinal Section of Watercourse 10/IA

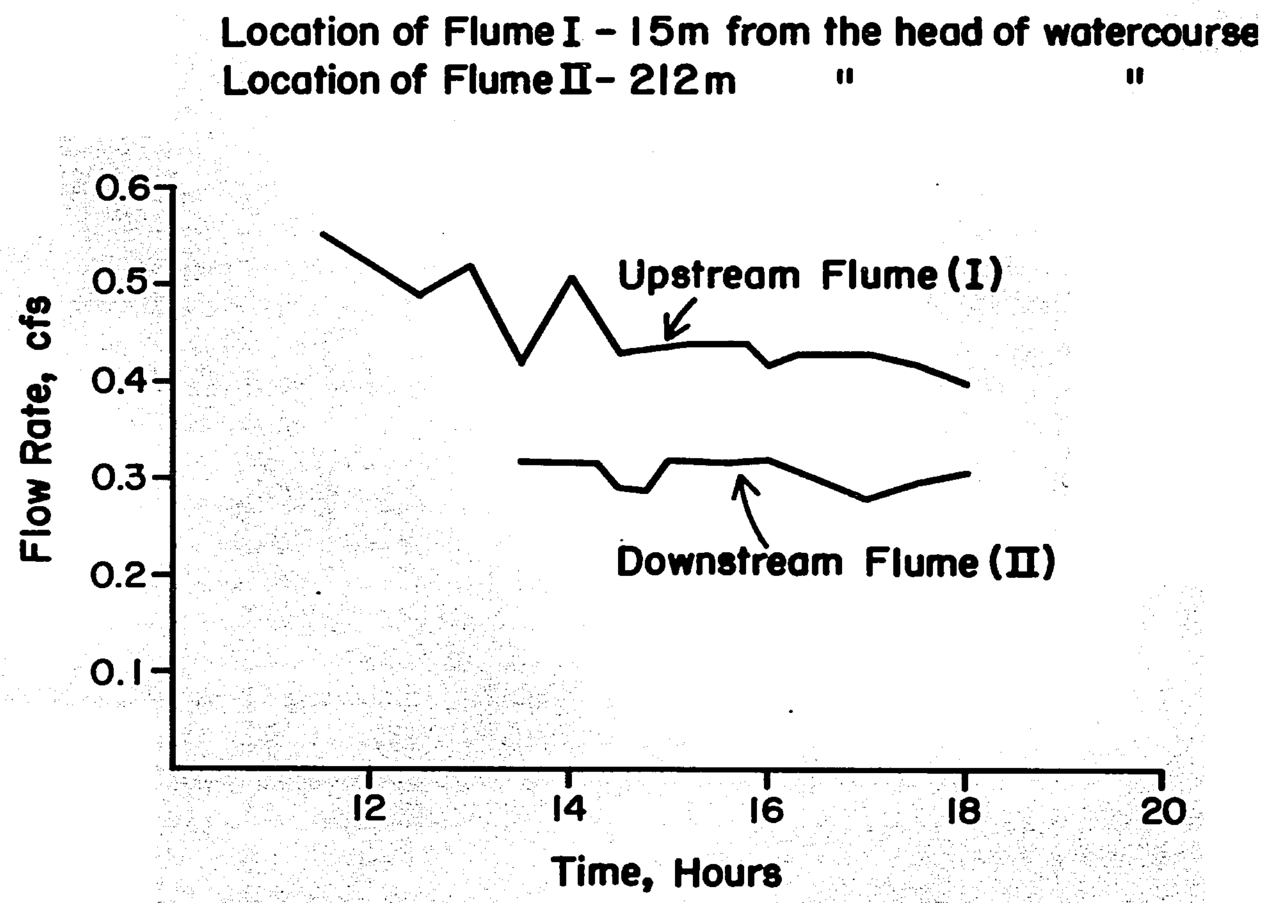


Figure B-7. Inflow-Outflow Measurements on Watercourse 10/IA of Sihol Minor

b. Application System

Two borders were selected for evaluation in Survey Number 673 and Survey Number 674. The bulk density and the water content of the soils were measured (Table B-2). The infiltration characteristics of the soils also were measured using cylinder infiltrometers (Figure B-8). The following infiltration functions were obtained from the infiltrometer data:

$$z_1 = 2.0t^{0.22} \quad (7)$$

$$z_2 = 1.7t^{0.22} \quad (8)$$

in which z_1 = cumulative infiltration function for Border 1; and z_2 = cumulative infiltration function for Border 2. The field slope was nonuniform as shown in Figures B-9 and B-10 and negative slopes were evident.

The soil-moisture deficiency before irrigation was estimated for Field 674 (Tables B-3). The moisture deficiency data was assumed to be the same for Field 673. An actual irrigation was observed, along with advance and recession data as shown in Figures B-9 and B-10. The actual inflow rate into the fields also was measured. The field was situated only 30 m from the outlet. The inflow data are presented in Table B-4.

The area of the borders was 560 m (80m x 7m). The flow rate characteristics into the borders were as follows:

	Border 1	Border 2
Average flow rate	0.50 cfs	0.52 cfs
Duration	46.0 min	36.0 min
Depth applied	7.10 cm	5.6 cm

The moisture deficiency before irrigation was 5.0 cm for both the fields; the application efficiencies were 71 percent and 87 percent, for Borders 1 and 2, respectively.

Using the advance and recession data and the infiltration function, the average depth infiltrated in Basin 2 was calculated to be 4.8 cm. However, from the inflow rate data, the average depth infiltrated was 7.0 cm. Therefore, the infiltration function must be adjusted. The proportionality constant in the infiltration function was adjusted to 2.92 instead of 2.0. The depths infiltrated at different locations in the field were estimated using the modified formula. The distribution uniformity, using Christiansen's equation, was found to be 0.987. Similar analysis for Basin 2 resulted in 0.95 uniformity. The adjusted infiltration coefficients for the borders are as follows:

$$z_1 = 2.92t^{0.22} \quad (9)$$

$$z_2 = 2.40t^{0.22} \quad (10)$$

The depths infiltrated in the borders are given in Figures B-9 and B-10.

Table B-2. Soil Water Content Data at Field Capacity

IDENTIFICATION 10 A/L of Sihol Minor OBSERVERS A. S. Parekh
DATE March 6, 1981
REMARKS: Field #673 and 674

Station	Depth cm	Can No.	Wt. Can Tare g	Wt. Can & Soil Wet g	Wt. Can & Soil Dry g	Wt. Soil Dry g	Wt Water g	Water Content % by Weight	Bulk Density γ_b	Water Content % by Volume	Water Depth d mm
	0-30	10	47.0	181.3	168.2	121.2	13.1	10.8		15.7	47.1
	30-60	11	47.3	136.6	124.5	77.2	12.1	15.7	1.45	22.8	68.4
H	60-90	12	47.3	126.5	115.5	68.2	11.0	16.1		23.3	69.9
	0-30	40	47.7	158.3	147.5	99.8	10.8	10.8		15.7	47.1
	30-60	41	47.5	140.2	127.6	80.1	12.6	15.7	1.45	22.8	68.4
	60-90	42	47.4	144.3	130.8	83.6	13.5	16.2		23.5	70.5
	0-30	43	47.6	174.4	161.3	113.7	13.0	11.4		16.5	49.5
	30-60	44	47.7	173.0	153.5	105.8	19.5	18.4	1.45	26.7	80.1
M	60-90	45	47.2	161.2	143.5	96.3	17.7	18.4		26.7	80.1
	0-30	48	47.3	197.6	181.0	133.7	16.6	12.4		18.0	54.0
	30-60	49	47.0	176.4	153.2	110.2	19.2	17.4	1.45	25.2	75.6
	60-90	50	47.6	164.3	143.1	95.5	18.2	19.1		27.7	83.1
	0-30	37	47.0	178.0	166.5	119.5	11.5	9.6		13.9	41.7
	30-60	38	47.9	150.2	136.8	88.9	13.4	15.1	1.45	21.9	65.7
T	60-90	39	47.9	134.7	122.7	74.8	12.0	16.1		23.3	69.9
	0-30	46	47.1	166.0	154.0	106.9	12.0	11.2		16.2	48.6
	30-60	47	47.9	141.3	128.4	80.5	12.9	16.0	1.45	23.2	69.6
	60-90	51	47.4	148.1	134.1	86.7	14.0	16.2		23.5	70.5

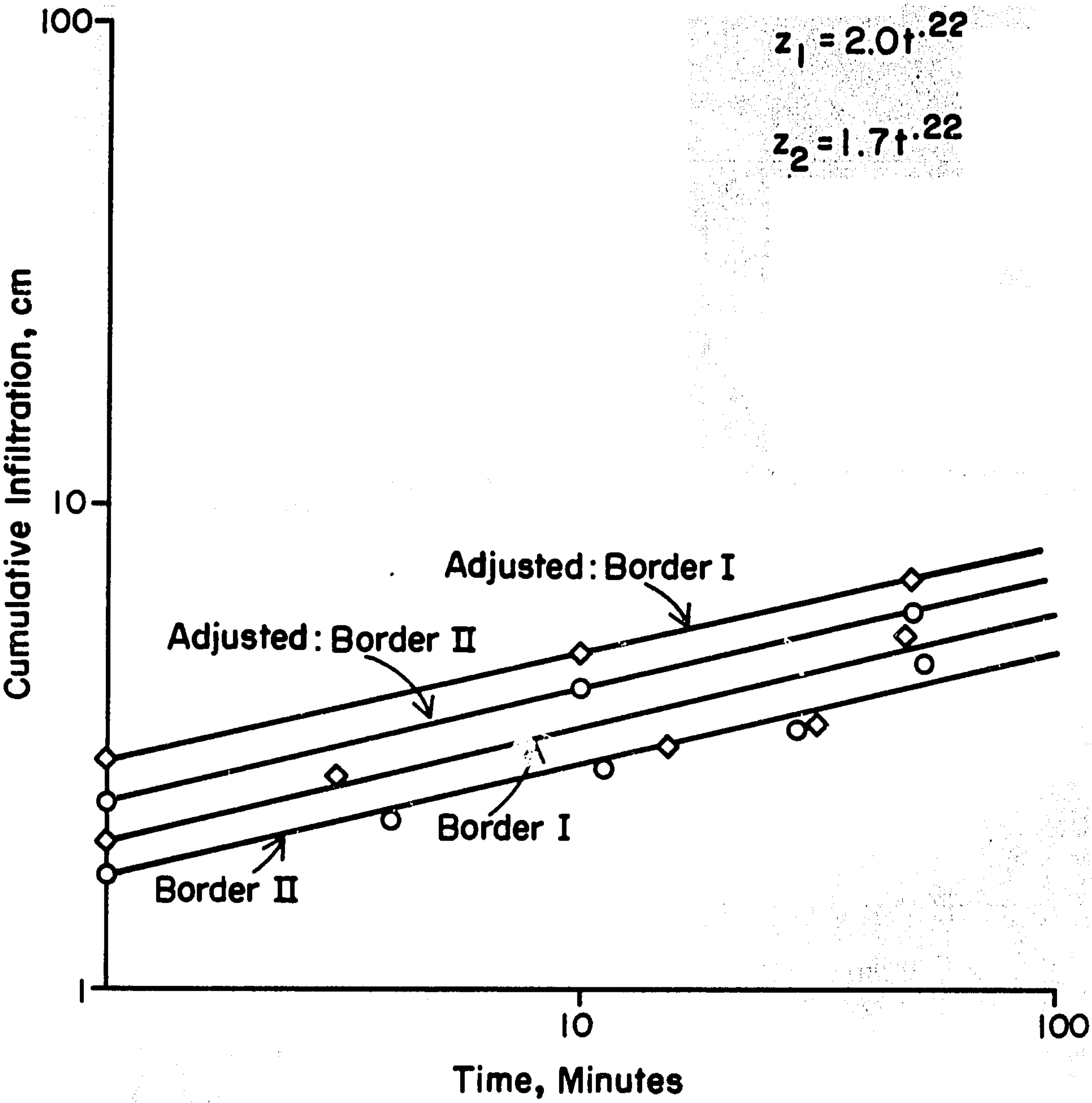


Figure B-8. Infiltration Characteristics of Soils in Borders 1 and 2 of Outlet 10/LA of Sihol Minor

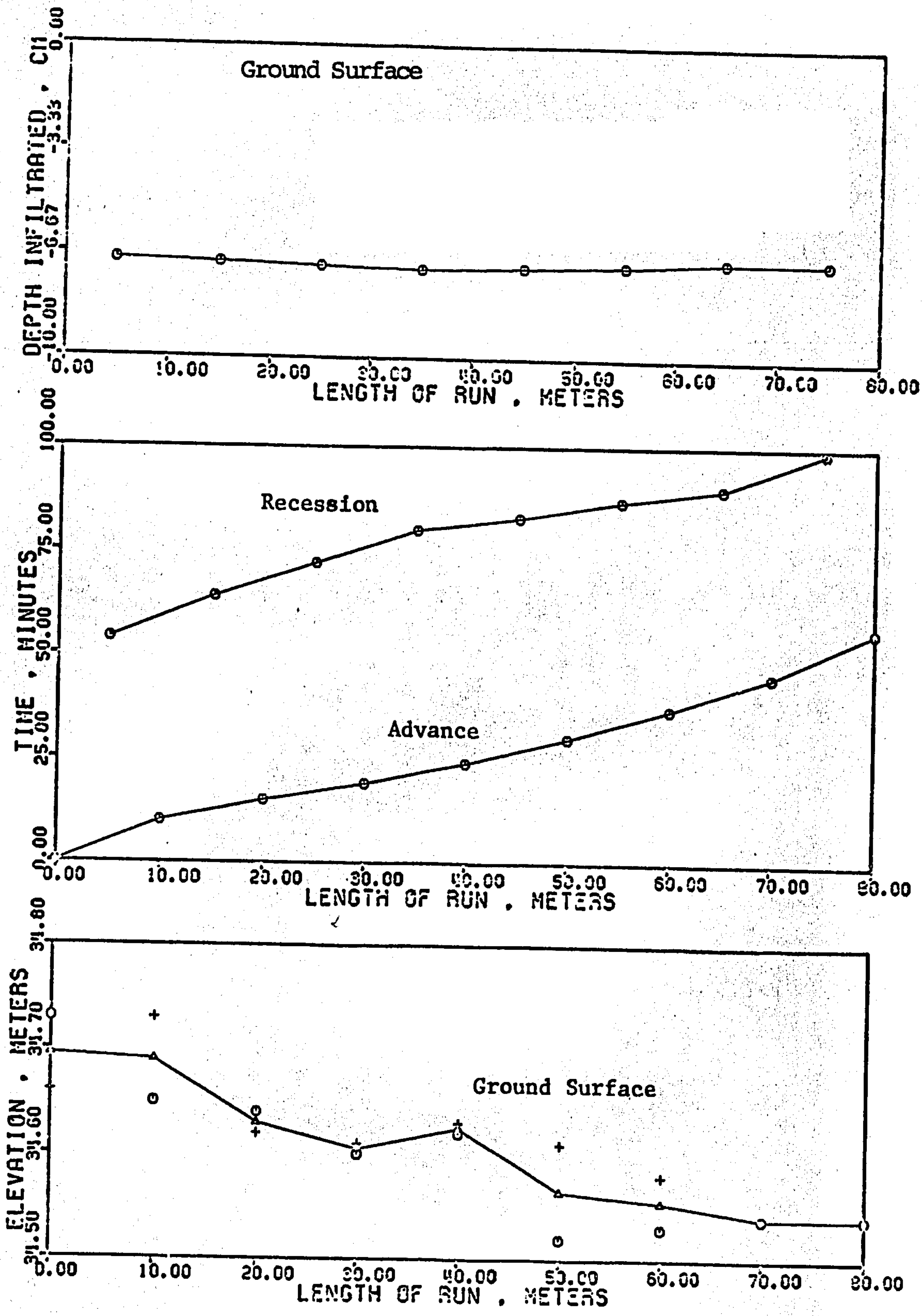


Figure B-9. Field Slope, Advance and Recession, and Depth Infiltrated in Border 1

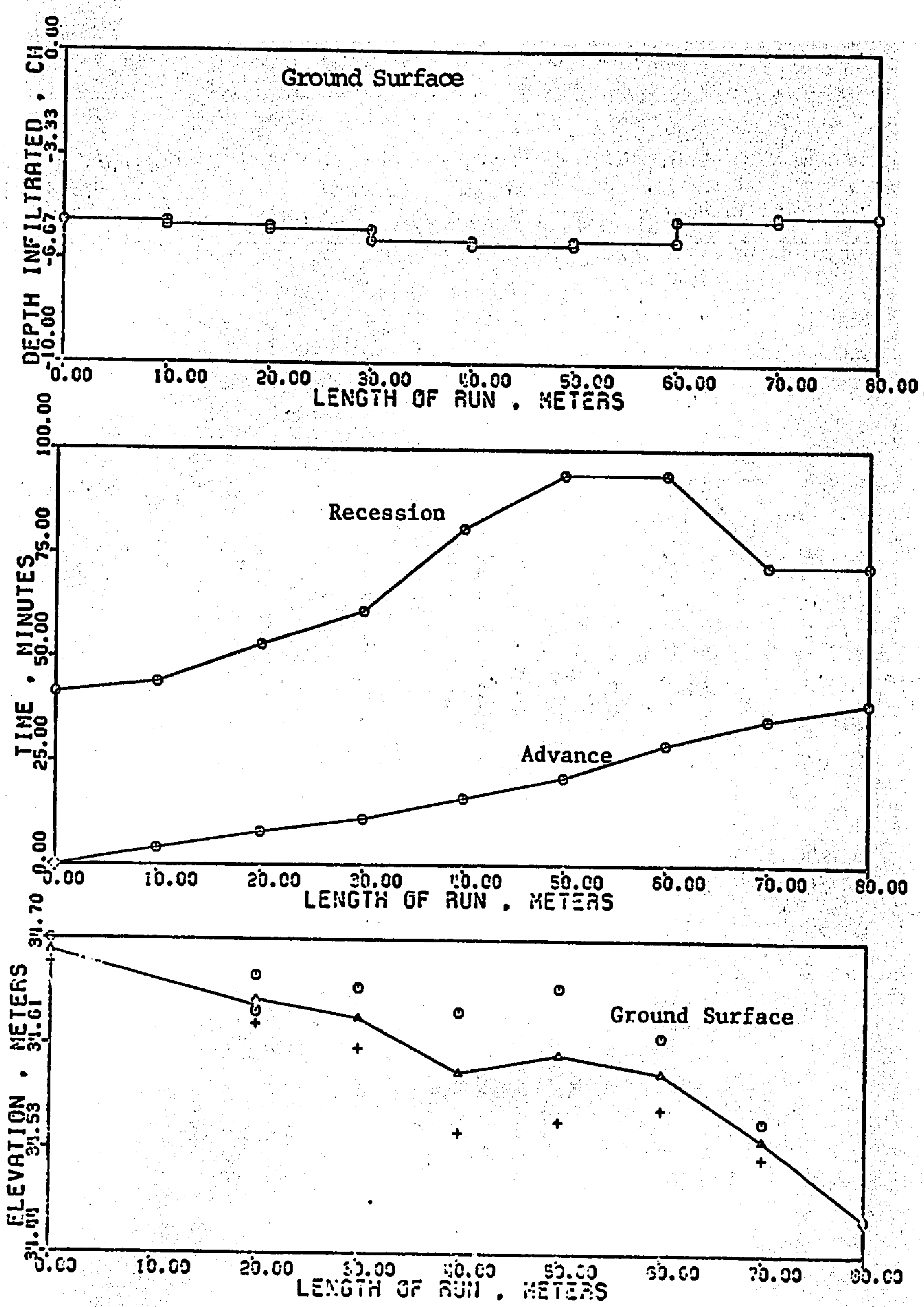


Figure B-10. Field Slope, Advance and Recession, and Depth Infiltrated in Border 2

Table B-3. Soil Moisture Deficiency in Survey No. 674 of Outlet 10/IA of Sihol Minor

	Depth in cm	Water Content by Volume	Water depth cm	Mean depth in cm		Deficiency in cm (27% of depth) i.e. (8.1 cm - (4))
	0-30	15.7	4.71			
	30-60	22.8	6.84			
	60-90	23.3	6.99	0-30	4.71	3.39 cm
Head	0-30	15.7	4.71	30-60	6.84	1.27
	30-60	22.8	6.84	60-90	7.02	1.08
	60-90	23.5	7.05			5.74 cm
	10-30	16.5	4.95			
	30-60	26.7	8.01			
	60-90	26.7	8.01	0-30	5.17	2.92
Middle	0-30	18.0	5.40	30-60	7.78	0.31
	30-60	25.2	7.56	60-90	8.16	(-)0.06
	60-90	27.7	8.31			3.18 cm
	0-30	13.9	4.17			
	30-60	21.9	6.57	0-30	4.51	3.58
Tail	60-90	23.3	6.99	30-60	6.77	1.33
	0-30	16.2	4.86	60-90	7.02	1.08
	30-60	23.2	6.96			
	60-90	23.5	7.05			6.00 cm

Assume Pc = 27%
or = 8.10 cm

Assume Wt. = 13.5%
or = 4.05 cm

$\frac{14.90}{3}$ cm

= 4.97 cm
say 5.00 cm

Table B-4. Inflow-outflow Loss Measurement Data Sheet

DATE 6/3/81
EXPERIMENTER Mallya/Umraosingh

LOCATIONS

Location of the conveyance system Sihol minor

Location of the test channel section 010/LA

Location of the upstream flow measurement at outlet 10/LA

Location of the downstream flow measurement nil

Distance between flow measurement locations ________________ m

Flow measurement device used Parshall flume (6" throat width)

Flow measurement readings

Staff Gage Readings

1. Upstream: Flume I	Time	h	h	Flow rate cfs	Comments
	12.00	0.4	0.07	0.48	1. Free flow condition
	12.30	0.39	-	0.47	as submergence is
	13.00	0.39	-	0.47	less than 60%
	13.30	0.39	-	0.47	2. Only one flume is
	14.00	0.41	-	0.50	installed as total
	14.30	0.41	-	0.50	length of WC up to
	15.00	0.42	-	0.52	the field is only
	15.11	0.42	-	0.52	30 m.
	15.30	0.42	-	0.52	
	15.55	0.42	-	0.52	

3. Evaluation of Outlet 12/L of Sihol Minor

a. Conveyance System

The watercourse 12/L takes off at RD 14,500 feet on the Sihol Minor. The outlet has a command area of 110 acres with a cultured command area of 49.65 acres. The design discharge of the watercourse was 0.80 cfs. The elevation of the watercourse bed at the head was 34.195 m. The free surface level in the minor was at an elevation of 34.03 m. Hence, the farmers get water into the watercourse from an unsanctioned outlet upstream where the free surface level was 34.225 m against a designed level of 34.10 m.

The longitudinal profile and the cross sections of the watercourse at several locations were measured (Figures B-11 and B-12). The elevations of most of the fields in the command area were higher than the full supply level of water in the watercourse. The existing bed slope was very irregular (negative slope), and the average slope of the watercourse bed was 1 in 900 or 0.0011. No erosion of the watercourse was visible.

No study to measure the conveyance losses was made because the length of the reach where a cultivator was ready to take water was very short and no cultivator in the tail reach was irrigating. Due to poor maintenance and subsequent weed growth, the discharge carrying capacity of the watercourse in some sections was inadequate. Significant losses due to overtopping and leakage were obvious.

b. Application System

Field 686/1 was evaluated. No data on the infiltration characteristics and advance and recession were collected; however, a detailed survey was undertaken. The elevation contours of the field are shown in Figure B-13. The elevation difference of the grid points was of the order of 14.5 cm near the boundary of the field along a belt of about 5 m; 3.5 cms in the central portion of the field had a length of 30 m and a width of 20 m. The actual depth of application of water ranged from 0.5 cm to 13.5 cm. Some high spots received no irrigation because of the irregular topography of the field.

Field 678/1 , with five borders, also was grid surveyed. The elevations are shown in Figure B-14. All the borders had reverse slopes. The statistical parameters of the borders including the mean elevation of the field, standard deviation, and the minimum-maximum elevations are presented in Table B-5. Border 1 had a significant differences in elevations. These fields were operated as if they were level.

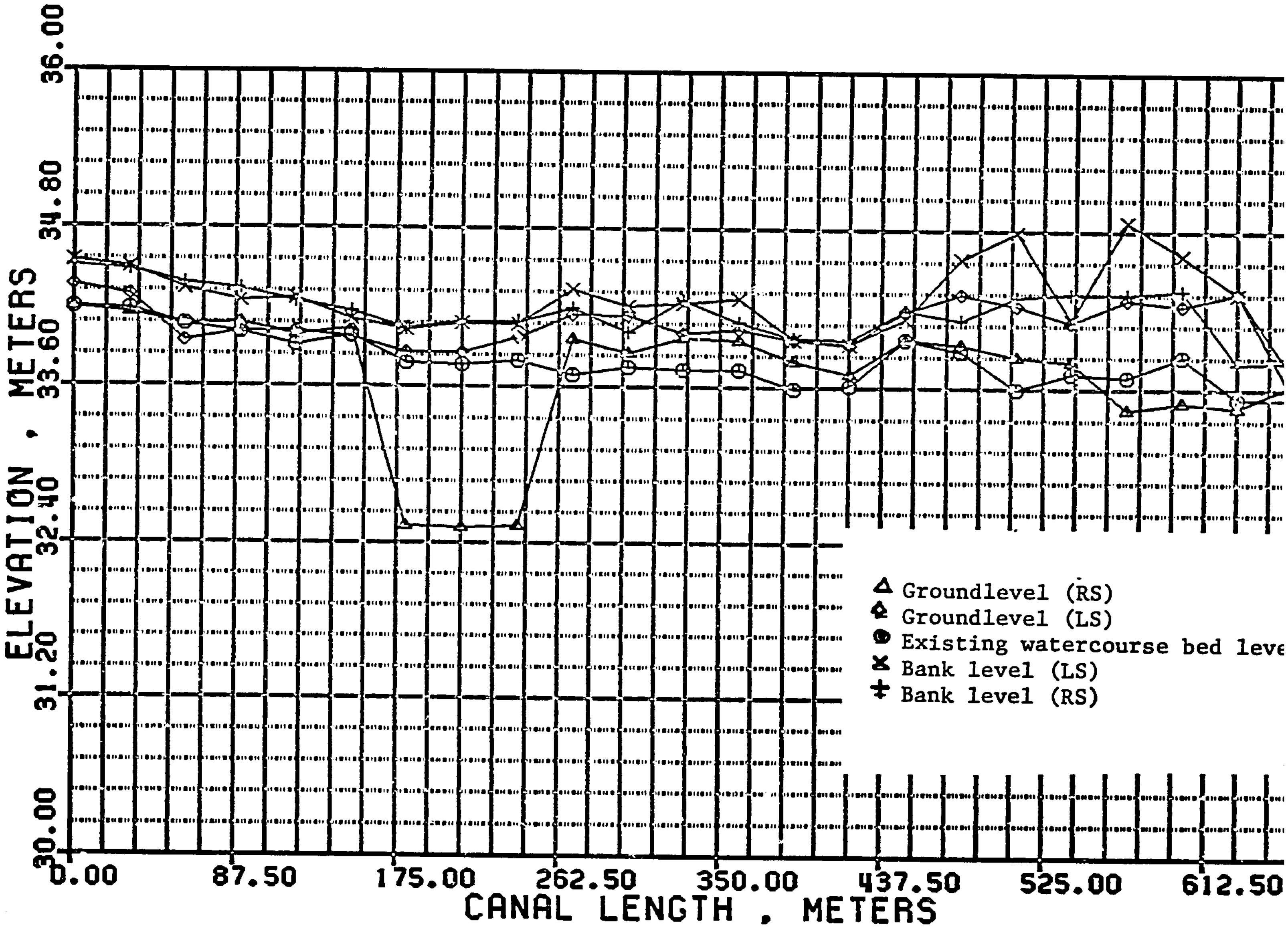


Figure B-11. Longitudinal Section of Watercourse 12/L

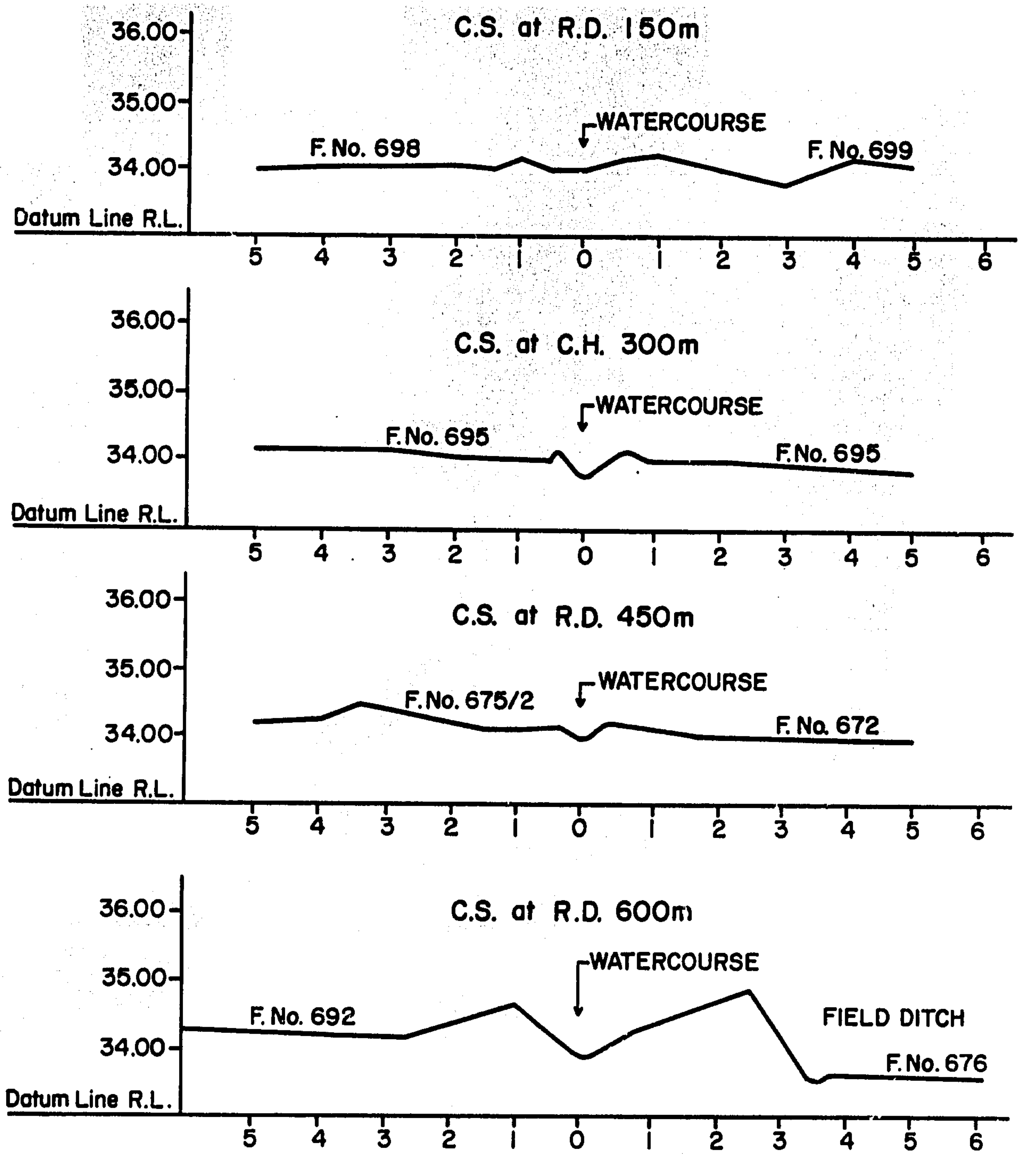


Figure B-12. Cross-sections of the Watercourse 12/L at Several Locations

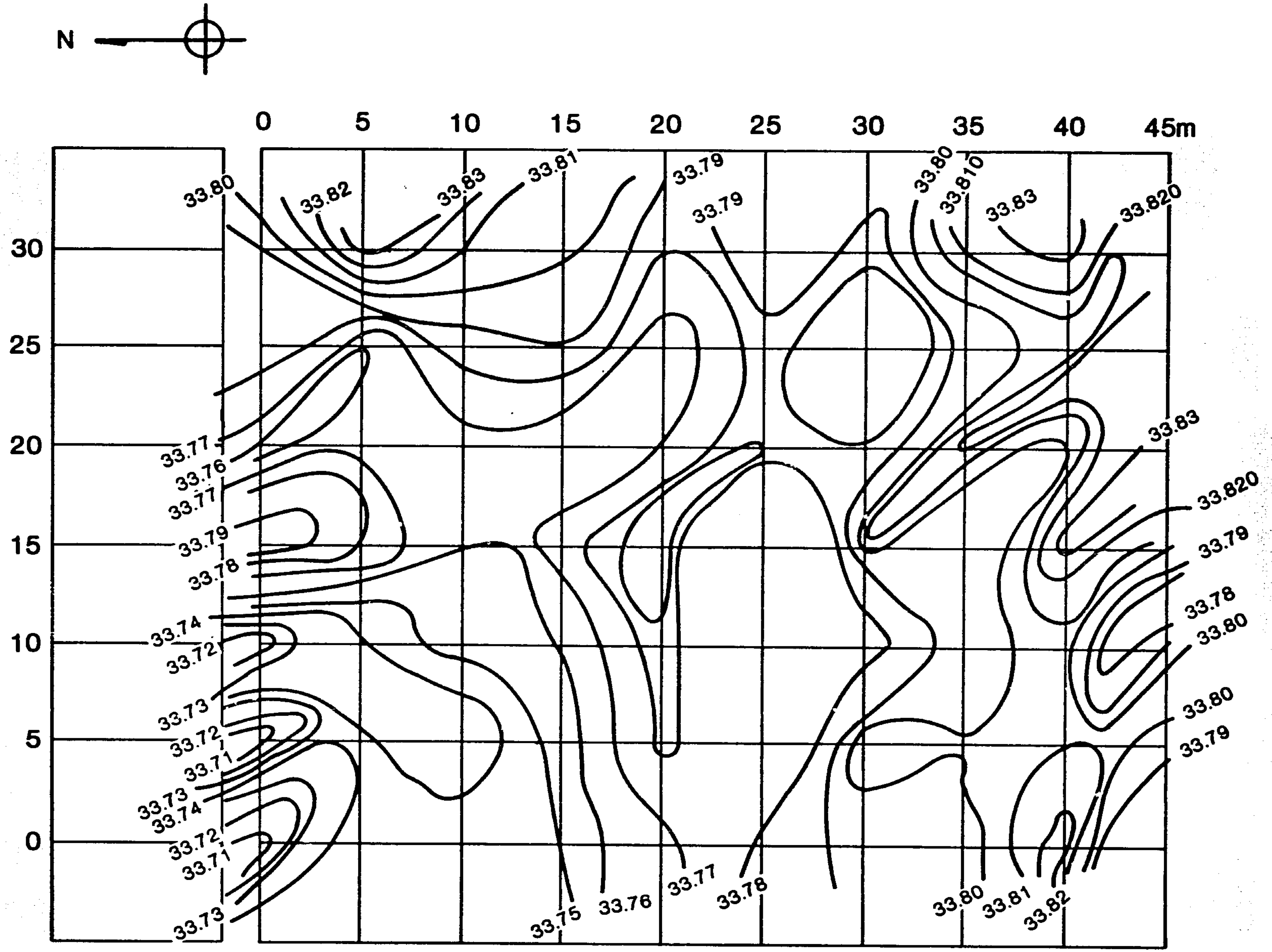


Figure B-13. Elevation Contours in Field 686/1

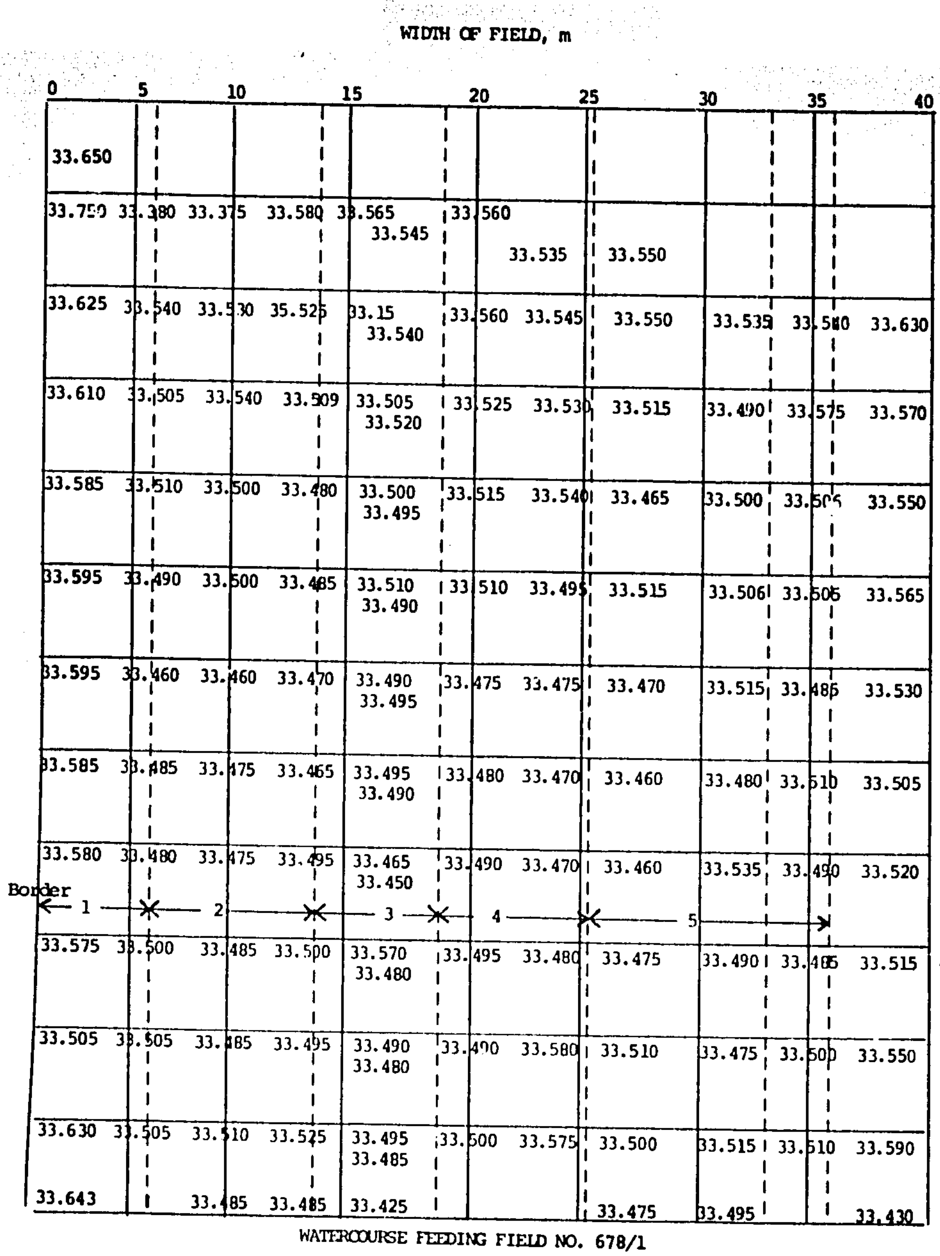


Figure B-14. Grid Elevations and Layout of Borders in Field 678/1

Table B-5. Mean, Standard Deviation, and Range of Elevations in Field 678/1

Statistical Characteristics	Mean	SD	Range
Border 1	33.551	0.077	33.380 - 33.750 m
Border 2	33.493	0.036	33.375 - 33.580 m
Border 3	33.499	0.032	33.425 - 33.570 m
Border 4	33.508	0.038	33.425 - 33.580 m
Border 5	33.499	0.027	33.460 - 33.550 m

4. Evaluation of Outlet 01/R of Subminor 10R—Chikhodara Distributary

a. Conveyance System

Watercourse 01/R takes off at RD1100 feet of Subminor 10R. The outlet to the watercourse had a screw gate. The watercourse had steep slopes (1 in 169). Lack of control structures combined with the steep slope resulted in severe erosion of the existing watercourse bed and the banks. The losses were due mainly to rodents, overtopping, and seepage. Since the watercourse was closed, seepage measurements were made by the ponding method. Two contiguous reaches of 10 m each were selected. The sections were dammed and filled with water. The water surface levels were observed at specified intervals and the loss rate in the reaches at the operational level was found to be 3.36 cm/hr and 1.73 cm/hr in Reaches 1 and 2, respectively (Figures B-15 and B-16). The cross sections of the watercourse were measured at five locations in each reach (Figure B-17). The loss rate in the watercourse sections was found as follows:

For Reach 1,

$$Q\ (\text{lps})/100\text{m} = \frac{dd}{dt}\ (\text{cm/hr}) \times TW\ (\text{cm}) \times 0.0028$$

$$\frac{dd}{dt} = 3.36\ (\text{cm/hr})$$

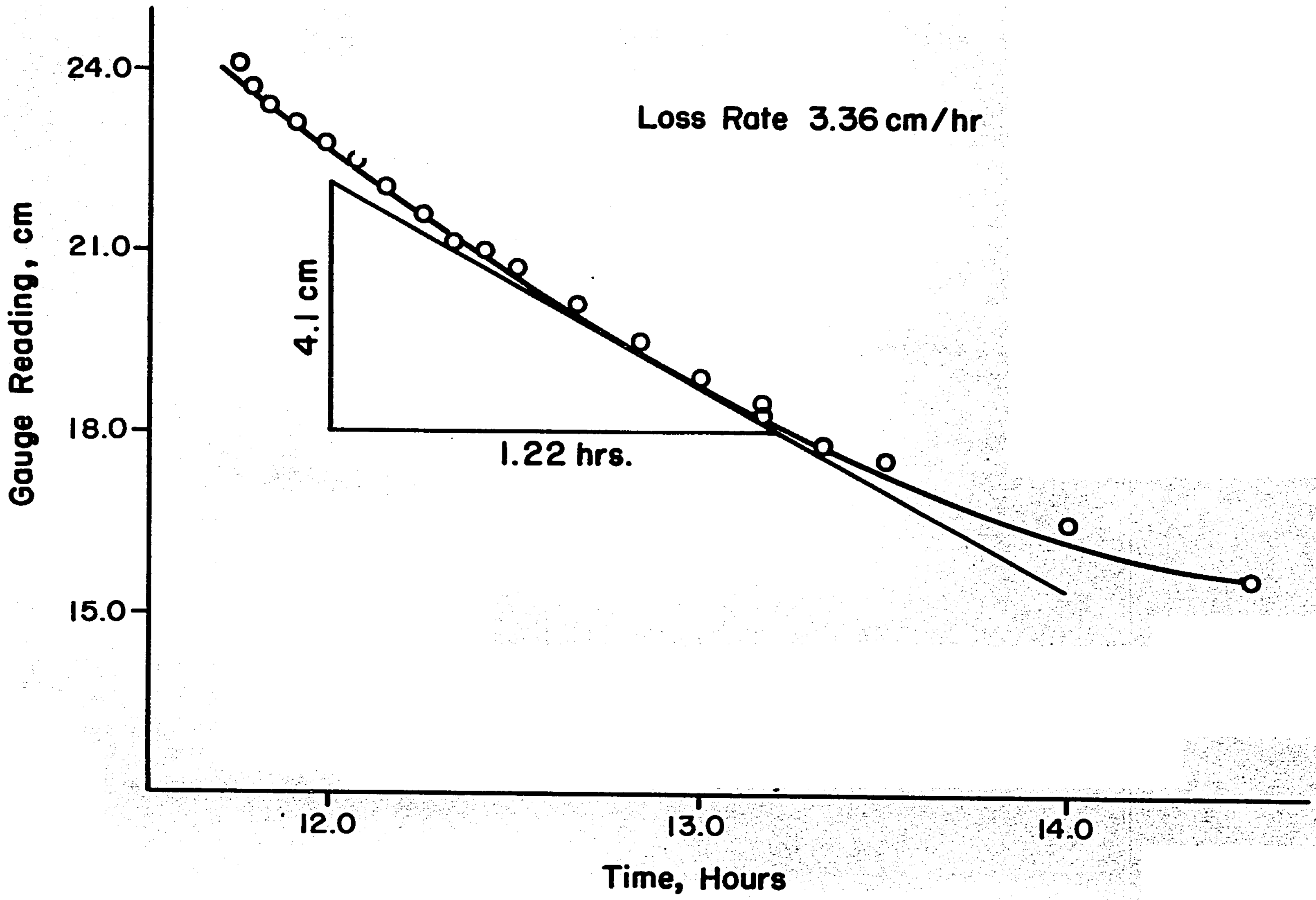
$$TW = 97\ \text{cm}$$

$$Q_L\ (\text{lps}) = 3.36\ (\text{cm/hr}) \times 97\ \text{cm} \times 0.0028$$

$$= 0.9126\ \text{lps}/100\ \text{m}$$

$$= 0.0098\ \text{cfs}/100\ \text{ft}$$

The average wetted perimeter of the canal was 1.12 m. As mentioned above, the section was 10 m long, therefore, the loss rate per m^2 was:



.gure B-15. Time Versus Gauge Reading at Reach 1 of the Watercourse 01/R, Subminor 10R

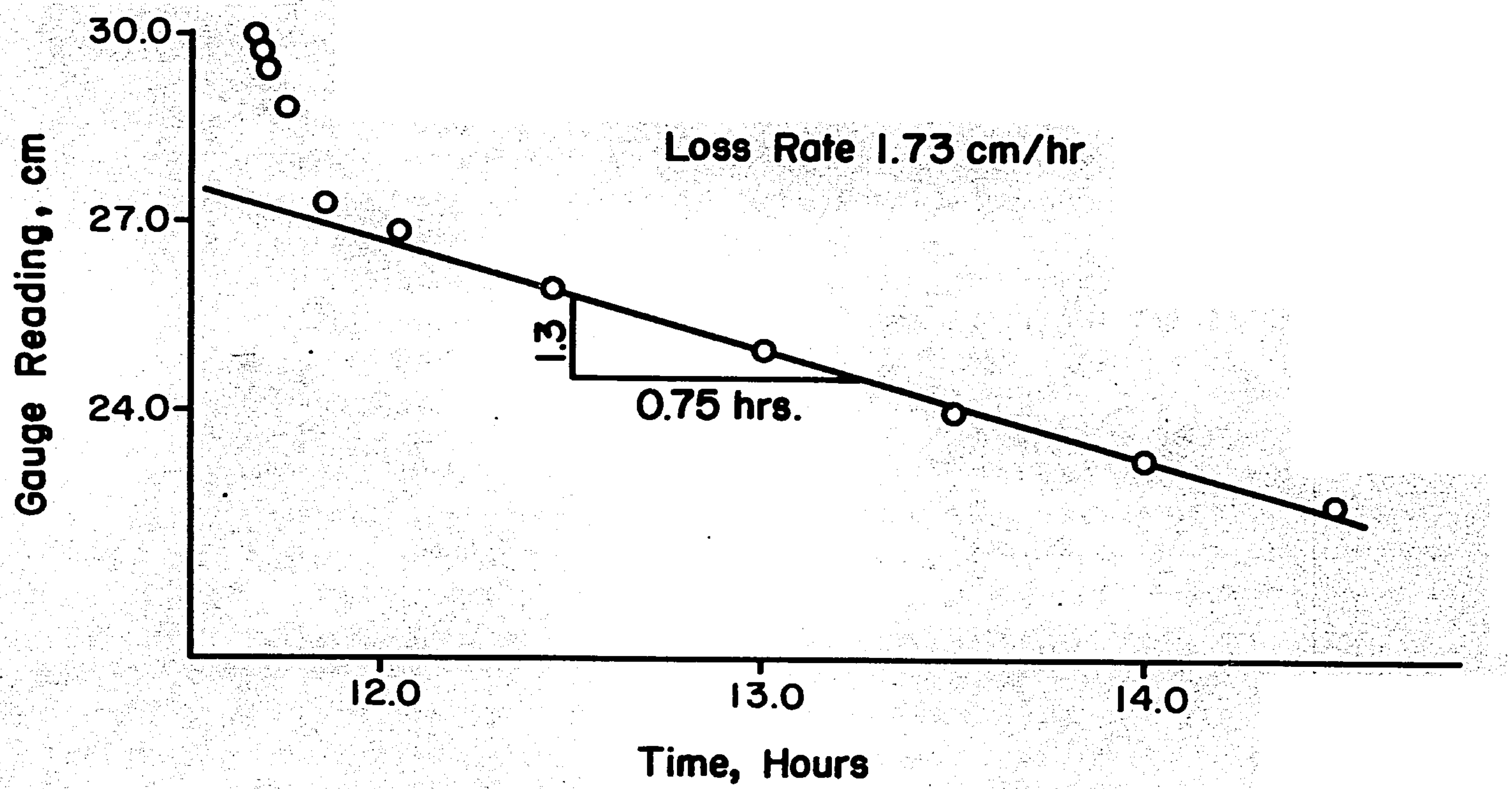


Figure B-16. Time Versus Gauge Reading at Reach 2 of the Watercourse 01/R, Subminor 10R

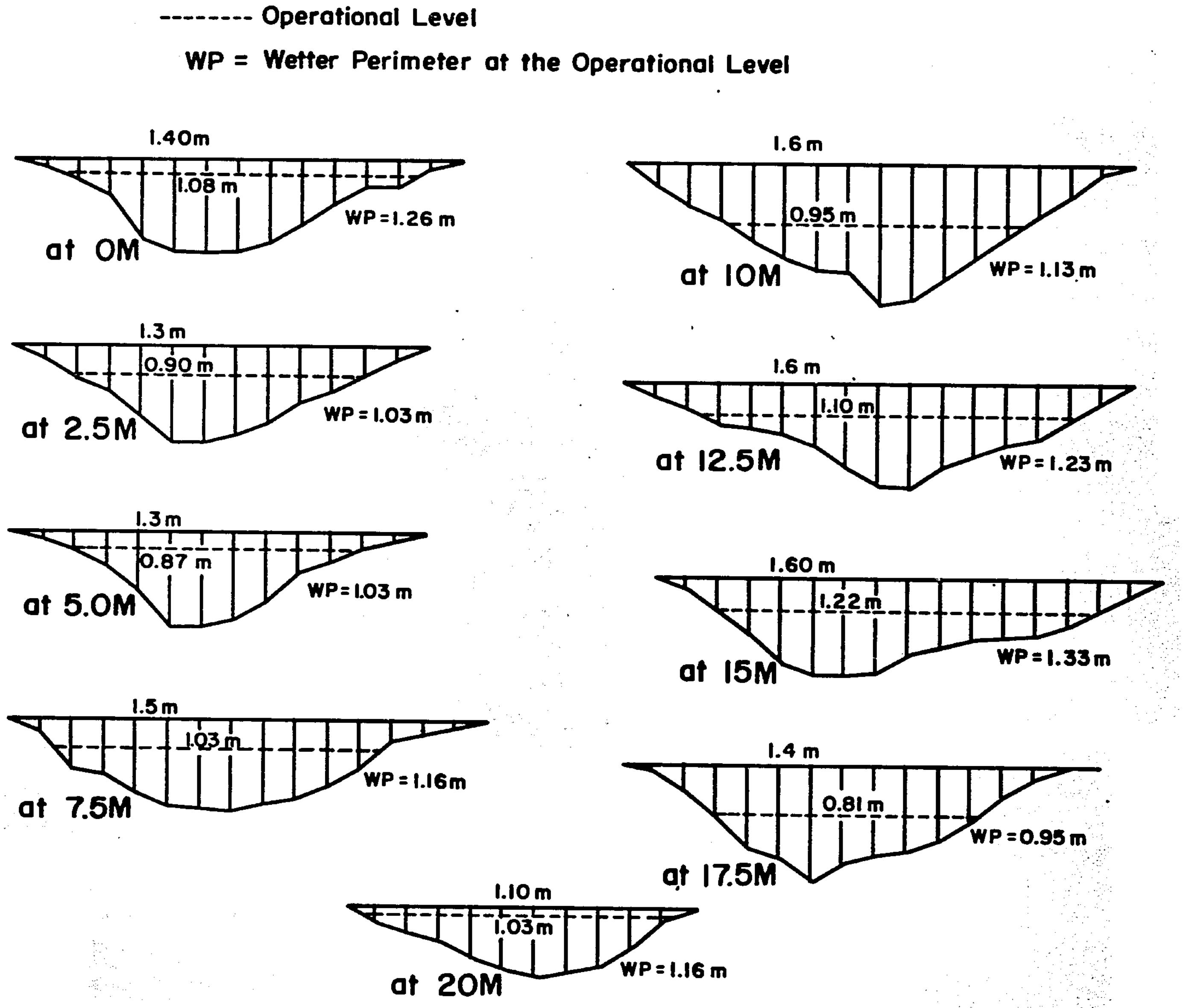


Figure B-17. Cross-sections of the Watercourse at Contiguous Locations, Outlet 01/R of Chikhodara Subminor 10R

$$Q_L/m^2/sec = 10\ m \times \frac{(0.97 + 1.42)}{(2)} \times 0.0336\ m/hr$$

$$\times \frac{1}{3600} \times \frac{1}{11.24\ m^2} \times 1000\ l/m^3$$

$$= 0.0099\ lps/m^2 \text{ of WP}$$

$$= 0.0000099\ m^3/s/m^2 \text{ of WP.}$$

For Reach 2,

$$Q_L(lps)/100m = \frac{dd}{dt}\ (cm/hr) \times TW\ (cm) \times 0.0028$$

$$= 0.489\ lps/100\ m$$

$$= 0.0053\ cfs/100\ ft$$

The average wetted perimeter of the channel was 1.16 m and the average width, at the operational level, was 1.01 m. Therefore, the loss rate per m was:

$$Q_L/m^2/sec = 10m \times 1.01m \times 0.0173\ m/hr$$

$$\times \frac{1}{3600} \times \frac{1}{11.6m^2} \times 1000\ l/m^3$$

$$= 0.004184\ lps/m^3 \text{ of WP}$$

$$= 0.000004184\ m^3/m \text{ of WP}$$

b. Application System

Since the watercourse was closed, no fields were evaluated under this outlet. Farmers used graded borders in this area. The fields had uneven topography and steeper grades (1 in 106). Farmers applied water on every rotation and, in most places, overirrigation was obvious; standing water was found in the fields three days after irrigation.

5. Evaluation of Outlet 05/L of Subminor 10R--Chikhodara Distributary

This outlet is located at the tail of the Subminor 10R at a distance of 6800 ft from the head of the canal. The outlet was provided with a screw type gate and a trapezoidal flume for measuring the flow rate. The following characteristics of the subminor and the outlet were noted:

	Subminor 10R	Outlet 05/L
Channel Bed Level	42.15 m	40.55 m
Free Surface Level	42.45 m	40.85 m
Design Discharge	not available	1.27
CCA	—	61.50 (24.90 ha)

The conveyance and the application systems were evaluated.

a. Conveyance System

The outlet was a 9-inch diameter pipe and the discharge was regulated through a 9-inch x 1 ft screw-type gate. The dimensions of the watercourse were as follows:

Bed width - 0.45 m

Top width - 1.35 m

Depth - 0.45 m

The elevation at the outlet of the watercourse was 42.52 m, and 410 m from the outlet was 40.79 m (Figure B-18). Therefore, the average gradient of the watercourse bed was 0.0042 m/m, which is higher than the recommended non-erosive grade. Except in the first 30 m, the watercourse did not have any negative gradients. The cross sections of the watercourse at different locations are given in Figure B-19. The official flow rate of the canal was 1.27 cfs. The actual flow rate measured in the watercourse on March 12, 1981, was 0.89 cfs. To evaluate the conveyance efficiency, flow rate at two locations situated 384 m apart (Figure B-20) was measured . The second flume was located near Field 275 which was 1,356 ft (414 m) from the outlet. The average flow rates at the head of the watercourse and the field were 0.89 and 0.73 cfs, respectively. The constant loss rate was 0.0127 cfs/100 ft (1.18 lps/100 m), and the percent flow rate was 1.43/100 ft (4.68/100 m).

The actual cultivated area and the cultivable command area were 31.83 acres and 61.50 acres, respectively. Therefore, the irrigated area was 52 percent.

b. Application System

Field 275 was evaluated. The field was 69-m long and 57-m wide. It has nine borders. The field elevations are presented in Table B-6. Two borders were considered (Borders 7 and 8). From the cylinder infiltrometer test data (Figure B-21), the following infiltration functions were obtained:

$$z_7 = 2.05t^{0.204} \quad (4)$$

$$z_8 = 2.80t^{0.204} \quad (5)$$

The average flow rate into Border 7 was 0.80 cfs (Figure B-20). The irrigation time was 31 minutes. The advance and recession times were noted. The area of the border was 483 m^2. Since there was no runoff, the depth of water

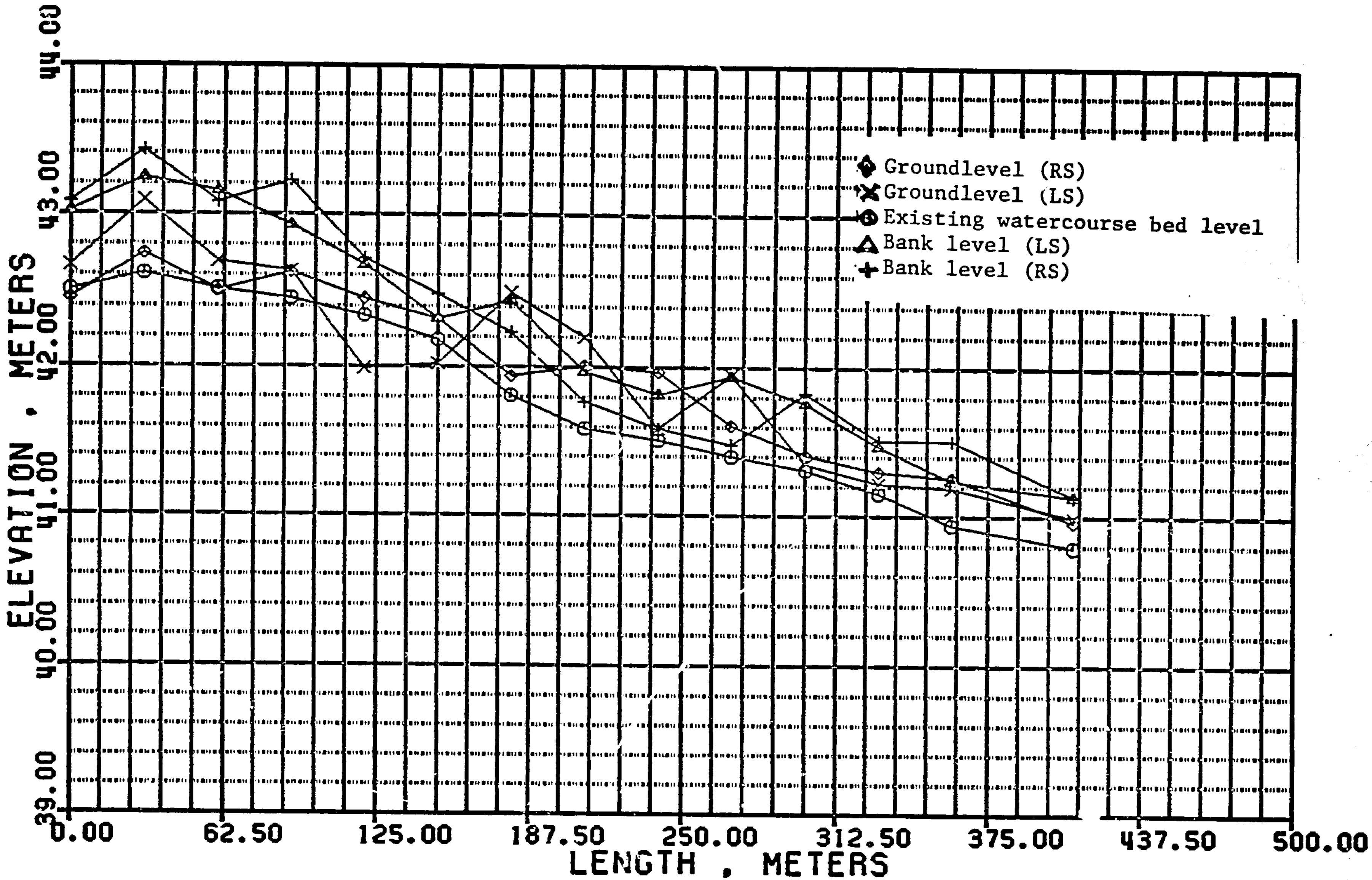


Figure B-18. Longitudinal Section, Outlet 05/L, Subminor 10R

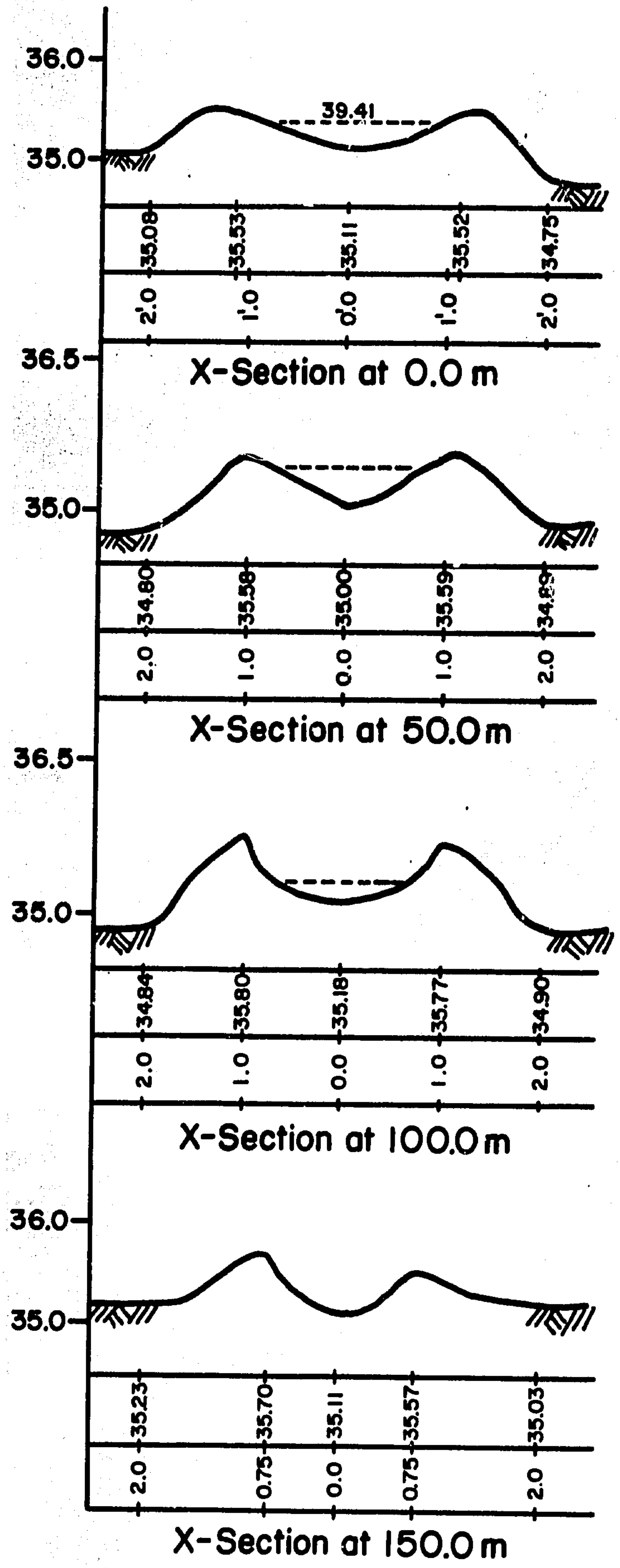


Figure B-19. Cross-sections of the Watercourse at Different Locations

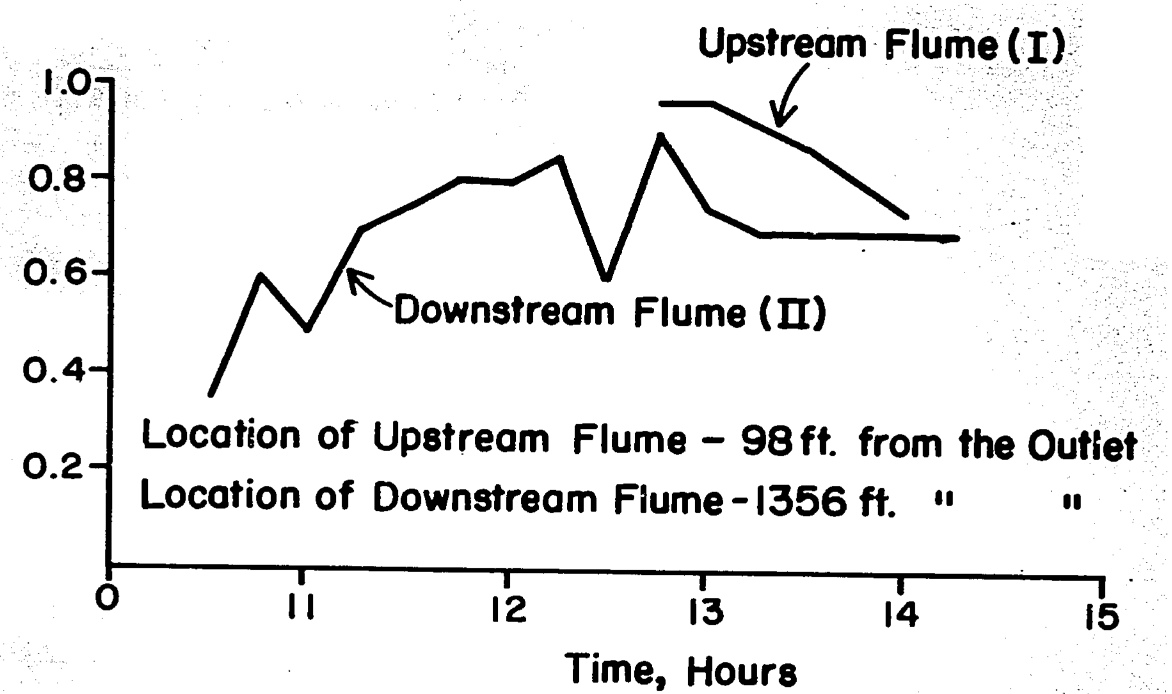


Figure B-20. Flow Rate Measurements at Two Locations on Watercourse 05/L, Subminor 10R

Table B-6. Elevations in Field 275

Distance (m)	Field Elevation (m)	
	Row 1	Row 2
Border 7		
0	40.94	40.92
10	40.88	40.83
20	40.88	40.91
30	40.94	40.89
40	40.89	40.83
50	40.84	40.81
60	40.79	40.79
69	40.79	40.79
Border 8		
0	40.93	40.96
10	40.87	40.91
20	40.86	40.89
30	40.89	40.84
40	40.84	40.84
50	40.80	40.81
60	40.86	40.79
69	40.77	40.79

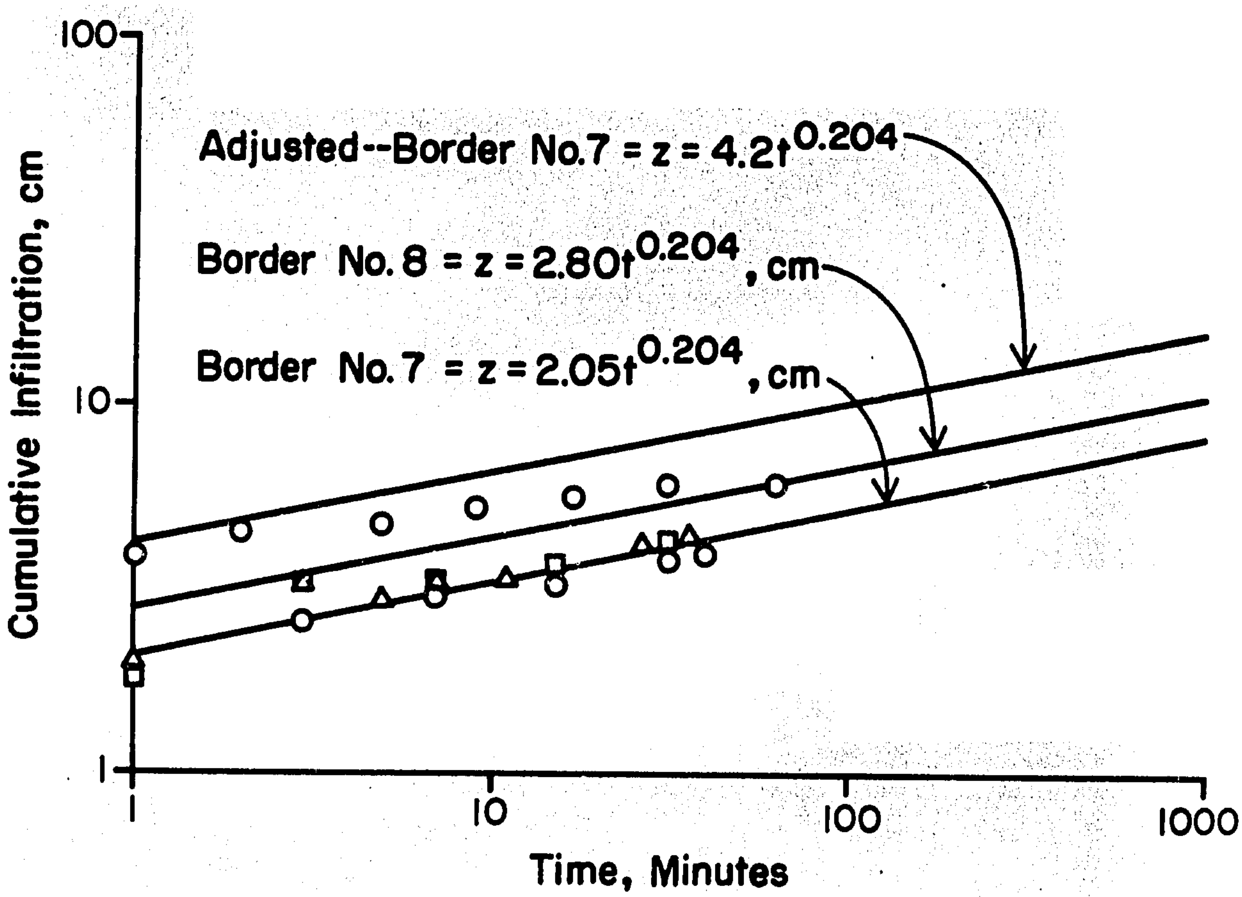


Figure B-21. Infiltration Characteristics of Borders 7 and 8 at Outlet 05/L, Subminor 10R applied was 8.73 cm. The slope of the fields was nonuniform and is as shown in Figures B-22 and B-23. Using the infiltration function, and the advance and recession curves (Figure B-22), the average depth infiltrated in Border 7 was estimated to be 4.26 cm which is significantly less than the actual depth of water applied. Therefore, the infiltration function was adjusted. The constant of proportionality was changed to 4.20, and the infiltration function for Border 7 then was given as:

$$z_7 = 4.20t^{0.204} \qquad (6)$$

The area of Border 8 was 490 m^2. The average flow rate into the border was 0.73 cfs and the time of irrigation was 23 minutes. The average depth of application was estimated to be 5.59 cm. From infiltration Equation 5, and advance and recession data (Figure B-23), the average depth infiltrated was 5.63 cm which is very close to the actual depth applied. Therefore, Equation 5 was assumed to be correct.

The soil-moisture deficiency before irrigation was estimated also (Tables B-7 and B-8). The application efficiency of Border 7 and 8 was 100 percent because the fields were underirrigated. The depths of water infiltrated in different sections of the borders are shown in Figures B-22 and B-23. A uniformity coefficient of 0.97 was obtained for both the borders.

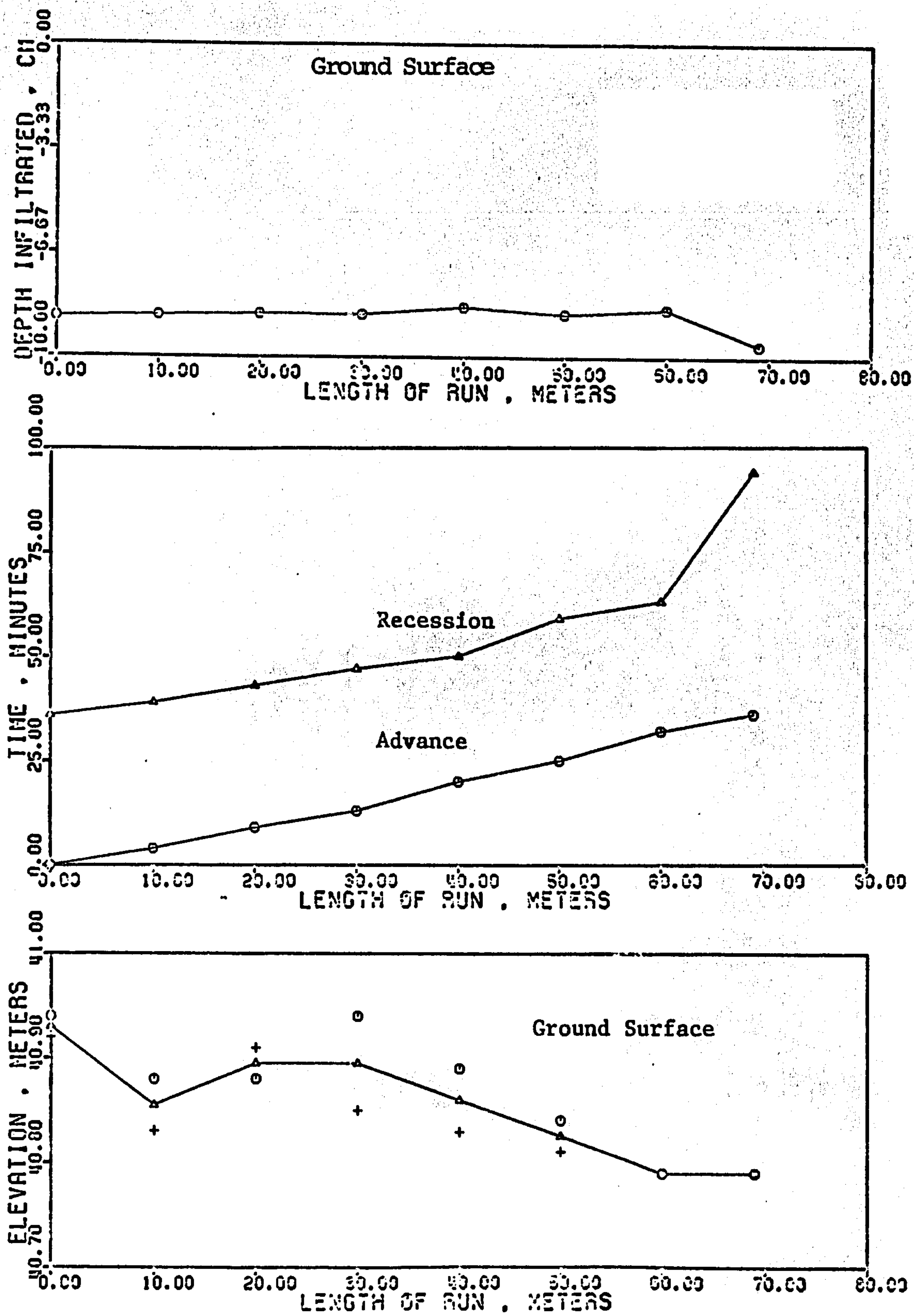


Figure B-22. Field Slope, Advance and Recession, and Depth Infiltrated in Border 7

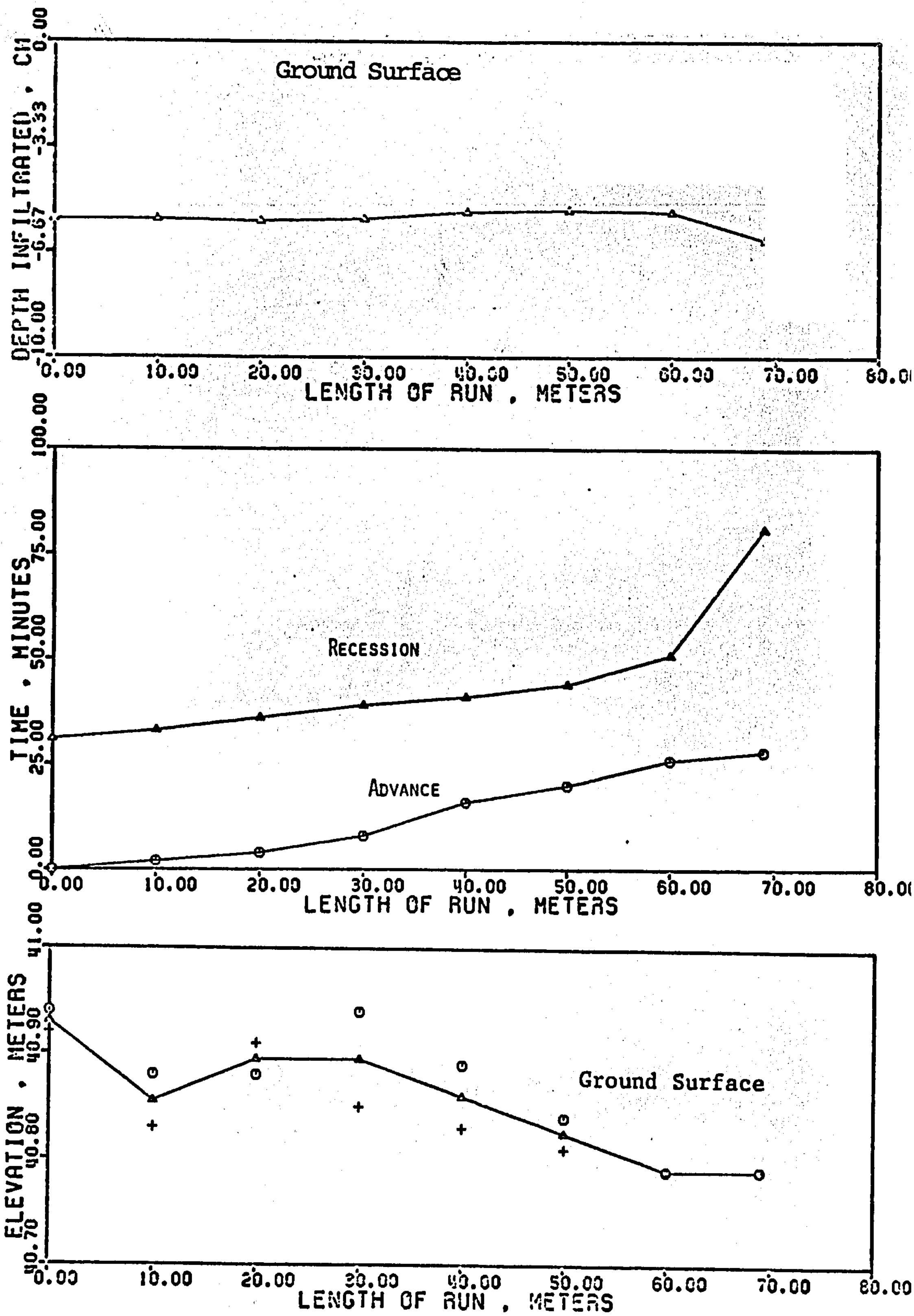


Figure B-23. Field Slope, Advance and Recession, and Depth Infiltrated in Border 8

Table B-7. Form 10—Soil Water Content Data

IDENTIFICATION Sy. No. 275/05L of SMIOR OBSERVERS A. S. Parekh

DATE March 12, 1981 ______ BEFORE / AFTER IRRIGATION

REMARKS:

Station	Depth cm	Can No.	Wt. Can Tare g	Wt. Can & Soil Wet g	Wt. Can & Soil Dry g	Wt. Soil Dry g	Wt. Water g	Water Content % by Weight	Bulk Density γ_b	Water Content % by Volume	Water Depth d mm
	0-30	73	48.5	293.0	269.9	221.4	23.1	10.4		14.9	44.7
	30-60	74	48.6	296.5	266.4	217.8	30.1	13.8	1.38	19.0	57.0
H	60-90	75	48.1	265.2	239.5	191.4	25.1	13.4		18.5	55.5
	0-30	76	48.0	243.4	231.8	183.8	11.6	5.0		6.9	20.7
	30-60	77	48.7	258.7	240.9	192.2	17.8	9.0	"	12.8	38.4
	60-90	78	48.0	213.6	197.0	188.9	16.5	8.78		12.1	36.3
	0-30	79	48.6	309.0	290.4	241.8	18.6	7.69		10.6	31.8
	30-60	80	48.5	257.2	233.0	185.0	18.7	7.40	"	10.2	30.6
M	60-90	81	48.5	274.5	242.7	194.2	27.8	14.31		19.7	59.1
	0-30	82	49.0	223.3	212.1	163.1	11.2	8.86		9.5	28.5
	30-60	83	49.3	202.2	187.8	138.5	14.4	10.27	"	14.2	42.6
	60-90	84	48.6	253.6	222.5	183.5	21.1	11.47		15.8	47.6
	0-30	85	48.5	173.4	164.5	116.0	8.9	7.67		10.6	34.8
	30-60	86	48.1	183.2	170.5	122.4	12.7	10.37	"	14.3	42.9
T.	60-90	87	48.5	181.0	168.1	119.6	12.9	10.78		14.9	44.7
	0-30	88	48.0	210.8	198.2	150.2	12.6	8.38		11.6	34.8
	30-60	89	49.2	180.1	168.2	139.0	11.9	8.56	"	11.8	35.4
	60-90	90	48.9	238.1	217.3	168.2	20.8	12.35		17.0	51.0

Table B-8. Soil-water Deficiency in Survey Number 275, Outlet 05/L, Subminor 10R, Chikhodara Distributary

Location	Depth (cm)	Site 1,	Site 2	Average	Depth (cm)	Deficiency (cm)
1	2	3	4	5	6	7
	0-30	14.9	6.9	10.90	3.27	4.83
Head	30-60	19.0	12.8	15.90	4.77	3.33
	60-90	18.5	12.1	15.30	4.59	3.51
						11.67
	0-30	10.6	9.5	10.05	3.02	5.09
Middle	30-60	10.2	14.2	12.20	3.66	4.44
	60-90	19.7	15.8	17.75	5.33	2.78
						12.31
	0-30	10.6	11.6	11.10	3.33	4.77
Tail	30-60	14.3	11.8	8.05	2.42	5.69
	60-90	14.9	17.0	15.95	4.79	3.32
						13.78

*Deficiency = 8.1 - Column 6

$$\text{Average deficiency} = \frac{11.67 + 12.31 + 13.78}{3}$$

$$= 12.59 \text{ cm}$$

Assumed field capacity = 27%

= 8.1 cm

Permanent wilting = 13.5%

= 4.05 cm

C. List of Participants and Workshop Schedule

WORKSHOP SCHEDULE
February 17 to March 19, 1981
MAHI-KADANA IRRIGATION PROJECT
Anand, Khedi District, Gujarat State, India

WEEK I:

Administration, Organization and Overview of Course
Project background in Agronomy, Irrigation and Socio-Economics

Discipline and Team Preparation for Reconnaissance
Execute Reconnaissance Studies

WEEK II:

Discipline and team training activities for Detailed Studies
Execute First Detailed Study

WEEK III:

Analysis and Synthesis of Detailed Study
Plan Detailed Study
Execute Second Detailed Study

WEEK IV:

Teamwork Training
Analysis and Synthesis of Detailed Study
Plan and Execute Third Detailed Study

WEEK V:

Analysis and Synthesis of Detailed Studies
Report Presentation and Discussion
Course Evaluation
Closing Ceremonies

Participant Teams for the Professional Development Workshop

Discipline	Jaismand	Anand	Chambal
Agronomy:	Shri Bhatnagar V. N. Singh Assistant Agronomist Kankroli - 313324 Udaipur, Rajasthan India	Shri A. S. Parekh Agronomist c/o Office of the Joint Director of Agriculture (Irrigation Project) Nadiad - 387001 Gujarat, India	Shri Um Rao Singh Assistant Agronomist Soil & Water Management Research Station Command Area Development Chambal Kota Rajasthan, India
Economics:	Shri Keshar Singh Khamesra Assistant Agriculture Economist Udaipur - 313001, Rajasthan India	Shri B. I. Solanki Deputy Director of Agriculture (Statistics) c/o Director of Agriculture Gujarat State, Ahmedabad - 38006, India	Shri S. H. Shah Statistical Officer c/o Office of the Area Development Commissioner Kadana Project, Ahmedabad - 380009 Gujarat, India
Engineering-Irrigation	Shri N. L. Solanki Assistant Engineer Irrigation Subdivision Salumber, Udaipur Rajasthan, India	Shri M. I. H. Shaikh Deputy Engineer Drainage Subdivision Anand - 388001, District: Kheda, Gujarat, India	Shri C. A. Robinson Executive Engineer World Bank Division Kota - 324001 Rajasthan, India
On-Farm:	Shri Vinod Shah Assistant Engineer Master Plan Division Irrigation, B-90, Ganesh Marg Jaipur - 302004, Rajasthan India	V. K. Bairathi Executive Engineer Irrigation Design Div. No. 1. Opp: M.R.E.C. Jaipur - 302004, Rajasthan, India Shri N. S. Mallya Divisional Soil Conservation Officer Kadana Project Godhra, District: Panchmahals Gujarat, India	Shri R. N. Bhatnagar Executive Engineer Research Design Planning Division LDP., C.A.D., Kota - 324001 Rajasthan, India
Extension:	Shri Ram Chandra Verma Vikas Adhikari, Salumber, District: Udaipur, Rajasthan, India	Shri A. N. Sindha Assistant Agronomist c/o Office of the Joint Director of Agriculture Nadiad - 387001 Gujarat, India	Shri M. L. Sharma Deputy Director of Agriculture Command Area Development Kota - 324001 Rajasthan, India

D. <u>Glossary</u>

Bigha	-	1/2 acre or 0.2 ha of land
CADA	-	Command Area Development Authority
Chowkidar	-	canal gatekeeper or watchman
HYV	-	high-yielding variety of crop
Karkoon	-	canal inspector who supervises chowkidar
Kharif	-	monsoon cropping season from June to October
Lathis	-	power
Patel	-	a high caste
Panchayat	-	village-level government body
Panchnama	-	a fine issued for any infraction of rules
Pora hal	-	a single row drill consisting of a stick plow with a funnel and tube attached to the handle of the plow which extends to the base of the shear. Seed is fed into the funnel by hand.
Pucca nakka	-	improved, concrete, or high-quality structure
Rabi	-	dry cropping season from November to February
Talati	-	revenue official
VLW	-	visitation-level worker, or extension worker
Warabundi	-	rotation of water supply according to a fixed schedule

SECTION VII - REFERENCES

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