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PROBLEM IDENTIFICATION MANUAL

Prepared by
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Development Process for Improving Irrigation Water Management on Farms

PROBLEM IDENTIFICATION MANUAL

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PROBLEM IDENTIFICATION MANUAL

PREFACE

This manual is designed as a resource for identification of farm system constraints on irrigated agriculture. Information contained in this manual will provide a means for determining what components of the system are not functioning adequately to achieve improved crop production goals. The farm water management system, the focus of this manual, has strong interrelationships with various subsystems. As shown in the idealized description of a farm irrigation system (Figure 1), definite physical boundaries are delineated. The first major boundary is the canal itself which is linked to the total irrigation system including storage, diversion, and drainage facilities. The drainage system is another physical boundary that demarcates the farm irrigation system. Within the farm system there are physical boundaries including conveyance channels, farm fields, irrigation basins, and drainage ditches.

The farm irrigation system is also an open system since it is linked with not only the larger physical irrigation system, but with many organizations that regulate it and supply essential inputs. These organizations include irrigation and agricultural bureaucracies, and private and public organizations that supply essential inputs such as credit, fertilizer, insecticides, seed, and farm equipment. Institutional linkages also include markets and policy-oriented agencies.

The farm irrigation system is man-made. Irrigation is one of the most significant ways man manipulates physical and human resources to increase crop production. The purpose of the farm system is to provide an adequate physical, chemical, and organizational environment for the production of crops to meet basic human needs. In arid and semi-arid climates, irrigation is usually required to grow crops, and on-farm water management is often the greatest constraint to increased agricultural productivity.

This manual provides a systematic set of procedures for describing and analyzing the system in relationship to this purpose. A description

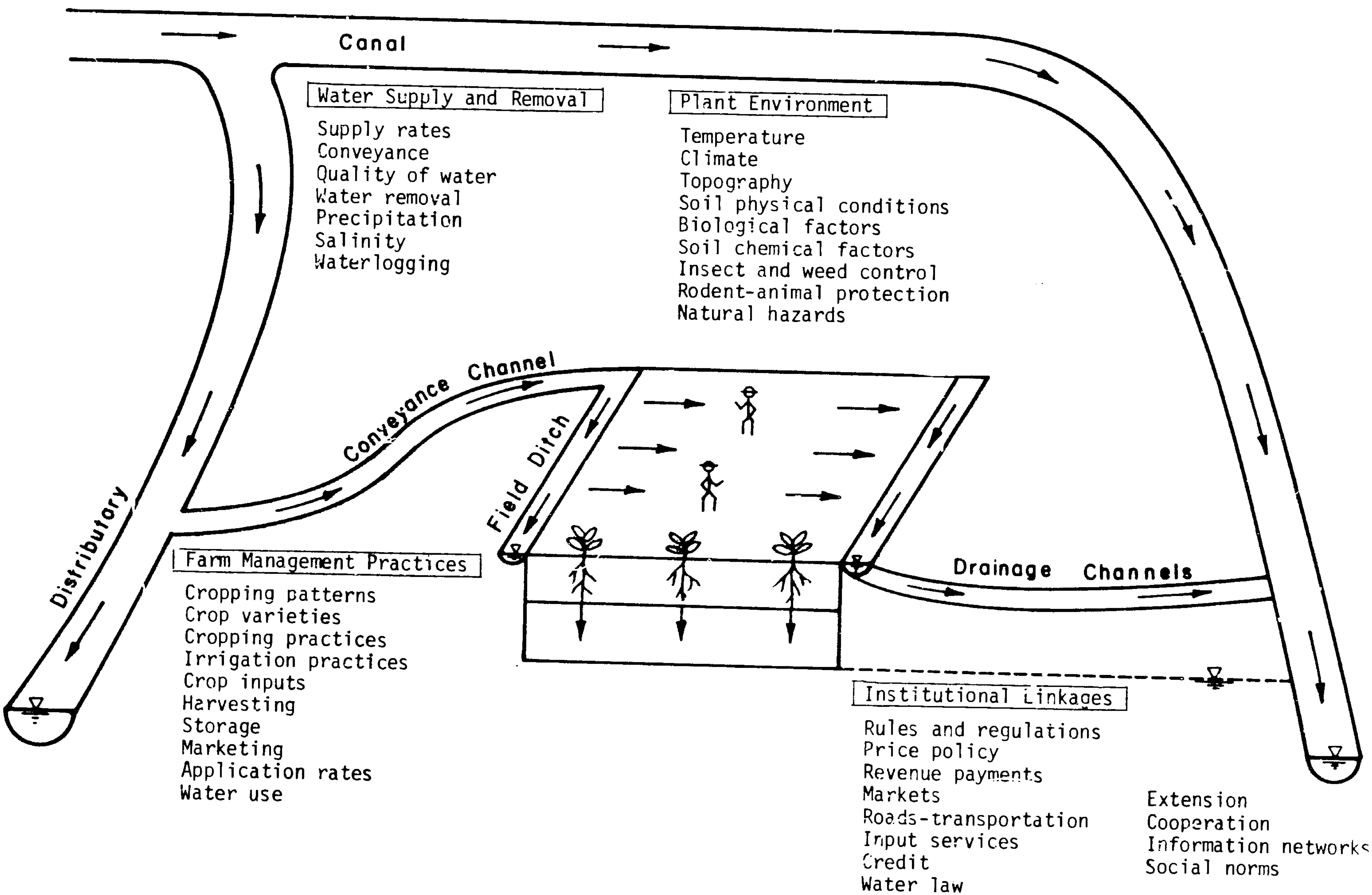

Figure 1. Idealized sketch of a farm irrigation system.

of the system and its operation is developed initially from quantitative measurements defining the operational parameters of each of the four major subsystems. These subsystems include the plant environment, farm management practices, water supply and removal, and the institutional linkages as shown in Figure 1.

Several specialists are involved in analyzing the farm system. The engineer measures the efficiency of water distribution, adequacy of volume and rate of water supply, water use, water removal, water dependability, and other aspects. The agronomist is concerned with all the factors that influence the plant environment and measures these factors in relationship to their impact on crop yields. The economist identifies the levels of resource input and output for crop production and farm income. The sociologist identifies the decision-making processes of the farm manager and social factors such as behavior norms, institutional restraints, knowledge status, and information transfer processes that influence farmer decision-making. The perspectives and methods of each discipline are utilized cooperatively to establish a quantitative and qualitative description of each of the four major subsystems and the total operation of the farm water management system.

Information presented in this manual is designed around the four major subsystems: the plant environment, farm management practices, water supply and removal, and institutional linkages. Additionally, Chapter I provides a description of the manual and its use. Chapter II discusses problem identification. Chapters III through VI provide field procedures for describing and identifying problems in each of the four subsystems. Chapter VII discusses the analyses applied to the data collected under the four subsystems and the interpretation of these analyses.

Development Process for Improving
Irrigation Water Management on Farms

PROBLEM IDENTIFICATION MANUAL

ABSTRACT

Problem Identification is the first of three phases in the development process with the other phases being the Development of Solutions and Project Implementation. The Problem Identification phase consists of two subphases; namely, Reconnaissance and Problem Diagnosis. The Reconnaissance subphase consists of: setting preliminary program objectives; developing a general overview of the irrigation system; conducting reconnaissance field investigations of the plant environment, farm management practices, water supply and removal, and institutional linkages; preparing a preliminary listing of problems; and refining the program objectives. The Problem Diagnosis subphase consists of: designing diagnostic studies; conducting diagnostic field studies; analyzing and interpreting the findings; identifying criteria for the selection and ranking of problems according to program objectives; and reporting findings of priority problems and their apparent causes.

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CHAPTER I

DESCRIPTION AND USE OF THE MANUAL

This manual is designed to provide a flexible set of guidelines, concepts, procedures, and methods for identification of factors that may inhibit efficient functioning of farm irrigation systems. Procedures are provided for a systematic approach to objective evaluation of existing farm irrigation systems. This is done as preparation for a systematic search for socio-technical solutions to problems that may occur.

The authors have extensive experience in research and development related to irrigation systems, and are well aware that irrigation systems have unique physical, social, economic, and legal characteristics that have complex interdependencies. While irrigation systems have many "site-specific" factors that must be analyzed individually, there are procedures that can be utilized for understanding general problems.

This manual provides several aspects that should be considered in evaluating a farm irrigation system. The factors and methods of investigation described can serve as a checklist to emphasize important variables that may require systematic examination if adequate data do not already exist. This manual is designed to provide guidance in developing an understanding of water management constraints in irrigated agriculture.

The flexible systematic approach for evaluating existing farm irrigation systems explained in this manual will help delineate priority research needs and improvements. A major assumption is that all irrigation systems can be greatly improved in terms of efficiency and increased benefits to farmer-clients. However, there are several aspects that will not be covered in this manual. This manual DOES NOT PROPOSE:

- To provide a universal technique that can be used without adaptation to specific situations.
- To provide guidelines to study problems that are simply interesting to the particular investigators.
- To provide a guide for the identification of all problems of any irrigation system.

- To provide guidance for surveys that are so comprehensive they are of little use to applied researchers and practitioners.
- To assume to do more than serve as a flexible guide to practitioners and researchers who have the task of improving complex farm irrigation systems

ORIGIN OF THE MANUAL

The authors have intensively studied their own assumptions and approaches regarding irrigation systems. They have determined there is a need for using a more objective and systematic approach. Their approach was field tested in Pakistan with respect to research and development activities. A theoretical framework, A Research-Development Process for Improvement of On-Farm Water Management[1], has been developed and should be consulted by the reader

This manual of procedures and methods is the first phase of a much larger team effort[2] in describing the development process for improving irrigation water management on farms. Manuals have been prepared to provide procedural guides for each of the three phases:

I. Problem Identification

This combines an interdisciplinary approach with farmer participation to achieve an understanding of system operation. Results of this method are an objective, quantitative definition of priority problems.[3]

II. Development of Solutions

The interdisciplinary staff combines knowledge and experience with systematic research to develop acceptable solutions to priority problems Applied, adaptive, and evaluative research methods are also used under farmer conditions for the assessment of solutions. These results are used to define solution packages.

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[1]Clyma, Wayne; Max K. Lowdermilk; Gilbert L. Corey, 1977. A Research-Development Process for On-Farm Water Management. Water Management Technical Report No. 47, Colorado State University, Fort Collins.

[2]William Franklin and William Stewart, Agronomy; Gaylord Skogerboe and Doral Kemper, Engineering; Ed Sparling, George Radosevich, and Warren Smith, Economics; Max Lowdermilk, Dave Freeman, and James Layton, Sociology; and Jack Hautaluoma, Psychology.

[3]op. cit. p. 8.

III. Project Implementation

A development project evolves when decision-makers select a solution package for implementation. Trained personnel use the carefully designed technological package to work directly with farmers to solve their problems.

NEED FOR PROBLEM IDENTIFICATION

Those concerned with improving farm irrigation systems around the world should not have to be convinced of the need to identify problems systematically. In the past, however, many problems have usually been identified in this manner.

Financial resources are now being allocated to solving the problems of irrigation water management. Previously, few systematic approaches to evaluate existing irrigation systems, analyze weaknesses and failures, and prescribe technologies for improvement were developed. Usually, each system that was evaluated became an individual case study. Improvement programs were developed within a short time period utilizing little more than the experience of the project leader. Frequently, these improvements treated symptoms rather than real problems. Such conventional approaches generally ignore the farmer, his attitudes, his knowledge, and his constraints. Previous approaches have not resulted in sufficient significant improvements at the farm level.[4]

Water management improvement is important because there are an estimated 200 million acres of land presently under irrigation. New areas are being added at the rate of less than 10 million acres annually. Many irrigation systems operate at relatively low levels of water use efficiency and at low levels of production.[5] Thus, a major need is for the improvement of existing systems for the following reasons:

- To conserve water supplies by improved management for rapid increases in food production;
- To improve the return on investments of existing systems;

[4]Wiener, Aaron. 1972. The Role of Water in Development. McGraw-Hill Book Co., New York, p. 422.

[5]Bos, M. G. and Nugteren, J. 1974. International Institute on Irrigation Efficiencies, Pub. No. 19, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

- To reduce the costly waterlogging and salinity problems that are often symptoms of poor management;

- To identify the methods small farmers can use to increase net agricultural productivity by participating in new production possibilities;

- To reduce the need for large capital investments in new systems; and

- To gain knowledge that can provide new criteria for the development and management of other systems with a focus on participation of farmer-clients.

A concerted effort to improve irrigated agriculture, if focused at helping the subsistence farmer having small landholdings, could bring improved income and living conditions to a substantial percentage of the world's disadvantaged.

> The cost of expanding the present 85 million irrigated hectares by 90 million hectares is estimated at $130,000 million. This is not only exceedingly costly, but also a slow process because projects from design to completion often take 10 to 12 years. Investments in new projects will continue but more quick yielding programs seldom improve the efficiency of farm water use, therefore, the focus in the years ahead must be given to farm-level problems. There is much exciting drama in building large structures but we must not forget the small and often tragic dramas that take place daily on millions of small holders' farms where water conservation is a matter of success and failure and even life and death.[6]

STRUCTURE OF MANUAL

This manual is designed for quick reference and each chapter is delineated below.

Chapter II answers three basic questions about problem identification. These questions are:

- Why do problem identification studies?
- What is the problem identification process?
- How is problem identification done?

Chapters III through VI provide both reconnaissance procedures and detailed diagnostic methods for the examination of factors related to:

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[6] World Bank, 1975. The Assault on World Poverty, John Hopkins University Press, Baltimore, Maryland, pp. 95-96.

- The Plant Environment (Chapter III)
- Farm Management Practices (Chapter IV)
- Water Supply and Removal (Chapter V)
- Institutional Linkages (Chapter VI)

In each of the four chapters special factors are discussed along with the suggested reconnaissance and detailed diagnostic procedures and methods for use in field investigations. The most important factors have been included; however, there are likely others that the readers will want to add for their site-specific situation. Checklists are provided at the end of Chapter III through Chapter VI for convenience. The reader is encouraged to utilize this checklist to determine if all essential factors have been covered.

After each major section the factors of one section are related to those of the next section. For example, the last section of Chapter III shows how optimal plant growth factors relate to farm management practices which are the subject of Chapter IV.

Chapter VII provides a description of the interdependence of the four subsystems in a problem identification study, with a focus on the importance of close project staff collaboration. The analyses applied to the data generated from the diagnostic field studies are discussed, along with the interpretation of these analyses.

This is followed with appendices that provide several aids for the field manager including:

- Equipment needs;
- Data management aids,
- Selection, training, and evaluation of field investigators; and
- Example forms for farm budget analysis.

In addition to this manual, there is a series of technical field methods published by the Egypt Water Use and Management Project at Colorado State University through funds from the USAID. These are referenced in this text for easy referral by the field workers.

GLOSSARY OF IMPORTANT TERMS

Important concepts and definitions utilized throughout the manual are provided. While there can be much debate about certain definitions, the definitions in Table 1 represent the authors intent when used in these manuals.

Table 1. Glossary of terms.

Term	Definition
Action Research	A systematic investigation conducted specifically for a defined program which does not conclude with data collection, but leads eventually to project implementation. Testing is conducted under the conditions of the recipient of the research.
Adaptive Research	A systematic investigation to fit new technological advances into different environments.
Agronomic Subsystem	A system that utilizes the resources of soil, solar energy, and water in combination with necessary inputs to create an adequate environment for the growth of crops of the types and amounts required.
Applied Research	The direction or utilization of knowledge to the improvement or change of specific materials or conditions.
Communication	The transmission of thoughts, ideas, and information from one individual or group to another individual or group.
Conflict Resolution	The process where disagreement among members of the research staff is confronted and a decision is made on how that disagreement will be resolved.
Economic Factors	The allocation or utilization of all physical, chemical, biological, human, and organizational resources in such a way as to maximize economic and social goals from farm production efforts as determined by individual decision makers and public policy.

Evaluative Research	The process in which the scientific method is consciously applied for the purpose of making a judgment about the value of methods, processes, and programs about which there is concern utilizing various types of data, decision rules, and criteria.
Farmer-Client	The focus of a research project that encourages the concentration of the researchers to be centered on the farmers and also develops proper attitudes towards working with farmers.
Farm Water Management	Water management in agriculture is the process by which water is manipulated and used in the production of food and fibers. Water management is how water resources, irrigation facilities laws, farmers, institutions, and procedures in soil and cropping systems are used to provide water for plant growth. It encompasses all water used for that purpose including irrigation and water from natural precipitation.
Interdisciplinary Approach	An approach where different academic disciplines are combined to examine a research problem. The output of the study consists of an integrated approach where each discipline considers the effects of the other disciplines in analysis and recommendations.
Management Focus	Recognization by the researchers that a farmer is a decision-maker, and that the operation of the farm results from a rational approach of identifying a problem, developing alternative solutions and implementing the solution on the farm. Any recommendations by the research group must be analyzed as to the consequences.

Problem Identification	The procedure through which the understanding of an irrigation system is attained in order to define specific shortcomings that prevent the irrigation system from being fully effective in its operation.
Reconnaisance	Preliminary observations of an area which allows researchers to obtain general information to serve as a means for providing an initial direction for research activity.
Research Team	Individuals who work together on a research problem.
Social Subsystem	The social and organizational supports at the macro- and micro-levels needed for successful manipulation of the farm irrigation system to achieve desired individual and collective goals over time.
Systems Approach	A research approach with the objective to study all the components pertaining to a specific research problem. With respect to irrigation management, such aspects would include physical and institutional properties.
Team Building	The process in which individuals involved in a research program change from single purpose investigations by each participant to an integrated study involving the contributions of all the participants.
Water Application Process	A process to supply desired amounts of water uniformly to meet the needs of seed germination, plant emergence, salinity control, soil physical conditions, erosion, aeration, temperature, and surface drainage in a manner to adequately grow crops.

<u>Water Delivery System</u>	A system to convey water from the supply source to the fields to be irrigated at the proper time, volume, and flow rates required for the cropped area considering losses occurring within the system based upon design criteria.
<u>Water Removal System</u>	A system to maintain proper salinity levels, physical soil conditions (for root aeration and workability of soil), and to reduce health and environmental hazards.
<u>Water Use Requirements</u>	The adequate supply of water at the proper times in the quantity and quality necessary for crops to maintain acceptable levels of soil salinity, soil-air temperature, and soil physical conditions for crop growth.

CHAPTER II

THE PROBLEM IDENTIFICATION PROCESS

PURPOSE AND OBJECTIVES

The goal of the Problem Identification phase is to understand the traditional farming system and isolate the major constraints that inhibit its adequate functioning. It is assumed the purpose of the system is to increase agricultural production, improve the standard of living for all classes of farmers, and to conserve natural resources. The objectives of the Problem Identification phase are:

1. To provide a systematic approach for understanding the farm irrigation system,
2. To identify constraints that inhibit agricultural production,
3. To identify constraints that impede the progress of small operations,
4. To provide output from the Problem Identification phase as input to the Development of Solutions phase, which requires more intensive research, and
5. To provide data that can be utilized within a short period of time (one or two irrigation seasons) depending on the particular conditions and needs of the Problem Identification phase.

RATIONALE

There are several important reasons why increased attention should be given to problem identification studies of irrigation systems in low income nations. These reasons are listed below:

1. Little is known about the content and structure of traditional farming systems,
2. Valid empirical farm-level data for systematic planning of research is typically not available,
3. There is always a danger of treating problem symptoms rather than causes in dealing with complex farming systems, and
4. Most available research covers a limited subject area that generally neglects systems problems.

In the absence of good problem identification research, agricultural policies and programs are often implemented that place further constraints on improving production possibilities.[7] There have often been pressures to continue solving problems even before the real problems have been identified. Solutions for "assumed problems" are often not acceptable or usable by farmers. In many low income countries there is not an adequate data base to provide policy makers the information needed for rational planning purposes.

Problem identification will reduce the danger of development programs treating symptoms rather than problems. For example, the desalination plant on the Colorado River treats the symptom, salinity, rather than its cause--excessive application of irrigation water. Another example is the costly research and development program in Pakistan to control the twin menaces of waterlogging and salinity.[8] Previously, researchers in Pakistan assumed that farm conveyance efficiencies were about 80 to 90 percent without actually measuring losses. When problem identification investigations were conducted, actual efficiencies were found to be only 40 to 50 percent.[9]

Instead of making assumptions about problems, the researcher should examine the situation carefully in order to understand the farmers' perceptions of the problem. In other words, a complete analysis is needed to identify the symptoms before solutions are made and specialists are called for assistance.

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[7] Mellor, John, May, 1973. "Developing Science and Technology Systems: Experiences and Lessons from Agriculture." Occasional Paper No. 63, Department of Agricultural Economics, Cornell University.

[8] This does not mean that the SCARP Program in Pakistan did not greatly reduce waterlogging. They made a substantial contribution, but it was not realized that part of the problem was related to farmers' irrigation practices.

[9] World Bank, January 28, 1976. Pakistan Special Agriculture Sector Review. Volume III; Annex on Water Management. This report states that a 1 percent error in the efficiency of the system is equivalent to 1.4 MAF of water. In terms of storage cost of the Tarbella Dam, this error in efficiency is equivocable to $1 billion.

Special focus in problem identification is given to listening to the farmer-clients, understanding their needs, and their perceptions of major farm constraints. This procedure helps build credibility with the farmers by increasing their awareness and interest in solving farm problems. Farmers' perceptions often provide useful insights into the problems. Second, without listening to the farmer it is unlikely that one will gain an understanding of how the farming system actually works. If development programs are to be successful, more understanding of how traditional farming systems work is necessary

The role of the farmer has a central focus in the Problem Identification phase. Basic assumptions made about the farmer are listed.

1. The farmer is central to the irrigation system.

2. The farmer is rational in decision-making with respect to the constraints.

3. Traditional farmers will respond positively to improved technologies that are technically sound, economically profitable, and culturally compatible.

4. Farmers will participate in improvement projects that demonstrate visible and tangible results if positive and concerted efforts are made to develop credibility by including farmers in the planning and evolution of these programs.

MAJOR BENEFITS

A major benefit derived from the Problem Identification phase is understanding the system as composed of many interdependent factors. Answers must be found for such questions as: What are the system boundaries? What is the system supposed to do? How well does it function? What are the critical components of the system and how do they interact? What components are not functioning adequately? Since the farmer is an important aspect of the system, information must be obtained about what he does, why he does it, and what are the results.

A second benefit is the objective identification of major problems that inhibit increased crop production based on empirical field data. All problems cannot be included; therefore, it is necessary to focus upon significant crop production problems. Stated criteria are used for ranking problems in relationship to their importance in limiting crop production. Both quantitative and qualitative methods of ranking are used.

Other benefits include provision of empirical data for input into the solution phase, provision of data for use in the evaluation of the program, participation of the farmer, procedures for developing and maintaining credibility with farmers, opportunity to train host country personnel in interdisciplinary procedures for problem identification, and saving of time and other scarce resources.

There are always pressures in research and development programs to provide fast results for anxious host country officials and donors. Time spent in the Problem Identification phase is time saved in the Development of Solutions phase, as one researcher[10] has suggested.

> Difficulty in isolating the problem is often due to the tendency to spend a minimum of effort on problem definition in order to get on to the important matter of solving it. Inadequately defining the problem is a tendency that is downright foolish on an important and extensive problem-solving task. A relatively small time spent in carefully isolating and defining the problem can be extremely valuable both in illuminating possible simple solutions and in ensuring that a great deal of effort is not spent only to find that the difficulty still exists--perhaps in greater magnitude.

CONCEPTS IN THE PROBLEM IDENTIFICATION APPROACH

Problem identification is the combination of an interdisciplinary team approach with active farmer involvement to achieve an understanding of how the farm irrigation system operates and to identify in a systematic and objective manner a quantifiable definition of system problems. Clyma, Lowdermilk, and Corey (1977) has a detailed explanation of this process.

Systematic Approach

The problem identification process is one that is systematic in contrast to a fragmented approach. Because of the complexity of the

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[10] Adams, J. L. 1974. Conceptional Blockbusting: A Guide to Better Ideas. W. H. Freeman and Co., San Francisco, CA, p. 14.

farm irrigation system with its physical, biological, legal, organizational, and social characteristics it is impossible for single researchers to understand adequately or describe the system by focusing on single components, or to identify their interactions. The problem identification approach requires researchers who plan carefully and work closely together to establish preliminary objectives, do field reconnaissance, and design and implement diagnostic field studies. Research efforts must include coverage of the whole farm irrigation system, and not simply those aspects that someone assumes are important (Table 2). Teamwork is highlighted for all major activities and this requires good management if the process of problem identification is to produce the desired results.

Management Approach

The emphasis throughout this manual is MANagement. This concept is used in two particular ways. First, the focus and objective of the Problem Identification phase is to ascertain the effectiveness of the management of the present system. This requires understanding the system from the position of the farmer. Often the complex task of managing all the factors related to the farm system is not fully appreciated. Unlike the specialized roles of individuals in industry, the farmer must perform the role of cultivator, buyer, seller, bookkeeper, along with other functions. The complexity of the farmer's management tasks is shown in Figure 1. It should be noted that some of these factors can be controlled by the farmer while others cannot be controlled by the farmer. This makes management even more complex and creates extreme risks for the decision-maker.

Researchers should attempt to understand the farmer's situation as they investigate farm problems. This perspective will help the project staff recognize that problems involved in farming systems are multi-dimensional and require a strong interdisciplinary approach. No one discipline or single researcher can hope to comprehend these complex interrelationships alone; therefore, a group approach is the only reasonable method that will produce results.

Table 2. Checklist of problem identification activities for use by the program team manager.

Preparation for Problem Identification Studies	
____	Selection of investigators
____	Selection of a team leader
____	Team building training
____	Discipline training in field methodologies
____	Setting of objectives of problem identification studies
Gaining an Overview of System	
____	Identification of available research
____	Discussion with officials from relevant organizations about their views
____	Obtain maps and other relevant resources
____	Development of checklists of possible problem areas
____	Development of lists of other people to contact
Organization of Initial Field Visits	
____	Criteria for field sites to visit
____	Responsibilities of team members for initial field visits
____	Logistics for initial field visit
Implementing Initial Field Visits	
____	Visits to farms
____	Observation methods for all team members
____	Nonstructured interviews with farmers and those who work with farmers directly
____	Selected measurements
____	Team collaboration and preparation of preliminary report on initial field visits
____	Establish criteria for selection of sample sites for formal problem identification studies
Design of Detailed Diagnostic Field Studies	
____	Decisions on site selection
____	Develop objectives for problem identification
____	Decisions on methodologies
____	Design and test survey instruments
____	Design selection criteria for field workers
____	Establish responsibilities for all field workers
____	Design evaluation methods for field workers
____	Develop checklist for equipment needs and logistics
____	Establish time frame for problem identification studies
____	Establish data management plans
Implement Formal Investigation	
____	Develop required maps
____	Develop methods for data quality control and field supervision
____	Collect data
____	Analyze and interpret data
____	Write team report on findings
____	Rewrite report for selected audiences
Establish Criteria for Selection	
____	Clarify assumptions used
____	Clarify quantitative or qualitative methods
____	Rank problems in terms of criteria

This leads to the second dimension of management. Just as the farm manager must coordinate many factors, the manager of individual researchers must know how to manage the staff effectively. Without good management, there is the danger of individual researchers doing what they prefer. Without careful coordination, collaboration, and communication, it is doubtful if problem identification investigations will result in either an understanding of the complex farm system problems or an identification of the priority problems that require solutions (Table 2 shows some of the activities a group leader must coordinate). The program leader (also called team leader, group leader, team manager, or program manager in this text) is in a position similar to the farm manager. While not directly responsible for each activity listed, the program leader must make decisions about all these factors. However, many of these decisions can be delegated to others. Unlike the farmer who learns through long experience, very few administrators of interdisciplinary research groups have had either long experience or training. Where possible, special training should be obtained.

The sequence of activities in Table 2 is not inflexible; however, the team manager is responsible for their execution. This guide or checklist can be used by the manager to direct all staff to a systematic approach in the Problem Identification phase.

Interdisciplinary Approach

Problem identification requires an effective interdisciplinary research staff to understand the farm irrigation system. Along with technically qualified, experienced professionals in the disciplines required, other essential components are commitment to the project, management skills, open communication, and close collaboration of team members with each other and with the farmers. Perhaps the three most essential elements for effective interdisciplinary teamwork along with expertise include respect for the contributions that each discipline can make; desire to establish effective communication with all disciplines and farmers; and the desire to learn from each other and from farmers in particular.

Ideal requirements for successful teamwork is listed in Table 3. It may seem impossible to find experts with these qualifications. However,

Table 3. Basic requirements for successful teamwork.

Requisites	Checklist of Attributes
Commitment	_____Expertise in discipline
	_____Broad training and experience
	_____Respect for contributions of other disciplines
	_____Flexibility
	_____Emotionally mature and secure
	_____Demonstrated ability to work well on teams
	_____Committed to interdisciplinary research
	_____Commitment to farmer-clients
	_____Willingness to learn
Management	_____Demonstrated management abilities
	_____Skills in program planning
	_____Skills in conflict resolution
	_____Skills in task assignments
	_____Gives attention to detail
	_____Ability to communicate
	_____Does not favor a single discipline
	_____Evaluation skills
	_____Ability to communicate and skills in human relations
	_____Incentive system design
Communication	_____Open communication, no hidden agenda
	_____Regular staff meetings for planning
	_____Communication feedback utilized
	_____Communication to and from clients
	_____Communication to and from all team members
	_____Communication to and from officials
Collaboration	_____Goal setting
	_____Developing a framework and design of study
	_____Agreement on methodologies
	_____Selection of sample
	_____Problem-solving
	_____Evaluation of work
	_____Data management plans
	_____Analysis of data and reporting

this ideal list provides goals that can be obtained over time if the staff are willing to communicate, learn, and appreciate each other and their disciplines.

On-Farm Client Focus

The problem identification approach, unlike many research approaches, provides strong focus on the farmer and the farm system. Actions in any portion of the Problem Identification phase are developed from farm level data without prior assumptions about farm problems. Assumptions too often dictate research and development efforts.

The Hadith, one of the Holy Books of Islam, for example, provides a significant statement about learning that relates to problem identification studies at the farm level. It is translated as "if there is knowledge in China, go there and learn." The authors of this manual are saying to all researchers, "there is knowledge at the farm level and from the farmer; go there and learn how the farm irrigation system works." To use an arabic term to stress the point, a true Talib Elm (Arabic for "seeker after knowledge"), will search for knowledge at the farm level and from the farmer and not try to find an easy way out. This strong focus on farm level conditions and the farmer-client is an important concept for problem identification studies.

Problem Identification should be viewed as a learning experience. A simple diagram emphasizing mutual learning on the part of the farmer and the researcher is presented in Figure 2. Unless the environments of the researcher and the farmer are properly linked, learning is inhibited. Unless the research situation is geared to the real farm situation, it is unlikely that the farmer can be significantly helped by researchers.

The analogy of the doctor-patient can also be used to indicate the importance of mutual learning. The doctor (researcher) examines the physical condition and asks significant questions of the patient (farmer) in order to understand his particular situation. The farmer provides knowledge of his condition in order that a diagnosis is possible. The researcher then provides the farmer with knowledge drawn from his diagnostic skills to assist the client. If this analogy is accepted as basic to the Problem Identification phase, then the general principles listed below should prevail throughout the process.

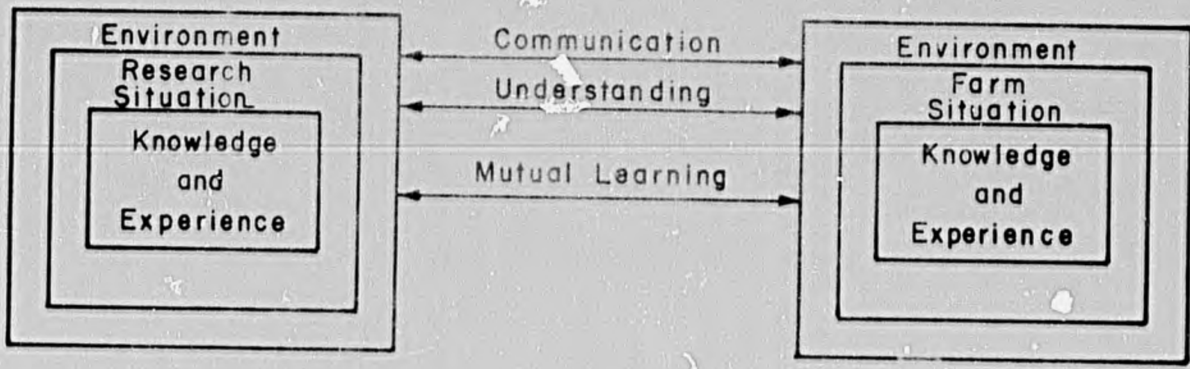


Figure 2. Diagram showing the farm level learning dimensions of researchers and farmers.

1. Problem Identification should include all disciplines required, as well as farmer-clients to assure that a systems approach is utilized.

2. Problem Identification should be task-oriented, rather than oriented toward prestige maintenance of one discipline over another. Each discipline is necessary and one discipline is no more important than another.

3. Problem Identification should be educational for researchers and clients and lead to greater understanding of the farm system and its subsystems.

4. Problem Identification should be experimental in that it is never final in the research and development process. At stages other than problem identification, the researchers may have to search for sources of problems ignored earlier.

<u>Barriers to Problem Identification</u>

There are several barriers that cause researchers to disregard the basic learning model of the Problem Identification phase. These barriers have been identified often by observation of researchers at work. These are as follows:

1. Inability to see the farming community as a system,

2. Inconsistency of the researcher's image of how the system should work with how it actually does,

3. Lack of interaction and communication among researchers in planning for problem identification,

4. Impatience in identifying the real problems first before solutions are determined,

5. Inability to appreciate contributions from other disciplines,

6. Assumption that the "expert" should know what the problem is and how to solve it without verification in a specific field situation,

7. Lack of appreciation of the local culture which clients have acquired and lack of acceptance of the clients' role in decision-making,

8. Assumption that development problems can be solved quickly by applying more technology without considering the social factors, and

9. The lack of understanding and sensitivity to cross-cultural differences that exist between researchers and farmers and among farmer-clients.

THE PROCESS OF PROBLEM IDENTIFICATION

To accomplish problem identification it is necessary to understand the sequence of major activities including reconnaissance field investigations, designing diagnostic studies, conducting diagnostic field studies, analyzing and interpreting findings, and selecting criteria for ranking significant problems.

Sequence of Major Activities

The systematic approach of the Problem Identification phase includes some overlap of activities. This does not mean, however, that activities are random or to be conducted as separate procedures. Experience indicates there is a general sequence of events that can be delineated. The sequence of the major activities that can be used for problem identification studies is shown in Figure 3.

Setting Preliminary Objectives

First, there is a need for clearly stated preliminary objectives. The preliminary objectives may, for example, be similar to the following:

1. To gain an understanding of how the organization of the system and the conditions of the situation influence farm decisions,

2. To identify the major physical, biological, socioeconomic, and organizational constraints in the farm system that limit agricultural production, and

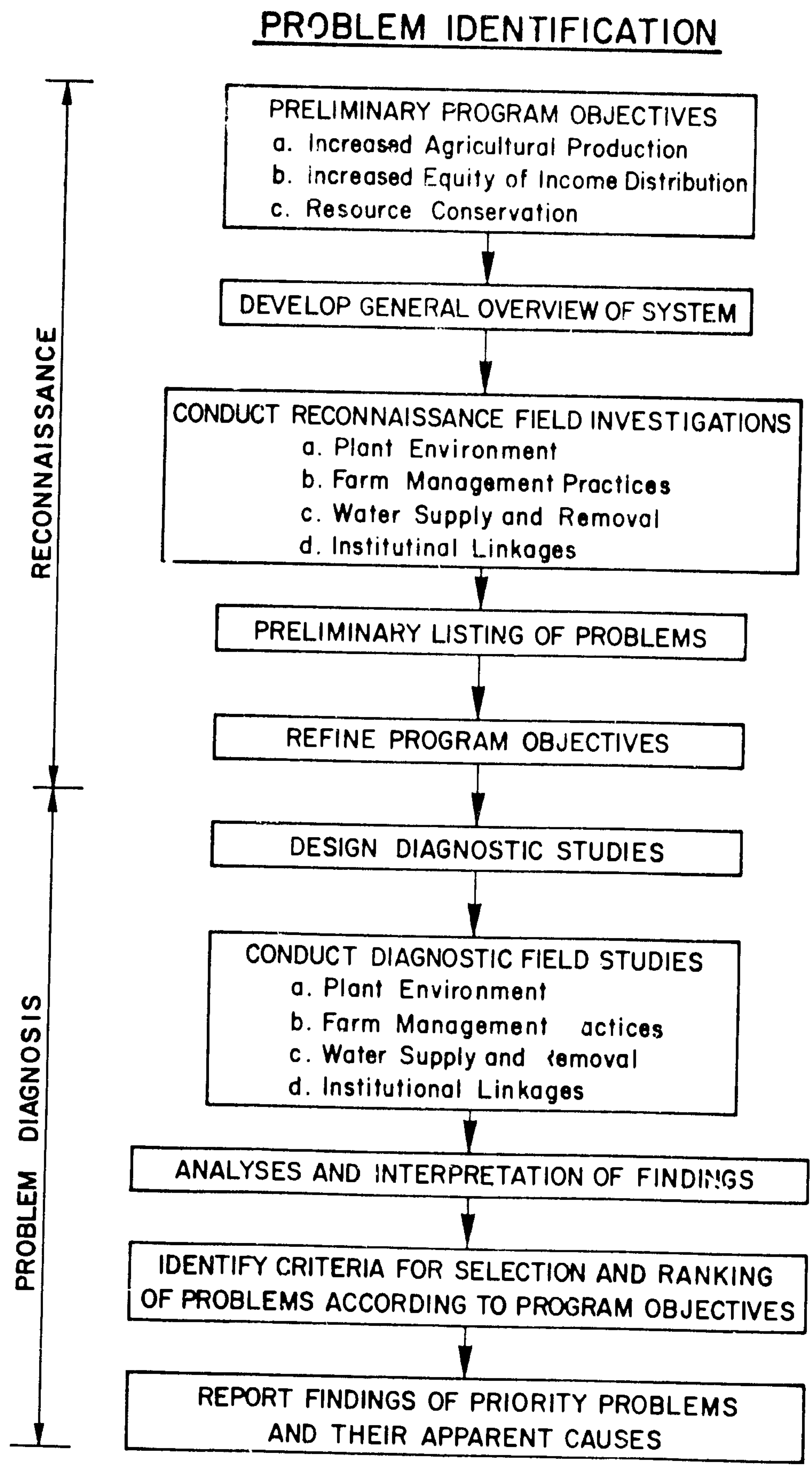


Figure 3. Flow diagram of sequential activities in the Problem Identification phase.

3. To provide an understanding and overview of the system and its problems to provide input for the design of more detailed diagnostic studies.

These preliminary objectives are such that they provide definite focus to the researchers involved. The focus is on the farm, constraints to agricultural production, and developing a preliminary list of problems that may need to be considered for the diagnostic field studies.

Reconnaissance Overview of the System

The reconnaissance phase or overview of the farm system is a basic learning situation that provides an opportunity to increase the general understanding of the farm situation. This includes the acquisition of background information from previous research that should be summarized. An agronomist, for example, will need information on climate, soils, current soil-water-crop management practices, and levels of current yields. Visits should be arranged with selected officials of organizations related to agriculture, such as governmental departments and universities; and selected personnel at research institutes. Staff must remember in such visits, however, that there is usually an "official view" that may or may not completely represent the realistic view. Project members involved in the reconnaissance should remain objective and reserve their views until empirical field data documents the real problems.

Reconnaissance activities also include informal interviews with selected farmers. These interviews should seek information about the farmer's views concerning crop production levels and constraints, management practices, economic conditions, and sociological aspects of the operation. Experience in Pakistan and Egypt has shown the number of researchers approaching the farmer should be relatively small to avoid intimidating the farmer. Questions should be carefully prepared in advance to obtain useful information. Also, those who interview farmers should be prepared and skilled in interview techniques. Information obtained from the farmer should be compared to that provided by officials and research stations by staff who should conduct meetings at the end of each day's activities.

Reconnaissance also includes preliminary field surveys, which should not be confused with the more detailed diagnostic surveys conducted later. The preliminary field survey is designed to provide an understanding and overview of the farm system and general areas where more intensive focus may be needed in the detailed survey.

At this stage selected field investigations will focus on the plant environment, farm management practices, water supply and removal, and institutional linkages. For example, the agronomist will want to gain an understanding of the general soil and water conditions, the growth status of various crops, and current cropping practices. Likewise, the agricultural engineer may want to learn about current irrigation practices, flow rates, drainage problems, and other factors. Prior to visiting the field the staff should have compiled sufficient background information combined with their own expertise and experience to develop a list of things to observe or questions to ask. For example, the agronomist may want to observe plant growth characteristics and experience in that area will help determine if growth is normal or abnormal. The agronomist may want to observe "above ground characteristics" such as the status of plant nutrition, water relationships, pest infestation, or weeds. The agronomist may also want to make observations of root systems, crop stands, physical soil characteristics, and current crop management practices.

Individuals on the staff will collect preliminary data for planning the detailed field studies. However, it is possible to collect too much data or information at this stage. Information should be obtained from farmers about their fields, selected individuals who work directly with farmers, and officials. Information about the farm situation should be used to prepare a more detailed or diagnostic field study.

Preliminary Listing of Problems

The general information obtained from the initial field reconnaissance should be discussed in detail by team members who will propose a preliminary list of problem areas that may require intensive investigation. This can be done by referring to the preliminary objectives that provide criteria for selection of major problem areas. These criteria may include factors that limit crop production and the productive capacity of small farmers, factors that inhibit the improved well-being of farmers, the conservation of soil and water resources, or other criteria established by the government, a funding agency, or staff members. It is important to be clear about the criteria because there must be priority in the areas that can be examined within limited resources of time, personnel, and funds.

A careful listing of priority problems that emerged from the problems identified on the farm system is much better than designing the diagnostic studies from unfounded ideas and assumptions that reflect only the interests or biases of researchers or officials of a funding agency.

Refining Objectives

The research team and officials of relevant agencies should then refine the preliminary objectives with respect to the knowledge gained from the reconnaissance field investigations. These objectives should be more clearly stated and specific than the preliminary objectives. For example, these objectives may include some of the following:

1. To make diagnostic studies of conveyance and field water application losses.
2. To determine the constraints of waterlogging and salinity on crop production.
3. To determine the constraints farmers face with regard to supplies of essential inputs.
4. To determine the constraints of present water codes and regulations on farmers' irrigation practices and maintenance of the farm irrigation system.
5. To determine the fertility problems in relationship to crop production levels.
6. To rank the major constraints to improved crop production for all classes of farmers for the Development of Solutions phase.

This brief listing is indicative of only some possible objectives for the more intensive diagnostic field studies.

Designing Diagnostic Studies

The next step is to design the diagnostic field studies. It cannot be stressed too strongly that this activity requires close collaboration with all concerned along with sufficient time to do a good job. Time utilized effectively in design of the field studies will be saved in producing good results.

A checklist is provided in Table 4 which shows some of the detailed activities involved in both the reconnaissance and the problem diagnosis subphases of problem identification (Figure 3). This list does not include every activity involved; however, it provides a method for the planning process. Those activities marked by an asterick (*) usually require team decisions and actions.

Conducting Diagnostic Field Studies

The detailed field studies are implemented to confirm constraints in crop production, some of which may have been tentatively identified in the informal reconnaissance field investigations. For example, more detailed measurements may be needed to ascertain yield and quality of crops.

Collaboration among the staff is required throughout the field studies. Just as there has been careful cooperation in the reconnaissance studies and the design of the more detailed diagnostic studies, there must be continued teamwork in the collection of field data. There is a tendency for researchers to work individually and become involved only with their particular activities. While various individuals will have specific tasks to perform, many of the field activities overlap and are the mutual responsibilities of two or more staff members. Close cooperation is also needed because the data and the work output of one discipline is required by another. For example, maps will be used by all for the collection and recording of data. If the engineers develop or obtain a base map of farm irrigation sites to be studied, this map can be copied and made available for crop surveys, soil surveys, topographical surveys, cross sections, slope and length of the conveyance system, location of outlet structures, field ditches, drainage channels, recording groundwater fluctuations, farm size distribution, irrigation basin size, farm ownership patterns, tenure patterns, land

Table 4. Activities checklist for designing problem identification (P.I.) studies.

Sequence	Activities
Preparation for P.I. studies	*Selection of investigators *Selection of a team leader *Team building training Discipline training in field methodologies *Setting of priority objectives for reconnaissance
Obtaining a general overview of system	Identification and review of available research *Discussions with selected official/organizations *Obtaining maps and other relevant resources *Develop initial checklists of information needed *Maintain current list of people to contact
Organization of initial field visits	*List objectives of visits *Establish criteria for field sites to visit *Determine responsibilities of each team member *Review checklists *Examine logistics
Implementing initial field visits	*Visit farms *Encourage observational methods for all team members *Conduct nonstructured interviews Selection of measurements *Team collaboration on findings for each day *Establish criteria for PI site selection
Prepare preliminary list of problems	*Team collaboration *Devise criteria for selection of problems *List problems *Consult with all parties concerned

Table 4. (continued).

Sequence	Activities
Design of diagnostic field studies	*Decide on site selection *Develop PI objectives Design and test survey instruments *Determine methodologies *Select criteria for field workers *Establish responsibilities for field workers *Design and implement field workers' orientation *Design evaluative methods for field workers *Design checklist of equipment needs *Determine logistics *Set time frame *Determine data management plans

*Denotes collaborative decision making.

fragmentation, and other important data. In other words, cooperation is not only essential, it is also a condition for successful interdisciplinary research in problem identification.

An example of the method by which group members might identify the data collected by one discipline which would be used by another cooperating discipline is shown in Table 5. It is obvious from the list that while all the data collected are used by the staff as a whole, certain types of data provided by disciplines with certain expertise are provided to other team members. This type of cooperation should occur throughout data collection activities to provide quality data without duplication and overlap.

Data Analysis and Interpretation

After the data are collected, data analysis and interpretation must be completed as a cooperative activity. Data analysis must be carefully planned at the time of design of the field studies if it is to provide useful findings. Most often data management including analysis is not planned adequately until after data are collected when it may be too late. Individual researchers may know how they will analyze their data; however, they seldom know how the data of several disciplines will be analyzed.

For example, a researcher would want to know what major factors influence the yields of specific crops in an area. Data may be available from field studies on fertilizer use, seed rates, water applications, sowing dates, and farmer extension contacts from several of the participating disciplines. In order to run a multiple regression or a stepwise regression, these data have to be from the same farms and of a quality that can be correlated. The point is that it is never sufficient to simply have data on the above factors by the various disciplines. Unless data are in a form so correlations can be made with the dependent variables, many types of analyses cannot be completed. Data must be analyzed and interpreted objectively and correctly to be useful.

In brief, data analysis should be designed so the results will indicate the priority farm problems limiting production. To provide a long list of problems without showing their relative relationship to each other is not sufficient. Problems or constraints to crop production

Table 5. Outline of selected types of data collected by one discipline and utilized by another discipline.

Collected By	Primarily Used By	Types of Data
Sociologists	Sociologists Engineers	Farmers perceptions about night and day irrigation, major water problems inhibiting increased yields, solutions to major water problems
Sociologists Economists	Engineers Agronomists Sociologists Economists	Farmer decision-making processes related to crop decision-making, when to irrigate a given crop, when to stop irrigation, water lift methods, who applies water at given irrigation
Sociologists	Engineers Agronomists Sociologists	Farmers estimations of depth of infiltration of water, depth of crop root system penetration, crop water requirements, critical water demand periods and stages of growth, sources of major losses, magnitudes of losses, waterlogging
Sociologists	Engineers Agronomists Economists Sociologists	Propensity of farmers to cooperate in water lifting, trading of irrigation turns, farm implements and machinery sharing, sharing of work, patterns of both formal and nonformal cooperation
Agronomists	Economists Engineers Agronomists	Farm management practices: cropping patterns and intensities; seedbed preparation; levels of farm technologies; seed rates, quality, and seeding methods; fertilizer inputs, timing, amount and placement methods; harvest methods; storage methods
Sociologists Economists	Agronomists Sociologists Economists	Adoption-diffusion of improved technologies: rate of adoption, time required for adoption, disadoption, channels and courses of information used at each stage in the process, characteristics of the innovation, farmer credability with information source

Table 5. (continued).

Collected By	Primarily Used By	Types of Data
Economists	Engineers Economists	Economic returns and costs: lifting water (alternative methods), various crop mixes, storage systems, transportation, marketing
Sociologists Economists	Economists Agronomists Sociologists	Legal and organizational factors: delivery of water to command area, distribution of water, pricing of water, settlement of disputes formally and informally, farmer interaction with river irrigation officials, dejure compared to defacto, sanctions, incentives
Engineers	Agronomists Engineers	Water supply and removal: conveyance efficiency, field application efficiency, water quality, consumptive use, return flow, field topography
Economists Sociologists	Engineers Economists Sociologists	Information for farm decision-making: marketing, irrigation schedules, closures, extension, quality and quantity of information

must be ranked in relationship to specified criteria. Examples of criteria that may guide the analyses may include constraints to crop production, constraints to small farmers' crop production, or levels of living of small farmers. Quantitative analysis alone will not necessarily provide the ranking of problems because sound judgments based upon experience also guide the data analyses and interpretation.

Criteria for Ranking Priority Problems

The ranking of priority problems requires that specific criteria be established. Decisions about criteria to be used may be political and reflect the philosophy or objectives of the government, or the government and a donor or funding organization. For example, it is assumed that the primary goals established by the government for improvement of farm irrigation systems are increased agricultural production, improved rural income distribution, and improved conservation of soil and water resources. These goals can be used as criteria for ranking the major problems that the Development of Solutions phase will investigate. An example of how problems might be ranked in terms of priority are shown in Table 6.

Table 6. Criteria for ranking priority problems.

Criteria	Indicators and Dependent Variables	Methods of Ranking
Agricultural production	1. Yields/ha and aggregate yields	1. Regression analysis, analysis of variance, team consensus
Income distribution	2. Increased yields/ha and increased net income/ha for small holders	2. Regression analysis, cost-benefit farm management analysis, team consensus
Resource conservation	3. Decreased water losses Decreased waterlogging Decreased nitrate leaching More productive land made available	3. Regression analysis, cost-benefit analysis, team consensus

If increased agricultural production is the primary objective, the major factors that significantly limit increased production will become central to the Development of Solutions phase. If income distribution is also a top priority by the government, the major factors that limit small farmers' productivity will also be included. Often these factors may be somewhat different from those that limit production on larger farms.

Finally, the judgments of the staff are also important and should be used in ranking priority problems along with statistical analyses. It is important to build a strong objective case for priority problems to present to officials who otherwise might attempt to influence the findings. Without good relationships and professional reporting in language that can be understood, individuals who are often not sensitive with local farm problems may attempt to force their conventional wisdom on the process.

Reporting the Findings

Findings of the diagnostic field studies should be prepared for two major audiences. Specially designed summary reports without too much technical emphasis should be prepared for policy-makers who need to be informed of the field studies. Often some problems identified in the field for which only political decisions are needed for solutions will be considered seriously by these policy-makers who need the field data for decision-making. Also, policy-makers need empirical data for use with internal and external organizations for funding purposes. More technical reports are required for the Development of Solutions phase to provide background data and benchmark data for their applied, adaptive, and evaluative research efforts to ascertain feasible solutions.

The chapter that follows provides the user with both reconnaissance and detailed diagnostic procedures for investigations related to the plant environment. Chapters III through VI contain procedures and checklists that should be considered for investigation. Much variation exists between countries and regions within countries as to available data that can be used for problem identification studies. Valid and reliable data existing for specific factors listed in Chapters III through VI should be utilized. Variation also exists among countries as to time and manpower available for these studies; therefore, the manual provides procedures for both short- and long-term diagnosis on irrigated farming systems.

A transition to the actual methods for reconnaissance and detailed diagnostic studies are described in Chapters III through VI. Figure 1 provides an overview to the four subsystems to be covered. In Chapter III the focus is on the plant environment, while Chapter IV is related to farm management practices. Chapter V covers water supply and removal, and Chapter IV discusses institutional linkages. The reader should remember that these subsystems are closely interrelated; however, each subsystem is examined and are treated separately in order to more clearly present the material. Then, in Chapter VII, the relationships between these subsystems are discussed along with analyzing and interpreting the findings about each subsystem.

CHAPTER III

THE PLANT ENVIRONMENT

The potential crop yield is first a function of the genetic character of the particular type and variety. The maximum attainable yield is a function of several interdependent positive growth factors. These growth requirements include 1) plant population (stand), 2) heat requirement (solar radiation), 3) carbon dioxide and oxygen requirement, 4) nutrient requirement, and 5) water requirement (soil moisture supply). Soil serves as a physical support system, a nutrient supply source, and a moisture storage reservoir for the crop plant. Solar radiation along with carbon dioxide and water are basic ingredients for producing sugars by the photosynthetic process in the plant. Oxygen is necessary for root respiration. Crop plants have specific requirements for nutrients, water, carbon dioxide/oxygen, and heat. If one or more of the requirements is less than or more than optimal, then crop production falls below the maximum attainable level.

Since optimum levels of all growth factors for all crop plants are not available at any given time or place in the world, it becomes the task of the farmer to manipulate, adjust, and manage all the positive growth factors so acceptable high crop yields are obtained. In addition, the farmer must contend with several negative growth factors. Weeds compete with the crop for water, nutrients, and radiant energy. Insects, diseases, and animals decrease yields or destroy crops. Inclement weather such as frost, hail, and excessive wind cause crop yields to be less than maximum. The delicate balance of all these factors results in the actual yield obtained by the farmer. Thus, major factors that need to be examined in order to identify crop production constraints are types of crops grown, soil, climate, irrigation water, plant protection, and cultural practices (Figure 4).

CROPS AND CROPPING PATTERNS

When the problem identification process is applied to crops and cropping patterns, crop inventory, crop stands, crop damage, potential versus actual yields, and crop quality/nutritional value should be

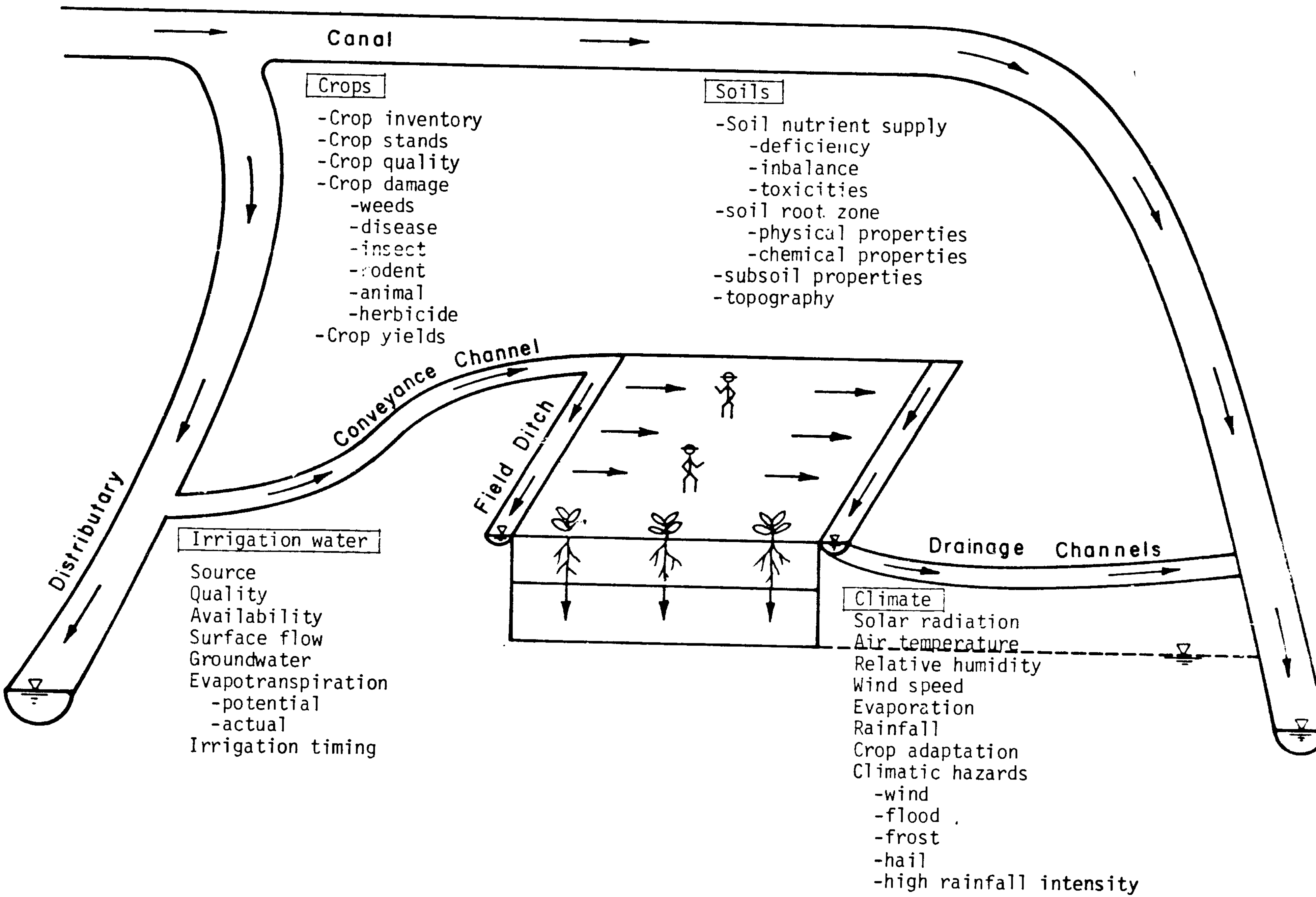


Figure 4. Idealized sketch of the plant environment.

considered. A brief explanation of each of these items follows, and at the end of this section there is a checklist of activities or methods that can be considered when applying the problem identification process to the plant environment. The checklist is divided into activities that could be accomplished during the reconnaissance phase and activities that could be considered during a more detailed problem diagnosis.

Crop Inventory

One of the first steps in determining specific crop constraints is making an inventory of all crops grown in an irrigated area. More detailed inventories that include acreage and total production are usually restricted to major crops important to goals of the project. The general inventory should include all crops because each minor crop may not be of much importance; however, an aggregate of all minor crops may require considerable expenditure of land, water, labor, and other resources. The usual sequence in which crops are grown (cropping pattern) should be included as part of the inventory. The crop inventory is essential to determine constraints from such considerations as agronomic, engineering, economic, legal, and social factors.

Crop Stands

The plant population must be near optimum in relation to growth requirements if satisfactory crop yields are obtained. Optimum plant population should be determined in the climate and culture where it is grown. Generally, crop stands should be comparatively thinner as row width increases and for long-season varieties.

The crop stand attained is primarily dependent upon seed quality, proper seedbed preparation, seeding rate, method of seeding, time of seeding, seed treatment for disease control, soil and seed temperature, and moisture availability. Poor quality seed may contain undesirable varietal mixtures, weed seed, plant diseases, and other crops. Poor quality seed may also have low germination, which in turn, may be related to overaged seed, harvesting before maturation, freezing before maturation, heat damage, and improper storage conditions.

Crop Damage

The positive growth factors may be optimized for a given crop, but low yields or even complete crop loss may occur from crop damage. Crop damage may result from weeds, diseases, insects, rodents or other animals, bad weather, and herbicides.

Potential and Actual Yields

Potential yield is defined as the amount obtained with the best adapted crop variety grown with optimum nutrient and irrigation water levels, and the best-known management practices with adequate plant protection, all within the particular climatic setting. Actual yield is the results obtained by the farmer under his particular set of conditions.

Crop Quality and Nutritional Value

Quality and nutritional value of crops should be as carefully evaluated as the total yields. Yields of poor quality may be of less value than lower yields of higher quality.

SOILS

In examining soils, several aspects should be considered including the nutrient supply; physical, chemical, and biological conditions of the root zone; subsoil properties; and topographical problems. A checklist of reconnaissance and detailed diagnostic methods provided at the end of this plant environment chapter will serve as a guide in problem identification of soils.

Soil Nutrient Supply

Essential nutrient elements for most crops are considered to be the following:

Macronutrients: Ca, Mg, K, N, S, and P

Micronutrients: Fe, Cl, Zn, B, Mo, and Cu

Micronutrient requirements of plants are trace amounts.

Visual Observations

If no existing data concerning crop nutrient deficiencies and supply is available, visual observations should be done. Severe nutrient deficiencies can usually be identified in the field by characteristic plant symptoms. However, symptoms cannot always be observed at all stages of crop growth. This is especially true in the seedling stage because a seed usually contains enough nutrients, except nitrogen, to sustain the plant through that period.

General descriptions of nutrient deficiency symptoms are listed according to the probability of occurrence in irrigated arid-land soils, first for macronutrients and then for micronutrients.

Nitrogen: (N) Nitrogen deficiency symptoms on non-leguminous crop plants produce a leaf of pale green to yellow color. Nitrogen deficiency symptoms tend to be prominent on older leaves with more severe chlorosis followed by necrosis (death) of cells. This results in a characteristic "firing" of the lower leaves.

Phosphorus: (P) Phosphorus deficiency symptoms on crop plants are usually indicated by a general stunting of all crop parts. Leaf color is usually a dull greyish-green and frequently anthocyanin (red color) accumulates in the leaf tissue and dying leaves.

Potassium: (K) Potassium deficiency symptoms on crop plants are usually indicated by necrotic areas starting at the tips of leaves and spreading along the marginal edge. When N and K are simultaneously deficient, plants are stunted and their leaves are small with a somewhat ash-grey color, dying prematurely first at the tips and then along the outer edges. The fruit or seed is small in quantity, size, and weight. Deficiency symptoms usually appear first on the lower leaves or plants, progressing toward the top as the severity increases.

Sulfur: (S) Sulfur deficiency symptoms on crop plants are similar to those of N except the symptom is characterized by uniformly chlorotic plants--stunted, thin-stemmed, and spindly. Unlike N, S does not appear to be easily translocated from older to younger plant parts under stress caused by deficiency.

Calcium: (Ca) A deficiency of Ca results in the failure of the terminal buds and the apical tip of roots of plants to develop. As a result of these two things, plant growth ceases. In corn, and to some extent, cereal grains, Ca deficiency prevents emergence and unfolding of new leaves whose tips are covered with gelatinous material that causes leaves to adhere to each other. This results in the classic "ladder-effect" in Ca-deficient corn plants.

Magnesium: (Mg) Magnesium deficiency symptoms often appear first on the lower leaves because it is a mobile element and is readily trans-located from older to younger plant parts. In most crop species, the deficiency results in an interveinal chlorosis of the leaf so that only the leaf veins remain green. In more advanced stages, the leaf tissue becomes uniformly pale yellow, and then brown and necrotic. In some species, notably cotton, the lower leaves may develop a reddish-purple cast that gradually turns brown and finally necrotic.

Iron: (Fe) A deficiency of Fe shows in the young leaves of plants. Iron does not appear to be translocated from older tissue to the meristematic tip, and as a result, growth is diminished. The young leaves develop an interveinal chlorosis that rapidly progresses over the entire leaf. In some cases, the leaves turn completely white.

Zinc: (Zn) Deficiencies of Zn have been observed in corn; sorghum; deciduous citrus fruit, and nut trees; legumes; cotton; and several vegetable crops. Zinc deficiency first appears on the younger leaves starting with interveinal chlorosis followed by a great reduction in the rate of shoot growth. In many tree crops this produces a symptom known as "rosetting."

Boron: (B) Boron is not readily translocated from older parts to the meristematic region, and the first visual symptom is cessation of terminal bud growth, followed shortly thereafter by death of the young leaves. The youngest leaves become pale green, losing more color at the base than at the tip.

Manganese: (Mn) Like Fe, Mn is a relatively immobile element and deficiency symptoms show up first in the younger leaves. Deficiency of Mn results in interveinal chlorosis, both on broad-leaf plants and members of the grass family, but is less conspicuous on the latter.

Molybdenum: (Mo) Deficiencies have been reported for many crops, including clover, alfalfa, grasses, tomato, sweet potato, soybean, and other vegetables. Symptoms of Mo deficiency differ with various crops, but they are first observed as interveinal chlorosis. Legumes usually turn pale yellow and become stunted; symptoms characteristic of N deficiency. These symptoms are consistent because Mo is required by Rhizobia for N-fixation and by non-legumes for NO_3 reduction.

Copper: (Cu) Crops responding to Cu fertilization include red beets, carrots, clover, corn, oats, and fruit trees. Deficiency symptoms vary with different crops. In corn, the youngest leaves become yellow and stunted and as the deficiency becomes more severe, the young leaves become pale and the older ones die. In advanced stages, dead tissue appears along the tips and the edges of the leaves in a pattern similar to K- deficiency. Small grains deficient in Cu lose color in the younger leaves that eventually break and the tips die. Leaves of many vegetable crops lack turgor, develop a bluish-green coat, become chlorotic and curl, and flower production fails to occur.

Miscellaneous: Sodium, chloride, and silica have been shown to be beneficial for some crops, but no definite deficiency symptoms occur. Cobalt is reported to be beneficial for legumes and some non-leguminous plants and is essential for ruminant animals. Vanadium has been reported as beneficial for green algae and N-fixing bacteria.

It is often difficult to distinguish among deficiency symptoms in the field if more than one element is inadequate. Confirmation of deficiencies by visual observation is frequently difficult or impossible if the deficiency is marginal. Also, disease and insect damage frequently will resemble certain micronutrient deficiencies. Therefore, it is usually necessary to employ supplementary techniques to refine or verify visual observations.

Tissue Tests

Another method for identifying soil nutrient problems is to take tissue tests. Important corollary factors that must be considered in interpretation of tissue test results include the general appearance and vigor of plants, level of other nutrients in plant, evidence of disease and insect damage, soil moisture content, soil conditions such as poor aeration or poor tilth, climatic conditions such as unseasonable cold or heat, and time of day.

To take tissue tests, plant sap is extracted with reagents or by pressure. Tests for N, P, K, Mg, and Mn are made with various reagents giving semi-quantitative values interpreted as high, medium, and low. The best part of the plant to use for testing is generally that showing the greatest range as the nutrient goes from adequate to deficient levels. The part of the plant to be used is specified in the instructions for each commercial test kit. The parts recommended are based on mobility principles as illustrated by the following examples. As the supply of N decreases, the upper part of the plant, where maximum utilization of plant nutrients is in progress, will first show a low test for NO_3. The reverse is true for P and K. Young leaves should not be tested, but leaves from an area that is somewhere between young and old, based on the area where deficiency first occurred, should be selected.

In general, the most critical stage of growth for tissue testing is at bloom time or from bloom to early fruiting. During this period maximum nutrient utilization occurs and low nutrient levels are more easily detected. In corn the leaf opposite and just below the uppermost ear at silking stage is usually sampled. Thus, reconnaissance surveys should closely coincide to the early reproductive stage if possible. However, early diagnosis of deficiencies in the post-seeding stage enables the application of fertilizer that results in increased yield the same season the deficiency is detected. The time of day a sample is collected influences NO_3 levels in plants since NO_3 usually accumulates at night and is utilized during the day when carbohydrates are synthesized. This results in higher NO_3 levels in the morning than in the afternoon if the supply is short. Therefore, tests should not be made either early in the morning or late in the afternoon. Plant analyses are based on the premise that the amount of an element in a plant is an indication that supply of that nutrient is directly related to the availability in the soil. However, a deficiency of one element will limit growth, and other elements may accumulate in the cell sap and show high levels regardless of the supply. The apparent high levels may actually be inadequate if the most limited nutrient is raised to an adequate level. Periods of intense cold or heat, and conditions of poor aeration may significantly alter the uptake level of different nutrients.

Paint and Spray Tests

Especially useful for diagnosing and confirming micronutrient deficiencies are paint and spray tests. If a uniformly chlorotic plant is found, 3 to 5 percent solutions of Fe, Mn, Zn, Cu, and a combination of all can be applied to different leaves with a paint brush. Leaf color changes occurring within a few days indicates deficiencies and response. Solutions may be sprayed on whole plants in a field or an area if a field is chlorotic.

Imbalances and Toxicity

An excess of one element can produce an imbalance in other nutrients and reduce crop yields. For example, an excess of Mg can produce a calcium deficiency. Micronutrients, such as excessive B, Zn, Mo, and Cu, produce a toxicity. Toxicity and nutrient imbalances produce somewhat different symptoms on different crops. Only the most skilled diagnostician is able to identify these problems visually. Usually plant analyses under laboratory conditions are necessary for satisfactory resolution of these complex problems.

Chemical Soil Tests

Advantages of analyzing soil samples are that 1) precise quantitative measures of available nutrients from thoroughly researched extractants can be obtained, and 2) analytical results from representative samples taken before the crop is planted can be used as guidelines for obtaining optimal yields. In some cases, sampling during the cropping season at periods of peak nutrient demand may be advisable. Certain nutrients on some soils may become limited during peak demand periods, such as initiation and reproduction.

General Fertility Guidelines

General guidelines for interpreting available nutrient levels are shown in Table 7.

Table 7. General fertility guidelines for some nutrients.

	Very low	Low	Marginal	Adequate	High
Organic Matter		1%			
P		0-7 ppm	7-15 ppm	15 ppm	
K		0-60 ppm	60-120 ppm	121-180 ppm	> 180 ppm
Fe		0-2.5 ppm	2.6-4.5 ppm	4.5 ppm	
Zn	0-.25 ppm	.26-.50 ppm	.51-1.0 ppm	1 ppm	
Mn		0-1 ppm		1 ppm	
Cu		0-.2 ppm		0.2 ppm	

Plant Analyses

Plant analysis in the laboratory is more precise, and a greater variety of analytical techniques can be used resulting in more quantitative data than with tissue tests. These analyses can be used in relation to more specialized problems such as determination of efficiency of N-fertilizer usage.

Physical and Chemical Properties of Soil Root Zone

Portable equipment may be taken to the farmers' fields to study root zone properties. Tools needed include shovels, soil sampling tubes, a pocket knife, a bottle of 6N HCl, and a portable soil pH-test kit. Pits should be dug in representative areas to expose the full root zone depth. Systematic notes should be recorded for major horizons or layers in relation to factors such as root proliferation, texture, structure, compaction, lime content, salinity, pH, gypsum, and aeration.

For a detailed analysis, penetrometer, infiltration, and four-probe measurements may be required. The penetrometer can be used to measure resistance to penetration in compact zone and hard-pan layers. This will give a quantitative measure that can be related to observed root penetration. Infiltrometers can be used to measure the relative difference between water movement in different layers. This is usually done with a double-ring infiltrometer. A vertical four-probe device can be calibrated and used to obtain measurements of root zone soil salinity (e.g., 15 cm intervals to 120 cm depth).

Subsoil Properties

Subsoil properties can be identified from visual observation of pits or soil cores. Notes on water table level, textural changes, and lateral permeability should be taken. Permeability measurements are usually made by the auger-hole and piezometer methods. These measurements are used to assess drainage feasibility and to calculate drain spacing.

Topography

If topographic maps are not available, measurements of elevation and slope must be taken. Elevation affects the quality of the incident solar radiation absorbed by the crop. Thus, information concerning the general elevation of an irrigated area and its variations should be obtained. Depressions and low-lying areas that may be more susceptible to frost or cold air drainage should also be considered. Low-lying terraces along rivers that may be more subject to flooding and a fluctuating high water table should also be noted. Amount of sloping land in the area should be obtained, as well as measurements of the degree of sloping. Evidence of erosion indicating an improperly designed irrigation system should be acknowledged. Very flat land with little or no slope may represent drainage problems. Special precaution must be made to note a "closed-basin area" in which no surface or subsurface drainage occurs away from the irrigated area.

CLIMATE

Climate of an irrigated area generally controls the crop production attained since it cannot be changed much by man. Climatic data, therefore, are necessary to determine and evaluate many crop production restraints including water supply, crops produced, crop water requirements, incidence of insect pests and diseases, and availability of soil nutrients.

CHECKLISTS

An example checklist is shown in Table 8 for reconnaissance of crops and soils. For the Problem Diagnosis subphase, Table 9 provides a checklist for studies of crops and soils.

Table 8. Checklists on reconnaissance methods for crops and cropping patterns and soils.

*NOTE TO USER: These checklists are to be used as a guide and are not complete for every situation. Areas of investigation may have to be added to meet project requirements. Particularly in the reconnaissance phase, utilization of existing data will save much time. However, observations on the farms and personal contact with farmers to verify the data must be made by project personnel.

CROPS AND CROPPING PATTERNS

Crop inventory:

_____Obtain existing information, including general maps, from official agricultural statistical agencies.
_____Obtain existing information, including possible detailed field maps, from irrigation officials.
_____Obtain aerial photos used in soil surveys showing field layout farms.
_____Gather information by interviewing selected farmers.
_____Observe crops grown on-farm.
_____Other (specify)_______________

Crop stands:

_____Field observation: well-trained agronomist can estimate plant population with considerable accuracy.
_____Calculate plant population from seeding rate and purity under various conditions.
_____Other (specify)_______________

Crop damage:

_____Obtain existing information from such sources as plant protection officers or experiment station personnel.
_____Make field observations at various times during the cropping season to identify types of damage occurring.
_____Interview farmers for general information on damage factors.
_____Other (specify)_______________

Potential yields:

_____Obtain data on potential yields from local experiment station. (Exercise judgment in determining how closely optimum conditions have been met).
_____Interview local "best farmers" for insight into potential yields in the area.
_____Other (specify)_______________

Actual yields:

_____ Obtain field observations of harvest.
_____ Interview local farmers.
_____ Obtain agricultural statistics from government agencies.
_____ Other (specify) _____________________

Crop quality/ nutritional value:

_____ Observe and evaluate qualitatively crops by trained agronomists and nutrition specialists.
_____ Place qualitative value on total calorie content from generalized knowledge of average carbohydrate, protein, and fat content.
_____ Other (specify) _____________________

SOILS

Soil nutrient supply:

_____ Obtain existing data from agricultural agencies.
_____ Use visual observation of plants.
_____ Take soil and tissue tests.
_____ Conduct paint and spray tests.
_____ Other (specify) _____________________

Root zone physical & chemical properties:

_____ Check root proliferation: depth and pattern of root development. Should record changes in rooting habit with textural changes or other layer changes. Shallow restricted root zone is evidence of a root-zone problem.
_____ Determine soil texture. Moisture retention is mainly related to texture.
_____ Note soil structure type and degree of development. Also, record evidence of aggregate breakdown, surface crusting, and cracking.
_____ Study compaction. Evidence of compaction or "plow sole" can usually be seen and confirmed by resistance when pushing a soil sampling tube into the soil.
Record lime content as low, moderate, or high as judged from effervescence of CO_2 when HCl is dropped onto soil. Physically hardened layers should be noted.
_____ Obtain evidence of salt accumulation if present at either the surface or in root zone. Detrimental accumulations of salt can usually be tasted with the tip of the tongue, whereas lime and gypsum cannot.

_____Field-test pH. A field-test of pH of 9 or more indicates either excessive Na or excessive Mg. A lower pH, however, does not eliminate either Na or Mg as a problem.

_____Examine gypsum layers within the root zone. Thick gypsum layers may impede root development because of infertility or physical hardening, impede water movement, and may lead to subsidence of land under irrigation.

_____Check aeration. Waterlogging and reducing conditions result in a mottled soil color.

_____Other (specify) ____________

Subsoil properties:

_____Check water table level. Shallow water table results in poor root aeration and acceleration of salt accumulation in the root zone.

_____Note abrupt changes in soil texture from silt or clay to sand or gravel. These changes impede water penetration and can cause a "perched water table."

_____Other (specify) ____________

Topography:

_____Measure elevation of fields.

_____Check amount of sloping land in area.

_____Measure degree of sloping in the area.

_____Other (specify) ____________

Table 9. Checklists on detailed diagnostic methods for crops and cropping patterns and soils.

CROPS AND CROPPING PATTERNS

Crop inventory:

____ Take aerial photographs to determine field patterns and sizes.
____ Calculate acreages involved from average field patterns and sizes.
____ Interview more farmers and at greater length than before.
____ Other (specify) ____________

Crop stands:

____ Obtain field measurements. Stand counts in a measured area at several places in the field may be used to calculate a mean plant population for the entire field.
____ Calculate germination percentage. Germination percentages should be determined from seed sold by dealers and seed held over from previous seasons by farmers.
____ Take impurities tests. Determine amount and kind of weed, other crop seed, and varietal mixing in representative crop seed from the irrigated area under investigation.
____ Investigate low germination seed. Signs of excessive heat, excessive cracking, shattering from freezing, interrupted germination, or excessive shrinking from respiration during storage will help determine the causes of low germination.
____ Examine seedbed. Look for evidence of soil crusting; excessively shallow or deep seeding; or lack of moisture or excessive moisture. These parameters may explain poor stands when seed has a high germination rate.
____ Study time of seeding. Check time when the seed was planted. Seeding when the soil temperature is too hot or cold may cause low germination and poor stands.
____ Investigate seed and seedling disease. Field examination at emergence or post-emergence may be necessary to detect stand loss from seedling diseases.
____ Other (specify) ____________

Crop damage:

____ Take complete inventory of weeds, diseases, insects, rodents and animals, weather conditions, and herbicides in location under examination.
____ Other (specify) ____________

Potential yield _____Cooperate with local farmer to observe fields under carefully defined and controlled conditions to determine the potential yields of various crops.

Actual yield: _____Use spot field measurements in small sample areas of local farmers' fields.
_____Interview farmers to determine amount of crop sold, consumed by the family, and needed for barter payments.

Crop quality/ nutritional value: _____Take chemical analyses to determine specific kinds and contents of sugar and starch in carbohydrates, amino acids in protein, and kinds of lipids in fat.
_____Analyze vitamin and mineral content.
_____Evaluate changes brought about by processing and cooking.
_____Other (specify) ______________

SOILS

Soil nutrient supply: _____Analyze soils for organic matter and nitrate, lime content and pH, phosphorus, potassium, sulfate, boron, iron, zinc, manganese, and copper.
_____Do plant analyses.
_____Use field fertilizer trials.
_____Other (specify) ______________

Root zone physical & chemical properties:
_____Take soil samples. Characterize by saturated paste extract, ammonium acetate extract, pH, cation exchange capacity, calculation of SAR, lime content, and gypsum content
_____Take penetrometer measurements.
_____Make infiltration measurements.
_____Measure soil salinity with four-probe device.
_____Other (specify) ______________

Subsoil properties: _____Check lateral permeability in the fields.
_____Other (specify) ______________

INTERDEPENDENCY OF PLANT ENVIRONMENT WITH FARM MANAGEMENT PRACTICES

Providing optimum growth conditions for crop plants in order to attain high levels of production are complex and sensitive processes that are usually intricately related with management. In the Problem Identification phase, identifying a deficiency of a particular growth factor is usually only the initial step in identifying the exact cause or causes of the problem. A particular growth factor deficiency or inefficient utilization of the growth factor by plants can generally be traced to management-related causes. The cause of the problem may not be readily apparent, but in most cases the cause can be revealed by studies of farm management and farm services in an irrigated area. Most farmers can seldom, if ever, be accused of deliberate mismanagement. Poor management is created most often by lack of knowledge or specific information and unfavorable economic factors, sometimes by social constraints, and quite often by factors beyond the control of the farmer. Therefore, careful studies of the farm setting and management practices are mandatory for identifying problem causes. Guidelines for such studies are explained in Chapter III, "Farm Management Practices."

The following hypothetical example illustrates how a general fertility problem, such as N-deficiency, might be traced to management-related causes. The general problem is presented and different specific causes are listed in Table 10.

Case Study

Observations of plant growth by technicians in the field during a reconnaissance survey of farms indicated a nitrogen (N) deficiency for a given summer crop. This was confirmed by plant tissue tests. More detailed studies of plant samples also showed the N-fertilizer that was applied by the farmer was not used efficiently by the plant which had a low N-recovery. Interviews of farmers within the area revealed that N-fertilizer was not available on the local market at the time fertilizer was normally applied due to a strike by transportation workers. After some delay, the farmers planted the crop without the usual broadcasting (throwing material by hand onto the ground surface) of fertilizer and

Table 10. Hypothetical case study of symptoms and causes of nitrogen deficiency.

Fertility Problem

1. Nitrogen (N) deficiency
2. Low N-recovery by plant

Visual Symptoms

1. Pale leaf color
2. Firing of lower plant leaves

Measurements of N-deficiency and N-recovery

1. Plant tissue tests
2. Plant sample analysis

Possible Cause or Causes of N-deficiency

1. Low inherent N-fertility
    a. Low soil organic matter content
    b. Low rate of organic-N mineralization
    c. Failure to incorporate crop residues in soil
    d. Continuous deposition of silt from irrigation water

2. Low N-recovery
    a. Ammonia volatilization of broadcast ammonium-N or urea-N, fertilizer not mixed into soil quickly
    b. Leaching of nitrate-N below root zone by excessive irrigation conditions
    c. Nitrate reduction and gaseous-N escape under reducing conditions
    d. Ammonium-N fixation by mica and vermiculite clays
    e. Deficiency of other nutrients such as P

3. Application of N less than that required to produce a given crop yield
    a. Fertilizer too costly
    b. Fertilizer not available on open market
    c. Fertilizer not distributed uniformly over field
    d. Inaccurate fertilizer recommendation

4. Fertilizer not applied at recommended time
    a. Lack of information about timing
    b. Fertilizer not available when needed
    c. Insufficient labor or machinery at critical time
    d. Inaccurate fertilizer recommendation

working it into the soil before planting. The strike was settled and farmers bought fertilizer after the crop had emerged and broadcast the fertilizer on the soil surface but could not incorporate it into the soil. The fertilizer (urea) sat in the hot sun on the ground surface several days before irrigation water was first applied. Farmers observed that the crop did not grow normally and since an above-normal supply of water was available at that particular time, extra heavy irrigations were applied with the hope that extra water would improve crop growth. Crop yields for this particular season were substantially lower than the previous average.

In this case study, no one particular cause can be cited for the N-deficiency. It is highly probable that volatilization losses of ammonia from the urea were high because the urea sat in the hot sun for several days. It is also probable that further losses of N below the crop root zone resulted from overirrigation. Some loss in yield probably resulted from the delay in planting the crop as well. Thus, part of the management problem was due to circumstances beyond the control of the farmer. The failure of the farmers' attempt to compensate by overirrigating was due to lack of knowledge concerning the leaching process.

CHAPTER IV

FARM MANAGEMENT PRACTICES

Good farm management practices are essential to increased agricultural production. In order to identify problems that impede optimum production, the Problem Identification phase must include a close examination of the farm management practices in the irrigated area under study. As with each phase of this process, examining the problems with farmers is important to success. This chapter will focus on inventories of management practices, cropping patterns, and resources; farm budgets; the farmers' decision-making environment; and the interdependency of the management practices with the farmers' community (Figure 5).

There is a natural overlap between many aspects of the plant environment and farm management practices. This is true for the agronomist and agricultural engineer who are concerned with soil and water management practices employed by farmers on cultivated fields. Much of this information is used by the social scientists. The farm management economist is concerned with cooperative costs and benefits of alternative management practices. Both the economist and sociologist or anthropologist is interested in the decision-making environment and its impact on farm management practices.

IRRIGATION PRACTICES

The specific methods of irrigation for various types of crops need to be identified and evaluated for effectiveness. Field application evaluations will help determine whether the farmer is overirrigating or underirrigating in relationship to crop demands and water required to maintain adequate control over salinity problems. These evaluations should supply data on the desired volume of water distributed uniformly over fields, erosion and salinity control, drainage problems, and the economic feasibility of the methods used. Important variables in these irrigation evaluations include water supply rate, field geometry (length and width), slope, infiltration rates, surface roughness, channel slope,

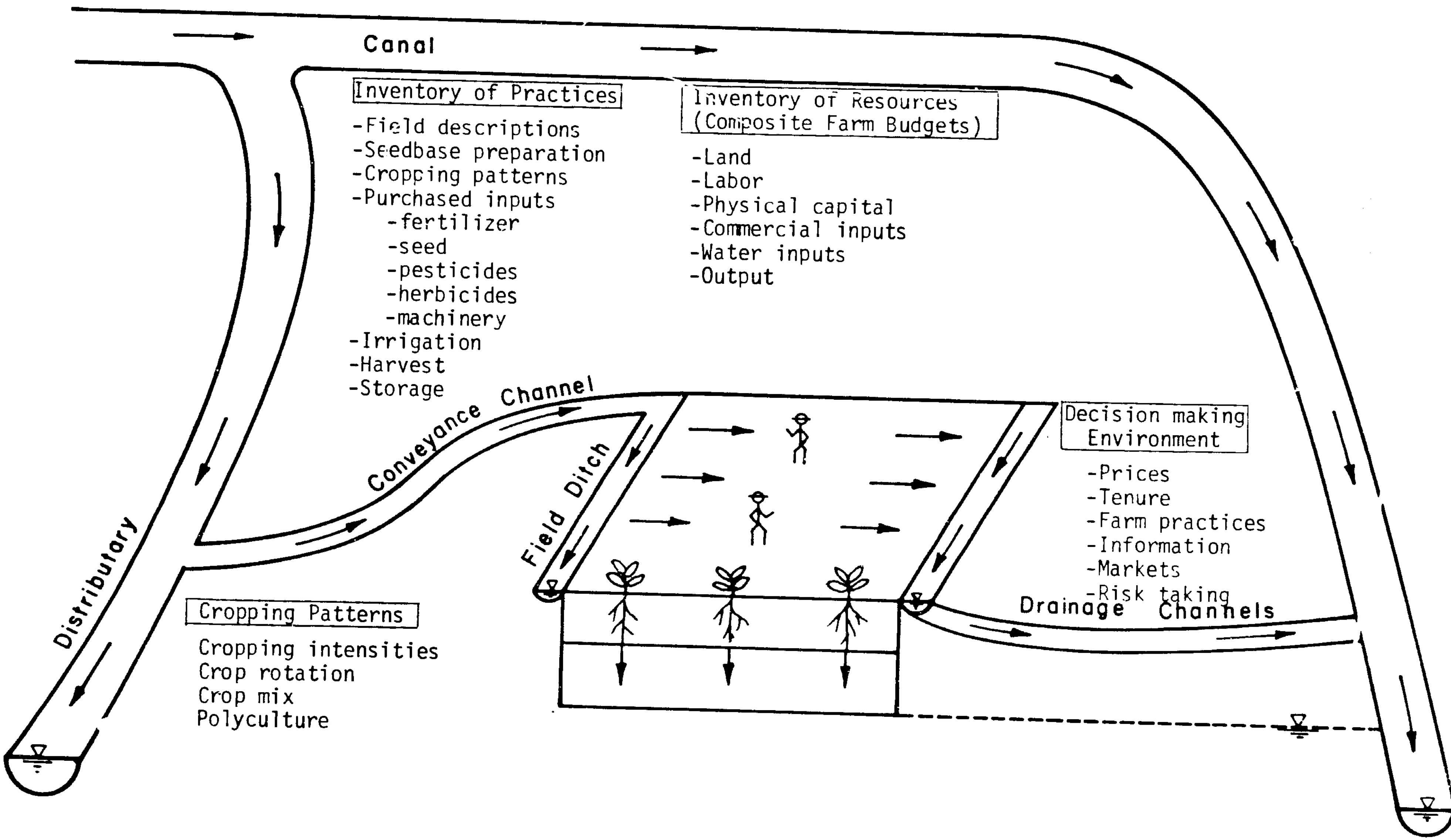


Figure 5. Idealized sketch of a farm irrigation system and farm management practices.

and management decisions related to the methods. Three basic questions that need answering are: How does the farmer irrigate? When does the farmer irrigate? How much water does the farmer apply to various crops? The major task is to evaluate irrigation practices in relationship to costs of alternative methods.

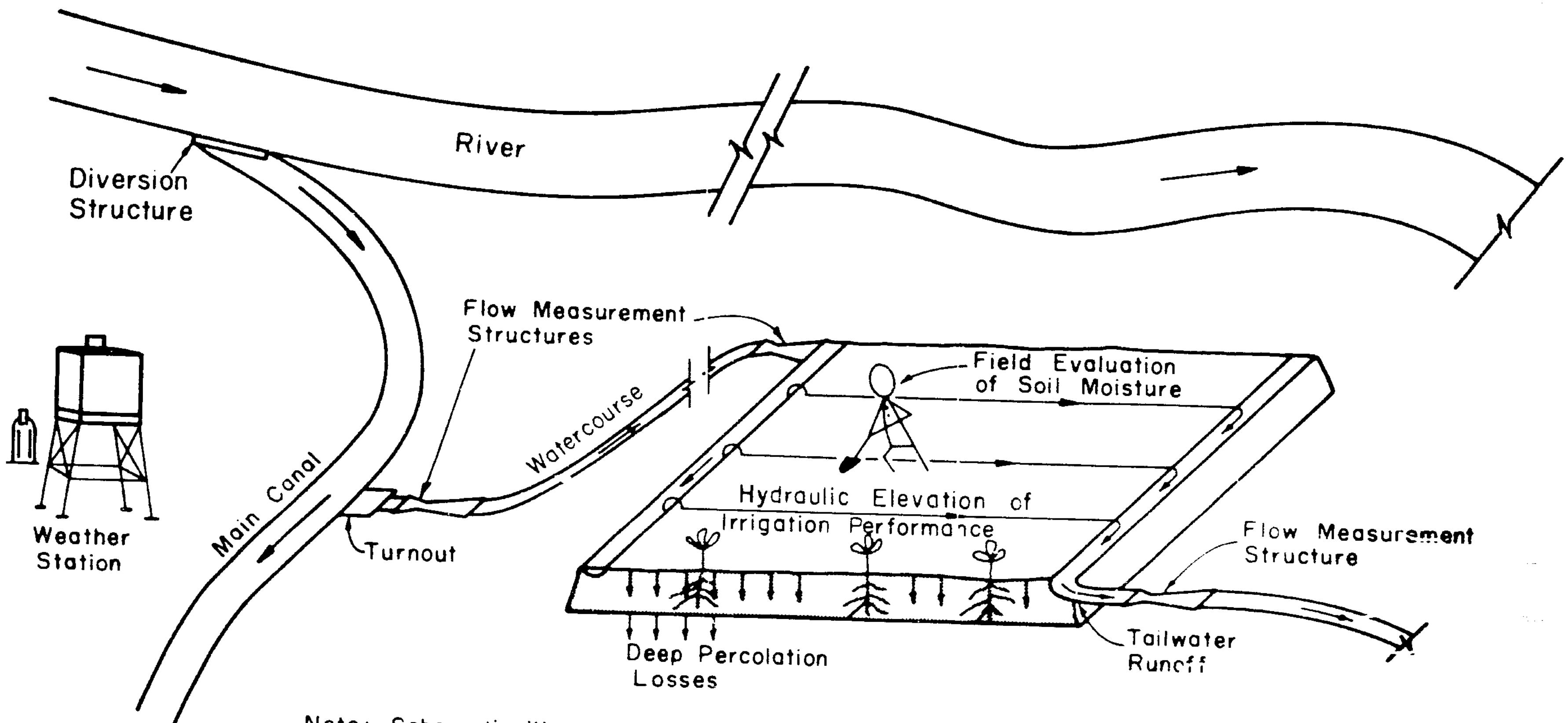
Farm Water Use Efficiency

Farm investigations constitute the largest proportion of work involved in the evaluation of an irrigated area. The primary component of this investigation is the farm efficiency studies which include evapotranspiration, infiltration, tailwater, irrigation method analysis, and vegetative land use mapping.

The amount of water diverted is also very critical in establishing the water-salt budgets for a farm or a field. All of this water must be measured and accounted for, and it is allocated to any one of three main catagories. The surface hydrology categories are (a) evapotranspiration, (b) infiltration and (c) tailwater runoff (Figure 6). In areas with a high water table, there can be a substantial amount of water that moves upward via capillary action from the water table and is used by the plants. This capillary water will usually contribute significantly to soil salination problems. The subsurface hydrology categories are head ditch seepage and deep percolation losses. The variables that must be considered in an on-farm irrigation investigation are schematically illustrated in Figure 7.

Many of the parameters such as drainage discharges, watercourse diversions, water quality, and precipitation can be measured directly. Others must be investigated indirectly. These indirect measurements of parameters are related mostly to groundwater movement and soil hydraulic characteristics and can be monitored using techniques such as piezometers, wells, and soil sample analyses.

Because so many of the parameters in the water and salt budgets cannot be evaluated directly on a large scale, peripheral investigations are usually made in which a portion of the area is examined in detail. Such investigations include farm efficiency studies that indicate the relative proportion of evapotranspiration, deep percolation, and soil moisture storage; vegetative land use mapping of the entire irrigated



Note: Schematic illustrates furrow irrigation. Border irrigation would be similar. Basin irrigation would not have tailwater runoff.

Figure 6. Schematic of instrumentation required for on-farm hydrology investigations.

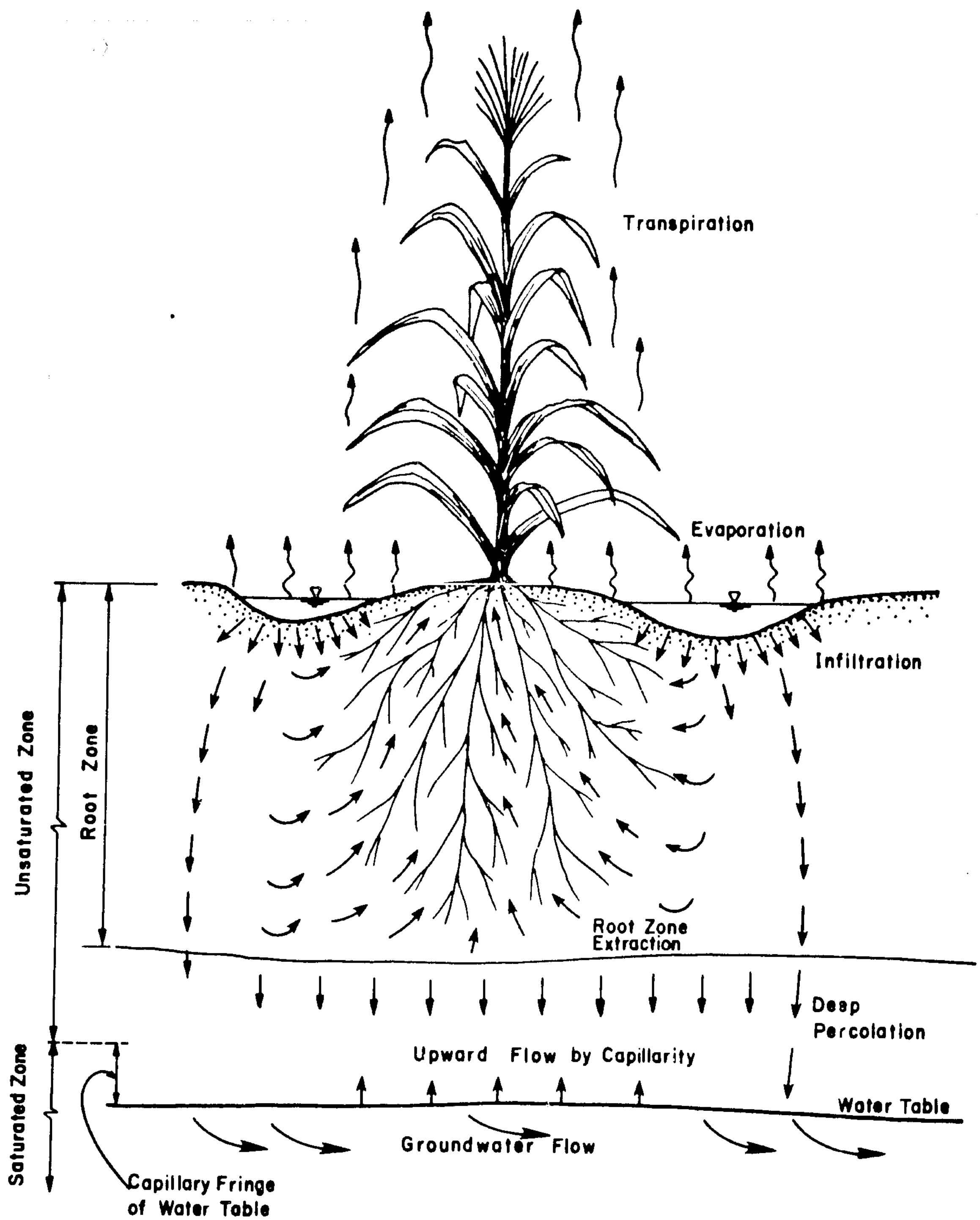


Figure 7. Schematic of the hydrologic variables to be considered in an on-farm subsystem investigation.

area so that the total consumption of water for the area can be calculated; and other studies pertaining to specific conditions of water and salt movement. There is no substitute for good field data collection. The United States Geological Survey (1968 to 1976) has published 34 manuals on techniques used for water resource data collection, many of which are very useful for irrigation studies.

Four types of basic data are required for on-farm water use investigations. These are crop parameters, soil parameters, water quality information, and climatic data such as evapotranspiration and precipitation data.

Crop parameters are important to many of the irrigation method decisions and the plant sensitivity and ionic toxicity response to salinity, growth rates, and evapotranspiration demands. Crop responses to salinity are discussed by Bernstein and Hayward (1957), Bernstein et al. (1954), Black (1968), Maas and Hoffman (1977), Robinson (1971), and others.

Soil parameters considered as basic data include field capacity, permanent wilting point, and bulk density for each soil layer with depth. Since field soil-moisture sampling procedures are gravimetric, the bulk density is needed to relate gravimetric to volumetric moisture content which is used in most analytical procedures. An attempt should be made to obtain several samples from numerous locations to approximate the average conditions of the field (Warrick, 1977; Karmeli et al., 1978). Basic soil chemistry reactions, electrical conductivity and ionic content of the soil solution should also be determined. Black et al. (1965), Food and Agricultural Organization of the United Nations (1975), Quirk (1971), Richards (1954), Chapman (1966), and others describe the soil-chemistry-plant relationships and procedures for data collection and analysis.

Quality of the incoming water can greatly influence management and operation of an irrigation system. If the water is of poor quality, it can limit many of the alternatives for pollution control. Ayers (1976), Ayers and Westcot (1976), Christiansen et al. (1976), Kemp (1971), Kovda et al. (1973), Wilcox and Durum (1967), and others present information regarding water quality in irrigated agriculture.

Crop Water Use

Evapotranspiration (ET) or consumptive use (CU) is the sum of the amount of water evaporated from the soil surface and the amount of water transpired by the crop. The primary factor controlling ET is the thermal energy of solar radiation reaching the surface of the earth. However, solar radiation, air and soil temperature, humidity, vapor pressure, wind velocity, and specific crop and variety are all inter-related factors in the ET process. Potential evapotranspiration (ETp) is a convenient weather index or reference point by which weather-related evaporative conditions can be related to specific crop-water needs. Potential ET has been measured as open-pan evaporation and calculated by various formulas that include varying amounts of climatological data with and without corrections for altitude and latitude. The Jensen-Haise method uses calculated ETp from solar radiation for alfalfa as a reference crop. Actual evapotranspiration (ETa) is usually less than potential evapotranspiration because of moisture stress experienced by the plant prior to irrigation, unless sufficient irrigation water is applied frequently.

Some data on ET may already exist at universities, experiment stations, or governmental agencies. Data for crops in other irrigated areas with similar climatic conditions transferred directly to local settings may be accurate enough for some purposes. In the absence of ET data, calculations can be made from existing weather data for the local irrigated area using crop coefficients developed in other areas.

Determination of ETa at the peak, with maximum rates occurring near the onset of flowering and minimum rates occurring near the germination and late maturation stages, is necessary to determine the proper time for irrigation. Probably the most accurate way to measure ETa is from lysimeters; however, gravimetric moisture or neutron probe measurements taken before and after irrigation under field conditions where no water table exists near the crop root zone can be satisfactory. Weighing lysimeters surrounded by the same crop can furnish daily ETa data more easily than soil moisture sampling. Considerable care must be taken to duplicate conditions of the natural environment or else results will not duplicate those found in the field.

Inflow-outflow studies along with accurate water table level measurements can furnish sufficiently accurate average data for large areas. Crop water-use coefficients (k or K) can be developed from ETa data at the various stages of crop growth for particular ETp data.

Open-Pan Evaporation

Open-pan evaporation data can be used as a direct measure or index of ETp. Daily data can be summarized for various growth periods by months or for different seasons.

Other Devices for Measurement of Evaporation

Piche tubes and atmometers have been used in many places but have not achieved popularity in the United States. Use of these devices would necessitate the development and use of some different crop coefficients than for open-pan evaporation.

Calculation from Weather Observation Data

Potential evaporation has been calculated or estimated by many different formulas varying in complexity. The following formulas are listed in a decreasing order of the amount of weather data needed: Penman, Christiansen, Hargreaves, Jensen-Haise, Blaney-Criddle, Thornewaite, and Lowry-Johnson. The Penman and Thornewaite formulas are best adapted to humid, well-vegetated areas.

Tanner (1967) and the World Meteorological Organization (1966) provide an excellent review of the procedures and methodologies used for the measurement of potential evapotranspiration in the field. Measurement of evapotranspiration should include the means for the actual measurement of consumptive use and a complete weather station to measure air temperature (including maximum and minimum daily temperatures), dew point temperature, relative humidity, precipitation, wind run, solar and net radiation, and evaporation (Class A pan). Doorenbos (1976) presents an excellent discussion on the establishment and operation of a weather station and the calibration of empirical evapotranspiration indices to actual evapotranspiration measurements. The World Meteorological Organization (1970 and 1971) presented much information on the collection and analyses of hydrometeorological data.

Lysimeters

Probably the most accurate measurement of evapotranspiration is obtained by the use of lysimeters. A lysimeter is a device that is hydrologically isolated from the surrounding soil. This device contains a known volume of soil, is usually planted to the crop under study, and has some means to directly measure the consumptive use of water. Lysimeters must be representative of the surrounding conditions and the soil types if they are to provide useful evapotranspiration measurements. Lysimetry establishes a datum for evapotranspiration calculations because it is the only method of measuring evapotranspiration where the investigator has complete knowledge of all the terms of the water balance equation. Harrold (1966) presents a comprehensive review of the use of lysimeters for measuring evapotranspiration.

Two types of lysimeters, which have worked quite well for calibration purposes, are the constant water table and the hydraulic weighing lysimeters. The constant water table lysimeters (Figure 8) are usually planted to grass or other crops with shallow root systems. On the other hand, the hydraulic weighing lysimeters (Figure 9) are usually planted to deeper rooted crops, such as alfalfa or corn.

Irrigation Timing

Irrigation water must be applied frequently enough so the crop is not subjected to a great degree of soil moisture stress in order to achieve full production. Proper timing depends on the water requirement of the particular crop, the stage of crop growth, the moisture storage capacity of the soil, and availability of water to the irrigator. Maintaining readily available soil water is essential if crops are to achieve satisfactory growth.

Field Observations

Determination of soil moisture content can be done by the Touch and Feel method. Soil that will not form a ball is an indication of inadequate soil moisture. A dark green color and signs of wilting by the crop indicates that soil moisture is limited. However, these symptoms may be difficult to distinguish from the symptoms of salinity.

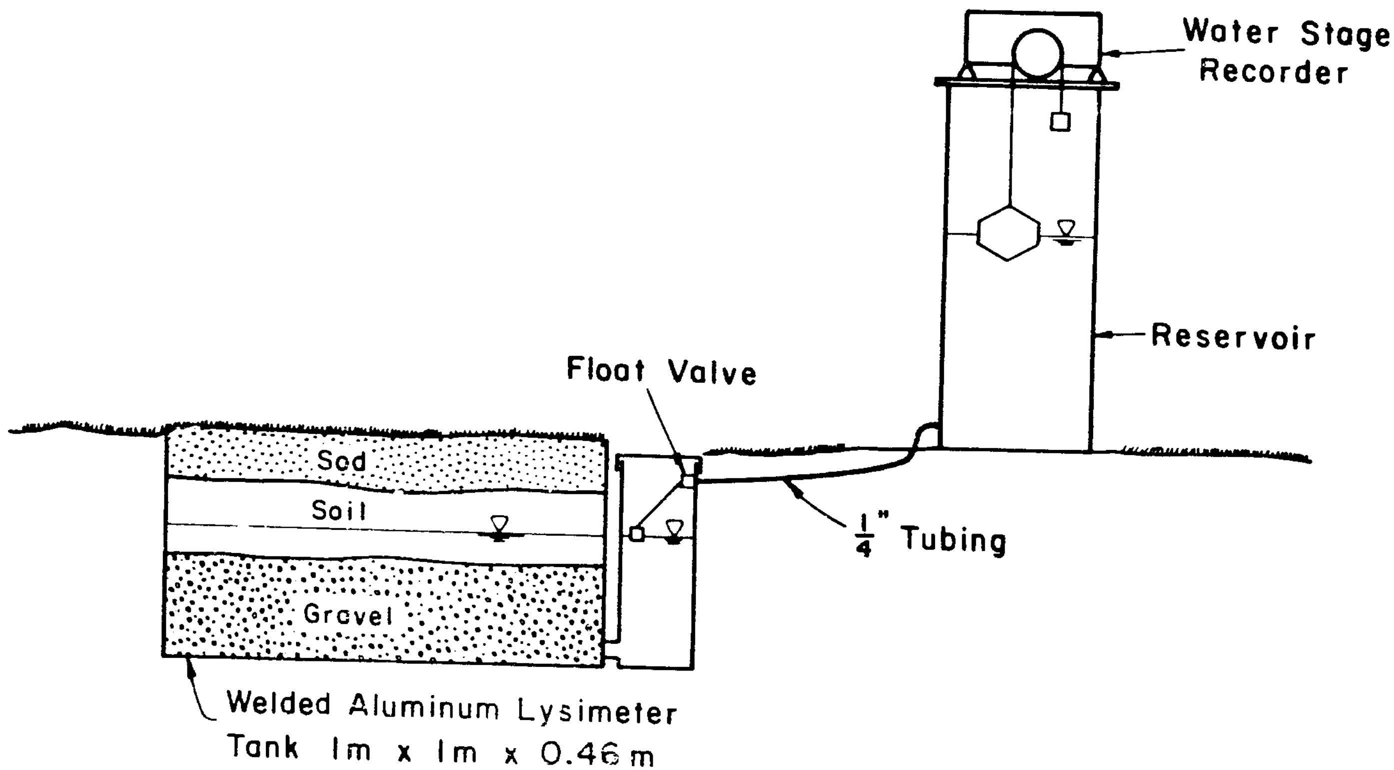


Figure 8. Schematic of constant water-table lysimeter.

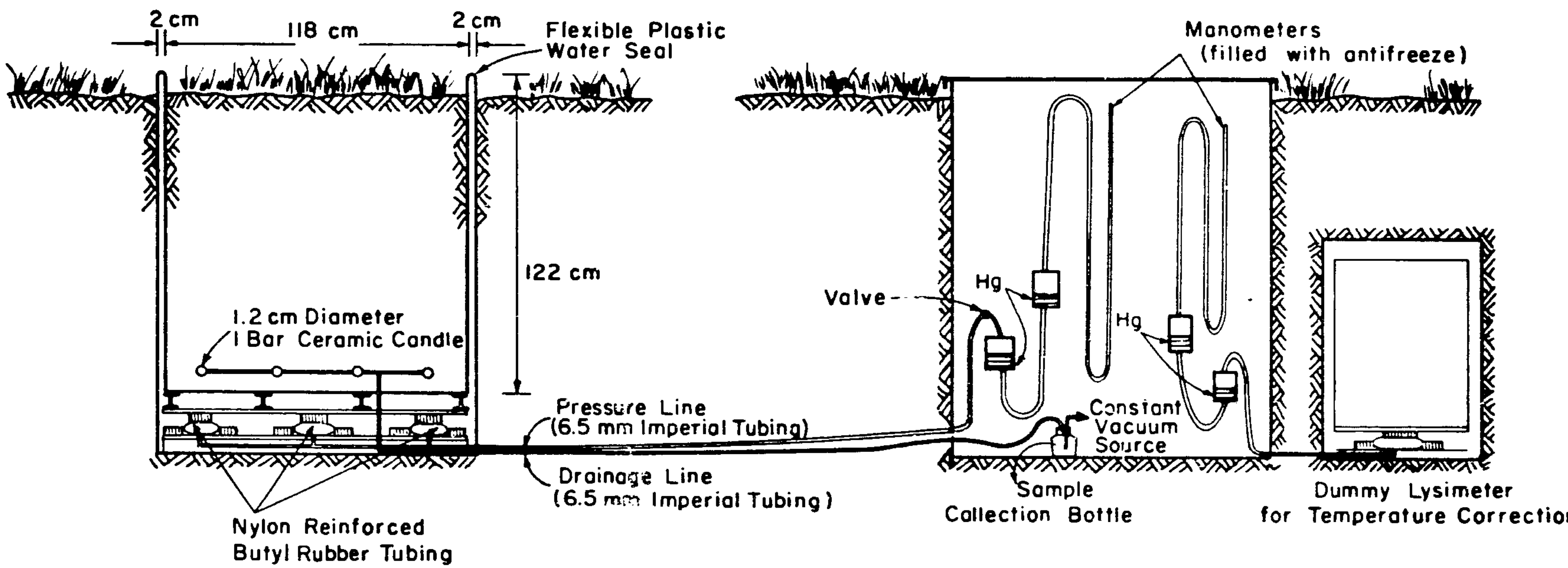


Figure 9. Schematic of the construction of a hydraulic weighing lysimeter.

Calculations of ETp and ETa from Existing Data

Estimates of soil moisture-holding capacity along with ETa estimates for a specific time period give a reasonably good indication of the rate of crop-water use. If available water stored in the root zone at each irrigation is less than estimated ETa for that period, calculations indicate that irrigation is applied too infrequently.

Field Measurements

Fundamental characterizations for evaluating proper irrigation timing is the determination of field capacity, wilting point, and amount of available soil water stored between these two values for a given soil. Usually the best crop growth will be obtained if soil moisture does not fall below 50 percent of the available supply, generally called the "readily available" supply. In terms of soil moisture stress, the readily available moisture usually falls into the range of less than 1-2 bars tension.

Tensiometers, Gypsum Blocks, or Fiberglass Blocks

Tensiometers are well-adapted for sandy soils. The range in their measurement is from 0-1 bar tension. The range in gypsum and fiberglass blocks is from 1-15 bars tension and these are best adapted to medium-to-fine-textured soils. The above devices can be used as a check to see if irrigation frequency is satisfactory or as a guide to application time.

Gravimetric and Neutron Probe Moisture Measurements

Either gravimetric soil moisture samples or neutron probe measurements can be used to evaluate the acceptability of the usual timing of irrigation. These measurements can also be used to develop guidelines for the best irrigation timing practices. Measurements of this type are usually fundamental for any "water budget" or "water balance" studies, which are defined in the next chapter. Direct measurement of soil moisture is potentially the most accurate method for evaluating irrigation timing, especially if groundwater is utilized by plant roots.

Irrigation Timing as a Function of ET Estimates

Estimates of ET from open-pan measurements and/or climatic data entail somewhat less work than gravimetric moisture sampling or neutron probe measurements since they are independently determined. If it is possible to change the time of irrigation, then it can be adjusted to fit climatic changes.

CROPPING PRACTICES

Cropping Patterns

Cropping patterns, as shown in Figure 10, refer to the cropping intensities and crop rotations including fallow, crop mixes, polyculture, and relay cropping. The first step is to determine the definition of cropping intensity being used in the region or country. Usually there is one accepted definition used by the agricultural census or the Department of Agriculture in a country. Some definitions and examples of cropping intensities are given in Table 11.

Crop Rotation

Investigation of crop rotations ascertains the actual sequences of crops grown on different fields. Also, the use of fallow for each field over time is recorded.

Crop Mixes

The purpose of a crop mix study is to check the types of crops cultivated for individual farms and a large area. For example, is the farm primarily a wheat-cotton farm, a wheat-fodder farm, a vegetable farm, or one with a variety of crops?

Polyculture

Polyculture is the degree of intercropping of several crops in a single irrigation basin or field, and should be determined. In many parts of the world there are sound reasons for polyculture. Farmers with small acreages report that such practices exist for several reasons such as there is a more even distribution of income over the year, a lack of sufficient land to feed family and animals, insurance against one

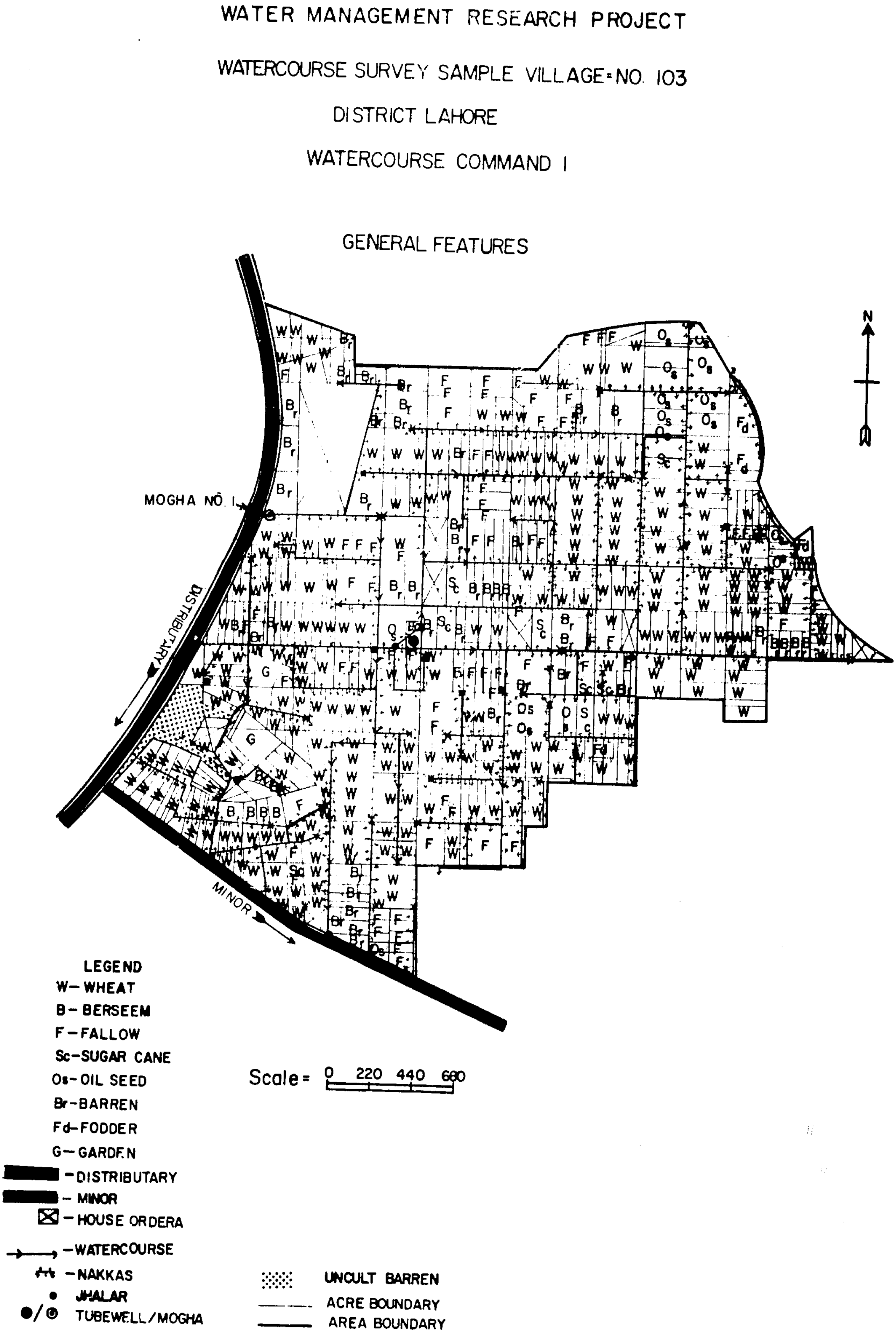


Figure 10. Example of agricultural land use mapping.

Table 11. Definitions of cropping intensity.

Definition 1:

$$\frac{\text{Total area in acres or hectares cropped for two major seasons}}{\text{Total area of cultivated acreage or hectares}} \times 100$$

Example: A farm has 5 acres and two seasons (two crops per year can be harvested). If the farmer cultivates the five acres each season, then a total of 10 acres is cultivated each year and the cropping intensity is

$$10/5 \times 100 = 200\%$$

Definition 2:

$$\frac{\text{Total area in acres or hectares cropped for more than two major crops}}{\text{Total area of cultivated acreage or hectares}} \times 100$$

Example: If a farm having 5 acres can grow three crops in a year and 5 acres are cultivated one season, 3 acres another season, and 4 acres for another season then the cropping intensity is

$$12/5 \times 100 = 240\%$$

Definition 3:

$$\frac{\text{Total area in crops harvested in two or more seasons}}{\text{Total area cultivated}} \times 100$$

Example: A farm has 20 cultivated acres but 10 acres are in perennial sugar cane harvested once a year and 10 acres in other crops for 2 seasons per year, the cropping intensity would be

$$30/20 \times 100 = 150\%^{*}$$

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*The 10 acres of sugar cane are counted as 10 acres because they are harvested on a yearly basis (which would also be true for tree crops). The other 10 acres produces 2 crops per year, so it is counted as 20 acres in the numerator.

crop failing, an improved crop cover, better utilization of water and fertilizer inputs, symbiotic (nitrogen fixation) relationships of some crops, insect protection, along with other advantages. However, little experimental work has been completed related to this widespread practice on many farms around the world.

FARM BUDGETS

Farm Management Inventory

It is necessary to collect data from farmers about their actual management practices (Table 12). Checklists are provided in Tables 13 and 14 for evaluating farm management practices. Data obtained from a representative sample of farmers can help program staff answer many questions about farm management.

Resource Inventory

In addition to technical information about actual farm practices, it is necessary to gather information about resources available to the farmers and the values of these resources in production. Preparation of budgets require price information and inventories. When price information is complete, detailed farm budgets can be constructed for use in analyzing the farmer's production choices and the value of his resources.

Farms should be separated into homogeneous groups with respect to their availability of resources and their productivity. For example, farm size, tenure, and location may be adequate indices by which to categorize farms. Thus, one category might be "small, low-land, tenant-operated farms." The area map mentioned earlier should be useful to determine the categories. Each category is then used to compute an average or representative farm budget. As part of the detailed diagnosis, a sample of land, physical labor, capital, an' ıls, water, and outputs should be made.

Land

Soil types and productivity, accessibility to markets for products and inputs, size and shape of fields, size of holdings, access to water, ownership and tenure arrangements, and markets and prices should be

Table 12. Format for inventories of actual practices for major crops.

A checklist in a formulated systematic approach for obtaining and preserving management data is as follows:

---

1. Name of farmer Date
2. Legal description of farm
3. Field designation
4. Field size
5. Preceding crop
6. Preceding fertilizer application
   a. Amount of N, P, K, micronutrients applied
   b. Manure
7. Present crop
8. Seedbed preparation
   a. Type or types of tillage operation
      1. Number of times and sequence
      2. Type of power (animal, machine, man)
      3. Desired seedbed condition (firm, mellow)
      4. Planting system and method of planting
   b. Time and labor required
9. Number of irrigations applied during land preparation
10. Fertilizer applied
    a. Amount (N, P, K, micronutrients)
    b. Method of application (broadcast, banded, split)
    c. Number, type, and time of tillage operation to incorporate fertilizer into soil
    d. Commercial fertilizer cost
11. Seed
    a. Source
    b. Seeding date or dates
    c. Purity (weed and other crop free)
    d. Opinion of quality
    e. Amount of seed planted (calculate seeding rate)
    f. Cost
    g. Method of planting
    h. Seeding depth
    i. Condition of seedbed (firm, mellow, moist, dry)
    j. Type of power (man, animal, machine)
    k. Time and labor required for seeding
    l. Cost of custom work
12. Weed eradication
    a. Preplant spray; material
    b. Mechanical cultivation; man, animal
       1. Date, number of times
       2. Time and labor required for weeding
       3. Cost of custom work

Table 12. (continued)

13. Irrigation
    a. Method of irrigation
    b. Dates and number of times
    c. Irrigation intervals
    d. How much applied each time
        1. Amount of water received
        2. Length of time on field
        3. Amount of runoff (calculate field efficiency)
    e. Labor required
14. Insect problem if noticed
    a. Amount, type, and number of sprays
    b. Cost of sprays
    c. Time and labor involved
15. Disease problems if noticed
16. Other damage to crop
    a. Farm animal, rodent or other, wind
17. Harvest operation
    a. Date (period) of harvest
    b. Method of harvest
        1. Power source
    c. Time and labor required
18. Yields
19. Storage facilities
    a. Capacity
    b. Amount stored
20. Cropping patterns
    a. Cash crops
        1. Number, sequence, and time and duration during year
    b. Subsistence crops
        1. Number, sequence, and time and duration during year
    c. Crops grown together (crop mixes)
    d. Intercropping practices (polyculture)

Table 13. Checklists on reconnaissance inventory for farm management practices.

Cropping patterns:	_____Consult available data
	_____Discuss with farmers and those who work directly with farmers
	_____Make direct field observations where possible
	_____Other (specify)__________________
Irrigation practices:	_____Consult available data from research stations, etc. as to comparative benefits of various practices used
	_____Field visits to observe the alternative practices used
	_____Discussions with farmers and extension personnel of comparative benefits of alternative methods
	_____Other (specify)__________________
Resource inventory/ farm budgets:	_____Consult available data: census, agriculture department, agricultural studies, anthropological studies, marketing board, ministry of trade, labor data
	_____Check existing data for farm size, tenure system, water rights, capital availability, pricing policies, government policies
	_____Determine government policies on agriculture commodities, quotas, prices, and distribution of fertilizer
	_____Check with agriculture extension agents for existing data and to see if government policies are effective
	_____Other (specify)__________________
Decision-making:	_____Determine degree of fluctuation in prices of commerical inputs and crops. Compute statistical variance, range, and use a scatter diagram to detect special patterns in the data
	_____Determine role of government control in crop prices and input prices
	_____Check dependability of marketing services
	_____Investigate land tenure system, check security of system from government officials, legal documents, studies, and extension agents
	_____Other (specify)__________________
Crop varieties:	_____Obtain available data from agricultural officials and available research
	_____Gain information from farmers and extension workers

_____Compose estimates of yield results from leading and average farmers of various varieties of given crops
_____Other (specify)____________________

Seedbed preparation:

_____Consult available information from agricultural officials, and research and extension specialists
_____Make preliminary field observations of farms and discuss with farmers
_____Other (specify)____________________

Planting/sowing dates:

_____Consult available data about costs and benefits of optimum versus nonoptimum dates for selected crops
_____Discuss with farmers their views of optimum versus nonoptimum dates and perceived costs
_____Other (specify)____________________

Seed source, quality and seed rates:

_____Consult available 'ata on costs of seed from various sources, ›enefits of using seed of a known quality, and cost-benefits of optimum seed rates for selected crops
_____Discuss with farmers and extension workers the cost of seed, the availability of quality seed, and the value of certain rates of seed per hectare or acre for selected crops
_____Other (specify)____________________

Fertilizer cost, availability, use, and methods of application:

_____Establish from available data the actual cost to various farms for fertilizer, degree of availability of fertilizer, the costs, benefits of various levels of use, and costs and benefits of various methods of application
_____Discuss with farmers and extension workers their perceptions of the questions above
_____Other (specify)____________________

Weed and insect control methods:

_____Establish from available data the costs and benefits of various control methods
_____Discuss with insecticide agency staff and researchers
_____Make initial field observations and discuss with farmers and extension workers to determine their perceptions of costs and benefits and the degree of control that should be used
_____Other (specify)____________________

Other crop damage:

_____Obtain available data from research stations and other organizations
_____Discuss with farmers and extension workers and estimate the losses in production to all farms due to crop damage
_____Other (specify)__________________

Tillage operations:

_____Consult research station personnel and farm machinery companies about benefits of alternative methods of all tillage operations
_____Observe in the field what different operations are used with what types of implements and machinery
_____Discuss with farmers and extension workers alternative costs and benefits of various methods
_____Other (specify)__________________

Harvest operations:

_____Consult available data to determine the benefits in terms of actual yields of various methods
_____Observe operations in the field and join farmers' and extension workers' views of the losses in crop output of various types of harvest operations
_____Other (specify)__________________

Storage facilities:

_____Consult available data as to crop losses of various storage methods. Document the types of facilities from farm level to market centers to national storage schemes
_____Discuss with market personnel the relative benefits of various storage systems
_____Observe various storage systems from farm to market center
_____Discuss with farmers losses from rodents, mold, temperature, insects; and various storage methods for major crops
_____Other (specify)__________________

Market facilities:

_____Consult available data from government offices and marketing centers
_____Document modes of farm to market transportation and costs of each
_____Discuss with farmers the costs of marketing farm products, including costs of middlemen, transportation, and taxes
_____Other (specify)__________________

Credit facilities:

_____Consult available data about sources of credit, availability, use, and types and terms of credit from credit institutions
_____Discuss with those who work directly with farmers the questions above
_____Other (specify)__________________

Table 14. Checklists on detailed diagnostic methods for farm management practices.

Cropping patterns:	_____Conduct crop survey and enter on map of each field and season
	_____Interview farmers using a grid system designed for the units used (acres, hectares, etc.). Data collector should verify reports by checking the field individually for certain crops.
	_____Take aerial surveys if possible to do with adequate detail and at proper time.
	_____Other (specify)_____
Irrigation practices:	_____Conduct field surveys to document the various practices used and reasons why
	_____Utilize data from irrigation engineers to document the actual losses of water and costs of that water
	_____Utilize data from engineers and agronomists to document the influence of the application of too much and too little water, and quality of water on yields
	_____Utilize data from engineers and agronomists to estimate costs and benefits of various methods of improved return flow of water.
	_____Other (specify)_____
Resource inventory/ farm budgets:	_____Conduct a sample survey to check land, labor, capital, animals, water inventory, and outputs
	_____Other (specify)_____
Decision-making:	_____Determine prices and yields from direct observation.
	_____Observe terms of tenancy to verify or modify information already obtained.
	_____Observe farmers when they are planting, irrigating, cultivating, and caring for their crops.
	_____Note how farmers adjust to problems of uncertainty. Ask questions such as: "What recourse do farmers have if they lose most of their major crop? Is credit or support easily available through the family? What food reserves do the farmers maintain? What minimum risk crops do they plant? What is the amount of farmer's savings (very difficult to determine)?
	_____Other (specify)_____
Crop varieties:	_____Document the crop varieties along with cropping patterns on field maps used by farmers.

Crop varieties:

_____Document the crop varieties along with cropping patterns on field maps used by farmers.

_____Analyze the benefits in yields attributed to varietal differences from on-farm data and data at research stations.

_____Other (specify)_______________

Seedbed preparation:

_____Conduct farm level surveys to document the benefits and costs of various methods in terms of yields and net farm income.

_____Other (specify)_______________

Planting/sowing dates:

_____Conduct field surveys with farmers and acquire data from experiment stations to analyze the reductions in yields resulting from variations in sowing and planting dates for major crops.

_____Determine if the range of sowing/planting dates for various crops provide adequate margin for farmers in terms of field operations.

_____Other (specify)_______________

Seed source, quality, and seed rates:

_____Conduct farmer interviews to determine source of seed, availability, and quality of seed.

_____Obtain data from experiment stations about seed quality and variations in yields resulting from various levels of seed rates.

_____Establish the economic levels for various seed rates in relationship to yields.

_____Other (specify)_______________

Fertilizer costs, availability, use and methods of application:

_____Conduct farmer survey to determine the costs of fertilizer, availability at time needed, credit availability, rates applied, and methods of application.

_____Compose recommended levels of fertilizer and methods of application for selected crops from research stations and farmers' practices.

_____Compare project field data with that of fertilizer companies.

_____Ascertain the economics of fertilizer use by farmers

_____Other (specify)_______________

_____Analyze the benefits in yields attributed to varietal differences from on-farm data and data at research stations.
_____Other (specify)____________________

Seedbed preparation:

_____Conduct farm level surveys to document the benefits and costs of various methods in terms of yields and net farm income.
_____Other (specify)____________________

Planting/sowing dates:

_____Conduct field surveys with farmers and acquire data from experiment stations to analyze the reductions in yields resulting from variations in sowing and planting dates for major crops.
_____Determine if the range of sowing/planting dates for various crops provide adequate margin for farmers in terms of field operations.
_____Other (specify)____________________

Seed source, quality, and seed rates:

_____Conduct farmer interviews to determine source of seed, availability, and quality of seed.
_____Obtain data from experiment stations about seed quality and variations in yields resulting from various levels of seed rates.
_____Establish the economic levels for various seed rates in relationship to yields.
_____Other (specify)____________________

Fertilizer costs, availability, use and methods of application:

_____Conduct farmer survey to determine the costs of fertilizer, availability at time needed, credit availability, rates applied, and methods of application.
_____Compose recommended levels of fertilizer and methods of application for selected crops from research stations and farmers' practices.
_____Compare project field data with that of fertilizer companies.
_____Ascertain the economics of fertilizer use by farmers
_____Other (specify)____________________

Weed and insect control methods:

_____Conduct field studies to determine actual losses in crop yields due to losses from weeds and insects.
_____Establish the economics of improved methods versus farmers' methods.
_____Other (specify)____________________

Other crop damage: _____Conduct field surveys to determine from farmers actual cost of losses from animal, natural, and human sources

_____Other (specify)_____________________

Tillage operations: _____Conduct field surveys to determine the capital and labor costs of major tillage operations.

_____Determine from field surveys the benefits of timely operations.

_____Determine the recurring costs involved from purchased farm machinery and animal power.

_____Other (specify)_____________________

Harvest operations: _____Document in field surveys the costs of all operations and the value of timeliness in operations.

_____Compare the costs and benefits provided by equipment salesmen and farmer users.

_____Include in field studies the seasonal availability and costs of labor

_____Other (specify)_____________________

Storage facilities: _____Obtain data at the farm level about estimated losses of crops in farm level storage

_____Obtain data from market centers and other storage centers as to losses in storage and calculate a total loss due to inadequate storage facilities

_____Compare the costs and benefits of alternative types of storage facilities and practices.

_____Other (specify)_____________________

Market facilities: _____Conduct farm level and market center surveys to determine costs of transportation, middlemen, and levies to the farmer.

_____Compare costs of various types of marketing practices in which farmers are involved.

_____Other (specify)_____________________

Credit facilities: _____Conduct field surveys to document source of credit, type of credit, and costs of both institutional and noninstitutional credit to the farmer. Also, ascertain credit availability to all classes of farmers.

_____Obtain information on credit availability and terms of credit from both institutional and noninstitutional sources.

_____Estimate the need for productive versus consumptive credit needs for all classes of farmers.

_____Other (specify)_____________________ included in the resource survey. A map is also useful to help summarize all of this data and for suggesting representative farm groups.

Labor

Information should be collected on age, sex, health, number, and education of family laborers. Also, it is important to know the tasks performed by various family members and the availability of hired labor. It is necessary to know the terms of hiring, the calendar availability of off-farm work for laborers, and the wages to be paid.

Capital

Several questions should be answered such as What are the financial sources? Is it the farmers own savings or credit? If it is credit, where was it obtained? Was it obtained from family, a money lender, farmers, a cooperative, a bank, the government? How much does each farmer pay and under what terms? What is the interest rate, repayment schedule, and security?

Animals

An inventory of all animals, either raised for food or work should be assembled. The animals' condition, consumption requirements, market value, labor required to keep them, and susceptibility to disease should be noted.

Water Inventory

The availability of water at specific times, and other inputs required to use it, including labor, machinery, and animal inputs should be checked.

Outputs

Each crop should be inventoried according to its yield, its requirements for specific timing of inputs, the cash costs of inputs, and the prices on outputs.

Decision-Making Environment

Individual farmers do not allocate their resources independently of their neighbors; rather, they are part of a complex web of obligations connecting them with their neighbors and relatives. Farmers also depend on average or normal returns such as those derived in the representative farm budgets. The farmers are subject to extreme variations in yields resulting from causes beyond their control such as rainfall, disease, pests, sickness, market changes, and political changes. Both competition between farms and variations related to prices and other variables influence the individual farmer's decision-making framework. Therefore, these factors need to be carefully considered to understand basic causes of farm production problems.

Interdependency with Farmer's Community

A thorough study of farm management practices along with data on crop potentials allows investigators to construct: (a) representative farm budgets reflecting what farmers actually do, and (b) alternative budgets reflecting what they could do, either with existing resources or added factors. However, the farmer's real choices are strongly conditioned by factors that are difficult for researchers to comprehend, let alone quantify. These include uncertainty and obligations with neighbors and relatives and the farmer's village environment as a whole, which is the topic of Chapter VI.

INTERDEPENDENCY OF FARM MANAGEMENT PRACTICES WITH WATER SUPPLY AND REMOVAL SUBSYSTEMS

As a means to show how farm management practices are closely related to the water supply and removal subsystem, a hypothetical case is utilized. It is assumed that crop stands on a farm are very poor and limiting production. The agronomist investigates and discovers that in both leaf tissue tests and analysis of soil samples there is a definite nitrogen deficiency. The farmer reports, however, that he applied the recommended rates of nitrogen. In turn, the hydrologist locates a high water table resulting from poor drainage. Later, from measurements of water losses from poorly maintained field channels and overirrigation, it was found that irrigation efficiencies are only 25-30 percent. Also, it was discovered that 40-50 percent of the nitrates applied were leached through the soil profile to groundwater. Further interviews with the farmer revealed that he applied what water he could every week when water was allotted on a fixed rotation system. It was learned that the farmer applied all the water he could to his fields because of (a) lack of knowledge of the appropriate amount to apply, and (b) concern that canal supplies might not be regular.

In such a case, the investigator must be careful not to confuse symptoms of problems with causes. Also, the investigator must learn to search for multiple causes. For example, if the problem is defined as poor crop stands, nitrate leaching and poor drainage are only symptoms. The causes of the problem may be overirrigation resulting from both lack of knowledge and a rigid and unreliable irrigation rotation system. Many irrigation symptoms such as waterlogging have been treated at a great cost to farmers and the public while the real cause of the problem was the behavior of the farmer which, if corrected, would have resulted in long-term improvements at lower costs.

CHAPTER V

WATER SUPPLY AND REMOVAL

The water supply and removal subsystem includes the supply of water from all sources for the farm system, delivery of water to farms, and removal of water through the drainage system. Water supply involves climatic data including rainfall and rainfall distribution, solar radiation, air temperature, relative humidity, wind speed, and other factors that influence the total amount of water made available to the farm system. In addition, climatic data includes information about hazards such as excess supplies of water from flooding (Figure 11).

Water supply and delivery is the conveyance of water from the supply source to the farmers' fields. Water removal is the removal of excess surface or subsurface water.

The institutional arrangements related to water supply and removal are included in Chapter VI. Special attention is given to several critical dimensions of the total area served. For example, topography, land capability, and location of structures are included. These dimensions may require development of detailed maps.

CLIMATE

Climatic Data

Most countries maintain some weather stations. It is preferred that weather data are to be obtained from stations in close proximity to the irrigated area. Types of data needed for collection include solar radiation, air temperature, relative humidity, wind speed, open-pan evaporation, and rainfall distribution.

Solar Radiation

Radiation from the sun not only furnishes energy for photosynthesis, but is the primary source of heat for air and soil. Solar radiation is sometimes measured as part of basic climatological data. The basic measurement is generally recorded as calories/cm^2 of

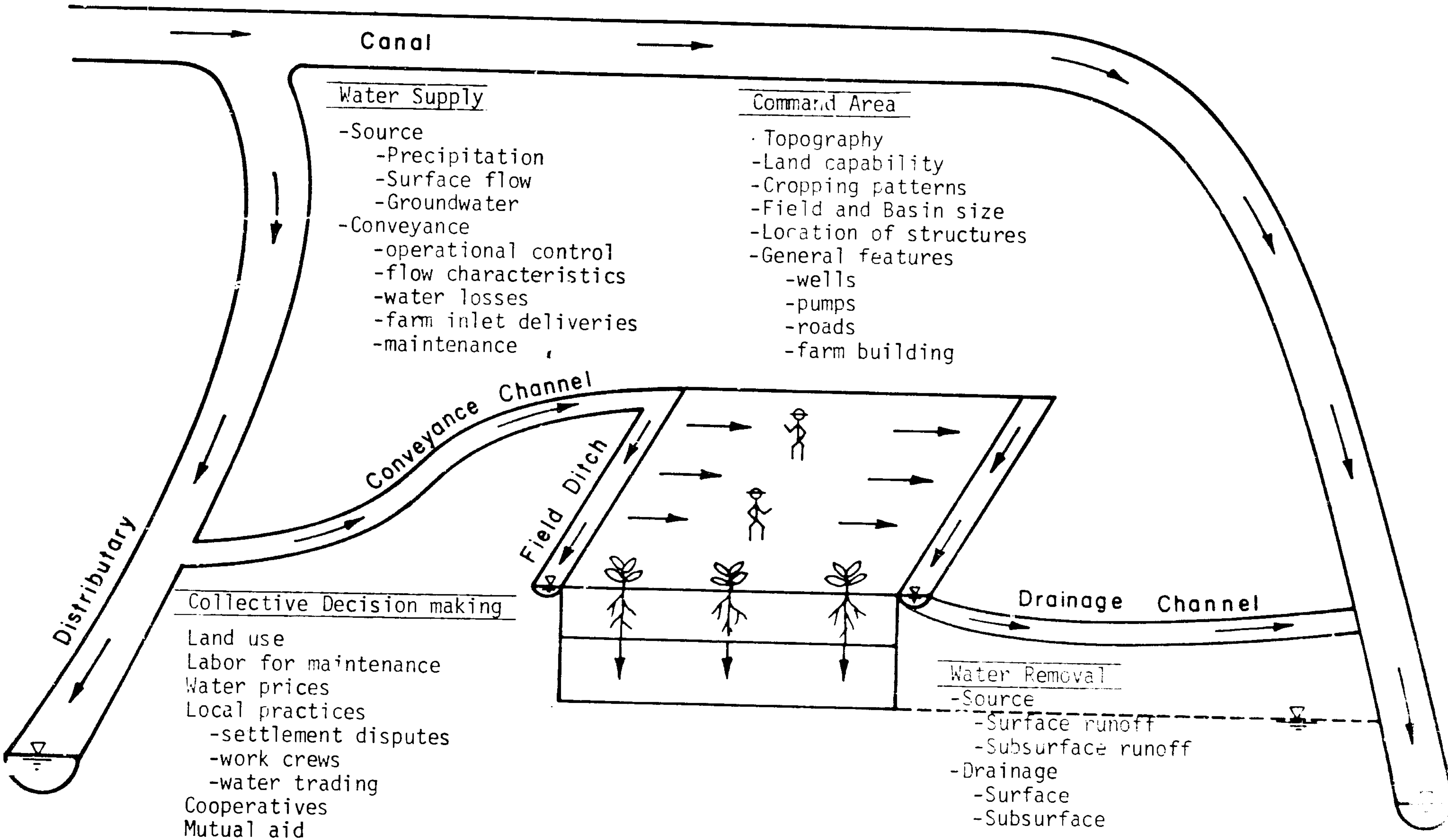


Figure 11. Idealized sketch of a farm irrigation water supply and removal subsystem.

incident radiation over a period of time and is generally reported as monthly or seasonal mean values. Solar radiation data are primarily used for calculation of evapotranspiration by various crops.

Air Temperature

Basic climatic data measured daily are maximum and minimum temperatures, and are logged as mean as well as maximum and minimum temperature. These data are usually summarized into weekly, monthly, seasonal, or annual values. The data are needed to determine appropriate growing seasons for crops in terms of time periods with temperatures above a minimum and below a maximum, or in terms of frost-free days. Temperature data are used to calculate growing degree days (heat units) from daily temperature and are accumulated daily for particular crops. For example, adjusted growing degree days (GDD) for corn (maize) are calculated as the sum of mean temperature -50°F for each day. When calculating the mean temperature for a day, any minimum temperature below 50°F (10 C) is counted as 50 and any with a maximum above 86°F (30 C) is counted as 86. A day with 44 and 80 would have ½ (50+80)-50=15 GDD or heat units. A day with 60 and 94 would have ½ (60+86)-50=23 GDD or heat units. Corn hybrids and some other crops tend to mature according to heat units produced rather than an exact number of days. This adjustment process allows for some vegetative growth in corn when temperature is above 50°F only part of a day, with the best corn growth being at 86°F with growth beginning to taper when it is greater than 86°F. Air temperature data are used along with other climatic data to estimate evapotranspiration for various crops.

Relative Humidity

Basic climatological data usually include measurements of relative humidity. This is done by wet and dry bulb temperature determinations or with a recording hygrometer. Relative humidity is one of the determining factors in calculating evapotranspiration directly, or estimating pan evaporation indirectly.

Wind Speed

Wind speed is measured with an anemometer and is usually recorded as accumulated miles or kilometers per day and summarized with other climatic data. Information on direction of prevailing wind should be also noted.

Open-Pan Evaporation

These data are usually not included in standard weather measurements but are collected within the irrigated area under study.

Rainfall and Distribution

Rainfall is usually measured once a day with a standard rain gauge and occasionally with a continuous-recording gauge. Data from a continuous-recording gauge is especially useful for giving information about rainfall intensity. The data are usually summarized by month or by a particular cropping season. Data can be plotted to show the distribution of rainfall through a particular cropping season or throughout the year. Data over several years can be used to calculate probability of occurrence statistics that are useful for determining irrigation requirements.

Weather Observation Stations

If sufficient climatic data are not available, it may be necessary to establish a network of observation stations in a particular irrigation area. These stations can be used to gather data for determining water supply problems, groundwater recharge problems, irrigation requirements, and crop adaptation problems.

Water Supply Problems

Data needed to predict yearly water supplies usually consists of rainfall or snow depth, water content, and temperature measurements to predict amount and time of runoff.

Ground Water Recharge Problems

If the recharge source of groundwater used for irrigation is located away from the irrigated area, rainfall and possibly other data are necessary to assess the amount of recharge water available.

Irrigation Requirements

Basic data helpful for determining irrigation requirements include net solar radiation, temperature, relative humidity, windspeed, open-pan evaporation, and rainfall. Irrigation requirements can be summarized in relation to the above as

$$IR = \frac{100(ET_a + LR)}{E} - (Pe + Mc + Mg) + Lc$$

where IR is the irrigation requirement, Et_a is actual evapotranspiration, LR is the leaching requirement, Pe is effective precipitation, Mc is the carry-over soil moisture, Mg is groundwater contribution, E is field irrigation efficiency in percent, Lc is conveyance and operational losses. The amount of data needed varies considerably from one irrigated area to another. For example, only one measurement of solar radiation may be necessary, but many measurements of rainfall may be necessary if rainfall is variable over the irrigated area.

Crop Adaptation Problems

To study crop adaptation problems, much of the data already gathered will be used. In most areas the climate usually fits into two or more broad categories such as cool-season, hot-season, and cold season. Minimum and maximum tempertures are needed for assessing germination problems. Growing seasons can be categorized into frost-free days, days over or under minimum, or over maximum temperatures necessary for optimum growth of a particular crop. In addition, number of hours of daylight and/or percentage of sunshine are usually needed for photo-period-sensitive crops. Often this information can be generalized from the latitude position of the irrigated area. The quality of solar radiation is often of interest. Generalized information can usually be determined from elevation measurements with the intensity of shortwave radiation increasing as elevation increases.

Climatic Hazards

In the process of accumulating weather data, any climatic hazards to crop production should be noted and considered. Some hazards that especially need consideration are wind, floods, frost, hail and high intensity rainfall.

Gale-force winds that can cause mechanical or other damage should be noted. Records or other information concerning frequency of occurrence should be obtained. Hot, dry monsoon-type winds can create conditions that increase consumptive use (evapotranspiration) of most crops.

Frequent flooding of low-lying land results in a serious restriction of crop growth. Even if inundation does not damage the crop, often the deposits of silt will be damaging. Information concerning the occurrence of crop-damaging frosts or crop-killing frosts should be gathered. Also, the time or season and frequency of hail damage should be obtained.

High intensity rainfall of long to moderate duration may cause serious erosion problems in one part of an irrigated area, and a serious silt-load problem in another. High intensity rainfall, even of short duration, frequently results in severe crusting of many soil types. Erosion of soil could represent a severe loss of soil nutrients. If the irrigated area is broad and flat, high intensity rainfall may constitute a severe surface drainage problem.

WATER AND SALT BUDGETS

The evaluation of the hydrologic and salinity parameters for an area requires a large amount of data and lengthy computational procedures. Hydro-salinity modeling is necessary to determine the magnitude and effect of each segment of the hydrologic system, which is described in Chapter VII. A water and salt budgeting procedure is typically used that is essentially a mass balance or conservation of mass approach. In many cases, salinity is not a significant problem, so that only the accounting of water transport is necessary. When salinity is important, the data for water budgets is a necessary prerequisite to developing salt budgets. The following discussion covers both water and salt budgeting, but the reader can ignore the salinity studies and the discussion is equally valid for water budgets alone.

The hydro-salinity procedure integrates various aspects of the local hydrology. For example, measured flows diverted from the river into the main conveyance system are segregated into measured seepage and measured watercourse diversions. Operational losses are calculated by the difference between the main diversion, seepage and watercourse diversions. The watercourse (also called lateral) diversions are likewise delineated into seepage and root-zone diversions (measured). Root-zone diversions are further separated into root-zone soil moisture storage (measured and/or computed), deep percolation (usually by difference, but sometimes measured) and consumptive use (measured or computed).

Evaluation of the water and salinity sources is conducted on several levels with objective procedures that systematically and continuously refine the various elements of the hydro-salinity flows to the required degree of accuracy. There are basically four steps for this evaluation procedure:

1. Definition of the components of the hydrologic system as to their function such as water delivery, water use, or water removal,

2. Establishment of a large-scale instrumentation network to monitor the quantity and quality of each component of the hydrologic system for the area,

3. Establishment of criteria for classifying the existing performance of the various subsystems for both time-specific events and seasonal or annual analysis, and

4. Definition of the relationships expressing the existing system performance as functions of management and/or methods of operation.

Defining the components of the hydrologic system is necessary in order to properly design a monitoring network that evaluates contributions from each subsystem. The next step is to establish the network of instrumentation to monitor the surface and groundwater hydrology and to define the hydrologic components of the area in question. A monitoring network usually consists of flow measurement structures that collect information on canal, headgate, on-farm diversions, and surface tailwater flows. A network of observation wells and piezometers is required to collect information on groundwater gradients, flows, and elevations for subsurface returns to the rivers or lakes. Water quality information is also collected from all of these sources simultaneously with the other measurements. From an analysis of these data, the total on-farm component of the irrigation hydrology is determined. A smaller study area of several farms should then be selected for farm efficiency investigations, and the individual segments of this subsystem evaluated.

IRRIGATION WATER

Water must be available to furnish the full irrigation requirement for all crops under irrigation if full production is to be achieved. The quantity must be available and deliverable to meet peak evapotranspiration (consumptive use) demands. The quality of water must present no appreciable salinity or cropping hazard, and little physical or economic burden if special management practices are necessary to safely use the water for irrigation. To study the water supply for irrigation, the source and availability of water, crop water use, water quality, and irrigation timing must be investigated.

Source and Availability

All water sources need to be considered to assess the adequacy of irrigation supplies. This assessment begins with measuring and analyzing precipitation records, then analyzing streamflow and reservoir storage records, followed by analyzing groundwater recharge and pumpage.

Precipitation

Rainfall data can be evaluated either as a source of irrigation water from outside the irrigated area or as the amount of precipitation within the area that contributes to reducing the irrigation requirement. Acceptable data sources are official observation stations and farmer measurements within the irrigated area.

A network of rain gauges can be established to obtain rainfall data or to provide additional local data in an existing network of rain gauges. Inexpensive plastic rain gauges that are precalibrated can be loaned or given to specific farmers in the irrigated area for data collection to study rainfall distribution.

Surface Flows, Reservoirs, and Dams

Data covering the amount of surface water in rivers and streams adjacent to the irrigated area should be collected near diversion points to assess the total supply and variation in runoff throughout the cropping season or seasons and from year-to-year. Alternatively, data of water stored in reservoirs or dams should be collected. Measurement of water diverted into irrigation canals from each source is of primary importance. Method and type of measurement, such as instantaneous discharge or mean flow, should be noted. Daily records should be summarized and graphically presented for monthly, seasonal, or yearly runoff and diversion. A variety of devices and instruments are available to measure small and large stream flows. Suitable sites near points of diversion should be chosen for measurement of stream or river flows. Generally, instantaneous discharge measurements are adequate where flow is relatively constant. Continuous recording devices are desirable where flow fluctuations are large. Reservoir and dam storage measurements should include inflow, outflow, and storage at specific times to assess seepage and evaporation losses. The quantity of flow diverted for irrigation should be measured daily at each diversion point. In many instances it is necessary to measure the amount of flow arriving at the irrigated fields in order to assess seepage losses in the delivery conveyance system.

Groundwater Pumpage and Recharge

In irrigated areas groundwater is frequently pumped for single or multiple purposes. Groundwater may be the only source of irrigation water or may be used to supplement rainfall or surface water supplies. In other instances the principle reason for pumping may be to lower the water table and prevent waterlogging and accumulation of salts in the soil root zone. In this case, use of groundwater for supplemental irrigation water is a secondary purpose. Existing data should be obtained to determine the amounts of water pumped throughout the irrigation season. Any data concerning the number of wells, pumping rate, and number of days pumped should be collected in the absence of data relating to amounts pumped. This information may be obtained through government agencies, well-drillers, or farmers. Also, measurements of static groundwater level and drawdown depth should be collected, preferably throughout the irrigation season. Information about sources of recharge of aquifers being pumped, especially those outside the irrigated area, should be collected. The latter information is most frequently obtained from groundwater hydrological survey bulletins.

A network of representative wells should be chosen to measure pumped groundwater. Wells are chosen on the basis of similarity of design, casing size and depth, and pump power and discharge size, representing the total area pumped. The total number of wells and time of pumping needs to be included. Static water table levels should be measured in an established network before, during, and after the pumping season. Drawdown should be measured after pumping is started. Observations on water table and drawdown help establish the frequency that pump flow measurements need to be taken. The quantity of flow from a horizontal pipe can be measured with a current meter to obtain velocity and flow calculated from this rate and the cross-sectional area of the pipe. Discharge is usually estimated from the trajectory of discharged water according to vertical height-horizontal component relationships. Static water table and drawdown measurements over the irrigation season can aid in evaluating ground-water supply. The groundwater data described above can be combined with data on precipitation, water conveyance and on-farm water use to develop water budgets. These budgets allow the groundwater recharge to be calculated. Water budgets are described in Chapter VII.

Water Quality

As a first approximation, information concerning water quality can be obtained from chemical analyses. However, water quality cannot be evaluated on the basis of chemical analyses alone. Knowledge of soil characteristics, type of crop grown and crop sensitivity, and details of the irrigation system and specific water management practices within the system must be employed to make more than a superficial evaluation of water quality.

Existing Water Quality Data

Data relating to mineral ion content (total dissolved solids, TDS) and the silt burden of surface waters and TDS of groundwaters should be collected from agencies or other sources. Data consisting of date and location sampled, temperature at sampling time, pH, EC, Ca, Mg, Na, K, CO_3, HCO_3, SO_4, and Cl, as well as silt content should be sought both at the diversion point and after the water reaches the irrigated area to evaluate possible changes occurring during transport. Analyses of total mineral ions should be cross-checked for consistency before doing any summarization. To cross-check, total cations in me/l should equal or be close to the total anion content; $ECX10^6$ x .01 should approximate but not equal total cation or anion content in me/l.

Field Spot-Checks

Conductivity can be measured quickly in the field with a portable conductivity bridge and a dip-cell to give an estimate of TDS. Salt in water measuring more than 750 micromhos/cm can usually be tested.

Individual Sample Analyses

If no data are available, samples need to be analyzed on an exploratory basis to learn basic characteristics of the water and to aid in establishing a compositing procedure for long-term characterization.

Silt Burden

Sediment content is usually determined gravimetrically and reported as mg/l or ppm. Instantaneous discharge measurements should be taken if there is much fluctuation in daily flow.

Mineral Ion Content (TDS)

Usual analyses are: electrical conductivity (EC), pH, Ca, Mg, Na, K, CO_3, HCO_3, SO_4, Cl, NO_3, B, F, Li, and Si. Analysis for Se should be made on selected samples. Instantaneous or mean discharge and water temperature are recorded at the time of sampling.

Polluted Water

Waters contaminated by pollutants from various sources usually have to undergo additional analyses depending on the source of pollution. These analyses may include bacterial, fungal, or virus counts; or tests and determination of heavy metals, such as Zn, Pb, Cd, Fe, and Mn; and determinations of pesticide or herbicide residues.

Composited Samples

Analyses of individual samples become extremely burdensome. Usually average values are satisfactory for many purposes, so daily samples can be composited to represent several days or even monthly averages. Different composites are usually determined by salt measurements and made when EC deviates from predetermined ranges. Compositing of daily samples is done on a time-weighted mean flow basis. Analyses of ions or other factors of interest are made on the composite samples. The determinations may range from partial to complete analysis.

Water Suitability for Irrigation

Water cannot be evaluated for suitability on the basis of water analyses alone. Specific soil, crop, and management practice factors must also be considered to make these evaluations. As water salinity increases, soil permeability must be great enough to transmit the necessary leaching fraction for the control of root zone soil salinity. The land must be level enough to allow uniform infiltration of water over the field. The crop must be tolerant to the salt, sodium, or other ion content of the water for a given leaching fraction. The crop must have sufficient economic value to allow adoption of special seedbed forms and more frequent irrigation as salinity increases.

COMMAND AREA

The command area is defined as the land served by a water supply source. Thus, the command area of a canal contains all of the watercourse command areas served by the canal. In delineating the critical features of a command area, five specific dimensions must be examined. The topography of the area, land capability, cropping patterns, indicators of field and basin size and levelness, and location of general features should be determined.

Topography

In any irrigated area, topography plays a significant role in the location of canals and watercourses, the method of irrigation, types of crops in some cases, soil erosion, and drainage requirements. Besides needing to know the location of hills and ridges, the location and extent of low-lying areas that may require drainage should be delineated. The slope of the irrigated lands is important in determining the appropriate method(s) of irrigation, as well as modifications to existing irrigation practices for increasing the efficient use of water.

Land Capability

Land capability describes the ability of the soil and water conditions to support crop production. The most significant input to defining land capability is an accurate soils classification map. In addition, vegetative mapping of the command area that includes types of crops, phreatophytes, water surfaces, and barren lands is highly useful for showing areas having high groundwater levels, extent of waterlogging, and areas requiring improved management practices. In addition, those areas that have experienced significant erosion should be delineated, as well as saline or sodic areas.

Cropping Patterns

Reconnaissance observations of cropping patterns include the initial gathering of information, via observation and interviews with informed and involved people, under four general topics: 1) existing information, 2) existing crop situation, 3) present inputs into crops, and 4) farmer cropping practices. Crop survey maps and other secondary information about existing cropping patterns should be gathered. Observations of crops presently in the fields should be conducted, and the area of concentration of specific crops (if any) should be determined. Is one type of crop grown only in one section of the area, or are the crops dispersed throughout the whole area?

The percent of the area cultivated should be considered so that the extent of fallow and barren land can be established. The impact of present agricultural inputs, such as water, fertilizer, seed, and farm management practices, on the cropping pattern should be determined. In addition, cropping intensity, use of polyculture, and crop rotations used by farmers should be determined.

Constructing vegetative maps is a critical component to any detailed investigation of cropping patterns. This will establish what crops are planted and where they are planted. Also, information should be gathered on the following topics that were mentioned above to supplement the map:

- What is the actual value of the total area that is cultivated?
- What are the different crops that are cultivated and what percentage of the toal area does each crop utilize?
- What inputs are utilized for the crops?
- How accessible are the various inputs?
- What are the major factors seen by the farmer as determining their choice as to what crop is to be planted?
- What is the cropping intensity?
- What is the degree of polyculture?
- How knowledgeable are the farmers with regard to the on-farm management of their crops?

Field Size and Levelness

Delineating the size of cultivated fields provides information about requirements for the water delivery network, cultivation and harvesting practices, and the economics of the farming enterprise. The levelness of a field is an important index of the expected soil moisture distribution in a field from irrigation and the resulting variation in expected crop yields within the field. This information is also highly important to the Development of Solutions phase.

Location of General Features

There are many general features in a command area that have some importance in the Problem Identification phase. The location of canals and watercourses in relation to farmers' fields usually has a significant impact on irrigation practices. The location of villages, the services available in a village, and the road network are important to agricultural enterprises. Other important features will be drainage channels, ponds, and grazing areas.

WATER REMOVAL

The water removal subsystem is defined as the removal and disposal of surface and subsurface water from land to improve agricultural operations. The objective of drainage is to provide an environment for plants that will result in optimal production of crops. The sources of water may be from precipitation, irrigation, seepage from ponds and canals, seepage from adjacent groundwater aquifers, floods, and application of water for special purposes such as temperature control. In most irrigated areas, natural drainage is inadequate and drainage systems are needed to supplement natural drainage. Care must be taken to differentiate betweeen drainage as a problem or a symptom of another problem such as over-irrigation or an undesirable leaky canal system.

The water removal subsystem has the following primary functions:

1. Provide a salt balance in the root zone.
2. Provide proper root aeration.
3. Improve workability of lands.

Root Zone Salt Balance

All irrigation waters contain salts which, if allowed to accumulate within the root zone, will reduce crop yields. Some water must be allowed to percolate through the root zone to the water table in order to maintain a given or selected salinity level within the root zone. This excess water must be removed from the area either naturally or by artificial drains in order to prevent waterlogging conditions.

The amount of water that must pass through the root zone to keep salinity at acceptable levels is called the leaching requirement. To evaluate this, the following information is required:

1. Amount of salts in the irrigation water,
2. Crop evapotranspiration rates,
3. Crop type in order to select allowable soil moisture salinity levels within the soil, and
4. Salt disposal site.

The amount of salts entering the soil is roughly proportional to the product of electrical conductance of irrigation water and the depth of applied irrigation water. Additional salts may be added by such sources as fertilizers, but this will be small compared to that added by the irrigation water. The amount of salts leaving is proportional to the product of electrical conductance of the drainage water (or groundwater) and the depth of drainage water. Salts removed by the harvesting of crops is small and may be neglected. (The USDA Handbook No. 60, "Diagnosis and Improvement of Saline and Sodic Soils," prepared by the U.S. Salinity Laboratory Staff, has more information).

Aeration Requirements

Excess water in soils will prevent adequate root development. If the gaseous phase does not exist throughout the soil profile, oxygen will not diffuse through the root zone at a rate sufficient to supply respiration needs of the plant. Carbon dioxide and other products of metabolism will not diffuse away as fast as it may be produced by microorganisms and the plant roots may then accumulate toxic concentrations. Anaerobic decomposition may occur and produce toxic gases and chemicals such as sulfides and methane. Also, some minerals may become insoluble and consequently unavailable to plants. All of these factors limit production of most crops.

A notable exception is rice which is able to survive in submerged soil for long periods of time due to the fact that diffusion of gas can also take place through the plant structures. In addition, oxygen can diffuse from one portion of the root to another, through the intercellular ventilating system.

Plant species vary widely in ability to transfer gases from atmosphere to root tips and to withstand the products of anaerobic conditions. Although some plants will grow only in soils submerged in water, the majority require aerated soil. All plants, however, are able to extend their roots into unaerated soil for a limited distance.

It has been estimated that if the soil contains air to fill approximately 15 percent of the void space than aeration problems are minimal. To provide the proper aeration zone requires that the depth to water table be maintained at an adequate level.

Workability of Lands

The presence of water in soils reduces the capacity of soils to resist shearing and compressive stresses. When plowed or worked over by other equipment in a wet state, soil compresses. Upon drying, the compressed soil may form hard clods and less permeable dense layers below the cultivated layer. Large clods would interfere with the preparation of the seed bed, and the dense, less permeable layers would interfere with normal root extension, thus reducing the volume of soil that may be occupied by roots. It is desirable to have well-drained soil so that cultivation or other soil preparations can proceed with a minimum delay following rains or irrigations. The effect of water on compressibility of soils is more important as the amount of clay in the soil increases.

Another mechanical effect is the increase in heat capacity due to the presence of water. More heat is required to raise the temperature of wet soil than would be required for the same volume of dry soil. Furthermore, evaporation of water requires heat and may take place without change in temperature. The combination of these two factors results in wet soils remaining colder during periods of increasing atmospheric temperatures and can delay seed germination during the planting season as well as retarding growth after germination. Conversely, wet soil remains warmer during periods of decreasing atmospheric temperature and can reduce the effects of freezing conditions.

The concentration and type of salts in the water affect the mechanical behavior of soils due to the reaction of clay minerals to electrolytes in solution. Three general types of clays are recognized and differ in chemical composition. In addition, there are many subtypes differing in respect to crystalline form. The three main types are kaolinite, montmorillonite, and illite.

Sources of Drainage Water

A given field may contain one or more problems in that the excess water may be due to one or more sources. The identification of the problem and a solution to the problem depends on the source of the excess water. In most cases, it is necessary to control the water table from rising too high for too long a period of time. Specific sources of problems may be:

1. Impermeable substratum - The source of the excess water is local and enters in the area by infiltration from the ground surface. The impermeable substratum is too shallow and level over a large area so that the perched water cannot drain sufficiently under natural conditions.

2. Artesian aquifer - Excess water enters soil due to water pressure in an artesian aquifer below the agricultural lands. The source may be local in that it enters the soil at the point near where the problem exists.

3. Non-local source - Seepage from canals, lakes, etc. flows through the soil to a lower spot where an excess amount accumulates.

4. Low permeability - The soil will not transmit water adequately to provide proper aeration and/or leacning.

5. Excess application - Water is supplied in excess of that which normally good grainage can remove in a reasonable period of time.

6. Large level area - Hydraulic gradient of subsoil aquifer is too flat to remove water as fast as percolation to the water table takes place.

7. Elevation too low - Land may be at an elevation too near that of a lake, sea or ocean. There is no subsoil outlet at a sufficiently low elevation.

8. Basin - Subsoil of surrounding land all drains toward the area. There is no natural drainage away from the area.

Evidence of Drainage Problems

The need for drainage will be evident from:

1. Shallow root penetration,

2. Prevalence of plants normally found in swamps, such as cattails,

3. **Soil mottling** (soil marked with spots of different colors, usually gray and bluish gray) due to reduced compounds,

4. An odor of methane or other gases of reduced compounds,

5. Soil which dried slowly, even during prolonged dry periods,

6. A high water table, that is, water stands in open holes and ditches at a depth less than a meter below the surface,

7. Presence of salts on the soil surface, and

8. Standing water for prolonged periods of time.

CHECKLISTS

For the water supply and removal subsystems, example checklists for the Reconnaissance subphase are provided in Table 15, while the example checklists for the Problem Diagnosis subphase are given in Table 16.

INTERDEPENDENCY OF WATER SUPPLY AND REMOVAL SUBSYSTEMS WITH INSTITUTIONAL INFRASTRUCTURE

The institutional infrastructure required for the farm management system to function adequately is as complex as it is important. The purpose is to provide the organizational supports necessary for successful manipulation of the farm system to achieve both individual and social goals. There is a direct relationship between how water is supplied and used at the farm level by farmers; and the removal of excess water through drainage and the macro- and micro-level organizational arrangements. For example, Table 17 shows some of the major types of organizational arrangements as related to the water supply and water removal subsystem. Chapter VI suggests several other organizational supports needed for successful functioning of the total farm management system.

Table 15. Checklists on reconnaissance methods for water supply and removal.

Climatic data:	_____Obtain solar radiation data. _____Measure air temperature. _____Measure relative humidity. _____Measure windspeed and direction. _____Measure rainfall. _____Determine rainfall distribution. _____Other (specify) ____________
Climatic hazards:	_____Obtain windspeed records. _____Gather flood data. _____Gather frost data information. _____Record frequency of hail. _____Check records of high intensity rainfall. _____Other (specify) ____________
Source and availability:	_____Check existing data for rainfall. _____Check data for surface flows, reservoir, and dam storage. _____Check existing data for groundwater. _____Spot-check irrigated fields. _____Other (specify) ____________
Water supply:	_____Check existing records. _____Make preliminary interviews with long-time residents. _____Observe surface flows in the area. _____Take quick and available measures with flow meters, etc. _____Observe fields for visible signs of water-logging, leaks, spills, dead storage. _____Observe maintenance of channel banks, check sediment deposits, location and extent of phreatophytes, and condition of irrigation structures. _____Other (specify) ____________
Water quality:	_____Obtain existing water analysis data. _____Make spot-checks in irrigated fields. _____Other (specify) ____________
Command area:	_____Check the conditions of the area: terrain, hills, depressions, irregularity of relief areas. _____Use existing maps and records to note topography. _____Make informal interviews with people in the area.

_____Check land capability: Look at internal conditions--soil texture, soil zones, climate, vegetation, landforms, soil water conditions, and organisms present.
_____Observe uniformity of soil type throughout the area.
_____Check critical external conditions such as erosion, waterlogging, lack of water, crops grown, saline areas, sodic areas, and barren areas.
_____Observe existing crop patterns--concentration of crops, percent of area cultivated, and extent of fallow and barren land.
_____Observe slope or topography.
_____Note sizes of farm fields and irrigation basins.
_____Check location of roads, pumping stations, village boundaries, common areas, grazing areas, drainage and conveyance channels, check and diversion structures, and location of field inlets.
_____Other (specify) _______________

Water application:

_____Check available data.
_____Observe methods of water application used.
_____Estimate level of irrigation basins and infiltration rates.
_____Discuss with farmers their perceptions of benefits of irrigation methods used.

Crop water use:

_____Determine actual evapotranspiration.
_____Determine crop water coefficients.
_____Other (specify) _______________

Irrigation timing:

_____Determine "field capacity" and "wilting point."
_____Use tensiomenters, gypsum blocks, or fiberglass blocks to check irrigation frequency
_____Use gravimetric moisture samples or neutron probe moisture measurements to determine soil moisture storage before and after irrigation.
_____Other (specify) _______________

Water removal:

_____Utilize existing data on tailwater runoff, and subsurface flow and drainage.
_____Interview appropriate people about runoff problems, subsurface flows, drainage problems, and subsurface drainage characteristics.
_____Identify existence of nearby drainage projects which may indicate cost-effectiveness of drainage.
_____Examine existing wells.
_____Other (specify) _______________

Table 16. Checklists for detailed diagnostic methods for water supply and removal.

Climatic data:

_____Set up weather observation stations.
_____Check water supply problems.
_____Gather data from area on source of groundwater.
_____Calculate irrigation requirements.
_____Check crop adaptation problems.
_____Other (specify) ____________

Sources and availability:

_____Set up network of rain gauges to obtain rainfall data.
_____Measure stream and river flow.
_____Measure reservoir and dam storage, including inflow, outflow, and storage at given times to assess evaporation losses.
_____Set up a network of representative wells to measure pumped groundwater.
_____Other (specify) ____________

Water supply:

_____Develop monthly frequency diagrams of precipitation.
_____Check measurements of surface water flows: stream flow records, capacity of conveyance works, and diversions.
_____Measure quality of flow--sediment loads, water-borne diseases, and salinity.
_____Measure quantity of water flow being pumped.
_____Check variability in pumping rates.
_____Check depth of groundwater.
_____Measure salinity concentration.
_____Check ionic constituents of groundwater
_____Record delivery schedules.
_____Determine if the system operates on a demand basis or according to available flow.
_____Measure the apportionment of available flows.
_____Measure water surface levels.
_____Record types and sizes of irrigation control structures.
_____Measure seepage in ditches, canals, pipelines, etc. (ponding and inflow-outflow measures).
_____Measure leakage through and around headgates and other structures.
_____Measure consumptive use by phreatophytes and hydrophytes.
_____Measure discharge by Cutthroat flume.
_____Measure discharge by subtracting seepage losses from canal deliveries.

Water quality:

_____Take individual sample analyses, including determination of silt burden, mineral iron content, and polluted water.
_____Obtain composite samples.
_____Other (specify) ____________________

Command area:

_____Make a topographic map.
_____Make a map of soil types.
_____Construct a crop pattern map.
_____Determine distance from watercourse to the various fields.
_____Note elevation difference of fields.
_____Check watercourse slope and cross section of channels to farmers' fields and field outlets.
_____Determine drainage systems; length, depth, and cross sections.
_____Prepare a survey map of general features of concern. It should include all of previous observations plus cropping patterns, structures, field boundaries, barren areas, and village area.

Water application:

_____Measure length and width of fields and basins.
_____Measure water supply rate to fields.
_____Determine field topography.
_____Measure the infiltration of water into soil profile.
_____Estimate the field application efficiency.

Crop water use:

_____Obtain existing evapotranspiration data.
_____Calculate ET from available weather data.
_____Other (specify) ____________________

Irrigation timing:

_____Make field observations.
_____Calculate potential and actual evapotranspiration from existing data.
_____Estimate critical water use periods of crops to be grown.
_____Other (specify) ____________________

Water removal:

_____Develop map showing all minor and major drains, outlets, inlets, and structures above and below ground and topography of area.
_____Identify all sources of excess water.
_____Determine the leaching requirements for control of salinity.
_____Determine bedrock elevations, soil types, and other geological features that relate to water removal.
_____Establish water table elevation over time throughout cropping cycle.
_____Determine direction of groundwater flows.
_____Determine the extent of existing and probable drainage problem areas.
_____Determine hydraulic conductivity of soils and bulk density of soils.

Table 17. Major organizations related to water supply and removal.

Types of Organizations	Relationship to Water Supply and Removal
A. Macro Level	
1. National Planning Commission	National planning for development and improvement of water supplies and removal in relationship to national goals.
2. Ministry of Irrigation	Research, planning, and evolution of new and improved systems; policy and codes regulating water supplies and drainage.
3. Revenue Department	Joint planning with relevant agencies related to water revenues and levies and subsidies for farm level improvements.
4. Ministry of Agriculture	Joint planning with Ministry of Irrigation on water supplies required on seasonal and yearly basis.
B. Micro Level	
1. Provincial and District Irrigation Authorities	Implementation of irrigation policy, codes, operation and maintenance of the water supply and removal subsystem.
2. Provincial and District Agricultural Authorities	Implementation of programs with irrigation authorities related to maintenance and improvement of system; collection of revenue.
3. Research and Extension	Research related to water supplies, water use, and removal and transfer of technology.
4. Farmer Organizations	Cooperatives, water user associations, and informal organizations for operation, maintenance and improvement of water supply and removal system.
5. Other Organizations (Health, Credit, etc.)	Regulations about health hazards, related to water supply and removal; credit facilities for improvement of water supply and removal system.

CHAPTER VI

INSTITUTIONAL LINKAGES

In order to comprehend the whole system, the institutional linkages must be understood. These include relationships with water/irrigation institutions, agricultural services, and the socio-cultural network (Figure 12).

WATER IRRIGATION LINKAGES

To understand the water/irrigation institutional infrastructure there are two major concerns. First, how are the critical components of the infrastructure identified? Second, how are the actual practices as well as the written legal constraints of the water management improvement program recognized? Four areas that must be included in considering these questions are policies, laws/regulations, organizations, and linkages.

Policies

A policy is a statement of objective intent enacted by the governing body, either local, regional, provincial, or national. It provides guidelines for implementing organizations. Points to be considered when looking at policies include specific policy statements, preambles to laws that may specify policy, and general governmental policy statements.

Laws, Codes, and Regulations

In searching for specific laws, codes, and regulations and their administration, the following should be done:

- Identify laws, codes, and regulations
- Identify the differences between the law as written and as practiced
- Identify how the law is to be carried out--control, sanctions, and penalties

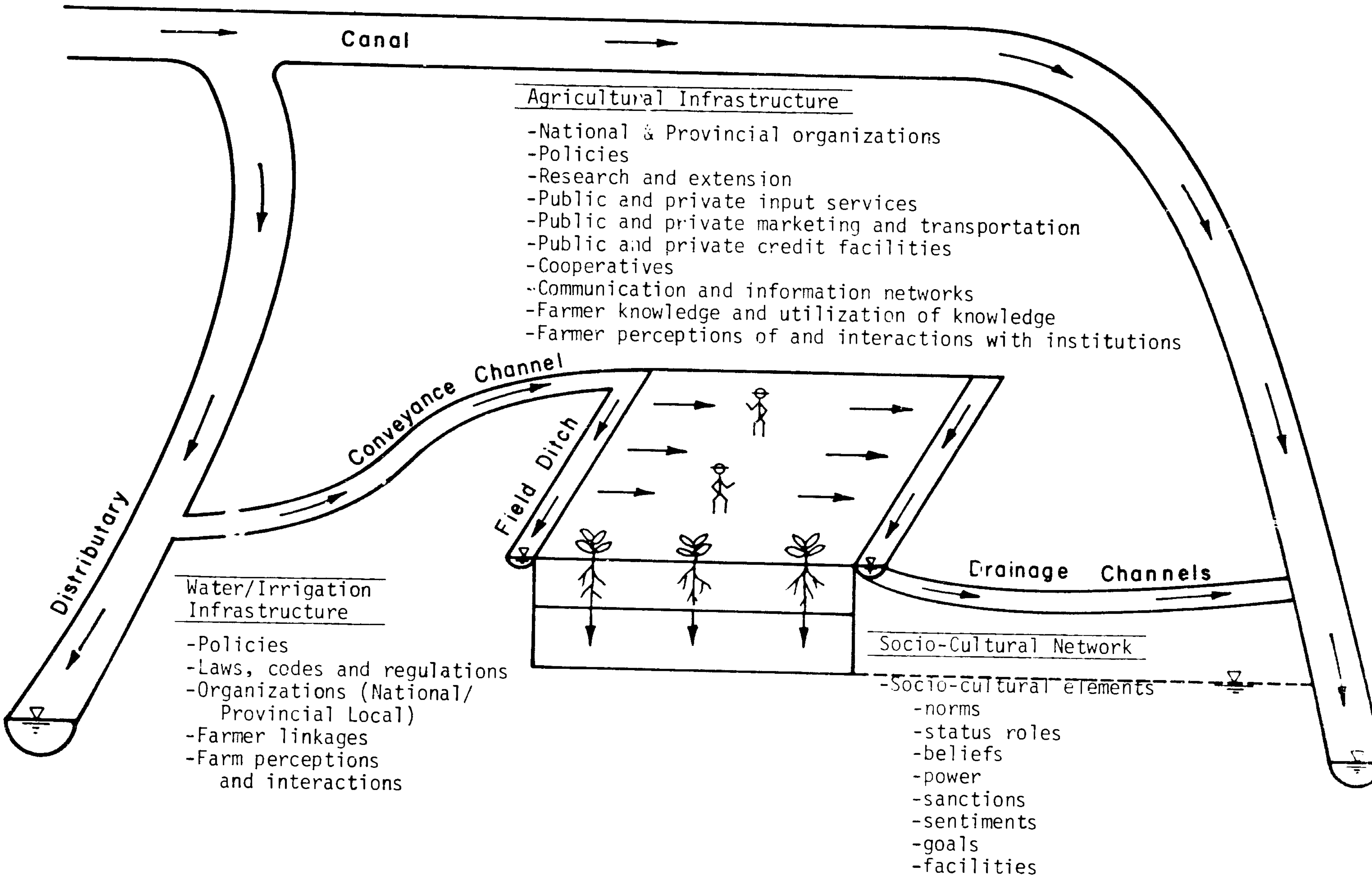


Figure 12. Idealized sketch of the institutional infrastructure for a farm irrigation system.

- Identify if the system of law is national or federated
- Examine legal priorities
- Check land tenure legislation

Organizations

To examine the organizations involved in dispensing the law, several areas should be investigated including:

- The hierarchical structure of the involved organizations such as leadership patterns
- The flow of formal and informal communication
- The structure of the organizations including size and complexity
- The rules and regulations of the organizations
- The relationships of the various organizations to each other and to the people, emphasizing conflict and cooperation
- The actual performance of these organizations at the farm level

Linkages

Linkages among the various governmental organizations can be described by examining the types among various governmental organizations, and among the organizations and clients. The degree of cooperation, conflict, and communication both formally and informally should be studied.

AGRICULTURAL INFRASTRUCTURE

In addition to the various water and land-related organizations and institutions within the country, there are many agricultural services that must be investigated for their potential input or constraint on the development program. Generally, these agricultural services not only include the type of service that is made available and the program under which the services are promoted, but also the organization that has responsibility for carrying out the program. That responsibility includes the laws, rules, and regulations creating the organization and directing the scope of activities.

Agriculture and Water Organization

Most countries have both a national federal Department of Agriculture and a similar organization at the provincial, state, or regional level. At the outset it is essential to identify the organizational structure of the agriculture department at both the provincial and national levels to identify the basic scope of authority and become aware of programs.

Key personnel at both the national and provincial levels within the agricultural and irrigation department should be identified. Program reports and other research conducted by the agriculture and irrigation departments on topics related to the development program should be reviewed. This same process should be followed with the water resources planning and development agency. Interviews should be conducted with key personnel and farmers as to their outlook on departmental programs and adoption of improved water management practices. In addition, the farmers should be interviewed to determine their attitude toward the capability of the departments to implement an improved water management program at the farm level.

Research and Extension

One of the important aspects of the reconnaissance investigation is to identify and describe the research and extension organizations, their facilities, location, and program within the portions of the provinces affected by the proposed on-farm water management development program.

The two functions of research and extension should be segregated. Then, research reports relevant to the problems of the proposed water management development program should be obtained. These reports should be reviewed for comprehensiveness, usefulness in the proposed program, and the extent of past utilization of the reports. In addition, a thorough investigation should be undertaken of the research capability in terms of personnel, facilities, and jurisdiction. Also, the degree of cooperation between research institutions and between the research institutions and government agencies should be identified.

The activities of the extension services should be ascertained. The type of personnel employed, the past topics or type of services embraced, the capability of extension personnel to undertake the extension-type activities required under the proposed program, and credibility with agricultural communities should be evaluated.

Agricultural Input Services

During the reconnaissance subphase, the extent to which the government has formed a structure for providing such agricultural input services as seed, fertilizers, and agricultural chemicals for pesticide and herbicide control should be determined. Introduction of appropriate equipment for preparation of planting and harvesting of crops, as well as other equipment necessary for the type of rural farm life found in the areas to be affected by the program should be made. During the problem diagnosis subphase, a detailed examination of the extent and availability of the agricultural services identified during the reconnaissance should be conducted. In this process, the agency that has responsibility for the various services should be identified along with organizational aspects of its involvement, type of personnel employed, and the extent that programs have been completed. In addition, from a sample survey, the perception of the farmer as to the success or problems with the input services should be determined. The extent to which the private sector makes the various agricultural input services available, and the types and costs of the various services must be evaluated.

Marketing and Transportation

During reconnaissance, the extent of government involvement and the extent of the private sectors' involvement in storage, marketing, and transportation of agricultural commodities should be identified. In addition, the organizational structure and responsible persons for those services should be determined. Having identified the extent of government and private sector involvement in storage, marketing, and transportation of agricultural commodities, it is important to determine the location of the storage facilities, type of commodities handled, cost to the agriculturalist for use of the services, and problems that the agriculturalist has experienced in the past. The marketing segment must be examined to determine the local, regional, national, and international aspects of the marketing component, and again to determine the cost and involvement of the agriculturalist in price control. Transportation is critical for many commodities, thus it is important to determine the extent of the transportation network throughout the country as it affects the commodities grown in the areas affected by the proposed water development program.

Credit Institutions

The program staff should obtain reports, rules and regulations, and specific program information from the various credit institutions, particularly in the regions to be affected by the proposed program. Also, the extent of branch banking services and requirements of the credit institutions for farmer participation in the programs should be identified. Informal credit arrangements are also important and must be determined from interviews.

Cooperatives

During reconnaissance, the national or provincial law on cooperatives should be obtained and the structure of the cooperative organizations from the highest level down to the local level within the districts or villages determined. In addition, the annual reports prepared by the cooperative societies should be obtained and their involvement in the agricultural sector ascertained.

During the problem diagnosis subphase, key people in the cooperative organizations at the high levels who provide information on the internal rules and regulations and degree of control over the various cooperatives should be identified. In addition, the requirements for agricultural involvement in these cooperatives should be determined, as well as the type of cooperatives that have been organized in the past and their number and location throughout the country. A survey should be made to determine the degree of acceptability of the cooperatives as a mechanism for improving agricultural production.

Communication and Information Networks

The agency at the federal level responsible for licensing and controlling communication networks should be determined. Then, the laws, regulations, and reports on the location of radio stations and requirements they may have regarding announcing the availability of agricultural services and agricultural programs can be obtained. A detailed examination of the communication network can be conducted. Also, whether there are information networks within the various government organizations concerned with water, agriculture, and land to which communication can be conveyed directly to the rural communities can be determined. Also, the extent to which religious and community practices can provide an information network into the rural communities can be evaluated.

Farmer Perceptions of Institutions

It will be very difficult during reconnaissance to determine the extent of the farmer's knowledge and his uses and perceptions of the various institutions described in the items above. However, it may be deemed important to identify points throughout the country which indicate the segments of society to be affected by the proposed program and to conduct a limited number of informal interviews with selected informants to obtain a basic understanding of the farmer's perception and knowledge. Later, a selected number of farmers should be subjected to a rather extensive interview as to their knowledge and availability of these services, the extent that they have utilized them in the past, whether they consider the services are beneficial or harmful, and whether or not these services have potential for assisting in the implementation of the proposed water management development program.

SOCIO-CULTURAL NETWORK

From the perspective of institutional linkages, the major focus of study in a problem identification effort centers around the irrigation behavior of the farmer. This section presents a format that may be utilized to delineate specific institutional variables that describe the conditions influencing the farmer's behavior regarding irrigation. This format will be constructed in a manner that will provide an organized design from which researchers may direct their thinking when pursuing answers to such questions as why farmers irrigate the way they do.

The farmer as a decision-maker is subject to many influences which direct the way that he chooses to behave. The major influences emerge from two general environments: the physical and the institutional.

With regard to the physical environment, the farmer must learn to adapt or adjust to the existing natural constraints such as topography, soil types, quantity of water available, quality of water available, climate, and other aspects. Concerning the institutional environment, the farmer is thrust into a network of rules, organizations, beliefs, and interaction patterns that shape the experiences to which the farmer must react to and act upon. These two environments provide the benchmark from which decisions regarding the irrigation behavior of the farmer are to be made.

All aspects of the two environments will not directly affect the farmer. There are aspects of the physical environment which may be present in the general area of the farmer but do not have any detectable effect upon that person's situation. For example, there may be a specific type of soil in the area, but if that soil is not on the farmer's property it has no effect on the farmer in making his decision on fertilizer and pesticides. The same idea also pertains to the institutional environment surrounding the farmer. There are many organizations in this environment which do not touch the lives of the farmer. What is of importance is to point out that not only is the farmer integrated into the physical and institutional environments which surround him, but also the degree of integration is highly variable due to many circumstances in the farmer's existence. Also, there are aspects of both the physical and institutional environment over which the farmer has varying degrees of control. These range from factors over which he has no control such as climate and soils to decisions about specific crops to grow and inputs to utilize over which he has more control. Farmers usually have limited influence over markets, prices, and other policies which affect his behavior greatly.

The goal of problem identification is to find the significant aspects of the two environments which influence the farmer's irrigation behavior. For the sociologist, that goal pertains to the institutional environment. Since an irrigation system comprises a patterned set of relationships which exist among farmers, between farmers and organizations, and among organizations, it can be seen that the behavior of the farmer will be subject to many different types of influences. What must be determined, given the parameters of the situation and the specific physical problems of the area, is how do these various influences affect the behavior of the farmer at a particular time.

In attempting to examine how the different influences affect the behavior of the farmer, it is necessary to delineate what influences affect that person's behavior. A format where the numerous influences affecting the farmer may be categorized is shown in Table 18.

Table 18. Format of major sociological categories affecting the decision-making process of individuals.

Situation				Action
Setting	Culture	Structure	Process	Result
Size Time	Activities (Sentiments & beliefs)	Placement of the individual (Status Role position)	Communication	
Territori-ality	Relationships (Sentiments & beliefs	Characteristics of the Individual	Boundary Maintenance	Decision-Making
Facilities	Rules (Sentiments & beliefs)	Capacity of the individual (Power and Stratification)	Systematic Linkage	
			Social Control	

This format is first divided into two major sections: 1) the situation section and 2) the action section. The situation section describes the conditions surrounding the farmer. The action section describes the behavior of the farmer with respect to irrigation, in terms of that individual's response to the situation surrounding him. Within the two sections five categories are presented which consist of the major areas of influence encompassing an individual. What is to follow will be a detailed discussion of those areas and the dimensions making those categories.

The Setting for Social Action

Conditions for social action are those attributes that create a particular setting of territory, size, and time.

Territoriality

This is the spatial arrangements and requirements of a social system. It may include the placement of the village with regard to the fields.

Size

Size is the geographic area comprising the social system. For example, it describes the command area of the watercourse.

Time

Time is the framework within which a social system operates. Seasonality of crops and their influence on the farmer's work habits is an example of the affect of time.

Facilities

Facilities are the means to achieve the ends. Establishment of a credit system to purchase fertilizer for placement on fields is an example of the effect of having facilities.

Elements for Social Action

Elements are units of analysis that describe social interaction. They are classified as cultural and structural elements.

Cultural Elements

Culture describes the patterned ways of thinking, feeling and behaving in the social setting. Three general dimensions that provide the parameters for examining culture are:

- Activities - those deeds and actions performed by the farmers.

- Relationships - the social interaction between actors involved in a specific activity.

- Rules - the normative behavior governing what relationships are established and what activities are defined as socially acceptable or unacceptable.

Behavior is not the only criteria used to describe cultural conditions; under each of the dimensions beliefs and sentiments are also important to acknowledge. Beliefs are aspects of the institutional environment that are accepted as true (knowledge) while sentiments are feelings about the situation into which the farmer is placed. An example of a belief may be the view of the farmer that root systems of crop plants are very shallow. An example of a sentiment may be the farmer's feeling about government officials or the feeling that fellow farmers will not cooperate.

Some of the aspects of culture are norms, sanctions, beliefs, sentiments, and goals. These terms are described below.

Norms. Standards or rules that prescribe what is socially acceptable or unacceptable are called norms. For instance, the practice of trading water between farmers on a watercourse is acceptable in one country, while it is considered illegal in another. The norm is if and how the water is traded.

Sanctions. Rewards and penalties meted out by a social system to its members to induce conformity to the norms are defined as sanctions. A farmer, for example, is caught trading water in which the norm is not to trade water and is fined an amount of money as a punishment.

Beliefs. Beliefs are aspects of the universe that are accepted as true by the social system at large. Farmers as a whole may believe that cotton needs a particular amount of water to survive. This belief mav be verified scientifically or it may be demonstrated that a lesser amount of water is sufficient. Regardless if the belief is true or false, the people may believe it is true.

Sentiments. Feelings about the world as expressed by the general population are called sentiments. They may include the feelings of solidarity surrounding the membership in a brotherhood group.

Goals. Changes that members of a social system expect to accomplish through the operation of the system are called goals. A goal may be to increase crop yield by putting fertilizer on the fields of the farmers.

Structural Elements

Structure is the aspect of a social system which describes the relationships established in that setting. Structural dimensions include 1) placement of the individual in a social system (the status-role position), 2) characteristics of the individual, and 3) the capacity of the individual in terms of power and stratification.

Status-Role. This is an organized subsystem describing the behavior of individuals and their interpersonal relationships via reciprocal orientations. For example, two status positions would be an area farmer and an irrigation official. Each have a particular set of behaviors they perform. The farmer plants crops and raises animals, and the irrigation official distributes water. These two status-role positions interact when the farmer is allowed to consume only so much water for his irrigation turn. The rules governing the interaction provide the orientation surrounding that interaction between the two persons.

Characteristics of the individual. These include personal descriptions of the individual such as age, sex, marital status, etc.

Capacity of the individual. Power may be defined as the ability to control others. For example, landlords can force their tenants to perform specific work tasks for the landlord such as cleaning irrigation canals or providing fodder for the landlord's cattle.

Stratification is the unequal distribution of valued resources such as wealth, power, and prestige. For example, farmers along a watercourse are stratified according to the amount of land they own, their income, and their relative position on the watercourse.

Processes for Social Action

Processes are continued actions that create a different ordering and arrangement of the elements of a social system. They determine the development, the persistence, and the change of social systems. Included in the processes are communication, evaluation, decision-making, boundary maintenance, and systematic linkage.

Communication

The process by which information, decisions, and directives pass through a social system is called communication. It also includes the ways in which knowledge, opinions, and attributes are formed or modified. For example, the extension program communicates to farmers new programs concerning hybrid crops and new fertilizers to change their old farming habits so that farmers may increase their yields.

Boundary Maintenance

The process where the social system maintains its identity and interaction patterns is boundary maintenance. For example, some groups will not allow their members to marry someone from another group.

Systemic Linkage

This process combines elements of at least two social systems so that they function somewhat as a unit. An example might be the university extension program that forms a linkage with the farmer to initiate new farm techniques

Social Control

Social control is the process by which deviance is counteracted. An example of social control is the enforcement of laws to make sure farmers do not trade water amongst themselves, steal water from canals, or steal water from each other.

The Resulting Social Action

The result constitutes the action position in this format. In the sense of problem identification the result only refers to the decisions farmers make about their operations given the situations in which they are placed. Thus, decision-making will be defined as the process where alternative courses of action are available and acted upon so some sort of action proceeds within the social system. An example would be where a farmer decides on what crops to plant based on his perception of climate, water supply, credit, seed availability, and other inputs.

Individual Decision-Making Environment

First, individual farmers do not allocate their resources independently of their neighbors, rather they are part of a complex web of obligations connecting them with their neighbors and relatives. Second, farmers do not depend on "average" or "normal" returns such as those derived in the representative farm budgets. Rather, the farmers are subject to extreme variations in yields due to causes beyond their control (rainfall, disease, pests, sickness, market changes, political changes). Both farm-to-farm competition and variations related to prices and other variables influence the individual farmer's decision framework. Therefore, these factors need to be carefully considered to understand root causes of farm production problems.

The Collective Decision-Making Environment

An individual farmer's choice of alternative is restricted and defined by the relationship he has to the whole community, and this is especially manifested when certain resource allocation decisions are made at higher levels. For example, in communal systems the decision of when and where to plant are usually taken at the village or extended family level. Another example is that of water users' associations which collectively decide on schedules, shares of water, and allocations of costs for maintaining the watercourse. Finally, national government decisions affect availability and prices of inputs (e.g., chemicals, transportation, credit). Prices of outputs are often set by the government and in some cases farmers are obliged by the government to grow certain crops. In examining this collective decision-making environment, the following dimensions should be examined: land, labor, water, credit, and output.

Format for Irrigation Studies

The different types of conditions that can affect an individual farmer are depicted in general terms in Table 18. In Table 19, those same conditions are presented in the context of the irrigation behavior by the farmer. As can be seen, the Action-Result section pertains to the different decisions a farmer may make with regard to the utilization of his irrigation water. The different dimensions within the situation section represent a number of factors which have the possibility of influencing that farmer's irrigation behavior. As can be seen, the list of factors in this general diagram is extensive and the researcher must not allow himself to become tied down in the morass of detail which can emerge. The purpose of this format is to only provide a guide for the researcher who pursues problem identification only.

SUMMARY

Problems are obstacles on the way to the accomplishment of goals. In the case of water management, the major goal is to increase the productivity of resources in an irrigation system. It is fitting, therefore, that this manual uses the plant environment as a starting point for identification of problems in productivity. Inputs to the plant are nutrients and water which are supplied through a complex system of human endeavor. The farmer also depends upon larger systems for sustenance and many of the inputs used in caring for crops.

Symptoms of problems occur, by the nature of the program goal, at the plant or farm level. Primary obstacles to productivity may, however, be far removed from the farmer's field. Thus, when the agronomist finds that soil nutrients or condition limits crop production, the researcher needs to begin examining the system to determine the reason that the best practices were not used. It could be lack of knowledge, lack of incentive at the farm level, or lack of access to necessary inputs. In the last two cases, the source of the problem may extend into the system as far as the institutional infrastructure. Furthermore, even if initially the problem is ignorance, it is possible that removal of ignorance will lead to the discovery that other obstacles are constraining. Consequently, it is the responsibility of the problem identification staff to determine the causality to its origin.

During the Reconnaissance subphase, the checklists provided in Table 20 can be used as a guide in studying institutional linkages. The checklists in Table 21 are intended as guidelines for evaluating institutional linkages during the Problem Diagnosis subphase.

Table 19. Format of sociological components affecting the irrigation behavior of a farmer.

SITUATION				ACTION
SETTING	CULTURE	STRUCTURE	PROCESS	RESULT
Size: - Size of irrigation area - Length of watercourse - Length and size of diversions	Activities: - Farming procedures (sowing, planting caring for crop, harvesting, etc - Irrigation procedures: (diverting water, application of water, drainage of water) - Use of groundwater and surface water - Use of Infrastructure (obtaining credit, buying fertilizer and other inputs, selling crop, extension, etc)	Placement of Indiv.: (Status role) - Ownership - Tenure - Brotherhood/caste/family - Position in organization (if any) in agric infrastructure (co-op, WUA, etc.) - Position (if any) in the village - Position (if any) in the government	Communication: - Farmer with other farmers - Farmers with organizations in infrastructure - Farmers with organizations in infrastructure - Farmers with government - Farmers with non-agricultural organizations	Decision Making:
Time: - Seasonality of crops - Multicrop - Time of irrigation delivery				Farm Management and irrigation behavior
Territoriality: - Placement of village - Placement of farmers to each other - Placement of farmer on watercourse - Fragmented plots - Placement of services to farmer - Placement of irrigation to urban areas - Placement of irrigation area to government services	Relationships: (B&S) - Farmer to family - Farmer to farmer - Farmer to organization in infrastructure of local areas - Farmer to government - Farmer to non-agricultural sector	Characteristics of the Individual - Demographic charac. (age, place of residence, migration, marital status, size of family, etc.) - Attitudinal characteristics	Boundary Maintenance. - Among the farmers - Among infrastructure organization - Between ultrastructure organizations and farmers - Between agricultural organizations and non-agricultural organizations - Between the government and local area	
Facilities: - Technology available - Qualitative level of structures - Areal level of canal and laterals - Infrastructure support material - Farm equipment availability and quality of that equipment - Other physical parameters (amt. of water, etc.)	Rules: (B&S) (Formal & Informal) - Rules governing family relations (i e , fragmentation) - Rules governing association and interaction among farmers - Rules governing farmer interaction with infrastructure - Rules governing farmer interaction with government (i e , water laws, etc) - Rules governing farmer interaction with non-agricultural sector - Rules vs. the actual practices (de jure vs. defacto)	Capacity of the Individual: - Power - Prestige - Wealth - Linkage (influence) with other farmers - Linkage (influence) with organizations in agricultural infrastructure - Linkage (influence) with government - Linkage (influence) with non-irrigation organizations	Systematic Linkage: - Refer to boundary spanning section Social Control: (Formal & Informal) - Between farmers - Between farmers and infrastructure organization - Within infrastructure organization - Outside infrastructure	

Table 20. Checklists on reconnaissance methods for institutional linkages.

Water/irrigation:

Policy

_____ Look for existing policies.
_____ Interview knowledgeable people about policies.
_____ Check news reports for information.
_____ Search records, laws, speeches to extract policy statements.
_____ Other (specify) _____________

Law

_____ Obtain existing material.
_____ Observe how laws are implemented.
_____ Interview appropriate people.
_____ Check daily news.
_____ Other (specify) _____________

Organization

_____ Obtain existing data on by-laws and procedures.
_____ Observe leadership roles, communication channels, organization structure.
_____ Interview members of various organizations.

Linkages

_____ Obtain existing data on committees with farmers, letters of agreement, liaison personnel, public relations efforts.
_____ Interview appropriate people.
_____ Observe linkages.
_____ Read news reports.
_____ Other (specify) _____________

Agricultural services:

_____ Identify organizational structure of the agriculture department at both the provincial and national levels.
_____ Identify basic scope and authority and existing programs of the agriculture department.
_____ Describe the research and extension organizations, their facilities, location, and program within the portions of the provinces affected.
_____ Determine government input services for seed, fertilizers, chemicals for pesticide control, and equipment.
_____ Determine the extent of government and private involvement in storage, marketing, and transportation of agricultural commodities.
_____ Determine organizational structure for marketing and transportation services.
_____ Obtain reports, rules and regulations, and specific information about various credit institutions in the region.

_____Identify the extent of branch banking services and requirements for farmer participation in the programs.
_____Check national and/or provincial law on cooperatives.
_____Determine structure from national to local level of cooperative organizations.
_____Obtain annual reports of cooperatives.
_____Determine what agency at national level is responsible for licensing and controlling communication networks.
_____Obtain laws, regulations, and reports on the location of radio stations and requirements they may be under in announcing availability of agricultural services and programs.
_____Interview farmers about their knowledge, use, and perceptions of agricultural organizations.
_____Other (specify)_______________

Socio-cultural network:

_____Check existing studies of the social system.
_____Observe elements that superficially seem important in the problem area.
_____Make preliminary interviews with various farmers and leaders in the area.
_____Observe changes or potential changes occurring in the social system in the area.
_____Determine degree of fluctuation in prices of commercial inputs and crops.
_____Determine the role of government control in crop prices and agricultural input prices.
_____Determine the dependability of marketing services for both crops and agricultural inputs.
_____Determine broad outlines of the land tenure system.
_____Check formal laws governing the relationships between tenants and landlords, family members to extended families, farmers to village leaders, and villages to local officials.
_____Other (specify)_______________

Table 21. Checklists on detailed diagnostic methods for institutional linkages.

Water/irrigation:

_____Search intensively through records, laws, and speeches to extract policy statements.
_____Interview farmers and leaders.
_____Identify laws, codes, and regulations.
_____Check differences in the law as written and as practiced.
_____How is the law categorized--surface water control, groundwater control, etc.
_____Is system of law national or federated?
_____What are legal priorities?
_____Check land tenure legislation.
_____Determine who controls access to land.
_____Check implications on ownership of land.
_____Check for minimum wage laws in urban areas.
_____Check village labor market for specialties by craft, caste, or family.
_____Check who controls timing and quantity of irrigation.
_____Determine who controls cost of water.
_____Determine who controls maintenance of water system.
_____Interview organizational leaders.
_____Formally check different aspects of organizations (leadership, goals, communication, procedures).
_____Study linkages and transactions resulting from those linkages.
_____Other (specify)_____________________

Agricultural services:

_____Identify major personnel within the local and national agriculture department.
_____Review program reports from the irrigation department's development activities.
_____Interview department leaders of these programs to check the success of past programs, outlook of personnel for this type work, and perceptions about water management programs.
_____Interview water users to check past successes and failures of development programs. Also, check their perceptions of the government departments to implement an improved water management program at the farm level.
_____Obtain research reports. Check them for comprehensiveness, usefulness and extent of past use of reports.
_____Identify research capability of personnel, facilities, topic, and geographic jurisdiction.

_____Check degree of cooperation between research institutions and government agencies.
_____Describe extension services, type of personnel employed, past services, capability of the service to relate to agricultural communities.
_____Identify agencies responsible for various services.
_____Survey farmers to get their perceptions about success or problems with government services related to agricultural inputs.
_____Check with farmers about available private input services including type and costs of various services.
_____Determine location of storage facilities.
_____Check type of commodities handled and costs for marketing and transportation to the farmer or agriculturalist.
_____Check involvement of agriculturalist in determining price control.
_____Check extent of transportation network throughout country.
_____Identify important people in cooperatives to get information about internal rules, regulations, and degree of control.
_____Determine requirement for agriculture involvement in cooperatives, and type of cooperatives, number and location of cooperatives.
_____Determine acceptance of cooperatives by farmers as a mechanism for improving agricultural production.
_____Interview a few farmers intensively to determine their knowledge, availability of services, and benefit of available services.
_____Other (specify)____________________

Socio-cultural network:

_____Prepare detailed interview/survey instruments.
_____Interview farmers and village leaders to obtain information on status-role, power, stratification, norms, beliefs, sanctions, sentiments, goals, and facilities.
_____Determine crop prices and yields by direct observation.
_____Observe terms of tenancy.
_____Observe farmer behavior during cultivation, irrigation and harvest.
_____Observe farmers in situations of uncertainty.
_____Determine who controls access to land.
_____Determine village decision-making process.
_____Determine limitations on ownership of land.
_____Determine village mechanisms in paying for goods and services.
_____Determine village labor specialties.
_____Determine sources of credit.
_____Other (specify)____________________

CHAPTER VII

DATA ANALYSES AND INTERPRETATION

In the flow diagram for the Problem Identification phase (Figure 3), the activity that follows the diagnostic field studies described in Chapters III through VI is the "Analyses and Interpretation of Findings." A flow diagram for this activity is shown in Figure 13 on the following page. This activity is subdivided into two subactivities: (1) problem diagnosis analyses; and (2) interpretation of findings. Before discussing these subactivities, a discussion will be presented on the interdependence of the system components: (a) plant environment, (b) farm management practices, (c) water supply and removal, and (d) institutional linkages. This discussion provides some insight into how the different analyses will be utilized in interpreting the findings.

INTERDEPENDENCE OF SYSTEM COMPONENTS

The interdependence among the components of the plant environment, farm management practices, water supply and removal subsystems, and the institutional infrastructure has been emphasized in this manual. If the farm system is to be understood and improved, then a focus on any one subsystem is not sufficient to significantly enhance the operation of the total system. One way of viewing the interrelationships of the system components and program objectives is shown in Figure 14. As the diagram shows, each of the major components is related to each other, and no single component is viewed as major or minor. For example, a change in water supply influences the practices a farmer uses that in turn directly influence the total plant environment. A change in water supply is also closely linked with the institutional and organizational structure that allots water supplies, establishes water codes, sets water rates, and provides services required by the farmer. This figure ..) suggests that a change in any of subsystems influences and changes all other components to various degrees. However, a single change in one

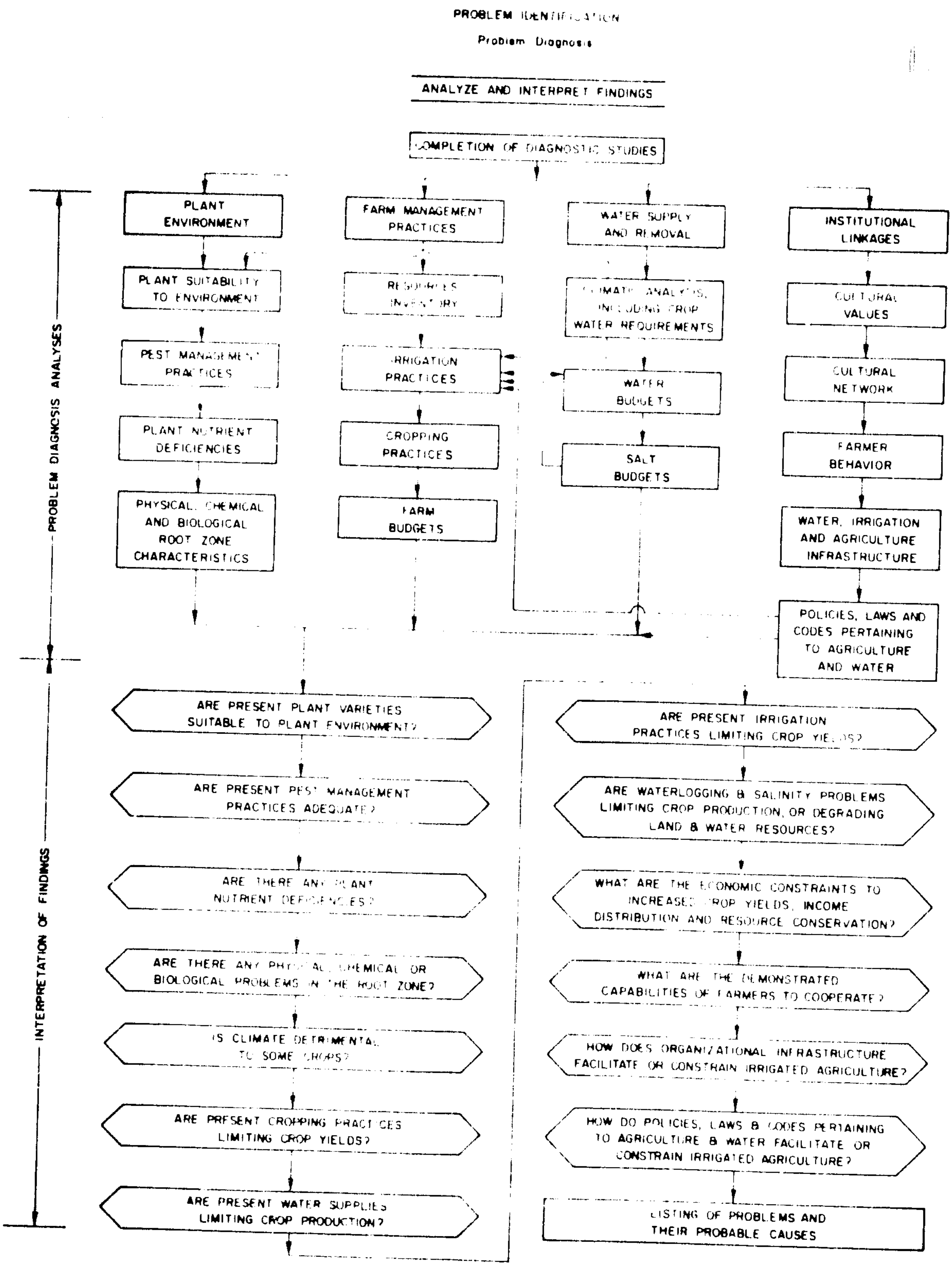


Figure 13. Flow diagram for data analyses and interpretation of findings.

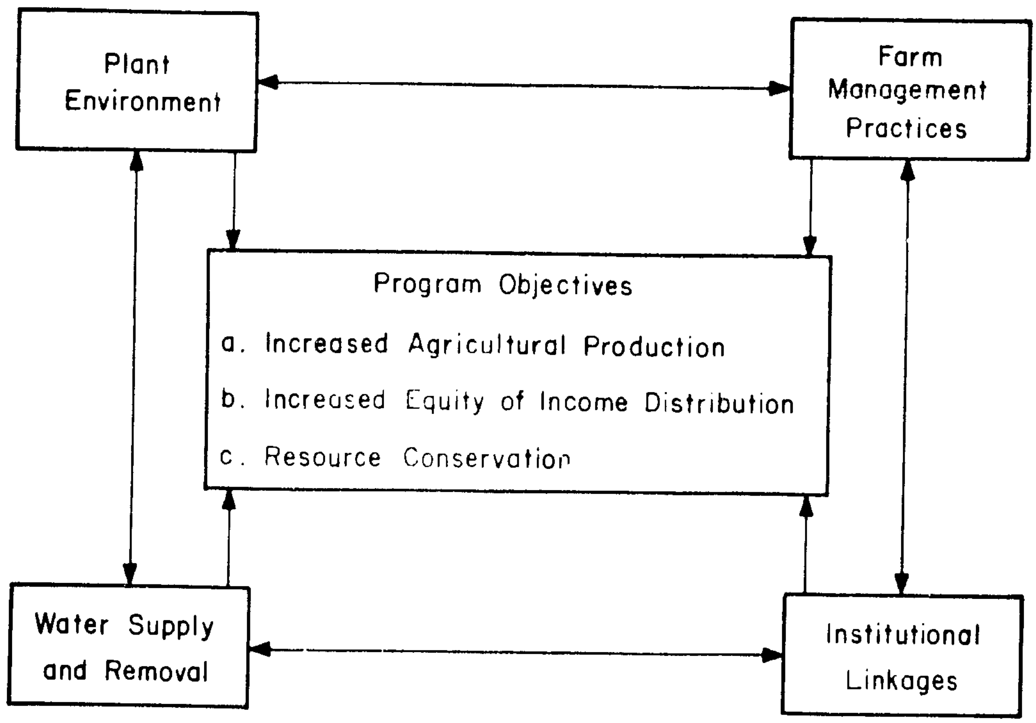


Figure 14. Interdependence of irrigation system components and program objectives.

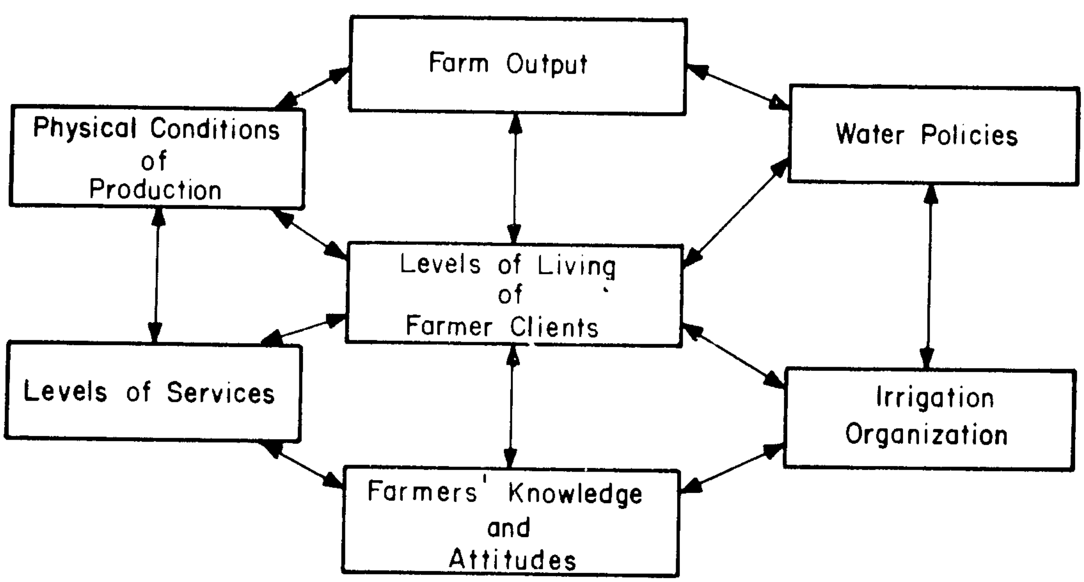


Figure 15. Factors affecting levels of living of farmer clients.

subsystem will probably not cause the total system to function significantly better. For example, an improvement in conveyance efficiencies alone will not insure improved farm irrigation efficiency. More water may be made available to farmers' fields which is applied less efficiently. Too much water applied can result in damage to crops and soils, as well as create critical drainage problems, which will reduce crop yields.

Another example is provided in Figure 15 to stress the importance of system interdependencies. It is assumed the goal of the farm water management system is to improve the levels of living of farmers through increased production. The figure shows some of the factors affecting levels of living of farmers. Changes are needed in all these factors to substantially improve the farmers' standard of living.

If the goal is to improve the levels of living of farmers, changes are needed in all the factors listed that are closely interrelated to each other. For example, the physical conditions of production including soils, water supply, and water quality may be such as to limit or enhance production. Government services such as poor input supplies, inadequate extension services, and outdated water policies influence farmers' attitudes and farm output that in turn affect levels of living. However, many of these factors are not directly controlled by farmers. Other factors, though, may be under more direct control of the farmers.

The farmer needs researchers and policy makers to help improve the total system, not just a single problem of interest to an academic researcher. The task of a research group in the Problem Identification phase is to examine the system as a whole and improve all components to establish a more effective performance level.

PROBLEM DIAGNOSIS ANALYSES

After completing the diagnostic field studies under the problem diagnosis subphase, the process of analyzing the data can proceed. This process is illustrated in Figure 16. The analyses for each of the four components (plant environment, farm management practices, water supply and removal, and institutional linkages) is shown in this diagram, as well as the interdependency between some of the analyses.

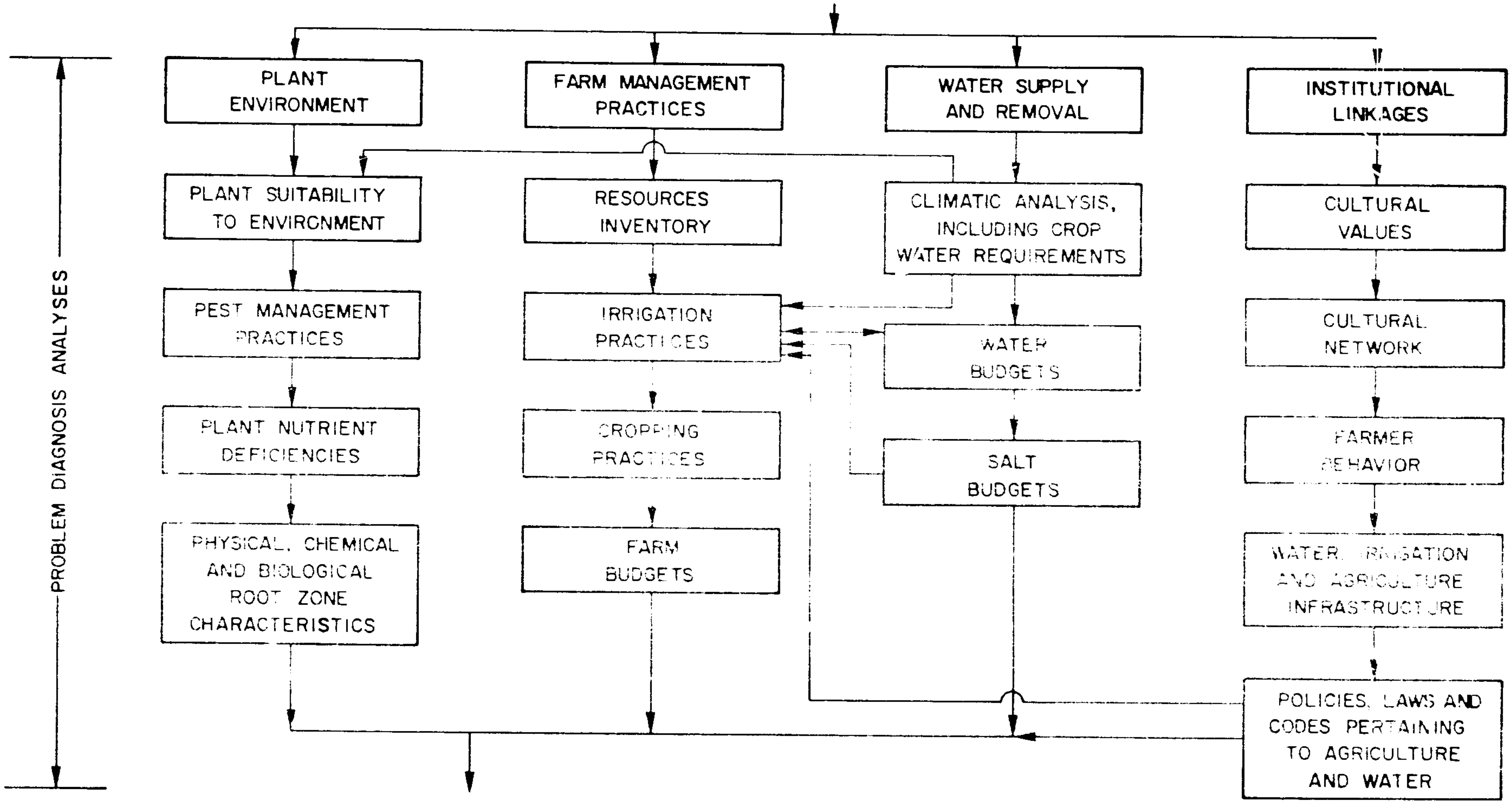


Figure 16. Flow diagram for Problem Diagnosis analyses.

Plant Environment

To analyze the suitability of various plants to the environment is dependent on the climate, soils, and the plant variety. The climatic analyses will be discussed in the section on Water Supply and Removal. A knowledge of the interaction of these parameters is required to establish the suitability of various plant varieties, as well as the likely problems that would be associated with the production of each variety.

Problems associated with pest management practices, plant nutrient deficiencies, and the physical, chemical, and biological characteristics of the root zone are established by field and laboratory tests as discussed in Chapter III. Much of the difficulty in analyzing the field and laboratory data lies in the interactions between these subcomponents. Many of these interactions are complex, while others are readily identified. In fact, to adequately define some of the complex interactions may have to await the Testing and Adaption subphase under the Development of Solutions phase.

Farm Management Practices

The resources inventory and cropping practices (Figure 16) are both obtained by field interviews and observations. The information is compiled in a manner for analysis in preparing farm budgets. Also, this information is valuable in the Development of Solutions phase.

Irrigation Practices

A comprehensive procedure for the evaluation and improvement of irrigation systems is suggested in Figure 17. The procedure is based on the analysis of the performance of the system for an individual application, along with the irrigation management regime (intervals and depths of application), resulting in an analysis for the whole irrigation season.

The performance of the system for an individual application is evaluated by four performance parameters:

1. The irrigation pattern or the "Distribution Uniformity" - U_d;
2. The "Delivery Efficiency" - E_d;
3. The "Deep Percolation Efficiency" - E_p; and

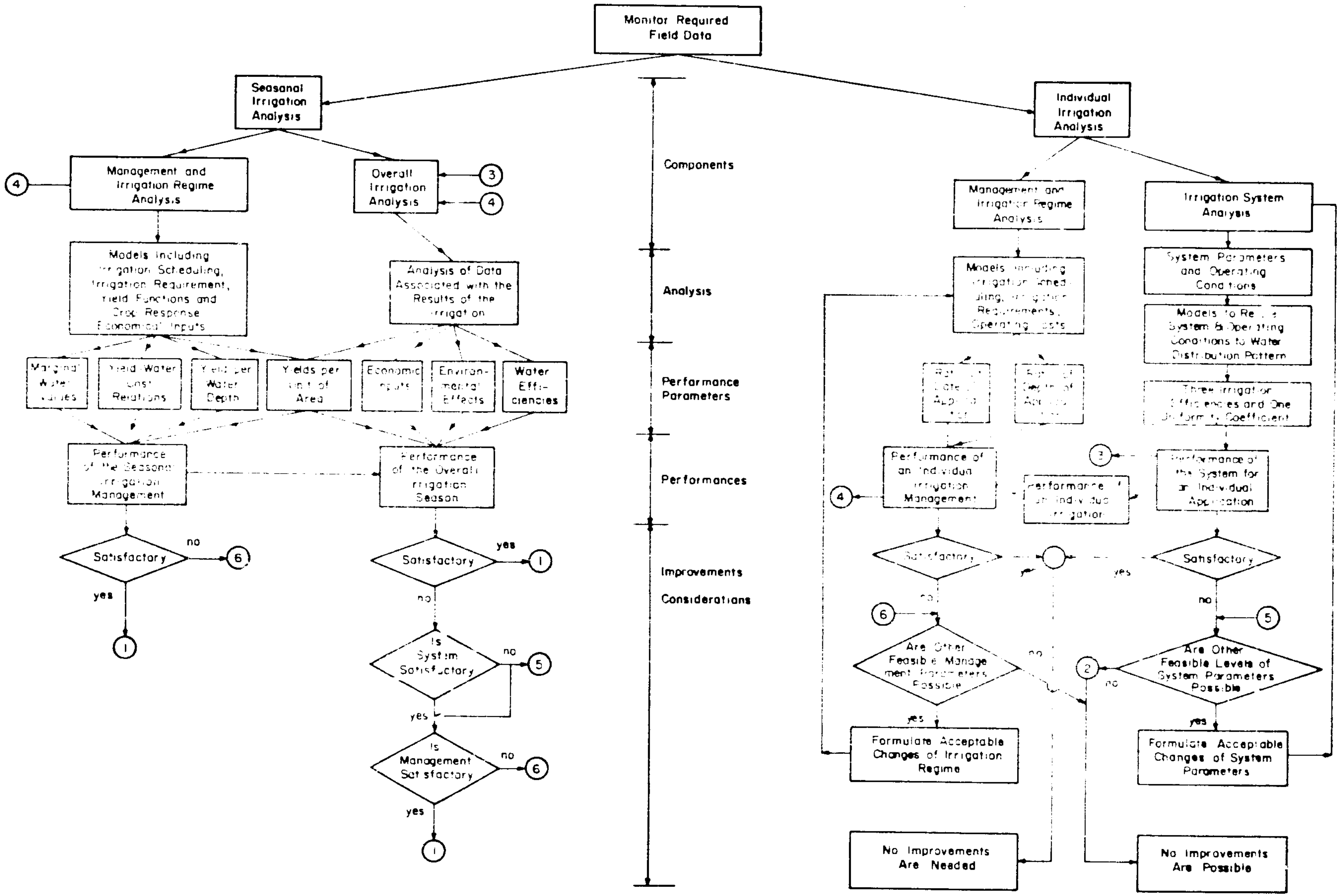


Figure 17. Procedure for the evaluation and improvement of irrigation systems (Peri and Skogerboe, 1979).

4. The "Storage Efficiency" - E_s.

These four performance parameters are sufficient to define the performance of the system for an individual application.

The storage efficiency, E_s, is the fraction of the available root zone water storage (at the time of irrigation) that is filled by the irrigation. The deep percolation efficiency, E_p, is the fraction of the total water absorbed in the irrigated area which contributes to filling the available root zone water storage (at the time of irrigation); it is a measure of the water which is lost to deep percolation. The delivery efficiency, E_d, is the fraction of the water delivered to the irrigated area which is absorbed by the soil through infiltration; it is a measure of the water that is lost to factors other than deep percolation, i.e., the losses to runoff (even if collected by a tailwater reuse system), wind drift, evaporation, etc. The distribution uniformity, U_d, is the fraction of the total water absorbed in the irrigated area that contributes toward filling the root zone or is lost to deep percolation; this is a measure of the distribution of water over the field by the irrigation.

Values for the four performance parameters are derived from the use of available models that utilize the present existing values of the system parameters (dimensions, pressures, flows, soil properties, slope, etc.) as well as feasible ranges of values for these system parameters. Each of the major irrigation methods (basins, borders, furrows, sprinkler, and trickle) is analyzed by a specific model designed to evaluate the four different performance parameters in the study of a specific system.

The system evaluation and improvement is an iterative procedure where, following an initial establishment of levels of performance parameters, other levels may be reached using the same models but with different levels of satisfaction, established by the farmer, design engineer, operator, planner, etc. Unsatisfactory levels of performance parameters require improvement of the irrigation system by changes in the system parameters as shown in Figure 18.

The following publications can be used as references for analyzing irrigation practices:

1. Peri, G. and G. V. Skogerboe, Evaluation and Improvement of Irrigation Systems, Technical Report 49A, Water Management Research Project, Colorado State University, Fort Collins, 1979.

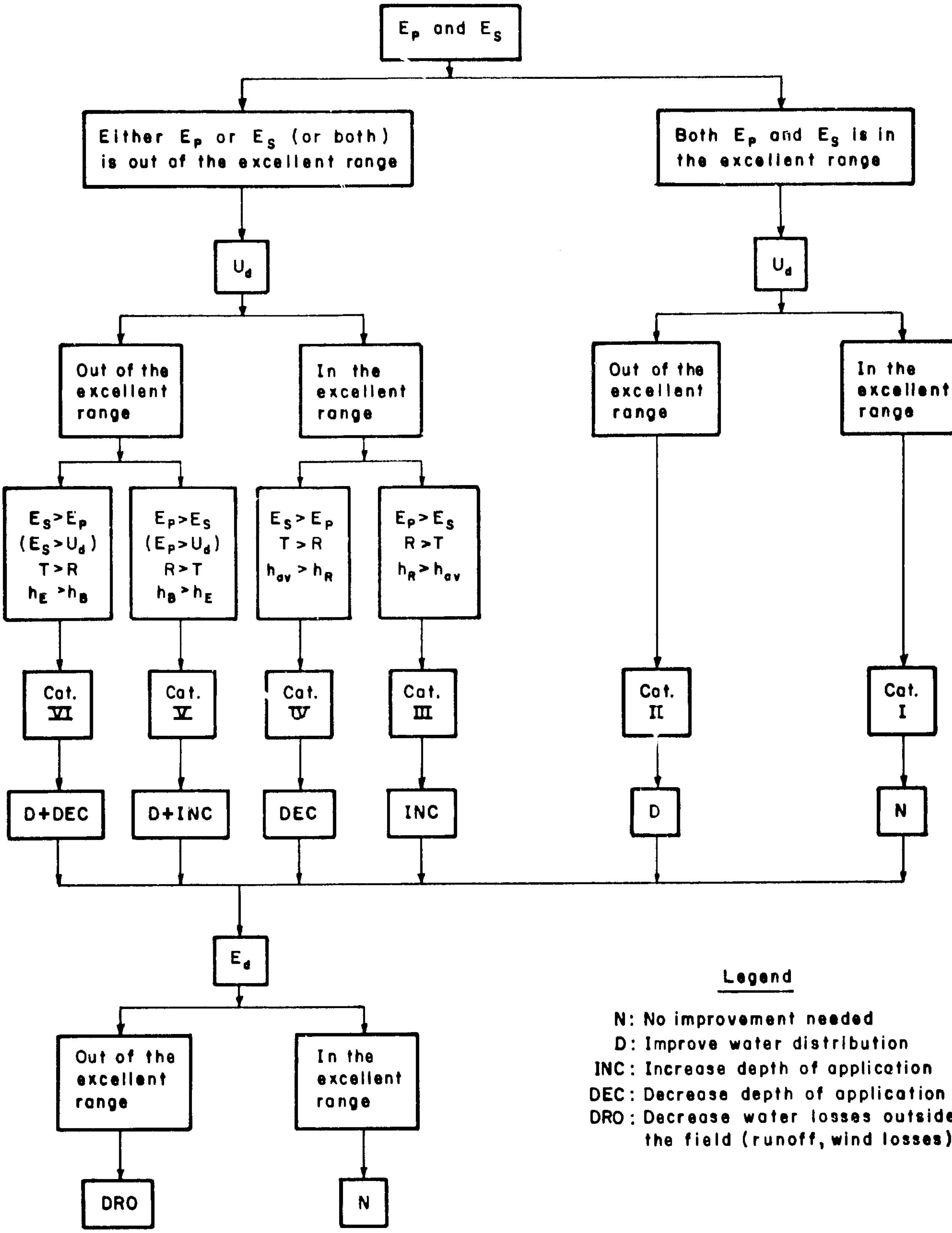


Figure 18. Categories of irrigation performance for individual application (Peri and Skogerboe, 1979).

2. Peri, G., G. V. Skogerboe and D. I. Norum, Evaluation and Improvement of Basin Irrigation, Technical Report 49B, Water Management Research Project, Colorado State University, Fort Collins, 1979.

3. Peri, G., D. I. Norum and G. V. Skogerboe, Evaluation and Improvement of Border Irrigation, Technical Report 49C, Water Management Research Project, Colorado State University, Fort Collins, 1979.

Farm Budgets

A farm budget, or more correctly, a combination of complete and partial budgets, is useful in presenting the present operation of a farm, as well as the potential for the farm. A farm budget is a logically consistent device for planning alternative systems of production and for measuring the returns from each system. It provides a method for describing the production relationships between resources (inputs) and products (outputs). A farm budget shows the capital and products such as wheat, rice, and cotton. The data for a farm budget includes facts and relationships drawn from the physical, biological, and social sciences including the "applied" sciences. Data for the farm budget also includes observations and experience of the persons developing the plan.

A farmer can use a farm budget to plan a production program in the light of his knowledge of productive resources and their possibilities in the productive processes. The problem identification staff uses the farm budget to synthesize the farmers' operations, which not only provides insight into the causes of problems, but is extremely valuable in providing foresight as to potential improvements that might be explored in the Development of Solutions phase.

Farm budgets may vary in the amount of detail they include. A relatively simple farm budget should consist of:

1. A land use plan,

2. A livestock plan,

3. A livestock feed plan,

4. An inventory of depreciable assets,

5. An estimate of expenses,

6. An investment summary, and

7. An income and expense summary.

Examples of the forms used for each of these steps is included in Appendix IV.

These plans do not have to follow any prescribed format as long as the plan is complete and logically consistent. Farm budgets are also used in negotiating for credit and for purposes of getting counsel and advice from people with special knowledge. Consequently, the budget should be capable of communicating alternative production plans to someone other than the person who wrote the plan.

Two good references describing farm budget analyses are:

1. Perrin, R. K., D. L. Winkelmann, E. R. Moscardi, and J. R. Anderson. 1976. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Information Bulletin 27, Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico City.

2. Friedrich, K. H. 1977. Farm Management: Data Collection and Analysis. FAO Agricultural Services Bulletin 34, Food and Agriculture Organization of the United Nations, Rome.

Water Supply and Removal

Climatic Analysis

Usually, the climatic data to be analyzed first of all is temperature and precipitation. Weather data in the irrigated area is used if available. If not, weather stations should be installed so that local climatic data can be correlated with nearby stations having long-term records. This way, if local temperature and precipitation data is not available, then a long-term synthesis record can be generated by correlation analysis.

Both temperature and precipitation records are analyzed on a monthly basis, and sometimes on a weekly or daily basis. Besides determining averages for the time frequency used in the analysis, the probabilities of different values of temperature and precipitation occurring during each time period should be computed. Then, frequency diagrams can be drawn such as the example in Figure 19.

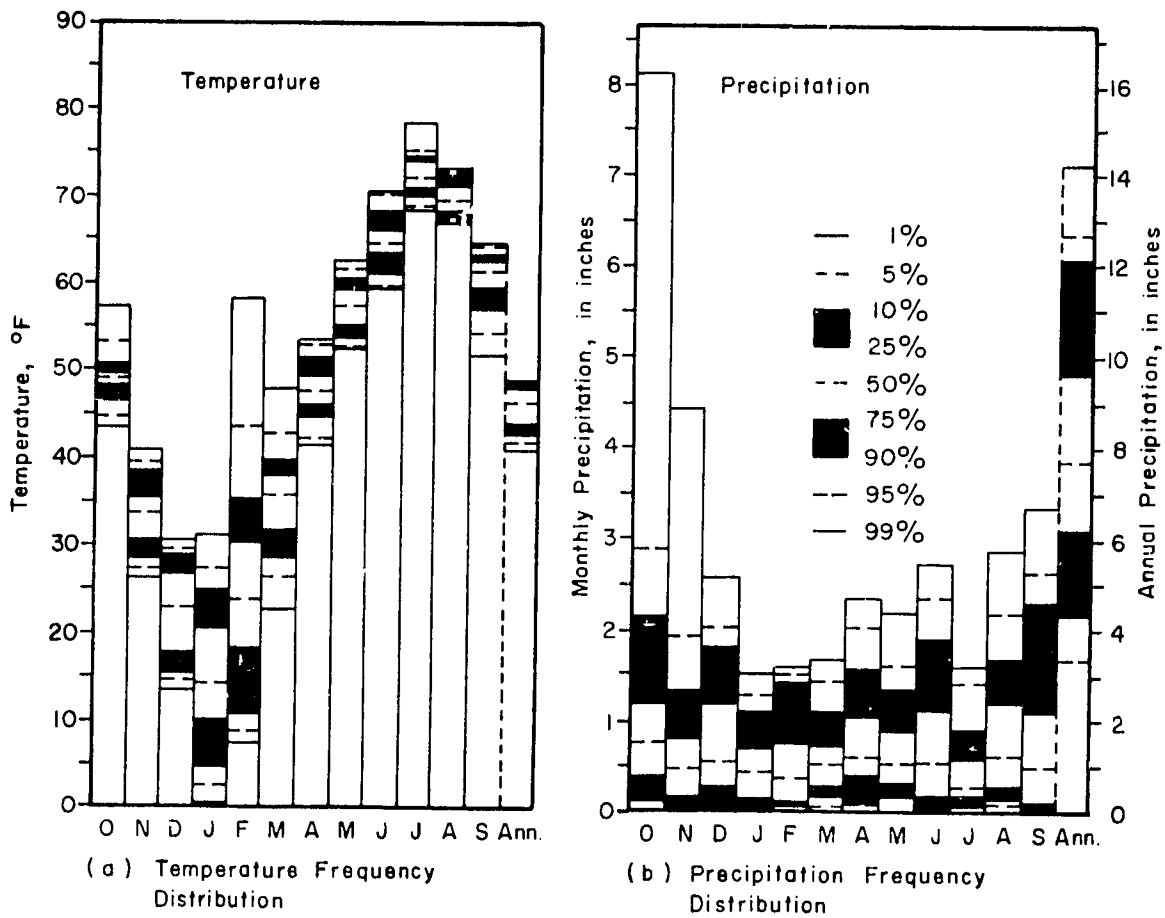


Figure 19. Example of monthly and annual frequency distribution for precipitation and temperature.

If the irrigated area experiences freezing temperatures, then the temperature data would be analyzed for the last date of freezing before the irrigation season and the first date of freezing at the end of the irrigation season. In addition, the probabilities of different temperatures near freezing (e.g., -4°C, -2°C, and 0°C) occurring on different calendar dates would be calculated.

The most important climatic analysis for an irrigated area is the evapotranspiration or consumptive use by crops and phreatophytes. A review of the alternative approaches to estimating the volume and rates of water evaporated from wet crop and soil surfaces or transpired by the plants can be found in several sources (Jensen, 1973; Doorenbos and Pruitt, 1977; Horton, 1973). There are many methods by which evapotranspiration (ET) can be calculated. The three most common approaches to estimating evapotranspiration are: (a) the Blaney-Criddle method (United States Department of Agriculture, Soil Conservation Service, 1964b); (b) the Modified Jensen-Haise methods; and (c) the Penman Combination method. These methods represent the range of sophisticated techniques available today, varying in detail from a temperature dependent analysis (Blaney-Criddle) to an analysis of energy balance and convective transport (Penman).

Depending on the estimating formula used, data required for consumptive use studies can include climatic data such as daily solar radiation, air temperature, dew point temperature, relative humidity, wind speed, and precipitation. Some consumptive use formulas require information on the monthly percentages of daylight hours, latitude, altitude, crop height, depth of root zone, crop and phreatophyte growth stage coefficients, and the areal percentage of plant cover.

Evapotranspiration is a very important part of any irrigation system analysis since it can account for the majority of the water delivered to an irrigated area. The accuracy of these measurements and resulting calculations can seriously affect the validity of the results. It is necessary that this value be determined as accurately as possible, and it is imperative that the method of estimating evapotranspiration be calibrated for local conditions. Attempts to base conclusions on uncalibrated consumptive use equations would be extremely presumptuous. These equations are usually calibrated by the use of field measurements. A detailed discussion of the calibration procedure and comparisons of the three main estimating formulas mentioned above can be found in Evans et. al. (1978). An example taken from this reference is shown in Figure 20 where measured lysimeter data compares very well with the Penman equation for an alfalfa crop.

Water and Salt Budgets

The simplest analysis is to evaluate inflows and outflows for either the total irrigated area, or only a portion, depending upon the available hydrologic data. Of primary importance is being able to define the hydrologic boundaries for an inflow-outflow analysis. Boundaries are selected that minimize the number of unknowns in the hydrologic cycle, as well as considering the accuracy of the hydrologic data at the boundaries. The first step is to prepare a mean annual inflow-outflow analysis. Then, a seasonal and a mean monthly inflow-outflow analysis can be prepared. If salinity concentrations, as well as flow rates and volumes are known at the boundaries, then even the accuracy of the water balance will be enhanced by computing salt balances.

After completing the inflow-outflow analyses, then more detailed water and salt budgets can be prepared using hydro-salinity analysis, which can be computed by hand, but is often accomplished on a computer. The process of hydro-salinity modeling is basically one of formulating a series of water budgets for each hydrologic segment. These budgets are expansions of the mass balance hydrologic equations. This is the first step of hydro-salinity investigations.

The most important consideration for developing water balances is to select the system boundaries to use the available information to the best advantage. This boundary selection procedure will also assist in designing the monitoring network and in determining the extent of the field investigations. Many of the variables such as canal diversions are known, but it is necessary to develop as many water balance equations as there are unknown variables. The time frame, monthly or yearly, of the budgets must be determined at the start of the process.

Salinity problems from irrigated agriculture generally result from subsurface return flows. The capability of a hydro-salinity model to provide necessary information for arriving at technological solutions is,

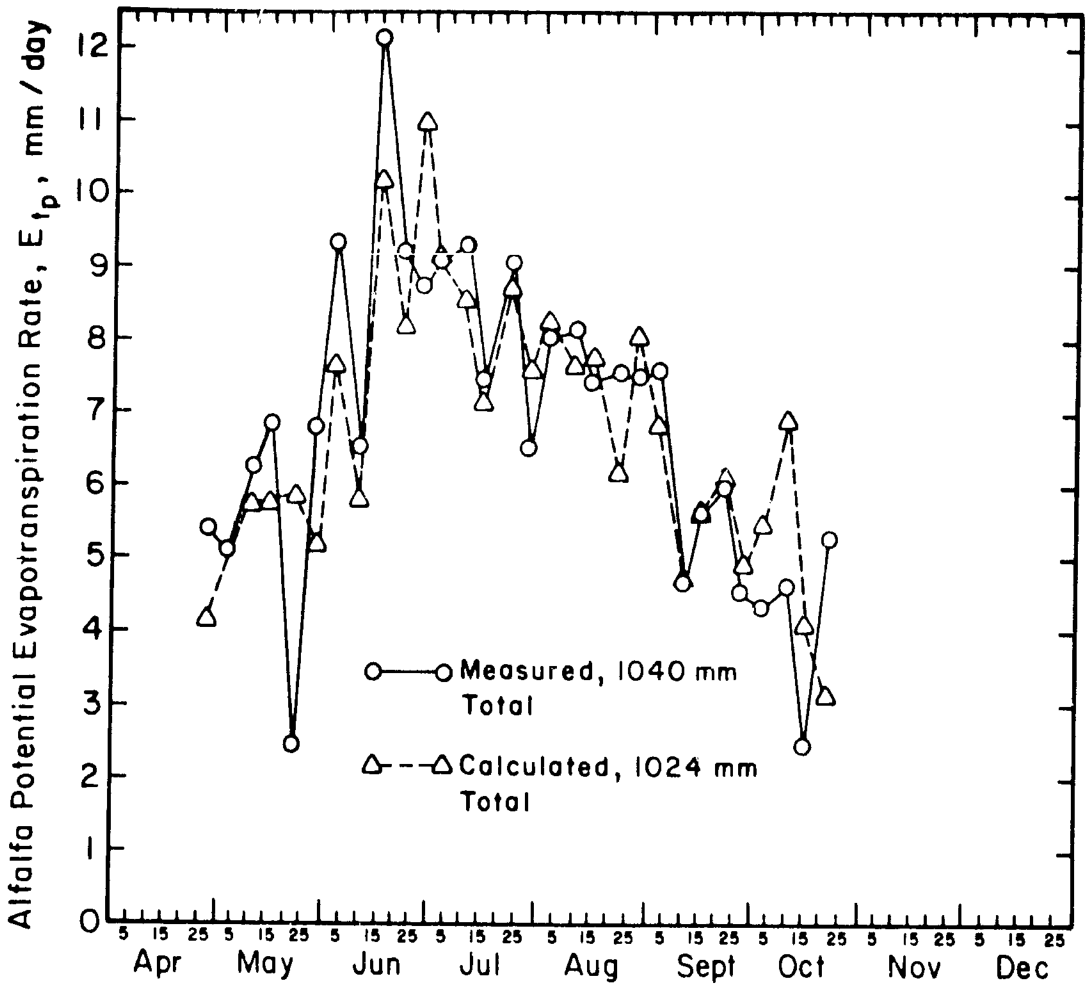


Figure 20. Comparison of lysimeter data and the Penman equation estimate for alfalfa in 1975 (Evans, Walker, Skogerboe, and Smith, 1978).

therefore, dependent on the accuracy of groundwater field data and analysis. A problem often encountered during preparation of water and salt budgets is the reliability of the measured data. Usually, the precision of measurement varies with the scope of the investigation and the area under study. Since the hydrologic system is difficult to monitor and predict, it is impractical to expect models to operate without applying some adjustments in order that all components will balance. The budgeting procedure is defined as a weighting of the contributing factors in water and salt flows until all parameters represent the closest possible approximation of the conditions of the area. A schematic diagram of a general hydro-salinity model is shown in Figure 21. Oster and Wood (1977) discussed the sensitivity of some hydro-salinity models to various input parameters.

One of the early steady-state hydro-salinity models was developed by Walker (1970) and applied to the Grand Valley of western Colorado. The following description of the respective components of this model sufficiently describes the principles used in similar models, a few of which are referenced later.

Cropland Diversions

Diversions to the croplands are accounted for by simple numerical budgeting procedures. The water flows are divided into several categories depending on the physical constraints of the system. For example, gravity irrigation supply is usually diverted by means of diversion dams. It is then conveyed through irrigated lands with water being lost by seepage, spilled into wasteways, evaporation, and discharged through turnout structures into watercourses or farm supply ditches. Canal regulations by spillage may be facilitated by wasteways such as natural washes and man-made drains which may be located throughout the irrigated lands. These wasteways may also serve as outlets for subsurface return flows. Diversions into the watercourse system are also reduced by seepage. Evaporation from canal and watercourse surfaces is usually insignificant.

Root-Zone Flows

The goal of irrigation is to recharge the soil-moisture of the root-zone with sufficient water to meet the needs of the crop until the

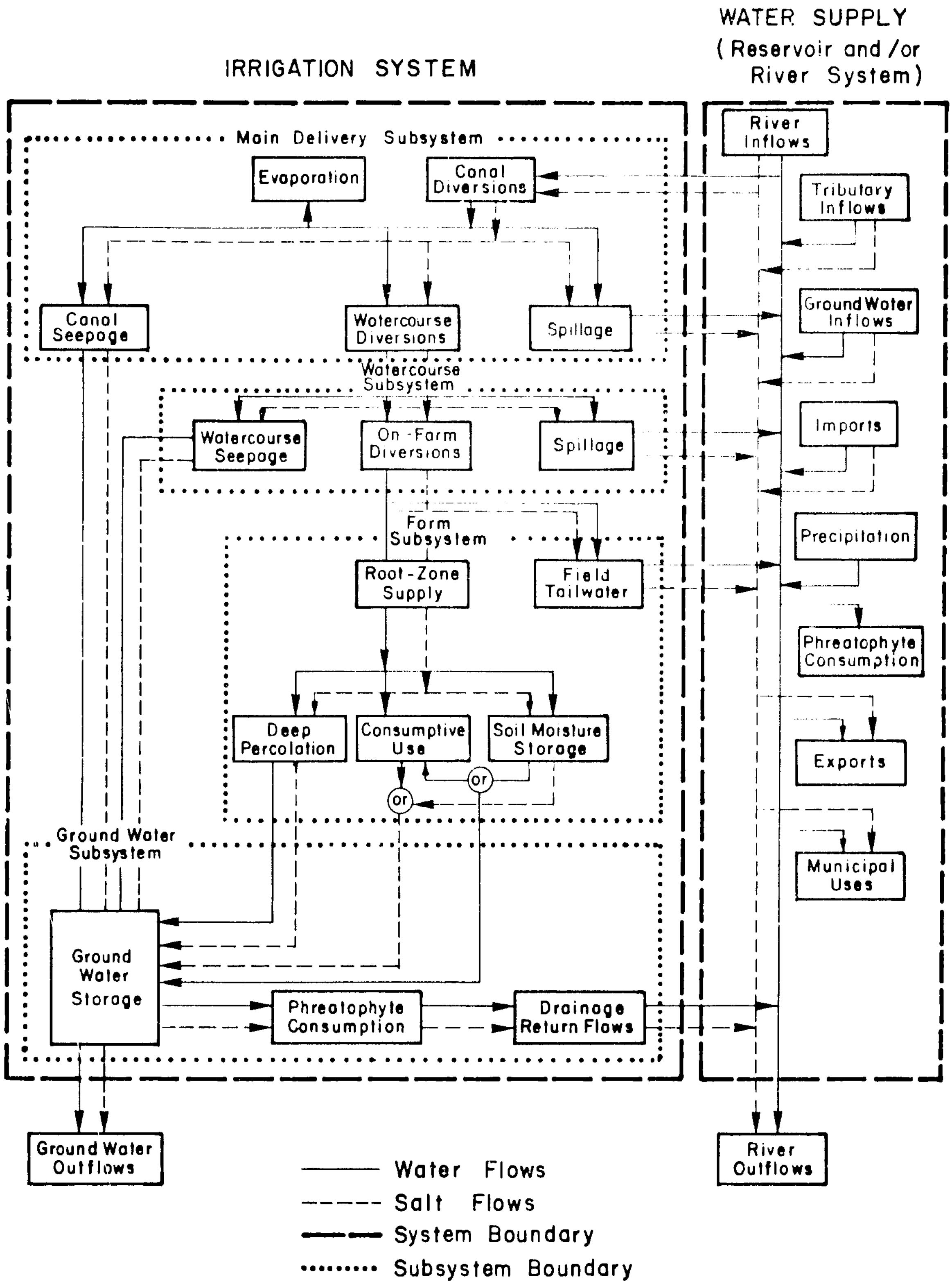


Figure 21. Schematic of a generalized hydro-salinity model (Walker, 1970).

next irrigation. Irrigation also serves to maintain an acceptable salt concentration in the root-zone. Overirrigation produces high water tables (waterlogging) and salinity problems in many areas. The root-zone submodel makes a detailed examination of the various flows occurring within the root-zone in order to quantify the water and salinity problem.

The important water movements within the root-zone are evapotranspiration and deep percolation with water storage changes also occurring. Separation of these flows by taking measurements on a large scale is impractical. Consequently, empirical computational methods are employed. The model described herein accounts for these basic water and salt flows by a budgeting process. The operation of this model assumes that irrigations are applied uniformly over each hectare of cropland. Phreatophyte vegetation in the area is assumed to extract water only from groundwater flows or only use natural precipitation which falls on the area occupied by these plants. A generalized flow chart of the root-zone budgeting procedure is presented in Figure 22.

Several methods for estimating evapotranspiration can be used in this model. The locally calibrated Blaney-Criddle Method has provided an acceptable degree of accuracy for many studies. The Jensen-Haise Method and the Penman Method are more precise but require more climatological data.

With the evapotranspiration data and field measurements of moisture holding capacity, infiltration rates, and rooting depths, the budgeting scheme proceeds with computation of deep percolation losses from the root-zone. Calculations are initiated by assuming the crops use soil-moisture at the potential rate until the wilting point is reached, assuming that there are no adverse effects on the plant due to crop stress. The calculated potential consumptive use is limited to the water added by irrigation and the existing available soil-moisture storage. If irrigation water added to the root-zone is insufficient to meet demands of the crops, but storage of soil-moisture is sufficient to make up the difference, the need for water is satisfied. The assumption is also made that no deep percolation occurs while the available soil-moisture storage level is below field capacity, and that deep percolation and

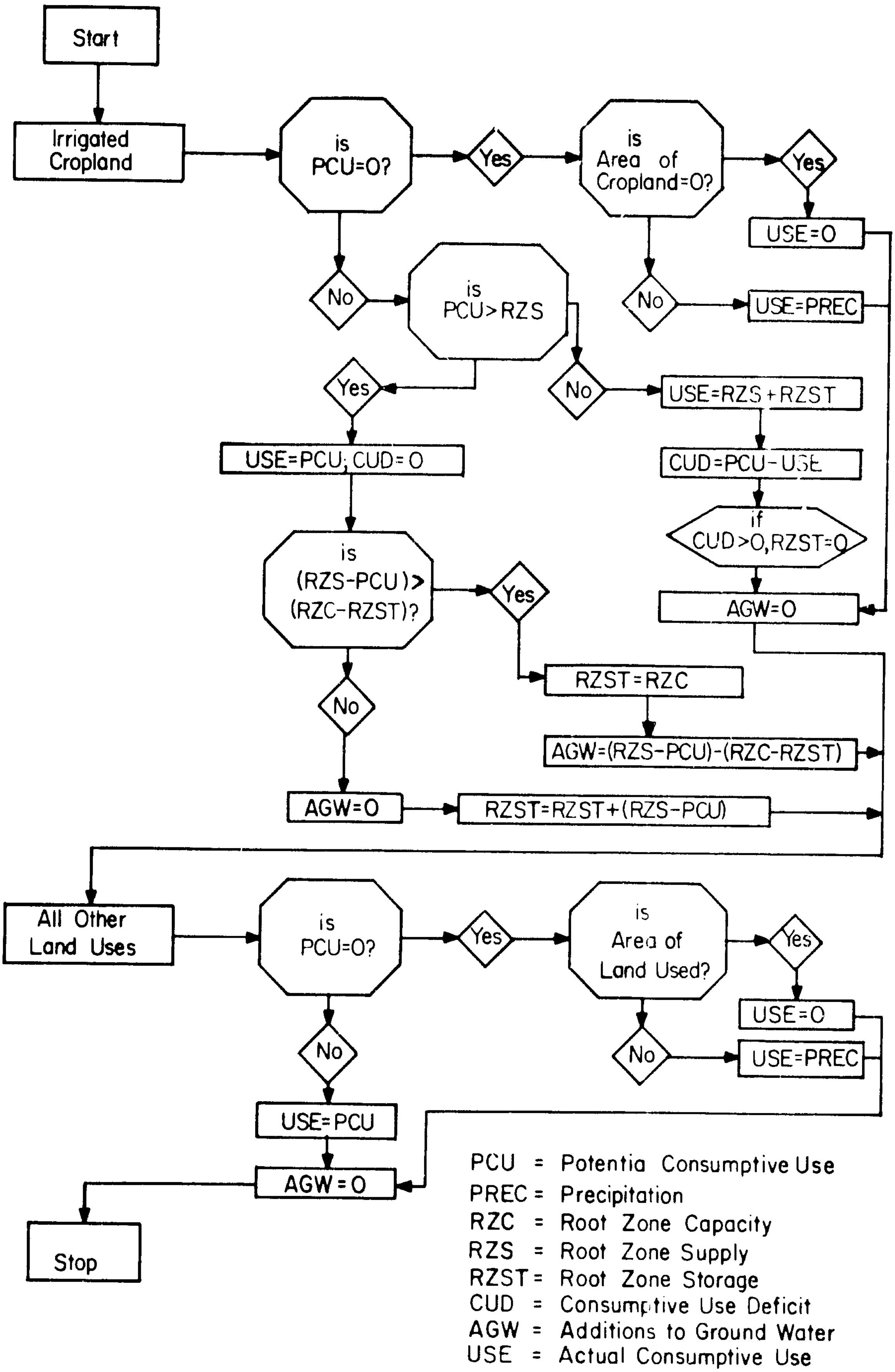


Figure 22. Illustrative flow chart of the root-zone budgeting procedure (Walker, 1970).

leaching occurs above this value. If the total available moisture for the period between irrigations is insufficient to meet the total demand, the crops use all water available. A term called "consumptive use deficit" is defined as the difference between potential and actual water utilization.

Salts in the water applied to the crops move into the root-zone where they become concentrated by evapotranspiration. The behavior of specific ions is complex and has not been considered in this particular model.

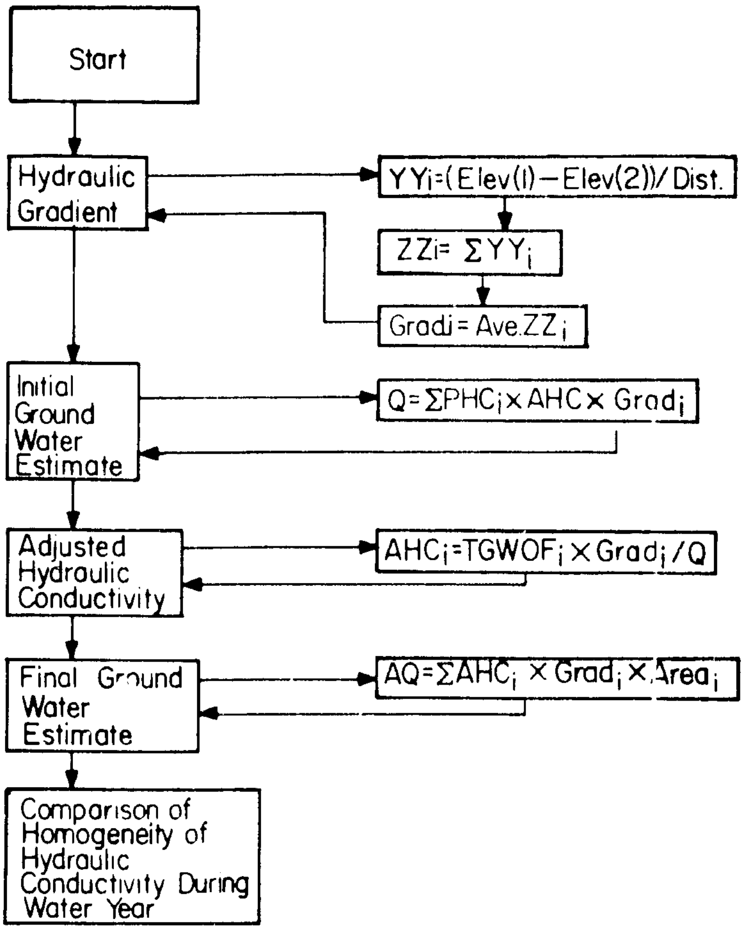
Groundwater Model

Most of the water in the soils and shallow groundwater aquifers originate as seepage from canals and laterals, deep percolation from the irrigation of croplands, and tributary subsurface inflows. Groundwater discharges eventually reach a local river or stream as surface drainage interception or subsurface return flows. The flows in the surface drainage system can be measured by installing flow measuring devices at the outflow points. Subsurface return flows are estimated from water table elevation data, the hydraulic gradients, and the estimated hydraulic conductivities of the aquifer. It should be noted that in any hydro-salinity model, these estimated hydraulic conductivities contain the largest potential for error. Therefore, considerable effort must be made to properly evaluate the necessary parameters in the groundwater computations. For purposes of this model, Darcy's steady-state equation is used,

$$Q = AK \frac{dh}{dx}$$

in which Q is the discharge, A is the cross-sectional area of flow, K is the saturated hydraulic conductivity, and dh/dx is the hydraulic gradient in the direction of flow. Transient groundwater flows can be evaluated by other procedures such as those developed by Glover (1974 and 1975), and Morel-Seytoux and Daly (1975).

The groundwater analysis used in the Walker model, illustrated in Figure 23, starts by comparing the values for subsurface return flow, obtained from a mass balance of the area, to values obtained by computer calculation which uses field data. Therefore, two estimates of



i = Refers to i^{th} Strata

Grad = Hydraulic Gradient

Q = Computed Ground Water Outflow

PHC = Field Values of Hydraulic Conductivity

AHC = Adjusted Values of Hydraulic Conductivity

TGWOF = Total Ground Water Outflow from Mass Balance Analysis

AQ = TGWOF

Figure 23. Flow chart of the groundwater modeling procedure (Walker, 1970).

the subsurface return flows are formulated. The model is then adjusted until both methods yield the same values, thus obtaining a satisfactory alignment between the hydrologic and salinity parameters if no significant sources or sinks have been overlooked. Because the model only focuses on the relative magnitude of hydraulic conductivities, only the relative cross-sectional areas of the strata are important. The width can be any convenient value. The values for cross-sectional areas can be adjusted and used with the known hydraulic model which are only known for selected points in the aquifer. The model adjusts the values of strata hydraulic conductivity until both estimates of the flows are equal. Since this is done on a monthly basis, the model calculates 12 values of hydraulic conductivity yearly for each strata. When adjustments in the model finally result in homogeneous annual values of hydraulic conductivity, the model represents the "best fit" between monitored and estimated data.

Available Models

In addition to the hydro-salinity model reported by Walker (1970), several other models may be utilized. Hillel (1977) presented a simulation model that evaluates precipitation, infiltration, runoff, evapotranspiration, deep percolation, capillary rise from the water table, and groundwater drainage of an agricultural field. A similar model was designed by Makkink and Van Heemst (1975). The chemical quality aspects of irrigation return flows are simulated in models by Shaffer et. al. (1977), the United States Department of the Interior, Bureau of Reclamation (1977), Crawford and Donigian (1973), and Hill et. al. (1973).

Institutional Linkages

Identifying institutional linkages is largely a descriptive exercise, particularly in analyzing cultural values, the cultural network, and farmer behavior. The cultural network can be diagrammed to supplement the descriptive material. Some aspects of farmer behavior can be presented in tabular form and frequency diagrams.

The water, irrigation, and agriculture infrastructure can be presented with organization charts, enabling legislation, and present programs. The linkages between these organizations can be diagrammed.

The policies, laws, and codes pertaining to agriculture and water consists primarily of written legislative and judicial material, much of which should be contained in the appendices of a report on this subject. The body of the report should summarize the policies, laws, and codes pertaining to the water management development program. A discussion of the de facto exercise of these policies, laws, and codes should then be presented along with the summaries.

INTERPRETATION OF FINDINGS

The success in being able to define the probable causes of problems is highly dependent upon the capability of the problem identification staff to interact in a strong interdisciplinary manner in interpreting the results of the problem diagnosis analyses. A flow diagram for the "Interpretation of Findings" is shown in Figure 24. This is a process of answering the questions in sequence listed in the flow diagram using the results of the problem diagnosis analyses and the capability and judgment of the interdisciplinary team. The combination of quantitative and qualitative analyses, capability and judgment of individual staff members, and interdisciplinary interaction will be utilized in preparing a list of problems and the probable causes of each problem.

COMPLETION OF PROBLEM IDENTIFICATION PHASE

The final activities (Figure 3) under the Problem Identification phase are:

1. Identify criteria for selection and ranking of problems according to program objectives; and

2. Report findings of priority problems and their apparent causes.

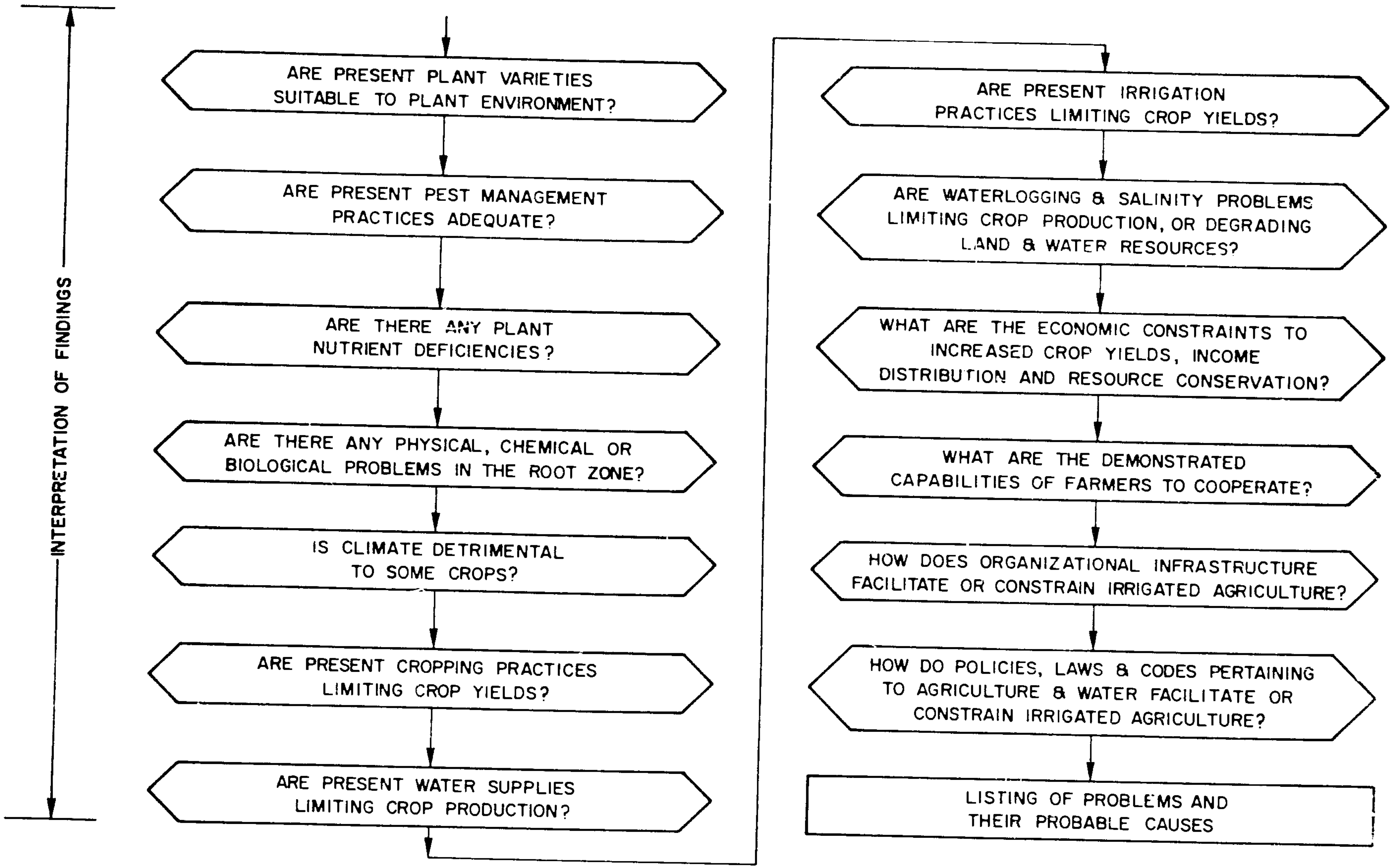


Figure 24. Interpretation of findings from the Problem Diagnosis analyses.

These activities were discussed in Chapter II, so the reader should refer to that discussion in order to complete the Problem Identification phase. However, additional insight into the causes of priority problems will be gained in the Development of Solutions phase.

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APPENDIX I. NEEDS FOR MATERIALS AND EQUIPMENT

APPENDIX II. DATA MANAGEMENT AIDS

APPENDIX III. SELECTION, TRAINING, AND EVALUATION OF FIELD WORKERS

APPENDIX IV. EXAMPLE FORMS FOR FARM BUDGET ANALYSIS

APPENDIX I

NEEDS FOR MATERIALS AND EQUIPMENT

In pursuing the problem identification program, it is necessary to utilize various materials and equipment in the measurements. The following list of equipment evolved from different aspects of problem identification with regard to water management. Developing a list and procuring equipment is a task of management. Unfortunately, this is often left until last.

Water Delivery Measurements

Mogha Delivery:

1. Flumes
2. Staff gauges
3. Levels
4. Field notebook
5. Flow meters

Tubewell Delivery:

1. Carpenter's square
2. Folding rule
3. Field notebook
4. Flow meters
5. Flumes

On-Farm Measurements

Topographic Mapping

1. Farm level and/or alidade
2. Steel tape
3. Stakes and range poles
4. Field notebook

Field and Watercourse Orientation Mapping:

1. Plane table
   a. Tripod
   b. Map paper (plain, gridded, transparent)
   c. Drawing board (18 x 31" or 46 x 79 cm)
2. Alidade equipped with peep-sight alignment hairs
3. Rod
4. Measuring tape
5. Scale
6. Compass
7. Small spirit level
8. Field notebook

Surveying:

1. Level
2. Staff rod
3. Stakes or chaining pins
4. Turning points
5. Field notebook

Soil Moisture Sampling:

1. King-tube sampler (or other type)
2. Plastic bags (15" x 15")
3. Scales
4. Hammer
5. Straight edge
6. Touch-feel chart
7. Field notebook
8. Oven
9. Plastic sheets (2-6 ml thick, 24 in^2)

Soil Fertility/Salinity Sampling:

1. Shovel or spade
2. Soil sampling augers
3. Tubes and buckets (Stainless Steel or Plastic)
4. Field notebook

Observation Well Installation:

1. Pipe
2. Threaded cap for pipe
3. Auger
4. Coarse sand
5. Concrete
6. Plastic tube (3 mm diameter)
7. Plug
8. Measuring tape
9. Field notebook

Socio-Economic Observations:

1. Field notebook
2. Checklists
3. Calculator
4. Computer cards and keypunching facilities

Miscellaneous Equipment

1. Data management facilities to store records and data
2. Writing materials
3. First aid kits
4. Snake bite kits
5. Medicines
6. Red Cross Manual

APPENDIX II

DATA MANAGEMENT AIDS

The following are examples of data management aids. They include formats for daily observation of farmers, irrigation evaluation, topographic mapping, soil moisture sampling, and operation of tubewells and animal powered pumps. Their purpose is to help organize data into some systematic and coherent form to allow utilization by the researchers in the most effective manner. Whenever data is gathered, aids such as these are of great value in examination of the material.

IRRIGATION EVALUATION SUMMARY SHEET

Collected: ____________
Copied: ____________
Checked: ____________

Outlet # ____________
T/W# ____________
Chak ____________
Village ____________

$\frac{1}{Ea}$ = %C

Distributary: ________________________
Canal: ________________________
District: ________________________

Plot No.	Farmer S/O	C/B	Field Location AC/sq	H/T	Crop & Height	Field Size	Area (AC)	Time of Irrigation Start	End	Hrs.	Doli	SMD (in)	Average Q. Field inlet (cfs)	Water Applied (in)	Average Q. outlet (cfs)

TOPOGRAPHIC SUMMARY SHEET

Name of Sample Farmer	Caste	Posi-tion H, M or T	Field loca-tion Sq Ac	Topo Data Inten-sity*	1st Elev	2nd Elev	3rd Elev	4th Elev	5th Elev	6th Elev	7th Elev	8th Elev	9th Elev	10th Elev	11th Elev	12th Elev	13th Elev	14th Elev	Mean Elev

*Topographic Data Intensity (a) one shot per acre, (1/A): (b) one shot per bunded unit (1/BU): (c) four shots per [illegible]

Instructions: IF one shot per acre was taken, list the elevation for all acres on one farm in columns 7-21 and proce[illegible] for each acre. Repeat for each sample farmer.

IF one shot per bunded unit was taken, list the elevations for all bunded units in one acre in column[illegible] calculations. Repeat for each acre.

IF four shots per bunded unit were taken, list the elevation for that bunded unit in 7-10 and proceed[illegible] Repeat for each bunded unit.

SOIL MOISTURE SAMPLING REPORT

Observers____________and____________
Date____________
Date of last irrigation____________
Date of next irrigation____________

Weight of plastic bag____________g
Hours drying time____________
Diameter of king tube____________cm
Volume of sample 6"______cc 12"______cc

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

Rep	Trtmt	Depth	WetWt(g)	DryWt(g)	WtH_2O	NetDryWt	%MC-Wt	DBD	%MC-Vol	ASM(in/ft)
		1(0-6")								
		2(6-12")								
		3(12-14")								
		4(24-36")								
		5(36-48")								
		6(48-60")								
		7(60-72")								

FIELD RECORD SHEET

Outlet Number		Owner Status	Small
Watercourse		Cultivators' Status	Self
Field No.	73	Season Summer Crop	Cotton
Acreage of Field	2 acres	Variety AC 104 Data Planted	19/5
Acreage of Crop	2 acres		17/6/76

Date	Observation	Area worked (acres)	Man hours	Bullock or tractor hours
2.8.76	Irrigation - 12.00 - 16.00	1.0	4	
3.8.76	Irrigation - 13.00 - 17.00	1.0	4	
5.8.76	Inter-culture - 1 man 1 team	0.25	1	1(B)
6.8.76	Irrigation - 9.00 - 12.00	1.0	3	
15.9.76	Fert. Applic. - 10.00 - 11.00	2.0	1	
16.10.76	Spray Cotton - 8.00 - 11.00	2.0	3	
17.11.76	Picking 6 women 6 hours	1.0	18*	
18.11.76	" 1 " 4 hours	0.25	2	
26.11.76	" 10 " 6 hours	2.0	30	

Remarks: Yield seed cotton 856 pounds for 2 acres - insecticide 2 sprays all cotton DDT.

Note: Women labor is ½ value of male.

FORM FOR RECORDING HOURS OF OPERATION TUBEWELL AND ANIMAL POWERED WATER LIFT

Watercourse No. ______________
Distributary ______________
Canal ______________
District ______________
Field Office ______________

Public T/Well ______________
Private T/Well ______________
Animal Powered
Water Lift ______________
Location HMT ______________
(Check Appropriate
blank above) ______________
Owner's Name
(if private) ______________

Note: Each day the investigator will interview the operator and record hours of operation of the ______________.
(Enter well or pump above)

Date	Hours Operated	Date	Hours Operated	Date	Hours Operated

APPENDIX III

SELECTION, TRAINING, AND EVALUATION OF FIELD WORKERS

Particular importance is placed on recruitment of field personnel with desirable personality traits. For the Problem Identification phase, it is necessary to have workers who are primarily from agricultural backgrounds. Young high school graduates from small farms may be chosen if available, in an attempt to recruit workers who have empathy for the small landholders encountered in the survey. It is necessary that the field workers be respectful and appreciate farmers, be honest in their interpersonal dealings, conduct quality interviews, record data objectively, make reliable measurements, have sufficient physical stamina and commitment to work long hours and make nighttime evaluations, and possess sufficient intelligence and desire to learn the required field techniques. The field workers should also be adaptive and resourceful in meeting contingencies and unexpected situations that generally occur in most field survey situations. An approach used in the selection, training, and evaluation of field staff in one country consisted of the procedures described in this appendix.

The selection procedure to meet personal requirements involves three steps. The first step is for the candidate to complete a personal data form and an attitude questionnaire designed to place the individual in difficult hypothetical job situations and test reactions and predicted performance. Second, interviews are conducted with the individual to determine his background, attitudes, and technical competence. If the first two steps are successfully accomplished, the candidates are invited to a field trial, the third step. During the field trial, candidates are placed in selected situations that are intentionally designed to be both physically and mentally stressful. During the week in the field, performance and reactions of candidates are evaluated by a senior staff member using a special evaluation form. Candidates also complete self-evaluation forms before and after the week in the field. After the field evaluations are completed, information from the three phases are combined and evaluated to provide a composite rating for each candidate. Those who attain the minimum required score or higher are selected to work in the survey.

The field trial is the initial period of training for successful applicants. The field trial consists of a training exercise in actual data collection under farm conditions. When the field survey is initiated, senior investigators should spend at least 90 percent of their time with the survey team in daily training, observation, and evaluation of the effort. Periodically, evaluation forms are completed by the supervisors, trainees, and trainers to ascertain progress in skill acquisition and development of interpersonal relations with team members and farmers. The primary purpose of these evaluations is to help the individuals identify and improve strengths and weaknesses. This approach, along with others, has proved to be useful in maintaining team morale and good quality of data throughout the survey.

TEST TO USE IN SELECTION PROCESS

The following are descriptions of actual work situations. You are asked to mark ( ) the statement that best represents your true feelings about the situation or the statement that is closest to what you would do under these circumstances. There are no really correct answers, as each individual will have his own set of attitudes and foreseeable actions.

1. The following situation applies: You have been given a job to measure all the irrigation applications for a given area; yet an important religious holiday is going to fall during the rotation turn. However, the farmer still intends to irrigate on his regular turn that falls on the holiday.

_____a. I would instruct my assistant to remain and make the measurements.

_____b. I would make arrangements with my superiors to postpone the measurements until after the holiday when I return from my home.

_____c. I would stay to make the measurements as instructed.

_____d. None of the above describe my foreseeable actions.

_____e. I would do the following: ______________________________

____

____

2. My superiors have instructed me to collect a set of data using a prescribed procedure. This approach according to my knowledge is very likely to insult the farmers to the point of seriously jeopardizing all future work on the watercourse.

_____a. I would follow my superior's instructions completely.

_____b. I would follow my intuition and modify the approach to avoid the insult, at the risk of not collecting all the data or of not getting exactly the right kind of data.

_____c. I would discuss the matter with my superior.

_____d. None of the above describe my foreseeable actions.

_____e. I would do the following: ______________________________

____

____

3. My superiors have instructed me to do a certain job on the watercourse. I am assigned to attach a staff gauge to the outlet in order to obtain a rating curve for the discharge of the outlet. The farmers do not wish to have me do this because this might draw attention to the fact that they have paid to have the outlet modified from its original design specifications.

_____a. I would follow my superior's instructions without delay.

_____b. I would explain the problem to my superior so that he would make the decision.

_____c. I would explain my mission to the farmers and promise complete confidentiality about the data collected.

_____d. None of the above describe my foreseeable actions.

_____e. I would do the following:______________________________

____

____

4. I have been assigned to work directly with farmers on a given watercourse for the entire summer season. This involves being on the watercourse often at night to measure irrigation applications and on weekends to observe and record farmer production inputs.

_____a. I would prefer to rent a room in the village served by the watercourse.

_____b. I would prefer to live with the farmer whose actions I am studying.

_____c. I would prefer to live at the headquarters and commute to my work as the work requires my presence.

_____d. None of the above describe my foreseeable preferences.

_____e. I would to the following:______________________________

____

____

5. I have been assigned to work on a given watercourse to observe the farmer's inputs to crop production.

_____a. I feel that farmers are basically very trusting and that I can tell them most anything or do anything that will get my assignment completed.

_____b. I know the farmer's difficulties, and I will attempt to understand him, teach him, and help him when I can.

_____c. I realize that farmers are really quite clever and I must be very careful so they don't use me for their purposes.

_____d. None of the above describe my attitudes.

_____e. I would do the following: ______________________________
____
____

6. I have been assigned to live and work on an experimental watercourse. I realize the farmers are very hospitable toward me because I have won their confidence.

_____a. I really do expect to be taken care of while working in the field and have the farmers bring me tea or milk whenever available.

_____b. I really don't expect too much, so I will only help myself to radishes, or sugar cane or fruit on limited occasions.

_____c. I really don't want any material thing from the farmers, but on occasion I will accept some refreshment only out of courtesy on my part as a response to their courtesy.

_____d. None of the above would describe my foreseeable feelings or actions.

_____e. I would do the following: ______________________________
____
____

7. In my work on the farm irrigation system where I have been assigned I have been given several pieces of expensive equipment or measuring devices.

_____a. I will assign my assistant to look after the maintenance and security of these items.

_____b. I will personally be responsible for the security and maintenance of this equipment.

_____c. I know the farmers and that they won't harm my equipment, so security for the equipment wouldn't be a problem for me.

_____d. None of the above describe my attitude.

_____e. I would do the following: ______________________________
____
____

8. Much of my work on the watercourse involves measuring water and soil moisture. Both of these jobs can be quite tedious and dirty.

_____a. I will assign my assistant to make these measurements, after all I have trained him to do a good job.

_____b. I will personally supervise my assistant's data collection work to ensure precision in measuring.

_____c. I will make all measurements in the field personally and if necessary I will wade into the water to install a flume.

_____d. None of the above describe my foreseeable actions.

_____e. I would do the following: ________________________________

____

____

9. In accepting a job to work with an organization, I am faced with a conflict between choosing a position which will ultimately lead me to a long career or between a job which has a short longevity but which has many opportunities for me to learn new things and increase my engineering skills.

_____a. I would accept only those positions which are sure to get me promoted in the organization.

_____b. I would accept any position however short in duration, in order to increase my skills and knowledge.

_____c. I would only want to work and to be paid for it; these other considerations don't matter to me.

_____d. None of the above describe my attitude about these matters.

_____e. I would do the following: ________________________________

____

____

10. I face the problem of learning to determine soil moisture depletion by the touch and feel method. After considerable experience I am still not confident.

_____a. I will continue to make measurements as directed by my superior.

_____b. I will explain my problem to my superiors and ask for guidance.

_____c. I will make gravimetric soil moisture measurements to check my touch and feel technique.

_____d. None of the above describe my actions.

_____e. I would do the following: ____________________________
____
____

11. In accepting a job, I am faced with the problems of accepting a position of lower qualification and pay with the possibility of early promotion to the grade corresponding to my skills and qualifications or waiting for the right job to appear.

_____a. I would take any job now because I don't know how long it would take for the right job to come along.

_____b. I am fully willing to work hard at a job for which I am over qualified, knowing that hard work is readily repaid in promotions.

_____c. I am worried that in accepting the job with the lower qualification, I will face ridicule from my classmates and professors and will hurt my professional image.

_____d. None of the above apply to my attitude.

_____e. I would do the following: ____________________________
____
____

12. A group of farmers on the watercourse to which I am assigned have come to me for help. They want me to accompany them to a local irrigation supervisor to plead their case for increased water supply from their outlet.

_____a. I should help the farmers all I can.

_____b. I should express concern for the farmers complaints and handle the matter by myself.

_____c. I should h[illegible] the grievances but should remain outside of the controvers[illegible]

_____d. I should d[illegible]e of the above.

_____e. I would do the following: ____________________________
____
____

13. I am working for an organization which is very powerful and has a reputation of harboring many corrupt officials.

_____a. I should be willing to criticize the organization when others do so.

_____b. I should be willing to defend the organization with my loyalties in most circumstances.

_____c. I should not criticize, for every organization has its despicable persons, but I should try to influence others by my reputable behavior.

_____d. None of the above would be my course of action.

_____e. I would do the following: ______________________________

____

____

14. I have a co-worker who is not doing his job properly and recording fictitious data from no measurements.

_____a. I should convince him of his predicament and cause him to correct his behavior.

_____b. I should not talk to him but should report him immediately to my superiors since incorrect, fictitious data is unforgiveable in research activities.

_____c. I should do nothing as everybody eventually gets his due reward.

_____d. I would do none of the above.

_____e. I would do the following: ______________________________

____

____

15. A dispute has arisen on the watercourse where I work. Two families which have traditionally been fighting are now at odds over an irrigation turn.

_____a. I should listen to the case and try to convince the guilty party to change his actions before I go to the police.

_____b. I should listen to the case and help the two parties to come to some reasonable agreement.

_____c. I should remain out of the proceedings as my job is not to settle disputes on the watercourse.

_____d. I should do none of the above.

_____e. I would do the following: ______________________________

____

____

_____d. I should do none of the above.

_____e. I would do the following: ______________________________

____ ____

____ ____

Name of Evaluator________________

Name of Person Evaluated__________

WORK PERFORMANCE EVALUATION OF ENGINEERS, AGRONOMISTS, AND SOCIOLOGISTS PROBLEM IDENTIFICATION FIELD SURVEY

Date_______________

Place______________

Purpose: To improve methods of training for improved skills acquisition of persons participating in the watercourse survey team and arrive at more sound criteria for making judgments about the progress of each trainee.

Note: This is a first approximation of some evaluative points that can be utilized for the persons involved in this on-the-job training in watercourse survey methods and approaches. This is to be utilized primarily to improve the training and the skills acquisition of the trainees during the field experience.

Evaluation is necessary to help trainees to know how well they are doing. Trainees will be involved in self-measurement and the trainers will also evaluate each trainee. The feedback from this process should be useful in improving our training methods. Evaluation is necessary only for those tasks included in the job description: Engineer, Agronomist, or Sociologist.

Evaluative Points	Scale of Accomplishment (check only one)			
	Very Adequate (Very Good)	Adequate (Good)	Need Much More Experience (Fair)	Still Very Weak (Poor)
Job Performance				
A. Installing flumes	_______	_______	_______	_______
B. Reading flumes	_______	_______	_______	_______
C. Topographical surveys	_______	_______	_______	_______
1) Benchmarks	_______	_______	_______	_______

Performance Evaluation (continued)

	Very Adequate (Very Good)	Adequate (Good)	Need Much More Experience (Fair)	Still Very Weak (Poor)
2) Reading instruments	______	______	______	______
3) Closing survey	______	______	______	______
4) Recording data	______	______	______	______
5) Map design to scale	______	______	______	______
D. Evaluation of ditch losses				
1) Correct location	______	______	______	______
2) Correct length of time	______	______	______	______
E. Field Efficiency	______	______	______	______
F. Makes careful notes on irrigation behavior of farmers	______	______	______	______
G. Accuracy and legibility in recording data	______	______	______	______
H. Checking instruments for level accuracy	______	______	______	______
I. Crop surveys	______	______	______	______
J. Field geometry	______	______	______	______
K. Keeps regular daily diary of work and observations	______	______	______	______
L. Moisture samples	______	______	______	______
M. Organizes work daily	______	______	______	______

Performance Evaluation (continued)

	Very Adequate (Very Good)	Adequate (Good)	Need Much More Experience (Fair)	Still Very Weak (Poor)
N. Knows effective techniques	______	______	______	______
O. Developing farmer credibility	______	______	______	______
P. Working overtime to finish a job	______	______	______	______
Q. Speed in work	______	______	______	______
R. Arrives at location on time to set up instruments	______	______	______	______
Relationships with Team Members:				
A. Sharing	______	______	______	______
B. Cooperates with others	______	______	______	______
C. Participates in group decision making	______	______	______	______
D. Sharing of leadership	______	______	______	______
E. Follows instructions of leader	______	______	______	______
General Attitudes about:				
A. Willingness for extra work, long hours, etc.	______	______	______	______
B. Takes pride in work	______	______	______	______

APPENDIX IV

EXAMPLE FORMS FOR FARM BUDGET ANALYSIS

This appendix includes examples of forms that can be used for preparing a farm budget analysis. As stated in the text, there is no prescribed format that must be used in such an analysis. The forms included in this appendix are:

1. Land use plan,
2. Livestock plan,
3. Livestock feed plan,
4. Inventory of depreciable assets,
5. Estimate of expenses for one planning period;
6. Investment summary,
7. Financial summary, and
8. Partial budget form.

COMPLETE BUDGET FORM

LAND USE PLAN

	Production				Disposal				
Crop	Acres	Yield per acre	Total Product.	Livestock Feed	Seed	Home Use	For Sale	Expected Price	Sale Receipts
TOTAL									

LIVESTOCK PLAN

KIND OF LIVESTOCK OR PRODUCTS	BEGINNING OF THE YEAR		TO BE PURCHASED		NUMBER BORN	DISPOSAL						
						NO. DIED	HOME USE		NO. FOR SALE	WT. PER HEAD	PRICE PER UNIT	SALE RECEIPTS
	NO.	VALUE	NO.	VALUE			NO	VALUE				
1	2	3	4	5	6	7	8	9	10	11	12	13
TOTAL												

Note: The sum of livestock numbers in columns 4 and 6 should be equal to the sum of livestock numbers in columns 7, 8, and 10

LIVESTOCK FEED PLAN

KIND OF ANIMALS	NUMBER	LENGTH OF TIME TO BE FED	FEEDS TO BE FED
TOTAL REQUIRED			
AMOUNT TO BE RAISED			
AMOUNT TO BE PURCHASED			
COST OF PURCHASED FEED			

INVENTORY OF DEPRECIABLE ASSETS

KIND OF ASSET	SIZE OR CAPACITY	DATE ACQUIRED	ORIGINAL COST	ESTIMATED SALVAGE VALUE	ANNUAL DEPRECIATION
TOTAL					

ESTIMATE OF EXPENSES FOR ONE PLANNING PERIOD

ITEM	AMOUNT
LIVESTOCK PURCHASED	
FEED PURCHASED	
DEPRECIATION	
TOTAL EXPENSES	

INVESTMENT SUMMARY

DESCRIPTION	VALUE IN LOCAL CURRENCY
REAL ESTATE	
Total Real Estate	
WORKING CAPITAL	
Total Working Capital	
TOTAL INVESTMENT	
LIABILITIES	
Total Liabilities	
NET WORTH	

FINANCIAL SUMMARY

GROSS RECEIPTS:	VALUE IN LOCAL CURRENCY
Crop Sales	
Livestock & Livestock Product Sales	
Products Used in the Home	
Miscellaneous	
Total Receipts	
TOTAL EXPENSES	
NET FARM INCOME	
DISTRIBUTION OF INCOME:	
Return to the Farmer for his Labor & Management[1]	
Return to Net Worth	
Rate of Return on Net Worth[2]	

[1]Include unpaid family labor, if any.

[2]Ratio between return to net worth and net worth, multiplied by 100.

PARTIAL BUDGET FORM

Credits or Gains

Added Returns ____________________

____

____

____

____

____

Reduced Costs ____________________

____

____

____

____

____

Total Credits ____________________

Debits or Losses

Added Costs (prorate capital items) ____________________

____

____

____

____

____

Reduced Returns ____________________

____

____

____

____

____

Total Debits ____________________

Estimated change in income (Credits - Debits)