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IMPROVING IRRIGATION WATER MANAGEMENT ON FARMS: FINAL REPORT

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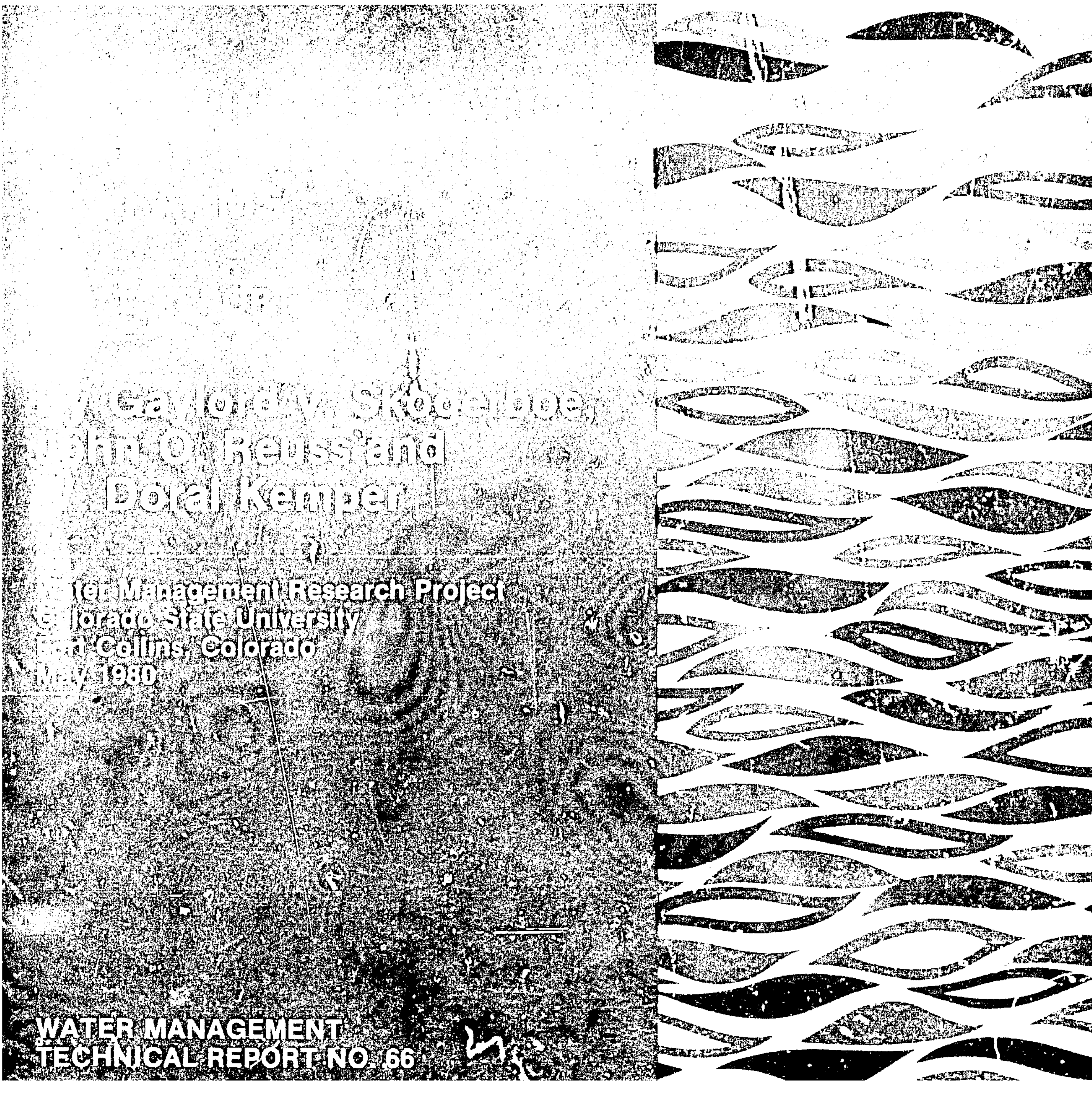

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Water Management Research Project
Colorado State University
Fort Collins, Colorado

May 1980

WATER MANAGEMENT
TECHNICAL REPORT NO. 66

IMPROVING IRRIGATION WATER MANAGEMENT ON FARMS

WATER MANAGEMENT TECHNICAL REPORT 66

FINAL REPORT

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A. Final Report Summary Sheet

Project Title: Improving Irrigation Water Management on Farms

Contract Number: AID/ta-C-1411; AID/ta-c-1100; and AID/csd-2126

Principal Investigators: Gaylord V. Skogerboe, John O. Reuss and W. Doral Kemper

Contractor: Colorado State University

Contractor's Address: Water Management Research Project
Engineering Research Center
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Fort Collins, Colorado 80523

Current Contract: April 1, 1977 to May 31, 1980 (AID/ta-C-1411)

Contract Period: March 28, 1968 to May 31, 1980

Total Expenditures and Obligations for Current Contract:	$2,500,000 April 1, 1977 to May 31, 1980
Total Expenditures and Obligations through Contract Period:	$6,421,712 March 28, 1968 to May 31, 1980

Narrative Summary

This Water Management Research Project has emphasized field research of the farm subsystem. The research activities involved cooperative efforts with most of the agricultural research institutes in Pakistan, the agricultural universities, and government action agencies. The greatest sensitivity to the farm subsystem was gained by working with farmers and developing a keen awareness of the many physical and socio-economic constraints that farmers contend with in agricultural production. One of the greatest satisfactions has been the growing awareness throughout Pakistan on the subject of on-farm water management. Cooperative efforts between the Government of Pakistan, the USAID Mission to Pakistan, the SCS and CSU led to the development of the $44 million Pilot Project ($22 million AID loan), which was initiated in 1976. The World Bank is presently working with the Government of Pakistan in establishing two projects that utilize the results of this research program. This exercise in project implementation proved to be a valuable learning experience.

Focusing upon farm-level field problems provides an important training ground for developing interdisciplinary teamwork as well as providing important training experiences for many host country personnel. Teamwork has been critical to this project, both in Pakistan and on-campus. The combination of physical scientists and social scientists requires an even stronger emphasis upon an interdisciplinary approach in order to move from identifying problems and developing solutions into project implementation. The farmers are important members in this development process because of their innate "interdisciplinary" familiarity with their system. The lesson learned is that both the development of solutions and their implementation should incorporate strategies that allow the farmers to do as much as possible for themselves, with the government providing only those inputs that are beyond the resources of the farmers. Another valuable lesson learned was the advantage in not having the Field Party placed in a counterpart role that is so typically advocated by international donor agencies (the accomplishments would have been less than half).

IMPROVING IRRIGATION WATER MANAGEMENT ON FARMS

B. Background

1. General

Inadequate water is the primary constraint on agricultural production in a large portion of the developing countries. The technology for using available water supplies most efficiently is either lacking or not adapted to the available resources, in many of these countries.

Recognizing that these water management problems were common to many countries, it was apparent that solutions gained in one country should be, to some degree, transferable to others. Consequently, it was decided that a coordinated effort should be made to build up a fund of transferable water management technology. A consortium of universities was formed to develop this fund of water management information and gain experience in the factors limiting or accelerating its adaptation in new countries. CSU was initially assigned the Near East-South Asia, with Pakistan and Vietnam as the study areas in which on-farm water management principles and concepts would be developed and adapted to resources similar to those available in many other developing countries. The present contract focuses upon: (a) continuing the on-farm water management research program in Pakistan; (b) developing the transfer process that can be utilized by other countries for improving their on-farm irrigation water management practices; and (c) providing limited technical assistance to AID Missions for initiating on-farm water management programs.

2. Pakistan

The irrigation system of Pakistan represents one of the largest modern conveyance systems in the world and is a marvel of engineering skill and technology. The hydraulic features, dams, barrages, canals, distributaries, structures, and appurtenances have been fully described in other publications. There is, however, a paucity of information and, indeed, a lack of understanding of that portion of the irrigation system with which the farmer deals. This refers to the system from the canal outlet (mogha) through the irrigated field. The farmer operates and manages this water with little or no governmental assistance. The procedures, rules, resources and constraints at his disposal determine his on-farm water management practices, which in turn determine the crop production per unit of irrigation water.

A modern irrigation conveyance system was constructed by the British in the late 1800's and it is one of the largest in the world. There are about 40,000 miles of canals which

command a gross area of over 33 million acres of fertile soils. About 25 million acres actually receive surface water. The system is not only large with a vast potential but it is unique in several other aspects. One dissappointing feature, however, is the present low production in light of the apparent highly suitable soil, water and climatic resources. These factors suggest a production potential many times greater than presently achieved. The "green" revolution increased production appreciably, but even this appears to be far below potential and in many respects this so-called revolution today is stalled.

Many experts agree that the farming practices, including irrigation water management, must be modernized in order to achieve higher production. There are important reasons for the low crop yields and lack of agricultural production, including insufficient water supply, lack of proper land leveling, lack of irrigation water control, lack of salinity control, lack of water management extension services, use of ancient cropping systems with ancient tools, or, in other words, there is a need for a much improved on-farm management system. The potential for increasing production through improved water management is great.

C. Project Objectives*

From the outset of its contractual association with the Agency for International Development in March of 1968, Colorado State University had the mission of producing information (research) and expertise (trained personnel) concerning on-farm water management and related farming practices in Asia with the goal of increased food production.

Additionally, CSU, together with the Council of U.S. Universities on Soil and Water Development in Arid and Sub-Humid Areas (CUSUSWASH) were to cooperatively:

1. Examine all available water management research findings to identify relationships having world-wide application; and, engage in and promote research for filling gaps in knowledge; and, publish a manual "Principles of Water Management" to provide guidance through the whole range of climate, soil and socio-economic situations;

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*The material in this section has been extracted from the AID report, "Evaluation of the On-Farm Water Management Research Project, Colorado State University" prepared by Dean F. Peterson, James L. Walker and E. Walter Coward, September 1979.

2. Identify, study and characterize the water laws and organizational arrangements of various countries to obtain information concerning the types of laws and the entities affecting water allocation, distribution and utilization in irrigation systems; and, use this information to advise developing countries, particularly those in arid and subhumid regions, on substantive, procedural and organizational alternatives in water laws and organizations that can be tailored to meet their needs.

The initial focus of the CSU mandate was Pakistan where it was intended that broadly applicable principles and concepts would be derived through attaining the following objectives under Contract AID-csd-2162:

1. Developing knowledge and data on how best to conserve and utilize water falling on the land as rain and the most efficient means of supplementing needed soil moisture by limited amounts of irrigation water;

2. Developing knowledge and data to use for the economic design and construction of water conveyance and delivery systems including structures for control and measurement of irrigation water especially on the farm;

3. Developing surface and subsurface water removal systems to eliminate the hazards resulting from surface flooding and high water tables;

4. Identifying important factors to be considered in land preparation and leveling of the various irrigated soils* in the major climatic zones and the relationship of these factors to water management, erosion, water infiltration, and good land use and cropping practices;

5. Developing and adapting* methods of water application, including time and amounts, suitable and efficient for different soils of varying physical properties with major crops;

6. Integrating the preceding water-use factors into productive cropping systems* consistent with farm size and available farming practices;

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*Amendment 7, May, 1973. These items were added under AID Contract AID/ta-C-1411.

7. Studying soil amendments, soil and water management procedures and the use of salt-tolerant crops where water quality, soil salinity and exchangeable sodium are problems;

8. Identifying institutional and policy factors influencing efficient distribution and management and utilization of water at the farm level.*

The basic contract AID/csd-2162 was subsequently amended to add the following objectives to the original ones:

(7-1-69) Produce a research and educational film on land preparation for level-basin irrigation.

(6-3-70) 1. Study, emphasizing on-campus, mathematical models, the types of skimming arrangements for collecting fresh water over saline strata;

2. In cooperation with the West Pakistan Department of Agriculture, advise on land preparation and water control field experiments (leveling, chiseling, slope, length of run, rate of application and method of irrigation);

3. On-campus completion of clay mineralogical studies of Pakistani soils and the relationships of ESP of these soils in the laboratory and greenhouse to applied waters of varying SARs;

4. Cooperatively with the Land Reclamation Directorate of the Department of Irrigation and the Water and Power Development Authority study utilization of saline groundwater for long-term irrigation;

5. Cooperatively with the Ayub Research Institute initiate field studies on management techniques related to water quality and cultural practices (including variables such as water quality, rate and frequency of irrigation, tillage and amendments);

6. Cooperatively with the West Pakistan Agricultural University, characterize and classify irrigation waters and soils as related to water quality and irrigation practices;

*Amendment 7, May, 1973. These items were added under AID Contract AID/ta-C-1411.

7. Continue studies on-campus on fluorescent dye loss in water flow;

8. Continue on-campus design of economic analysis and data collection and handling in the field; initiate analyses of economic rationale of on-farm input use;

9. Initiate studies on-campus of political science as related to the organization and administration of water management problems;

.0. Initiate studies of social science as it relates to the acceptance of water management programs.

By early 1970, these objectives had been defined in a context appropriate for West Pakistan and a Project Agreement was written cooperatively with USAID and the Government of West Pakistan establishing the specific research studies required to meet the objectives.

CSU activities were expanded to include the Mekong Delta region in Vietnam where operations commenced in early 1974. The objectives of this effort, while specific with regard to in-country efforts, were consistent with the project objectives previously mentioned. This activity ceased on 21 April 1975 due to the American evacuation from Vietnam.

During 1974, a new contract (AID/ta-C-1100), effective 1 April 1974, was signed with AID/W. In it, project objectives remained unchanged from those mentioned in the preceding paragraphs.

AID contract AID/ta-C-1411 was approved for the period of 1 April 1977 to 31 March 1980 and contract management was transferred from the Bureau for Development Support to the Bureau for Asia in November of 1978. This contract provided funds for a continuation of the research activities conducted by CSU under Contract AID/ta-C-1100. Thus, the objectives of the new contract were unchanged. However, this contract was more specific with regard to its conditions than was the previous project, in that it was expected that:

1. Most of the research would be conducted on watercourse areas being pilot tested under the USAID/Pakistan On-Farm Water Management Project No. 391-04130;

2. There would be cooperation with Cornell University personnel who were working on the AID funded research project "Determinants of Irrigation" (Project No. 931-1005).

The specific tasks under the general scope of work to develop, design and implement guidelines for improving irrigation water use efficiency and effectiveness on farms with emphasis on the pilot project area, were to:

1. Give technical guidance on watercourse rehabilitation and land leveling;

2. Test the essential improvements program;

3. Determine the maintenance and educational requirements of precision land leveling;

4. Analyze crop water needs and cropping patterns to efficiently utilize water;

5. Take field evaluations of tubewells and pumping devices to develop guidelines for designing and operating skimming wells;

6. Provide personnel assistance in designing a training program;

7. Prepare a manual describing and recommending minimum training requirements for various aspects of the water management improvement process;

8. Develop evaluative tools to measure the effectiveness of farmer organizations and then evaluate a number of such organizations in the pilot project area;

9. Document the economic benefit-cost ratios resulting from specific water management alternative technologies for ten pilot experimental watercourse areas;

10. Perform farm management studies to ascertain alternative changes in cropping intensities and crop mixes to increase net farm income resulting from the increased water supplies due to reduction of water losses and improved field application practices;

11. Analyze the costs of production of water from private tubewells;

12. Make an intensive socioeconomic benchmark evaluation on a sample of the 1500 watercourse areas in the pilot project;

13. Prepare a manual which can be utilized in LDCs in developing and implementing on-farm water management programs describing the methodology or systematic process (transfer model) which has evolved from the research experience in Pakistan;

14. Prepare, as in item 13 above, a set of technological manuals on:

    a. Watercourse improvement;
    b. Land shaping and field arrangement for efficient use;
    c. Crops and cropping patterns for efficient utilization;
    d. Institutional and organizational needs;
    e. System maintenance; and
    f. Augmentation of supply by wells and farm storage;

15. Provide limited (approximately 1 FTE) technical assistance to AID for irrigation water management project planning and evaluation.

Contract AID/ta-C-1411 was amended 8-29-79 to require the following specific manuals/reports at the time of contract termination:

a. Transfer process
b. Water Users Association Brochure
c. Water Course Improvement
d. Evaluation and Improvement of Irrigation Systems
e. Evaluation and Improvement of Basin Irrigation
f. Evaluation and Improvement of Border Irrigation
g. Design of Jet Junctions
h. Skimming Well Manual
i. Calibration of Cutthroat Flumes
j. Factors Affecting Losses from Indus Basin Irrigation Channels
k. Watercourse Cropping Systems
l. Training Manual for Water Management Extension
m. Water Users Associations (Pakistan)
n. Final Contract Report

In March 1980, this contract was again amended to extend the completion date to May 31, 1980.

Thus, over time, the focus of the CSU effort under the three AID contracts became more project specific, but at all times consistent with the objectives of the initial project funded in 1968.

D. U.S. AID Evaluation of the CSU Water Management Research Project

During the time period July-September 1979, U.S. AID assigned an Evaluation Team to review this project from the time of it's inception on March 28, 1968 to the present. This review was concerned about the transferability of research results, both in Pakistan and in other countries. They were also concerned about the quality and relevance of the research results and about conceptual, administrative and implementation matters. The summary of their report, "Evaluation of the On-Farm Water Management Research Project, Colorado State University," dated September 1979, is given below.

Methods and procedures developed to improve the control of irrigation water so that it is delivered to crops in timely and efficient fashion could lead to very significant increases in returns to farmers and to developing countries depending on large publicly - constructed canal irrigation systems, if countries and donors have the will to implement them. On those systems, efficient distribution of water depends on the operation of complex physical, agronomic and socio-economic systems at the farmer level. The nature of these systems has been delineated and documented; methods and procedures for their investigation and diagnosis identified; and institution-development and technological approaches to improving them devised. While individual cases vary, the approach is highly transferrable among the various cultural settings within the large canal system of Pakistan. The degree of transferability to other countries, e.g., Sri Lanka, Egypt, is being tested. But the process is not cut and dried. It's transferability in each case will depend upon the training, skill and imagination of multidisciplinary teams. Results indicate that efficiencies in the use of water on large projects can be increased by from 50 to 100 percent over present levels. If globally applied, in principle, these approaches could increase production potential on a substantial part of the 90 million hectares of irrigated land in developing countries by similar percentages. To do this will not be simple. It will require attention to literally thousands of individual irrigation distribution systems. However, the cost will be far less than bringing new areas under irrigation the same old way and of continuing to face the present level of unprofitable yields and waterlogging and salinity hazards.

These are the principal findings and implications of the centrally-funded farm irrigation water management research project initiated in 1968 and centered in Pakistan with Colorado State University (CSU) as the contractor. In 1979 this project, executed under three successive contracts, was transferred to ASIA Bureau and, in 1980, to USAID Pakistan.

Total dollar expenditures through termination on March 31, 1980 are programmed at $6,471,712. Because of cessation of AID activities in Pakistan, the field work was terminated in September, 1979. The general objective of the project was to improve the efficiency of water use in order to increase returns to farmers and to LDCs.

Pakistan has about 25 million acres of land under irrigation from canals diverted from the Indus River and its tributaries - the largest contiguous irrigation system in the world. The irrigation facilities were initiated a century ago by the British and have been extended continuously since then. Canal irrigation is supplemented and the irrigated area expanded another 5,000,000 acres by wells. Since Independence in 1947, multi-billion dollar investments have been made in storage reservoirs (Tarbela, Mangla), the large link canals bringing Indus River water to its other more easterly tributaries and in government-owned groundwater developments, yet increased yields and production generally have been very disappointing. Crop yields are very low and problems of waterlogging and salinity are frequently severe.

The original contract terms were broad and the project experienced some delay in start up for various reasons which were compounded by the Pakistan war and other political factors. By 1972, the most promising lines of research and institutional linkages had been identified, the general research plan put into focus, and a four-person expatriate team, later increased to seven, put into place.

The most critical difficulty was found to be in the last element of the water distribution system. The government canals deliver streams of water to areas of about 400 acres each. From here to the farm (the watercourse) this water is poorly managed. The farmers are on their own. Neither Irrigation nor Agricultural Departments have the responsibility for management of this link in the system, and indigenous institutions are not developed in this "no-man's-land". There are, of course, other critical problems. Management and control of water on the farm itself, saline groundwater and drainage are among the principal physical ones. All of these are linked to deficiencies in institutions and human resources.

We* did not have the resources to collect social and economic data, but we were able to document significant information relating to the impact of the project and to draw some conclusions relevant to centrally-funded research,

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*In this report: We, Us, Our means the evaluation team, Team means the Colorado State field party in Pakistan, Project means the joint efforts of the Team, its Pakistani associates and the supporting CSU faculty.

CRSPs and Title XII programs. We think very significant progress has been made by the project and by projects spawned by it toward mitigating the serious difficulties arising from poor water management.

The team recognized from the beginning that socio-economic considerations could not be divorced from physical and agronomic ones. Watercourse surveys concurrently collected socio-economic and physical and agronomic data. These studies confirmed a dearth of institutional arrangements for watercourse management and development. With Pakistani colleagues the team developed a model water users association law which is now being seriously considered by the Pakistan government. Initiation of the sociologic studies was an important innovation. These lagged somewhat for reasons partly beyond the Contractor's control. For this reason, and because of their complexity, understanding of desirable watercourse organizations remains incomplete.

Field measurements, made for the first time in Pakistan by project personnel, showed that instead of 85 percent as commonly assumed, only 40 to 60 percent of the water turned out of canals to intended crops actually reached the fields. By working with farmers on selected watercourses using organizational and technological approaches devised by the project, the team and its Pakistani associates demonstrated that water efficiencies approaching those anticipated could be achieved economically, resulting in increased equity of water distribution among irrigators and increased crop production.

Importantly, by a series of measurements on 40 watercourses at 16 locations in Sind and Punjab made by the project, high-level Pakistani and donor officials were convinced of the need for a program to improve watercourse operation. This led to several very tangible results. In 1976, the USAID and Pakistan negotiated a $44 million matching loan agreement to finance the "On-Farm Water Management Pilot Project" to improve 1,500 watercourses (out of the 89,000 under the Indus System). To implement this project, the Pakistan Government formed a special unit in the central Ministry of Agriculture and in each of the agricultural departments of the provinces. In 1979, the Water and Power Development Authority (WAPDA) Planning Unit issued a policy report proposing increased emphasis on watercourse improvement in contrast to investment in large dams and reservoirs. This report called for rehabilitations of 60,000 watercourses by 1990. Other donors, World Bank and CIDA (Canada), have become seriously interested in financing watercourse improvement programs. The World Bank with WAPDA has initiated a two-year study of 61 watercourses to provide time series data. With initiation of the Pilot Project, the team turned its attention to training of personnel to support the Pilot

Project, working primarily with the University of Agriculture at Faisalabad in devising training materials and implementing training activities.

Extensive studies of water use on farms showed no general pattern but apparently serious overwatering occurs more frequently than had been thought particularly in areas served by both canals and public tubewells on fields favorably located on watercourses. Research on soil, water, crop and fertilizer relations show that crop yields can be doubled and risk decreased using fairly simple adjustments.

About one-third of Pakistan's irrigated area is underlain by saline groundwater with a shallow layer of fresh water on top. Besides providing irrigation water, pumping of groundwater is used to control waterlogging. Important experimental and theoretical contributions of how to manage pumping so that saline groundwater is not pumped onto cropped fields were made by the project. Much of the economic and engineering feasibility remains to be proven, however. No single counterpart organization or government agency was available, rather interest and responsibility was diffuse. Thus, the project engaged in developmental efforts with a dozen or more. The first watercourse surveys were conducted and a large share of the technology was developed, farmers on watercourses were organized and results measured on experimental watercourses working collaboratively with the Mona Reclamation Experimental Project of WAPDA. The watercourse was conceptualized as a socio-natural unit and socio-economic constraint to its maintenance identified. Results of socio-economic surveys were used in the design of the On-Farm Water Management Pilot Project.

Training and education programs in the U.S. and Pakistan for project personnel focused well on the project's objectives and proved to be important elements of the project's success. Partial support was provided for Pakistani graduate training in the U.S. Both Pakistani and U.S. graduate students did their thesis work in Pakistan. All Pakistani students returned to work in Pakistan. In country, nearly one hundred Pakistanis were trained for On-Farm Water Management teams. Some project concepts have already been transferred in designing projects in Sri Lanka and Egypt. In Egypt, the project got off to a running start because the essential methodology was already in hand.

A major strength of the project was its very heavy field orientation. The opportunity to work with a number of different organizations seems to us to have been a very positive advantage. Likewise, the broad terms of the contract permitted identification of the critical issues on the ground prior to drafting fixed work plans. We think this research project may have been unsuccessful had it been too thoroughly planned too soon.

The research project was somewhat unique in that it sequentially diagnosed the difficulties and moved into implementation without interruption. We think this scenario is important for developing country research projects; otherwise the hypothesis that the research is relevant is not tested. For this to happen, the problem must be of significant importance to the host country. Demonstrating that the problem really existed was an important project contribution.

The importance of centrally-funded research even in a single country is supported by the success of the project. We do not believe that the very critical problem of farm water management in Pakistan would have been tackled within the foreseeable future by either USAID or the Government of Pakistan. Both the contractor and present Mission personnel indicate that a principal reason that the team enjoyed good relationships with USAID was its independence.

The project demonstrated that to be successful the farmers under a watercourse must be fully involved in the planning details from the very beginning and must be willing to contribute resources of labor and preferably some financing also.

Several points which should be of interest to CRSP and Title XII activities are detailed. In addition to some of those mentioned above, these include the value of considerable flexibility in the mode of approach, the need to work under real conditions, e.g., on farms, in LDCs the need to identify problems of primary importance to host countries, the need to make the project a host country one, and the need for in-country funding especially if P.L. 480 funds are not available. We are impressed that training and institutional development, though not included in the project objectives, were essential activities at every step in the project and must have required a very significant share of the team's time and efforts.

In summary we believe a major breakthrough has been made toward improving the efficiency and equitability of irrigation water distribution under large canal systems, particularly the Indus system. To realize the potential, however, will require major efforts in developing people and institutions as well as in providing incentives and improving the assets of poor people. While the work accomplished is a necessary part, by itself it is not sufficient, realization of its potential will require exceptional commitment and persistance of the host country and its donors.

E. Accomplishments During the Project (March 28, 1968 to May 31, 1980

In discussing accomplishments, it becomes very easy to fall into the trap of taking credit for all farm water management activities that occurred in Pakistan. The reader must bear in mind that the CSU staff assigned to this Water Management Research Project (WMRP) were participants in such activities, and the real success of these endeavors resulted from the interest and responsiveness of the many Pakistani cooperators. Secondly, although the project staff would like to take credit for serving as catalysts in many of these activities, certainly many other people contributed their ideas and energies in developing improved water management practices. Finally, for whatever contributions made by the project staff, whether serving in Pakistan or on-campus, certainly these achievements are not the result of a single person, but the combined interactions of many individuals representing many disciplines. In many respects, these are the most meaningful accomplishments resulting from this research project.

1. Major Accomplishments

a. Research Focus

This Water Management Research Project has emphasized field research of the farm subsystem. In most arid countries of the world, there is very limited knowledge about farm water management relative to the irrigation delivery subsystem and the water removal (drainage) subsystem; yet, the purpose of water delivery and removal is to support the growth of plants on the farm, which in turn support human and animal life.

Although an interdisciplinary research approach was undertaken from the beginning of this project, the capability of the project staff to accomplish truly interdisciplinary research evolved into a growing strength with time. The emphasis on interdisciplinary teamwork proved to be highly rewarding, not only in terms of specific research results, but more importantly, by viewing the irrigation system in the broader perspective of national agricultural development.

This project attempted to achieve the objectives of "Improving Irrigation Water Management on Farms" through the broader goals of agricultural development by working with many government agencies and some private firms. The research activities involved cooperative efforts with most of the agricultural research institutes in Pakistan, the agricultural universities, and government action agencies. The project involved an increasing number of extension activities, which would have continued to increase had the project been continued. The long-term strategy was to: institutionalize water management research and training in the universities; have research institutes do more studies on farmers' fields

while strengthening their capability to conduct water management research; strengthen the capability of extension personnel to perform many water management activities, such as organizing farmers and conducting demonstrations on farmers' fields of improved agronomic and irrigation practices; developing stronger linkages between the research institutes and extension service; have small private firms manufacture such items as flow measuring flumes, nakkas, and farm implements; and facilitate the capability of government action agencies for implementing solutions.

The greatest sensitivity to the farm subsystem was gained by working with farmers and developing a keen awareness of the many physical and socio-economic constraints that farmers contend with in agricultural production, as well as recognizing the value of their input in the development of solutions. The importance of this particular approach was stressed, and then practiced, with many of the cooperating organizations in Pakistan. Throughout the life of this research project, major attention was given to assisting those farmers having small land holdings to gain an equitable share of the agricultural inputs such as seed, fertilizer, water and credit.

b. Training

One of the most easily measurable indexes of accomplishment for this research project is the number of people trained in on-farm water management. First of all, the project staff received valuable training resulting from the experience in Pakistan. Besides the 16 staff members who served in Pakistan (Appendix 3), there were many other faculty members (about 15) who made short-term trips to Pakistan and provided backup support on campus. In addition, three American graduate students did significant portions of their Ph.D. dissertation work in Pakistan, while three more Ph.D. students from other U.S. universities participated in the field research program.

A significant training program was having selected Pakistani cooperators obtain academic training on campus and then return to Pakistan for doing the field research for their degree. These Pakistanis were selected based on their demonstrated willingness to work with their hands and get their feet muddy in the field. Although only 13 Pakistanis graduated under this program, they continue to do serious field work, thereby contributing in a very substantial manner to the development of their country.

The U.S. AID Mission to Pakistan provided support for a number of Personal Service Contract (PSC) personnel to work directly under the supervision of the CSU Field Party. Many agronomists, agricultural engineers and economists, most of them recent college graduates, received valuable field

training. Then, after one or two years, the CSU Field Party assisted them in being relocated in a government position that could utilize their expertise, thereby enhancing that agency's capability for performing water management activities.

One of the most productive relations in terms of both research and training occurred in the cooperative efforts with the Mona Reclamation Experimental Project (MREP). In the early years of this project, the Field Party interacted largely with senior researchers at MREP, but later most of these individuals were promoted into higher positions in Lahore. From that time on, considerable training occurred with younger staff members, many of whom later moved to higher positions and new staff again had to be trained. About 25 MREP staff were involved through the years in water management research. Also, many Field Assistants (about 40) who are high school matriculates, received field training for a variety of technical tasks, most of which were related to performing extension activities with farmers.

The CSU Field Party worked cooperatively with eight faculty, representing six departments, at the University of Agriculture, Faisalabad (UAF) in training the Agricultural Officers for the On-Farm Water Management Pilot Project, which is discussed in the next section. Each field team has one Agricultural Officer, whose assignment is to work with farmers on advising them of improved agronomic and irrigation practices so that they will more effectively utilize their increased irrigation water resulting from the improved watercourse. Also, the Agricultural Officer advises farmers on cleaning and maintenance activities for their improved watercourse. Essentially, the 4-1/2 month training course, which provides 30 percent of the instruction in the classroom and 70 percent in the field, allows the Agricultural Officer to really serve in the capacity of a Water Management Extension Specialist. About 92 individuals, representing all four provinces, have received this training.

Each Field Team under the On-Farm Water Management Pilot Project (OFWMPP) consists of nine members: one Team Leader; two Watercourse Development Officers; five Land Development Officers; and one Agricultural Officer. All team members receive training at the Training and Research Center at Niaz Beg. U.S. Soil Conservation Service (SCS) personnel serve as advisors for the training program; however, the CSU Field Party has been involved with the training program for the Watercourse Development Officers, who are usually college graduates in agricultural engineering. (An interesting sidelight is that agricultural engineers had serious difficulty in obtaining jobs at the time that the CSU Field Party first started employing them as PSC's in 1973; but, by 1977, these people were in great demand by a number of government agencies.) There are now about 47 teams in the field. A real measure of

the value in training these Field Teams is that they are now receiving important psychological feedback because their services are in great demand by the farmers.

c. Implementation of the On-Farm Water Management Pilot Project

This research program was particularly fortunate in being able to utilize the research results directly in an implementation project. Cooperative efforts between the Government of Pakistan, the U.S. AID Mission to Pakistan, the SCS and CSU led to the development of the project paper. CSU campus and Field Party staff participated in the preparation of the documentation for the $44 million Pilot Project ($22 million AID loan), which was initiated in 1976.

This exercise in project implementation proved to be a valuable learning experience. The CSU Field Party became involved in the UAF training program described above, the training program for agricultural engineers in watercourse improvement, the formal and informal arrangements for organizing farmers on a watercourse, and the monitoring and evaluation of this Pilot Project.

Although the project staff had previously advocated the formal organization of farmers on a watercourse into a Water Users Association, the implementation of this Pilot Project focused attention on the critical nature of this topic if farmers are to maintain their improved watercourses. This subject was being given consideration until termination; unfortunately, a major research effort is still required.

d. Growing Awareness for Improving Irrigation Water Management on Farms

One of the greatest satisfactions to the project staff has been the growing awareness throughout Pakistan on the subject of on-farm water management. The research results on watercourse losses and irrigation field application efficiencies were met with extreme skepticism by many organizations, largely because they were contrary to two decades of reports by consulting engineering firms. There is still skepticism today in many quarters, but the degree of acceptance has grown substantially. The major changes in emphasis by the Government of Pakistan regarding water resources development reflect this awareness.

The World Bank is presently working with the Government of Pakistan in establishing two projects that utilize the results of this research program. The governments of Canada, United Kingdom, and West Germany have demonstrated an interest in providing funding for on-farm water management development projects.

There have been a number of consultations between the Food and Agriculture Organization (FAO) of the United Nations and CSU staff regarding utilization of the research results. FAO is presently developing a strategy for on-farm water management that can be utilized in developing countries.

2. Specific Accomplishments

a. Water, Soil and Crop Management

Plant-soil-water-fertility experiments have been conducted cooperatively at most of the major agricultural research institutes in Pakistan. The crops that have been given the most attention are wheat, sugarcane, maize, cotton and rice. A primary concern has been the problem of inadequate crop stands that is so commonly encountered in Pakistan, particularly during the kharif (summer) season. Past results have indicated that stands and yields could be improved for maize and cotton by methods such as bed and furrow planting, crust control by mechanical methods or irrigation water timing, field drainage, and land leveling to avoid loss of crops due to flooding of low areas of the fields.

Recently, results on sugarcane experiments were consistent with those previously reported in that the effect of interaction between nitrogen and water on cane yield was small, indicating that nitrogen response was not much affected by water stress. Highest yields were generally obtained with a total of 55 inches or more of water applied, but 80 to 85% of maximum yields were obtained with only 30 inches of water providing that adequate nitrogen was used. Optimum N and water levels depend on the cost of water, but in general, N levels near 200 lbs N per acre are most economical, even under conditions of water stress.

Even though a strong interaction between water and nitrogen has been encountered for cotton, the general pattern of little or no interaction has been encountered for several years at numerous locations for wheat and sugarcane. This general pattern strengthens our previous conclusion that if uncropped land is available, additional water available as a result of improved water conveyance is best used to increase cropped acreage, even though moderate water stress may result at some point in the growing season. These conclusions are consistent with results from linear programming models that generally indicate optimum cropping patterns are those that use irrigation levels below full irrigation requirement as long as land availability is not limiting. Only when land availability constrains increasing cropped area should crops be grown at full irrigation requirement, unless high water tables or use of saline ground waters render the land especially vulnerable to salt accumulation.

Research cum demonstration trails over several years have provided insight into those problems that appear to be the most serious in limiting production, as well as the effectiveness of practices intended to alleviate these problems. Along with fertility and crop stands discussed above, weed control consistently emerges as one of the most important factors affecting production.

Hand weed control has been consistantly shown to be highly effective in increasing crop yields in our field trials. Even in a labor intensive economy, it is often impossible to attain the needed level of control by this method. Chemical control is in its infancy in Pakistan, but some effective chemicals are available. Weed control trials on maize and wheat have recently demonstrated that at least one effective and easily used chemical method is available for each of these crops. Unfortunately, there are also materials available that are either ineffective or likely to result in crop damage. Serious efforts are required to provide more widespread testing, make available those materials that are safe and effective, and to remove inappropriate materials from the market.

b. Consumptive Use

Under the project, consumptive use studies on wheat, berseem and cotton were initiated in collaboration with the Punjab Agricultural Research Institute at Faisalabad and continued there for several years. Consumptive use test sites were also located at the Mona station. Beginning about 1976, a network of consumptive use studies using eight sites throughout the country was implemented by the Pakistan Agricultural Research Council utilizing PL-480 funding and working directly with USDA. The project played a significant role in getting the work started and then a continuing limited role in helping to refine techniques and operating procedures.

c. Farm Cultivation Equipment

During 1978 and 1979, the Field Party had the capability for developing farm implements. The emphasis was upon implements that would improve crop stands during the kharif season. While the potential of bed and furrow planting of such crops as cotton and maize for stand improvement was recognized, there was no adequate bedding and planting equipment available for even planting good demonstration plots, let alone for encouragement of farmers to adopt such practices. Such equipment is not available in Pakistan, and imported equipment is not well adapted. Therefore, new bedding and planting equipment that is better adapted to local conditions has been designed and several units fabricated for use in demonstration trials during the coming seasons. This equipment is presently tractor-mounted, but modifications for bullock-drawn equipment for use by small farmers was developed which consisted essentially of constructing furrows in the basin.

d. Flow Measurement

The development of an awareness regarding the importance of on-farm water management in Pakistan can be largely attributed to introducing the Cutthroat flume for measuring watercourse losses. The calibrations for the particular sizes of Cutthroat flumes used in Pakistan was developed under the AID 211(d) grant to CSU. The first Cutthroat flume was installed in Pakistan during November 1973. This particular flume was developed for use in very flat gradient irrigation channels, so it was ideally suited for measuring losses in the watercourses.

Cutthroat flumes are fabricated in Pakistan. Project personnel have worked with a small fabricating shop to develop good quality control. Now, other shops in Pakistan also fabricate these flumes. By 1977, approximately 300 Cutthroat flumes had been fabricated.

Efforts were underway at the time of termination to have Cutthroat flumes installed at all of the major agricultural research centers. In the past, because there were no flow measurement devices available, the amount of irrigation water received by any crop was reported as the total number of irrigations during the crop season multiplied by three inches for each irrigation.

e. Watercourse Losses

For the first time, seepage and operational losses of water in delivery from the canal turnouts to the farmers' fields were measured under operating conditions. Instead of 10 to 15 percent seepage losses as had been assumed by planners in Pakistan, real losses were found to be 40 to 60 percent. Much effort on the part of the CSU team and its Pakistani associates went into establishing the credibility of these findings with high Pakistan government officials and their consultants and donor constituency. The experiments have been repeated over Pakistan first on 40 and then on 61 sample cases. The evidence has been accepted and led to the $44 million ($22 million AID loan) On-Farm Water Management Pilot Program initiated in 1976 and to suggestions for major revisions in Pakistan's water management strategy from large water supply works to emphasis on conservation and management as evidenced by the recent report of WAPDA's Planning Division entitled "Revised Action Programme for Irrigated Agriculture" dated April, 1979. This draft plan, which still faces the obstacle of obtaining high-level approval, shifts emphasis from large capital intensive structures toward better water management including the partial lining of 29,000 watercourses in saline groundwater zones and rehabilitation of 60,000 more in freshwater zones. The plan calls for lining 24,000 watercourses and rehabilitating 48,000 more by 1990 and states with regard to partially lined watercourses:

"Recent studies by Master Planning (WAPDA) and Colorado State University, and demonstrated experience in India, have shown that partial lining is economic and the best technology for unusable groundwater areas."

f. Farm Irrigation Losses

Experiments were conducted to determine whether or not fields were over- or underirrigated. No overall general pattern can be deduced. At Mona, in a SCARP area, 71 percent of 64 fields studied showed losses due to overwatering greater than 70 percent; however, in a nonSCARP area near Faisalabad, losses greater than 10 percent occurred on only about one-third of the 246 fields studied. Poorly leveled land was shown to be a major factor related to overirrigation. Other factors correlating with overwatering are whether or not supplemental well water is available and whether or not the field is located in a SCARP. Serious overwatering occurs more frequently than has previously been thought. A common statement is that each irrigation applies an average water depth of 3 inches over the bunded basin, but measurements showed this was rarely possible because of unlevelness of the basin surface. Instead, in order to cover the high spots with water, irrigation depths of 3 - 11 inches were measured, with depths of 5 - 7 inches being very common. Overwatering increases waste of water and waterlogging; underwatering permits damaging accumulation of salts in the root zone. One or the other case is the rule rather than the exception.

g. Identification of Socio-Economic Constraints

An important contribution to watercourse development in Pakistan was the broad conceptualization of a watercourse as a socio-natural unit involving agronomic, engineering, economic and social aspects. With this concept in hand, project researchers were able to take a broad view of the variety of factors influencing water management behavior at the watercourse level and the various constraints that would need resolution if improvements were to be achieved. Research methods were developed and applied first to the survey of a single watercourse and then to a larger sample of watercourses. The success of these activities led to the formulation of a larger study to be done at 24 different locations throughout the Punjab and 16 locations throughout the Sind. Fieldwork for this study of 40 watercourses was done during 1975-76. This larger study was conceived as a fundamental activity in the process of problem identification; i.e., identifying the range of social and technical problems existing at the watercourse level. Among its important findings was:

1. The identification of factors related to the low level of watercourse maintenance;

2. The lack of effective local organization to mobilize labor and other resources;

3. The lack of knowledge among farmers regarding the magnitude of watercourse losses; and

4. The lack of technical knowledge among farmers for improving their watercourses.

The results of these socio-economic-physical surveys were used in the design of the present On-Farm Water Management Pilot Project. Furthermore, this work led to the initiation of a WAPDA/UNDP/World Bank watercourse study that investigated 61 additional watercourses for a two-year period, thus providing time-series data. Interim reports are being prepared by WAPDA regarding the results of these long-term studies.

h. Watercourse Improvement Technology

Having established the magnitude of watercourse losses, the Project began in 1974 to examine what might be done to reduce them. Various types of linings and treatments, turnout devices, and other appurtenances and rehabilitation procedures were developed and tested. This work was centered at WAPDA's Mona Reclamation Experimental Project (MREP).

Before initiation of watercourse rehabilitation work, extensive discussions were held with farmers regarding acceptability of linings, turnouts, etc., and their own participation. In all cases, farmers participated extensively, providing the labor; and in some cases, purchasing turnouts. Full lining of watercourses was found to be too expensive, but the studies found that most of the losses could be prevented by programs of rehabilitation of earthen watercourses, lining of critical reaches and installation of manufactured turnouts (nakkas).

Training materials for watercourse improvement were jointly prepared with the SCS advisers for the OFWM Pilot Project. Finally, in 1980, a Watercourse Improvement Manual was published that is quite comprehensive. (See Water Management Technical Report No. 58.)

i. Irrigation Control Structures

A significant development, that is highly desired by farmers, is the concrete nakkas that control the flow of water between watercourse branches. This development was a painstaking process that required attention to detail and quality control. These structures were developed in collaboration with a concrete artisan near Sargodha. Acquiring these concrete nakkas is a strong incentive to farmers for participating in the OFWM Pilot Project. During canal closure in

early 1980, the Government of Punjab had a crash program of heavy cleaning and maintenance on nearly 10,000 watercourses, installed 1,877 nakkas, and have placed orders for many thousands of concrete nakkas which will be installed in the near future.

Another structure of interest that was developed under this project was the "jet pump" or "jet juncture." This is a structure that combines the canal water in a watercourse with tubewell water, which results in raising the watercourse water level downstream from the structure and lowering the water level in the watercourse upstream from the structure. The primary advantage is being able to irrigate higher fields more efficiently, while a secondary advantage in some cases is to keep the mogha from being submerged so that the maximum amount of canal water is received in the watercourse.

j. Basin-Furrow Irrigation

As described above under Farm Cultivation Equipment, a tractor-drawn bed shaper and a bullock-drawn furrower had been developed as a means for improving crop stands in the kharif season by constructing furrows in a basin. Some demonstrations have been conducted. This is a very important effort with tremendous potential for increased crop production. There are many agronomic and irrigation advantages favoring basin-furrow irrigation as compared to basin irrigation. Because of it's high potential, some means should be developed to continue this research component.

k. Skimming Wells

Perhaps one-third of Pakistan's irrigated area is underlain by saline groundwater with a shallow layer of fresh water on top. These freshwater supplies are badly needed in the overlying areas; however, extracting the fresh water without drawing in excessive quantities of saltwater is physically very difficult. The project has field tested some well arrangements designed to skim off the shallower fresh waters and to prevent upward coning of saltwater into shallow wells. Considerable work was also done by the project using hydrodynamic theory and mathematical modeling.

The research results show that fractional tubewells (less than one cusec) should be used in saline zones. In many cases, fractional tubewells having a capacity of only 0.2 cusecs should be used. This is a dramatic finding considering that most public tubewells have been installed in these saline areas with capacities of 3 - 5 cusecs. The use of fractional tubewells has many socio-economic advantages because they can be installed by private individuals, and if small amounts of credit could be made available, then farmers with small land holdings could also reap the benefits of having a tubewell. (See Water Management Technical Report No. 63.)

l. Irrigation Water Users Associations

The work initiated by the project represents the first effort to explore issues of appropriate local irrigation organizations for the Indus irrigation system. The initiation of this work is a significant achievement. There have been two directions to this work. One is the work on irrigation law and the identification of needed legislation to provide legal arrangements for organizing water user associations. A proposed water user's association law has been drafted and discussed in all four provinces of Pakistan. In a high-level policy-making meeting of Federal and provincial leaders in Islamabad on May 15, 1980, agreement was reached that each province (water is a provincial matter) should enact legislation authorizing Water Users Associations. This will likely be done before the new OFWM Project is funded by the World Bank, which is presently scheduled for initiation on July 1, 1981.

Second, is the program of various field studies that have sought to understand the basic social organization of the Punjabi village, and more specifically, the Punjabi watercourse. These studies had the twin objectives of discovering existing patterns of organization for watercourse management and maintenance as well as identifying structural principles and value systems relevant to attempts to create water user groups. A number of important factors have now been identified. (See Water Management Technical Report No. 55.)

At the time of project termination, this particular research effort would have to be considered the most important to the future of agricultural development in Pakistan. Somehow, some means must be developed to continue this research effort as soon as possible. Hopefully, other donor agencies will recognize the importance of this topic and provide some assistance in the immediate future.

m. Training Water Management Extension Officers

Saving water in watercourses is not productive unless the water is used effectively to increase crop production. CSU has worked with the University of Agriculture, Faisalabad (UAF), in developing a training program which prepares one Water Management Extension Officer for each water management development field team under the On-Farm Water Management Pilot Project. His responsibility is to help farmers improve their production through better management of his expanded water supply, leveled land and other essential inputs (seed, fertilizer and weed and pest control). The Punjab, Sind, North West Frontier and Baluchistan provincial governments developed agreements with the University of Agriculture, Faisalabad for this training program. CSU has helped develop training materials that can be used by all four provinces. (See Water Management Technical Report No. 60.)

F. Water Management Research Needs in Pakistan

The campus staff of the Water Management Research Project held meetings in February, 1979 for the purpose of delineating future water management research needs in Pakistan. Additional discussions on research needs were held in Lahore by the Field Party staff during March and April of 1979. With project termination, it is appropriate that these research needs be included in our Final Report.

Instead of preparing a long "laundry" list of research needs, project personnel have focused first of all on specifying the major topics requiring research, then describing in general terms the research needs under each topic, and finally an attempt has been made to prioritize these major topics. During this process, it was also kept in mind what research efforts could be combined into logical projects for technical assistance. In addition, an estimate of the number of expatriates required for each project, along with their required disciplinary background, is provided.

The six major topics, in order of priority, are:

1. Water Utilization;

2. Institutional Arrangements for Improving Irrigated Agriculture;

3. Water Management Research and Training at the University of Agriculture, Faisalabad;

4. Strengthening Water Management Activities at Research Institutes;

5. Baluchistan Water Management Research and Training Project; and

6. Waterlogging and Salinity.

Although each topic can operate as a separate project, it is also possible to combine topics into a single contract. In particular, topics 1-4 could be combined into a single contract, or topics 1 and 4 into a single contract, or topics 1, 2 and 4. Such combinations could result, if necessary, in a reduction of necessary expatriates.

1. Water Utilization

There has been considerable progress made in developing appropriate technologies for watercourse rehabilitation, but little progress has been made in improving the utilization of the additional water supplies reaching farmers fields as a result of watercourse improvement. The major goal

of on-farm water management is the proper utilization of water on croplands in order to increase crop production and alleviate waterlogging and salinity problems.

The basic thrust of this program would be the development of improved agronomic and irrigation practices suitable to conditions encountered in Pakistan, followed by developing appropriate techniques for implementing improved practices. Logically, this research effort should result in the development of an AID Project Paper with the implementing agency in Pakistan being the Extension Service.

As a minimum, four expatriates should be assigned to this research effort; namely, one Agronomist, one Agricultural Engineer (Irrigation), one Agricultural Economist, and one Anthropologist or Sociologist. There would be considerable advantage in having six expatriates by adding one Agricultural Engineer (Power and Machinery) and one Soil Scientist or Agronomist.

This program should be done on a five-year contract. This should be followed by another five-year contract in which the research effort would provide direct support to a larger-scale implementation program by the Agricultural Extension Service.

2. Institutional Arrangements for Improving Irrigated Agriculture

This research program would have two major thrusts. First, the present research program regarding Water Users Associations would be continued. Second, research would be initiated with the Irrigation Department to improve their role in both serving and interacting with farmers through Water Users Associations.

The major focus of this research effort would be to strengthen the capability of farmers to interact collectively for their common good. The present research program on Water Users Associations is very important to this effort. Although formal organizations for farmers is highly desirable, this cannot be expected to occur in a short time. Instead, the capability of farmers to move from informal arrangements to formal organizations must "evolve" over a long time period. This evolutionary process for strengthening the capability of farmers to work together, as well as interact with government agencies, must be developed.

The present CSU water management research efforts are particularly weak as regards the participation of the Irrigation Department. The following research should be undertaken:

1. Modifications to Canal and Drainage Act;

2. Modifications to warabundi;

3. Legal and economic aspects of land and water revenue practices;

4. Scheduling of canal deliveries; and

5. Strengthening the role of the Irrigation Department with farmers.

This research program should have a minimum of two expatriates; namely, one Agricultural Economist and one Social Scientist with some expertise regarding irrigation organizations. In addition, backup support would be required by one half-time legal specialist in water resources.

This research program should be undertaken for five years, with an evaluation after three years to determine further research needs under this topic.

3. Water Management Research and Training at the University of Agriculture, Faisalabad

A research proposal has already been prepared for rupee grant funding, "Water Management Research and Training Program for Rural Development," by some of the faculty at the University of Agriculture, Faisalabad. The primary intent of this research program would be to provide valuable field research experience on small farmers fields for faculty, students and participants in special training programs for Agricultural Officers under the provincial On-Farm Water Management Development Projects. Besides strengthening the capability of the faculty for developing not only improved agronomic and irrigation technologies, but also the mechanisms for implementing such technologies, both students and trainees will be provided valuable field experiences as part of their training. In time, improved water management skills would be incorporated into the university curriculum, thereby internalizing the entire water management development process. A major payoff from this effort would be that university graduates would be much better equipped to participate in agricultural development.

Four expatriates are recommended for this project; namely, one Agronomist or Soil Scientist, one Agricultural Engineer (Irrigation), one Agricultural Economist, and one Anthropologist or Sociologist. As a minimum, two expatriates should be assigned to this research effort (one physical scientist and one social scientist).

The initial proposal has been written for a five-year period. This should be followed by a second five-year contract. The results of this research program, including the development of training materials, should be extended to the Sind Agricultural University through the Canadians, while some mechanism will need to be developed for extending these research and training results to the University of Peshawar.

4. Strengthening Water Management Activities at Research Institutes

Much of the CSU effort during the past seven years has been working with the staff of the Mona Reclamation Experimental Project (MREP). This particular research center has become the leader in developing improved on-farm water management technologies. Although there is a competent professional staff at MREP, there are still considerable benefits to be derived in continuing to work with this staff in order to maintain the leadership role that they have developed.

There is still considerable need to strengthen the role of many of the agricultural research institutes in Pakistan to play a stronger role in participating with small farmers to increase their crop production. In turn, this will provide important feedback to the researchers that will strengthen the research programs being conducted at their research stations. Even more importantly, there is an urgent need to strengthen the interaction between research institutes, extension personnel and farmers.

A minimum of two expatriates should be used in this effort. A physical scientist would be used to advise on developing improved agronomic and irrigation practices, while a social scientist would be employed to advise on techniques for implementing improved agronomic and irrigation practices.

The initial five-year contract should include coordination with the research activities to be funded by the Canadians in the Sind, where a research facility comparable to MREP will be constructed, along with research activities at the Sind Agricultural University. Under a second five-year contract, the role of the agricultural research institutes should be included in a larger-scale development project to strengthen the Extension Service as cited under the first priority project, "Water Utilization".

5. Baluchistan Water Management Research and Training Project

The water management problems in the Province of Baluchistan are dramatically different from problems in the other three provinces of Pakistan. There is no agricultural college or university in Baluchistan. Historically, only a very small fraction of Baluchis that leave for professional

training ever return. Consequently, there is a strong need to train Baluchis within the province to solve the water management problems being faced by farmers. Farmers already place a very high value on water, when compared with farmers in the Punjab or Sind, because of water scarcity.

The most logical framework for developing a provincial capability for not only water management research and training, but also agricultural development in general, would be to begin with a Baluchistan Research and Training Institute. Perhaps an existing agriculture research institute could be utilized. Much of the training would be conducted on farmers fields, so that researchers and trainees from provincial government agencies would become sensitized to the problems being faced by farmers. Later, this institute could become the Baluchistan Agricultural College. Then, much later in time, depending upon the rate of maturity of the faculty and the breadth of course offerings, this college could become the Baluchistan Agricultural University.

This program should be undertaken for at least a 20-year time period. During the first five-year period, a team of four expatriates should be employed consisting of one Agronomist or Soil Scientist, one Agricultural Engineer (Irrigation), one Agricultural Economist, and one Anthropologist or Sociologist. Before the completion of the first five-year period, a Project Paper should be developed consisting of two major components: (a) a small loan program to be implemented by provincial government action agencies to work with farmers in improving their agronomic and irrigation practices; and (b) a grant for converting the institute into the Baluchistan Agricultural College through the construction of additional physical facilities and participant education abroad, where the participants return to Baluchistan to do the necessary research for their degree program. During the second five-year period, the number of expatriates should be expanded to eight, with emphasis upon having individuals with different backgrounds in the agricultural sciences. These expatriates would not only assist in the expansion of the research institute into an agricultural college, but would also assist in the development project being implemented through the provincial government. Although it is difficult at this time to predict the number of expatriates required during the second decade of this project, it is not difficult to visualize a need for 10 - 12 expatriates. Hopefully, after 20 years, sufficient progress would have been made in the development of human resources that the status of a university would be warranted for this complex.

6. Waterlogging and Salinity

There is an urgent need in Pakistan to develop a cost-effective package of appropriate technologies for alleviating

waterlogging and salinity problems in many parts of the country. Although this subject has been given considerable attention during the past two decades, it is obvious that appropriate remedies have not been developed. Large nvestments have been made in the installation of public tubewells in Salinity Control and Reclamation Project (SCARP) areas, but this technology alone is not sufficient in most areas. Fairly large-scale studies are needed in various portions of the country, which would most likely have to be undertaken by the Water and Power Development Authority (WAPDA). However, the implementation of programs to alleviate this problem will most assuredly require the combined efforts of WAPDA, the Irrigation Department, and the Agriculture Department because the package of remedies will likely require reducing seepage losses from the water delivery subsystem, minimizing deep percolation losses from the croplands, and lowering groundwater levels by employing fractional tubewells and perhaps subsurface tile drainage.

The first five-year period should be used to investigate at least two canal command areas having serious waterlogging and salinity problems, with one area being in the Punjab and the other area in the Sind. During this time period, the sources of the waterlogging and salinity problems would be identified, water and salt budgets would be developed, and the transport mechanisms for water and salt described. Then, a variety of solutions that might alleviate such problems will be delineated. During the second five-year period, the variety of remedies would be implemented on a pilot area basis and their effectiveness evaluated. The results from these tests under actual field conditions would provide the necessary information for developing the most cost-effective package of technologies that would in turn be acceptable to farmers. Then, it would be possible to implement a national program for alleviating waterlogging and salinity in major problem areas.

During the first 10-year period, about 7 expatriates would be required consisting of one Groundwater Hydrologist, one Soil Physicist, one Soil Chemist, one Agronomist, one Agricultural Engineer (Irrigation), one Agricultural Economist, and one Anthropologist or Sociologist.

G. Dissemination and Utilization of Research Results

Throughout the project in keeping with program objectives, special efforts have been made which have resulted in wide dissemination and utilization of research results. As credibility with the Government of Pakistan has been increased as a result of a wide range of project activities, interest in on-farm water management from farmers to government officials has accelerated. The major results of project efforts are: 1) continued implementation of the comprehensive On-Farm

Water Management Pilot Project; 2) the training of a large number of host country personnel for research and development activities; 3) the institutionalization of water management research activities in research stations and with other organizations; 4) the assistance to WAPDA Master Planning, the University of Agriculture, Faisalabad (UAF), and other institutions in action oriented research and development activities; 5) focus on the need to improve water laws and codes and the provision of incentives for farmers to organize for improving their farm irrigation systems; 6) increase linkages with international organizations active in Pakistan and elsewhere with a concern and focus for on-farm irrigation problems; and 7) utilization of project personnel for reconnaissance surveys to irrigated projects in other low income nations.

As the pilot watercourse improvement program has evolved at Mona, a steady stream of at least 1000 visitors annually from the provincial and federal government, USAID, FAO, the World Bank and several other countries have visited the projects, talked to the farmers and seen the improvements. This on-site inspection has been reported as a major factor helping bring about the acceptance of the water management program by various agencies in the Government of Pakistan.

Because of the important role played by Mona in the Punjab, the Canadian International Development Agency (CIDA) has developed plans in conjunction with WAPDA to support a similar facility in the Sind. In the proposed program, which is scheduled to get underway in the very near future, faculty at the Sind Agricultural University at Tandojam would also play a significant role in the water management research programme. CSU personnel have enthusiastically endorsed this effort by WAPDA and the Canadian Government.

When the USAID funded OFWM Pilot Project is terminated either December 31, 1980 or June 30, 1981, the World Bank intends to provide support to the Government of Pakistan to continue this effort. Based upon the second joint USA-Pakistan evaluation of the OFWM Pilot Project in September-October, 1979, some modifications are being made in the proposed OFWM Project. This project will have a total cost of roughly $50 million for a three-year period. CSU personnel have been assisting in the formulation of this proposed project.

Expertise developed in the research and surveys conducted in Pakistan is providing a substantial springboard for the water management project in Egypt where aspects of the problem identification surveys found effective in Pakistan are proceeding at an accelerated pace in Egypt because they have been able to avoid some of our mistakes and because Pakistan Field Party members who have returned to campus are available to give support and on-the-spot guidance to the Egypt Water Use and Management Project.

The relative success of the farm water management research in Pakistan in helping develop a viable national water management improvement program has led to a continuing stream of requests for information concerning how the research programs were conducted and the available findings. In terminating this project, numerous technical reports and manuals have been prepared. A listing of these reports are given in the appendices of this Final Report. During the last contract year (since April 1, 1979), twenty-four reports were published. These publications will be disseminated according to an international mailing list maintained by the WMRP. Arrangements have been made with the U.S. AID Mission to Pakistan for distribution of these reports throughout Pakistan.

H. Development Process for Improving Irrigation Water Management on Farms

During this last contract period, considerable effort by campus project personnel has been devoted to describing a process for improving irrigation water management in any country. We have utilized our experiences in Pakistan, the western USA, and other countries in an attempt to describe such a process. Frankly, this has been an extremely difficult and time-consuming task.

This "Development Process for Improving Irrigation Water Management on Farms" has been published in four volumes: (1) Executive Summary; (2) Problem Identification Manual; (3) Development of Solutions Manual; and (4) Project Implementation Manual. The three phases of this development process has also been subdivided into subphases as listed below.

Phase	Subphase
Problem Identification	Reconnaissance Problem Diagnosis
Development of Solutions	Identification of Plausible Solutions Testing and Adaption of Solutions Assessment of Solution Packages
Project Implementation	Project Authorization Project Organization Project Operation

The diagrams illustrating the activities under each phase and subphase are shown in the three accompanying figures.

I. Lessons Learned During the Project (March 28, 1968 to May 31, 1980)

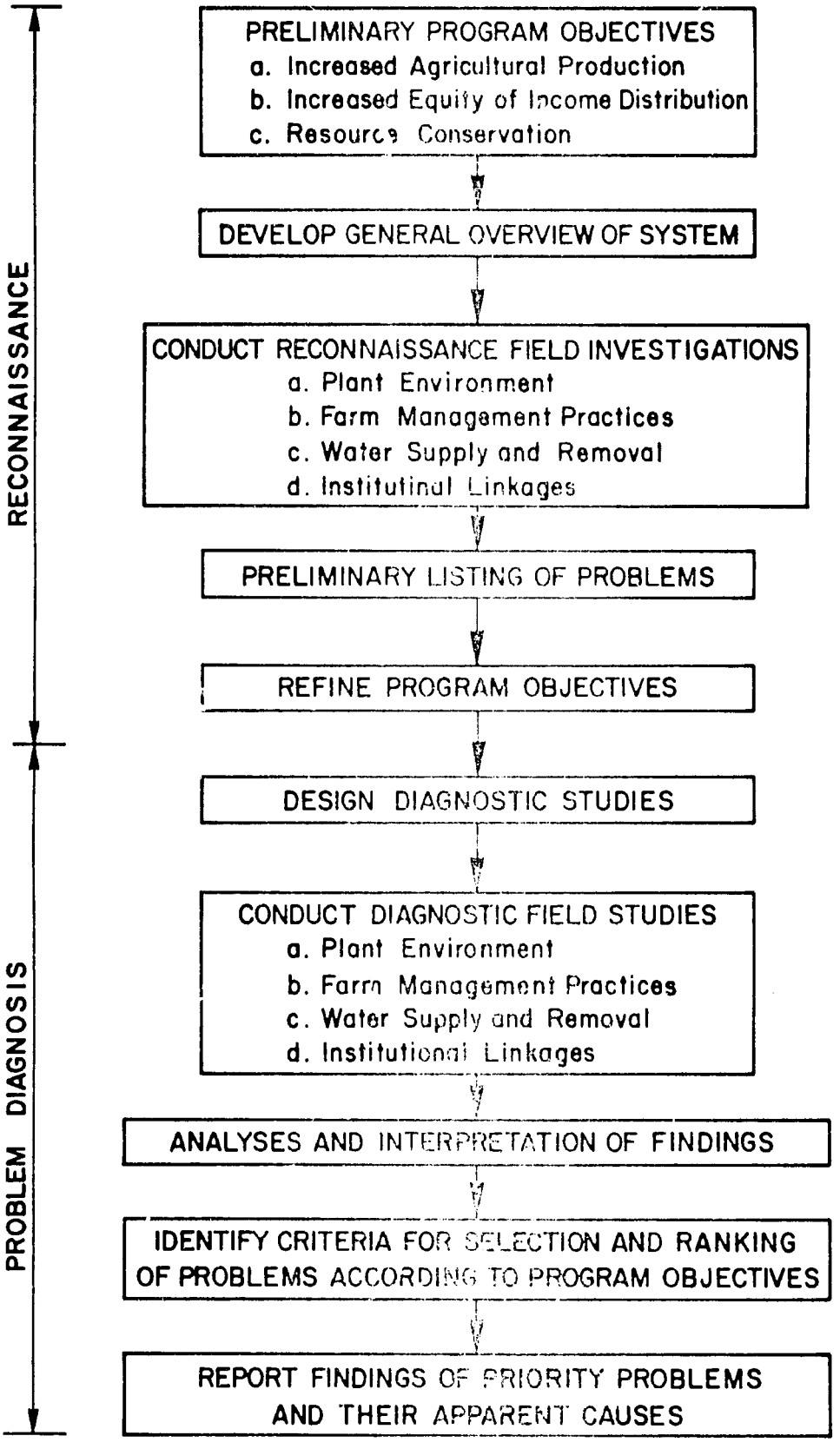
1. Project Organizational Arrangements

This project received funding from U.S. AID/Washington, which is termed a centrally funded research project. However, the local currency costs were provided by the U.S. AID Mission to Pakistan, who also provided support services such as housing and later, vehicles and host country administrative personnel, along with paying the salaries of host country professionals who worked full-time under the supervision of the CSU Field Party. The local currency support was important to the research activities, while such support services as housing, mail and commissary privileges were very important to family morale and allowed the Field Party to concentrate more on the research activities.

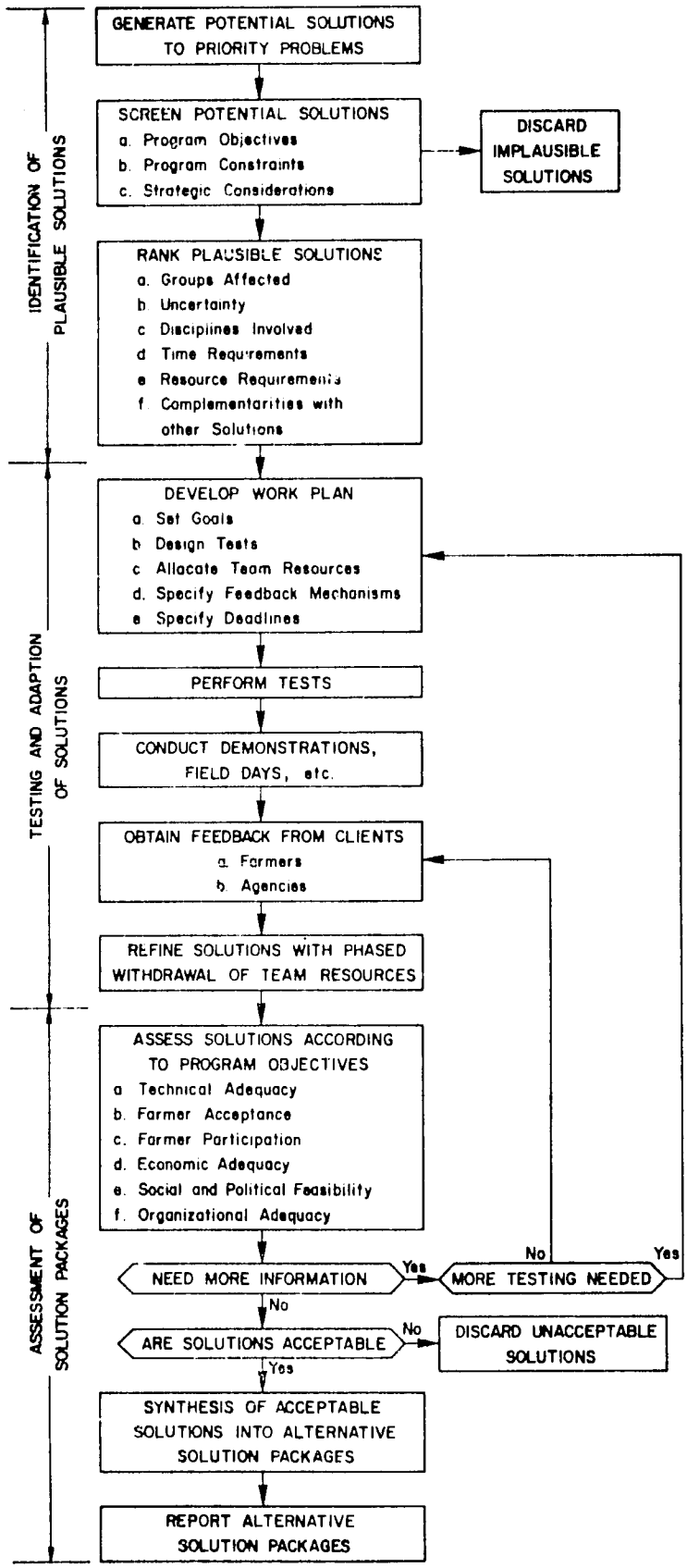
There was a strong effort by the Field Party to maintain good relations with Mission staff. The principal advantage of being centrally funded was not getting brought into so many "brush fires" that the Mission staff must contend with. This again facilitated the Field Party in being able to concentrate on research activities; however, the Field Party did undertake a number of short-term exercises at the request of the Mission staff.

One of the most valuable lessons learned was the advantage in not being placed in a counterpart role that is so typically advocated by international donor agencies. The accomplishments of this project would have been no more than 1/3 of what was accomplished had the Field Party been placed in a counterpart role. There are a host of reasons for this contention. First of all, this project did undertake research activities with some organizations in Pakistan the results of which would have to be considered essentially failures. One of these organizations could easily have been selected as a counterpart agency. Secondly, there is considerable time lost in getting research activities underway and often times the amount of delay cannot be foreseen; therefore, the Field Party always laid out more activities in the Annual Work Plan than could actually be accomplished because they recognized there would be delays, but they could not be sure as to which activities would be delayed. This approach proved to be fortuitous even in the later years of the project. Thirdly, working with a single counterpart agency would result in the Field Party becoming frustrated because of the time delays that invariably occur which result in idle time and a lack of productivity, inheriting problems between the counterpart agency and other host country organizations, being more susceptible to the in-house bickerings and office politics that exist in

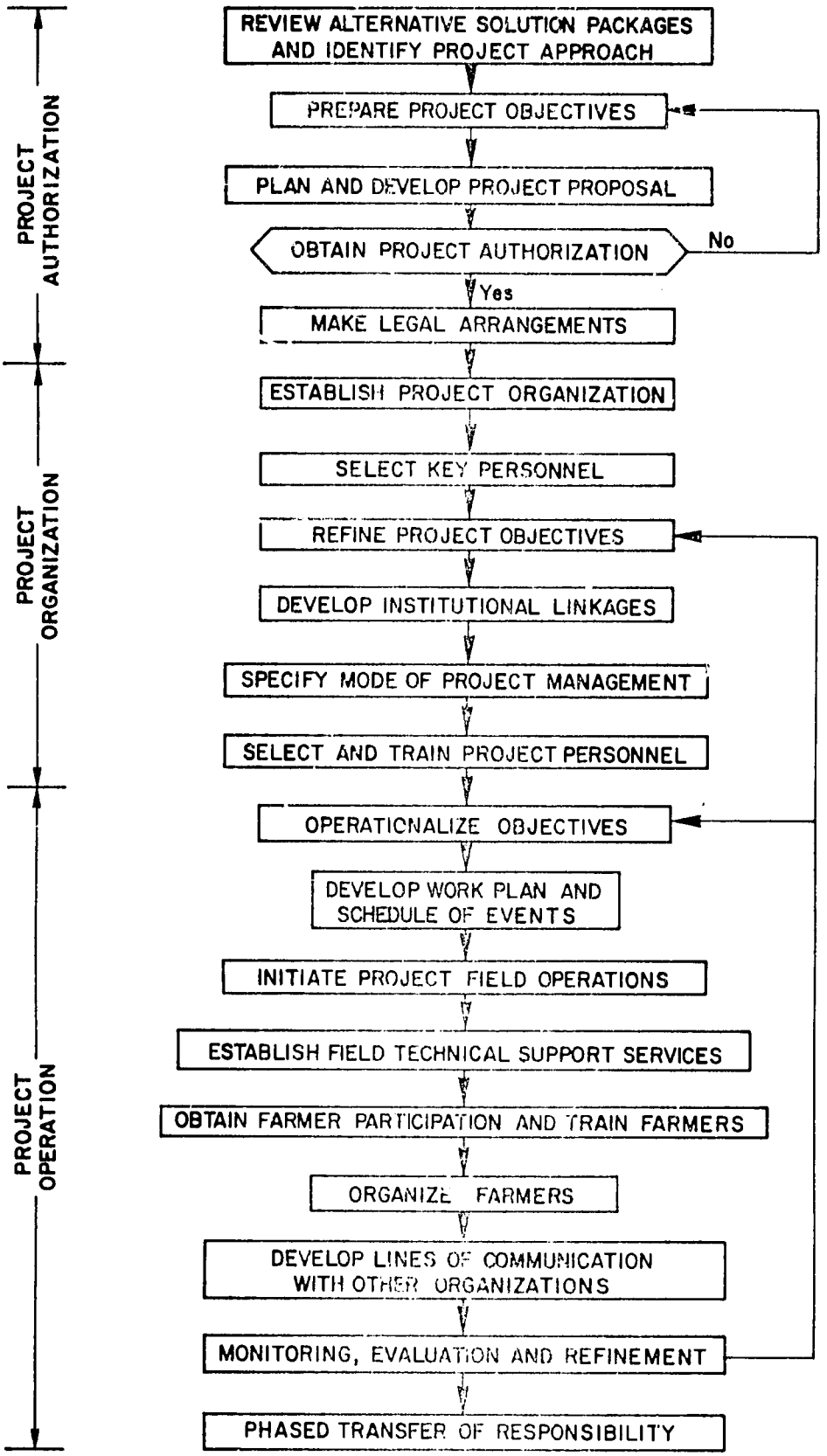
PROBLEM IDENTIFICATION



DEVELOPMENT OF SOLUTIONS



PROJECT IMPLEMENTATION



many agencies, and contending with the resource constraints that usually exist for the counterpart agency personnel. Flexibility in working with many agriculture and water agencies that impact the irrigation system is not only important in assuring productivity of the research effort, but is paramount in the larger concern for agricultural development.

2. Concern with Agricultural Development

Although on-farm water management has been the primary topic of this research project, it was recognized that this topic must be placed within an overall framework of agricultural development. The real objective of exploring means to improve water management practices is to increase crop production, with other primary objectives being the equitable distribution of income and resource conservation.

To understand farmer constraints requires a knowledge of the institutional infrastructure that impinges upon the activities of farmers. To develop solutions that will correct the major problems requires a knowledge of how the organizations dealing with water and agriculture, along with the laws, policies and regulations governing these agencies, can be utilized in relaxing constraints and implementing change. At the same time, identifying problems and developing solutions are an important mechanism for developing human resources.

Implementation of improved water management practices involves serious considerations regarding institutional development. To implement a project requires new roles to be played, which usually involves the strengthening of existing organizations. Thus, agricultural development is strengthened by having a concern with improving both the physical (hardware) and institutional (software) portions of the irrigation system.

3. Interdisciplinary Approach

Throughout the life of this project, a strong emphasis has been placed on an interdisciplinary research approach. The primary disciplines have been agronomy, agricultural engineering, agricultural economics, rural sociology and anthropology, with important inputs being made by natural resources law and organizational psychology. The combination of physical scientists and social scientists requires an even stronger emphasis upon an interdisciplinary approach in order to move from identifying problems and developing solutions into implementing solutions.

Teamwork has been critical to this project, both in Pakistan and on-campus. Two criteria used in selecting personnel for assignment with the CSU Field Party in Pakistan has been: (a) a professional record that demonstrates a

capability for cooperating with other researchers; and (b) an ability to share with others (relatively unselfish). With a team in Pakistan and a team on-campus, it becomes very important to develop a strong rapport between the two teams. In particular, it is important that the Field Party feel that they are being adequately supported by the campus team.

4. Farmer Involvement

Farmer involvement is an effective method for gaining information about the dynamics of the farm system and of identifying sources of support or obstacles to change. Farmers generally have extensive relevant information as well as an intuitive understanding of how their system works; yet, they are often ignored by professional people. In the approach advocated by this project, the farmer is regarded as an important source of ideas for solutions that experts may overlook. Furthermore, because of their innate "interdisciplinary" familiarity with their system, the farmers assisted the project in understanding the system's dynamics and in anticipating consequences of proposed changes.

A valuable lesson learned early in the project was the value of farmer participation in the implementation of solutions. When the government introduced brick-and-mortar watercourse lining, the farmers refused to do the necessary maintenance because of their feelings that the lining belonged to the government. As a result, the On-Farm Water Management Pilot Project utilized improved earthen watercourses with the farmers on the watercourse doing most of the work, while the government inputs were minimized. The lesson learned is that both the development of solutions and their implementation should incorporate strategies that allow the farmers to do as much as possible for themselves, with the government providing only those inputs that are beyond the resources of the farmers.

5. Attacking Field Problems

The history of irrigation system development shows a preoccupation by engineers and politicians in "hardware" development; namely, the construction of dams and canals. Unfortunately, the "management" of the irrigation system, particularly the farm subsystem, has not received adequate attention. This research project has focused upon on-farm water management, which can be subdivided into four components: (a) plant environment; (b) farm management practices; (c) water supply and removal; and (d) institutional linkages. The emphasis has been first-of-all to conduct research on farmers' fields and then develop an understanding of the higher levels of the system that impinge upon the farmers' agricultural and water management activities.

An important aspect of agricultural development, which also provides a greater appreciation for the importance of farm-level field problems, is gaining the participation of university faculty, researchers at agricultural and water institutes, and government action agency personnel in identifying the problems in the irrigation system, including the constraints that farmers must contend with in agricultural production. These people can benefit tremendously from such field experiences. Also, they can more easily believe the findings if they have discovered such results for themselves. If they also participate in the development of solutions, then they are more likely to be enthusiastic in supporting the implementation of solutions.

6. Training

Focusing upon farm-level field problems provides an important training ground for developing interdisciplinary teamwork. Such problems have strong linkages between the physical and institutional components of the irrigation system, thereby providing an important role for many disciplines.

Concentrating on field problems provides important training experiences for many host country personnel. Field work is viewed by many professionals as demeaning. Also, a lack of capability for doing field measurements results in an individual avoiding such activities; whereas, once trained by doing such tasks many times, the individual then has confidence and may be enthusiastic in undertaking field investigations.

Providing academic training to host country personnel on-campus proved highly rewarding provided the student returned to Pakistan for the research portion of the degree program. In every case, the thesis or dissertation research was accomplished in the field. The final defense of the research was done in Pakistan with CSU Field Party and recognized Pakistani researchers serving as the examining committee. Pakistani's obtaining graduate degrees from CSU under this program have continued to do highly important field studies.

This research project has also provided an important opportunity for a few U.S.A. graduate students to do their research in Pakistan. They are an important asset to the team because they can concentrate on doing field research and are less likely to be encumbered with management and administrative activities. There is a high likelihood that such students will continue to be involved with international development.

7. Dissemination of Research Results

Considerable emphasis and time have been spent in documenting research results. Typically, papers have been written

in Pakistan as soon as research results are known. Frequently, these papers are co-authored by cooperating Pakistani's and one or more CSU Field Party members. The distribution of each paper to interested persons is important for gaining acceptance of the research results and later having support for implementation projects.

The Annual Technical Report prepared by project staff is quite voluminous. Most of this report consists of appendices that describe research findings during the preceding year. Consequently, copies of each Annual Technical Report provides a quick reference on project activities and results. This exercise was also important for ensuring that research results were written in a short time period.

Once a research activity has been completed, the results are presented in a Field Party Report, which is then distributed throughout the country. Prior to project termination, brief writeups were prepared for each Field Party Report (see Appendix 7) for distribution in Pakistan to a broader mailing list, who could in turn request a complete copy of the report if interested in more detail. If a Field Party Report contains significant findings that would be of interest to the international agricultural and water community, it was then reproduced on-campus as a Water Management Technical Report and then distributed using an international mailing list. Brochures and slide shows have also been prepared as a more illustrative means of disseminating research results.

APPENDIX 1

Water Management Research Project

BRIEF PROJECT HISTORY

Contracts

The Water Management Research Project was initiated on March 28, 1968 with funding from Contract AID csd-2162, which terminated March 31, 1974. This was followed by Contract AID/ta-c-1100 for the period April 1, 1974 through March 31, 1977. The current contract, AID/ta-C-1411, began April 1, 1977, and was to terminate March 31, 1980, but was extended to May 31, 1980.

Project Leadership

The Project Director under Contract AID csd-2162 was Dr. Maurice Albertson (Civil Engineering). At the same time, Dr. Albertson was director of the 211(d) grant. Because of the mounting workload, Dr. W. Doral Kemper (Agricultural Engineering and Agronomy) was hired in July, 1972 to direct the activities of the Water Management Research Project on a full-time basis, with Dr. Albertson still retaining over-all control as Program Director of this project and the 211(d) grant, as well as being Project Director for the 211(d) grant.

With the initiation of Contract AID/ta-c-1100 on April 1, 1974, Dr. Kemper became the Project Director with complete CSU responsibility for the project. Effective July 1, 1974, Dr. Kemper became Chief-of-Party of the CSU Field Party in Pakistan, and the Project leadership was shared with Prof. Gaylord V. Skogerboe (Agricultural Engineering) working half-time as Project Co-Director. Under the present Contract, AID/ta-C-1411, Dr. Kemper returned to CSU in August 1977 and continued to share the project leadership with Prof. Skogerboe until his departure in August 1978, when Prof. Skogerboe assumed the role of Project Coordinator.

Field Programs

The CSU Water Management Research Project had a field program in Vietnam as well as an on-going field program in Pakistan. The annual reports of this project should be consulted regarding the objectives and activities of these field programs.

Vietnam

The field program in Vietnam was undertaken as a portion of the Mekong Delta Soils Project in May, 1973. Dr. Sidney A. Bowers (Agronomy) was the Chief-of-Party and sole CSU

faculty member during the two-year life of this project. At the time of termination, most facilities had been completed for an agricultural research station to be operated by faculty of Can Tho University. The field research was geared towards identifying agricultural practices for producing crops during the dry season under water control conditions.

Pakistan

The field program was initiated in Pakistan with the arrival of Dr. Gilbert L. Corey (Agricultural Engineering) during the summer of 1970. A larger scale research program was undertaken two years later with the arrival of three field party members; namely, Dr. Wayne Clyma (Agricultural Engineering), Dr. Jerry Eckert (Economics), and Dr. C.J. deMooy (Agronomy). Dr. Corey served as Chief-of-Party of the CSU Field Party in Pakistan for four years. Upon his departure in June 1974, he had established an effective network of linkages with many agricultural research experiment stations, universities, and Government of Pakistan action agencies responsible for improved water management and increased agricultural production.

Dr. Doral Kemper became Chief-of-Party on July 1, 1974. In September 1975, Dr. Alan C. Early (Agricultural Engineering) joined the Field Party. Dr. Jerry Eckert returned to campus and was later replaced in October 1975 by Dr. Sam H. Johnson III (Economics). Dr. John O. Reuss (Agronomy) became an additional Field Party member in September 1975. Later, in November 1975, Dr. Sidney A. Bowers, who had left Vietnam in April 1975 and returned to campus, was reassigned to the Field Party in Pakistan.

Dr. C.J. DeMooy returned to campus in February 1976. The Water Management Research Project began involving U.S. graduate students in the field program when Mr. Thomas J. Trout (a Ph.D. student in Agricultural Engineering) spent the summer of 1975 at the Mona Reclamation Experimental Project. In April 1976, Mr. Larry J. Nelson (Ph.D. student in Agronomy) joined the field staff and was located at the Mona site.

Dr. Wayne Clyma returned to the CSU campus in August 1976. He was replaced in September 1976 by Mr. Tom Trout.

In May 1977, Dr. Alan Early left to join the staff at I.R.R.I., Philippines. In July 1977, Dr. Kemper returned to campus and Dr. John Reuss became Chief-of-Party on August 1, 1977. Dr. Sam Johnson left to join the staff of Ford Foundation in Thailand in September 1977.

While the field staff was at a reduced level during the latter part of 1977, Mr. Norman S. Illsley (Agricultural Engineering) joined the field staff in April 1977 on TDY to begin preparation of the first water management training course to be conducted at the University of Agriculture, Faisalabad. He was followed in September 1977 by Prof. Skogerboe, who continued work on the training program until November 1977. Mr. Larry Nelson returned to campus in December 1977 to continue his graduate studies.

In February 1978, the field staff was increased with the arrival of Dr. Helmer C. Holje (Economics), Dr. Dwayne G. Westfall (Agronomy Extension) and Mr. Normal Illsley. Mr. Douglas J. Merrey (Sociology) arrived in April 1978. The field staff was completed in September 1978 with the arrival of Mr. Dwayne E. Konrad (Agricultural Engineering Extension).

Mr. Tom Trout returned to campus in September 1978 to complete his graduate program. In November 1978, Dr. Sidney A. Bowers left the field staff to assume a position with AID in Pakistan.

The Field Party faculty personnel at the time of termination were John Reuss, Helmer Holje, Norman Illsley, Dwayne Konrad, Douglas Merrey and Dwayne Westfall.

Campus Support

The campus activities and support under the Water Management Research Project has involved the departments of Agronomy, Agricultural and Chemical Engineering, Civil Engineering, Economics, Political Science, Psychology, Sociology and Technical Journalism. After 1974, the work was being done by personnel in the departments of Agronomy, Agricultural and Chemical Engineering, Economics, Psychology, Sociology and Technical Journalism.

Faculty

The on-campus faculty personnel in the Agronomy Department who have been primarily involved with this project are Dr. Willard R. Schmehl, Prof. William Franklin, Dr. C.J. deMooy and Mr. William Stewart. The primary personnel in the Agricultural and Chemical Engineering Department have been Dr. A.T. Corey, Dr. William E. Hart, Dr. W. Doral Kemper, Dr. David B. McWhorter, Dr. Gideon Peri, Prof. Gaylord V. Skogerboe and Dr. Wynn R. Walker. In Economics, Dr. R.A. Tinnermeier, Dr. Larry Mack and Dr. Edward Sparling have been involved with this project. In addition, Dr. George E. Radosevich, a lawyer specializing in natural resources, is locaed in the Economics Department and

has played a key role in studies regarding water law and water users associations for organizing farmers. From the Psychology Department, Dr. Jacob Hautaluoma has added expertise in the area of interdisciplinary program management. The Sociology Department has played an important role in this project with the efforts of Dr. Max K. Lowdermilk, Dr. David M. Freeman and Dr. James J. Layton. In Technical Journalism, Dr. Dan Lattimore has been very instrumental in recent publication efforts aimed at reaching non-technical audiences.

Graduate Students

A graduate program of study was initiated in which host country students received academic training at CSU and then returned home to do the required research for a thesis or dissertation. Three Vietnamese students (two in Agronomy and the other in Agricultural Engineering) were brought to campus for M.S. work, but plans had to be modified to allow these students to complete their research on campus. Thirteen Pakistanis graduated under this program. They continue to do serious field work, thereby contributing in a very substantial manner to the development of their country.

Program Development

Funding

The total funding received under Contract AID/csd-2162 was $2,200,000. During the last two years of this funding (March 28, 1972 to March 27, 1973 and March 28, 1973 to March 31, 1974), the level of field activity is represented by 23% of total man-months and 32% of total salaries during the next-to-last year, and 37% of total man-months and 47% of total salaries for the last year, being for full-time field faculty personnel.

Under Contract AID/ta-c-1100 (April 1, 1974 to March 31, 1977) total funding was $1,721,712. Field faculty personnel represented 37% of total man-months and slightly more than 50% of total salaries. The percentages would have been higher for the second year, but the termination of field activities in Vietnam resulted in six months of Dr. Sidney Bowers time being spent on campus before being reassigned to Pakistan.

Under the current contract, AID/ta-C-1411, funding for the period April 1, 1977, through March 31, 1979, has been $1,750,000. Funding for the final year has been finalized at $750,000, for a contract total of $2,500,000.

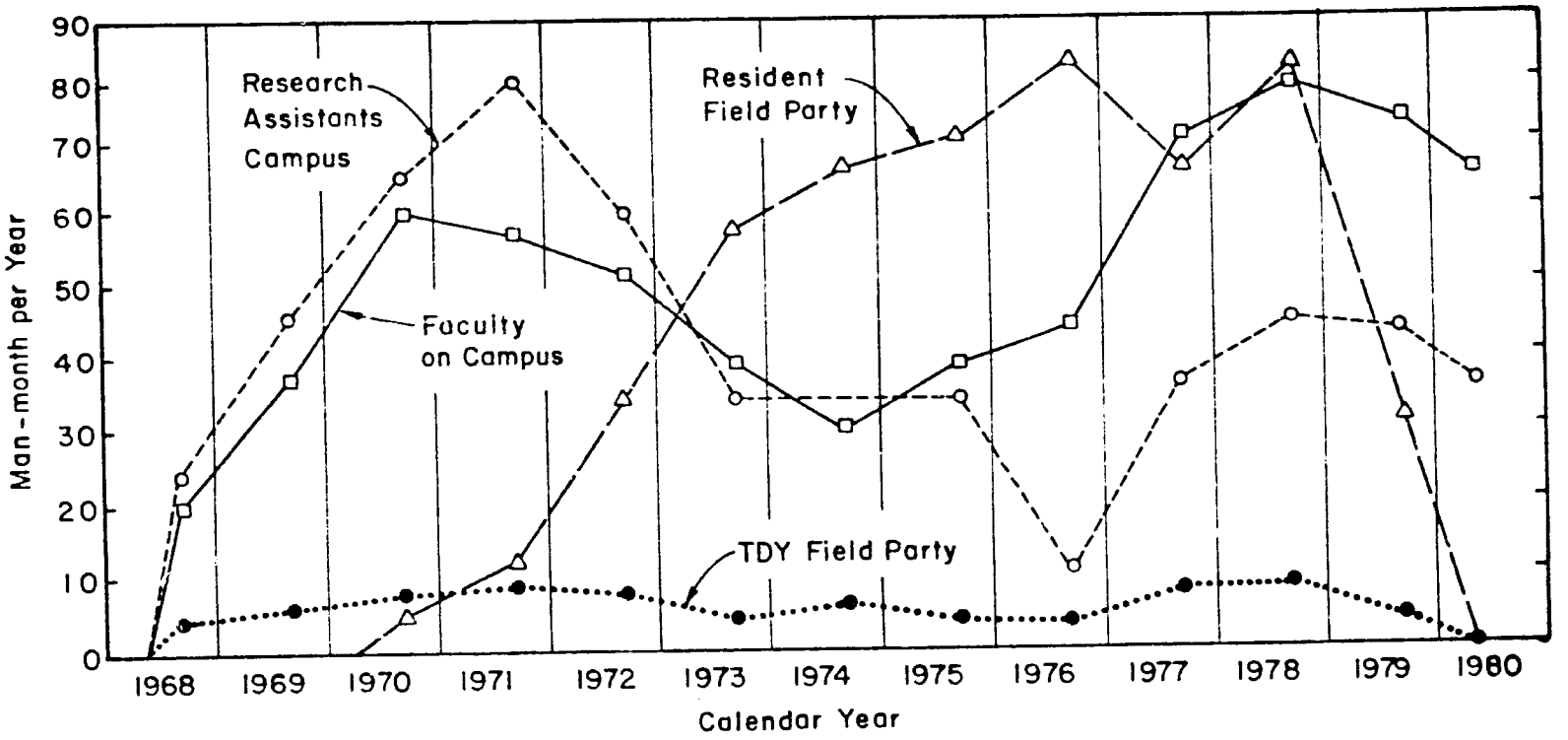
During the first year of the Contract, field faculty personnel represented 32% of total man-months and 38% of total salaries. This reduced level of effort in the field was due to four vacancies during the last half of 1977. During the second year of this contract, field faculty personnel represented 33% of total man-months and 42% of total salaries. These percentages do not include short TDY activities, which are now billed with on-campus salaries. During the final year of the Contract, field faculty personnel represented 33% of total man-months and 40% of total salaries.

Field Experience

One of the primary difficulties in attempting to successfully pursue water management research in developing countries is acquiring a competent staff having field experience. This has been a slow process, but there was definite improvement with each year. Now, we have a faculty of nine who have had considerable field experience, along with another 4-6 faculty who are capable of undertaking field studies in developing countries. Thus, a significant corps of field-qualified personnel have been developed for undertaking studies in other countries. The development of this expertise was a continual major goal of the Water Management Research Project.

Interdisciplinary Research

Having a competent staff has little utility in improving water management practices in developing countries (or for that matter, developed countries) unless the staff is capable of integrating it's efforts into a truly interdisciplinary research effort. The Water Management Research Project staff slowly developed into a more integrated interdisciplinary team. A major goal of this research project was the strengthening of interdisciplinary team work. In May 1978, Colorado State University presented this project with a special award in recognition of outstanding leadership in interdisciplinary environmental research



Location of Manpower Used by CSU on the Water Management Research Contracts

APPENDIX 3

Colorado State University
Water Management Research Project
Field Party Personnel

Names	Post	Date of Arrival	Date of Departure	Man-Months	Location May 1980
Gilbert L. Corey	Lahore/Islamabad	7-1-70	6-1-74	47	USAID/Washington
Jerry B. Eckert	Islamabad	7-13-72	6-26-75	36	Lesotho-USAID Contract
Wayne Clyma	Islamabad	7-25-72	8-1-76	48	CSU
C.J. deMooy	Islamabad	10-29-72	2-11-76	40	CSU
W. Doral Kemper	Islamabad	7-2-74	7-6-77	36	USDA/Snake River Cons. Res. Cen.
Alan C. Early	Islamabad/Lahore	9-17-74	5-15-77	32	IRRI
John O. Reuss	Lahore	9-29-75	10-31-79	49	CSU
Sam H. Johnson	Lahore	10-7-75	8-22-77	23	Ford Foundation-Bangkok, Thailand
Sidney A. Bowers	Lahore	11-11-75	11-18-78	36	USAID/Bangkok
Larry Nelson	Bhalwal	6-5-76	12-2-77	18	CSU
Tom Trout	Lahore	9-4-76	9-4-78	24	CSU
Helmer J. Holje	Lahore	2-11-78	8-11-79	18	Montana State University
Norman Illsley	Lahore	3-3-78	11-23-79	21	Cairo, Egypt-USAID Contract
Dwayne C. Westfall	Lahore	3-2-78	9-25-79	19	CSU
Douglas J. Merrey	Faisalabad	4-26-78	9-25-79	17	University of Pennsylvania
Dwayne E. Konrad	Lahore	9-4-78	8-24-79	14	CSU

APPENDIX 4a

WATER MANAGEMENT TECHNICAL REPORTS*

Consortium for International Development

Colorado State University

No.	Title	Author	No. of Pages	Cost
1	Bibliography with Annotations on Water Diversion, Conveyance, and Application for Irrigation and Drainage, CER69-70KM3, Sept. 1969	K. Mahmood A. G. Mercer E. V. Richardson	165	$3.00
**2	Organization of Water Management for Agricultural Production in West Pakistan (a Progress Report) ID70-71-1, May 1970	P.O. Foss J.A. Straayer R. Dildine A. Dwyer R. Schmidt	148	$3.00
3	Dye Dilution Method of Discharge Measurement, CER70-71 WSL-EVR47, January 1971	W.S. Liang E.V. Richardson	36	$3.00
4	Not available			
**5	The Economics of Water Use, An Inquiry into the Economic Behavior of Farmers in West Pakistan, MISC-D-70-71DW44, March 1971	Debebe Worku	176	$3.00
**6	Pakistan Government and Administration: A Comprehensive Bibliography, ID70-71GNJ17, March 1971	Garth N. Jones	114	$3.00
**7	The Effect of Data Limitations on the Application of Systems Analysis to Water Resources Planning in Developing Countries, CED70-71LG35, May 1971	Luis E. Garcia-Martinez	225	$3.00
**8	The Problem of Under-Irrigation in West Pakistan: Research Studies and Needs, ID70-71GNJ-RLA19	G.N. Jones R.L. Anderson	53	$3.00
9	Check-Drop-Energy Dissipator Structures in Irrigation Systems, AER70-71, GVS-VTS-WRW4, May 1971	G.V. Skogerboe V.T. Somoray W.R. Walker	180	$3.00
**10	Maximum Water Delivery in Irrigation	J.H. Duke, Jr.	213	$3.00

*Reports are available from Publications Office, Engineering Research Center, Colorado State University, Fort Collins, CO 80523. Price: as indicated until supply is exhausted; subsequent Xerox copies obtainable at 10 cents per page. Postage and handling: $1.00 in the U.S.; $2.00 to foreign addresses.

**Supply exhausted.

No.	Title	Author	No. of Pages	Cost
11	Flow in Sand-Bed Channels	K. Mahmood	292	$3.00
**12	Effect of Settlement on Flume Ratings	T.Y. Wu	98	$3.00
**13	The Problem of Water Scheduling in West Pakistan: Research Studies and Needs, ID71-72GNJ8, November 1971	G.N. Jones	39	$3.00
**14	Monastery Model of Development: Towards a Strategy of Large Scale Planned Change, ID71-72GNJ9, November 1971	G.N. Jones	77	$3.00
**15	Width Constrictions in Open Channels	J.W. Hugh Barrett	106	$3.00
**16	Cutthroat Flume Discharge Relations	Ray S. Bennett	133	$3.00
**17	Culverts as Flow Measuring Devices	Va-son Boonkird	104	$3.00
18	Salt Water Coning Beneath Fresh Water Wells	Brij Mohan Sahni	168	$3.00
19	Installation and Field Use of Cutthroat Flumes for Water Management	G.V. Skogerboe Ray S. Bennett Wynn R. Walker	131	$3.00
20	Steady and Unsteady Flow of Fresh Water in Saline Aquifers	D.B. McWhorter	51	$3.00
21	Dualism in Mexican Agricultural Development: Irrigation Development and the Puebla Project	H.H. Biggs	28	$3.00
22	The Puebla Project: Progress and Problems	H.H. Biggs	23	$3.00
**23	Pakistan Government and Administration: A Comprehensive Bibliography, Volume No. 3	G.N. Jones	259	$3.00
24	Index for the Eight Near East-South Asia Irrigation Practices Seminars	W.L. Neal C. Stockmyer	58	$3.00
25	A Bibliography and Literature Review of Groundwater Geology Studies in the Indus River Basin	Alfred J. Tamburi	33	$3.00

No.	Title	Author	No. of Pages	Cost
26	Planning Sediment Distribution in Surface Irrigation Systems	Khalid Mahmood	67	$3.00
27	Practical Skimming Well Design	F.A. Zuberi D.B. McWhorter	61	$3.00
28	Physical, Salinity, and Fertility Analyses of Selected Pakistan Soils	W.T. Franklin W.R. Schmehl	29	$3.00
29	Program for Computing Equilibrium Solution Composition in $CaCO_3$ and $CaSO_4$ Systems from Irrigation Water Compositions	Dhanpat Rai W.T. Franklin	42	$3.00
30	Conjunctive Use of Indus Basin Waters--Pakistan: A General Summary of Ph.D. Dissertation	M.T. Chaudhry	37	$3.00
**31	Informational Sources on Water Management for Agricultural Production in Pakistan with Special Reference to Institutional and Human Factors, Volume I	G.N. Jones A.R. Rizwani M.B. Malik R.F. Schmidt	170	$3.00
	Volume II		251	
32	Crop Water Use and Yield Models with Limited Soil Water	H.M. Neghassi	119	$3.00
33	Design of Irrigation Drop Structures	Soon-kuk Kwun	123	$3.00
**34	A Study of Village Organizational Factors Affecting Water Management Decision Making in Pakistan	A.H. Mirza	129	$3.00
35	Village Organizational Factors Affecting Water Management Decision-Making Among Punjabi Farmers	A.H. Mirza D.M. Freeman J.B. Eckert	62	$3.00
36	Organizational Alternatives to Improve On-Farm Water Management in Pakistan	George E. Radosevich	252	$3.00
37	Improving Farm Water Management in Pakistan	Gilbert L. Corey Wayne Clyma	32	$3.00
38	The Importance of Farm Water Management in Pakistan	Wayne Clyma Gilbert L. Corey	28	$3.00

No.	Title	Author	No. of Pages	Cost
39	Irrigation Practices and Application Efficiencies in Pakistan	Wayne Clyma Arshad Ali M.M. Ashraf	36	$3.00
40	Calibration and Application of Jensen-Haise Evapotranspiration Equation	Wayne Clyma M.R. Chaudhry	16	$3.00
41	Plant Uptake of Water From a Water Table	Chaudhry Nuruddin Ahmad	88	$3.00
42	Physical and Socio-Economic Dynamics of a Watercourse in Pakistan's Punjab: System Constraints and Farmers' Responses	M.K. Lowdermilk Wayne Clyma Alan C. Early	106	$3.00
43	Water Management Alternatives for Pakistan: A Tentative Appraisal	Jerry Eckert Niel Dimick Wayne Clyma	61	$3.00
44	Water User Organizations for Improving Irrigated Agriculture: Applicability to Pakistan	George E. Radosevich	34	$3.00
45	Watercourse Improvement in Pakistan: Pilot Study in Cooperation with Farmers at Tubewell 56L	CSU Field Party and Mona Reclamation Experimental Staff (Pakistan)	93	$3.00
46	Planning and Implementing Procedures for Contracting Agricultural-Related Research Programs in Low Income Nations	Max K. Lowdermilk Wayne Clyma W. Doral Kemper Sidney A. Bowers	46	$3.00
47	A Research-Development Process for Improvement of On-Farm Water Management	Wayne Clyma Max K. Lowdermilk Gilbert L. Corey	58	$3.00
48	Farm Irrigation Constraints and Farmers' Responses: Comprehensive Field Survey in Pakistan			
Volume I - Summary		Max K. Lowdermilk Alan C. Early David M. Freeman		$5.00
Volume II - Purpose of the Study, Its Significance, and Description of the Irrigation System		Max K. Lowdermilk David M. Freeman Alan C. Early		
Volume III - Consequences of the Present Farm Water Management System		Alan C. Early Max K. Lowdermilk David M. Freeman		

No.	Title	Author	No. of Pages	Cost
	Volume IV - Major Constraints Confronting Farmers Explaining the Consequent Low Crop Yields	Max K. Lowdermilk David M. Freeman Alan C. Early	250	
	Volume V - Farmer Responses to Major Constraints: Viable Options Under Present Conditions	David M. Freeman Max K. Lowdermilk Alan C. Early	52	
	Volume VI - Appendices	David M. Freeman Max K. Lowdermilk Alan C. Early	319	
	Volumes II through VI are sold as a set only			$20.00
49A	Evaluation and Improvement of Irrigation Systems	Gideon Peri G.V. Skogerboe	92	$3.00
49B	Evaluation and Improvement of Basin Irrigation	Gideon Peri G.V. Skogerboe Donald Norum	179	$6.00
49C	Evaluation and Improvement of Border Irrigation	Gideon Peri Donald Norum G.V. Skogerboe	105	$3.00
50	Factors Affecting Losses from Indus Basin Irrigation Channels	Thomas J. Trout	201	$6.00
	Special Technical Reports			
	Institutional Framework for Improved On-Farm Water Management in Pakistan	Water Management Research Project Staff	88	$3.00
	Recalibration of Small Cutthroat Flumes for Use in Pakistan	G.V. Skogerboe Abbas A. Fiuzat Thomas J. Trout Richard L. Aust	82	$3.00
51	Farm Water Management in Upland Areas of Baluchistan	W.D. Kemper Mazher-ul-Haq Ahmad Saeed	77	$3.00
52	Operational Irrigation Evaluation of Pakistan Watercourse Conveyance Systems	Thomas J. Trout S.A. Bowers	104	$3.00
53	Irrigation and Honor: Cultural Impediments to the Improvement of Local Level Water Management in Punjab, Pakistan	Douglas J. Merrey	61	$3.00

No.	Title	Author	No. of Pages	Cost
54	Constraints on Small Farmers in the Precision Land Leveling Program in the Pakistani Punjab	Raymond Z.H. Renfro	123	$6.00
55	Organizational Problems and Their Consequences on Improved Watercourses in Punjab	Ashfaq Hussain Mirza and Douglas J. Merrey	186	$6.00
56	Watercourse Improvement Research in Pakistan	W. Doral Kemper Wayne Clyma Gaylord V. Skogerboe Thomas J. Trout	107	$6.00
57	Optimization of Lengths of Alternative Watercourse Improvement Programs	John O. Reuss	49	$3.00
58	Watercourse Improvement Manual	Thomas J. Trout W. Doral Kemper	258	$9.00
59	Field Evaluation of Methods for Measuring Basin Irrigation Performance	Satyansu S. Kundu Gaylord V. Skogerboe	135	$6.00
60	Training Manual for Agricultural Water Management Specialists	Edited by Dwayne G. Westfall	700	$9.00
61	Analysis of Basin-Furrow Irrigation	Gideon Peri Gaylord V. Skogerboe		$3.00
62	Matching Cropping Systems to Water Supply Using an Integrative Model	John O. Reuss	208	$6.00
63	Summary of Skimming Well Investigations	David B. McWhorter	89	$3.00
64	Development and Design of Watercourse Junction Jet Pumps	Thomas J. Trout W. Doral Kemper Richard A. Aust	121	$6.00
65A	Development Process for Improving Irrigation Water Management on Farms: Executive Summary	Gaylord V. Skogerboe Max K. Lowdermilk Edward W. Sparling Jacob E. Hautaluoma		$3.00
65B	Development Process for Improving Irrigation Water Management on Farms: Problem Identification Manual	Max K. Lowdermilk William T. Franklin James J. Layton George E. Radosevich Gaylord V. Skogerboe Edward W. Sparling William G. Stewart		$6.00

No.	Title	Author	No. of Pages	Cost
65C	Development Process for Improving Irrigation Water Management on Farms: Development of Solutions Manual	Edward W. Sparling W. Doral Kemper Jacob E. Hautaluoma Max K. Lowdermilk Gaylord V. Skogerboe William G. Stewart		$6.00
65D	Development Process for Improving Irrigation Water Management on Farms: Project Implementation Manual	Jacob E. Hautaluoma David M. Freeman W. Doral Kemper James J. Layton Max K. Lowdermilk George E. Radosevich Gaylord V. Skogerboe Edward W. Sparling William G. Stewart		$6.00
66	Improving Irrigation Water Management on Farms: Final Report	Gaylord V. Skogerboe John O. Reuss W. Doral Kemper		$3.00

APPENDIX 4b

FIELD PARTY REPORTS*

1. Operational Conveyance Losses on Tubewell 81-R Watercourse, by Tom Trout, S.A. Bowers, Mohsin Wahla, Hayat Ullah Khan, Mohd. Yasin and M. Iqbal, Water Management Research Field Report No. 7. July 1977.

2. Fertilizer Water Interaction Experiment on Wheat, by S.A. Qureshi, Noor Mohd. Chaudhry, and J.O. Reuss, Water Management Research Field Report No. 8. June 1977.

3. Watercourse Conveyance Losses in the Mona Reclamation Experimental Project Area, by Tom Trout and Mohammad Munir, Water Management Research Progress Report No. 10. February 1977.

4. Optimization of Lengths of Alternative Watercourse Improvement Programs in Pakistan, by John Reuss. Progress Report No. 11. 1979.

5. Operational Irrigation Evaluations of Three Watercourse Systems by Ch. Rahmat Ali, Mohammad Ashraf, Tom Trout, Waryam Ali Mohsin, Mahmood Ahmad, Nazir Ahmad Anwar, and Mohammad Umar Khan. WAPDA Publication No. 1. August 1978.

**6. Abstracts of Reports and Publications by Colorado State University, Water Management Research Project in Pakistan. December 1978.

*This list of CSU Field Party reports includes only those not published in the Water Management Technical Report series.

**This particular publication includes a listing of all papers and reports, with abstracts, published in Pakistan by the CSU Field Party in collaboration with Pakistani cooperators.

APPENDIX 4c

THESES

Name	Title	Degree	Date
Under AID/csd-2162			
Mohammad Talib Chaudhry	Conjunctive Use of Indus Basin Waters - Pakistan	Ph.D.	3/73
Ata Mohammad Nazar	A Laboratory Study of Bed Material Withdrawal in Farm Turnouts	M.S.	5/73
Ahmad Saeed Khan	Economics of Saline Water Management in Indus Riber Basin of Pakistan	M.S.	9/73
Robert L. Chandler	Salt Water Coning in Anisotropic Media	Ph.D.	12/73
Alfred J. Tamburi	Geology and the Water Resource System of the Indus Plains	Ph.D.	6/74
Fang-Hong Wu	Conjunctive Use of Surface Water and Groundwater with Different Salinities in the Indus Basin of Pakistan	Ph.D.	6/74
Under AID/ta-C-1100			
Muhammad Jameel Khan	Economics of Farm Mechanization and Water Development Policies in Pakistan: A Case Study	Ph.D.	Fall/74
Chaudhry Nuruddin Ahmad	Plant Uptake of Water From a Water Table	M.S.	3/75
Under AID/ta-C-1411			
Muhammad Siddique Shafique	Land Leveling and Water Improvements for Pakistan	M.S.	Sp/77
Mushtaq Ahmad Gill	Irrigation Scheduling in Pakistan	M.S.	Fall/77
Ghulam Hussain	Irrigation Water Quality Evaluation Under Pakistan Conditions	Ph.D.	Sum/78
Kenneth Litwiller	Computer Evaluation of Surface Irrigation Systems	M.S.	Sum/78
Mohammad Akram	Infiltration as Affected by Compaction of Soil and the Pressure and Water Content at the Time of Compaction	M.S.	Sum/79
Thomas J. Trout	Factors Affecting Losses from Indus Basin Irrigation Channels	Ph.D.	Sum/79
Muhammad Mohsin Wahla	Training for and Analysis of Essential and Comprehensive Water Management	M.S.	Sp/80
Zahid Saeed Khan	Soil Compaction and Water Content Effects on Cotton Seed Germination and Emergence	M.S.	Sp/80
Barkat Ali	Optimal Watercourse Improvement in the Pakistan Punjab: A Mixed Integer Programming Model	M.S.	Sp/80
Khalid H. Gill	Irrigation-Nitrogen Management Studies on Sorghum, Corn and Wheat	Ph.D.	Sp/80
Muhammad Hanif	Irrigation and Nitrogen Management in Paddy Rice	Ph.D.	Sum/80

APPENDIX 4d

JOURNAL ARTICLES

Water and Nutrient Response of Semi-Dwarf Wheat Under Improved Management in Pakistan: Agronomic and Economic Implications by J.B. Eckert, M.M. Chaudhry and S.A. Qureshi. Agronomy Journal, Volume 70, pp 77-80, January-February 1978.

Water Problems in the Indus Food Machine, by Sam H. Johnson III, Alan C. Early and Max K. Lowdermilk. Water Resources Bulletin, Volume 13, No. 6. December 1977.

Planning Procedures for Research Programs in Low Income Nations by Wayne Clyma, Max K. Lowdermilk, Sidney A. Bowers and W. Doral Kemper. Journal of the Society of Research Administrators. January 1978.

Implementing Procedures for Research Programs in Low Income Nations, by Max K. Lowdermilk, Wayne Clyma, W. Doral Kemper and Sidney A. Bowers. Journal of the Society of Research Administrators. April 1978.

Improving Irrigation Water Management in the Indus Basin by Sam Johnson, III, W. Doral Kemper, and Max K. Lowdermilk. Water Resources Bulletin, Vol. 15, No. 2. April 1978.

Land Leveling and Watercourse Improvements for Pakistan by Mohammad Shafique, Wayne Clyma and Sidney Bowers. Presented at the 1978 summer meetings of American Society of Agricultural Engineers, June 1978. ASAE Technical Paper No. 78-2021.

Farm Water Management Constraints to Indus Basin Crop Production by Alan Early, Max Lowdermilk and David Freeman. Presented at the 1978 summer meetings of American Society of Agricultural Engineers, June 1978. ASAE Technical Paper No. 78-2023.

Physical and Socio-Economic Dynamics of Irrigation in Pakistan by Max Lowdermilk, Wayne Clyma and Alan C. Early. Proceedings of the ASCE Specialty Conference on Legal, Institutional and Social Aspects of Irrigation and Drainage and Water Resources Planning and Management, June 1978.

Use of Gypsum Stones to Lower the Sodium Absorption Ratio of Irrigation Water, by Bashir Ahmad, W.D. Kemper, Ghulam Haider and M.A. Niaza. Accepted for publication by the Soil Science Society of American Proceedings.

Infiltration of Soils as Affected by the Pressure and Water Content at the Time of Compaction by Mohd. Akram and W.D. Kemper. Accepted for publication by the Soil Science Society of American Proceedings.

Procedure for Evaluation and Improvement of Irrigation Systems, by Gideon Peri, Gaylord V. Skogerboe and David Karmeli. Presented at the 1979 summer meetings of ASAE and CSAE, June, 1979. ASAE Technical Paper No. 79-2089.

JOURNAL ARTICLES (continued)

Operational Evaluation of Village Level Irrigation Conveyance Systems, by Thomas J. Trout and S.A. Bowers. Presented at the 1979 winter meeting of ASAE, December, 1979. ASAE Technical Paper No. 79-2567.

Consequences of and Farmers' Reactions to Indus Basin Water Management Constraints, by Alan C. Early, David M. Freeman and Max K. Lowdermilk. Presented at the 1979 summer meetings of ASAE and CSAE, June, 1979. ASAE Technical Paper No. 79-5054.

Irrigation Scheduling in Punjab of Pakistan, by Mushtaq A. Gill and Alan C. Early. Presented at the 1979 summer meeting of ASAE and CSAE, June, 1979. ASAE Technical Paper No. 79-5052.

Development of Improved Water Management Practices in Pakistan, by Gaylord V. Skogerboe, W. Doral Kemper and John O. Reuss. Submitted for publication to the International Journal of Water Supply and Management.

Watercourse Improvement Strategies for Pakistan, by John O. Reuss, Gaylord V. Skogerboe and Douglas J. Merrey. Submitted for publication to the International Journal of Water Supply and Management.

APPENDIX 4e

MOVIES AND SLIDE SHOWS

Land Forming for Irrigation, Part I, prepared by CSU Office of Educational Media and WMR Project staff. 1974.

Land Forming for Irrigation, Part II, prepared by CSU Office of Educational Media and WMR Project staff. 1974.

Pakistan: Land of Promise, by Max K. Lowdermilk, George Bargsten and Richard L. Aust. 1978.

Investments in Water Management, by W. Doral Kemper and Richard L. Aust. 1979.

Watercourse Improvement, by W. Doral Kemper and Dan Lattimore. 1979.

APPENDIX 4f

BROCHURES

Improving Agricultural Production Through On-Farm Water Management, Dan Lattimore, editor; Jim Mealler, illustrator; and Dale Rosenbach, designer. 1979.

Improving On-Farm Water Management Through Irrigation Associations, James J. Layton, George E. Radosevich, and Gaylord V. Skogerboe; Dan Lattimore, editor; Jim Mealler, illustrator; and Dale Rosenbach, designer. 1980.

APPENDIX 5

GRADUATE STUDENTS SUPPORTED UNDER WATER MANAGEMENT CONTRACTS

Name	Present Title and Institution	Location of Thesis Study	Degree attained and Specialty
Under AID/csd-2162			
J.W. Andrew			
Robt. L. Chandler			Civil Engineering
Mohammad T. Chaudhry	Consulting Firm, Pakistan		Civil Engineering
Robt. S. Dildine			Political Science
Svresh Doddiah			Civil Engineering
James H. Duke, Jr.			Civil Engineering
Arlene C. Dwyer			Political Science
Mohammad I. Haque			Civil Engineering
Ahmad Said Khan			Economics
Soon-Kuk Kwun	Korean Ag. Eng. Res. Ctr. with 211(d)		Ag. Engineering
Della L. Langeland	USGS		Civil Engineering
W.A. Lemma			
W.S. Liang	Geo. Wash. Univ. Faculty		Civil Engineering
Ashfaq Mirza	Assoc. Prof. Dept. Rural Sociology and Economics Univ. of Ag. Faisalabad	Pakistan	Sociology M.S.
Mehdi Monoadjemi			Agronomy
Khan J. Muhamad			Economics
Ata M. Nazar		Afghanistan	Civil Engineering
Paul S. Osborne	New Mexico		Ag. Engineering
James L. Pickett			Agronomy
Dhan Pat Rai			
Allah Rakhn			Civil Engineering
Emilio Rios			Civil Engineering
Abdur-Rehman Rizwani	Deceased		
Robt. F. Schmidt			Political Science
Alfred J. Tamburi			
Connie S. Trautoran			Sociology
Debebe Worku	Ethiopia		Economics
T.Y. Wu	Taiwan	plus 211d	Ag. Engineering
Yasumi Yamaguchi			Civil Engineering
F.A. Zuberi	Wapda, Lahore		Ag. Engineering
Fang-HongWu	Taiwan		Civil Engineering

Name	Present Title and Institution	Location of Thesis Study	Degree attained and Specialty
Under AID/ta-C-1100			
Bashia Ahmad	UAF Faculty	Pakistan	Economics
C. Nur-ud-Din Ahmad	Assoc. Dir. Land & Water Reclamadation Directorate, Lahore	Pakistan	Agronomy, M.S.
Jacob Dane			Agronomy
Khalid Gill	Fertili[illegible] Institute, Multan	Pakistan	Agronomy, Ph.D. (partial)
Mushtaq Gill	Dept. [illegible] On-Farm-Water Management Development Program, Punjab	Pakistan	Agronomy, M.S.
Ghulam Hussain	WAPDA Mona Reclamation Experimental Project	Pakistan	Agronomy, Ph.D.
Sam Johnson	Ford Foundation, Bangkok	Pakistan	Economics, Ph.D.
Muhammad J. Khan	Australia		Economics, Ph.D.
David A. Laver	Watercourse Survey, Pakistan	Pakistan	Sociology
Kenneth Litwiller	Church Agric. Mission	Africa	Ag. Engineering
Larry J. Nelson	18 months in Pakistan		Agronomy, M.S.
Ramchad Oad	Mehrnas Univ. of Engineering and Technology, Nawabshah, Sind	Indonesia	Cornell, Ph.D., 2 yrs. Special CSU Training
Mohan J. Reddy	Pak. Watercourse Data Analysis		Ag. Engineering
Muhammad S. Shafique	WAPDA-Mona Reclamation Experimental Project	Pakistan	Ag. Engineering, M.S.
T.M. Shariatmadar	Shrine Univ. Iran		Ag. Engineering
Miguel Solanes		Argentina	Economics
Thomas J. Trout	CSU Staff	Pakistan	Ag. Engineering
Under AID/ta-C-1411			
Barkat Ali	WAPADA-Mona	Pakistan	Economics, M.S.
Mohammad A.R. Farooqi	Irrigation, Drainage & Flood Controls Research Council, Lahore	Pakistan	Agronomy, Ph.D.
Chaudhry M. Hanif	Punjab On-Farm-Water Management Development Project, Training and Research Center, Lahore	Pakistan	Agronomy, Ph.D.
Muhammad A. Kahlown	WAPDA-Mona	Pakistan	Ag. Engineering, M.S.
Zahid S. Khan	UAF Research Staff	Pakistan	Ag. Engineering, M.S.
Ray Renfro	TDY Pakistan	Pakistan	Economics
Mohammad M. Wahla	WAPDA Master Planning, Lahore	Pakistan	Ag. Extn. M.S.

APPENDIX 6

USAID/PAKISTAN SUPPORT FOR WATERCOURSE AND ON-FARM WATER MANAGEMENT

	Title	Project No.	Obligation
I.	DOLLAR FINANCING FOR ON-FARM WATER MANAGEMENT PILOT PROGRAM		
	OFWM (for watercourse improvement & precision land leveling)	Loan 0413	$7,500,000
	OFWM (technical assistance)	Grant 0413	2,349,604
		TOTAL	$9,849,604
II.	LOCAL CURRENCY GRANTS FOR WATER MANAGEMENT		
	Water Management Research	204-75-3	Rs.1,314,000
	Watercourse Improvement	204-75-4	1,421,000
	Water Management Survey	204-76-1	411,000
	OFWM-NWFP	204-77-1	1,346,000
	Water Users Association, ARC-CSU-TD	204-77-3	512,000
	Punjab Water Management Research & Water Management Advisory Training, CSU-SCS-TD	309	1,000,000
	Water Management Research-WAPDA		12,505,000
	Water Management Research-Faisalabad University/CSU		9,060,000
	Strengthening of Water Management Project Activities-Federal/ WAPDA/SCS/CSU		18,360,000
		TOTAL (Rs Grants)	Rs.45,929,000

APPENDIX 7

Examples of announcements for Field Party reports.

Ways to Conserve Water In Rice Production Found

In three separate studies, ways to conserve water in rice production were investigated. One study found that when total water was reduced 39 and irrigation water by , there was only a 9% yield reduction.

When there is a water shortage, it may be best to achieve acceptable rice yields by holding water in the paddies at moisture contents between saturation and field capacity. (Acceptable yields being less than maximum possible, but achieved with less water.)

Basmati rice experimental plots.

(over)

Another study found that Thailand's Lab Mue Nakg-111 variety of rice had the best yield of 27 varieties that matured out of 90 planted in a flooded zone near Ravi River bottom lands near Lahore. This study suggests that some varieties of rice may be able to use the full season including flooding time in areas that are often hurt by early flooding. Thus, less water would be required if the early season floods could be utilized.

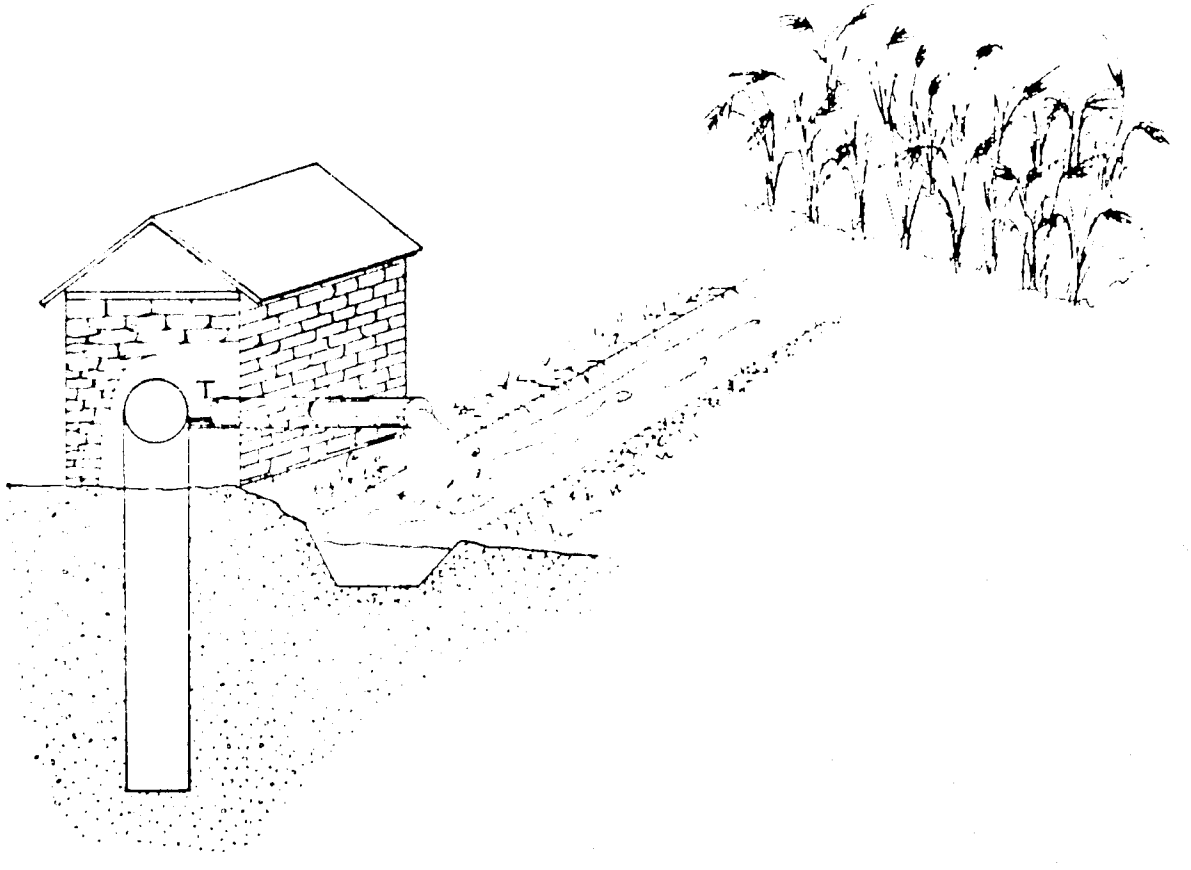
In a third study a methodology for evaluating irrigation practices is outlined with data forms and suggestions for computation. While Pakistan's rice crop is one of the major cash crops, yields are lower here than in most of the world. Field experience shows both under-irrigation and over-irrigation exists. This evaluation methodology is suggested to help in identifying specifi problem areas where water losses may be reduced, and crop yields increased.

ADDITIONAL INFORMATION: The complete reports are: S.A. Bowers, Siddique Shafique, and M. Yasin, "Influence of Water Level and Soil Puddling on Yield of Basmati Rice;" "Deep Water Rich Variety Trial;" and A.C. Early and Zahid Sayeed Khan, "Irrigation Evaluation Procedure for Flooded Rice Crops." These may be obtained from Dr. John O. Reuss, USAID/Lahore, P.C. Box 660, Lahore.

Earthen Watercourse Reconstruction "Stretches"

Critical Groundwater Water Supplies

The development of a fresh water aquifer beneath watercourses and irrigated land, through seepage, provides a valuable stored water resource during periods of critical crop need. The recharge of this aquifer occurs during the monsoon season, from watercourse seepage losses and from deep percolation of irrigation water.



(over)

Earthen watercourse improvement allows improved water delivery without seriously disrupting the storage-recycling procedure. Improved capacity of the reconstructed watercourses provides for more efficient delivery of both surface water and that which is recycled by pumping from the underground aquifer.

Delivery of water at the time of peak field crop requirements is a "must" if crop yields in Pakistan are to be improved. This system aids in providing additional flexibility at the time of peak water demands.

ADDITIONAL INFORMATION: The complete report is Tom Trout and John Reuss, "Utilizing Irrigation Seepage for Groundwater Storage." It may be obtained from Dr. John O. Reuss, USAID/Lahore, P. O. Box 660, Lahore.

GOOD LEADERSHIP IS ESSENTIAL FOR EFFECTIVE WATERCOURSE IMPROVEMENT

Leadership in organizing farmers to improve and maintain watercourses must come from the farmers.

The experience of the CSU Water Management Team at the Mona project indicates that a three-person executive committee selected by local farmers from among themselves is sufficient to provide the necessary supervision of the construction of watercourses, to plan the program, and to carry out the committee assignments.

Here a Pakistani extension worker is discussing with the executive committee ways to motivate the farmers.

There are commonly 30 to 100 farmers on each watercourse. An executive committee of fellow farmers that the other farmers will support is necessary to make and carry out decisions for watercourse improvement and maintenance. The technical advisers, such as those from Colorado State University, can assist the executive committee in those decision, but ultimately the advisers, too, must agree to the executive committee's decisions.

The three basic ingredients for success of a development program are:

1) The program is physically sound and has potential for returning high benefits compared to costs.

2) The farmers be provided with what they cannot otherwise obtain and no more. (for example, information, technical services, capital)

(over)

3) The farmers must understand from the beginning that the development program is theirs---that there are limits and regulations governing the extent of government participation, and within those limits the farmers are in charge and the success or failure of the program is their responsibility.

This last ingredient is perhaps the most difficult. It requires considerab thought and planning on the part of those working with the farmers. The advisers must let farmers know that they respect the farmers' wisdom and judgment in all matters and are available at the farmers' request to give technical guidance on the program.

Specific executive committee responsibilities, information needs and prerequisites for the first meeting are included in the report.

ADDITIONAL INFORMATION: The complete reports are: Max Lowdermilk, David Freeman, Alan Early, George Radosevich, W. Doral Kemper and Ashfag H. Mirza, "Organizing Farmers to Improve Irrigation Water Delivery-The Problem and Prospects For Solutions in Pakistan," and W.D. Kemper,"Farmer Organization to Improve and Maintain Watercourses." These may be obtained from Dr. John O. Reuss, USAID/Lahore, P.O. Box 660, Lahore.

Increase of Water Delivery is Only Incentive Needed For Watercourse Improvement

Improvement of watercourses can be accomplished without any incentives other than assurances that there will be considerable increase in water deliveries to the farmers fields.

This was the conclusion of a study of essential watercourse improvements on the watercourse at Tubewell 60. This study resulted from the delay in other watercourse improvement projects caused by installation of concrete control structures. Thus, this investigation sought to find out if the increased water supply was sufficient incentive to motivate farmers, or if government-provided structures were essential incentives to cause farmers to improve their watercourses.

(over)

Farmers at Tubewell 60 perceived that the water supply to their fields averaged about 160 percent of water supply prior to improvement--a larger increase than had been measured on other watercourses where more intensive improvements had been made.

The tendency to overrate accomplishments emphasizes the importance of letting farmers take leadership in the project when possible. It helps in advertising the program by bringing farmers from other watercourses to hear these farmers tell the enthusiastic story of their improvement program.

Some farmers having larger farms are able to pay for their own concrete control structures, but a general program which required farmers to pay for their own stuructures would be a hardship on the poorer farmers. Thus, this study recommended that the improvement programs either have no provision for control structures, or, if such structures are included, that they be provided at government expense.

The low cost to the government of this "essential improvement" of the watercourse at Tubewell 60, benefits perceived by the farmers, the enthusiastic participation and the rapidity with which the improvement was accomplished all argue for further consideration of this type of an improvement program to assist the country to quickly bring about the first major improvement of water supply to the farmers' fields.

ADDITIONAL INFORMATION: The complete report is Moh'd Mohsin Wahla, W.D. Kemper and M. Munir Chowdhry, "Essential Improvement by Farmers of the Watercours Serving Tubewell 60." It may be obtained from Dr. John O. Reuss, USAID/Lahore, P.O. Box 650, Lahore.