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ASSESSMENT AND FIELD REVIEW

OF

WATER MANAGEMENT RESEARCH

BY

COLORADO STATE UNIVERSITY

Colorado State University: Pakistan
Contract AID/csd-2162

February 1976

Report Prepared by

Howard Haise, Agricultural Engineer-Agronomist
John Pehlan, Agricultural Engineer
Douglas Caton, Agricultural Economist

FORWARD

The panel appreciates the assistance of the officials of the Government of Pakistan and Punjab Province, the USAID Mission in Pakistan and the Colorado State University research team in collecting the information needed for this report. The many courtesies extended to the panel are appreciated.

Special thanks are due to Mr. Shafiq Malik, Mrs. Jincy Boerner, Mrs. Barbara Judy and Mrs. Susan Endter, who spent long hours in providing the panel with administrative and typing assistance.

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ASSESSMENT AND FIELD REVIEW OF WATER MANAGEMENT RESEARCH BY COLORADO STATE UNIVERSITY

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Contract AID/csd-2162
February, 1976

I INTRODUCTION

A review panel consisting of Howard Haise, Team Leader, John Pehlan, and Douglas Caton conducted an assignment of research content and design, progress from inception to date and prospective results of the CSU water management project in Pakistan together with the supporting research being conducted on the CSU campus. Dr. Haise is a senior Agricultural Engineer-Agronomist, formerly with the Agricultural Research Service, USDA; Mr. Phelan is a senior Agricultural Engineer, formerly Director of Engineering of the Soil Conservation Service, USDA, and Dr. Caton is Senior Agricultural Economist, AID, Washington, D.C.

The panel assembled in Islamabad, Pakistan, Tuesday, January 27, 1976 and continued its review and report preparation through February 13, 1976, ending with a discussion of findings and reporting procedure with USAID Pakistan staff, CSU team members and Dr. D. L. Plucknett, Chief, Soil and Water Management Division, TA/AGR; and Mr. Charles Antholt, Asia/TD/DR, on February 12. The panel assessed program progress and relevance by reviewing the annual reports, the present work plan, project agreements, the status of the field projects, utilization of research results, and reactions from the Mission and host country officials.

The CSU research is proceeding, and has since its inception in June 1968, under the following set of general and specific objectives:

GENERAL OBJECTIVE

The general objective of this research is to increase food production in the arid and sub-humid lands of the less developed countries with appropriate consideration given to increasing employment in the rural sector and utilizing local resources through the improvement of water management practices and the utilization of those with other good management procedures.

SPECIFIC OBJECTIVES

1. Development of 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 a limited amount of irrigation water.

2. Development of knowledge and data that can be used 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. The development of surface and sub-surface water removal systems to minimize the hazards resulting from surface flooding and high water tables.

4. Identification of important factors to be considered in land preparation and grading of the various 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. Development and adaptation of methods of water application, including time and amounts, which are suitable and efficient for different soils of varying properties (water-holding capacities, intake rate, etc.) with major crops.

6. Integration of these water use factors into productive cropping systems consistent with farm size and available farming practices.

7. Development of means for increasing crop production by using amendments and management practices which will improve water and soil properties and by using salt tolerant crops in those areas where water quality, soil salinity and exchangeable sodium are problems.

8. The identification of institutional and policy factors (legal, social, economic, religious, manpower, credit, etc.) that influence the efficient distribution, management and utilization of water at the farm level.

ISSUES

To assist the panel to make its assessment the team was furnished a set of six (6) issues by the Soil and Water Sections of TA/AGR, AID, Washington based upon the Agency's understanding and impressions of CSU research contract activities. The Panel Chairman was not bound to these issues in structuring the review, but each was noted and discussed. By specific heading the "issues" paper given the team prior to its leaving the United States were:

1. Lack of research strategy or focus of the program.

Here the concern was the possible fragmentation of the program into a series of projects unrelated to the central focus: on-farm water delivery systems, field layout, and use of water.

2. The total effort of the research program is concentrated in Pakistan.

Here the concern was with efforts to develop "state-of-the-art" studies in other countries, and the broader than Pakistan relevance of the research.

3. The value of the "Consortium" and/or cooperative approach to water management research.

Here the concern is "that a comprehensive and coordinated attack on water management problems has (not) evolved to date from the consortium....invisioned (by) CUSUSWASH (CID)."

4. Future direction and involvement.

Here the concern is with the direction of future research relative to resolutions of Issue 1.

5. Value of publications to the LDC situation.

Here the concern is not with the number of formal technical publications produced but with the need to prepare publications based on the adaptive research being conducted in Pakistan for general use.

6. End of project statement.

Here the concern, as this assessment is being made at the 7th year of the project, with the following set of questions:

1. When will the work be efficiently completed in Pakistan?
2. What is being done to see that the country can carry on after CSU leaves?
3. What has been the effect of the project on CSU? Has institutional competence increased?
4. What is the plan for utilization of results?
5. Should the work be continued as research and if so, how: or is there now need for a technical service project more related to transfer of the technology rather than research?

QUESTIONS

In making its assessment of research substance and evaluation of research findings and adaptations, together with its general properties, the panel was asked to make specific recommendations regarding disposition of the project after its present funding date which ends March 31, 1977, e.g.

1. If termination is recommended, what should be done prior to the termination date to facilitate utilization of results obtained?

2. If aspects need further study, describe specifically what outputs would be sought, what the purpose would be, and what specific inputs will be needed from the Contractor, the Mission in Pakistan, other Missions, the Government of Pakistan, other governments, and TAB.

In making its assessment the panel was to "determine which, if any, phases of the project are essentially complete; which show little or no progress; which can be turned over to host country agencies, and which could be realistically incorporated into the Mission program." Also, "particular attention should be given to if and how the host country can assume responsibility through action agencies to adopt the research findings." The Chief of the Soil and Water Section, TA/AGR also wrote: "keep in mind that this is a centrally funded research project and as such must have a reasonable degree of transferability. Those of us close to the project realize there have been impressive accomplishments in Pakistan and we are concerned that maximum pay off is achieved from it. Can this be achieved in Pakistan with an early withdrawal of the CSU team? Can this expertise be utilized in other countries to increase food production where similar water management problems occur?"

Several documentations and materials preparation requests were made of Colorado State University, on-campus and in the field, in early December to assist the review panel to make an "in-depth" as well as an assessment complete as to research scope, project history, and progress.

A. Questions of a statistical nature included:

1. The Mission budget for your project broken down into prior fiscal years and estimated expenditures until March 31, 1977.

2. The Government of Pakistan budget for your project.

3. The dollar level of central funding over the life of the project to date.

4. A summary of the technical advisory services by discipline and by location in terms of man months.

5. A listing of publications resulting directly from this contract.

B Questions of a substantive nature included:

1. What is the specific purpose which your project is designed to achieve if completed successfully?

2. What conditions and situations will exist if the project achieves its purpose? Describe an identifiable point which will be considered the logical end of the project, how will you or anyone else know when the project purpose has been achieved?

3. Is the project entirely site specific to Pakistan? Or are there portions which are extendable and if so where and how?

4. What are the specific outputs to be expected from the successfully completed project?

5. What, if any, inputs are limiting? (Include host country and Mission support.) What are some of the constraints?

The schedule of work under which this panel operated is attached as Appendix A.

II THE AGRICULTURAL SETTING

By the end of 1975 the human population of Pakistan was estimated at 72 million, with an annual growth rate of over 3 percent. There are expected to be 97-100 million people in Pakistan by 1985, mostly concentrated along the major inland watercourses, as shown in Figure 1.

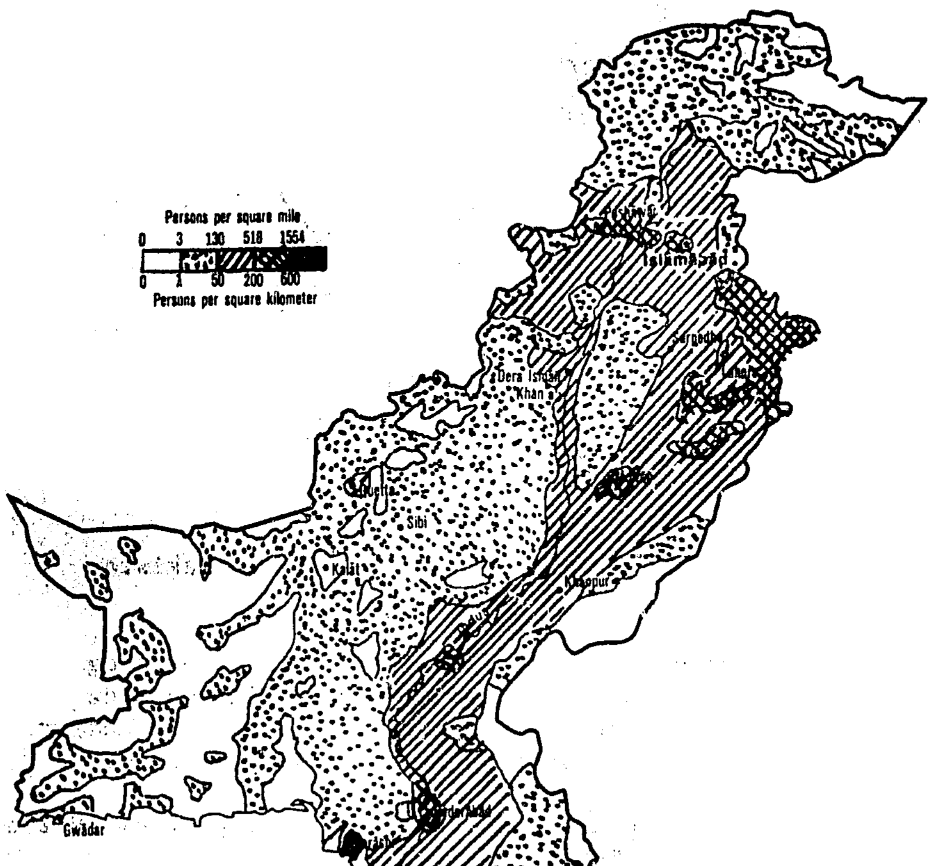

Figure 1 - Population Density of Pakistan

The agricultural and land use in Pakistan, Figure 2, clearly corresponds with population distribution.

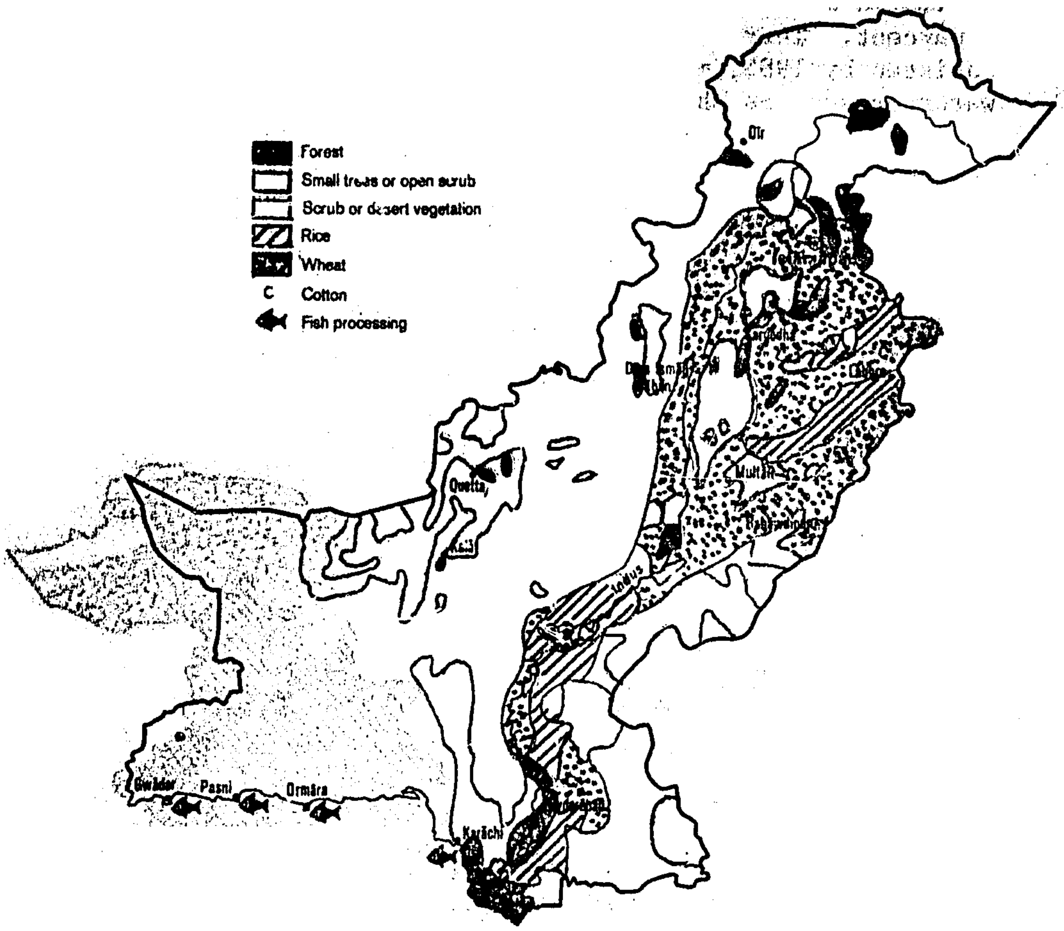

Figure 2 - Agriculture and Land Use in Pakistan

Ethnic distribution, Figure 3, has a much wider geographic distribution, with some ethnic groups essentially outside of the intensive agricultural areas, being primarily nomadic and/or pastorial as far as relation to agricultre is concerned.

The agricultural profile of Pakistan compiled from 1972 country statistics is given in Table 1.

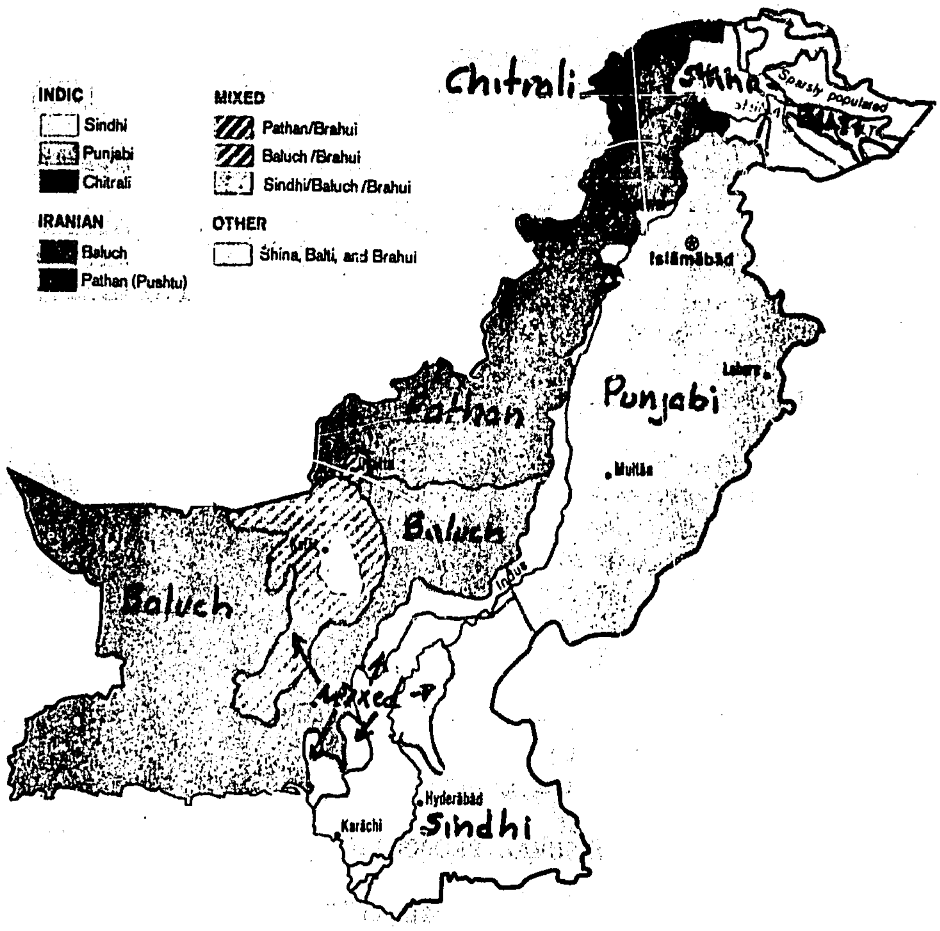

Figure 3 - Ethnic Distribution in Pakistan

Agriculture is Pakistan's most important industry. Over 37 percent of GNP comes from agriculture. Seventy percent of the people live in the rural areas. Seventy percent of farm income comes from crops and almost 30 percent from livestock.

Self-sufficiency in food grains, especially wheat, is a major goal of Pakistan. Today, Pakistan is a net importer of wheat. Yields can easily double in rainfed areas with more high yielding seed varieties and more fertilizer use. Several fold increases in output could be obtained in irrigated areas by better water management, more fertilizer and improved cultural practices. Wheat, rice, cotton and sugarcane production grew steadily during the past few years, whereas production of coarse-grains, pulses and oilseeds (except cottonseed) was almost stagnant. The tentative FY 1980 targets are: 12.7 million tons of wheat, 3.9 million tons of rice, 30.4 million tons of sugarcane, 6.2 million tons of cotton, 2.0 million tons of coarse-grains, and 1.02 million tons of pulses.

TABLE 1 - PAKISTAN AGRICULTURAL PROFILE 1972

LAND

Total area	80.4 million hectares
Arable land and land in permanent crops	19.2 million hectares
Irrigated land included above	12.5 million hectares
Permanent grassland	5.0 million hectares
Forests and woodland	1.8 million hectares
Other lands	54.3 million hectares

POPULATION (1974)

Total	70.5 million
Total agricultural population	49.7 million
Percent of total in agriculture	70.5%
Percent of agricultural total that are economically active	70.5%

POPULATION GROWTH INDEX

1961 - 1965 = 100
1973 = 132.5
Annual growth - 3.25%

INDICES OF AGRICULTURAL PRODUCTION (1961-1965 = 100)

Total Crop Production in 1973	- 162
Total Agricultural Production in 1973	- 162
Total Food Production in 1973	- 162
Per Capita Indices	
Agricultural Production in 1973	- 122
Food Production in 1973	- 122

PRODUCTION VALUES

Total value of all agricultural products	$ 1,172,000,000
Total value of all foods produced	$ 967,000,000

A severe drought held wheat production to an estimated 7.1 million tons in FY 1975, but the Government is embarking on a revitalized program to reach a target of 9 million tons in FY 1976 and 10 million tons in FY 1977.

Cotton is a major cash crop and the most important source of foreign exchange. The export of raw cotton, yarn and cloth earned $364 million in FY 1974. Estimates place the FY 1975 cotton crop at 4.3 million bales with estimated export earning of $335 million.

Rice production has increased steadily from the use of high yielding seed varieties, more fertilizer, and increased acreage. The FY 1974 export of yearly 600,000 tons earned about $210 million representing 20 percent of export earnings. FY 1975 export earnings are estimated at $280 million.

Sugarcane production has fluctuated widely and supplies are being rationed. FY 1974 crop production was estimated at 22.7 million tons, a 16.8 percent increase over the FY 1973 crop. For FY 1975 estimates place sugarcane production at 22.0 million tons, slightly less than the previous year.

Production of the poor man's protein, pulses, for FY 1975 is estimated at 750,000 tons, almost the same level as FY 1967.

Pakistan's primary agricultural productive zones and crop distribution profile are identified in Figure 2.

Of the feed grains, most of the wheat is produced in Central Punjab. Rice is primarily produced in the south and in eastern Punjab. Only those areas with perennial canal or canals plus tubewells are able to practice continuous and multiple cropping. Pakistan 1972 crop production, and a mapping of the correspondence of cropping with rainfall, and irrigation are located in the appendix to this section.

Pakistan expects to increase the output of its major crops sharply over the coming five years. The target for wheat, for example, is to essentially double production. (Figure 4)

For additional detail on crop distribution zones and cropping practices, see Appendix B.

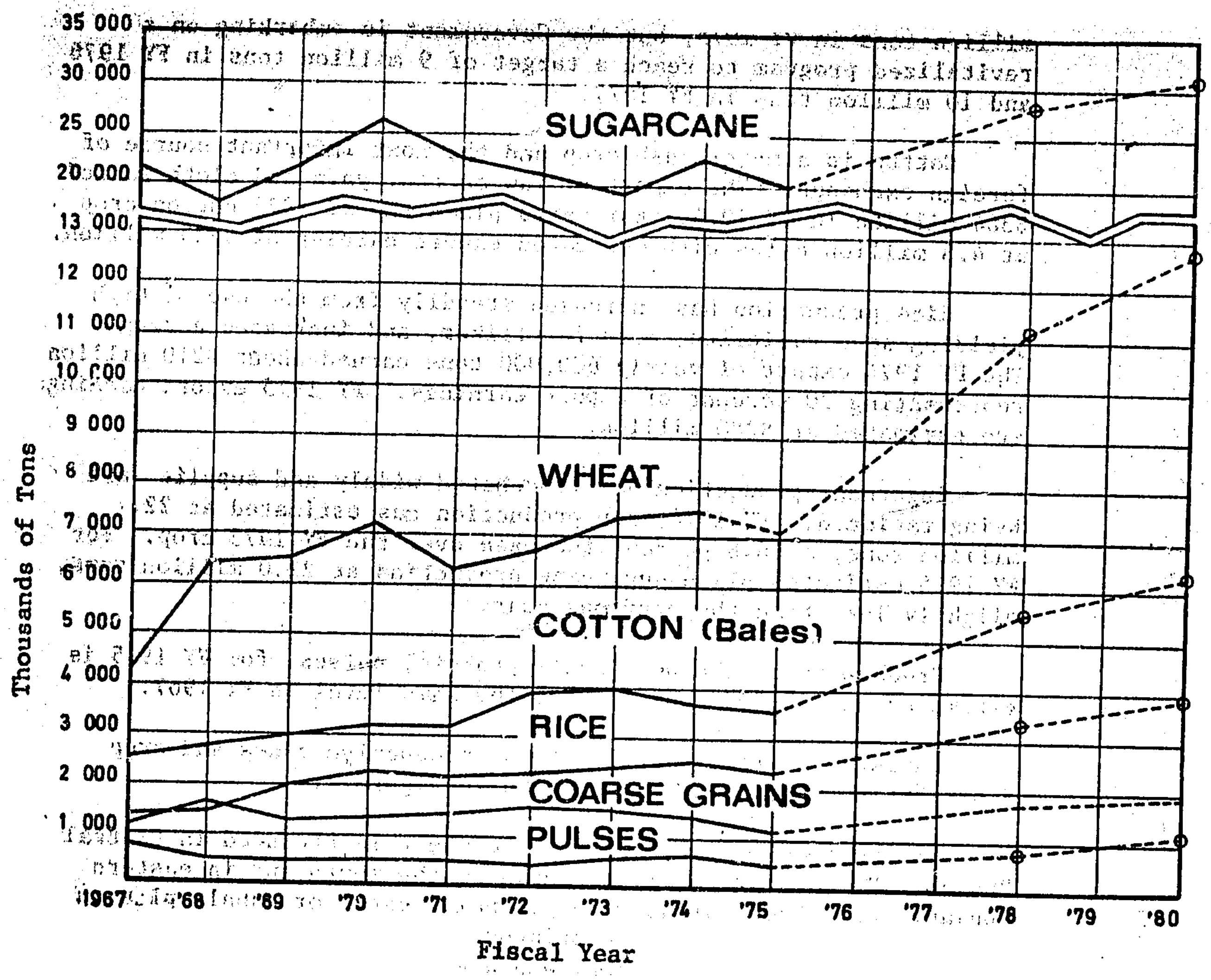

Figure 4 - Production of Major Crops in Pakistan

III PROJECT HISTORY[1]

CONTRACTS

The Water Management Research Project was initiated on March 28, 1968 with funding from AID Contract csd-2162, which terminated March 31, 1974. The present contract, AID/ta-c-1100, became effective on April 1, 1974 and was scheduled for termination on June 30, 1976. This contract has been extended to March 31, 1977.

PROJECT LEADERSHIP

The Project Director under AID Contract 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 the present 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.

FIELD PROGRAMS

The CSU Water Management Research Project has had a field program in Vietnam and has 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

[1]This section was prepared in part by Gaylord V. Skogerboe.

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 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.

The present Field Party faculty personnel are Doral Kemper, Wayne Clyma, C.J. deMooy, Alan Early, John Reuss, Sam Johnson and Sid Bowers.

CAMPUS SUPPORT

The campus activities and support under the Water Management Research Project has involved the departments of Agronomy, Agricultural Engineering, Civil Engineering, Economics, Political Science and Sociology. Presently, the work is being done by personnel in the departments of Agronomy, Agricultural Engineering, Economics and Sociology.

Faculty

The on-campus faculty personnel in the Agronomy Department who have been primarily involved with this project are Dr. Willard R. Schmehl and Prof. William Franklin. The primary personnel in the Agricultural Engineering Department have been Dr. A.T. Corey, Dr. William E. Hart, Dr. David B. McWhorter and Prof. Gaylord V. Skogerboe. In Economics, Dr. R.A. Tinnermeier and Dr. Larry Mack have been involved with this project and the return of Dr. Eckert to campus strengthens the capability of the Economics Department in accomplishing project objectives. In addition, Dr. George E. Radosevich, a lawyer specializing in natural resources, is located in the Economics Department and has played a key role in studies regarding water law and water users associations for organizing farmers. The Sociology Department is playing an increasingly important role in this project with the efforts of Dr. Max K. Lowdermilk and Dr. David M. Freeman.

Graduate Students

A graduate program of study has been initiated in which host country students receive academic training at CSU and then return 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. There are now two M.S. students in Agricultural Engineering back in Pakistan to complete their research, as well as two Pakistani Ph.D. students in Agricultural Engineering who spent the summer of 1975 in Pakistan at the Mona Reclamation Experimental Project. Present plans call for Mr. Trout to spend two years in Pakistan beginning July 1976 to assist in the research program and complete a dissertation. Mr. Larry Nelson, a Ph.D. student in Agronomy, plans to spend one year in Pakistan in the immediate future to field test the results of his M.S. research.

PROGRAM DEVELOPMENT

Funding

The total funding received under Contract AID/csd-2162 was 2.2 million. 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 percent of total man-months and 32 percent of total salaries during the next-to-last year, and 37 percent of total man-months and 47 percent of total salaries for the last year, being for full-time faculty personnel.

Under the first two years (April 1, 1974 to March 31, 1976) of Contract AID/ta-c-1100, field faculty personnel represent 37 percent of total man-months and slightly more than 50 percent 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.

Tables 2 and 3 give the level of TA/AGR support and the local support costs of CSU personnel assigned in Pakistan. Table 4 gives a breakdown of the actual and projected technical advisory services by discipline from CSU during the period March 1968 through March 1977. Figure 5 gives the distribution of manpower with time as furnished by the campus and the field. It should be noted that beginning in 1972 there was a definite trend to field operations.

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

TABLE 2 - TA/AGR SUPPORT OF THE WATER MANAGEMENT RESEARCH CONTRACT, COLORADO STATE UNIVERSITY

	6/28/68 to 3/27/72	3/28/72 to 3/27/73	3/28/73 to 3/30/74	4/ 1/74 to 3/31/75	4/ 1/75 to 12/31/75	Total
Personnel	$574,568	$228,420	$255,660	$297,091	$227,407	$1,583,146
Travel and Allowances	93,734	89,709	98,450	70,841	61,635	414,369
Other Direct Costs	65,432	20,972	32,000	28,858	32,797	180,059
Equipment & Supplies	82,639	32,500	10,000	24,720	0	149,859
Research Operations	72,771	0	16,000	20,862	7,663	117,296
Overhead	352,505	109,400	123,650	123,340	97,948	806,843
Totals	$1,241,649	$481,001	$535,760	$565,712	$427,450	$3,251,572

TABLE 3 - MISSION SUPPORT OF THE WATER MANAGEMENT RESEARCH CONTRACT, COLORADO STATE UNIVERSITY

FY 1968 thru 1971	Not available
FY 1972	Rs. 134,208
FY 1973	482,418
FY 1974	641,932
FY 1975	1,104,077
FY 1976 (budgeted)	1,262,100
Part Total	Rs. 3,624,735

TABLE 4 - MAN MONTHS OF TECHNICAL ADVISORY SERVICES BY DISCIPLINE

Location		Agric. Eng.		Agric. Econ.		Agr. & Soils		Soc., Law & Exten.	
		To 1/76	2/76 to 3/77*	To 1/76	2/76 to 3/77*	To 1/76	2/76 to 3/77*	To 1/76	2/76 to 3/77*
Mona Reclamation Expt. Proj. (WAPDA)		9.2	5	61	11	13	11	3	1
Integrated Rural Development Shadab and Lar		1.4	2	9	4	3.5	4	2	1
Punjab Agricultural Research Institute	Soils Institute (Lyallpur)			0.5		6	2		
	Small Grains Institute (Lyallpur)	6		0.7		1	2		
	Cotton Institute (Multan)	2							
	Rice Institute (Kala Shakaku)	2							
	Maize & Millets (Yousafwalla)	1		0.1					
College of Agriculture, Tandojam		2.1				2			
Land Reclamation Directorate				0.1	0.5				
Islamabad University				1.1	0.5	1			
Engineering University - Lahore				0.6	0.5				
WAPDA -Other than Mona - Incl. Survey		1.1	1	9	4			3	1
University of Agriculture - Lyallpur		0.5	2	2	2	1	1	2	
USAID		4.5	1	7	3	6		4	1
Other		0.3	1	6	2	5	1		

*Planned for February 1976 through March 1977

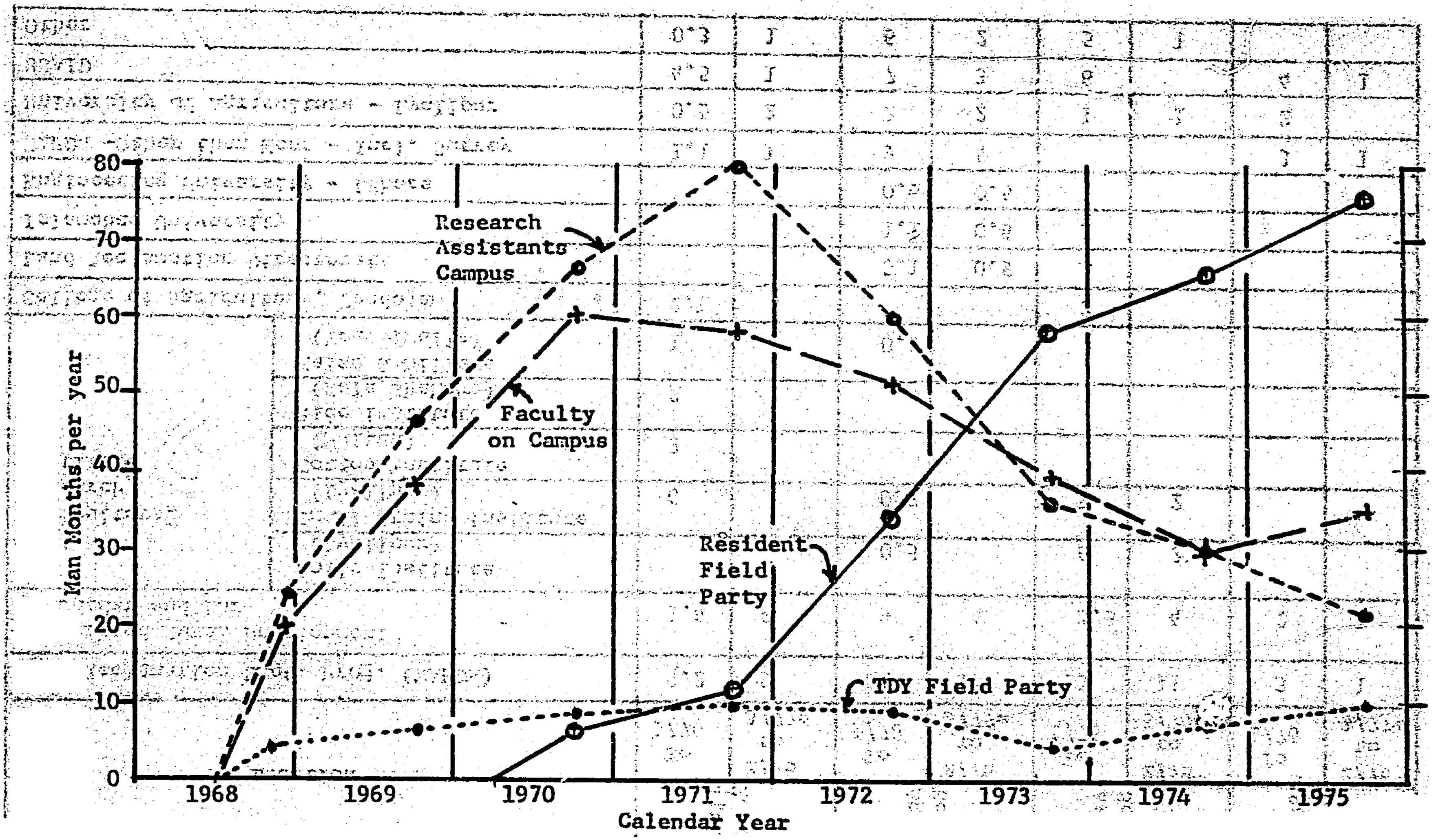

Figure 5 - Location of Manpower Used by CSU on the Water Management Research Contract

process, but there has been 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 will be 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 its efforts into a truly interdisciplinary research effort. The Water Management Research Project staff has been slowly developing into a more integrated interdisciplinary team. A major goal of this research project has to be the strengthening of interdisciplinary team work.

Previous Reviews

On January 24-28, 1972, Marvin Jensen, Snake River Conservation Research Center, Earl Heady, Iowa State University, and Leland Anderson, USAID/Pakistan made an in-depth review of progress under the Utah and Colorado State Universities water management research programs. The Review Committee stated at the outset that

"we....are aware of the tremendous impact improved on-farm water management can have on food production in less developed countries. Improved water management will also minimize the frequency and intensity of soil water deficits with its resulting detrimental effects on plant growth. The development and implementation of improved water management practices, however, will not be as rapid as changes in varieties of the addition of fertilizers. Research and application of improved on-farm water management is complex because it involves the management of crops, soils, fertilizers, rainfall, irrigation water, excess or drainage water and soil salinity in an integrated manner. Improved on-farm water management also usually requires capital outlays and improved practices must take place within the socio-economic constraints of the region.

"Our team reviewed the projects relative to the broad, general objectives stated in the contracts, but placed more weight on those activities that were directly associated with on-farm practices. Most of the recommendations that follow are of a positive nature since we feel that both projects should be continued through their original durations, and should be extended another three-to-five year period to capitalize on the developing technology and scientific expertise at these universities." (See Appendix D for additional background of Jensen-Heady-Anderson project review.)

IV FIELD REVIEW AND OBSERVATIONS

MONA RECLAMATION EXPERIMENTAL PROJECT

Watercourse Studies

A major effort in watercourse improvement and evaluation is being conducted in cooperation with the Water and Power Development Authority (WAPDA) supported by local currency funds provided by the Mission.

Initial measurements indicated that losses in watercourses greatly exceeded those commonly assumed in design and in many instances were the major losses in the water supply system. There was considerable reluctance on the part of the irrigation authorities to accept these findings and it was only after a meeting of high level staff from WAPDA, the Irrigation Department and their consultants that a workshop complete with a field demonstration was arranged by the CSU staff that these findings began to be accepted. Many still remain unconvinced but the degree of acceptance is growing and the Government of Pakistan now seems committed to developing programs to overcome this deficiency.

Present research efforts at Mona are for the purpose of developing and testing methods for watercourse rehabilitation and maintenance to decrease water losses and their feasibility for adoption in Pakistan. Work is underway to develop and evaluate watercourse improvements in terms of costs and benefits for various alternative types of watercourse modifications.

Tubewell 122 - One watercourse which is served by canal water on a nonperennial basis and by Tubewell 122 has been improved with 13½", 9" and 4½" rectangular brick masonry lining. This installation was not observed by the panel.

Tubewell 78 1/ - On another watercourse served by perennial canal water and by Tubewell 78, Figure 6, a number of "pucca" (structural) linings were installed for testing. Included were 13½", 9" and 4½" brick masonry rectangular sections; a rectangular section constructed from 4"x6"x12" soil-cement bricks; and brick masonry and concrete trapezoidal sections.

Other types of improved watercourse construction that probably should be tested include pipelines, "canalettes" (precast semicircular or parabolic concrete sections supported on masonry piers), and precast concrete linings on earthen beds.

The durability and the maintenance requirements of the several types of permanent watercourse improvements need to be determined under Pakistan conditions. The farmer acceptability of the various types of improvements as well as their benefit-cost ratios need be known to plan a sound watercourse improvement program. A monitoring and evaluation program is underway to obtain this information.

1/ See photos Appendix I-1(A,B,C,D) and I-2(A,B)
Captions are self-explanatory.

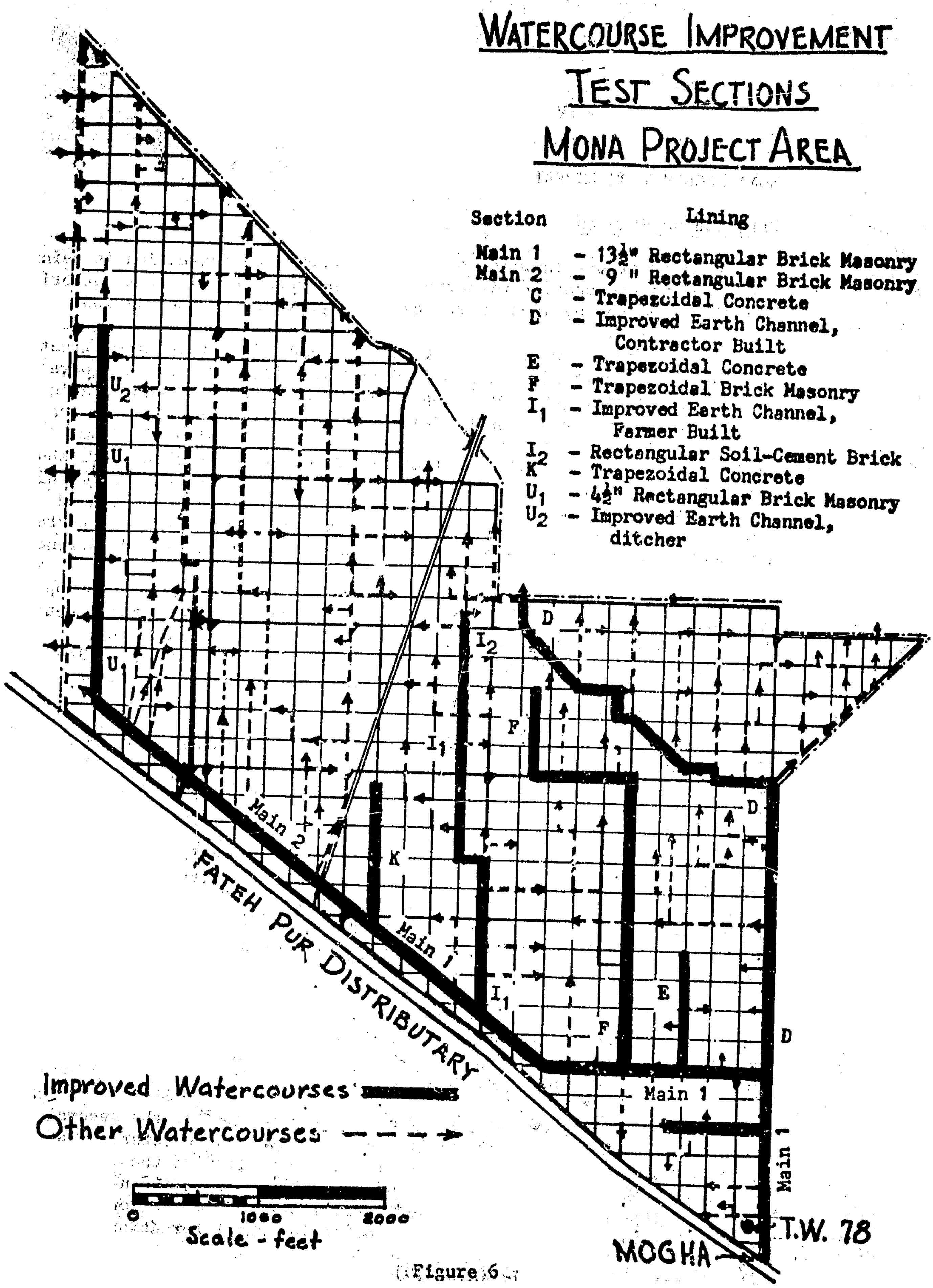
WATERCOURSE IMPROVEMENT
TEST SECTIONS
MONA PROJECT AREA
Section Lining
Main 1 - 13½" Rectangular Brick Masonry
Main 2 - 9" Rectangular Brick Masonry
C - Trapezoidal Concrete
D - Improved Earth Channel, Contractor Built
E - Trapezoidal Concrete
F - Trapezoidal Brick Masonry
I1 - Improved Earth Channel, Farmer Built
I2 - Rectangular Soil-Cement Brick
K - Trapezoidal Concrete
U1 - 4½" Rectangular Brick Masonry
U2 - Improved Earth Channel, ditcher
U2
U1
U1
I2
I1
I1
F
F
K
D
D
D
E
Main 2
Main 1
Main 1
Main 1
FATEH PUR DISTRIBUTARY
T.W. 78
MOGHA
Improved Watercourses
Other Watercourses
0
1000
2000
Scale - feet

Figure 6

In addition, improved "kutcha" (earthen) ditches were installed using three different methods of construction: (1) by contractors; (2) by using tractors and ditchers; and (3) farmer built. Branch I,[1] a farmer improved watercourse was a trial that holds promise for additional installations. (See Fig.7) The farmers served by Branch I were approached by the Agricultural Engineers with the proposition that the Mona Project would provide concrete or masonry control structures if the farmers would construct the watercourse channel and banks to proper dimensions. Since Branch I is between two branches which had been previously lined with brick and concrete at no expense to the farmers, it was not too surprising when the farmers refused this proposition. At this point the Mona extension personnel were asked to assist since they have worked with these farmers for several years. They told the farmers that the experimental brick and concrete test sections were all built, that the improved kutcha construction would reduce the crop damage from seepage in the upper section, would increase their water supply and that the "pucca" control structures would save them much work and would last for many years. The farmers formed an informal user's association and agreed to the original proposition.

Losses were measured on Branch I and the steady state losses were about 40 percent. One carefully measured water budget of all water delivered to the nakkas (field inlets) compared to the water supply at the head of the branch indicated that total losses were near 60 percent. After the farmers built the banks and installed the "pucca" control structures, the losses appear to have been reduced from over 0.8 c.f.s. per 1000 feet to about 0.4 per foot of channel. The farmer's labor was valued at approximately Rs. 0.5 per foot of channel. Similar improvements constructed by contract cost Rs. 14 per foot of channel.

Siphons were introduced on Branch I to encourage the farmers to deliver water into sub-branches or into their fields without cutting the banks of the watercourse. To date only two cuts have been made in the improved section and the identity of the culprit is apparent. It is the intent of the extension agent and the user's association to focus an "education program" on this individual.

Tubewell 56[2/]- Using the experience gained on Branch I of Tubewell 78, a third watercourse served by a perennial canal and Tubewell 56 has been improved using farmer labor to reconstruct the channel and banks and eliminate the primary source of seepage. (See Figure 7) Reasonably priced nakkas have been installed to eliminate operational and spillage losses. These "nakkas" have been developed by the CSU staff working with a local manufacturing firm. Results to date are very promising and further perfection is underway.

In addition to the conventional structural elements in the watercourse design such as nakkas, checks, division boxes and culverts, some specialized structures have been necessary to meet local needs. Water buffalo wallows needed to be provided so that the canal banks

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1/See photo Appendix I-6(B)

2/See photos Appendices I-2(C,D); I-3(A,B,C,D); I-4(A,B,C,D) and I-5(A,B). Captions are self-explanatory.

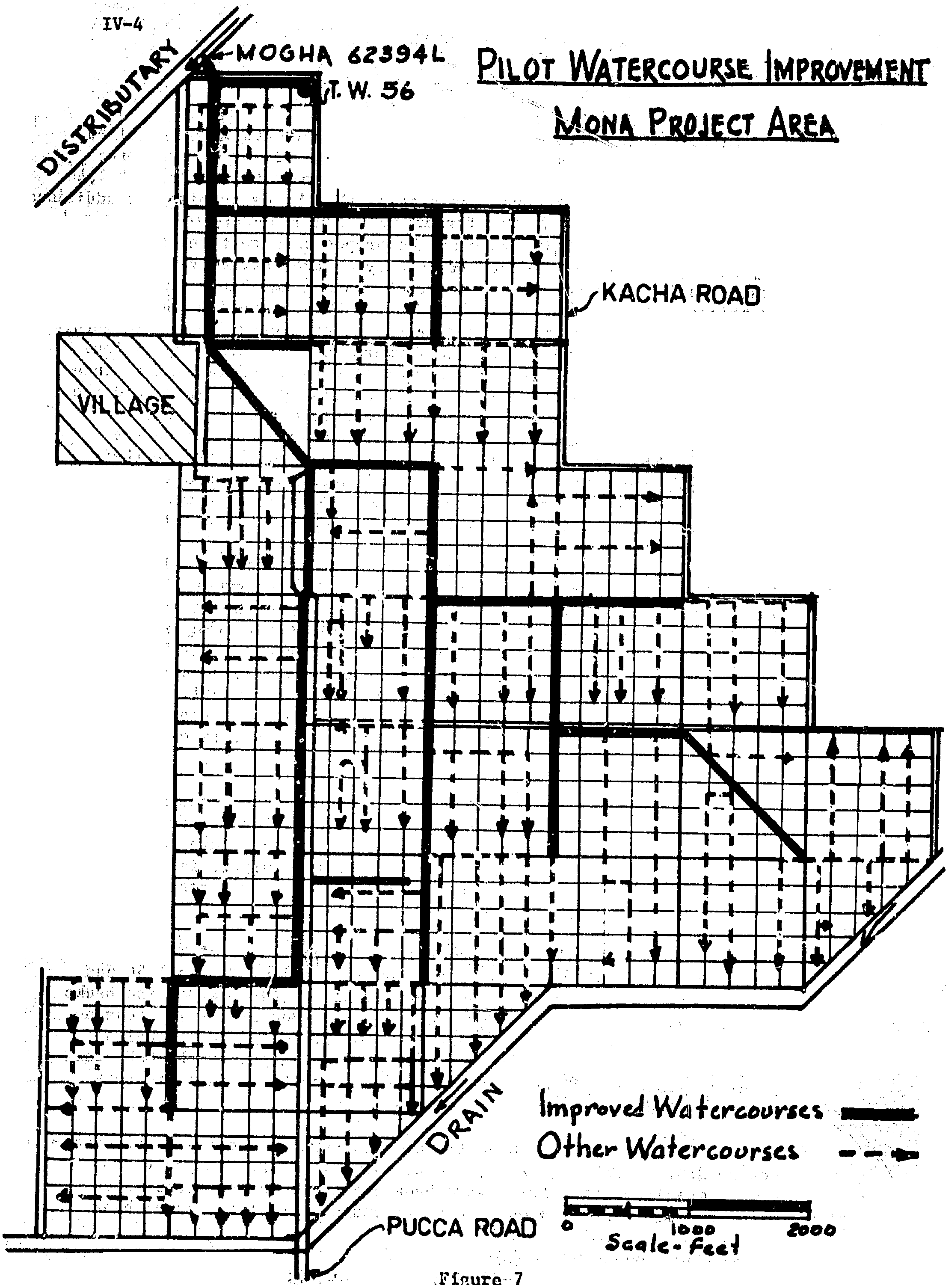
PILOT WATERCOURSE IMPROVEMENT
MONA PROJECT AREA
DISTRIBUTARY
MOGHA 62394L
T. W. 56
KACHA ROAD
VILLAGE
DRAIN
PUCCA ROAD
Improved Watercourses
Other Watercourses
0
1000
2000
Scale - Feet

Figure 7

will not be damaged by animal traffic. Provisions were also made for areas where the village women could do their laundry.

This kutcha watercourse has been essentially completed. To date 60 farmers have spent 40 days on the improvements and it is estimated that 35 farmers can complete the finishing work in 7 days. Materials for the needed structures have been provided by the Mona project.

The panel had the opportunity to meet the village committee that is guiding the effort in providing the work force and in settling disputes. They are highly respected villagers who are convinced of the value of the improvements, have taken an active part in the planning of the work and who are adept in utilizing village social pressures to keep the work moving.

Preliminary measurements indicate that the farmers at the lower end of the watercourse have heads of water available that are approximately double their original supply. Evaluations of watercourses, structural adequacy, maintenance requirements, longevity, and costs and benefits are presently underway.

The panel feels that the method of improvement and the job organization used on Tubewell 56 shows considerable promise in providing a practical and effective watercourse system. Further work needs to be done in the design of appurtant structures. The wingwalls used to tie the structures into the earthen banks are probably too short and erosion protection must be provided at structure inlet and outlets. The design of the checks could be improved by providing a means of overflow to protect the watercourse banks when all the nakkas in the system are inadvertently closed.

The practicality of the improved kutcha watercourses will largely depend upon the length of time that the compacted banks will retain their low seepage characteristics and the amount of work the farmers are willing to do to maintain flow capacity. A monitoring and evaluation program of the installations now in place will help provide this information.

Skimming Wells [3/]

In much of the Indus plain, a body of fresh water overlies more saline water and investigations are underway to develop techniques for extracting this valuable fresh water supply. Wells especially designed to obtain water of best quality under these conditions are called skimming wells.

Initial theoretical analyses supported by laboratory investigations were developed at Colorado State University in 1971-1976. Early analyses were approximations based on the assumption of immiscible fluids of different densities as developed by the oil industry. A

3/See photo Appendix I-6(D). Caption is self-explanatory.

more complicated and realistic case where the transition zone between the fresh and saline waters can increase in thickness as mixing takes place has been modeled on a computer. However field data is needed to test and refine this program.

A study is underway to obtain the needed information. Fine aquifer materials in the initial well tested, which had a depth of 35 feet, would not provide adequate flow rates to raise the interface over about six feet and consequently another well was constructed at Phullarwan that is 60 feet deep. This well cost Rs. 3000 and has sufficient capacity (0.5cfs) to raise the interface 30 feet or more. The movement and shape of the interface has been carefully monitored during the following pumping. The data obtained (i.e. Figures 8 and 9) will be used to test and refine the computer program. The objective is to provide guidelines for well design and pumping rates and durations to achieve satisfactory quality water from aquifers with known salinity profiles.

One nearby operating well has been modified using criteria developed from the theory and the salinity of the water has decreased from 2400 ppm to 800 ppm and is providing a satisfactory supply for the research farm.

At the request of the Sind Province, data was collected on four problem wells. Modifications were recommended on one. It is predicted that the salinity of the water produced can be decreased from 1400 ppm to 700 ppm with only a 20 percent decrease in the flow rate of the well by simply reducing the well depth by filling with sand to a prescribed level and installing a concrete plug.

In the Mona Project area, over 10 percent of the wells originally installed are no longer used because of degraded water quality. WAPDA has requested that salinity profiles of these wells be determined and has requested the CSU staff to recommend needed modifications.

The panel feels that this research is reaching the payoff stage and the work proposed for the coming season will be especially important. A writeup of the tentative guidelines should be made and these further refined from data collected by monitoring the operation of those rehabilitated wells for which complete data is available. If skimming wells can be successfully designed, they will have application in many parts of the world.

However, the panel realizes that skimming wells will only buy time, so to speak, and that the long range solution will require arranging to maintain a favorable salt balance.

Optimum Management for Crop Production

Optimum management programs for wheat during rabi 1974-75 and maize during kharif 1975 have been conducted on precision leveled fields at Tubewell 78 and at Tubewell 122.[1/] The results of these experiments are providing demonstrations to the farmer of improved cropping practices and improved water management in order to increase

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1/See photos Appendix I-7(A,B). Captions are self-explanatory.

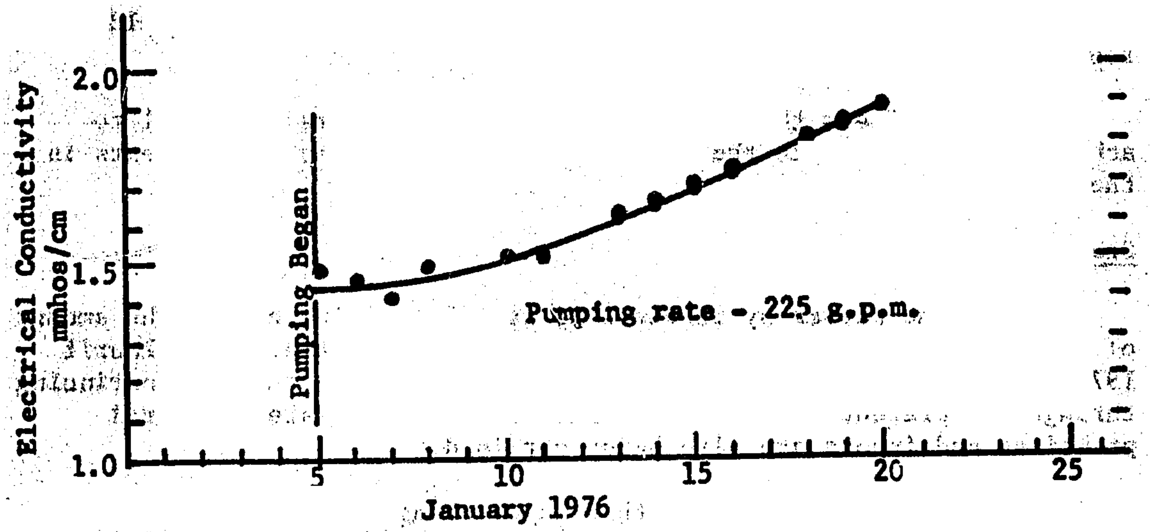

Figure 8 - Electrical Conductivity of Well Water vs. Time

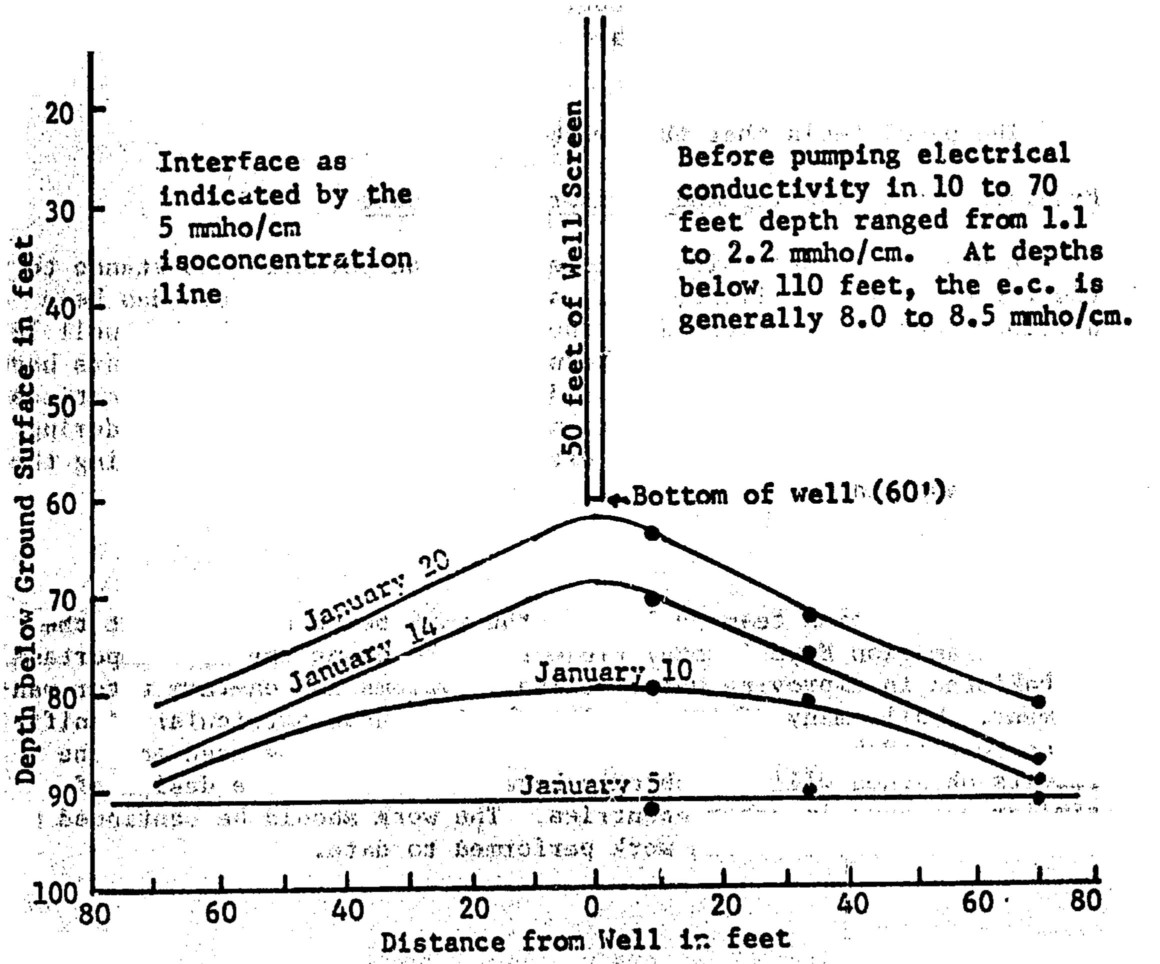

Figure 9 - Saline-Fresh Water Interface vs. Time

yields in the area served by the improved watercourses. The results of these experiments provide documentary data for the potential yield levels for this area and the reduction in the water use that can be achieved through improved water management. Improvement in yields and reduced water losses have been achieved.

The panel feels that programs of this nature are essential to achieve and demonstrate the benefits made possible by improvements in the water delivery system.

Seasonal Irrigation Practices

Four farms served by Tubewell 78 have been selected and the amount of water applied to each field was observed during the entire kharif 1975 season. These data are under analysis and the study is continuing through the present rabi season. Data on the associated cultural practices and inputs are also being obtained.

Preliminary data indicate that major changes in cropping practices are occurring as a result of the improved water supply and that major impact is at the tail end of the watercourse. These farmers need assistance in planning their cropping system in order to more fully utilize their improved water supply. An analysis of the period-by-period water supply, water demand and water utilization rates for these farms is in progress.

The panel feels that this work should be continued.

Precision Land Leveling and Advisory Assistance

A program of precision land leveling and advisory assistance to the farmers for fertilizer, seed, and irrigation practices has been developed and is in progress on the watercourse served by Tubewell 78. A number of acres have already been leveled and farmer agreements have been obtained to follow recommended cropping and irrigation practices. A goal has been set for an additional 100 acres to be leveled during this rabi season. Mona project extension personnel are providing the advisory assistance.

General Conclusions

The evaluation team feels that the work being conducted at the Mona Reclamation Experimental Project may be among the most important in Pakistan in improving water delivery systems and on-farm water management. While many of the results obtained have particular significance to the Pakistan situation, the techniques being used and the results obtained will undoubtedly have an impact in the design of similar programs in other countries. The work should be continued to obtain full value from the work performed to date.

INTEGRATED RURAL DEVELOPMENT RESEARCH PROJECT

Shadab

Time did not permit a field review of all research projects under IRDP but the panel did observe progress being made on improvements on the Kanjra watercourse at Shadab as a part of the thesis program for Messrs. Mushtaq Gill and Sadiq Shafique. These two energentic and motivated individuals have just returned from CSU having completed their academic requirements for the MS degree in Agricultural Engineering. They now have excellent academic training and are acquiring the practical experience to implement a comprehensive program of watercourse improvement, precision land leveling and in providing advisory assistance to the farmers. Mr. Shafique has assumed responsibility for the watercourse improvements and Mr. Gill is dealing with the water scheduling problems. (See photos I-5-C,D; I-6-A.)

A well designed division box controls the flow from the "mogha" (canal turnout) into three separate watercourses. A cutthroat flume equipped with recorders is located immediately above the division box. A meteorological station has been installed to record rainfall amounts and intensity, solar radiation, evaporation, wind velocity, humidity and maximum and minimum temperatures.

The watercourse represents a condition where obtaining cooperation among the farmers is difficult and the students have had to devise different cooperative arrangements to get the work done. At this time the work is progressing well and they have high hopes of completing their project on schedule.

The data collected will permit an exploration of the feasibility or utilizing soil, climatic and crop information for scheduling irrigation on farmers fields and/or regulating the release of irrigation water at the mogha. Computers available at WAPDA in Lahore will be used to determine when the crops need irrigating and how much water to apply.

The panel is impressed with CSU's arrangement to develop trained personnel where graduate academic training is obtained at CSU and the students return to their home country to complete work on their thesis involving solutions to practical field problems.

Other

At a nearby location, Mr. Mohammad Hanif, Agronomist, is conducting research on yields and consumptive use.

The panel observed wheat variety plots fertilized at various rates with one important additional comparison, i.e. one plot represented traditional farmer practices performed by him and at his discretion.

Treatment descriptions of the experiment are as follows:

Treatment No. 1 - Traditional Fertilizer, i.e. 50 lbs N applied at time of sowing; traditional irrigation; and sowing by broadcast. 1/

Treatment No. 2 - Improved fertilizer, i.e. 75 lbs P and 80 lbs N (DAP and Urea) applied at the time of sowing and an additional 50 lbs of N (Urea applied at the second irrigation; traditional irrigation; and sowing by broadcast.

Treatment No. 3 - Improved fertilizer (same as in Treatment 2); traditional irrigation and sowing by Pora. 2/

Treatment No. 4 - Improved fertilizer (same as in Treatment 2); improved irrigation as determined by soil sampling; and sowing by pora. 2/

Treatment No. 5 - Improved fertilizer (same as in Treatment 2); improved irrigation as determined by evaporation pan observations; and sowing by pora. 2/

1/ Decisions made and all operations by farmer.
2/ Method of sowing seed with a funnel shaped seed tube attached behind a plow.

All treatments were replicated twice.[1/](See photos I-7-C,D.)

These kinds of demonstrations should be of great educational value not only to the farmers in the immediate area but also to the academic and extension community who disseminate the results obtained. The well fertilized treatments (2 through 5) showed vigorous growth and have a potential for an excellent yield. Siteing of the evaporation pan used to control irrigation on Treatment 5 could and should be improved. In fact, there is no reason why evaporation rates from the Class A standard US Weather Bureau pan installed by Messrs. Gill and Shafique could not be used.

If logistics permit, an even better approach would be to use the Modified Penman or the Jensen-Haise equations to schedule irrigations on Treatment 5. This would require updating climatic inputs at least once a week and preferably twice a week.

AGRONOMIC RESEARCH

Small Grain Research - Punjab Agricultural Research Institute

The foremost plant breeder for wheat in Pakistan is Dr. S.A. Qureshi who recently worked under Dr. Borglauf at CYMMIT. Field plots observed were impressive and indicated good field plot technique. In addition to

1/See photos Appendix I-7(C,D). Captions are self-explanatory.

the standard varietal trials, factorial experiments to determine potential yields and interactions to various treatments and combinations of soil moisture and fertility are a direct influence of Jerry Eckert and John Reuss.

Wheat experiments with incomplete soil moisture and fertility factorials were designed and conducted by Dr. Jerry Eckert, in cooperation with Dr. Qureshi, shortly after his arrival in Pakistan. Data from these experiments were used to develop plant response surfaces for economic analysis. Irrigations were scheduled at a given stage of plant development and/or on a calendar basis. Currently under the direction of Dr. Reuss, complete factorial experiments with three soil moisture levels and subplots of N and P of various rates and combinations are being conducted. Soil moisture levels are imposed using the 1, 4 and 8 bar tension levels imposed at various depths prior to irrigating the crop. Response to nitrogen was readily apparent at the time these experiments were observed.

Consumptive Use (ET)

At the Punjab Agricultural Research Institute, the panel observed another factorial experiment planted to wheat with variables of soil moisture and fertility.[1/] All plots were being sampled to determine ET rates at various growth stages and seasonal ET. This program, originally set up by Dr. deMooy, is financed in part by the PL 480 Program under the U.S. Department of Agriculture. Other similar ET studies are being conducted in the Punjab, at the Mona Reclamation Experimental Project (WAPDA) and at Mean Channu and Bhakkar by the Land Reclamation Directorate located at Lahore, in the Sind at Tandojam by the Sind Agricultural College, and in the Northwest Frontier Province at two locations by the Agricultural Research Institute, TAR-NAB.

Based upon a previous knowledge of water use as influenced by fertility treatments, one can predict that little differences in water use rates will occur once complete crop cover has been established, even though there are notable differences in growth due to fertility. And, unless the plants are severely stressed due to soil moisture deficits, there also is likely to be only a small difference in water use for the various soil moisture levels imposed. Another disturbing observation was the bare soil on the broad borders between plots and the bare access road bordering one end of the experimental plot area. There is the possibility that ET rates and seasonal values may be elevated due to the advected energy received from these bare areas. Seeding the borders in the future would help to overcome this problem.

The panel recognizes the need for a multidisciplinary approach in developing the ultimate technological package for rehabilitated watercourses and preseason leveled farm fields and thus does not underestimate the value of factorial experiments to fill gaps in cropping systems and management and particularly the "learning" process that accrues in developing a competent staff of Pakistan agronomists and soil scientists. However, the panel feels that too much effort is

1/See photo Appendix I-6(C). Caption is self-explanatory.

being expended in using multifactor experiments to determine consumptive use for a single crop such as wheat. From a practical viewpoint, seasonal consumptive use can be estimated to within 10 percent using various estimating procedures. Some methods (Penman, Hargraves, Jensen-Haise, etc.) with various combinations of climatic inputs including solar radiation, mean temperature, humidity, and wind speed can estimate potential evapotranspiration (ET_p) for shorter periods (7-10 days). This fact is well illustrated by the 1973 publications entitled, "Evapotranspiration and Irrigation Requirements for Pakistan," by Wayne Clyma and, "Calibration and Application of the Jensen-Haise Evapotranspiration Equation," by Clyma and Chaudhary. Even though it was necessary to use crop coefficients developed from ET data gathered in the U.S.A., reasonable values of ET for a number of crops grown in Pakistan were developed.

A more productive approach for the PL480 consumptive use project would be to use larger replicated plots (at least two) adequately fertilized and irrigated where major crops grown are included each year at the five consumptive use sites. With an adequate soil sampling program, crop coefficients developed in the U.S.A. can be modified as required to fit the climatic conditions in Pakistan and upgraded at the various locations with the goal of establishing an irrigation scheduling program to predict when a crop should be irrigated and how much water to apply. Such information in the hands of an Extension specialist could be very useful in advising the small farmer how much water his crop had used since he last irrigated, the approximate date of the next irrigation and the depth (amount) of water to apply. This "service" would hopefully develop an awareness among farmers that they may need, for example, only four instead of seven irrigations for optimum production of a given crop. This implies a knowledge of the crop rooting depths at various stages of crop development, soil water holding capacity, etc., and diligent use of a soil probe to examine soil moisture conditions using the "feel test."

The development of improved crop coefficients adapted to Pakistan's conditions could serve another useful purpose, namely, to develop simulated cropping systems for rehabilitated watercourses geared to the additional water supplies anticipated from such improvements. If long term records of solar radiation and mean temperatures are available in Pakistan, one might be able to screen and/or develop multiple cropping systems using such simulation techniques which could then be verified by demonstrating the most promising possibilities among the farmers along a given watercourse. To achieve this goal in the time frame of this project, soil moisture extraction data already available can be used to improve the crop coefficients (Kc) needed for simulating irrigation schedules and/or cropping systems. Suggested criteria for selecting "usable" data follows:

1. The sampling period should cover at least 5 to 7 days to allow adequate time for profile drainage.

2. The water table should be at least 10 feet deep for most crops. A deep rooted crop like berseem (alfalfa) may need an even greater depth.

3. The depth of water applied should not be excessive but more nearly representative of that amount needed to replace the soil moisture depleted by the crop.

4. Where possible, exclude periods with excessive rainfall (0.25" or greater).

5. ET periods selected should represent an adequate number of soil samples (at least duplicates). Soil samples taken from fertility subplots can be combined for additional replication where available.

6. Select treatments that are adequately irrigated, i.e. soil moisture does not limit plant growth.

In summary, the panel recommends:

1) a reorientation of consumptive use studies as described above (this implies a reduction in the number of factorial experiments being conducted),

2) a greater emphasis to multiple-cropping systems adapted to demonstrate selected watercourses particularly as related to available water supplies, fertility, preseason land leveling, cultural practices, etc., and

3) an evaluation of the practicality of using irrigation scheduling procedures to determine when to irrigate and the amount of irrigation water to apply using simulation techniques and/or simple field experiments adequately fertilized. Periodic monitoring of soil moisture is desirable to determine if irrigation scheduling procedures are on target.

Cultural Practices

At the Mona Reclamation Experimental Farm, the panel observed a "bedding" experiment and the dramatic effect that furrow and ridge culture has on seed germination and establishment of cotton stands. Some attempts have been made to develop a combination lister type planter adapted to the desi plow. Although the panel feels that the highest priority in implementing improved on-farm water management practices is conveying and applying the water to the farmers' fields in an efficient manner, the cultural aspects of the technology package should not be overlooked. Whether or not the CSU team has the personnel to tackle this aspect of the problem or whether a cooperative agreement can be worked out with the proposed Pakistanian "arm" of the International Rice Research Institute, farm machinery division, remains to be seen. However, it is an important problem that should be dealt with if adequate stands of row crops are to be established. There are precedents in the Southwestern U.S.A. irrigated farms that attest to this need where basin or "dead-level" irrigation systems are used. The principles of stand establishment are transferable but a whole new generation of simple hand-operated and/or bullock drawn equipment will be needed for the Pakistani farmer.

IDENTIFICATION OF PHYSICAL, ECONOMIC AND SOCIAL CONSTRAINTS

A socio-economic survey of the watercourses serving Tubewells 78 and 122 at Mona has been conducted. The general objectives of this survey was to evaluate the perceptions of the farmers concerning the benefits and problems related to the improvement of channels and to seek problems that have developed because of these improvements.

The farmers have taken the attitude that these watercourses were Government watercourses because the financing and execution of improvements has been done at Government expense by contractors without appreciable interactions with the farmers in the planning or execution of the improvements. They were generally perceptive of the advantages of these watercourses and were impressed by the increased supply of water that has been made available. However they did not generally feel responsible for the maintenance of these watercourses.

Informal water users associations have been organized on two branches and these user associations have initiated programs of maintenance and cleaning.

A conclusion of the survey was that there are definite disadvantages in the improvement of watercourses without involving the farmers. Experience from several watercourses indicate that there are many difficulties in obtaining farmer cooperation. Improvements done through contract generally complete the work quickly but since the farmers do not do part of the work themselves, they tend to decline responsibility for maintenance. Farmer reaction suggests that the time and effort spent by extension personnel in gaining farmer cooperation and input on improvements is a prerequisite to farmer participation in construction and assuming responsibility for maintenance.

Water Management Technical Report No. 42, "Physical and socio-economic dynamics of a watercourse in Pakistan's Punjab: System constraints and farmer responses," by Max K. Lowdermilk, Wayne Clyma and Alan C. Early provides excellent detail on another watercourse located outside Lahore City. (See also Section V.)

The panel concludes that this effort to evaluate farmer attitudes has a high payoff potential in providing criteria for the selection and organization of future watercourse improvement projects. The perfection of criteria for selection can eliminate many false starts and an intimate knowledge of farmer attitudes can provide guidance in developing operation and maintenance organizations. While the information obtained to date has specific application to Pakistan's Punjab Province, the techniques used can provide guidance for similar surveys in other provinces and LDC's where cultures may be quite different.

OTHER MISCELLANEOUS ACTIVITIES

Time did not permit visits by the panel to review the work done at the Integrated Rural Development Project, Lar; the Cotton Institute, Multan; the Rice Institute, Kala Shakaku; and Maize and Millet Project, Yousafwalla; the College of Agriculture, Tandojam; the Land Reclamation Directorate; Islamabad University; and the Engineering University, Lahore. However the CSU field party had reports and information available for review. (See Appendix G for list of publications.)

The panel feels that the advisory assistance provided to these institutions is playing an important part in creating an awareness among Pakistan's agricultural scientists of the need for emphasizing improved water management. Contact with these and other similar institutions should be maintained although it is recognized that the time spent must necessarily be limited.

V CAMPUS CONTRIBUTIONS

Prior to 1972, the research on campus was over 60 percent in the Department of Civil Engineering studying problems in canal delivery, sedimentation, broad scale hydrology, conjunctive use of canal and ground waters, and methods for measuring flow in large channels. In response to a 1972 review committee recommendation, the campus research program was redirected toward the expressed needs of the CSU field party. As personnel return to the campus after experience in developing countries, the campus activities are being tied more and more to specific problems in developing countries.

The activities listed below plus the half-time salary paid to G. V. Skogerboe as director of the project, account for at least 90 percent of the expenditure on campus for professional salaries.

WATER LAW AND WATER USERS ASSOCIATIONS

In 1971, George Radosevich was asked by USAID/Pakistan and USAID/Afghanistan to study the laws and policies of these countries with relation to how they affect efficient use of water. On TDY trips he identified the lack of water users associations and laws facilitating the formation of such associations. He then coordinated with David Daines of Utah State to classify, describe, and observe insofar as possible, the types of water users associations used successfully in the irrigation systems of the world. The Mission then asked for an assessment of which of these laws, policies, and organizations would be most feasible and valuable in Pakistan. The results are found in the reports as follows: 1) "Organizational Alternatives to Improve On-Farm Water Management in Pakistan," by Radosevich; 2) "Water Users Organizations for Improving Irrigated Agriculture: Applicability to Pakistan," by Radosevich and 3) draft manuscript "Institutional Framework for Improved On-Farm Water Management in Pakistan," by Lowdermilk, Eckert, Radosevich, and Skogerboe, which is is being used by the Mission as one of the primary source documents for writing the proposed Water Management Loan Project.

GOP officials expressed concern of too much involvement by foreign nationals in the "organization of farmers" into groups which could have strong political power. There will not be an American recommendation on any particular type of water users association.

SOCIOLOGICAL FACTORS AFFECTING WATER MANAGEMENT

The constraints to watercourse improvement and water delivery efficiency on a watercourse involving 20 to 60 farmers are very often socio-economic in nature. Unless they are well organized, there is little to guarantee a fair return to a farmer for his work. Moreover, the farmer has no device for measuring water flow and consequently he does not fully perceive the benefits of watercourse improvement.

Max Lowdermilk conducted a survey at Mohlenwhal Khurd and analyzed the data as a campus activity. Report No. 42, "Physical and Socio-Economic Dynamics of a Watercourse in Pakistan's Punjab: System Constraints and Farmer Responses," by Lowdermilk, Clyma and Early resulted.

From the survey and other experience, Lowdermilk designed questionnaires and procedures to evaluate physical factors, farmers' attitudes, and constraints affecting water management and at the request of the USAID Mission brought them to Pakistan in May 1975. All of his activities are paid from the on-campus portion of the Water Management Research Project budget.

ECONOMIC FACTORS AFFECTING WATER MANAGEMENT

Crop production vs. water and fertilizer has been measured for several seasons in Pakistan. Eckert, who designed most of these studies, is now on campus incorporating the results into a more comprehensive crop production model, i.e., Eckert, Ryan, and Early, "Water Management in Irrigated Cropping Systems of Pakistan, Nov. 1975."

PUCCA NAKKAS AND ASSOCIATED WATERCOURSE IMPROVEMENT

Deficiencies and high costs of steel slide nakkas were recognized early and Dr. William Hart was asked to catalog and evaluate types of nakkas reported in the literature and do preliminary design and construction on some of these at CSU. Subsequently, he was asked to come to Pakistan on TDY during the summer of 1975 for two months to build, install and test the most promising and least expensive of these nakkas. These improvements included the inclined slide nakkas and installation of rubber gaskets on the round orifice nakkas, both of which have helped to reduce nakka leakage. He was assisted in the evaluations of these nakkas by Thomas Trout, graduate research assistant. All of their salaries are charged to the on-campus portion of the CSU water management budget.

SKIMMING WELL DESIGN AND TESTING

The theory and computer program developed on campus for the most realistic miscible displacement case show great potential for providing guidelines for well design and pumping rate to provide good quality water from aquifers where good water overlies saline water. These theoretical developments by Art Corey, Dave McWhorter and their graduate students require testing in a field situation before the assumptions made in the computer program can be adequately tested and accurate predictions assured. Consequently the skimming wells and associated sampling and observation stations were constructed and the requisite tests are under way. Results from these tests will be sent back to the campus where they will be used to evaluate and possibly modify and improve the assumptions which go into the computer model. The tested (and possibly improved) model will then be used to generate the guidelines for well design and pumping rates to be used to achieve optimum quality of water from aquifers with known salinity profiles.

Mr. Thomas Trout has been assisting on this project at CSU and while on TDY here in Pakistan for two months in the summer of 1975.

IMPROVING STANDS AND YIELDS OF KHARIF CROPS BY MODIFYING CRUSTS AND SOIL TEMPERATURE THROUGH WATER MANAGEMENT

Cotton and maize have particularly poor yields in Pakistan and this appears due largely to poor stands. Field studies indicated that high temperatures and crusting at time of seedling emergence are causes of poor stands. However, the control available in the field was not sufficient to determine whether these were the causative factors. Consequently seed of the varieties of cotton and maize grown in Pakistan were sent to CSU and tested by Willard Schmehl, Larry Nelson, and John Olsen under controlled growth chamber conditions. These tests have demonstrated conclusively that temperature, crusting and initial water content of the seed are primary factors determining stands. It has now been proposed that Larry Nelson come to Pakistan for the entire kharif season and use this knowledge to grow good crops of maize and corn using bed shaping and proper timing of irrigation to control soil temperature and crust strength during this critical period.

EFFECTS OF IRRIGATION METHOD ON CRUST STRENGTH, PERSISTENCE OF LARGE SIZE PORES AND LEACHING OF SALTS AND FERTILIZERS FROM THE ROOT ZONE

The flooded basin method of irrigation is used on over 90 percent of the fields in Pakistan. deMooy, Kemper and their Mona cooperators noted in 1972 that: (1) this method leaves the sediment from the water distributed over the whole soil surface in a thin seal that decreases infiltration rates of subsequent rain; (2) it causes all the surface to be wet quickly by flooding rather than slowly by capillary action, resulting on drying in hard dense crusts on the soil surface above the seed or adjacent to the plants; (3) because the direction of the water movement is straight down, basin irrigation is more effective in leaching salts and fertilizer down and out of the root zone.

While these deficiencies of basin flooding irrigation are qualitatively obvious and are primary suspects for causing the poor kharif stands and yields, it is difficult to provide the controlled conditions in the field which can result in quantitative evaluation of the effect of basin and other methods of irrigation on water content of soils crust strength, persistence of large size pores and leaching of salts and fertilizers from the root zone.

Consequently soils with the characteristics of the problem soils of Pakistan were used in controlled lysimeter studies at CSU to evaluate these factors. The results are presented in the papers titled "Irrigation Method as a Determinant of Large Pore Persistance and Crust Strength of Cultivated Soils," and "Fertilizer or Salt Leaching as Affected by Surface Shaping and Placement of Fertilizer and Irrigation Waters," by Kemper, Olsen and Hodges.

While the principles determined in these studies are generally applicable to soils in all the developing countries, they are specifically applicable to soil and water management and crop production in Pakistan. These principles have been used in Pakistan as a major part of the basis for the studies leading to the paper, "Water Management and Nitrogen Fertilizer Movement and Utilization in Soils," and for designing the studies on maize and cotton stands and yields which clearly showed the superiority of bedding and furrow irrigation as compared to basin irrigation in the studies conducted at Mona last kharif season (see reports by deMooy et al).

HYDRAULIC DISSOLUTION OF GYPSUM

During 1972 Haider and Kemper investigated the reasons for the high cost of gypsum in Pakistan and found that over 80 percent of its cost at the pit was due to the cost of crushing it from rocks to powder. The possibility of a major reduction in price of this amendment, which is the major amendment used for improving the quality of water for irrigation and the structure of soil, was apparent if the stones rather than the powder could be used. Consequently gypsum stones of various screened sizes from Pakistan and the U.S. were placed in flowing water of different qualities at the hydraulics laboratory at CSU and the rates of gypsum dissolution and change in water quality were determined as water passed through these gypsum fragments at different rates.

The results and general principles are outlined in the paper, "Dissolution Rate of Gypsum in Flowing Water," by Kemper, Olsen and deMooy. These results led to the preliminary studies on gypsum dissolution in watercourses reported in the 1974 annual report and to the design of the present study in which truckloads of gypsum will be placed in an enlarged section of the watercourse at tubewell 91, the improvement of the water quality (SAR) will be monitored along with the rate of gypsum dissolution.

This method of distributing gypsum to the fields can reduce the purchase and application costs of gypsum by more than Rs. 75 per ton and allow economic use of marginal quality water from many tubewells which cannot be used at present because of high sodium/calcium ratios in the water.

TRAINING OF SPECIFIC PERSONNEL TO HELP SOLVE SPECIFIC WATER MANAGEMENT PROBLEMS IN PAKISTAN

Prior to 1972 several persons from Pakistan were brought to CSU for training in water management. While the training was generally good it was not directed to the solution of specific problems whose solution would improve water management and crop production in Pakistan. Moreover, the trainees did not have firm commitments to return to Pakistan and a disappointingly large portion of them were going to other countries on completion of their training.

Consequently a training program was designed in 1972 in which: (a) Only persons working in GOP agencies with a mission and an in-country commitment to water management improvement are considered. (b) The GOP supervisors of prospective trainees participate with CSU field party members in the selection of trainees and the problems which they are to help solve.
(c) The trainee stays in the U.S. only for the time essential to obtain the academic training and conduct a survey of the available literature on the subject and then returns to Pakistan to conduct research on Pakistan's water management problems.
(d) The CSU field party members and selected USAID and GOP personnel serve as the committee directing research.
(e) The CSU graduate school and departments involved have agreed to having the dissertations written and final exams conducted in Pakistan on those research programs which can be used to complete requirements for advanced degrees.

The following trainees have returned to Pakistan under this program:

(1) Ashfaq Mirza, Department of Rural Sociology and Economics, University of Agriculture, Lyallpur, advised by David Freeman on campus, who conducted a study on socio-economic factors affecting cooperative maintenance and cleaning of watercourses under the direction of Freeman and Eckert. He is now on staff at the University of Lyallpur and is teaching and continuing research on this subject.

(2) Sadiq Shafique, Punjab Integrated Rural Development Program, Agricultural Engineer, who took course work on how to improve water management and how to motivate farmers to make the improvements under the direction of Skogerboe, Hart, and Lowdermilk. He is now conducting his research at Kanjra watercourse at Shadab under the direction of Clyma, Bowers, Early and Johnson.

(3) Mushtaq Gill, Punjab Integrated Rural Development Program, Agricultural Engineer, who took course work on how to improve irrigation practices and irrigation scheduling under the direction of Skogerboe, Hart and Lowdermilk. He is now conducting his study at Kanjra watercourse at Shadab, under the direction of Early, Bowers, Clyma and Reuss.

(4) Nuruddin Ahmad, Land Reclamation Directorate Irrigation Department, Soil Scientist, who took course work on water movement and conducted a literature review on contribution of high water tables to water needs of crops under the direction of Schmehl, Klute, and Reuss, and has just returned to the LRD where the details of his research are being formulated under the direction of deMooy and Reuss.

(5) Ghulam Hussain, Mona Reclamation Experimental Project, Soil Scientist, who took course work in water quality and water management factors affecting crop yields under the direction of Schmehl and Franklin. He has returned to Pakistan where his research will be directed by Reuss and Bowers.

(6) Khalid Hussain Gill, Punjab Agricultural Research Institute at Lyallpur, Soil Scientist, currently taking course work on water

management factors affecting crop yields, under the direction of Schmehl and deMooy. Scheduled to return to Pakistan in September 1976 to work with Dr. Bhatti under the direction of Bowers and Reuss.

Every man selected for training under this new program has returned or is definitely planning to return to his agency and the water management job assigned in Pakistan. This is in part due to the cooperation of the campus staff in emphasizing to these students the importance of working on developing country problems in the developing country. The salaries of these trainees while they are on campus are paid from contracted dollars and are listed as campus expenditures.

As noted previously, the panel had an opportunity to observe the benefits of two training programs in our visit to Shadab (see items (2) and (3) above). If the other students who have participated in this program do equally as well, the program should be continued within the campus budget allocations currently in effect at CSU.

THE VIETNAM PROGRAM

This included three Vietnamese trainees, from Can Tho University in water management on heavy clay soils, who are taking academic training and conducting literature reviews on campus prior to returning to Vietnam to do their research. When their support by USAID was terminated in 1975, Dr. Bowers, who had been advising the project in Vietnam, returned to campus and, with Skogerboe and the respective department heads, made arrangements for these students to work and complete their training.

Dr. Bowers remained on campus for about six months, writing up the final report on U.S. participation in the Mekong Delta Soils Water Management Project, reviewing recent literature on watercourse improvement and water management, and advising trainees in water management.

SPECIFIC OBSERVATIONS

The work completed, or underway on the CSU campus covering some ten (10) activities, ranges from the use of computer models to predict salt content of water to "policies and law" to facilitate formation of "effective" farm water user associations. A point of concern to the panel is the same point raised by a 1972 AID review committee. This committee, consisting of Jensen, Heady, and Anderson, on February 10, 1972, stated:

> "CSU-AID/csd 2162 - We recommend maintaining the current level of funding, but encourage streamlining project management to reduce administrative costs. We also recommend limiting funding of projects to those needed to obtain immediate goals, increasing the field program relative to on-campus activities, and bringing more experience in on-farm water management research into project direction and management." (See Appendix D for additional background information.)

The panel considers the 1972 statement still to be a valid consideration, although considerable improvement is noted (see figure 5). This panel also considers the extension and/or adaptations of the field and on-campus research to other countries (Issue 2), and the value and workability of the "consortium and/or cooperative approach" (Issue 3) to be an on-campus responsibility.

1. Issue number 2 states that:

   "With the discontinuance of the work in Vietnam, the total effort of the program is in Pakistan. Pakistan's irrigation system is very important and worthy of study; however, no effort has been made to develop state-of-the-art studies in other countries to determine the relevance of the Pakistan work to other areas and systems. It could be concluded that CSU is developing a water management research program for Pakistan, a highly interesting and perhaps worthy endeavor but does not satisfy the intended purpose of a centrally funded research effort."

2. Issue number 3 states that:

   "There is little evidence that a comprehensive and coordinated attach on water management problems has evolved to date from the consortium approach envisioned with the initiation of CUSUSWASH. There still seems to be division of labor and geographical areas.

   AID is concerned that perhaps CSU and Utah State (and Arizona) have not worked together on a technical level to develop comparable research strategies, staff exchanges, or coordinated research projects to increase the effectiveness of the diffusion. Many problems in irrigation water management are common in all areas of the world. It would seem that a coordinated-cooperative approach would have tremendous potential to expedite adaptations and the transfer of technology."

To this panel the requirement related to these issues calls for an effort by CSU on:

a) Coordination with Utah State University, and the University of Arizona, to pool existing data, and to build a comprehensive data bank on the "state-of-the-art" on arid and sub-humid soil and water management worldwide.

b) Coordinate with Utah and Arizona for future progress in on-farm water management. Emphasis should be on the adaptation and quantitative application of models which generate solutions for the particular agro-climatic, water supply, economic and institutional conditions. These models can illustrate the general applicability of modern models and computer solutions or simulations devoted to the parameters of water management under particular conditions.

At both Colorado and Utah State Universities additional effort should go into on-campus development of applied transfer models incorporating the Pakistan and Latin American data model testing results for validation which can be used to generate first approximation solutions to sufficiently identified problems in the field. Applied modeling validation portends site specific field sampling and data collection to adjust general model coefficients and to develop "cropping systems" models which can be brought down to an area specific basin.

The panel recommends, however, that the present on-campus projects also be carried to a "pay-off" point commensurate with building in the above effort.

VI. ASSESSMENT OF PROJECT IMPACT

DEVELOPING AWARENESS OF SOIL AND WATER PROBLEMS IN GOP

The panel found that most of the high level GOP officials responsible for irrigation developments in Pakistan are aware of the critical need to rehabilitate existing watercourses and initiate precision land leveling programs to make more efficient use of irrigation water. (See Appendix B-1 for list of official contacts.)

Original estimates made to determine irrigation requirements assumed that 80 to 90 percent of the water delivered at the mogha reached the farmer's field and 85 percent of that applied was used by the crop. These figures have been widely used by a number of consulting firms and by irrigation departments. The measurements reported by Clyma and Corey found that in reality the percentage of the water used by the crop as compared to the water delivered at the mogha in a SCARP area was in the order of 12 to 20 percent. This low efficiency was at first treated with disbelief by the GOP and the major lending organizations, such as the World Bank, but continued validation of the CSU measurements has now made them widely accepted. Field Report No. 2, "The Importance of Farm Water Management in Pakistan," is one of the most sought after publications so far released by CSU (1200 copies have been distributed) and it is credited with having created the existing awareness among GOP officials and external assistance agencies of the potential of extending existing water supplies to increase cropping intensities and food production by improved on-farm water management practices. (See Appendix E.)

Based upon the CSU research efforts in Pakistan on water problem identification, Mr. Iftakhar Ahmad, Chief, Water Resources, Planning Division, GOP informed the panel that Rs. 300,000,000 have been allocated in the current five-year plan towards the development of pilot projects of watercourse rehabilitation, precision land leveling and to initiate a multi-disciplinary approach for optimum crop production. This project is to be sponsored jointly by the GOP and USAID and will cost about 40 million dollars; 20 million of which will be paid by the participating farmer, 10 million by the GOP and 10 million by USAID. Mr. Iftakhar also said that they desired assistance from USAID and their counterpart CSU rather than from other sources of assistance (World Bank, FAO, UNDP, etc.) because CSU was far ahead of any other organization in pioneering water management problems and in conducting research on on-farm water management. Referring to CSU's Report No. 42, "Physical and Socio-Economic Dynamics of a Watercourse in Pakistan's Punjab: System Constraints and Farmers' Responses," by M. K. Lowdermilk, Wayne Clyma and A. C. Early, Mr. Iftakhar stated that in all his experience he had never seen a report that could equal its value in identifying the "grass roots" socio-economic problems that face farmers in conveying water to and using the water on their fields. He concluded by saying that the CSU Field Party has been and will continue to be a valuable resource to Pakistan because they have a direct line to farmers, can work with them, and their research is conducted in a highly scientific manner. He wants USAID and CSU to do the pioneering work on Pilot Projects.

In a closed session with Mr. Mohammed Ashraf, formerly Project Director of the WAPDA Project at Mona and recently promoted to Assistant General Manager (Survey and Research) in WAPDA in Lahore, the panel was told that there is a continuing need for the CSU Field Party to (1) produce the technological package that is needed for watercourse improvement and to optimize the management of water and crops at the farm level, (2) to assist the government to create an efficient organization to achieve the goal in (1) above, and (3) to work with these organizations to give them the training and impetus they need to effectively implement the programs undertaken. He felt that the CSU efforts have suggested and demonstrated solutions to the major water problems in Pakistan, but that they must be further assessed. The economics of the systems being proposed also must be determined if optimums are to be achieved.

The panel also met with Dr. Mohammad Naseem, Director General Agriculture (Field) of the Punjab Province. Prior to our session, Wayne Clyma indicated that Dr. Naseem had worked closely with Dr. Gilbert Corey on land leveling and watercourse programs but that these efforts were fraught with budgetary problems that lead to delays in project implementation. Further, as former director of the Integrated Rural Development Program, it was Dr. Naseem's responsibility to coordinate the services of all government agencies related to rural development and to make such information and services available to the farmer through extension programs--an impossible task.

In the closed session with Dr. Naseem, the panel was informed that the CSU effort to rehabilitate watercourses and to improve on-farm water management has been of the highest order and of the greatest demonstrational value. He indicated that the CSU program could be even more effective if it contained a training component.

RECENT DEVELOPMENTS AND UTILIZATION

As indicated above there has been an increased appreciation in Pakistan relative to the need for improving on-farm water management. This has occurred essentially during the past 15 months. Pakistan is moving surprisingly fast in adopting some of the concepts CSU has been promoting. A report prepared by the Chief of Party in January 1972 indicated that "the project (CSU/WMR) needs to expand slowly and deliberately since the merits of the program are not self-evident to local agencies." Yet one year later the actions listed below are taking place.

1. The President of Pakistan appointed a high level engineering team to study water management and make recommendations relative to important programs. The CSU Chief of Party was consulted on an informal basis by committee members. High on the priorities was land leveling, watercourse rehabilitation and water management on the farm.

2. A tubewell promotion scheme has been inaugurated by the Government. Farmers are given incentive to drill private wells to increase their water supplies. The CSU field party was consulted.

3. The Government has decided to promote small tubewells to lower water tables in saline affected areas.

4. A national effort is being promoted in precision land leveling. Two provinces have programs with USAID whereby Soil Conservation Service teams from the USA assist training centers in teaching precision land leveling techniques and in promoting the practice as a water management technique.

5. Watercourse lining is now being promoted by the Government of Pakistan. The Integrated Rural Development Program - Punjab has received funding for an experimental program to test the feasibility of such a program. It is proposed to line 150 miles of watercourses with a brick masonry type of lining in fifteen districts. These test sections will be used to demonstrate the benefits as well as determine farmer acceptance. The farmers are cooperating by furnishing all labor and in fact are acting as the contractors for construction. The Irrigation Department is providing engineering expertise for design and construction. The plans and discussions which led to this program were definitely influenced by the CSU field team through development of the Shadab research project and other contacts.

6. The World Bank as contractor for a UNDP grant of a $3,000,000 loan in conjunction with the Water and Power Development Authority (WAPDA) is considering a watercourse survey throughout Pakistan to identify areas of applicability of the CSU evidence. These surveys, patterned after procedures developed by CSU will measure seepage losses along watercourses, identify cropping patterns, chart water schedules, outline farmer organizations, record the use and maintenance of watercourses and/or tubewells, and identify major socio-economic constraints under which the farmer must operate.

Other evidences of the increased appreciation of on-farm water management include:

1. Practically all research agencies are now conscious of the necessity for better water and soil moisture measurements. The level of precision for these measurements has risen in Pakistan during the past year. There is a demand for measuring flumes, soil cans, ovens and infiltrometers. Small manufacturers are being assisted by the CSU field party to enable them to fill these needs. Farmers themselves are requesting siphon tubes and the manufacture of these is being promoted.

2. The Agricultural Research Council published the recommendations developed at the Water Management Seminar. These were printed in English and Urdu and distributed widely since they contained not only recommendations for priority research programs but also recommendations for the farmer on how to more efficiently utilize his water.

3. The Agricultural Research Council on 15 June 1973, requested the CSU field party to develop "a sound research program for Baluchistan for optimizing available resources of water supply for use in crop production there".

4. In the interest of developing better methods of watercourse rehabilitation, the Director of the Mona Reclamation Project and the CSU Chief of Party visited Turkey recently to study methods used there. As a result, a brick tile type lining utilized successfully there will be tested in Pakistan. Pipe manufacturers are being helped and encouraged to make rubber gasket irrigation pipe in Pakistan. These will be field tested on the Mona Project. Some of the techniques utilized by manufacturers in Pakistan have been adapted in Turkey as a result of this cooperative effort among the two countries. The benefits of such cross fertilization are not easily measured but could certainly prove to be very great.

5. The Director of the Mona Project presented a paper at the Water Management Research Seminar detailing the Problems of on-farm management as problems of (a) excessive applications of water due to poor land leveling, and knowledge of crop needs; (b) loss of water from ditches through spills and seepage. This information was also published as a Paper in INDUS, an engineering publication in Pakistan.

6. Personnel at eight research locations have requested assistance and made efforts at measuring water and soil moisture to make their research more quantitative. These include:

   a. Agricultural Engineering Directorate, Lyallpur

   b. Punjab Agricultural Research Institute, Lyallpur
      1) Cereals Section - three locations
      2) Soil Chemist Section
      3) Sugarcane Section

c. Rice Research Institute, Kala Shah Kaku

d. Cotton Research Institute, Multan

e. Maize Research Institute, Yousafwala

f. Agricultural Engineering, Agricultural University, Lyallpur

g. Mona Research Project, Bhalwal

h. Department of Agronomy, Sind Agricultural College, Tandojam

i. Maize Research Institute, N.W.F.P.

j. Tarnab Agricultural Research Institute, N.W.F.P.

7. Personnel at five locations have received training and practical experience on the evaluation of existing irrigation systems and practices needed to increase water use effectiveness, namely:

a. Agricultural Engineering Directorate, Lyallpur

b. Agricultural Engineering, Agricultural University, Lyallpur
   1) University Professor has used principles and procedures in teaching and in research programs.
   2) Twenty-six students were given training in classroom and field on principles and procedures for evaluation of irrigation systems. These students have used these procedures to evaluate farmer irrigation systems at several locations in Pakistan.
   3) Senior students are now required to do a field study as pre-requisite to graduation. Before CSU involvement, the students did a library thesis.

c. USAID sponsored class on land leveling design was given to 20 graduate engineers. CSU field party taught and gave field experience in the evaluation and design of irrigation systems.

8. Personnel of the Farmers Technical Training and Extension Center, Mian Channu were given training on the evaluation of farmer irrigation practices as well as the specific deficiencies of traditional methods of irrigation in comparison to modern irrigation methods.

9. There is a growing awareness of the need for increased efficiency of water utilization in terms of production.

As a result of CSU input, research agencies at some 7 locations are preparing to look into the interaction of soil fertility and other agronomic factors with soil moisture variables. At two of these locations field trials have been initiated even before funds have been made available. It is realized that besides the possible savings in water application and an improved distribution of water on the land, it also is possible to greatly increase the agricultural production per unit of water applied by improvement of production management practices. Experiments with cotton are in progress during this season whereby more careful attention is being paid than ever before to moisture levels, soil fertility conditions, crop stand and plant spacing in comparisons of ridge planting with planting in basins. No progress can be made unless all production factors are coordinated in this research. Crop breeders also should be involved in this work because new varieties are needed which can tolerate and utilize high levels of moisture, fertility, and management. So far, this kind of coordination has been lacking in Pakistan. The concept of a multiple discipline approach combined with greater precision in all research activities is rapidly being accepted.

10. Water quality research in Pakistan is headed for conclusions which are to some extent conflicting with the standards arrived at in the U.S. Permissible limits in total soluble salts, sodium absorption rates and residual sodium carbonate of soils and water tend to be viewed more liberally in Pakistan than in the U.S. Possibly this is caused by insufficient precaution against soil deterioration. If this is true, production and soil resources could be affected in the long term. Most of the important research in this area is being conducted with CSU cooperation. Whether or not water quality standards will coincide ultimately with those of the USA is undecided and remains a most interesting problem.

11. The CSU field party contributed to the International Conference on Waterlogging and Salinity at Lahore, October 13-18, 1975, which was sponsored by the FAO, the Engineering University and other Pakistan agencies with documents, publications and recommendations. The recommendations related to (1) initiation and establishment of area development projects, (2) pioneer projects and (3) education research and institutional programs. These recommendations were accepted by the conference. (See Appendix F.)

PROGRAM FOR INCREASED UTILIZATION

Certainly not all the above listed developments can be credited solely to the CSU project in Pakistan. The USAID Mission, other International assistance agencies, Pakistani organizations and others have been active in the program and fortunately the time was right to develop cooperation. Adaptation of findings and opinions is proceeding so fast that a definite risk exists that CSU's ideas and thoughts might be accepted before the necessary research has been done. TA/AGR should be careful not to put excessive pressure on reporting and adoption of incomplete research findings for this reason.

The current emphasis and enthusiasm within the Government of Pakistan will wane unless research keeps pace and defines limits and quantifies costs/benefits on the various technologies being adopted. Two significant projects have been developed to field test any on-farm water management technology which results from research either on the CSU campus or among cooperating stations in Pakistan. Technologies which have proven successful elsewhere can also readily be tested.

VII ASSESSMENT OF TECHNICAL ELEMENTS

Of prime importance is an understanding of where research stands in the agricultural development process. The first thing to be clear about is that groups of categories of activities exist in bringing information to farmers. But one must also understand that bringing knowledge to farmers doesn't get the job done. Farmers are as important to production problem identification as anyone else, and that to be motivated to put knowledge to use involves still another area which runs from policy decisions down through organizations and institutions. These must be fully operative, and capable of providing incentive. A farmer can organize and manage a cropping system, but national policy is responsible for developing and organizing a food system which makes the farmers efforts worthwhile.

Sticking only with the knowledge needed by the farmers is not enough. Knowledge must also be imparted to policy makers and it must be more than just technical; it must be socio-economic, including prescriptions on institutions; and training as necessary. Therefore on one side we have what is called technical and socio-economic research on information needs of farmers and policy makers. On the other side we have extension--the extenders who carry the message to farmers. These two sides may or may not be different, and in many cases they are one and the same. In the middle we have a "package" of knowledge and activity consisting of: 1) technology, 2) adaptation, 3) diffusion, and 4) farm level integration. Farmers, researchers, and extenders, all contribute to and draw upon this package.

The "package" concept is the concept of the CSU program. They are building it, refining, and modifying as they go along--reaching into research as need be, being their own extension agent, and integrating the packaged knowledge at the farm. Too often much development assistance has fallen into the trap of the "excluded middle" and, therefore development does not occur as a matter of research extension or institution building. Further, the role of external assistance is always that of providing a supplemental input which would not otherwise occur, and that only beyond the point where the gaps and/or deficiencies are met and filled by country effort.

In Pakistan, as elsewhere, population growth generally accounts for about 70 percent of total demand with income growth and changes in appetites and attitudes accounting for the remainder, e.g. a continuing income induced or preference induced shifting to higher valued and/or specialty commodities. Thus, each LDC can expect continuous demand growth and demand shifts far down the path of economic and agricultural development.

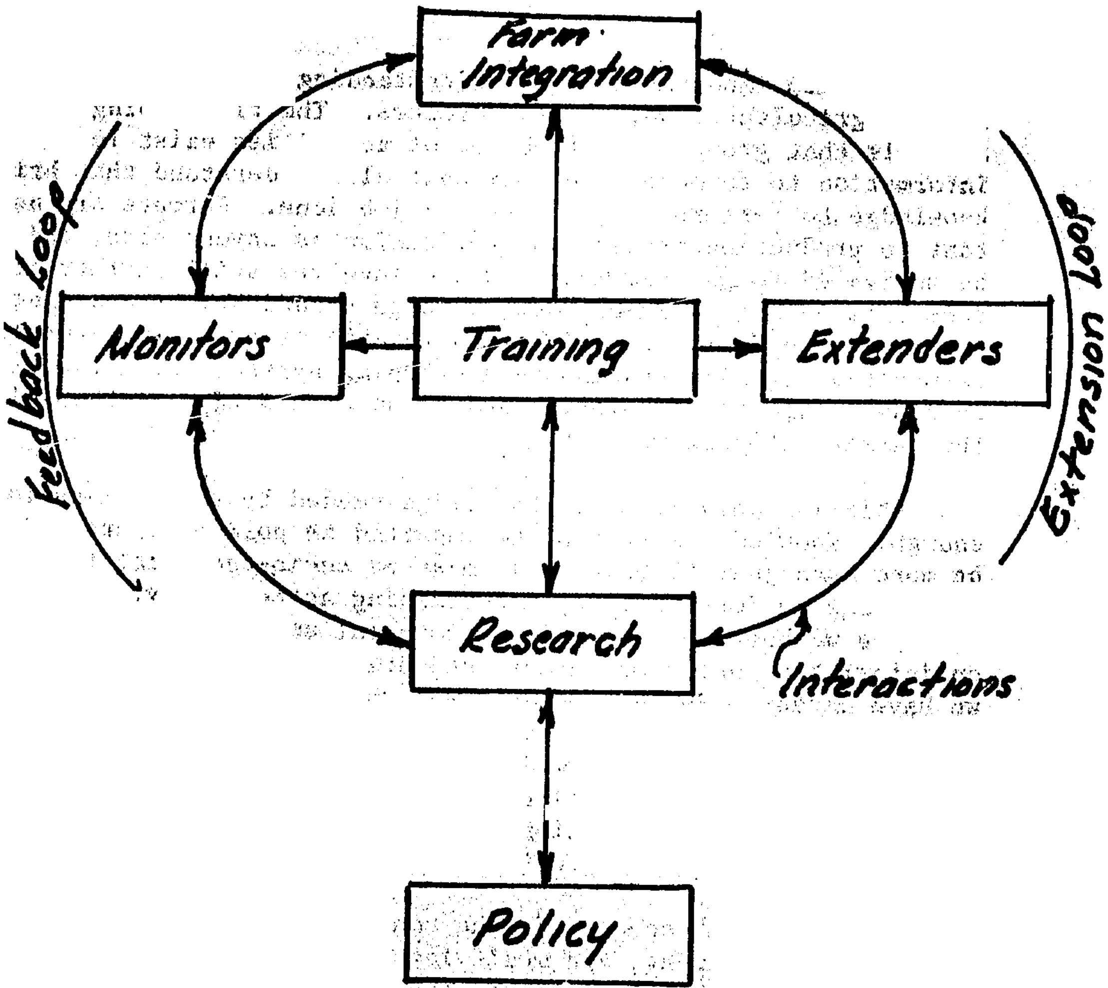

Fig. 10-The relation of Research, Extension and the Technological Package - General Form, Policy Loop

Figures 10 and 11 show the necessary functional relationship, but not organization. They show the interaction points, and the information flows and feedbacks of a completed system. Their usefulness is that they are an evaluative tool capable of systems identification and of isolating and describing a system's gaps and difficiencies in functional and relationship terms.

The first thing we note about Pakistan's agricultural system, general form, Figure 10 is that:

1. It is not "closed" and therefore not a complete system under systems notation; it is just a system.

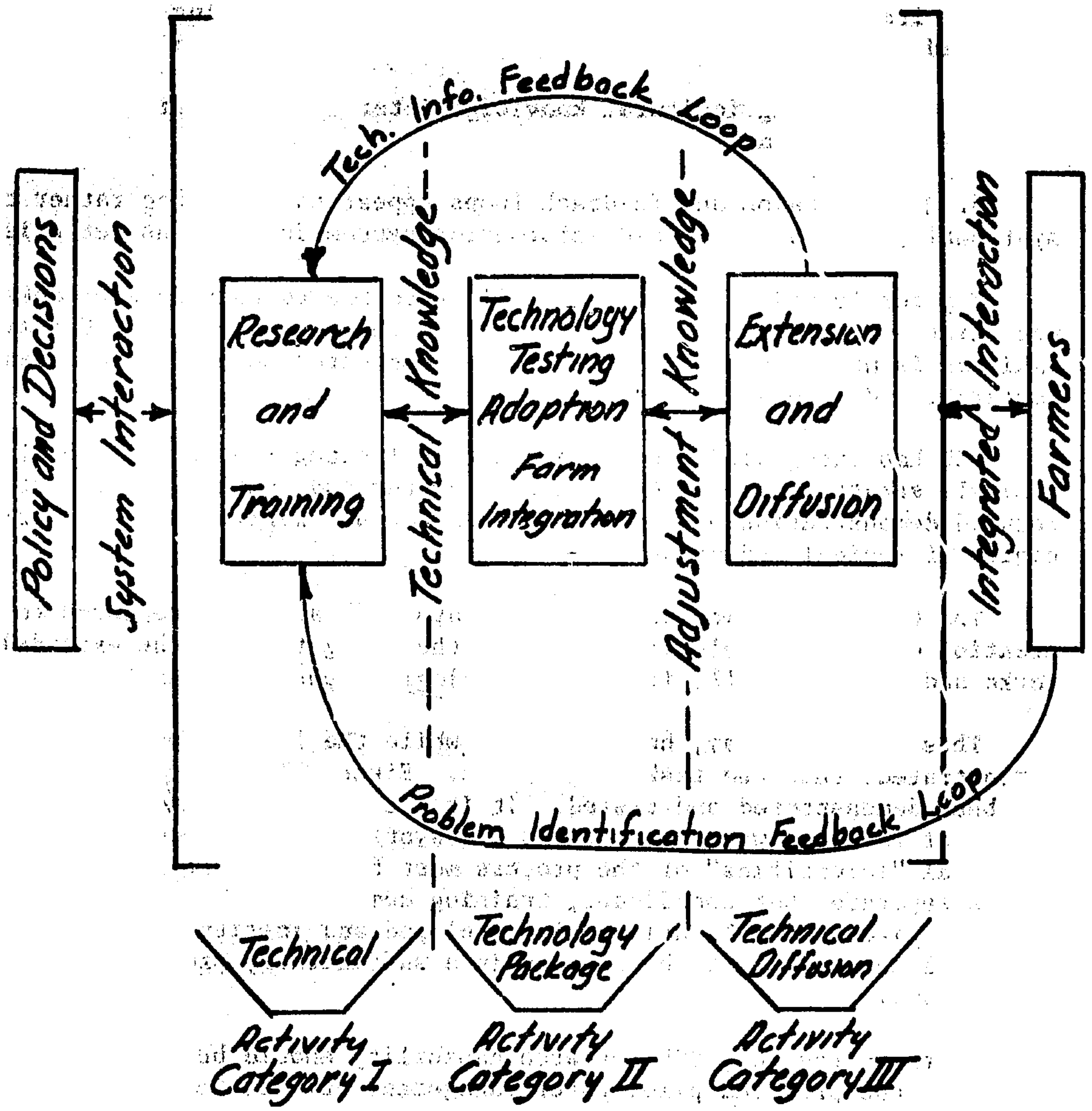

Figure 11 - The Relation of Research, Extension and the Technological Package - Specific Form, Farm Level Integration Loop.

2. Monitors exist, WAPDA, IRDP, etc. but are undermanned in the way of subject matter specialists.

3. The research-monitoring loop does not appear to be well connected; as does the loop between extendors and research.

4. Training may well be deficient in problem solving orientation, e.g. academic; and training of farmers appears tenuous and fragile.

5. Policy - agricultural knowledge interaction appears to be on the mend and building.

6. The extension and feedback loops appear to be ad hoc rather than systematic, e.g. a systemized information system does not as yet exist.

Figures 10 and 11 are not to call attention to what does or does not exist but, rather to call attention to the fact that the CSU team in Pakistan is using an applied methodology connected both to farmers and research, and involving trial and learning.

CSU has integrated the three functional categories of Figure 11 into a single strategy with a focus on soil, water and crops - under a straight forward demonstration of logical formulation and adherence to the principles of logical deduction.

The CSU team is working from the farm back and from research to the creation of the technological package, the thing that can be extended. If it works and pays off well, it (the technological package) can be diffused.

This is not to say, however, that while the logical process has been demonstrated, that the task is complete. First, only the logical process has been demonstrated and tested. It is yet to be integrated over all phases of soil and water management and systematized. Second, the technological "scientifics" of the process must be related to and integrated with a separate, but coordinate, training component. Third, the process in its entirety must be adequately developed and institutionalized, if food goal targets are to be reached in a sufficiently productive manner and on time.

In these regards, CSU research capability should be utilized by the GOP under the proposed pilot water management utilization project. CSU can assist with improving delivery systems, on-farm water use, drainage and maintenance so that water can be saved and better use made of water. CSU also could assist with the training and institution building.

ASSESSMENT OF SOIL AND WATER MANAGEMENT POTENTIALS REGARDING CROPPING TARGETS

Two basic concepts are at issue regarding any target assessment. The first of these is the concept of cropping systems. The second is the concept of a food system. The underpinning of any cropping system is crop, soil and water management. The underpinnings of any food systems are the socio-economic forces which are operating. Each of these systems, by their very name and nature, have commensurate organization, management, and administration.

Decisions are made on given alternatives, employing choice criteria - some technical and some economic. Scarce resources are allocated among enterprises in keeping with the value of their products. A simple illustration is matching the cost of an improved nakka against the value of water and labor saved.

Socio-political dimensions act as absolute constraints on growth of the food system, and "economics" acts as a variable constraint. Where a system breaks down is through lack of communication and understanding, resulting in various divergent attitudes and behavior patterns on the part of both government and farmer.

A lot has been accomplished in Pakistan's agriculture, and these efforts are commendable, but the task now is to provide the technical force and incentives to exploit as rapidly as possible the vast reservoir potential of human and bio-physical resources which exists. In everyday terms this means moving from the present traditional agriculture to a science based agriculture, and integrating at the farm, and every other level of the food system, the technology which is just waiting to be "packaged".

Generalizable Considerations

The primary demand on agriculture is a supply of food sufficient to maintain the population at a satisfactory level of nutrition. The relationship is simple and direct; food is either sufficient or it isn't, and it is either keeping pace with population growth or it isn't.[1] Therefore, in reality, a food/population ratio tells you nothing. It is necessary to know in what direction it is changing - like a barometer reading, the change tells you whether there is fair or foul weather ahead.

The evidence indicates that in Pakistan the annual food growth rate multiplier is less than population growth plus the economic growth rate multiplier, and per capita food supplies are declining - a situation which is reversable. And this is true because circumstances have provided Pakistan with one of the highest potentials of any irrigation systems in the world. However, in comparison to an agriculturally developed country such as the U.S., our estimate is that in productivity rates per land unit, the two agricultural situations compare about as shown in Figure 12.

This "guesstimate" indicates an approximate productivity ratio of about 30 percent between Pakistan and the United States, yet Pakistan could easily move up the curve and for some crops, wheat and rice among

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[1]Abstractly in mathematical form- $(a)P = (b)F$, if and only if $(a/b) = 1$

them, equal or exceed the United States. A good share of burden of moving higher on the food growth curve will depend upon improvements in soil and water management.

Referring to Figure 4, page II-6, the projected output of wheat averages approximately 988,000 additional tons per year for the 6 year period 1975-1980. The average rate of increase in wheat production, 1968-1974 was estimated as 167,000 tons, a difference of 821,000 tons annually.

Average yield for the 1972-73 growing season was estimated to be about 1200 pounds per acre. An average of 6.1 million acres are in wheat. Over the period 1968-1974, wheat yields were increased an average of 54 pounds per acre (54/2000 x 6.1 = 167,000 Tons). To reach yearly yield target objectives and an output of 12.7 million tons by 1980, wheat yields must be increased by about 325 pounds each year (325/2000 x 6.1 = 990,000 Tons).

There are various values associated with these readily achievable rates of wheat output. Food grains are being imported in large amounts. From the U.S. for example, 500,000 tons of wheat has been requested for 1976 under a long term PL 480 concessional agreement - involving in this instance somewhat over 200 million U.S. dollars. Loans are also being secured to import fertilizer, e.g. 40 million dollars asked from the U.S.

Soil and Water Impact Assessment (Illustrative):

CSU's estimates indicate that, conservatively, yields of 50-60 maunds of wheat per acre can be produced compared to the present 14.6, a factor of 3.8 times. Much higher yields than this, of course, are

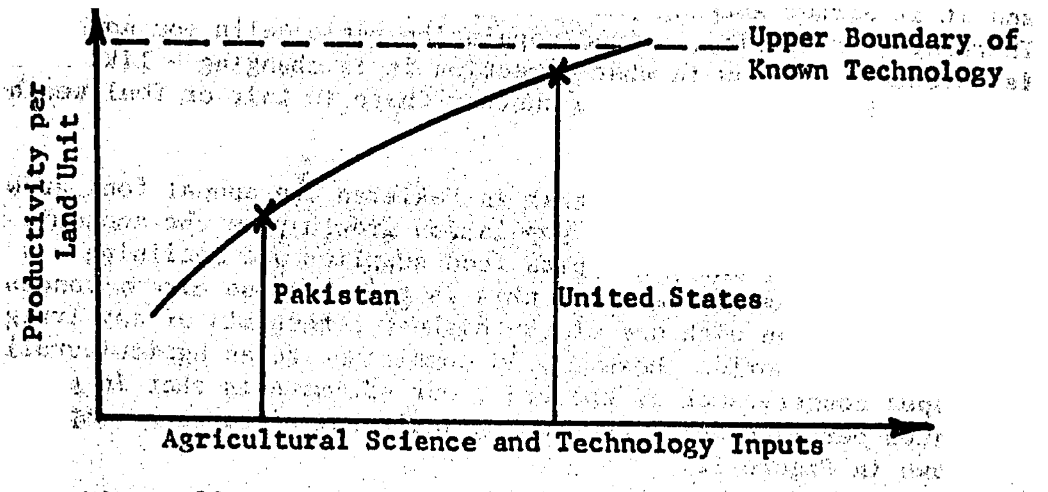

Figure 12 - Relationship between Scientific Input and Productivity

presently being attained on fields which receive the optimum levels of inputs, so 2100 pounds of wheat per acre (25.3 maunds/acre) is certainly within reach, with saving on water and labor helping offset the cost of improvements.

The cost of land leveling is amenable to long term amortization,[1] so the primary additional variable costs (which can be partly offset) are better seeds and more fertilizer. Farmers will need large amounts of capital investment and credit support.

More money is going to be needed for land leveling, planting and harvesting machinery and equipment, but these investments will, at the same time, help enhance the development of agri-business and rural employment. For example:

Nakka Building Employment Generation

1. Nakkas cost 150 Rs. (1975 price)
2. There are 88,000 watercourses in Pakistan
3. An average of 1 nakka is needed per 8 acres (probably 50 percent low)
4. There are at least 30,000,000 acres of irrigated land, probably more nearly 35 million acres.
5. There is a need for at least 3,600,000 nakkas, and perhaps as many as 5.4 million nakkas
6. At 150 Rs. per nakka, even if only 1 million nakkas were put in over the next 10 years, this would add Rs. 150,000,000 to agri-business income and about Rs. 15 million to labor income.

Impact Assessement of CSU to Food Output Generation Potential

It would not be fair to judge the field activity portion of the CSU work except from 1972 on. The CSU contract was actually started without a field location, although Pakistan was in mind. Viet Nam was not in the picture at the time. It took two years to gain entry to Pakistan, and even then Gil Corey, the first project leader, was in Pakistan alone for the first 18 months or so (see Figure 5) with the entire field layout and program development primarily on his shoulders.

It wasn't until Clyma, Eckert, deMooy, Kemper, Early and Lowdermilk arrived to take on the tasks laid out by Corey and build upon his spade work with their ideas and thinking, that the field effort really got started. In these regards, the broadening of the project, from primarily a focus on water delivery was due partly to the broader disciplinary makeup of the CSU team, and partly to the high correlation between related elements not only of water, but of soil, cropping systems, and social factors as well.

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[1] Land leveling is sometimes considered to be a capital investment

The first thing that needs to be said about this project is that it deals directly with the farmer, in his setting, and with his understanding and agreement. The dimensions of the farmer-farm situation are being dealt with from a water point of view, which is an association of elements which cannot be separated:

1. Water delivery systems
2. On-farm water use
3. Drainage and high water tables
4. Agronomic and cultural practices
5. Maintenance of systems and system components
6. Social considerations and constraints

In an objective sense, however, no coordinated, country-wide agriculture and rural development program for Pakistan appears beyond the planning stage. The economic and political situation in Pakistan has not been favorable for launching systematic programs. There is, however, an openness regarding the advancement of overall policy and a definite desire to launch rural uplift programs. This favorable atmosphere should insure rapid progress. But it is not only the technical end of the equation which affect farmers attitudes, the willingness to produce is a vital policy and administrative consideration. Involved is the development of a complete and integrated production program with emphasis on farmer associations and local organizations, and a unified area of impact approach.

Farmers need credit, leadership, tax relief, a voice in decision making, training, and a host of similar socio-economic considerations to build a viable agriculture and a more stable and improved way of life. Communal organization, emphasis on service to the farmer and his family, and health and education opportunity are essential to build positive attitudes toward a national effort. The technical factors, soil, water, and production inputs then, and only then, can become accelerators of rural development through increased crop yields. And only by following through on the concept of a national food system can Pakistan achieve this end.

In these terms, the core of the food system is an integrated well chosen cropping system. The CSU effort is hitting at key points and helping to establish the factual launching pad. Their activities, levels of effort, and areas of concentration are summarized in Table 4.

VIII DISCUSSION OF ISSUES RAISED BY AID

This section of the panel's report deals with the "Issues", (see page I-2) given the panel to consider in evaluating the focus of CSU's water management research in Pakistan; together with its problem solving relevance, dealing with: (1) water delivery systems, (2) on-farm use of water, and (3) socio-economic constraints.

The instructions issued to the panel state that "these issues are based on the Agency's understanding and impressions of contract activities and are not necessarily directed at contractor failure but reflect a need to generate discussions toward...focused objectives."

First, the panel considers that the project is focused upon a viable, agreed upon, target. These targets are well spelled out in the respective work plans and annual reports. Therefore, the panel's concern was mainly with the "range" of things done, or proposed to be done.

ISSUE #1: RESEARCH FOCUS

Research was needed to find out and to rank the order of soil, water and agronomic problems. These investigations disclosed a wide range of difference in substantive makeup and magnitude of commonly identified problems from place to place and socio-economic situation to situation. Consequently, there is no "most important" problem. That is, there is a food system in the overall, the basis of which is crop, soil and water management, but none of which means much unless requisite inputs are available, unless incentives are provided, and socio-economic constraints modified.

The focus of the CSU research has been mainly on water delivery systems and on on-farm water use. A project by project comparison shows all projects to be related, and that together they have direct bearing on water delivery systems and on-farm water use at the farm, and the planning and policy levels. The preliminary findings of this research have been particularly relevant to rehabilitation of watercourses, and are being utilized in a pilot project proposal "Improved Water Management in Watercourse Command Areas".(See Appendix H)

The approach of the CSU research involves a concept of a "cropping system" and the dynamics of the physical and socio-economics interaction relative to water systems and water usage. Until the start of the CSU research in 1972, very little had been validated on the physical constraints and the socio-economic problems which affect decisions of the farmers in Pakistan.

ISSUE #2: THE RESEARCH PROGRESS IN PAKISTAN

The CSU research has, or will soon be able to confirm, a set of principles which can be used as propositions for first approximations to problem identification and which could pose tentative solutions to common arid and sub-humid water management and problems. These principles could, and probably will, cover six areas of soil-water management: (1) delivery systems, (2) on-farm water use, (3) some drainage, (4) cropping systems, (5) maintenance, and (6) socio-economic constraints.

More on-campus effort might, however, be directed to the building of a data base, and water systems "modeling", coordinated perhaps with the start in this direction by Utah State University.

ISSUE #3: THE COOPERATIVE APPROACH QUESTION

The panel believes that the cooperative "approach" is not a field responsibility, but is something to consider between the on-campus leader and AID/Washington. The only comment the panel would make in this regard is that while it may be the case that each institution has appeared to go its own way, it does appear that "ideas" and "literature" have been interchanged, even though a common format and procedure may not, as yet, be established.

ISSUE #4: FUTURE INVOLVEMENT AND DIRECTION

This issue is dealt with under recommendations in the "End of Project Statement", Section XI.

ISSUE #5: VALUE OF PUBLICATIONS TO LDC SITUATION

The transfer question is dealt with in detail elsewhere in this report. The panel believes that it need only add that each member of the team "carries the message" to farmers and administrators concerned with getting, using, and making the most of available water.

ISSUE #6: END OF PROJECT STATEMENT

The panel sees a phasing out of the current effort, and a phasing in of a longer term, not necessarily entirely in Pakistan, developmentally focused, including program of research, technology transfer, and training. This requirement would include developing an improved data base, and modeling.

IX GENERAL OBSERVATIONS OF PANEL

1. Project coordination and direction is difficult under any circumstances, and is particularly difficult whenever separate parties are involved with differences in points of view and differences in responsibilities. There are six parties to this research related in one way or another, and at one time or another, to the CSU field and/or on-carmpus work: the GOP, USAID, Pakistan, CSU on-campus administration, CSU field leadership, AID East Asia Bureau, and AID Technical Assistance Bureau. Therefore, decisions often rest solely on the willingness of the Field Leader to accept responsibility and be willing to hold a course.

2. That the project made sense when it was originally conceived (Issue No. 1) in the panel's judgment has been amply documented. The panel is not as well satisfied with the transfer aspect of the on-campus end, but the on-campus contribution has nevertheless been substantial (see section V). In the overall the project has held course, has had a single focus "on-farm water supply and use" and each piece of work is focused on target. The additional economics work needed is outlined at the end of this section.

3. Training and institutional development are things which confront every project at some time. These things are necessary, and must be done by someone; however, what to do, and how to do them is a process of discovery as diagrammed in Figure 11. Unless this process is adequately developed, research should hold a fact finding course. In doing so, it must be in close communication with decision makers and planners, so they can become involved in comprehension of the problem "set", and better acquainted with the demand requirements of a cropping and food system.

4. A whole range of information and "how-to-do" documents need to be prepared for instructional and training purposes. This is a much neglected area of "tool" building but it, at the same time, may not be an area of research responsibility, being a field of communication specialty requiring its own specialists.

5. The CSU project may be considered as broadly ranging by some, but as it has reached into the on-farm situation, it has identified gaps and difficiencies in the cropping system, not just with respect to water, but agronomics, and socio-economic factors as well, which has changed the range of activity as the research matured.

6. On the question of this project's future: (1) CSU could refine what it is now doing--delivery systems and on-farm water use; (2) it could drop these and move on to drainage and systems maintenance, or (3) it could concentrate on water-crop agronomics. One thing it must do is settle on a set of general water management principles and

concepts which can guide problem identification and help derive solution postulates. It could then test these out in another area in Pakistan, or in another country.

Another thing it could do, and do well, is assist the GOP to develop a complete water management system on priority food crops. This would mean leaving some work on delivery systems, and moving on to drainage, maintenance and water/agronomics. There are sound arguments for this course. But there is still another problem in the picture and that is the tubewell/water table balance in two main categories: (1) as supplemental water, and (2) as the main source of water.

7. What has been accomplished to date by CSU must be viewed as being of the highest order, considering that CSU just sort of arrived in Pakistan in the person of Gil Corey, and has sort of made its own way every since. Trying to marry the research to the 211(d) format didn't help, because objectives became confused and dependence was put upon various monitors to indicate direction and emphasis. It was not until the project was centered in Agricultural Engineering that a concerted effort got underway--yet the payoff has been very high, particularly on engineering and socio-economics. Lowdermilk's social survey technique should be considered, after some more work, for generalization.

8. The CSU work should be correlated with the proposed IBRD water survey in two ways: (1) to provide background knowledge and technical coefficients, and (2) to determine the extent to which the CSU findings to date are generalizable to other production zones, crops, soils, and water situations.

9. A word needs to be said on farmers generally, and on small farmers particularly. The size of land holding has little effect on the makeup of a Pakistani farmer, what he knows, or his attitude about farming. It does effect his willingness to take risk, generally, or his ability to make investments, specifically, but leadership ability, inquisitiveness, and search for knowledge are individual.

The small farmer's real costs are generally much higher than the larger farm--having less access to credit, paying a higher cost, and paying more for transport and services. Minimizing costs, as he must, makes him and continues to make him a subsistence farmer.

10. Because of the nature of watercourses, farm village layout, religious association and the randomized distribution of farmers along watercourses in a water command area, an area approach is the lowest possible point of division of the farming community, which, in most instances is synonomous with the dimensions of each rural community. Technically, perhaps, each water command area has enough common elements and traits to be the integrating unit. (See Figures 6 and 7.)

11. In the rural area there exists, expressed in terms of rural economics, and rural development structuring, only a socio-economic community which depends upon agriculture for food and income. Therefore on technical components, but also embracing the social elements, is the very real possibility of Farmer Multiple Purpose Associations, under recognized local leadership, drawing upon both farmer and village. Innovative farmers, larger or smaller can also provide demonstrations of the possible. Since watercourses are common and contiguous farm to farm, labor sharing is a common denominator among farms, which means that a form of local cooperation, in associations, or by agreement is necessary.

As the economy moves beyond the realm of subsistence and labor sharing as association has added advantages over informal agreements. It can pool financial resources to procure inputs, borrow credit, make capital investments, develop local marketing, and serve as a voice and bargaining agent. It is also a reference point for training, and health services.

Therefore, in the greater sense of rural development vs. agricultural development, with emphasis on the human factor, technical assistance, and perhaps financial, is needed to facilitate formation of effective farmer associations. Such assistance should be as well versed on agriculture and rural culture, as on organizational techniques. Radosevich's work is relevant to this objective.

12. Mr. Ifikhar, Chief, Water Resources Section, Planning Division, GOP, agrees that CSU has taken a "grass roots" approach essential to rural and agricultural development, with inputs of fertilizer and credit now needed to capitalize on the "new" water supply and on-farm water use findings, incorporating the advanced agronomic work being done at Lyallpur University and elsewhere. He was in full accord with developing local cooperation and effective relationship of extension and "specialist" assistance to get Pakistan's agriculture moving. The movement requires going out and knowing the farmer and his problems, and convincing them about what they need, get them to want it, and to participate in the improvements. The breadth of such an undertaking is, of course, more than external assistance can manage, but the CSU research activity has certainly laid the ground work, and has helped to show the way.

13. Thus, the CSU field team has:

1. Found the middle ground between research and the farmer.
2. Taken a "grass roots" farmer and extension involvement in identifying farmers' soil and water problems.
3. Have focused attention on water management on farms and rehabilitation of watercourses.
4. Have conducted experiments in an acceptable manner, and with an innovative flair.

5. Located and pointed up the nature of technical, social, and economic constraints.
6. Brought out time as an important variable regarding growth rates and maintenance.

In brief, if CSU had not done what it did, the information now needed to develop the pilot program, and to underpin the IBRD survey would not be available. By stating this doesn't mean that the best techniques were always used, and that some conclusions do not need rechecking, or that more does not need to be done on cost/benefits, trade-offs, and programming elements, and a host of other economic and social issues[1/], but all together, the Colorado State University efforts, in this panel's judgment has supplied U.S. assistance with additional stature.

14. Economics is a major component of the water management assessment work of the CSU research. This component needs to be strengthened and moved forward rapidly at this time: (1) because a sufficient data base now exists for analysis, and (2) final farmer and policy decisions will, in part, depend upon economic analysis. A four point attack across the water/agronomic board needs to be made:

1) Reconstruction of cost/benefit ratio analysis to incorporate analytical refinements based upon marginal (production surface) analysis and uncertainty estimates;
2) extend and improve upon marginal analysis estimated by "getting at" true costs, particularly to the small farmer;
3) utilization of LP cropping systems models incorporating the "new" and traditional practices, and the CSU soil and water management data to compare cropping systems alternatives when feasible;
4) make a special study of risk and uncertainty and probability density estimates of farmer decisions with respect to these elements.

15. To the extent that the findings in one country development situation are transferable to another, savings in time and expenditure can be achieved in the process of solving problems in the second and succeeding countries. The CSU Water Management Research Project is nearing the point where this thesis can, and should, be tested.

a. Efficient field methods have been developed for determining the potential for physical improvement. (Watercourse transmission efficiencies, water application efficiencies, salinity profiles of the aquifer, etc.)
b. Survey methods have been developed to gain information of adequate validity with minimum expenditure of time.

[1/] Sam Johnson is getting into some of these now.

d. Specific techniques are being developed and tested in Pakistan which:

1) decrease water losses from watercourses (i.e., compacted earth cores in watercourse banks, improved control structures for junctions, rebuilt and new watercourses, lining of various types) at reasonable cost;
2) measure irrigation water adequately and evaluate crop consumptive use adequately to estimate over- and/or under-irrigation and give farmers advice on crop and water scheduling;
3) allow use of farmers' resources (labor, draft power, etc.) to improve his water transmission efficiency, his irrigation efficiency, crop stands and yields (by limited soil surface shaping); and,
4) obtain water of optimum possible quality and amount from aquifers where salinity increases with depth, and so forth.

Within the coming years, most of the above techniques will have been adequately tested in Pakistan to ensure their usefulness for diagnosing and solving water management problems. These techniques should then be written for international use, and along with trained personnel, should be made available for use in other countries. Short term consulting assignments in other developing countries should be anticipated and welcomed by CSU Water Management personnel who have become "authorities" in vital subject areas of watercourse delivery efficiency, irrigation application efficiency, crop and water scheduling to optimize production on limited water supplies, water management surveys, etc.

16. Documents for international use which should be written within the next three years include:

a. Irrigation application efficiencies and potential for their improvement in developing countries. To be written by Clyma, Early, deMooy and others as needed.
b. Watercourse Losses-Magnitude, Causes and Methods for Reduction in Developing Countries. (This may be 2 or more items in a series.) To be written by Kemper, Clyma, Bowers and others as needed.
c. Role of watercourse losses and irrigation application efficiencies in the drainage (pumping and tile) requirements and waterlogging of land and physical and economic evaluations of coordinated management programs best suited to maintain water tables at depths conducive to optimum crop production. To be written by Clyma, Kemper, Eckert, and others as needed.
d. Watercourse design handbook for developing countries (including: improved and low cost designs for control and measuring structures, head losses for such structures; a discussion of roughness coefficients as related to vegetation and cleaning

schedules; and methods and materials for construction including bank compaction, relative losses to be expected, necessity of maintenance and cleaning programs, etc.). To be written by Hart, Clyma, Kemper, Bowers and others as needed.

e. Handbook of Water Management Research Techniques for Developing Countries. (Including techniques, essential equipment and evaluation of their accuracy for measuring and estimating soil water content, flow in watercourses, salinity profiles in ground water, potential evaporation, etc.) To be written by Early, Clyma, Kemper and others as needed.

f. Water users associations. Their organization and their functions in contracting for help needed in watercourse improvements, organizing to achieve group action essential to improve water management, organizing for cooperative use of water management, equipment and socio-economic industrial factors which can be used to facilitate the formation and operation of users associations. To be written by Lowdermilk, Eckert, Radosevich, Early and others as needed.

g. Survey procedures for identifying potential for improving water management and crop production. To be written by Lowdermilk, Early, Clyma and others as needed.

X EVALUATION OF COSTS AND BENEFITS

According to the assessment charge for this review and evaluation of the CSU Water Management program-progress and results, this section of the report poses two alternatives:

1. Phasing out the program, closing it down by March 31, 1977.
2. Extension of the CSU Water Management Program through June 1980.

ALTERNATIVE 1 - CLOSING OUT THE CSU WATER MANAGEMENT RESEARCH CONTRACT ON MARCH 31, 1977.

<u>Costs through March 1977</u>

The funding of the CSU Water Management Research Contract from its inception in July 1968 through March 1977 will have included:

From USAID/Washington, TA/AGR $4,000,000
From USAID/Pakistan (as support funds) Rs.4,500,000

a total dollar equivalent of about $4,450,000 direct from AID.

In addition, CSU encouragement and assistance in Pakistan has resulted in Water Management Research Proposals from Government of Pakistan Agencies in the following amounts, which have been funded by USAID/Pakistan.

Agency	Budgeted to be spent by April '77	Total Available (Rupees)
Mona Water Management & Watercourse Imprv.	Rs. 4,200,000	4,700,000
WAPDA Planning Div. (Watercourse Survey	320,000	320,000
Int. Rural Devel. Program (Water Management)	900,000	1,000,000
CARE/Mona	550,000	550,000
Total	Rs. 5,970,000	6,570,000

A group of Pakistani Agencies was also assisted in organizing a Consumptive Use of Water Research Proposal under the auspices of the Pakistan Agricultural Research Council, funded by the U.S. Department of Agriculture. The total support for this project was about Rs. 5,400,000, of which Rs. 1,400,000 are to be utilized by March 31, 1977.

Pakistani Agencies which have worked with CSU on water management have invested substantial portions of their budgets in water management and the estimated total of these investments is Rs. 3,300,000.

The Total Water Management Research investment through March 1977 will be about $4,000,000
plus Rupees from the U.S. 16,470,000
plus Rupees from Pakistan 3,300,000
of which Rs. 3,800,000 might be recovered by the granting agencies if these projects were terminated at that time. Under a phase out and termination consideration, the field work would need to be phased down.

In addition the cost of the loss of dedicated, highly trained, and devoted personnel, already established and accepted by the GOP, its Agencies and Pakistani farmers is incalculable. Assessment of probable future contributions should be measured by marginal impact analysis; not a cost-budget item to be totaled with regard to a limit.

Benefits of On-Going Research through March 1977

Watercourse Improvement

With their cooperators the CSU teams have shown that the water reaching fields from watercourses in Pakistan is only about 50 percent of the flow from the canals into these watercourses. Previously it had been estimated that 90 percent of the water coming into the watercourses was delivered to the fields. Practically all of Pakistan's planning has been based on the 90 percent figure, and improving watercourses was disregarded as an important method of improving water supplies. The realization that water reaching the fields could be increased by as much as 100 percent by watercourse improvement has revealed an "additional supply" of water for these canal command areas, which includes more productive land than is presently being served.

A series of test watercourses ranging from masonry channels which should last many years (Rs. 50/foot) through channels with walls only a single brick thick (Rs. 10-25/foot), channels built of soil cement bricks (Rs. 6-20/foot) to channels built of simple compacted earth with inexpensive concrete control structures at junctions (Rs. 1-4/foot) have been constructed and are currently under test. Losses from the best test watercourses have been reduced to less than 20 percent of those on the unimproved channels.

Compacted earth channels with the specially designed control structures have reduced water losses on test sections from 50 percent to 25 percent of the incoming flow. Currently these methods are under test on 30,000 feet of watercourse channels which have been improved by farmers.

On this watercourse, with an inflow of over 4 cusecs, the apparent savings will average at least 0.5 cusec of water for over 300 days a year or about 300 acre feet of water per year. The improvements cost about Rs. 40,000 for structures (including buffalo wallow stations) and about 20,000 hours of farmer labor to make the new watercourse. Means to maintain this improvement are being tested. One promising maintenance program under test includes inputs of 6000 hours of farmer labor per year plus farm produce valued at Rs. 2500 per year to hire a watercourse guardian or "khal chowkidar."

If the saved water is valued at the cost of Rs. 100 per acre foot for SCARP tubewell water delivered to the field (Rs. 50/acre foot/50 percent delivery efficiency) this improvement will pay for itself in water saved in the first two years.

Special techniques for installing compacted earth cores in the centers of banks have been developed which along with proper use of the low leak control structures, may further reduce losses and save 1.0 cusec of water as was done in the test sections. Even tubewell water (at a cost of Rs. 100/acre foot) is generally a good bargain, since its real value in reasonably well managed crop production is up near Rs. 300/acre foot. Assuming this latter value for water, the benefit/cost ratio of watercourse improvement probably exceeds a factor of 5.

In brief, the value (or benefit) potential for increasing water delivered to the fields by improving watercourses has been identified and is being tested on a full field scale. At present about 50,000,000 acre feet of water reach the fields in the Indus Basin. The techniques of watercourse improvement may increase this amount by 10,000,000 to 25,000,000 acre feet per year. At a cost of Rs. 100 per acre, the improvement on 30,000,000 acres in the Indus Basin would cost Rs. 3,000,000,000 and would permit an added immediate produce value of Rs. 6,000,000,000.

Dams such as Tarbela and Kalabagh would have to have a useable capacity of over 30 million acre feet to be able to deliver 10 million acre feet to the fields at present water delivery efficiencies and would cost over Rs. 40,000,000,000. Assuming that half the cost of these dams can be paid for by their electric power (a common estimate on such dams), the cost attributable to the increased water supply would be Rs. 20,000,000,000.

The potential cost savings in obtaining new water supply by watercourse improvement as compared to building new dams appears to be Rs. 20,000,000,000 - 3,000,000,000 = Rs. 17,000,000,000.

Moreover, over 1/3 of the Rs. 3,000,000,000 needed for this new water supply can probably be farm labor used during excess labor periods and the remainder is in the form of bricks and concrete which can be manufactured within the country, requiring almost negligible expenditure of foreign exchange.

A potential increase in the water supply at the field from 50,000,000 to 75,000,000 acre feet with attendant savings in costs as compared to dam water of about Rs. 45,000,000 appear to be within range. However there are several components of this development plan that must be further tested, refined and adapted to achieve this potential. They include:

a) Develop motivational and training techniques which will help farmers properly use control structures and maintain their watercourses against degradation.

b) Work with farmers to help them develop the motivation and procedures to properly do the finish work which minimize leaks and seepage through watercourse banks.

c) Determine personnel and training needed to design watercourse improvement, motivate farmers to undertake those improvements and evaluate the changes and help farmers recognize those changes.

d) Determine how far the demonstration effect extends and the extent to which it motivates farmers to compare their own watercourses and ask for technical assistance.

e) Evaluate the institutions with potential for giving the training necessary for improved water management and work with those institutions and individuals best suited to develop, evaluate and refine that training.

f) To evaluate the adequacy of the training and selection and operational procedures in the water management development programs which USAID/Pakistan is developing to
   (i) Improve the program to achieve higher rates of success, lower costs and greater efficiencies.
   (ii) To document the successes carefully so they can be transferred insofar as possible, to other developing countries.

Items a) through f) can not be completed by March 1977, some can only be started, and it is questionable whether Pakistani personnel can be trained in that time. It will also take a sufficiently strong effort on the part of the GOP to overcome the resistance offered by many of the old guard who resent this course of action which is contrary to many of their cherished illusions and intrusted positions.

Improvement in Water Application and Cultural Practice

Studies by the CSU team and their cooperators show that irrigation application efficiencies average down near 40 percent, rather than the previously assumed 70 percent and there is considerable over-irrigation on many fields. Both of these facts represent additional opportunities for water management improvement.

The solution to these problems is a dependable supply of water and good estimates of evapotranspiration for the major crops so farmers will know when to irrigate and plant their crops and how much water to apply to achieve optimum crop production from their water supplies.

Consumptive Use Studies - A network of consumptive use studies has been set up to obtain crop/water coefficients which can be used to estimate water use by each crop from climatic data. This is a PL 480 funded study which will be no more than 1/3 complete by March 1977, and will require continued supervision by the CSU team, or a comparable group of water management specialists to ensure the quality of the data and assist with analysis.

Soil Crusting - Low yields and stands in kharif (summer crops) maize and cotton are a chronic constraint on food and fiber production in Pakistan. The reasons for these poor stands and part of the reason for the low yields is associated with surface crusting and the length of time water stands on these summer crops following monsoon rains or irrigations. Low areas on fields of maize and cotton have been found to have average stands that are only about 70 percent of those on higher areas. Yields per plant on low areas are only about 70 percent of those on high areas. This amounts to an average yield per unit area on low areas which is only about half those on higher areas.

Precision Land Leveling and Irrigation Scheduling - Leveling, proper amounts and timing of irrigations have been found to increase stands and yields. Planting on shoulder of bed between furrows and applying small amounts of irrigation to wet the crusts by capillarity have softened crusts, allowed emergence and increased stands and yields. However, additional work is essential to verify the benefits of these techniques and to develop or identify the equipment needed which will allow the farmer with bullock power and manual labor to make such furrows and plant properly.

These soil shaping and irrigation and crop scheduling advisory services will require appreciable works beyond March 1977, and will require an implementation stage. Data collected to date indicates that under reasonable fertility practices in Pakistan (i.e. achieving yields of 30 maunds of maize per acre) these improved irrigation and drainage practices can increase maize yields to 50 maunds/acre. Similar percentage increases in cotton yield can be achieved which could raise Pakistan's maize and cotton crop yields by 8×10^6 and 6×10^6 maunds respectively for a total value of increased crop of over Rs. 1,000,000,000 per year. However, these experimental increases must be verified on farmer's fields, tested for farmer acceptance, taught to extension agents and the extension process must be evaluated and refined before the technology can achieve its potential.

This work should be pushed with the GOP. At present, the program is supported primarily by USAID funding and CSU interest and expertise. Development of a national water management research program in which established government agencies incorporate this type of research into their on-going programs is a prerequisite to Pakistan's developing the internal capacity to overtake their population growth with increasing crop production.

Hydraulic Dissolution and Application of Gypsum to Improve Sodic Waters

The price of gypsum fragments at the quary is about 15 percent of the price for powdered gypsum. Data from the CSU hydraulics lab and initial trials on single gypsum blocks at Mona indicate the potential for eliminating the need for this costly powdering operation and mechanical distribution of the gypsum on the field, by directing the tubewell water through an enlarged section of a watercourse channel and dissolving away the gypsum.

The results of this study will provide guidelines which will allow each farmer who puts gypsum on his land to reduce the cost of gypsum by more than Rs. 75 per ton. This study will have preliminary results by March 1977, but will need to be publicized and extended to users.

Skimming Wells

How to obtain optimum quality and quantity of water from aquifers in which fresh water lies over saline water is an important problem for farmers in over two million of Pakistan's irrigated acres. Data is being collected in the field which, combined with a computer model on the CSU campus, will allow development of guidelines for remodeling of old wells and design of new wells to obtain the best possible quality and quantity of water. A major part of the investment in over 300 government tubewells, closed because their pumped waters were too saline, can probably be recouped by simply filling with sand and sealing with concrete: the length of the tubewell determined primarily by the pumping rate and the proximity of the saline water to the tubewell.

While an initial set of guidelines will be developed by March 1977, the utilization of these procedures to renovate over 300 government tubewells and several hundred private tubewells must be encouraged by demonstrations and training of Pakistanis to make the necessary measurements and by recommendations for improving old wells and for designing new wells which will probably be built. Redesigning the 300 inactivated government tubewells and sealing their bottom sections should cost only a few hundred rupees each, but should bring the average value of these abandoned wells back up to more than Rs. 20,000 on the average. This could recoup over Rs. 6,000,000 in this renovation aspect of the program alone. Benefits derived due to better design criteria for optimizing water quality should accrue to over 3000 wells to be constructed in the next 10 years for benefits in excess of Rs. 60,000,000.

Summary of Costs and Benefits through March 1977

The total cost of the research program initiated by CSU will be equivalent to $5,130,000 by the end of March 1977. The benefits which could result from new potentials defined for decreasing costs and increasing water supplies and using that water effectively to increase crop production, exceed a potential of Rs. 200,000,000, probably running to 4-5 times higher, that is Rs. 800,000,000 in Pakistan over the next 10 years.[1] However, these are "paper profits," not yet utilized. Their full achievement will require additional research, documentation and publication of the research results, convincing of Pakistan's planners of their validity and joint formulation of well designed development and extension programs. Proper development and effectiveness of these programs will require that their physical components, benefits, and interactions with farmers be continually documented and evaluated and that these observations be used to refine the programs to decrease costs and increase effectiveness. Only a small portion of this implementation research and program refinement will have been completed by March 1977.

ALTERNATIVE 2. EXTENSION OF THE CSU WATER MANAGEMENT PROGRAM THROUGH JUNE 1980.

This would involve completion of 1) needed research in Pakistan, 2) participation in the designing, evaluation and refinement of the development and extension programs essential to achieving the benefits derivable from the potentials defined by this research in Pakistan, 3) documentation of the research results and extension and development programs and integrating them with those from Utah State University for consideration and application in other countries, and 4) phasing out of Pakistan and into other countries as the need for help in evaluating water management needs and improving water management is realized. This assumes that help is requested by these other countries and the respective USAID Missions.

Estimated Costs through June 1980

Continuation of Overseas Support Services at approximately the same levels, phasing out of Pakistan and into other countries would require the equivalent of about $600,000 annually during the three year period (March 31, 1977 on) assuming 10 percent world inflation.

Since much of the training and development phases and institutional development of the needed programs are Mission responsibilities and should be integrated with Mission financed development programs, the Mission should develop a proposal for assistance in filling water management needs in training, development and institutional building as they see them.

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[1]At an accelerated rate of development achievable the actual could be greater by a factor equal to 10^2 or 10^3.

On-the-job, intermediate, and advanced training is needed in these regards and fields:

1. <u>Subject Matter Specialists</u>: trained people who can identify problems and make recommendations at the field level, and who can identify and refer new problems as they arise. These are subject matter specialists, to support extension workers.

2. <u>Cropping System Specialists</u>: trained people capable of assisting farmers to develop enterprise and input combinations, estimate input-output ratios for alternatives, and make decisions on economic and risk coefficients requiring both formal and "on-the-job" training.

3. <u>Local Organization and Administrative Specialists</u>: trained people who can deal with farmers and local communities to develop farmer cooperatives, factor procurement and marketing associations, and who can bring training and education to the village level.

4. <u>Food System Specialists</u>: analysts trained in systems, operations, and programming techniques, to provide a determination and prescription of changes to fill gaps and modify deficiencies in the food system at the area, regional and national levels. Requires formal training in both micro and macro analysis.

5. Researchers: trained at higher level, MS and above, people who can work on solving new problems, and pose innovative changes of higher order benefit in products and human welfare. This group works in five main fields: crops, livestock, soil and water, social and economic.

The total manpower requirement cannot be estimated with precision or exactness on the scarce data available on funds, or reservoir of trained resources, but from knowledge of the magnitude and order of existing problems, the following may be reasonable estimates:

1. Micro level emphasis is first priority, and it is at this level that the least is known, and the greatest number of people are needed. But, estimating 30,000,000 people assembled in 30,000 farm associations of 100 farmers each, and a rate of development of 1000 associations per year, with 5 fields of specialization to be covered, each covering 10 associations, the rate is 500 trained people per year for 30 years, no small task.

2. Fewer macro-level trained personnel are required, but their training will take longer, as will the training of technical research specialists, but with about 40 crops to cover (not counting forestry) and about 12 kinds of livestock, and ten

geographic (environmental) zones and as many soil and water situations. The trained people required appears to call for advanced training turnout of 200-250 per year over the next 30 years.

__Estimated Benefits Derived from Continuation from April 1977 through March 1980__

1. Achievement of 50 percent of the defined benefits outline for Pakistan rather than the 20 percent if these aspects of this work are not assisted through their utilization stages, 30 percent of 2 billion rupees, or at a factor of 4-5 (see above) 8-10 billion rupees, would average 6.7 billion rupees, of which 30 percent would be 2.3 billion rupees.

2. Documentation and development of the utilization stages for application in other developing countries. (Value to be dependent on involvement.)

3. Development of the process of entering new countries to assess their needs, interact with their personnel and evolve the needed research and utilization programs. (Value appreciable but not estimable at present.)

4. Development of a complete package of water management technologies which will provide the farmer with more water and help him to use that extra water supply to increase crop production (which can dramatically increase the value of the water).

Thus, by March, 1977, a large share of GOP decision makers will have been exposed to data which shows the potential for improving yield by control of water supply to fields by better management and from better management of water on the farms. However, a large number of physical and socio-economic components remain to be identified and integrated into development planning, and further testing and farm integration is needed to yield activities leading to maximization of benefit potentials.

Training of the leaders of this program is largely a person-to-person process involving interaction between host country professionals and advisers as they solve problems. These processes will be beginning by 1977, but a strong research and development program in water management which can be put on a country self sustaining basis, cannot be achieved unless a continued advisory service is provided during at least the first three years of the development program (until about 1980). Furthermore, if research of even higher benefit value potential is added, for which the need is apparent, much larger (and in some ways wider) assistance, with high pay off value as outlined, should be added--likely another 3-5 years, making 6-8 years ahead in all.

INCIDENTAL BENEFITS TO OTHER LDC

Physical Factors

Surveys have been designed which measure the transmission losses, the application losses, and estimate the water use efficiency (crop production per unit of water used). Where salinity of goundwater is a problem, and salinity in existing wells can be monitored as a function of depth, techniques are being developed for determining the improvement in water quality that can be achieved by modification of the depth and pumping rates of existing wells, or by designing new wells and pumping systems (also see Section IV).

Quick surveys necessarily obtain data at only one point in time. Adequacy of this data to represent the whole cropping season, or other cropping seasons is being determined at Mona and in cooperation with the WAPDA-Harza-World Bank Survey in which many of the components were designed by CSU. Key survey leaders were selected and trained by Drs. Early and Lowdermilk in their WAPDA-USAID survey.

The seasonal variation of water application efficiencies and other factors will be determined by Mona (estimated March 1977). Data on its variation at other locations throughout Pakistan should be collected (by July 1977). Use of these data to determine the seasons and frequency of data taking to insure desired levels of accuracy of survey estimates will depend on keeping Early and Lowdermilk in close touch with the WAPDA-World Bank survey.

The WAPDA-USAID survey planned and directly supervised by CSU was designed to determine the "state of the art" with regard to water delivery, application and use efficiencies in the Southern Punjab and Northern Sind. Their potential for improvement will be analyzed and the results will help determine the placement of the Water Management Development Program presently being planned by the Pakistan government and USAID, with CSU advisement.

Socio-Economic Factors

Working with farmers to help them improve their watercourses has not been successful in every case. The failures have been in situations where long standing dissension between farmers have overcome the desire to work together for the common good. (The most successful and efficient improvement was at the watercourse serving Tubewell 56 at Mona which was selected on the basis of cooperativeness of the farmers and leadership available within the group.)

When the farmers are cooperative and the leaders can be taken to see the consequences of improvement, the improvement project has a high probability of success (as shown by experience gained on this watercourse).

Experience of Pilot Projects

If an efficient pilot program is to be developed it will be essential to identify and select those optimum sociological "setups" where the physical improvement can be clearly demonstrated. When this demonstration is in place, farmers from surrounding watercourse command areas become excited and motivated. There are good possibilities that this enhanced motivation can overcome internal dissensions and lead to successful group improvement projects.

In initial pilot improvement study, certain objective criteria were used, but the decision was also supported by personal knowledge of extension agents who had years of experience working with farmers in these areas. Using this kind of subjective knowledge has some dangers as the informants are often motivated to direct the proposed benefits to their personal friends. Experience from further tests will help develop objective criteria and devise methods for sorting out the personal benefit factors often associated with participation of knowledgeable local persons in the selection process.

The high benefit/cost ratio apparent in the improvement of water management in developing countries are to some extent the result of the low cost of labor in these countries and the relatively high productivity of farmers who are working for their own benefit. Consequently, education of the leaders to the benefits is, again, a vital part of a successful group improvement program.

The physical potential for improvement is relatively easy to determine, but adequate survey criteria techniques to identify potentials of farmers to unite to achieve common goals are essential. Some are being tried and the experience gained may have important application in other cultures.

The work of CSU in developing techniques and criteria for identifying the economic and sociological factors and in developing a set of agricultural development accelerator principles can have important benefits. The next step involves trying them out in a country with a different culture and language (the Sind) and then preparing, along with the physical techniques of evaluation, general guidelines and procedures for use in determinating the potential for improvement in other developing countries.

XI CONCLUSIONS

1. The CSU research has been a process of evolution leading to an experimental pilot watercourse program:

   a. The work has now evolved to the point where it can begin to document costs and benefits, and indicate payoffs.

   b. The project has also reached the point where it can begin to help evolve a Pakistani institution(s) to take over the research and extension responsibility.

2. To gain these benefits, the CSU program should be continued, with the research feeding more and more into development:

   a. To have research this stage of identifying problems and ranking research priorities it has been necessary to build an experimental pilot watercourse and management program.

   b. This process has also been necessary to be able to establish criteria to infuse and involve Pakistani institutions in this process.

3. For a number of sufficient reasons, the learning process has favorably affected the CSU personnel on the program, and more favorably affected non-campus attitudes and participation:

   a. The relevancy of what happens on the campus has increased as more people gained field experiences, on TDY, or through returnees to Fort Collins.

   b. Campus support activity is becoming less a residual, and more an integral of a total program.

   c. CSU is learning that some things, modelling and data analysis, can better be done on campus because of field time constraints and facilities.

4. As the GOP-USAID demonstration pilot program on water management of command areas develops they are going to want to have someone supply these inputs, for which CSU is the most qualified resource.

   a. Unless the GOP has an organization which has the training and the water management knowledge and can also reach the farmer with a broad water management, precision land leveling, and cropping system program the loan effort may fail.

b. The experimental pilot watercourse research from Tubewell 56 will be a valuable data resource. CSU can also help by their knowledge of the jobs that need to be done, and how the people in the jobs should be organized (and trained) and related to farmer's water management problems.

c. Unless trained people are made available, and the total water management effort is institutionalized in Pakistan the long term potential food output and water savings benefits may not be realized.

d. Saving 1 percent of the water for use in the root zone is equivalent to increasing water supplies at the barrage by 1 million acre feet.

5. The CSU research will be important to developing a better regional food system, and a national system from the pilot project results.

   a. This possibility will depend upon how well a way is found to feed the results into the loan program demonstration pilot project and to farmers.

   b. It will also depend upon how well and how soon a follow up program is developed to diffuse the demonstrations regionally and nationally.

   c. The extension follow up will need organization, specialists, incentives, credit, and so forth.

RECOMMENDATIONS

Based upon this review the panel recommends continuation of the CSU program in Pakistan on the following components:

1. <u>Techniques to reduce losses from watercourses</u>

   a. Schedule to develop recommendations by March, 1977.

   b. to continue monitoring and evaluating watercourse rehabilited in the USAID Loan Pilot Project.

   c. Recommend alternative uses of underground pipeline distribution systems.

2. <u>Experimental Pilot Watercourse Program at Tubewell 56</u>

   a. Covers water management, precision land leveling practices, cropping practices, and irrigation advisory service (scheduling).

   b. to June, 1980.

3. Farmer maintenance and monitoring of precision land leveling

   a. to cover farmer utilization of land leveling by following farmer practices and maintenance.

   b. to June 30, 1980.

4. Land Shaping, Cultural and Agronomic Practices

   a. to cover cultural practices such as bedding, furrow, irrigation, cropping techniques, and fertilization to improve stands and yields.

   b. An opportunity exists to tie in with the IRRI farm machinery program to be located in Pakistan headed by Amir Khan

   c. to June 30, 1980.

5. Demonstration Pilot Watercourse Loan Program

   a. could be involved as part of evolution, institution building and forward planning (not the place to discuss details but must spell out in definite terms what can be expected from technical specialists employed).

   b. 2 man/years 1976 forward (indefinite).

6. Skimming Well Program

   a. Acceptable data is now being collected to complete modeling program at CSU.

   b. Planned second phase of program is to be by-passed with direct application of findings to wells that have failed in the Mona area.

   c. Training of individuals to analyze well salinity profiles and to recommend the modifications of old wells and design of new wells necessary to produce water of satisfactory quality.

   d. to June 1977.

7. Physical and Socio-Economic Survey of Watercourses

   a. This mission project has taken roughly 2 man/years of professional TA/AGR time, plus secretary time, and the time of 2 assistants

   b. to April 30, 1977.

8. Watercourse Maintenance

a. How to demonstrate to farmers how to organize themselves and maintain watercourses.

b. Should be integrated into the water management loan program

c. to June 30, 1980.

9. Training and Institution Building

a. CSU can provide information, train water management specialists to help organize farmers to assist themselves.

b. It would be reasonable to expect those trained and experienced on country problems to be called upon.

c. CSU has developed the start of an experimental pilot water management program. Their research will show how to work it, and how to get the results out to farmers.

d. to June 1980 (include on-campus report writing, TDY backstopping, and graduate assistantships at CSU, etc.).

10. One Year On-Campus Publication and Project Coordination Assistance

a. Returnees should be relieved of on-campus responsibilities for at least one year to prepare necessary technical and training documents to gain full benefit of the field work.

b. These documents and training tools are needed now in Pakistan and elsewhere in the arid and sub-humid areas of the LDC's.

c. Some of this time could well be spent on data coordination with Utah and Arizona.

d. To be paid for from project funds to June 30, 1980.

PROPOSED BUDGET

1. The above indicates an orderly phase-out of present research activities and priorities. Some of these activities will follow an orderly phase out starting immediately after the experimental pilot project determines which factors have the major impact and should have major emphasis.

2. The panel recommends a budget covering on-campus support, the returnees' time for one year, field effort, and for training and institution building of $600,000 + overhead for FY 1977-78, and a graduated budget support to June 30, 1980.

Budget Breakdown (dollars)

	TAB	GOP	USAID
Field	$315,000	(in kind)	$135,000
On campus	150,000	-	-
	$465,000		$135,000

TOTAL: $600,000 + overhead.

Appendix A-1

SCHEDULE OF WORK

27 Jan 1976	1100	Arrive at Islamabad
	1400	Meeting with Messrs. Newberg and Remington
	1500	Meeting with Messrs. Wolffer and Remington
	1600	Meeting with Messrs. Dimick and Remington
28 Jan 1976	0815	Meeting with Messrs. Newberg and Remington
	1000	Interviews with CSU staff and study of CSU materials
29 Jan 1976		Continue interviews and study of materials
30 Jan 1976	1000	Meeting with Mr. Syed Iftikhar Ahmad and Planning Division Staff, GOP and Mr. Mian Mumtaz Ali, Agricultural Develpment Commissioner, GOP
	1300	Continue study of CSU materials
31 Jan 1976 & 1 Feb 1976		Continue study of CSU materials
2 Feb 1976	0630	Lv. Islamabad via car
	1100	Meeting with Mr. Mommahud Ashraf, Project Director Mona Reclamation Experimental Project and staff.
	1300	Visited Phullarwan and Mona Tubewell 78
	1745	Ar. Mona Colony
		Dinner with staff of Mona Reclamation Experimental Project
3 Feb 1976		Visited Mona Reclamation Experimental Project Tubewell 56
	1415	Lv. Mona Colony via car
		Visited Hussnain R.C.C. Products Co., Sargodha
	1745	Ar. Lyallpur
		Dinner with Punjab Agricultural Research Institute (PARI) cooperators and University Personnel
4 Feb 1976	0830	Lv. Lyallpur via car
		Visited PARI research plots
	1445	Ar. Lahore
		Dinner with SCS-PASA Land Leveling Team
5 Feb 1976	0830	Meeting with Dr. Muhammad Naseem, Director General, Agriculture (Field)
	1000	Meeting with Mr. Mommahud Ashraf, Asst. General Manager, WAPDA and staff
	1230	Meeting with Mr. S.M. Ayoob, Secretary, Irrigation Department
	1400	Visited watercourse near Shahkanjra and Taraq plots
	1800	Lv. Lahore via PK-608
	2000	Ar. Islamabad

6 Feb 1976 thru 11 Feb 1976		Developed report, conclusions and recommendations
12 Feb 1976	1000	Review of conclusions and recommendations with Mr. Joseph Wheeler, AID/D and Mr. Richard Newberg, AID/AG and staffs.
13 Feb 1976		Continued work on report Visited barani areas
	1500	Wrap-up meeting with Mr. Richard Newberg and staff.
14 Feb 1976		Leave Islamabad

OFFICIAL CONTACTS IN PAKISTAN

GOVERNMENT OF PAKISTAN

Syed Iftikar Ahmad	Chief, Water Resources Planning Division
S. Naraid Nasii	Dy. Chief, Water Resources, Irrigation, Planning Division
Mashhood A. Kureishy	Dr. Chief, Water Resources, Reclamation, Planning Division
Mian Mumtaz Ali	Agric. Development Commissioner & Jt. Secretary, Min. of Agric.
Dr. Paul Knowles	Agronomy Advisor, Agricultural Research Council

WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA)

M. Baddarudin	Dy. General Manager (Planning)
Mommahud Ashraf	Asst. General Manager (Survey and Research)
G.R. Purnell	Master Planning Advisor, Harza Engineering Co.

MONA RECLAMATION EXPERIMENTAL PROJECT

Mommahud Ashraf	Project Director
Mohammad A. Qayyum	Technical Officer
Bashir Sabir	Sr. Research Officer (Agronomy)
Dr. Ghulam Haider	Sr. Research Officer (Soils)
Fazil Sabir	Sr. Research Officer (Statistics)
Masud Ahmad Cheema	Sr. Hydrologist
Mohsin Wahla	Sr. Officer (Extension & Training)
Muhammad Jahangir	Equipment Engineer
Shukad Ali	Tubewell Operator
Nazir Ahmad	Tubewell Operator
Muhad Afzah	Asst. Agric. Engineer
Muhad Iqbal	Asst. Agric. Engineer
Muhad Akram	Asst. Agric. Engineer

PUNJAB PROVINCE

Dr. Muhammad Naseem	Director General Agriculture (Field)
S.M. Ayoob	Secretary, Irrigation Department

UNIVERSITY OF AGRICULTURE, LYALLPUR

Dr. Amir Mohammad	Vice Chancellor
Ghulam Sarwar Sheikh	Dean, Agric. Engineering
Arshad Ali	Professor, Agric. Engineering
Dr. Ali Mohammad Chaudry	Dean, Faculty of Agric. Economics & Rural Sociology
Dr. Agha Sajjad Haider	Professor, Agric. Economics.

PUNJAB AGRICULTURAL RESEARCH INSTITUTE, LYALLPUR

S.A. Qureshi	Director, Small Grains Research
Mohammad Hayat Bhati	Prin. Investigator, Agric. Chemistry (Soils)
Nur Mohammad Chaudry	Asst. Botanist (Cereals)

PUNJAB PROVINCE (Continued)

INTEGRATED RURAL DEVELOPMENT PROGRAM

Mushtaq Gill	Agric. Engineer
Sadaq Shafique	Agric. Engineer
Mohammad Hanif	Agronomist
Farzand Ali Akhtar	Development Assistant

COMMERCIAL

Mr. Hassan	Hussnain R.C.C. Products Co. Sargodha (Punjab)

OTHER MISCELLANEOUS CONTACTS

Mohammad Hussain	Sr. Research Officer (Agric. Economics), Mona Project
Abdul Hamid	Exec. Engineer, Mona Project
Bashir Ahmad	Technical Officer, Mona Project
Bashir Ahmad	Jr. Agric. Engineer, Mona Project
Mohammad Azeem	Jr. Agric. Engineer, Mona Project
Mr. Kausar	Agric. Assistant, Mona Project
Colonel Bashir	Commandant, Mona Remount Depot
Major Gardezi	Second-in-command, Mona Remount Depot
Khalil Ur Rehman	Prin. Investigator, National Planning Div., Univ. of Islamabad
Henk Vander Haar	Research Asst. (Holland), Mona Project

USAID - ISLAMABAD

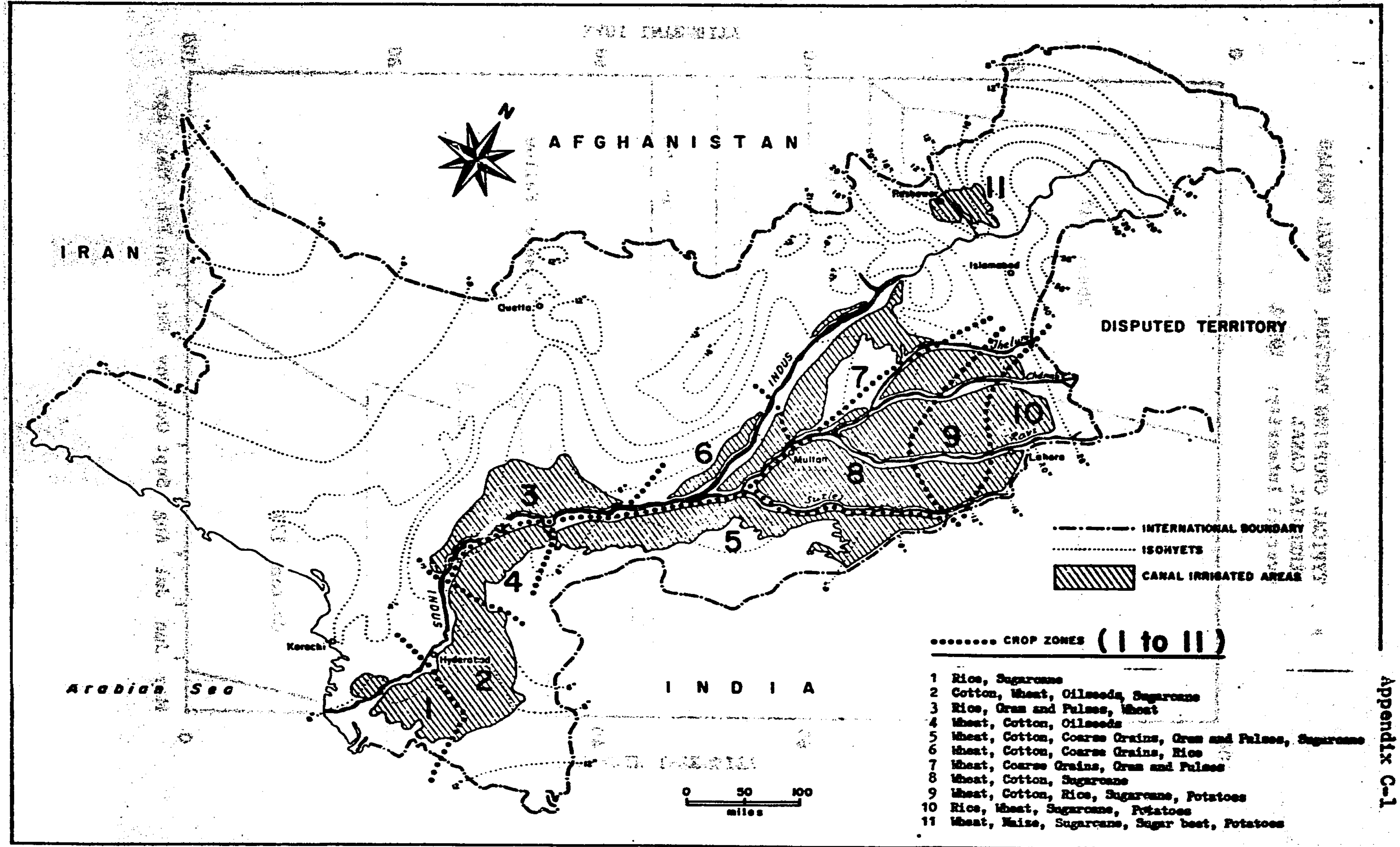
Joseph C. Wheeler	AID/D
William A. Wolffer	AID/DD
Richard R. Newberg	AID/AP
Stanley M. Remington	AID/AP
Niel A. Dimick	AID/AP
Floyd J. Williams	AID/AP
William R. Thomas	AID
Arthur S. Lenzen	AID

COLORADO STATE UNIVERSITY

William D. Kemper	Party Chief
Wayne Clyma	Agric. Engineer
Cornelis J. deMooy	Agronomist
Samuel H. Johnson	Agric. Economist
John O. Ruess	Agronomist
Sidney A. Bowers	Soil Physicist
Alan C. Early	Agric. Engineer
Jerry Eckert	Agric. Economist (TDY)
Max K. Lowdermilk	Rural Sociologist (TDY)

RAINFALL, CANAL IRRIGATED AREAS AND CROP DISTRIBUTION ZONES

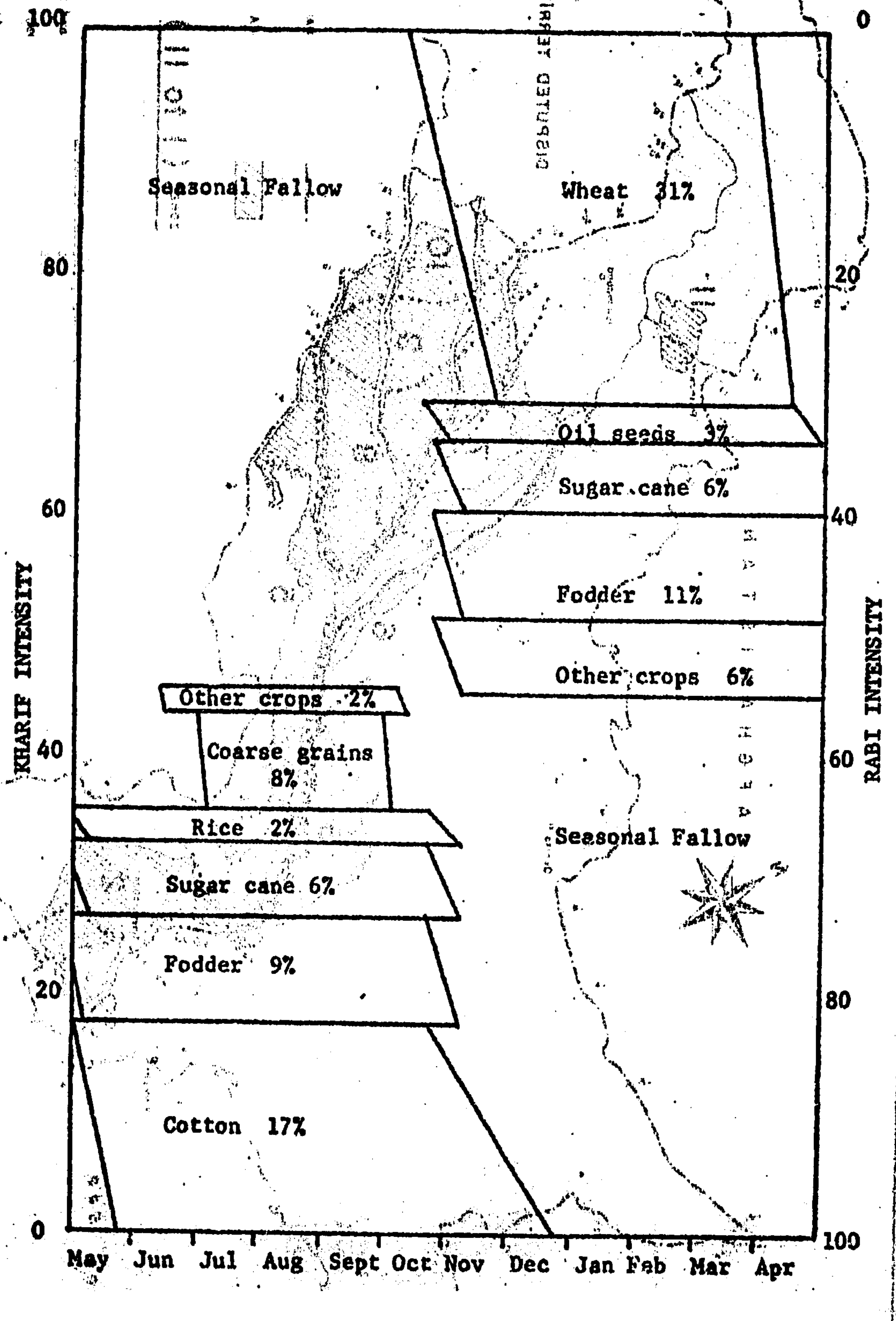
MAP I



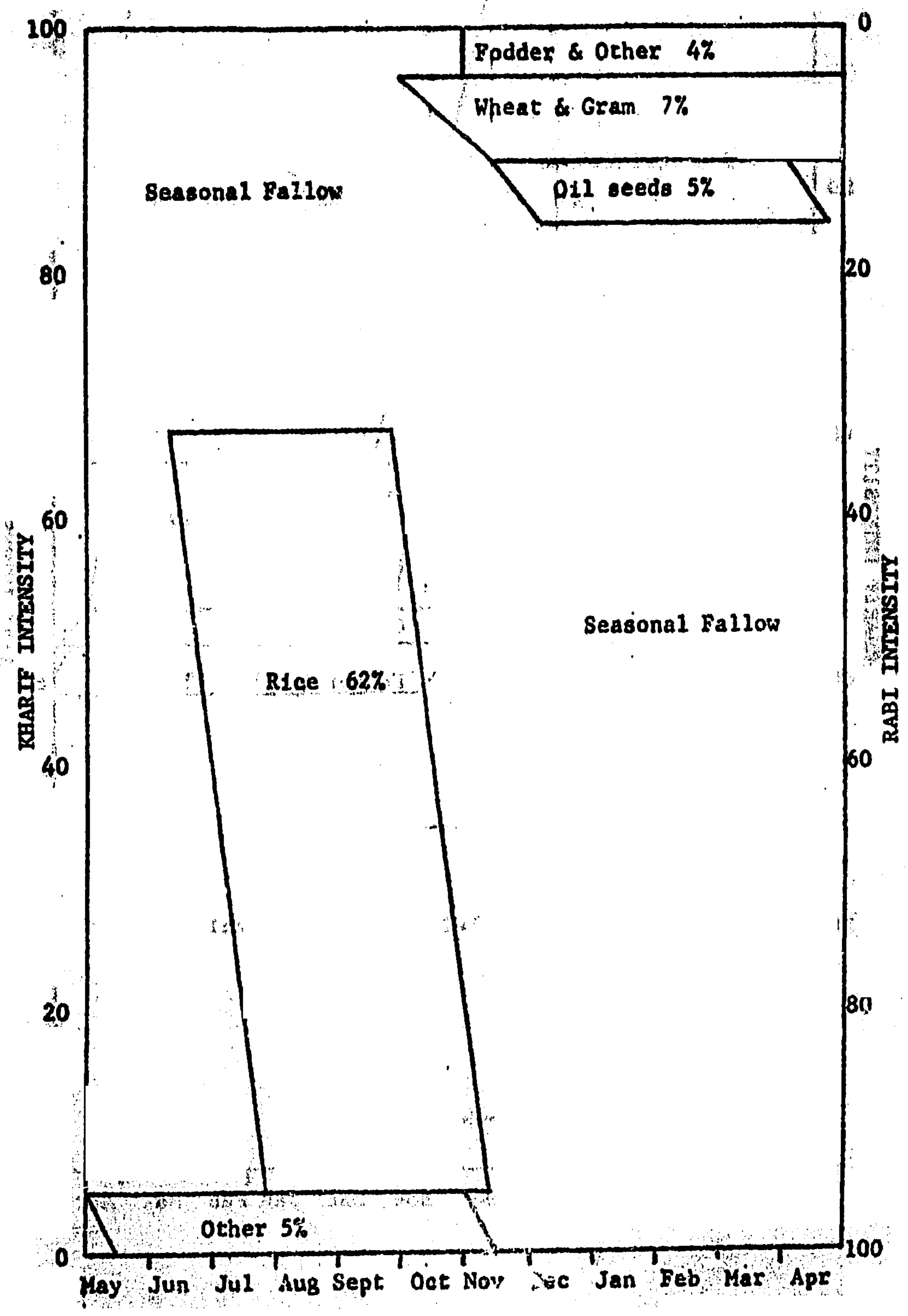
Appendix C-1

Appendix C-2

TYPICAL CROPPING PATTERN, CENTRAL PUNJAB
PERENNIAL CANAL
Overall Intensity: 102 %

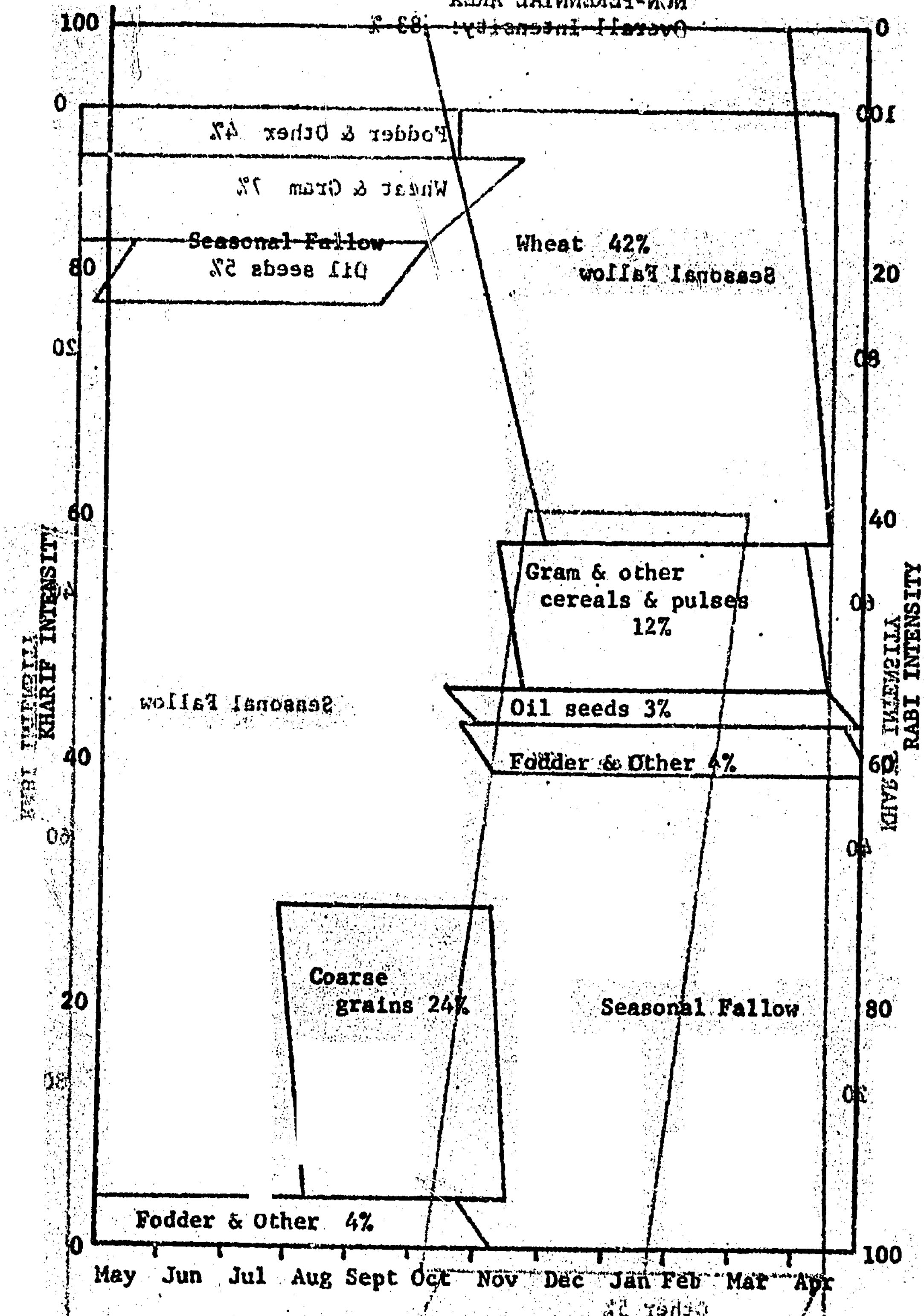


TYPICAL CROPPING PATTERN, SOUTHERN ZONE
NON-PERENNIAL AREA
Overall Intensity: 83 %

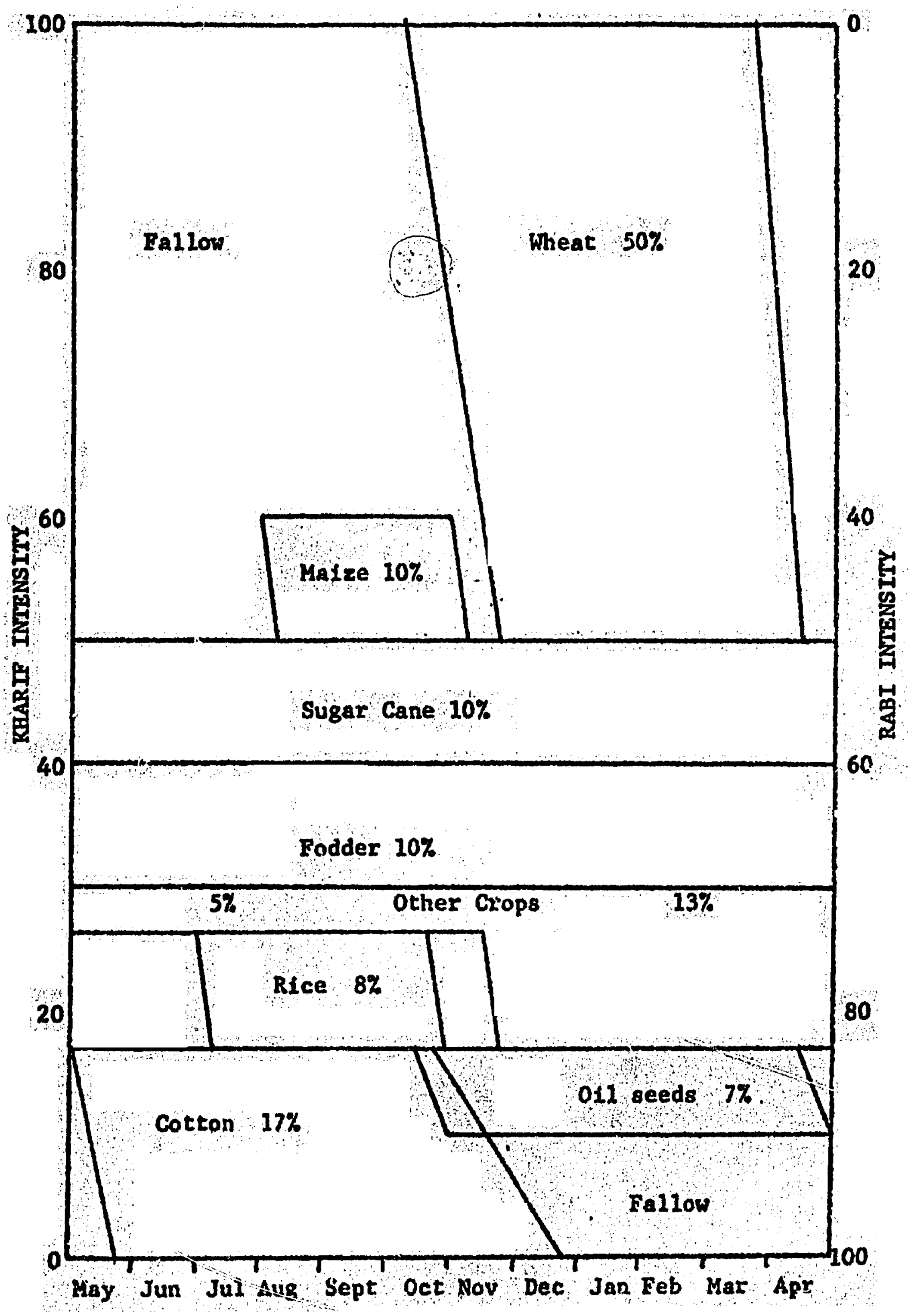


Appendix 4-3

TYPICAL CROPPING PATTERN, NORTHERN ZONE
RAINFED AREA
Overall Intensity: 92 %



TYPICAL CROPPING PATTERN, CENTRAL PUNJAB
CANAL PLUS TUBEWELL
Overall Intensity 150 %



UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
SOIL AND WATER CONSERVATION RESEARCH DIVISION
SNAKE RIVER CONSERVATION RESEARCH CENTER
ROUTE 1, BOX 186
KIMBERLY, IDAHO 83341

FEB 14 1972

February 10, 1972

AIRMAIL

Dr. Omer J. Kelley, Director
Office of Agriculture
Bureau of Technical Assistance
A.I.D., Department of State
Washington, D. C. 20523

Re: Intensive Review of Water Management Research Contracts AID/csd-2162 and AID/csd-2167 with Colorado State University and Utah State University, respectively, January 24-28, 1972

Review Committee: Dr. Marvin E. Jensen, Chairman
Director, Snake River Conservation Research Center, Kimberly, Idaho

Dr. Earl O. Heady
Director of Center for Agriculture and Economic Development, Iowa State University, Ames, Iowa

Mr. Leland Anderson, Deputy Assistant Director/ Agricultural Policy, USAID/Pakistan

Dear Dr. Kelley:

As requested in your letter of January 17, 1972, our team conducted a thorough, on-site review of the water management research contracts at Utah State University (USU) on January 24 and at Colorado State University (CSU) on January 25. At USU we spent most of the time with Dr. H. B. Peterson, Project Director and Dr. B. C. Palmer, Project Field Director because most of the assigned staff members are located in the field. Project leaders involved in the discussions were Drs. J. E. Christiansen, J. P. Riley, K. Unhanand, D. W. James, and A. LeBarron. At CSU we were able to discuss project activities with Dr. M. Albertson, Project Director, and each project leader from the six departments, (Drs. A. T. Corey, W. R. Schmehl, E. V. Richardson, K. C. Nobe, G. N. Jones, and D. M. Freeman), and other assigned staff members.

2/14/72

Dr. G. Corey, Party Chief, was not available. Additional discussions were conducted in Washington, D. C. on January 27 during a special review meeting held in Rm. 2884 of the New State Building (See attached agenda).

These two projects represent a major effort on the part of two universities, and according to Dr. Long, represent a significant portion of AID's central research program. Our team is well aware of the magnitude of these projects and their costs, but we also are aware of the tremendous impact improved on-farm water management can have on food production in less developed countries. Improved on-farm water management is essential over much of the world to realize the full potential increases from new varieties and fertilizers. Improved water management will also minimize the frequency and intensity of soil water deficits with its resulting detrimental effects on plant growth. The development and implementation of improved water management practices, however, will not be as rapid as changes in varieties or the addition of fertilizers. Research and application of improved on-farm water management is complex because it involves the management of crops, soils, fertilizers, rainfall, irrigation water, excess or drainage water and soil salinity in an integrated manner. Improved on-farm water management also usually requires capital outlays and improved practices must take place within the socio-economic constraints of the region.

Our team reviewed the projects relative to the broad, general objectives stated in the contracts, but placed more weight on those activities that were directly associated with on-farm practices. Most of the recommendations that follow are of a positive nature since we feel that both projects should be continued through their original durations, and should be extended for another three- to five-year year period to capitalize on the developing technology and scientific expertise at thse universities. We have, however, delineated several weak areas and have suggested modified approaches for project components.

Reasonable progress has been made in both contracts with some project objectives essentially attained. At USU, for example, several multivariable comprehensive field experiments are nearing the second crop year in South America; evapotranspiration deficit maps have been completed and printed for Ecuador; a water balance-salinity model is being evaluated in Colombia, and Chile has sent two engineers to USU to study methodology for using the model; and a water law digest of Latin America is nearing completion.

CSU has expanded the theory for operating "skimming wells" to remove fresh water from the aquifer without or with a minimum of saline water entering the wells; the development of a comprehensive bibliography on Pakistan Government and Administration and water related publications is nearing completion; a thorough analysis of soil samples from 11 representative soil profiles from Pakistan is near completion at CSU for sand, silt, and clay mineralogy, the dissolution potential of calcium-bearing minerals, and other chemical analyses related to exchangeable sodium and salinity; a multivariable experiment has been initiated in Pakistan to evaluate the effects of mixing saline well water with good quality canal water; and a movie has been prepared on land forming principles and techniques.

RECOMMENDATIONS: (Additional detail is given in the next section of this memorandum)

A. Funding:

1. CSU-AID/csd 2162 - We recommend maintaining the current level of funding, but encourage streamlining project management to reduce administrative costs. We also recommend limiting funding of projects to those needed to obtain immediate goals, increasing the field program relative to on-campus activities, and bringing more experience in on-farm water management research into project direction and management.

2. USU-AID/csd 2167 - We recommend increasing the level of funding for Utah State University to cover increased costs encountered due to increased salaries, overhead, allowances and travel requirements during the fiscal year to cover home leave or return of field scientists and their families. Project costs have been proportional to field activities in the development of the projects and opportunities are currently available for expansion of the program if funds are available.

B. Contract Direction and Management:

1. CSU - We recommend increasing the on-campus competence in on-farm water management in order to guide the funding of those projects that are more relevant to the immediate goals and to select those projects having a higher payoff potential.

2. We recommend a more active coordination of research planning, data analysis, and joint development and use of models for on-farm water management between the two universities.

3. We recommend CSU reconsider those project proposals for Pakistan which are not being activated by field counterparts. Vocal support without follow-up action implies Pakistan doubts about the merits or relevance of the projects.

4. We recommend that CSU reassess its priority rating of problems and the approval of project components. Some project components such as those conducted by the Civil Engineering Department appear to be premature relative to immediate goals.

5. We recommend that a clear policy be established on delineating priority problems. Once major research objectives are established, sufficient time must be allowed to develop, initiate and complete the research. These priorities can not be changed annually, or as AID Mission personnel changes if a viable research program is to be implemented in the field.

6. We recommend that CSU social science research focus on problems more specific to on-farm water delivery and use for agriculture.

7. We recommend that CSU scientists from the various disciplines should work jointly from the onset in selecting, formulating, designing and conducting the experiments.

8. We recommend that the economic research under both contracts oriented to water use and productivity be much more closely related to the specific problems for which the project was funded, and be a more highly integrated approach to major and common problems.

9. We recommend that future modeling work at CSU be an adaptation and quantitative application of models which generate solutions for the particular agro-climatic, water supply, and economic conditions of Pakistan.

10. We recommend that CSU adopt a funding policy that will encourage greater participation of scientists in off-campus research efforts with some regular support and guidance provided by senior scientists.

11. We recommend that USU select countries for field research projects in a more systematic frame-work so that the results will have greater generalization, cover a greater range of agro-climatic conditions, and have the largest economic payoff.

C. Specific Project Suggestions:

1. We recommend that CSU consider the existing Pakistan water delivery system as fixed in an alternative approach to developing improved on-farm water management practices. This approach would, in essence, consider the present operation of the canal network as an efficient system for delivery and recharge of an efficient ground water reservoir from which the bulk of the crop water requirements can be drawn by tube wells as needed and with great flexibility.

2. We recommend that both CSU and USU first compute the basic crop water requirements for all crops involved by growth stage and then use field experiments to validate the generalized computational procedures.

3. We recommend that CSU develop procedures to enable local research institutions to obtain field capacity data in situ instead of the 1/3-bar determinations which generally are not representative under all soil profile conditions.

4. We recommend that existing physical-biological-chemical plant growth models be adapted for predicting crop growth and that complex field experiments involving soil-water, fertilizer, and plant density be used to validate the predictions or calibrate the models for local use.

5. We strongly recommend that some projects with short term goals, but with high pay off potentials be initiated to develop confidence and rapport with the university scientists and to develop local support for the broader, more basic generalized, apsects of the research program.

6. We recommend that an entire water course in Pakistan be completely modified to demonstrate the best available technology and validate basic assumptions involved in the development of improved on-farm water management technology under the existing social and legal constraints, and technical capabilities.

III. ANALYSIS AND JUSTIFICATION FOR ACTIONS

B-2 University Coordination - While CUSUSWASH exists as a communication medium between the two universities, sufficient coordination of work is not yet evident. We recommend a more active coordination of research in terms of problem definition, applied models, research designs, problem coverage and general intellectual activities. This need extends beyond merely keeping each other informed and could even result in the joint preparation of models and methods of research and in generalizing findings for use in other countries for improved on-farm management of water.

B-3 Project Revisions - CSU should revise or prepare new field proposals for Pakistan. These projects should be less complicated and should be directly oriented toward short-term goals of improved on-farm water management. As these projects are completed, and as their benefits are demonstrated within test water courses, approval of future projects by Pakistan research and action agencies will move more rapidly. Action support should increase and vocal support without action should diminish.

B-4 Project Control - Since many projects and project components involve adaptive research, and many projects must be completed in sequence to continue progress toward immediate goals, a system for project control with approximate time tables should be considered at CSU to guide funding project components. Such a system also will simplify communication with AID relative to progress toward contract objectives.

B-6 Social Science and On-Farm Water Management Research - A large amount of work and output already has been attained at CSU in the general social sciences, particularly political science and legal aspects. Thus far, work in these fields has been descriptive of: (a) institutional, social, legal, natural, administrative and other variables and phenomena which condition agricultural development; and (b) the laws upon which water use and distribution is based in Pakistan. In general, much of the work in political science is broader than the problems of on-farm water use and management and has reference to conditions which may retard or promote agricultural progress generally in less developed countries. We recognize that much of this work has been conducted under funding other than this specific contract. However, for future work in the social sciences, we recommend that the focus be on research and problems more specific to on-farm delivery and use of water for approved agriculture within the context of the project. Future emphasis should be more precisely on analytical methods, quantitative models and operational procedures which serve as direct guides in the improvement of administrative and legal structures which promote greater efficiency in on-farm water use. In this context, work in the social science fields may need greater direct integration (e.g., to not stop with a bibliography of Pakistani water law, but to specify legal structures consistent with quantitative findings of economists of the value or marginal productivity of water used for different locations, crops, seasons, water sources, etc.).

B-7 Interdiscipline Projects - Both universities have drawn a relevant set of disciplines into their projects. An important opportunity for productive interdisciplinary research thus prevails for the future. However, we believe that there is not yet (a) evidence of sufficient interdisciplinary interaction in the design of specific research projects, or (b) prospects for coordinated solutions of prevailing problems. While the various disciplines are present, active communication of personnel from different fields prevails and a common language is evident, especially at Colorado State University, it does not appear that sufficient effort has been devoted to joint: (a) selection of the facets of particular problems to be tackled; and (b) design of approaches for researching them. This appears to be especially true between: (1) economics and the social sciences; and (2) engineering and the physical sciences. Economics and sociology appear more as "elements which have been appended", rather than sciences which have had an integral part in the selection, design and pursuit of research directed to particular problems. Rather than an associated but somewhat independent set of individual projects selected by scientists from separate disciplines, we recommend a much more highly integrated approach to major and common problems. In other words, scientists drawn from relevant disciplines should work jointly from the onset in defining the dimensions of the problem, in designing methods to quantify or solve it and in concurrent implementation of the research. We recognize that frequently only two or three disciplines can readily engage effectively in an interdisciplinary problem and that problems of high priority specific to a given discipline often prevail. However, presence of a group of persons from several disciplines working on independent problems which fall under a common umbrella does not necessarily provide an integrated interdisciplinary research program. In a similar context, research or experimental designs could better reflect the parameters necessary for both physical and economic on-farm improvements in use of water and other interacting resources.

B-8 Economics Research - Research and knowledge in agricultural economics still is lacking in both Latin America and Southeast Asia. However, research devoted to general problems of the agricultural sector (e.g., demand structure, aggregate supply response, general policies) could better qualify under projects other than those specifically oriented to on-farm utilization and management of water. We recognize, of course, that certain problems of more efficient use of water and related resources to promote economically efficient production increases frequently are external to the farm. We also recognize that there were initial phasing or sequencing problems (especially for Utah State University) in locating and initiating physical research to which economic research could then be related. For the future, however, we recommend that the economic research under both of these contracts oriented to water use and productivity be geared much more closely to the problem set for which the projects are funded. The problems selected for economic analysis should more nearly be central problems of water management and use. While demand, supply and policy analysis in general are relevant research topics in the countries involved, the justification for their pursuit should be under other projects funded by AID. Policy problems to be incorporated in water use and management projects would more nearly, for example, appear to be those of water pricing (or non-pricing), credit programs to allow sufficient investment in fertilizer, seeds and equipment for efficient use of water, effect of alternatives in water investment and use on employment and income distribution, districting and distribution to overcome farm externalities affecting water returns, tenure modifications to improve water use, etc. More specifically, central on-farm projects would seem to relate particularly to: (a) integrated research with agronomists to quantify interactions among water, fertilizer, salinity, soil and climate with economic mixes prescribed accordingly; (b) application of conventional programming models to determine efficient management programs for: (1) farmers with unlimited water supplies; (2) farmers with limited water supplies; (3) farm groups with externalities in water use; (c) multiperiod models to analyze multiple cropping and interperiod uses of water for maximum returns; (d) definition of optimal investments in water distribution and application equipment in interaction with cropping systems; (e) deriving normative values and demands for water as a basic for scheduling prices, equity payments and compensation, restructuring water laws, etc.; (f) developing efficient village systems of water delivery where inter-farm externalities in water use prevail; (g) applying stochastic models for efficient conjunctive use of climatic, underground and canal water supplies, and etc. In general, the emphasis should be on the adaptation and application of on-farm models to solve the specific economic problems of efficient water use by the various strata of farms in the major water supply regimes and regions.

B-9 Application and Validation of Models - A considerable proportion of the research on the Colorado State University campus has been devoted to general modeling. These efforts have resulted in an output of rather broad theoretical nature and applicability. For future progress in on-farm water management, emphasis should be on the adaption and quantitative application of models which generate solutions for the particular agro-climatic, water supply, economic and institutional conditions of Pakistan. These models can illustrate the general applicability of modern models and computer solutions or simulations devoted to the parameters of water management under particular conditions. In the course of changing the focus to greater emphasis in the application and adaption of models to the specific problems of Pakistan, greater attention also needs to be given actual interdisciplinary coordination and integration of the work. In the case of Utah State University, it is possible that some additional effort should go into on-campus development of applied models to be later applied and validated in the field.

B-11 Systematic Selection of Projects - Utah State University has effectively responded to country and mission demands. This response has allowed the university to initiate a country program directed to specific water management problems in Latin America and to have early "visibility in the field"; to augment the knowledge of its specialists of Latin American on-farm water management problems and their solutions; and to build up the body of knowledge that these specialists have extended to other countries.

However, for the remainder of the current project and for extensions of it over the years, we recommend that the university attempt to select countries, agro-climatic locations and water problems on a more systematic frame-work in terms of research approach and results which: (a) have greater generalization; (b) cover a larger realm of agro-climatic conditions; and (c) pose the largest economic pay off in terms of commodities, resources and countries included. We recognize that this shift in emphasis requires greater set-up time and program costs, than does responses to situations which provide opportunities of immediate implementation. However, given the degree of success in short-run program implementation, we believe that greater focus now be given to longrun returns in terms of breadth of country resources included and regional application. Future budget allocations and gauges of project progress should recognize the greater complexity and costs inherent in a research program which searches out problems and locations for more systematic and broader applicability, than one which is characterized by response to situations where conditions allow immediate implementation.

C-1 Capitalizing on the Merits of Existing Water Distribution Network - The research results from most CSU research proposals imply severely limited adoption or utility until massive water distribution system and delivery practices are changed. Short term projects should consider the existing water distribution systems as a stable, effective means of recharging the ground water reservoir with some water delivered directly to the land. Tube wells should be considered as the primary source of irrigation water to meet variable crop water requirements with on-farm land leveling and water distribution systems developed to optimize crop production within a water course. Long term studies should consider conjunctive use of canal and ground water to minimize salinization problems, and legal studies should consider the required legal framework.

C-2 Delineating Crop Water Requirements by Growth Stage - Basic crop water requirement data for each major crop by stage of growth are necessary to optimize water course water distribution systems in Pakistan. These data can easily be obtained with sufficient accuracy for short term goals by adaptive research. Procedures developed at USU may suffice for the potential evapotranspiration component. As field experiments are conducted these calculations can be verified by soil sampling or neutron scattering techniques. Projects underway or being initiated by the Agronomy and the Agricultural Engineering Departments will provide validation data if the required measurements are made.

C-3 Soil Parameters for Irrigation Design - The initial soil analyses conducted on-campus at CSU provide valuable basic data on mineralogical and plant nutrition characteristics of soils. However, procedures should be developed to enable securing field capacity data in the field instead of the 1/3-bar laboratory measurements since field capacity is strongly influenced by soil profile characteristics which cannot be preserved in small disturbed or undisturbed samples. Effective field capacity is also a function of evapotranspiration.

C-4 Crop Growth Models - Complex, multivariable field experiments involving irrigation, fertilizer, plant density variables provide a wealth of data, but are expensive to conduct and are very time consuming. The research results could be generalized to a greater degree if existing plant growth models were adapted to this problem or new models were developed utilizing basic plant growth model components. There are several such models under development or testing by other research institutions.

Sincerely yours,

Marvin E. Jensen, Chairman
Review Committee

(Retyped)

January 17, 1972

Dr. Marvin E. Jensen
Director, Snake River Conservation
Research Center
Route 1, P. O. Box 186
Kimberly, Idaho 83341

Dear Dr. Jensen:

As you are perhaps aware, AID is reassessing many of its activities and concentrating on reworking, if required, some of its on-going research projects. This is being accomplished by a series of intensive project reviews.

Our intensive project review is composed of several distinct parts. One of these is concerned with obtaining an outside evaluation of our projects by competent scientists. It is this task with which we are asking you to assist us. Your recommendations are made to this office for our use in our further evaluation of the work.

The basic objective of these reviews is to arrive at recommendations which will be presented to the Technical Assistance Bureau (TAB), the Research and Institutional Grants Council (RIGC), the Research Advisory Committee (RAC) and the Administrator for continuing, modifying, reducing, increasing, transferring or terminating individual projects or parts of projects.

This letter is to inform you that our Water Management Research Contract No. AID/csd-2162 and AID/csd-2167 with Colorado State University and Utah State University, respectively, will be reviewed during the week of January 24 to 28, 1972. We request your cooperation and participation.

The Review Committee will be composed of the following:

1. Dr. Marvin E. Jensen, Director, Snake River Conservation Research Center, Kimberly, Idaho.

2. Dr. Earl O. Heady, Executive Director of Center for Agriculture and Economics Development, Iowa State University, Ames, Iowa.

Dr. Marvin E. Jenser

3. Mr. Leland Anderson, Food and Agriculture Officer, USAID/ Pakistan, Rawalpende, Pakistan.

Prior to the review, you and the contractor will be provided with background information including: the RAC approved Project Summary Statement, minutes of RIGC and RAC meetings concerning the project, the Contractor's Annual Report, and a list of issues for consideration in the review. Also, a Committee briefing will be the first order of business at Utah State University when the Team convenes there on the 24th of January. It is planned that the Team make an On-sight Review at Utah State University on 24 January and Colorado State University on 25 January 2972. Most of the 26th would be used in travel to Washington. Team business would be completed in Washington on the 27th and 28th of January. Representative of this office and from both Utah State University and Colorado State University will be available in Washington for further consultation or explanation.

The Review Committee will enter into executive closed session at the appropriate time during the review to arrive at its conclusions and recommendations. It will be responsible for preparing a concise report of recommendations on (1) funding level, (2) actions to be taken, (3) parties responsible for each action, and (4) an analysis that explains and justifies the recommended actions.

The office will contact you concerning travel, per diem, and other arrangements.

I look forward to your participation in the project review as described.

Sincerely,

/s/ Madison Broadnax

Omer J. Kelley, Director
Office of Agriculture
Bureau of Technical Assistance

TA/AGR/OD/ADAyers:gt:1/17/72

Appendix E-1

THE IMPORTANCE OF FARM WATER MANAGEMENT IN PAKISTAN

Field Report No. 2

by

Wayne Clyma and Gilbert L. Corey

Prepared under support of

United States Agency for International Development
Contract No. AID/ta-c-1100
Water Management Research
in Arid and Sub-Humid Lands of the
Less Developed Countries

Colorado State University
Pakistan

September 1974

Appendix E-2

THE IMPORTANCE OF FARM WATER MANAGEMENT IN PAKISTAN

Wayne Clyma and Gilbert L. Corey

Abstract

A combination of events have resulted in intensive studies and major programs related to irrigation water management in Pakistan. These studies have all emphasized the necessity of controlling waterlogging and salinity and of increasing irrigation water supplies. The rationale on which all these studies have been based is that most (63 to 85 percent) of the water delivered to the canal outlet (mogha) is stored in the farmer's field and used by the crop. Studies over the world have suggested that such efficiencies may average nearer 40 percent and will frequently be lower.

Data from field observations of farmer practices and watercourse losses in Pakistan suggest that in SCARP areas this efficiency may average as low as 12 percent. Thus, there is great need in Pakistan for a program to improve on-farm water management in order to repress waterlogging and salinity as well as to provide more water for increased crop production. A number of practices that will improve on-farm water management are suggested.

Table 1. Water Loss Estimates from the Canal Outlet through the Farmer's Fields as Assumed by Various Studies.

Source	E_i	E_c	E_a
Lower Indus	67.5 (although the measured value was 50-60)		
Revelle Report	85 1/		
Harza	68	90	75
Tipton & Kalmbach	70	90 1/	78 1/
Gibb	65		
World Bank	63	90	70

E_i = irrigation efficiency = $\left(\frac{E_c}{100} \cdot \frac{E_a}{100}\right) 100$

E_c = water conveyance efficiency = $(W_c/W_{co})\ 100$

E_a = water application efficiency = $(W_{et}/W_a)\ 100$

W_c = volume of water delivered by the conveyance system

W_{co} = volume of water delivered to the conveyance system

W_{et} = volume of irrigation water stored in the soil and removed by evapotranspiration.

W_a = volume of water applied to the area ($W_a = W_c$)

1/ Derived from statements or calculations.

Table 2. Irrigation application efficiencies[1/] observed at Mona on traditionally farmed fields (from Clyma, Arshad and Ashraf, 1974b)

Application Efficiency Interval (Percent)	Crop: Wheat	Crop: Sugarcane	Crop: Fodders	Crop: Misc.	Total for Interval	Percent of Total Number of Observations Interval	Accum.
0 10	2	4	4	3	13	20	20
10 20	8	5	2	2	17	26	46
20 30	2	8	4	2	16	25	71
30 40	2	2	3		7	11	82
40 50		1		1	2	3	85
50 60			2	1	3	5	90
60 70		1			1	2	92
70 80							
80 90							
90 100		4	1		5	8	100
Total	14	25	16	9	64	100	

1/ Application efficiency = $\frac{\text{amount of water stored in the root zone}}{\text{amount of water applied to the field}}$

Appendix F-1

ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE

ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Via delle Terme di Caracalla, 00100-ROME Cables: FOODAGRI ROME Telex: 61181 FOODAGRI Telephone: 5797

Ref.

Dear Mr. Vice-Chancellor,

In accordance with our agreement of 18 October 1975, I have pleasure in sending you herewith the summary report of the International Conference on Waterlogging and Salinity held in Lahore from 13 to 18 October 1975. The report has been edited by us and I understand it will be published by the University, together with the Conference papers.

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The document is based on a consensus of the participants of the Conference, and particularly of the three Working Groups on Water Supply and Drainage, Soil and Water Management (at the farm level) and Agricultural Support Services respectively. The team of FAO officials and consultants has contributed to this consensus, and its views are largely in line with the conclusions reached. The team has been requested, however, to make a further contribution by briefly commenting on some major issues and concepts discussed at the Conference in the light of the Government's Accelerated Programme of Waterlogging and Salinity Control.

CONTROL OF WATERLOGGING AND SALINITY REQUIRES BETTER ON-FARM WATER MANAGEMENT

The Accelerated Programme provides for the construction of tubewells, the phased implementation of outfall drains, tile drainage and surface drainage for storm water discharge. These are all needed activities outside the scope of the individual farmer. There is no mention of improvement of on-farm water and soil management practices. It is recognized in Pakistan, however, that the considerable inefficiency in water use at the farm level and the otherwise inadequate irrigation practices contribute directly to waterlogging and salinization or sodization. It also implies that good quality water is lost while pumped water may be more salty and more expensive too. The team believes that any programme aiming at controlling waterlogging and salinity must include on-farm activities to conserve water and apply it to the land according to crop needs.

ON-FARM DEVELOPMENT : A GOVERNMENT RESPONSIBILITY

On farm development does not take place, or at least not at the desired rate, if left entirely to the farmers themselves. The farmers' knowledge of how to improve water courses, how to prepare land for irrigation, how to schedule water applications, how to irrigate the land and of how to adapt soil tillage and related

Prof.Dr. M. Islam Sheikh
Vice-Chancellor
University of Engineering and Technology
Lahore
Pakistan

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cultural practices is usually insufficient. They need help in these and other technical fields. They also need financial facilities and assistance in getting themselves organized and prepared to effectively participate in the improvement of their soil and water use.

The brochure on "Proposals for an Accelerated Programme of Waterlogging and Salinity Control in Pakistan, Government of Pakistan, Planning Commission, September 1973" does not include specific programmes for on-farm water and soil development as a means to better manage these resources and prevent waterlogging and salinization

In the view of the team, the Government should be instrumental in promoting on-farm development and should assume direct responsibility for, and leadership in, its planning and further guidance, through the establishment of the required institutional framework, the technical and scientific backstopping, and related activities.

IMPROVED ON-FARM WATER AND SOIL MANAGEMENT REQUIRES MOBILIZATION OF HUMAN RESOURCES

The absence of waterlogging and salinity is in itself no guarantee for better crop yields. It has become clear that in most improved areas, i.e. in areas where water of good quality is available in reasonable quantities, where salinity is not a problem and where the water table is deep, agricultural production has not come up to expectations. This suggests that other factors have become critical and that work must now be done on these. Better still, work should be done on them simultaneously with water development and drainage activities. The constraints relate primarily to farm level operations in soil and water management. The technical solutions are available. What is needed is the mobilization of the available human and financial resources to effectively implement the solutions.

FARMERS' PARTICIPATION THROUGH INCREASED KNOWLEDGE

Full and active participation of the farmers, in all stages of planning and implementation, of on-farm development programmes is indispensable. To obtain and maximise this participation, the farmers should acquire a clear view of the constraints and possibilities, solutions to problems and the related costs and benefits. There should be a continuous flow of knowledge from educational, research and governmental agencies to the farmers. There should also be a flow of information from the farmers back to these agencies. The team concurs with the recommendations to better achieve this aim.

WATER MANAGEMENT SPECIALISTS NEEDED

Improved irrigation and soil management at the farm level requires the services of engineers specially trained for that purpose. This type of agricultural engineer is presently being educated in small numbers at the Lyalpur Agricultural University. Reinforcement of the curriculum in irrigation and drainage, however, appears necessary at this university as well as at others. Of equal importance is the establishment of programmes in vocational training: they will be instrumental in the transfer of knowledge, particularly to extension services and, ultimately, to the farmer.

A SPECIAL WATER AND SOIL MANAGEMENT SERVICE IN THE MINISTRY OF AGRICULTURE

Water and soil management engineers are unlikely to make a significant impact unless they can work within an established institutional framework. The team agrees with the suggestion to establish, at the provincial or national level, a Water and Soil Management Service that would serve to co-ordinate and direct all ongoing and planned programmes in this field. Given its immediate scientific and technical ties to crop production, such a Service should preferably be housed in the Ministry of Agriculture.

AREA DEVELOPMENT PROJECTS UNDER UNIFIED COMMAND

Improved production requires a multidisciplinary approach. To that end the team considers development on an area basis as having considerable advantages over a sub-sector approach. Since the technology and expertise are available, the implementation of large-scale Area Development Projects may be embarked upon without delay. Effective implementation requires a unified command, i.e. a project administration that is responsible - and has the authority - for all phases and all types of development work, whether improving irrigation canals, installing tubewells, supplying seeds and fertilizers to farmers, or improving water courses and irrigation practices. Regarding the latter, much can be accomplished by utilizing the manpower that is abundantly available in the rural areas, thus keeping cash layouts to a minimum.

TUBEWELLS : TO BE CONTINUED AND EXPANDED, BUT COMBINED WITH PROGRAMMED MAINTENANCE OPERATIONS

Tubewells have played a major role in lowering the water table and in providing additional irrigation water. The programme should be continued and expanded wherever soil and groundwater quality permit. There are obviously problems of corrosion and encrustation, operation and maintenance, but it is believed that these can be overcome and that they do not provide a reason to cut back on the programme. The suggestion to embark on a programme to restore and maintain the capacity of tubewells as well as to demonstrate systems of inspection that provide advance information on maintenance needs, is fully endorsed.

For some time in the future there is probably little danger of groundwater mining by the wells because of the inhibiting economics of deeper pumping unless crop yields are significantly increased. Before groundwater mining becomes a major issue the Government of Pakistan should develop a national policy on the extent to which it is desirable to regulate private tubewell drilling and pumping. Irrigation farmers using tubewells will need reasonable advance notice of any such policy so as to amortize their capital investments in wells and related equipment.

WATER QUALITY : NEED FOR A NATIONAL POLICY

The water supply delivered to farms is limited in quantity and quality. Continued use of tubewells intensifies quality considerations. Therefore Pakistan should give serious consideration to a national policy regarding the future use of good quality surface water for reclaiming lands; using such water for reclamation increases water shortages for good land especially during the rabi season. When the quantity of a renewable resource is limiting production, then the optimum "matching of resources" for maximum production is essential. For maximum agricultural production Pakistan should treat its water and land in this fashion by using its surface water on its best lands first.

Several quality standards have been proposed over the last several years to govern the use of tubewell water. Recent research shows that, under specified conditions, the 1954 USDA standards may be relaxed. Standards, however, should be assessed in relation to such factors as climate, irrigation practices, drainage and soil type. It is therefore unlikely that one set would equally apply to all of the Indus Basin. Rather, standards must be developed area-wise.

The recommendation to develop models which would permit to forecast the effects of recirculation of salts and the long-term response of salty groundwater bodies to pumping is strongly endorsed.

DRAINAGE : TILE DRAINAGE TO BE INITIATED, SURFACE DRAINAGE EXTENDED TO FARM LEVEL

Horizontal drainage is the normal alternative to water table control where tubewells are not feasible. This may refer to open ditch drains, tile drains, or a combination of both. There is a vast expertise available on either, for widely differing conditions in many humid and arid regions of the world. As a rule, it would therefore appear possible to embark on implementation of tile and other drainage schemes without resorting to prior elaborate research programmes. Normal design surveys in project areas, possibly coupled with quick field tests, are probably sufficient.

Disposal drains are also needed when tile drainage is applied and the team concurs with the recommendation that studies be initiated to assess their urgency in various areas.

Surface drainage (primarily for overland flows) should not be restricted to major channels but should include minor drains at the farm level. The Government should provide guidance to the farmers for design and construction of these, as part of overall farm water management.

The report contains recommendations for action that serve to obtain improved production at a sizeable scale in a short period of time. They relate to the immediate initiation and establishment of area development projects, pioneer projects and educational research and institutional programmes. These projects and programmes are all urgently needed. They are also interdependent, the success of each depending on progress made with the others. Simultaneous undertaking of each is therefore essential. FAO is prepared to provide any further assistance that may be needed.

I should like to thank you sincerely, Mr. Vice-Chancellor, for the opportunity the team was given to participate in the discussions on waterlogging and salinity problems whose solutions are of so great importance to Pakistan. I hope that the views outlined briefly above, as well as in the reports of the Working Groups and in the recommendations for follow-up action, will contribute to serving the goals that you have set for the Conference.

Yours sincerely,

Pieter J. Dieleman
Team Leader
Water Resources, Development and Management Service
Land and Water Development Division

Publications Resulting Directly

from the

USAID

Water Management Research

Contract

with

Colorado State University

WATER MANAGEMENT TECHNICAL REPORTS*

Consortium for International Development

Colorado State University
December 1975

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8	The Problem of Under-Irrigation in West Pakistan: Research Studies and Needs, ID70-71GNJ-RLA19	G.N. Jones R.L. Anderson	53
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10	Maximum Water Delivery in Irrigation	J. H. Duke, Jr.	213

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6. Watercourse Losses By: Wayne Clyma, Arshad Ali, M. Ashraf	Proceedings of Lyallpur CENTO Conference 1975
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24.	Fertilizer or Salt Leaching as Affected by Surface shaping and placement of Fertilizer Irrigation By; Kemper, Olsen & Hodgdon	Soil Sci Soc Amer. Proc. Vol.39, pp 115-119
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(A PROPOSAL)

IMPROVED WATER MANAGEMENT IN WATERCOURSE COMMAND AREAS

On January 8, 1976, a meeting was convened by the Secretary, EAD, including the officials of the Federal Ministries and representatives of the Provincial Governments to discuss the various issues concerning the implementation of the pilot- experimental program during the next Five Year Plan which will have three major purposes:

(a) to bring about a significant increase in water-use efficiency;

(b) to develop and test technology and operational and administrative procedures for carrying out a large scale program of the type found technically feasible;

(c) to develop institutional capability and train manpower for the large program.

Decisions reached at this meeting and subsequently conveyed to USAID representatives, who later joined the meeting were:

1. that the project should proceed and include an integrated program with the following elements:
   - Improvements of those water delivery systems which have been identified as having high losses.
   - Precision leveling of land to permit uniform application of desired amounts of water.
   - Training of farmers on optimal irrigation timing and application rates and other cultural practices to optimize yields from available land, water and other inputs.

2. that the overall implementation and coordinating responsibilities at the Center will rest with the Ministry of Food, Agriculture and Rural Development and at the Provincial level, the respective departments of agriculture will undertake implementation of the project and that the coordinating responsibility will rest with the planning and development departments.

3. A committee was appointed at the Center including:

Mian Mumtaz Ali
Agricultural Development Commissioner
Ministry of Food, Agriculture & Rural Development.

Mr. Syed Iftikhar Ahmad Shah
Chief, Water Resources Section
Planning and Development Division

Mr. Ch. Altaf Hussain
Chief Engineering Advisor
Ministry of Fuel, Power and Natural Resources

to work with USAID personnel to develop a tentative project proposal and to carry out the discussions with the provinces regarding:

(a) details of the project design;

(b) assignment of responsibilities; and

(c) project implementation.

4. That the water management program will be carried out in all the four provinces but this might include scheduling of various elements of the project at different rates in different provinces.

5. That each province participating must prepare a PC-1 in consultation with USAID and Federal Government officials and get those approved in time for fiscal 76-77 funding. Further, all funds included for each province must be reflected in the annual development program of the province.

6. The Central, USAID and Provincial personnel working on project formulation will recommend a funding level for the fifth Five Year Plan. The proposed level should be conservative recognizing the possibility for augmentation in later years of the plan period, should the project progress as satisfactory as anticipated.

In a subsequent meeting between the Central committee members and USAID officials, it was decided that a working paper should be prepared so that more meaningful discussion contact can be held with the provinces. The material that follows constitutes this working paper. Whereas the section on project design is an extension of the various elements outlined in report entitled, "Improved Water Management in Watercourse Command Areas", circulated by USAID in the 1st week of January, new material has been added on (a) technical approach; (b) operational and administrative design; and (c) financial plan.

1. Project Design

Realizing that considerable efforts are still required to establish the operational feasibility of the program on a large scale, it is suggested that, in the initial stages, the project should be designed to be experimental and pilot in nature. Project of this scale can help in developing institutional capabilities and generate information for rapid project expansion. Operationally the project would best be restricted to one major area in each province. To be consistent with the concepts and the experimental objectives, each province should select a geographic unit which includes:

- both SCARP and non-SCARP areas
- both perennial and non-perennial canal areas.
- areas having low levels and areas having high levels of salt contents in the ground water.

Each province should attempt to identify and propose areas, which, as far as possible, should represent sub-areas characteristic of each of the above. To permit flexibility and objective application of criteria in selection of watercourse, each province should select an area approximately 10 times the size of the actual project. Once the project areas are earmarked, the following are the planned steps and activities for project implementation.

II. Technical Approach

The project will provide a combination of 1) watercourse reconstruction and improvement, 2) precision land leveling and 3) extension of modern irrigation and irrigated cropping techniques.

1) Watercourse Reconstruction will primarily mean reconstructed earth ditches with concrete structures. Most of the high water losses on

desi watercourses occur due to over topping, seepage through porous ditch banks and leaks at nakkas and junctures. Reconstructing the ditches to proper design specifications will prevent over-topping. Cutting down old ditch banks and replacing them with fresh earth will eliminate most of the extreme porosity causing seepage through the banks. Concrete structures of an inexpensive design have proved effective for eliminating leaks at nakkas and junctures.

Recently completed test watercourses have shown that in order to serve each square of land with an improved ditch, approximately 40 feet of watercourse must be reconstructed per acre of commanded area. Best current estimates of the cost for such reconstruction with installed concrete structures runs Rs. 4/- foot. Costs per acre will be Rs. 160/-. Seventy five percent of the delivery losses can be prevented for 80 percent of the delivery distance to the average field or a total of 60 percent (.75 x .80) of all delivery losses prevented.

On some soils it will be necessary to line portions of the watercourse. This will occur on very sandy soils where seepage is important and in selected areas (Baluchistan highlands) where water is extremely costly to develop. Of the lining techniques that have been thoroughly tested thus far, concrete lined, trapezodal cross section watercourses have the best benefit-cost ratio. Other designs currently being tested, such as soil cement brick and soil cement plaster may prove equally effective in reducing losses but considerably cheaper

For the present, the best approximation of cost for a concrete lined trapezoidal ditch capable of carrying 1-3 cusecs of irrigation supplies is Rs. 30 per foot including structures. Due to this high cost, lining must be limited to the main channel exclusively not to exceed approximately 20 feet per acre commanded. Total watercourse improvement cost would average about Rs. 600 per acre. Ninety percent of the losses for 70 percent of the delivery distance to the average field would be prevented. Hence 63% (.90 x .70) of total losses would be prevented.

The program will improve 1500 watercourses within five years. Of these 90 percent or 1350 watercourses will be reconstructed of earth with concrete structures. It is estimated that on 10 percent of the watercourses most of the main channel will be lined. In both cases, the engineering would be provided by the project. For improved earth watercourses most of the effort is labor and will be provided by the farmer. Concrete lining can be done by the farmers, their local masons or by private contractors.

2. Precision land leveling constitutes the second major element of the program. Even applications of irrigation water cannot be made unless the fields are adequately level. Without engineering, it is very difficult to achieve an adequately level field of any size and without efficient earth moving equipment it is very expensive.

The primary technique to be used for land leveling focuses around a tractor drawn scraper which has been extensively tested in Pakistan and is now in commercial production and use. The method is relatively efficient and inexpensive and obtains field levels suitable for the most modern irrigation techniques.

The project will, again, provide the engineering skills. Approximately two-third of the leveling expected in the first phase will be done by farmers using already owned or leased equipment. One third will be done by private contractors who specialize in land leveling.

Approximately 40% of the land leveling effort will be within the watercourses being reconstructed. The remainder will be in surrounding areas as farmer demand arises.

3. Extension is the third major component and one which is essential if the expected benefits of land leveling and watercourse improvements are to be achieved.

Farmers obtain very low yields per unit of water stored in the root zone. Modern irrigation practices and crop prodduction methods are largely unknown. Plant-soil-water relationships are neither adequately researched nor extended in Pakistan. If given better knowledge of techniques, farmers could achieve higher efficiencies in delivery and application even with existing ditches.

For these reasons, the program will include a strong extension component. This extension effort will differ in its substance from any currently available in Pakistan and consequently will require substantial retraining of extension staff. The concepts and practices to be extended include the following and others:

New methods of irrigation

Plant-soil-water relations

- Maintenance of field level
- Maintenance of watercourse improvements
- Interaction between irrigation and fertilization

It is expected that this program will be delivered by a field team composed as follows:

- One team leader
- Two watercourse engineers
- Five land development officers
- One AA level extension person
- One FA level extension person

This team can complete the reconstruction of a cluster of five watercourses in one year. At the same time they can complete the leveling of approximately 150 acres in each of the five watercourses plus an additional 1000 acres in surrounding areas. After having had one year exposure to the farmers of the five project watercourses in a cluster, the FA level extension person would remain permanently assigned to provide intensive extension of modern irrigated cropping patterns to those same watercourses. The rest of the team, at the close of one year would select a new cluster and implement the program at the new locations. A replacement FA will join the project each time a new cluster is begun.

III. Administrative and Operational Design.

Given the magnitude of the problem, the wide dispersion of the 88,000 watercourses, large area involved (30 million acres) and the investment required, it is clearly evident that the Government cannot carry out a program of watercourse improvement and land leveling directly for farmers. In fact, evidence indicates that when farmers plan and carry out improvement themselves the results are more favourable and more enduring. It will be necessary therefore for the Federal and Provincial Governments to develop means for stimulating joint and collective farmer planning and improvement actions, to facilitate establishment of private contractors to assist in specialized construction, and stimulate domestic production of the specialized equipment required. The Government's functions then will be:

to explain needs for and benefits from the program, motivate farmers and guide them in initial preparation of proposals for a feasibility studies;

technical assistance to farmers in conduct of feasibility studies on watercourse command area;

technical and financial review of the feasibility study and, as appropriate, provision of financial assistance partly as credit and partly as cost-sharing grants.

stimulation, training and some financial assistance to potential contractors to enable them to develop their capability for specialized watercourse construction and precision land leveling;

technical guidance on production of specialized equipment (this is already well advanced);

integrated training of private and government personnel as required for different functions and activities;

technical and financial evaluation and research and, as appropriate, redesign of the project;

preparation of plans for an expanded program when research and evaluation indicate this is appropriate.

Assignment of administrative responsibilities must be made to appropriate existing or new provincial agencies and plans and schedules prepared for achievement of operational capability of these agencies for:

1) Establishment of mechanism for coordination in inter-agency activity in the provinces (assigned to P&D on January 8 meeting) and overall operational responsibility (assigned to Agriculture).

2) Dissemination of information on project benefits and motivation of farmers and assistance to farmers individually and collectively in preparation of proposals for project assistance. This is an activity that might well be assigned to the extension service with its field assistants and to the IRDP with its network of development assistants.

3) Establish specifications and technical monitoring mechanisms. This requires specialized engineering and agronomic capability. This probably should be assigned to the same agency that will undertake feasibility studies on project watercourses. AG ENG Sec. Agr. Dept.

4) Conduct individual watercourse command area feasibility studies on proposals received. This is a specialized and somewhat complex activity involving a very substantial amount of highly trained engineering skill plus some agronomic, economic and administrative inputs. Given the relative importance of engineering this might be

assigned to Agricultural Engineering Section in the Department of Agriculture, and this section also be given the overall project responsibility. A number of permanent positions of agronomist, economist and administrators must be assigned to this section alongwith required additional engineering positions.

5) Design equipment, develop and establish manufacturers.

Equipment design action probably should be assigned to the same agency assigned responsibiiity for (4) above.

6) Provide Credit.

The provision of credit including review of feasibility studies and the financial feasibility should be separated from the feasibility study assistance function described in (4) It should be assigned to a specialized financial agency such as the National Bank of Pakistan or Agricultural Development Bank. The agency having responsibility for provision of credit and cost sharing would be expected to have sufficient expertise to conduct occasionally on-site inspections particularly pre-construction inspection and inspection of obs partially completed and final inspection before final payment is made.

7) Provide cost-sharing arrangements.

As in the case of credit this should be separated from the technical assistance described in (4) to insure independent review and evaluation. To improve efficiency and reduce administrative overhead, this function might be assigned to the agency which provides credit.

8) **Establish private contractors.**

The establishment of private contractors involves two major aspects; (i) the training of managers and technical personnel and (ii) provision of credit and tractors permits, etc. The technical aspect probably should be assigned to the same agency assigned the technical responsibility described in (4) The credit and tractor allocation functions might best be assigned to the same agency assigned credit and cost-sharing responsibility (6 and 7 above).

9) Establish an integrated training program.

Major responsibility for the integrated training program probably should be assigned to the technical agency given responsibility for (d) with some inputs from other agencies having specialized responsibility such as the credit and cost-sharing agency. Beyond that integrated training, some specialized training probably will have to be provided by each agencies for its own personnel.

10) Execute construction work.

The technical assistance on surveying, staking and on monitoring and checking for satisfactory completion should be assigned to the agency given responsibility in feasibility studies (4). The same agency should be responsible for both land leveling and water channel improvement. This agency also might provide some assistance in the first year on on-farm water management and water application. Thereafter the extension service would be expected to provide technical assistance to farmers. The actual construction would be either by the farmer or by the private contractor or by the combination of these, not in any case by the government.

11) Research and evaluation.

The project is to be carried out in four provinces. To ensure that all benefit from the collective experience in the four provinces, assignments should be made for coordination of research and evaluation. This probably should be the responsibility of the members of committee appointed at January 8 meeting, working in cooperation with the Agricultural Research Council, WAPDA through Mona Research Project and IRDP and the responsible provincial implementation agency.

IV. Financial Plan

It is our understanding that a sum of Rs. 20 crore is being allocated for on-farm water management project in the Fifth Five Year Plan. This allocation is based on an expected contribution of Rs. 10 crore by USAID, the balance to come from other donors and the provincial governments. With an equal contribution by the private sector, 40 crore rupees would become available for the project under reference. On the basis of the technical approach described under section 1, 1500 watercourses, each with an average command area of 400 acres, will be improved and approximately 527,500 acres will be precisely leveled. Details on the utilization of the allocated amount are presented below:

A. 1500 Watercourses

1. Watercourse command area is 400 acres each in Punjab and Sind and 150 acres in N. W. F. P.

2. Costs will be shared 60:40 with the Government taking the larger share.

a. Improved Earth Watercourses

1. To reach all sanctioned nakkas, a distance of 40 feet per command acre must be improved.

2. Assumed cost of improved earth with pacca structures is Rs. 4.00/foot.

3. 90% of project watercourses to receive this type of program.

Cost of Improved Earth Watercourses

(1350 watercourses x 400 acres x 40 ft/ac.

x Rs. 4.00/ft. x .6 Government Share) = 5.18 Crore Rs.

b. Concrete Lined Watercourses

Assume: 1. It will be necessary to line 10 per cent of the project watercourses.

2. Costs for concrete trapezoidal ditches run Rs. 30/ft. including structures.

3. Lining will be only done on the main watercourse which is equivalent to 20 feet/command acre on most layouts.

Cost of Lined Watercourses

(150 Watercourses x 400 acres x 20 ft/ac.

x Rs. 30/ft. x .6 Government Share) = 2.16 Crore Rs.

B. Balance Between Watercourses and P. L. L.

1.	Improved Earth Watercourses	5.18 Crore
2.	Lined Watercourses	2.16 Crore
3.	Total Watercourses	7.34 Crore
4.	Total Government Budget	20.00 Crore
5.	Balance for Land Leveling	12.66 Crore

C. Precision Land Leveling

Assume: 1. Cost Shared at 40% Govt., 60% Farmer

2. Total Cost Rs. 600/ac.

3. Government Share Rs. 240/ac.

12.66 Crore for Precision Land Leveling at 240 Rs./ac.

will complete:

527,500 acres

D. Approximate Provincial Distribution

Province	Percent	Improved Watercourse	Acres Leveled
Punjab	50	750	263,750
Sind	33	500	175,833
NWFP	10	150	52,750
Baluchistan	7	100	35,166

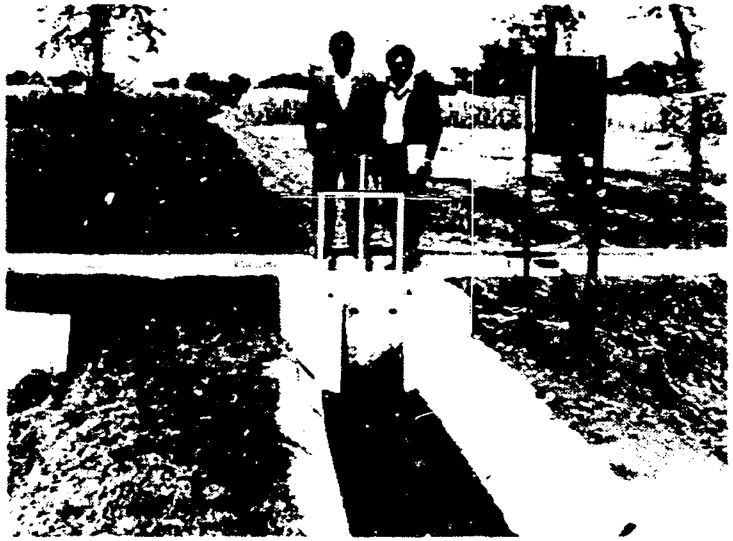
Appendix I-1

A. A typical branch watercourse showing grassy, porous banks. Note tree growth that consumptively uses water and occupies croppable areas (Mona Irrigation Project TW-78).

B. Tubewell 78 and junction in foreground with 13½ rectangular brick masonry channel lining. (TW-78 Main 1, see Figure 6)

C. Cutthroat flume operating in 13½ rectangular brick, masonry channel lining near site of photo B, above.

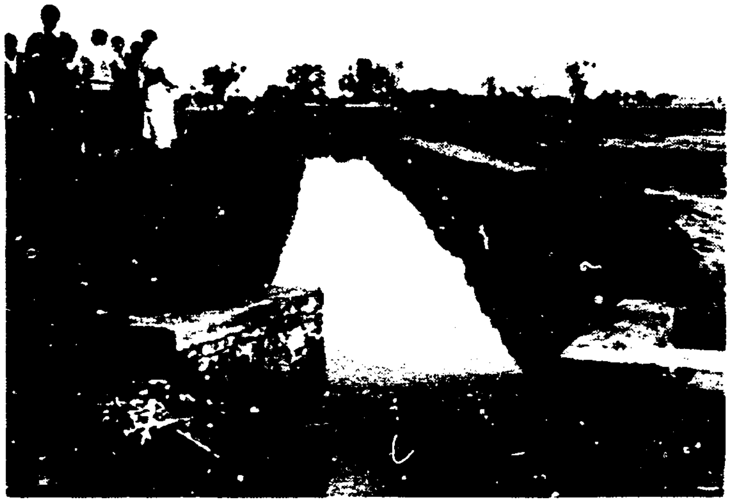
D. Rectangular brick masonry channel lining on Main 1 of tubewell 78 watercourse.



A. Trapesoidal concrete lined branch of Main 1, tubewell 78, showing metal and concrete inclined sliding gate, the latter designed and installed by Bill Hart.

C. Mogha (turnout) from distributary to watercourse (TW-56).

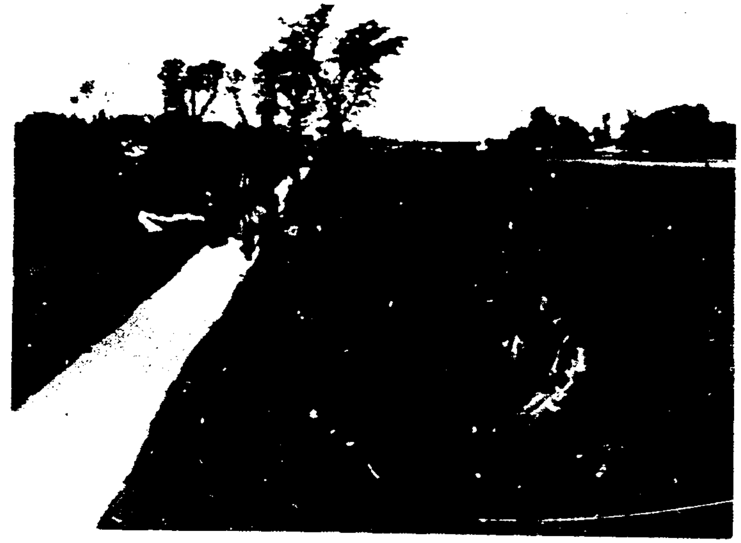
B. Inclined concrete sliding turnout (nakka) designed by Bill Hart for trapesoidal channels.



D. Settling basin to trap sand immediately downstream from Mogha shown in Photo C above.

A. Rehabilitated watercourse (TW-56) immediately downstream from foreground in Photo C, Appendix I-2.

B. Farmer-organized committee answering questions posed by review panel. Extension specialist (wearing checkered hat at left) organized farmers and is acting here as an interpretor.



C. Rehabilitated watercourse (TW-56). Note remnant of former watercourse at right and tree removal to allow straightening of channel.

D. Turnout (nakka) and check gate with concrete plugs designed by Dr. Kemper, one in main channel (center) and one in branch watercourse (at left).

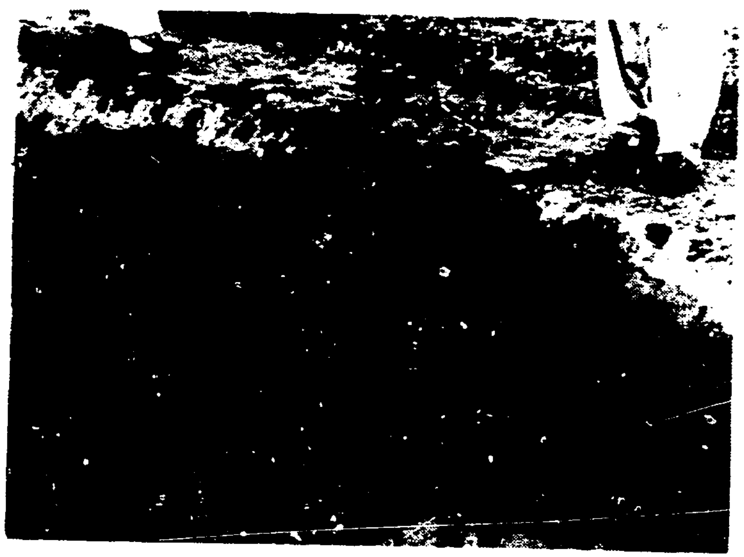
A. Concrete pipe turnout (nakka) prior to installation.

C. Nakka with experimental sponge rubber seal being tested as substitute for mud seal in buffalo wallow shown in Photo D below.

B. Dr. Kemper sealing annular ring around concrete plug with mud to form a water tight seal.

D. Buffalo wallow as part of watercourse. Note brick steps at center for animal use and brick walls that line edges of wallow.

A. Clothes washing facility immediately upstream from buffalo wallow shown in Photo D, Appendix I-4.

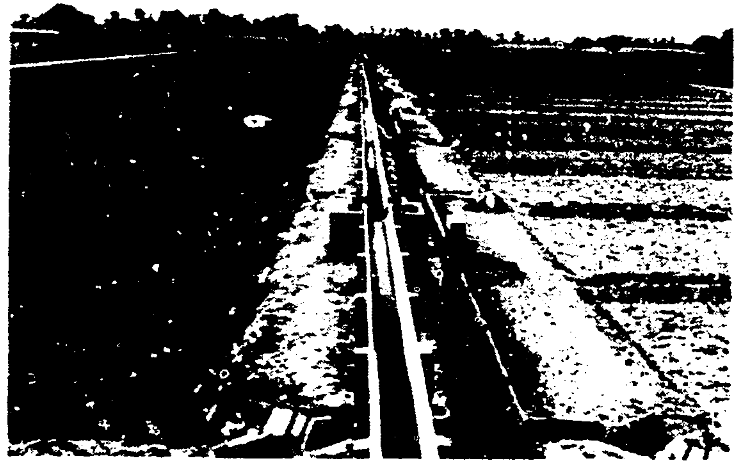


B. Example of rodent burrows that cause excessive channel leakage. Burrows will be plugged when rehabilitation of watercourse is complete.

C. Rehabilitation in progress on the Kanjra watercourse near Shadab. Work is being done by CSU students Shafique (at left) and Gill (left rear) to fulfill M.S. degree requirements.

D. Weather station to measure solar radiation, temperature, humidity, wind speed, and evaporation near site of Photo C above to determine feasibility of scheduling irrigations using soil, crop, and climatic inputs.

A. Section of rehabilitated watercourse downstream from site shown in Photo Appendix I-5-C. Leakage from original watercourse caused poor wheat stand at right.



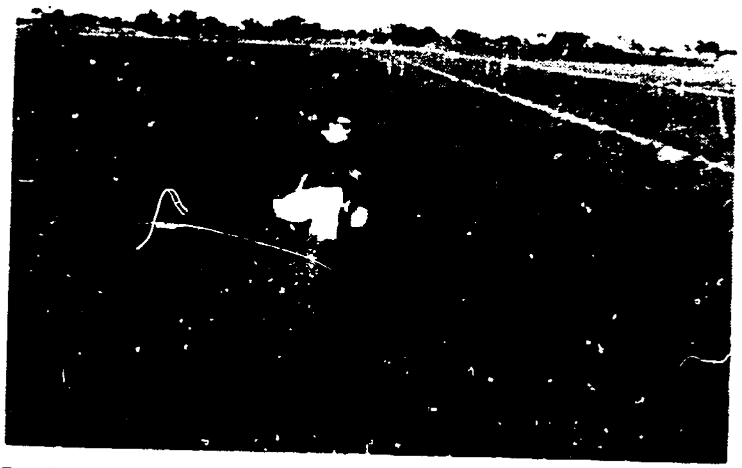
C. Consumptive use plots (left) and water quality plots (right) on the Punjab Agricultural Research Institute. Water applied to plots is measured volumetrically.

B. Branch I lined with soil-cement bricks one layer thick. Work was done by farmers located on unlined branch of TW-78 (see Figure 7, I_2).

D. Skimming well on Mona Reclamation Experimental Project (WAPDA). Water samples at predetermined depths are being taken using evacuated sampling bottles.

A. Optimum management plots showing leveled borders planted to wheat by farmer using traditional fertility, irrigation and seeding (broadcast). Note sparse stands.

C. Demonstration plots near site in Photo A, Appendix I-5. Farmer in photo stands in plot he managed using traditional fertility (50# N/A), seeding, and irrigation practices.



B. Same as Photo A above but fertilized with 125# N, 50# P, and 25# K using tractor driven rabi drill.

D. Plot adjacent to one in Photo C above with improved fertility (75# P and 80# N) and an additional 50# N at second irrigation.