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**ANNUAL PROGRESS REPORT
FOR WATER MANAGEMENT RESEARCH PROJECT
FOR YEAR ENDING OCTOBER 31, 1970**

Submitted to

**The U. S. Agency for International Development
Contract AID/csd-2162**

December 31, 1970



**Colorado State University
Fort Collins, Colorado**

SUMMARY

Significant Results and Utilization

The project is centrally funded by AID/Washington. Recommendations and advisory council are provided by CUSUSWASH in cooperation with AID's Research Advisory Committee. The Project Director, Dr. Maurice L. Albertson and staff of Colorado State University are shown on the Organizational Chart, Section I.

The general objective of this research project is to increase food production in West Pakistan through the improvement of water management practices to optimize economic returns from limited water resources.

Dr. Gilbert L. Corey, Chief of Party, reports encouraging contacts and planning results with GOP's Agriculture Research Council (ARC) and the Agriculture Research Coordination Board (ARCB) the responsible agencies for coordinating research programs throughout West Pakistan.

University personnel provided by CSU have made a good start through meaningful contacts with Pakistan officials resulting in coordinated planning and activation of some of the many research projects contemplated.

The University has successfully reached its objectives through research activities initiated in local GOP institutions. However, CSU's research specialists report some delays in project activation due to non-action or slow reaction of GOP personnel. Nevertheless, project research objectives will continue to be developed cooperatively with appropriate Pakistani personnel and CSU's policy will continue to be in an advisory, co-worker, or counterpart capacity rather than in planning and performing research activities themselves.

OUTLINE OF
ANNUAL PROGRESS REPORT FOR THE PAKISTAN
WATER MANAGEMENT RESEARCH PROJECT
FOR YEAR ENDING OCTOBER 31, 1970
(November 1969-October 1970)

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SECTION I. INTRODUCTION

This report continues the reporting of progress, as requested by AID/Washington, for the period November 1, 1969 through October 31 1970, for the Colorado State University project, "Water Management Research in Arid and Sub-Humid Lands of Less Developed Countries," Contract Number AID/csd-2162 and Amendments 1 and 2.

The general objective of the CSU research effort is to increase food production in the arid and sub-humid lands of the less developed countries through the improvement of water management practices and the integration of these with other good management and cultural procedures. Research is aimed at water management problems in the semi-arid lands of West Pakistan, but the results will be applicable in principle to similar conditions in other regions. This improvement of water management practices is necessary to obtain maximum economic returns from limited water resources and such inputs as improved seeds, increased use of fertilizers and pesticides, and supporting institutional structure.

During this reporting period CSU on-campus research projects, as outlined in Amendment 2 of the AID Contract, have been continued. On the basis of the on-campus research activities, research projects have been initiated in Pakistan to be performed by Pakistanis.

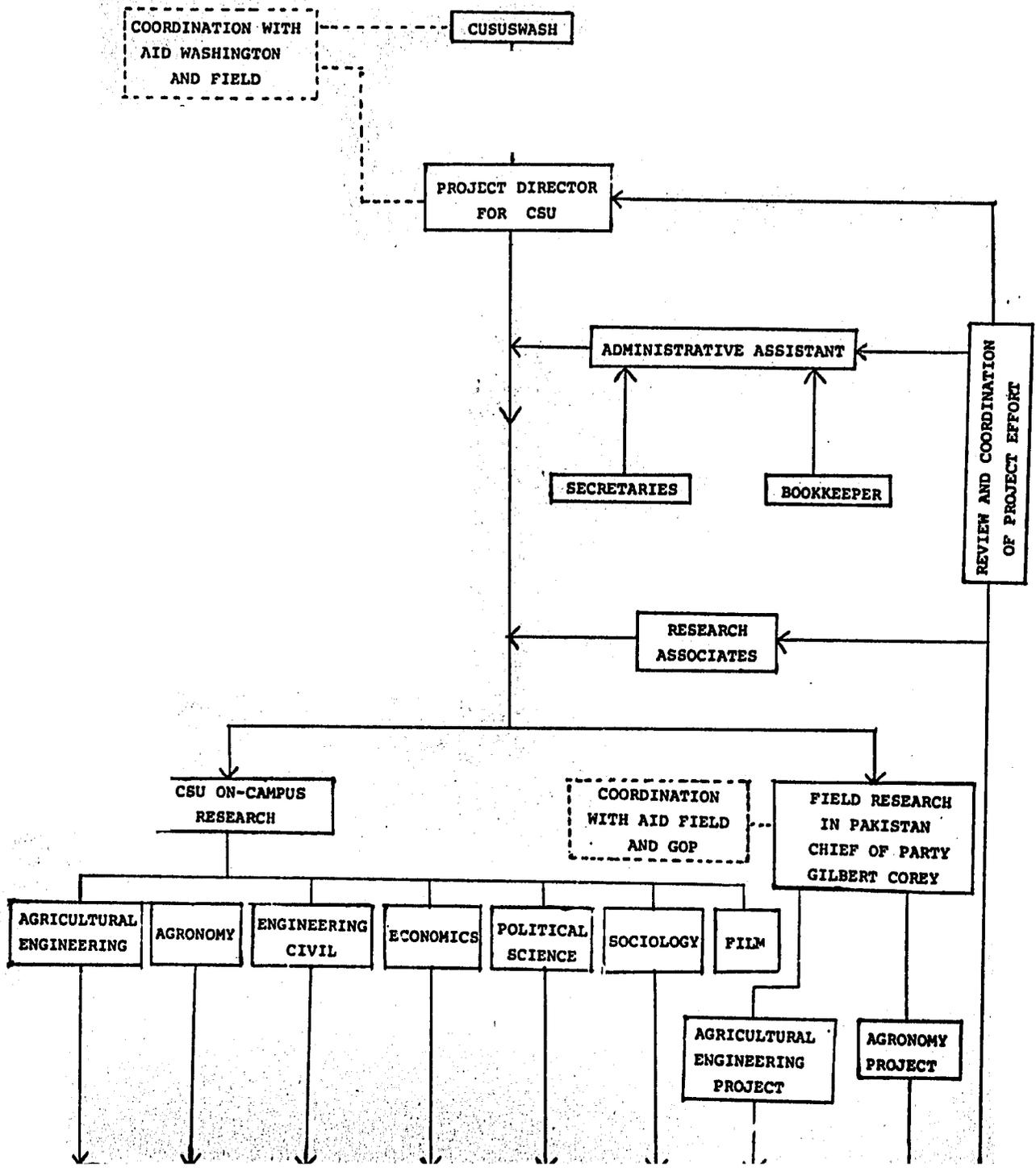
This report includes a general summary of activities in Pakistan, covering the following:

1. Progress made on the Film on Land Preparation for Level-Basin Irrigation,
2. CSU on-campus activities,
3. Water Management Project meetings,
4. Foreign travel,
5. List of project personnel, and
6. Project Contract.

Appendices A and B give the project plan for the two on-going research projects in Pakistan.

For lines of authority and responsibility please consult the Organizational Chart below.

WATER MANAGEMENT RESEARCH PROJECT



SECTION II. ACTIVITIES IN PAKISTAN

The CSU Chief of Party (Agricultural Engineering), Dr. Gilbert L. Corey, arrived in Pakistan on 27 August 1970. After a short period of orientation and getting "settled" in Lahore, a great deal of time was spent contacting Pakistani agencies and visiting agricultural areas to become acquainted with water management problems. By 1 November a total of 29 days had been spent in the field.

Previous contacts had been made by CSU specialists relative to initiation of research projects in Agricultural Engineering and Agronomy as established in the Project Agreement. Visits to Pakistan by CSU faculty and staff are summarized in Section VI. Foreign Travel. The Agricultural Engineering and Agronomy Department projects were initiated and presently are in progress. Details appear later in this section.

Discussions have been held with several GOP agencies relative to the possibility of working with them on water management research. A few of these plans may be slow in developing but most show good promise. These are summarized here:

1. Department of Agricultural Engineer - WPAU: A project involving village practices and interactions with water management practices and a project to study methods of irrigation including basin, border, furrow, and sprinkler. This department has the capability and equipment to pursue these studies.

2. Department of Rural Sociology - WPAU: A project involving social factors which explain on-farm water management decision making behavior. A project proposal has been developed by the CSU Sociology Department in cooperation with the Department of Rural Sociology and funds are being sought to initiate the first stage.
3. Water and Soils Investigation Division WAPDA (WASID): This agency is very receptive to technical assistance in water and soils which CSU can give. The Division is looking forward to the arrival of the soils scientist. WASID seeks advice on methods of monitoring the SCARP areas. This agency collects tremendous quantities of data on water quality, soil salinity, and agricultural production. However, the quality of data collection must be improved. Several discussions have already taken place regarding CSU's assistance to WASID.
4. Mona Project (WASID): This is a pilot project where WAPDA is attempting to develop methods and procedures of water management. Research and demonstration plots are located throughout the project area.

The scientists operating this project are also very receptive to advice from CSU specialists. Two visits to the area have been made.

5. Directorate of Agricultural Engineering: The CSU Agricultural Engineering Department project is presently working in cooperation with this agency. They are, however, interested in expanding this study into other areas of farm water control. Recently 60 additional acres of land was acquired primarily for this purpose.

An attempt is being made to combine most of these proposed projects into one water management project to facilitate fund requests from the GOP Agricultural Research Council (ARC). It is hoped that combining projects will also create closer working relationships between agencies doing similar research.

Two research projects are presently underway in the vicinity of Lyallpur. These are field experiments involving on-farm water control. In each, wheat is the present crop and plans include carrying each experiment through a sequence of crops for several years. Details are given below:

1. Water Control and Land Preparation: This project, involving hydraulics of border irrigation, is being carried out at the Machinery Demonstration Unit farm of the Directorate of Agricultural Engineering, Lyallpur, in cooperation with the Department of Agricultural Engineering at CSU. A detailed project proposal is included in Appendix A.

Early in September 1970 a 20 acre field was selected for the experiment. It has since been leveled to zero grade, the

tillage treatments applied, wheat planted and fertilized, and the borders constructed. To date one irrigation treatment has been applied.

The Directorate of Agricultural Engineering (WPAU) has indicated a keen interest in water management research. This agency is an arm of the Agriculture Department and one of its functions is to provide engineering services to land owners desiring land leveling for better water management. Therefore, if this agency through its own research can demonstrate better design, the impact should be felt country-wide. The Director is presently considering use of plots to demonstrate better water management procedures.

Water Quality-Leaching Fraction Experiment: This project involves the management of irrigation waters of varying salinities and is being carried on by the Punjab Research Institute, Lyallpur, in cooperation with the Department of Agronomy - CSU. A detailed work plan is included in Appendix B.

In order to have a supply of saline water, it was necessary to construct a tube well at the site. Since the location is near the center of the doab it was felt that saline water would be available. To date the tube well has been drilled and tubing and pump are being installed. The water is very saline, but a detailed analysis is not yet available.

The wheat varieties have been planted, salinity sensors installed, and the plots have been laid out. Since the tube well was not finished the first irrigation was applied with canal water on all plots. It is expected to start the varying salinity water levels during the second irrigation treatment.

The location of this experiment is excellent in that hydraulic structures are available for mixing and metering water. It is expected that work of this type can greatly be expanded at this site because of this excellent facility.

**SECTION III. FILM ON LAND PREPARATION
FOR LEVEL BASIN IRRIGATION**

The general objective of the film as per Contract No. AID/csd-2162, Amendment No. 1, is as follows:

The purpose is to produce a film based upon the results of research, that can be used by AID and other personnel to explain the basic principles of proper land preparation for irrigation to farmers, government officials, and students in foreign countries, particularly Pakistan and India, and the Middle-East countries.

More specifically the objectives are to:

1. Educate farmers and policy makers in South East Asia concerning the potential for improving on-farm water management by better land preparation methods
2. Show farmers and policy makers the need for providing agricultural engineering assistance to farmers (of the type provided by the SCS in the USA), and
3. Provide instruction for agricultural engineering students and equipment operators in regard to land-leveling engineering, equipment, and operational methods.

Messrs. Carlos Seegmiller and William Williamson (CSU camera team) completed filming in Pakistan during August and September 1970. They were also in Pakistan filming in November and December of 1969, but found it necessary to return to Pakistan because some important sequences filmed in West Pakistan in 1969 proved to be inferior in quality. Dr. Arthur T.

Corey, Film Project Director, was also in West Pakistan during November and December 1969 in connection with filming activities. Filming has taken place in Turkey, West Pakistan, Southern Rio Grande Valley in Colorado and the Salt River Project in Arizona.

Two separate films will be produced. The first is a general audience film concerning land forming for irrigation and will run for approximately thirty-five (35) minutes. The second film for which the script has not been written, is a specific training film on techniques of setting transits leveling etc. This film length will be about fifteen (15) minutes.

The first film is in the most advanced stage of completion and has been reviewed by Dr. O. J. Kelley, Deputy Associate Assistant Administrator, Research and University Relations, AID/Washington. The film was approved providing minor modifications were made. These changes have now been completed.

The next step will be to complete the script of the second film and then match the narration and background music with the pictures on both films. When this has been completed the films will receive a final review by AID/Washington before release of the films.

Personnel involved with the film project include:

<u>Project Leader(s)</u>	<u>Department</u>	<u>Capacity</u>	
		<u>Participant</u>	<u>Advisor</u>
Arthur T. Corey	Ag. Engineering	x	
Preston Davis	Educational Media	x	
<u>Cinematographers</u>			
Carlos Seegmiller	Educational Media	x	
William Williamson	Educational Media	x	

SECTION IV. COLORADO STATE UNIVERSITY
ON-CAMPUS ACTIVITIES

The on-campus activities have been carried out according to the objectives set forth in Contract No. AID/csd-2162 and Amendment No. 2 thereto. The primary intention of the CSU on-campus research is to set the stage and provide background and support for research in Pakistan. The on-campus activities of the Departments of Agricultural Engineering and Agronomy support their active research programs in Pakistan as per the Program/Activity No. 391-17-110-367. The Department of Sociology also has an item on the Program/Activity, in addition to Agricultural Engineering and Agronomy, and Sociology is developing a research program in Pakistan as discussed in Section II.

The Departments of Civil Engineering, Economics, and Political Science are conducting on-campus research in the hope that cooperative arrangements will eventually be made with Pakistani institutions for implementation in Pakistan. Detailed reports of all on-campus department activities are summarized in the remainder of this section.

Agricultural Engineering

In addition to their efforts in West Pakistan, the Agricultural Engineering Department is conducting on-campus research on "Skimming of Fresh Water from Aquifers in Which Fresh Water is Underlain by Saline Water." The research is aimed at finding methods by which fresh water can be pumped from a free-surface aquifer with maximum

efficiency and minimum displacement of underlying saline water. The following description of the on-campus research effort is given in

Contract No. AID/csd-2162, Amendment 2:

Continuation of possible types of skimming with arrangements for collecting fresh water over saline strata. Emphasis will be on the use of mathematical models. The most promising models may be tested in the field in Pakistan.

Personnel involved include:

- A. Resident Faculty Project Leader
Arthur T. Corey
- B. Graduate Research Assistant
Paul Osborn

The plan of work has been to use models to study the efficiency of several possible types of skimming well arrangements. It is hoped eventually to test the most promising schemes in the field in West Pakistan in an area with a shallow depth to salt water.

The skimming problem is being studied by both numerical and physical models. The numerical studies have been underway for more than a year and they have been concerned primarily with comparing the performance of vertical and horizontal collectors. These studies indicate that horizontal collectors are theoretically superior.

At the present time, improved numerical models are being developed which will accurately account for storage and flow of water above the water table. This is essential, especially with respect to analyzing flow into horizontal collectors that are placed just below the water table. The work reported in the 1969 Annual Report was done with numerical models that assumed no storage or flow above the water table.

A physical model for studying the performance of concentric wells was completed. The model will also be used to check the validity of the numerical models with respect to the performance of vertical wells especially the mathematical model of Flora Chu Wang for vertical skimming wells. Preliminary results are expected by December 1970.

Concentric wells are devices for pumping from two different depths from the same hole and keeping the discharge from the two zones separated. This technique has been suggested as a means of suppressing salt water coming under a fresh water well, and for pumping a minimum amount of salt water along with the fresh water. The method should permit the separation of salt water from the fresh water both within the aquifer and after it is pumped.

Agronomy

In addition to their efforts in Pakistan, the Agronomy Department is conducting an on-campus research program aimed at developing a basic characterization of West Pakistan soils. Specific objectives of the Department's on-campus effort are stated in Contract No.

AID/csd-2162, Amendment 2, as follows:

Completion of mineralogical analysis and quantitative determination of swelling and non-swelling clay mineral from Pakistan soils. This information will then be related to the laboratory and greenhouse reactions of these soils (ESP) to waters having varying sodium-absorption ratios (SAR). These studies will be directed toward solving field problems relating to water quality and methods, and rates of applying irrigation water in Pakistan.

The purpose of the research effort in the Agronomy Department is to determine the optimum use of irrigation water for various crops in relation to:

1. Water quality
2. Amount and frequency of application
3. Physical and chemical properties of the soil.

Specific objectives of the Agronomy effort are:

1. To determine the mineralogy of sand, silt, and clay fractions of selected sites in West Pakistan
2. To determine the extent of the dissolution of calcium minerals in Pakistani soils.
3. To determine Ca-Na equilibria in clays separated from Pakistani soils.

The present standards of criteria for irrigation water use in West Pakistan recommend that tubewell waters be 1000 ppm or less in total dissolved solids and have an SAR of 10 or less. Out of 1883 analyses in Scarp I, 29% of the tubewells have SAR's greater than 10. Nine percent of the tubewells have SAR's greater than 10 out of 416 analyzed in Scarp II. These standards can be met by mixing waters not falling within the limits with better quality canal water in the "perennial" areas partially in the "non-perennial" areas, but not in the "uncommanded" areas. The standards need re-examination to determine whether the limits can be extended for particular soil conditions. If the limits can

be extended, a greater utilization of both the tubewell and canal waters can be achieved and agricultural crop production can be increased.

Lime and gypsiferous minerals found in the soil may alter the ion composition of irrigation water as it enters the soil and becomes the soil solution. Soil gypsum, if present, invariably undergoes dissolution reducing the Na-hazard of irrigation waters of qualities found in West Pakistan. In many cases, dissolution of soil lime takes place which also, will reduce the Na-hazard of the irrigation water. Other minerals in the sand and silt fractions, such as calcic plagioclases and hornblende, have been reported to undergo significant dissolution and increase the Ca content of the soil solution. The activity of Na in soil solutions may even possibly be reduced by the formation of zeolite in strongly alkaline situations. Possible favorable changes in the ionic composition of irrigation waters upon entering the soil are not taken into account when water analyses alone are used as the sole basis for judging the suitability of water for irrigation. Criteria for including soil factors in quality assessments need to be developed.

The type of clay found in the soil affects the relative proportion of Na absorbed by the soil for a water of a particular ion content. High surface charge density clays, amorphous material, and organic matter have been reported to have a relatively greater "affinity" for Ca than lower charge density montmorillonitic clay. The swelling properties of the clay along with the salt and Na content of both the soil and water markedly affect the physical properties of the soil, particularly water transmission through the soil.

No reports of results of sand and silt mineralogy studies of West Pakistan soils were found in the literature. A study of the clay minerals from several surface soils in the Punjab region has been reported. However, there is some doubt whether reliable techniques were followed in separating the less than 2-micron clay-sized fraction from the coarser material when this was carried out in Pakistan. The data show a surprisingly high 50-63% quartz plus feldspar content of several samples. The main clay mineral types for the majority of the samples were mica (illite) with lesser amounts of chlorite. A second group was dominated by mica with lesser amounts of montmorillonite. This study indicates that non-expanding lattice clay types predominate in the soils sampled. However, it was pointed out in a recent report that the fundamental nature of the West Pakistan Clay minerals has been studied inadequately.

In general, somewhat higher levels of exchangeable Na can be tolerated in soils containing non-expanding clay without seriously reducing water transmission properties than can be tolerated by soils with predominately expanding montmorillonitic clays. If the occurrence of non-expanding lattice clays is widespread in West Pakistan, this would provide another avenue for raising the SAR limits now set on tubewell waters.

A summary of results follows:

A. Basic characterization of West Pakistan soils

1. Mineralogy of sands (Objective "a")

One objective for identifying minerals in the sand and silt fractions of Pakistani soils was to determine the presence of CA-bearing primary minerals which might undergo dissolution in irrigation water and reduce the SAR of the soil solution. Mineral assemblages were identified and grain counts made on the very fine sand fractions of two horizons from 11 soil locations. The results indicate that Ca-bearing primary minerals constitute only a small fraction of the mineral suite. Quartz and mica contents ranged between 60 and 83%. Plagioclase feldspar contents varied from about 4 to 12%. Oligoclase (An 10-30) was the predominate feldspar, although a range from albite (An 0-10) to andesine (An 30-50) was noted. Less than 2% of either hornblende or pyroxene minerals were present in the samples.

Total Ca and Mg analyses will be made on digested, composited sand and silt fractions to determine their relative compositions.

2. Mineralogy of clays (Objective "a")

The clay mineral suite of Pakistani soil samples determined from x-ray analyses was found to be: mica (illite), chlorite, and either low charge density vermiculite or high

charge density smectite. Total K analyses and cation exchange capacity, surface area, and quartz plus feldspar measurements were made to obtain a quantitative measure of mineral species present in 2-.2 μ and <.2 μ fractions. All analyses necessary for quantitative determination are not completed at the present time.

The total K analyses indicate that mica (illite) is the predominate clay mineral in the 2-.2 μ fraction and makes up about half those in the <.2 μ fraction.

B. Cation exchange equilibria studies (Objective "c")

Diffuse double-layer theory and some reports in the literature indicate that high charge density clays adsorb a lower proportion of Na for a given solution "sodium-adsorption-ratio" (SAR) than low charge density clays. This effect tends to become more pronounced as solution composition and SAR increase. Since the clays found in Pakistani soils mainly consist of high charge density minerals, lower Na adsorption would furnish a basis for using higher SAR irrigation waters than is now considered possible.

A study of Ca-Na adsorption by Pakistani clays from solutions varying in total salt concentration and SAR is being conducted to evaluate the magnitude of this effect.

C. Dissolution of calcium minerals (Objective

This will proceed as soon as the mineralogical analysis of sands and silts is completed.

Personnel involved from Agronomy include:

- A. Resident Faculty Project Leaders
Willard R. Schmehl (Project Leader)
William T. Franklin (Associate Project Leader)
- B. Visiting Faculty
Bashir Malik (Post Doctoral Fellow from W. Pakistan
starting June 1970)
- C. Graduate Research Assistants
Mehdi Monadjemi
James Puckett (Terminated 30 June 1970)

Civil Engineering

The Civil Engineering Department is conducting on-campus research in accordance with the objectives set forth in Amendment 2 of Contract No. AID/csd-2162 as follows:

1. Studies on the loss of fluorescent dye in water flow by interaction with sediment, dissolved solids, and biota.
2. A model study of farm turnouts used in West Pakistan.

In addition, the Civil Engineering group has used the last few months to refine their objective of establishing a project agreement with West Pakistan agencies to assist them in using modern decision oriented procedures involving high speed computers for improving the management and operation of their irrigation system. To achieve this, an interdisciplinary group is being formed with members initially from Agronomy, Political Science, and Civil Engineering, and emphasis is being placed on the sub-distribution system of a "chak". A chak is the land area, composed on the holdings of up to 25 farmers, that is served

by one irrigation outlet. Reorganization of the distribution systems of the chaks appears vital to the introduction of the results of the research presently underway in Pakistan. The secondary objectives are to conduct research at CSU and to promote research in Pakistan that will supply needed input data for the optimum management of the water delivery systems. Some of this data will come from the research of the other departments participating in the CUSUSWASH program.

Specific activities for this reporting period include:

1. A report on the use of fluorescent dye in solving problems in the flow of irrigation water has been prepared and is being processed for publication.
2. The study of the sediment passing characteristics of irrigation offtakes is progressing well and a report on the results obtained so far is being prepared. This will provide important data for the management and design of irrigation systems to reduce the high cost of maintaining the canals and waterways that are becoming clogged with silt.
3. The study of the application of systems analysis to the Cache La Poudre Irrigation System in Colorado has continued (Colorado funds) as a forerunner of a systems analysis on an Irrigation Circle in Pakistan.
4. A Ph.D. thesis on a statistical evaluation of river and canal data (much of it from Pakistan) to arrive at a better method

for the prediction of the real effects of sedimentation on the flow in irrigation canals is nearing completion by a Pakistan student with an active interest in the Water Management Research Project, although not being funded by it.

5. The Civil Engineering group is working with Garth Jones, Willard Schmehl, and William Franklin to finalize plans for a study of the water management problems in Pakistan. Initially, the study will concentrate on the distribution of the water available to the farmers in a chak in order to obtain the greatest return in the form of crop production. An existing computer program, developed partially at CSU, will be used to relate water usage to crop production and an additional program using techniques of computer optimization will be developed to aid in determining possible reorganizations of the distribution systems of a chak to take advantage of improved irrigation methods. Cooperation of Pakistan counterparts will be essential to the development of these programs and their utilization in Pakistan.

Personnel involved from the Department of Civil Engineering are:

A. Faculty

M. L. Albertson
E. V. Richardson
A. G. Mercer

B. Graduate Research Assistants

- K. Mahmood from Pakistan (no longer paid with AID funds)
- A. Rakha from Pakistan
- J. W. Andrew, Australia
- J. Duke, USA (not paid with AID funds)

Economics

The Economics Department is conducting on-campus research on "Economic Analysis of On-Farm Input Use in West Pakistan with Reference to Water." Research activities of the department are described in Amendment 2 of Contract No. AID/csd-2162 as follows:

Continuation of studies on methodological problems and data limitations. This phase of the project will require further study on design of analysis and data collection and handling in the field.

Initiation of studies to analyze the economic rationale of on-farm input use, especially water and other inputs as they relate to water allocation, and to appraise the effect of agricultural policies on the efficient allocation of these inputs.

The objectives of the Economic Department's research is to analyze the economic rationale of on-farm input use and to appraise the effects of agricultural policies on the efficient allocation of inputs. Emphasis is being placed upon the analysis of the use of water, but consideration will also be given to other inputs, particularly as they relate to the allocation of water. The specific objectives include:

A survey of available research and statistical information relating to the economics of on-farm input use in West Pakistan, to include the development of an annotated bibliography.

2. An analysis of the economic rationale of input use of Pakistani farms.

3. An analysis of the effect of agricultural policies on the on-farm use and allocation of inputs

Personnel involved from Economics include:

A. Resident Faculty Project Leaders:

H. H. Biggs

Robert Young (initiated September 1970)

K. C. Nobe

M. K. Skold (terminated August 1970)

B. Graduate Research Assistants

Debebe Worku, Ph.D. (planned completion, March 1971)

M. Jameel Khan, M.S. (initiated September 1970)

Progress: Debebe Worku, who has begun the writing stages of his dissertation, has investigated the efficiency of water resource allocation in West Pakistan. In so doing, he has examined the increases in Gross Value Product of the agricultural sector and analyzed the changes as to whether they may be attributable to physical factors or non-physical factors. His studies lead him to conclude that Pakistani farmers are quite responsive to price and other economic incentives, and that uncertainty and the desire to be self-sufficient in the production of food grains govern the cropping patterns of Pakistani farmers.

To analyze the physical factors that may have contributed to the increased Gross Value Product of agriculture, the Crop Cutting Experimental data made available through USAID/Lahore (Mr. Tyler Sturdevant) was used. The variables considered are water, acreage, yield, fertilizer, seed, plant protection, and changes in technology. Measures of the input variables are of questionable reliability as the

data are rough and often require heroic assumptions to translate into measurable quantities. Analyses of variance were performed to ascertain yield differences between various input treatments. Statistically, significant differences were found between seven of ten factors tested.

Next, functional relationships between wheat yields and input levels were estimated. Based upon these data and our analysis, it was found that the most important determinants of yield increases are Mexican Red Wheat seed, size of plot, and time of planting. Among the factors having negative effects on wheat yield are: use of C-591 seed, "broadcast" methods of seeding, and late planting.

The analyses, though often based on tenuous data, leads to the hypothesis that in general, Pakistani farmers tend to make economically rational decisions regarding the allocation of their inputs. Charges that they tend to overwater some crops and underwater others may be explained by the fact that the governmental water supply is not demand oriented, the water pricing mechanism is fixed, and the institutional factors prohibiting water reallocations.

Future Plans: Mr. Worku plans to complete his dissertation by March 1971. Mr. M. Jameel Khan will begin his research investigations by further examining the factors which contribute to growth of agricultural output in Pakistan.

The next step is to arrange and negotiate a cooperative agreement with West Pakistan and USAID to pursue the research objectives in

Pakistan. This will be attempted when explicit research work arrangements have been made with Pakistani counterparts (probably from the West Pakistan Agricultural University) directly involved with the research, and including possibly an on-location agricultural economist in West Pakistan.

Political Science

The Political Science Department is conducting research on "Organization of Water Management for Agricultural Production in Pakistan." The specific objective of the research activities as described in Amendment 2 of Contract No. AID/csd-2162 is:

"Initiation of preliminary studies in the Political Science field as it relates to the organization and administration of water management problems."

Personnel involved from the Department as of October 1970 are:

A. Resident Faculty Project Leaders

Garth N. Jones - Senior Faculty Project Leader
John A. Straayer - Senior Faculty Project Leader
Henry P. Caulfield - Senior Faculty Project Associate

B. Graduate Research Assistant

Robert Schmidt

A substantive progress report on the Department's activities was completed in May 1970 on the "Organization of Water Management for Agricultural Production in West Pakistan." The report was published as Water Management Technical Report Number 2, and presents the

preliminary findings of an investigation into the administrative aspects of water management in the area of agriculture in West Pakistan.

These sub-projects were delineated as follows:

1. A study of organization structure for water management.
2. A study of Pakistani personnel systems.
3. A study of agriculturally related problems.

Dr. Garth N. Jones joined the staff of the Political Science Department in July 1970 and assumed the leadership of the project from Dr. Phillip O. Foss. Dr. Jones was formerly a Senior Specialist at the East-West Center from September 1969 to July 1970 where he was involved in Asian studies. Dr. Jones is preparing a reference work entitled, "Information Sources on Water Management, With Special Reference to Institutional and Human Factors." The reference work will consist of the following:

A. Bibliography

1. Pakistan (completed during September 1970)
2. General (to be completed during November 1970)

B. Research Institutions

1. Pakistan (completed during September 1970)
2. General (to be completed during November 1970)

C. Glossary Pakistani Terms (completed during September 1970)

The reference work will be finalized for publication during the months of November and December 1970, and the target date to complete this

project activity is June 1971. The sections on Pakistan will be sent to Pakistan for review by appropriate Pakistani scholars.

A draft research design on the evaluation of irrigation systems was completed in November 1970. This will become a collaborative project with the Departments of Civil and Agricultural Engineering and Agronomy.

The basic materials have been collected for a planned edited work entitled, "Water Management in Pakistan: Institutional and Human Factors." The work is under the direction of Robert Schmidt and the target date for completion is March 1971, including the Pakistani inputs. The target date for publication is June 1971.

Mr. Robert F. Schmidt, a graduate research assistant supported by the Water Management Research project, completed his master's thesis, "Water Management in West Pakistan," in June 1970. The importance of water management in West Pakistan is examined and the agencies which administer water resources are described in the thesis. Each water management agency is analyzed according to its history, functions, structure, and linkages with other government agencies. A model for organizational change is also tested in the thesis. The tests indicate that the model is capable of measuring a wide range of factors which effect organizational change in a developing nation. The thesis was submitted to and accepted for publication by the West Pakistan Academy for Rural Development. The target date for publication is March 1971.

Mr. Robert Dildine, an NSF trainee, conducted research on the personnel problems of water management agencies in West Pakistan, with Professor Phillip Foss as his faculty advisor. Mr. Dildine completed the outline for his master's thesis in September 1970 and plans to complete the thesis by April 1971.

Mr. Colin Webster, a graduate research assistant who will be supported by the Institutional Development Grant, is developing an outline for a thesis that is scheduled to be completed by January 1971.

Sociology

One aspect of the on-campus effort of the Sociology Department has been the development of a proposal for implementation in West Pakistan to study the social factors that explain why farmers make "good" or "bad" water management decisions. Professors Ellenbogen and Freeman will travel to Pakistan in November to establish a research program as discussed in Section II.

The other aspect of the Department's on-campus effort is the coordination of the CSU team into a combined interdisciplinary research project. It was strongly recommended by AID's external Research Advisory Committee (RAC) during an April 13 and 14, 1970 meeting at CSU, that CSU develop a mechanism for integrating the various components of the CSU team.

The mechanism developed combines the several project components
by:

- A. Examining the research recommendations of the Agricultural Engineering, Agronomy, Civil Engineering, and Economic components as innovations which will be accepted or rejected by the Pakistani structure.
- B. Determining how the administrative and village decision makers receive and accept or reject the research innovation proffered by the agricultural engineering, agronomy, civil engineering and economic components.

For example, consider the problem of quality of irrigation water application. The agronomy research component will arrive at certain results and conclusions that if implemented would increase crop production through more efficient use of the total water resource. Where in the decision system will the innovation be processed (at what level of the administrative-bureaucratic structure) and what will be the effect at the village-farmer decision level? In order for the innovation to be effective it must be accepted and implemented, and by processing the innovation through the decision-making machinery it is intended that the keys to successful implementation can be predetermined.

The effort has resulted in the conceptual formulation of a model which consists of three components:

1. **Innovational Inputs**
2. **Administrative Water Management Decision-System**
3. **Village Water Management Decision-System**

The decision-systems are intended to receive an innovation and then determine a policy output that can be measured in terms of successful implementation of the innovations. Each decision-system has an effect on the other and these effects will be interrelated in the model.

The model was initially developed and presented to the CSU team in June 1970. Modification and elaboration of the model's logic, components, and variables have been underway since June. Work will continue on the decision-making model and ways to link the several CSU research components to it will be stressed.

Personnel from Sociology involved are:

A. **Resident Faculty Project Leaders**

David Freeman (Project Co-Director)
Bert L. Ellenbogen (Senior Faculty Associate)

B. **Graduate Research Assistant**

Lonnie O. Trautman

SECTION V. WATER MANAGEMENT PROJECT MEETINGS

The University of Arizona, Colorado State University, Utah State University, and the University of California have joined in creating an interuniversity council known as the "Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas" (CUSUSWASH or Council), for the purpose of enhancing their capability and capacity to respond to specific problems of international development related to arid lands and to advance their level of competence in the appropriate disciplines. The CUSUSWASH acts in an advisory capacity on this contract and other contracts for the same purpose with the other members of the Council.

Two CUSUSWASH meetings are held per year. For this reporting period Council meetings were held in Denver, Colorado in January 1970 and in Fort Collins, Colorado in August 1970. Also during 1970, an AID Research Advisory Committee meeting took place in Fort Collins during April 1970. These three meetings are summarized in the remainder of this section.

January 1970 CUSUSWASH Meeting

The third meeting of CUSUSWASH University representatives was convened on January 13 and 14 in Denver, Colorado to review the plans of work and to hear comments on other University programs at Cornell and North Carolina and the TVA program. Representatives of USAID

and of leaders of AID sponsored projects in soil management from Cornell University and North Carolina State University contributed significantly to the meetings.

Reports during the meeting covered the research activities under way on on-farm water management in several Latin-American countries by Utah State University and in Pakistan by Colorado State University, with the following locations and points of emphasis:

Chile--Irrigation during fall and winter to store water in soils that will support increased crop production under conditions of drought and limited water supply.

Colombia--Combining optimum irrigation and crop production practices under conditions of poor drainage and soil salinity.

Venezuela--Measuring the interactions of irrigation, soil management and crop production practices on fine clay soils and other soil and climatic conditions.

Brazil--A program is being planned to study irrigation and related farm practices on sandy soils of the San Francisco River Valley of the North East.

Pakistan--Studies are concerned with efficient use of water for improved crop production under conditions of limited water supply, salty soils, and poor quality irrigation water.

Additional studies are contemplated in El Salvador and in the country sites mentioned involving new designs for more drainage and

analysis of economic and social problems inherent in successful irrigation agriculture.

The locations and studies were selected because the problem conditions are representative of those in extensive areas in developing countries and because local participation and working conditions are conducive to the successful execution of the work plans.

The University of Arizona reported plans for studying improved water management under rain-fed conditions of North East Brazil. The University of California discussed plans for a major education and research program on water management in India sponsored by the Ford Foundation.

The studies of Cornell University on tropical soils and of North Carolina State University on soil testing and the fertility of soils of South America are closely related to the investigations of the Council of Universities on water management.

The studies reported have an important training component and ways are being evaluated for maximizing the development of human resources to better manage soil and water resources. Among the activities to accomplish this are the employment and training of graduate assistants from the U. S. and from cooperating developing countries in the research projects; working closely with appropriate in-country institutions including participation in their extension programs.

As the research programs develop, the Council is proving an increasingly effective agent for strengthening and coordinating the

individual programs. The periodic reporting of accomplishments and reviews of work plans provides an effective means for checking the quality of endeavors and for insuring the adequacy of work plans. The participation of several representatives of AID was particularly helpful in providing a professional tone and in assisting in the reviews at a level where changes can be readily effected.

August 1970 CUSUSWASH Meeting

A meeting was held on August 13 and 14, 1970 in Fort Collins of CUSUSWASH universities. More than 40 people representing the University of Arizona, University of California, Colorado State University, Utah State University, and AID/Washington attended the meeting.

The primary purpose of the meeting was to discuss the overview report coordinating the universities 211(d) annual reports. However, on August 14 Utah State University summarized their AID supported activities in South America, the University of Arizona summarized their independent activities with the University of Ceara in Brazil, the University of California summarized their research activities in India, and CSU summarized their research project in West Pakistan.

Other business included a discussion of information exchange programs at the various universities, a meeting and report of the Publication Task Force Committee, and a report by the On-Farm Water Management Seminar Task Force Committee.

April 1970 AID Research Advisory Committee Meeting

A meeting was held in Fort Collins on April 13 and 14, 1970 with the AID Research Advisory Committee (RAC). Three members of RAC review committee assigned to the CSU Water Management Research Project, attended the meeting in addition to CSU staff involved in the project and AID representatives. Members of RAC review committee in attendance were: Dr. Maurice L. Peterson, Professor of Agronomy, University of California, Davis; Dr. Roger Revelle, Professor of Population Policy, Harvard University, Cambridge, Massachusetts; and Dr. John Montgomery, Professor of Public Administration, Harvard University.

The purpose of the meeting was to review project activities for the RAC. Representatives from the Departments of Agricultural Engineering, Agronomy, Civil Engineering, Economics, Political Science, and Sociology presented their Department's progress. The official summary of the RAC decision regarding the CSU Water Management Research Project is as follows:

Water Management Research in Arid and Sub-humid Lands of the LDC's -- Colorado State University, Utah State University. Duration, 5 years; est. total cost of continuation funding for 3 years, \$3,450,000; FY 70 funds required, \$950,000. Revelle, Brady, Tanter.

"Decision: RAC recommended, following a subcommittee site visit (a) That Colorado State think very seriously about concentrating all of its research efforts in one manageable sized area, like one of the two Scarps or around Lyallpur, rather than spread out too much over the country. They should also think about the whole system from soil characteristics to economic conditions. (b) AID should insist that there be some full time people on the project

(at least one full time at Colorado State and two overseas). Advantage should be taken of other resources at Colorado State.

RAC also recommended that an advisory committee, consisting of both RAC members and non-RAC members, meet with members of the project semi-annually over the next few years. This committee would be responsible to RAC. "

SECTION VI. FOREIGN TRAVEL

Several trips to West Pakistan were made during this reporting period by CSU faculty to establish research projects in West Pakistan and cooperative arrangements with Pakistani researchers. Travel to West Pakistan by CSU faculty is imperative for the transfer of on-campus research to West Pakistan. Much "ground work" is needed before a research project can get underway in West Pakistan and close associations and working relationships with West Pakistanis must be established. Also, some travel to West Pakistan was incurred in connection with the film on Land Preparation for Level-Basin Irrigation, see Section III.

A brief summary of each trip is provided in the remainder of this section.

1. Della L. Langeland, Department of Civil Engineering
August - December 1969

To assist in the gathering of information for a comprehensive report on tubewells in Pakistan. Miss Langeland contributed substantially to the development of a revised tubewell questionnaire. She also gathered information for on the farm water-soil-plant relationships.

2. Arthur T. Corey, Department of Agricultural Engineering, and Carlos W. Seegmiller, Office of Educational Media
November - December 1969

To perform actual filming on field locations in West Pakistan and Turkey for the production of the film on Land

Preparation for Level-Basin Irrigation. Arthur Corey is the film producer and Carlos Seegmiller is cinematographer for the film.

Melvin D. Skold, Department of Economics
November - December 1969

To investigate and discuss possibilities for establishing research projects in West Pakistan and to develop contacts with AID personnel and Pakistani researchers who might be involved in future research projects.

4. John A. Straayer, Department of Political Science
November - December 1969

To collect documents, papers, etc., on Pakistani administration which are unavailable in the United States.

To seek to establish a permanent working relationship with one or more Pakistani social scientists who would then gather information and check our research findings on a continuing basis.

To interview Pakistani and US/AID personnel to check the validity of our current findings and assumptions.

5. Daryl B. Simons, Department of Civil Engineering
March 1970

To assist in coordinating and finalizing the Program Activity, to discuss Mundel rupees, and to discuss the progress and status of the project.

6. Gilbert L. Corey, Chief of Party
June 1970

To prepare for research to be done in Pakistan and prepare for his move to Pakistan.

To assist Willard R. Schmehl, CSU Department of Agronomy, in setting up research activities at the Ayub Research Institute.

- Gilbert L. Corey, Chief of Party
August 1970

To assume position of Chief of Party for CSU research effort in West Pakistan under the Water Management Research Project. Dr. Corey is now on a two-year assignment and is stationed at Lahore, West Pakistan.

7. Willard R. Schmehl, Department of Agronomy
June 1970

To set up research activities at the Ayub Research Institute and at West Pakistan Agricultural University as approved in the Program Activity document.

8. Carlos W. Seegmiller and William Williamson, Office of Educational Media
August - September 1970

To refilm critical sequences of educational film on Land Preparation for Level-Basin Irrigation in West Pakistan.

9. William Franklin, Department of Agronomy
October - November 1970

To start field studies at Ayub Research Institute for Agronomy Department.

To complete arrangements and plans for laboratory and field studies at the West Pakistan Agricultural University.

10. David Freeman, Department of Sociology
October - November 1970

To set up cooperative arrangements with West Pakistanis for Sociology's research project per the Program Activity document.

SECTION VII. LIST OF PERSONNEL

More than 39 CSU faculty, staff, and graduate students were involved in the project during this reporting period. A list of personnel are included in the remainder of this section.

Administrative Personnel

Maurice L. Albertson, Project Leader
L. Scott Tucker, Research Associate
Bonnie L. Frantz, Administrative Assistant
Gilbert L. Corey, Chief of Party (West Pakistan)

Technical Personnel

Department of Agricultural Engineering

Faculty: Arthur T. Corey, Project Leader
Gaylord V. Skogerboe
Stewart W. Melvin

Graduate Research Assistants: Paul S. Osborne

Department of Agronomy

Faculty: Willard R. Schmehl, Project Leader
William T. Franklin

Visiting Faculty: Bashir Malik, West Pakistan

Graduate Research Associates: Mehdi Monadjemi
James L. Puckett

Department of Civil Engineering

Faculty: Everett V. Richardson
Albert G. Mercer

Graduate Research Assistants: Della L. Langeland
Yasumi Yamaguchi
Mohammad I. Haque
Khalid Mahmood
Allah Rakha
Mohammad T. Chaudhry
Suresh Doddiah
Emilio Rios
Ata M. Nazar

Department of Economics

Faculty: Kenneth C. Nobe, Project Leader
Melvin D. Skold
Huntley H. Biggs

Graduate Research Assistants: Debebe Worku
Khan J. Muhamad

Department of Political Science

Faculty: Garth N. Jones, Project Leader
John A. Straayer
Phillip O. Foss

Graduate Research Assistants: Robert F. Schmidt
Arlene C. Dwyer
Robert S. Dildine

Department of Sociology

Faculty: David M. Freeman, Project Leader
Bert L. Ellenbogen
Linwood L. Hodgdon

Graduate Research Assistants: Lonnie O. Trautman
Rizwani-Abdur-Rehman

Office of Educational Media

Carlos W. Seegmiller
William C. Williamson
Preston Davis

SECTION VIII. PROJECT CONTRACT

The provisions of the Contract between AID/Washington and CSIR have been carefully followed. The studies that were initiated in West Pakistan are fully coordinated with AID/Washington, USAID, and CUSUSWASH, including appropriate agencies and institutions of the GOP. The specific objectives mentioned in the Contract were used as basic guidelines in planning the water management research program with Pakistani personnel. In cooperation with USAID and the GOWP, a Project Agreement was written to establish specific research projects in accordance with the Contract Objectives with high priority needs of the NESAs area and of West Pakistan. These specific studies are geared to meet the following 7 Contract objectives:

1. The 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 limited amounts of irrigation water.
2. The development of knowledge and data that can be used for the economic design and construction of 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 drainage systems to eliminate the hazards resulting from surface flooding and high water tables.

4. The identification of important factors affecting the degree of leveling of the various soils in the major climatic zones and the relationship of these factors to erosion, water infiltration, and good land use and cropping practices.
5. The development of methods of water application, including time and amounts, which are suitable and efficient for different soils of varying physical properties (water-holding capacities, intake rates, etc.) with major crops.
6. The integration of these water-use factors into a productive cropping system consistent with farm size and available farming practices.
7. Where soil salinity and exchangeable sodium are problems, studies will include soil amendments, soil and water management procedures and use of salt-tolerant crops.

The above objectives are described in Section II: Activities in Pakistan, and elaborated upon in Section IV: CSU On-Campus Activities, in support of the field work research in West Pakistan.

The objectives of the initial 21-month contract period have been met. The Project Director has visited Pakistan and the overall research program has been evaluated, methods of procedure determined, and an excellent relationship has been established with appropriate GOP institutions. A Chief of Party is now stationed in the cooperating country and is coordinating the activities with USAID/Pakistan and the GOP. A soils scientist has been recruited and will arrive in Pakistan no later than April 1971.

APPENDIX A. PROJECT PLAN FOR WATER CONTROL AND LAND PREPARATION

I. Project Title: Water Control and Land Preparation

II. Departments and Personnel:

A. Agricultural Engineering Directorate - MDU Farm
Abdul Hamid Chaudary, Director
Abdul Aziz, Assistant Engineer Research
Khalid Sharif, Assistant Agricultural Engineer
Roshan Ali, Assistant Agricultural Engineer

B. Colorado State University - Dept. of Agricultural Engineering
Arthur T. Corey, Agricultural Engineer
Gilbert L. Corey, Chief of Party

III. Objective:

To determine the best water application practices for various crops and tillage methods used in West Pakistan. Specifically, the application practices under consideration will be:

A. Length of run for various crops, tillage methods, soils, slope of border, stage of growth, and season of year.

B. Size of stream for a given width of border with these same variables.

C. Width of border for these variables, and for size of stream of water available.

IV. Justification:

Observation of irrigation systems in current use enables an irrigation engineer to make an educated guess concerning a suitable length of run and size of stream that will do an effective job of distributing water along a border with the methods of tillage currently being used in the Indus Valley. However, the rate of infiltration and depth of penetration of roots with this kind of tillage is unsatisfactory. With the introduction of subsoil tillage, or even only moldboard plows, crop production should be greatly improved. This may drastically change the optimum length of run and minimum size of stream. The first step in the investigation will be designed to discover the magnitude of this effect, and provide some basis for future recommendations.

V. Procedure:

This investigation will be carried out on the Machinery Demonstration Unit farm near Lyallpur, Pakistan.

Since a single experiment involving all of the variables mentioned in III would be too cumbersome and require too many plots and too much land to be practical, a stepwise investigation over a period of years is proposed.

The first step is described below. It is designed to provide the information most urgently needed. This information is: What will be the effect of introducing modern tillage practices on:

- A. The optimum length of run, and
- B. The minimum size of stream for a given width of border for deadlevel border irrigation. The variables of slope, crop, soil type, and quality of water will be introduced later. The crop initially tried will be wheat.

The experimental design for the first step will be as follows:

- A. Variables
 1. Size of stream - 4 rates
 - a. 0.100 cfs per ft. of border width
 - b. 0.075 cfs per ft. of border width
 - c. 0.050 cfs per ft. of border width
 - d. 0.025 cfs per ft. of border width
 2. Method of plowing
 - a. Subsoil and cultivator
 - b. Disc Plow and Disc Harrow
 - c. Cultivator
- B. Replications - 4
- C. Number of plots = $4 \times 3 \times 4 = 48$ requiring a total of about 20 acres.
- D. Each plot will be a border strip 18 feet wide (including bands) by 800 feet length, leveled to zero grade.
- E. The first irrigation will be made on fallow plot. Wheat will then be planted, and irrigations will

be applied as often and in amounts recommended by agronomists, 3-4 inch irrigations are considered standard in West Pakistan today.

F. Measurements to be made will be:

1. Rate of advance along border as front advances to end of border.
2. Distribution of water in profile both vertically, and horizontally following irrigation.
3. Infiltration rates before each irrigation.
4. Physical and chemical properties of soil and water.

G. From the results of these measurements, an attempt will be made to approximate:

1. Optimum length of run
2. Minimum size of stream for each tillage method and as a function of the number of irrigations following plowing.

VI. Interrelation with other Projects

This project will be carried on for several years at the same site. Crops will be rotated so that data for specific crops will be available.

It is anticipated that the results with the first crop may be inaccurate due to the heavy leveling necessary to prepare the plots.

This project relates directly to a project being conducted by the Punjab Research Institute and the Department of Agronomy, CSU. That project involves quality of water as it effects plant growth and soil moisture movement and should result in leaching requirements under various conditions.

Scientists working on each project are collaborating on various phases; for example Punjab Research Institute has agreed to provide chemical and physical analyses for plot soils.

It is hoped that the Agricultural Engineering Department at WPAU will become involved and a project can be developed on the University land assigned to that Department. Discussions are currently underway.

APPENDIX B. PROJECT PLAN FOR WATER-QUALITY-LEACHING FRACTION EXPERIMENT

I. Objectives: Crop I, 1970-71

- A. To determine the effects of irrigating with waters containing 4 levels of salinity on the yield of 2 wheat varieties.
- B. To determine the soil salt and sodium levels which result from irrigating with waters varying in salinity and sodium applied at various rates in excess of consumptive use.

II. Experimental site: Punjab Research Institute, Agronomy Section, Water Requirement Distribution System, approximately 2 acres.

III. Land Preparation:

- A. Survey for field leveling
- B. Land planning
- C. Moldboard - plowing to a depth of 9-10 inches
- D. Planking
- E. Soaking irrigation
- F. Cultivation or disk

IV. Fertilizers and rates (uniform application)

- N - 100 lbs./A.
- P₂O₅ - 50 lbs./A.
- Applied at time of seeding of crop
- Fertilizer source - nitrophosphate and urea

V. Crop sequence: Wheat, (tentative) fodder, berseem

- A. Wheat varieties: Mex-pak, Chenab 70
- B. Seeding rate:
- C. Rows spacing: 1' (12', 1' rows/plot)

VI. Experimental Variables:

A. Irrigation waters and qualities

- 1. Canal water: approximately (app.) 250 ppms, SAR 1.0
- 2. Tubewell (TW) water: app. 3000 ppm. SAR _____
- 3. TW-Canal Mix I; 1 part TW - 2 parts canal; app. 1000 ppm. SAR _____
- 4. TW-Canal Mix II; 2 parts TW - 1 part canal: app. 2000 ppm, SAR _____

B. Irrigation rates:

1. Irrigation rates will be determined on the basis of consumptive use (CU) measurements made during cropping. The basic consumptive use value will be obtained by taking moisture samples and calculating it for each irrigation period. Basic CU will be considered to be water used on plots irrigated with canal water. Moisture samples will be taken 24 and 48 hours after the first irrigation to determine a "field capacity" moisture percentages samples at: 0-6, 6-12, 12-24, 24-36, 36-48, and 48-50 inches (9 separate profiles after 24 hours, 36 profiles after 48 hours) and about 3 days before the next irrigation. Moisture samples should be taken at 304 days intervals on the plots irrigated with canal water during the irrigation cycle.
2. Irrigation water will be applied to bring the soil moisture to "field capacity" and to field capacity plus the leaching fractions.
3. Rates will be applied in relation to CU as follows:
 - a. Canal water:
 - (1) CU (brought up to field capacity)
 - (2) CU + 10% excess
 - (3) CU + 20% excess (LF)
 - b. TW-Canal Mix I (app. 1000 ppm)
 - (1) CU
 - (2) CU + 15%
 - (3) CU + 20%
 - c. TW-Canal Mix II (app. 2000 ppm)
 - (1) CU + 10%
 - (2) CU + 20%
 - (3) CU + 40%
 - d. TW (app. 3000 ppm)
 - (1) CU + 20%
 - (2) CU + 40%
 - (3) CU + 60%

VII. Crop Yield and Quality Measurements

- A. Straw (3 subsamples from each plot 2 rows x 10' long)
- B. Grain

VIII. Soil Samples and Analyses

- A. Before cropping: Composite sample of 5 borings within 3 replications at 0-6, 6-12, 12-24, 24-36, 36-48 inch depths
- B. After cropping: Composite of 4 borings from each plot (36) at above depths
- C. Analyses:
 - ECe - (saturated paste extract)
 - Saturation paste moisture - 90
 - SARe
 - NH₄ OAC Soluble Sodium
 - Cation exchange capacity (at least on initial samples)

IX. Infiltration observations:

The time the water is applied on each plot and the time all free water has disappeared from each plot will be recorded (started after the soaking irrigation) to note infiltration changes or differences between treatments.

X. Salinity sensor measurements:

Salinity sensors will be installed on one replication of each quality and LF plot to monitor the salt level.

XI. Plot Design: Split-split Plot

- A.
 - 1. Main plots - irrigation water quality (Q)
 - 2. Sub-plots - rates or leaching fractions (LF)
 - 3. Sub-sub plots - wheat varieties (V)
- B. Plot size: sub-sub plots 13.0 x 96 ft.
- C. Replication: 3 (R)
- D. Number of plots - 72 (4Q x 3LF x 2V x 3R)