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FIRST AND SECOND SEMI-ANNUAL PROGRESS REPORTS

28 June 1968 through 30 June 1969

for

WATER MANAGEMENT RESEARCH IN
ARID AND SUB-HUMID LANDS OF
LESS DEVELOPED COUNTRIES

CONTRACT NO.: AID/csd-2162

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INTRODUCTION

These Progress Reports are prepared in accordance with the requirements (Appendix A) of the Agency for International Development (AID) to report the progress of the total program and the individual research projects of Contract No. AID/csd-2162 which is entitled "Water Management Research in Arid and Sub-Humid Lands of the Less Developed Countries."

The first and second semi-annual reports are combined to cover the first year of this project in a more integrated manner than would be possible in two separate reports. The first six months was spent in planning the on-campus research and conducting a field investigation in West Pakistan to obtain detailed information regarding research needs and potential institutions and personnel for cooperative research. The last six months of this period was spent in further planning and implementation of research projects.

This report lists the various personnel involved in the project on the campus of Colorado State University and the staff members who were overseas for a short period of time. The report also includes the General Objectives, Specific Objectives, and Plan of Work as stipulated in the Contract. It then lists initial projects which were developed by the various cooperating departments at CSU to fulfill the specific objectives of the Contract.

The Future Plans for the projects are included to indicate the direction which the project is expected to take as it develops both on-campus and overseas.

Appendices include the memorandum from Dr. Alvin D. Ayers, Soil and Water Management Specialist, dated 29 October 1969 requesting these reports and the detailed description of the research projects being developed by the various departments at CSU.

ADMINISTRATIVE PERSONNEL

Maurice L. Albertson, Project Director

TECHNICAL PERSONNEL

Department of Agricultural Engineering

Faculty: Arthur T. Corey, Project Leader
Gaylord V. Skogerboe
John A. Brookman

Graduate Research Assistants:
Norm n S. Ills y
Paul S. Osborne

Department of Agronomy

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

Graduate Research Assistants:
Mehdi Monadjemi
James L. Puckett

Department of Civil Engineering

Faculty: Everett V. Richardson, Project Leader
Albert G. Mercer

Graduate Research Assistants:
Della L. Langeland
Wen-Sheng Liang
W. D. Liou
Yasumi Yamaguchi
Muhammad I. Haque
Khalid Mahmood

Department of Economics

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

Department of Economics (cont'd)

Graduate Research Assistants:
Debebe Worku
Stanley Hargrove

Department of Political Science

Faculty: Phillip O. Foss, Project Leader
Charles L. Garrison
John P. Vloyantes

Graduate Research Assistants:
Robert M. Freeman
Thomas J. Manninen
Robert F. Schmidt
Arlene G. Dwyer
Saeed Makhtatzada

Department of Sociology

Faculty: Carl W. Birky, Project Leader
David M. Freeman

Graduate Research Assistant:
Lonnie O. Trautman

GENERAL OBJECTIVES

The general objective of this research as stated in the Contract 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. The research under this contract will be aimed at water management problems in the semi-arid lands of the Near East-South Asia region but 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.

Studies will be initiated in West Pakistan in cooperation with A.I.D. and the appropriate agencies of the Government of Pakistan.

SPECIFIC OBJECTIVES

The specific research studies will be selected to meet the high priority needs of the NESA area and of West Pakistan. These studies will include but not be limited to:

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 project director will visit Pakistan for a period of two to three months. Other pertinent scientists will accompany him approximately the last month of his visit. During this time, working through the USAID, the overall research program will be evaluated, detailed methods of procedure will be determined, and agreed upon, and cooperative relations worked out with the appropriate country institution. This will include evaluation of those types of studies that can be done on the home campus and the nature and type of local adaptive research that can be gotten under way in cooperation with appropriate local institutions. Necessary laboratory and other facilities will be obtained and/or established depending upon what is available and can be worked out in cooperative undertakings. Follow-up trips by technical staff will be necessary. Contractor employees will not be stationed in the cooperating country for the first fifteen to eighteen months of this project.

PLAN OF WORK

In order to meet these general and specific objectives, the following CSU staff traveled to West Pakistan in October, November, and December 1968 to make tentative plans and collect data to establish research projects. These faculty were as follows:

Dr. Maurice L. Albertson, Project Director
Dr. Arthur T. Corey, Agricultural Engineering
Dr. Willard R. Schmehl, Agronomy
Dr. Melvin D. Skold, Economics
Mr. Carl W. Birky, Sociology

Dr. Albertson spent a month in Pakistan prior to the arrival of the staff members contacting individuals in the USAID Mission and governmental agencies and making preparation for the arrival of the CSU staff.

Each staff member spent approximately one month in West Pakistan discussing proposed research projects with the AID Mission and various government agencies of West Pakistan.

INITIAL PROJECTS TO FULFILL CONTRACT SPECIFIC OBJECTIVES

The on-campus research projects which were established and approved following the travel to West Pakistan are as follows:

Agricultural Engineering

Project Title: Skimming of Fresh Water with Aquifers in which Fresh Water is Underlain by Saline Water

To determine the methods by which fresh water can be pumped from a free surface aquifer with maximum efficiency and minimum displacement of underlain saline water.

Agronomy

Project Title: Evaluation of Mineral-Water-Ion Equilibria that Relate to Water Management Practices

Research studies are being done:

1. To determine the mineralogy of sand, silt and clay fractions of selected sites in West Pakistan;

2. To determine whether sufficient soil mineral dissolution takes place when irrigation with high SAR (sodium-adsorption ratio) water to favorably reduce the sodium hazards of the water; and

3. To investigate the effects of irrigation with high SAR waters varying in salt on permeabilities.

Civil Engineering

Project Title: Optimization of the Conveyance, Delivery, and Application of Water to the Farm

To determine the factors which affect the amount of water that can be delivered to the farm and affect the cost of operating, maintaining and managing the irrigation con-

veyance system and to study these factors to determine ways of optimizing the amount of water delivered and efficiently utilized for on-farm and minimizing costs.

Economics

Project Title: Economic Analysis to Achieve an Efficient Allocation of Water in Pakistan

To analyze data made available through USAID Mission, Lahore, on the crop cutting experiment with special reference:

1. To estimate the response of wheat in the Lyallpur district to water fertilization and other input variables;

2. To give specific attention to the water input to estimate its value when applied to the wheat crop;

3. To demonstrate how the information generated from this analysis is needed and how it will be useful information to those involved with planning the allocation of water to agriculture between enterprises on farms and between farms;

4. To demonstrate how a policy such as a high price support for wheat will affect the amount of water that will be allocated to this enterprise; and

5. If the results of the wheat analysis appear fruitful, to secure data for another crop in the Lyallpur district, to better demonstrate the allocation principles mentioned in sub-objects 3 and 4 above.

Political Science and Sociology/Anthropology

Project Title: Organization of Agricultural Development in West Pakistan

To determine institutional changes essential for optimizing water utilization in order to maximize agricultural production. This research will be emphasized by the following major dimensions:

1. To assist Pakistani scholars in the design and application of a research program which will contribute to increased agricultural production by focusing on the problems of systematic linkage in the organization of water management;

2. To study the structural linkage between the system of professional personnel in water management and on-the-farm client users of water in the village system;

3. To focus on existing social and governmental institution and their relationship to water utilization for agricultural production;

4. To show how various public agencies are involved in the activities of water management, what their role is, how they are related to each other, and their linkage to various non-governmental agencies and organizations involved in these processes at the community level for increased agricultural production; and

5. To investigate the interaction of social grouping with the water bureaucracy in terms of how these groups are affected by an attempt to structure the action and policy of administrative bodies.

Attached and to be considered a part of this report are the detailed departmental progress reports (Appendix B).

FUTURE PLANS

1. To continue the research as established for the improvement of water management for on-the farm practices as applicable to West Pakistan.

2. Through correspondence and staff travel to continue to gather research data and maintain liaison between CSU faculty, the governmental agencies and institutions in West Pakistan and the U.S. AID Mission. It has become quite apparent that by doing research only in the U.S., this has not been adequate to completely fulfill the objectives of the Contract and to fully benefit the people and the Government of Pakistan.

3. To establish a position of CSU research coordinator to assist in coordinating on-campus research and proposed research to be done in West Pakistan by the Pakistanis. This will enable CSU to have a coordinator to assist in dealing with the problems of getting fully effective cooperation from the governmental institutes and agencies, the Government of Pakistan and the USAID Mission.

APPENDIX A

Memorandum of request for Preparation of
Administrative and Substance Reports
on Water Management Research Contract

Bernie Frantz

REC'D DEC 12 '69

October 29, 1969

MEMORANDUM

TO: Dr. A. Alvin Bishop
Utah State University
Logan, Utah

Dr. M. Albertson
Colorado State University
Fort Collins, Colorado

FROM: Alvin D. Ayers
Office of Agriculture and Fisheries
Technical Assistance Bureau

SUBJECT: Preparation of Administrative and Substance Reports on Water Management Research Contracts csd-2162 and csd-2167

This is to reiterate our need for administrative and substance reports as required under Item 16 in the contracts and as discussed at the recent CUSUSWASH meeting. I recommend that these reports be prepared as of June 30, 1969 and on December 31 and June 30 of succeeding years. Ten copies of these reports will meet our needs.

I believe that we covered the preparation of the annual progress report, budgets and work plans in our discussion at Logan on October 24 and 25. We look forward to receiving this material by December 31, 1969.

Please call on me if I can be of any assistance to you in the preparation of these reports.

TA/ACF:ADAyers:cc:10/29/69
cc: TA/RUR,OJKelley

RECEIVED
NOV 4 1969
REC'D NOV 6 '69

DEPARTMENT OF STATE
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

October 29, 1969

MEMORANDUM

TO: Dr. A. Alvin Bishop
Utah State University
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Dr. M. Albertson
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Please call on me if I can be of any assistance to you in the preparation of these reports.

APPENDIX B

Approved Outlines of CSU On-Campus Research Projects

On-Campus Research Proposal

CUSUSWASH Project for Research on Water Management in West Pakistan

I. Department: Agricultural Engineering

II. Project Title: Skimming of fresh water from aquifers in which fresh water is underlain by saline water

III. CSU Project Personnel:
A. Resident Faculty Project Leader: Arthur T. Corey
B. Graduate Research Assistant: To be assigned (1/2 time)

IV. Location of Work: Colorado State University, Foothills Hydraulics Laboratory, Fort Collins, Colorado

V. Objective: The proposed research is a study of methods by which fresh water can be pumped from a free-surface aquifer with maximum efficiency and minimum displacement of underlying saline water.

VI. Justification: The fresh water in the aquifer of the Indus Valley is underlain by saline water. The saline water occurs at depths varying from zero to a few hundred feet. The fresh water-salt water boundary is not static but moves in response to motion of the underground water including both fresh and saline water.

In order to lower the water table and also to exploit the aquifer as a reservoir for irrigation water, pumping is taking place over a rapidly expanding area. Most of the wells, especially the deeper wells, have been installed where the saline water was (at the time of installation) at a considerable depth. The wells were intended to produce water that could be used for irrigation, at least after mixing with river water.

Pumping, however, tends to produce mounding of the saline water under the well and this sometimes results in an increase in salinity of the water produced. Furthermore, there are portions of the Indus Valley in which the saline water is already near the surface. In such places, deep wells cannot be installed without producing saline water, and there seems to be no practical

way of disposing of the saline water produced. Obtaining an equivalent amount of water from ordinary shallow wells requires many additional pumping plants and is a comparatively inefficient operation.

The water table depth (in regions where the saline water is close to the surface) is even more critical than elsewhere. The installation of horizontal relief drains below the water table and leading into pumped sumps is one way that this theoretically could be accomplished, but the cost of installation in the non-cohesive soils of the valley seems to make this solution impractical. Various types of skimming wells have been suggested as an alternative method of controlling the water table. The method usually suggested involves the installation of groups of several shallow tube wells, each group being operated by a single centrifugal pump.

A number of such installations are being tested at the present time. One such installation is being tested by the Irrigation Department at a site near Lahore and another is under investigation at the Agricultural University in Lyallpur. It would seem to be desirable, however, to conduct a systematic laboratory study to determine the more efficient arrangements of skimming wells and the proper methods of operating them before extensive field trials of alternative methods are undertaken.

VII. Plan of Work: The proposed research will begin with physical model studies involving fresh water on top of salt water in sands. Fresh water will be removed in a manner simulating pumping at various rates and with wells penetrating the fresh water zone to various depths. The spacing and arrangement of wells and the effects of pumping on various intermittent schedules will also be evaluated.

Observations will be made of the movement and dispersion of the fresh-salt water boundary as well as of the drawdown and yield of the wells.

From the initial model studies, it is hoped that sufficient insight into the phenomena can be obtained to permit delineation of the important variables and description of the processes mathematically. It should then be possible to scale the variables such that data from laboratory models can be used to predict field behavior. It may also be possible to obtain additional data through the use of numerical simulation techniques, if these are found to

agree with results from the physical model observations. With these results, it should be possible, at least, to narrow down possible arrangements and operating techniques for skimming wells which should be investigated further in the field.

VIII. Cooperators: Personnel and Department(s) Involved

Leader(s) and Degree	Department	Capacity Participant	Capacity Advisor
Project Leader:			
Arthur T. Corey, M.S. Engr. Ph.D. Soils	Agricultural Engineering	X	
Technical Advisor(s):			
D. K. Sunada, Ph.D.	Civil Engineering		X
E. A. Breitenbach, Ph.D.	Civil Engineering		X
Other Personnel:			
Graduate Research Assistant (to be appointed)	Agricultural Engineering	X	

IX. Bibliography

1. Bear, J., On the tensor form of dispersion in porous media. J. Geophysical Research, p. 66, 1961.

2. Bennett, G. D., Mundorff, M. J. and S. Amjad Hussain, Electrical analog studies of brine coming beneath fresh water wells. WAPDA, Water and Soils Investigation Division, Lahore, West Pakistan, 1968.

3. Nazir Ahmed, Hydraulics of tubewells, Scientific Research Stores, 4-Abkari Road, Lahore, West Pakistan. Contains a description of multiple strainer wells designed for water skimming.

4. Wang, F. C., Approximate theory for skimming well formulation in the Indus Plain of West Pakistan, J. Geophysical Research, p. 70, 1965.

Relationship of Proposal for Cooperating Work in West Pakistan Agricultural Engineering

After the most promising arrangements and operating techniques for skimming wells have been selected from on-campus studies, it is planned to test field installations in a region near the West Pakistan Agricultural University at Lyallpur. Lyallpur is in a region where the water table is at a shallow depth and only a thin layer of fresh water overlies the saline water. Skimming wells, therefore, would be expected to have an application in this region. Furthermore, the faculty of the Department of Agricultural Engineering have indicated an interest in cooperating in this investigation if funds can be found to support it. They have already installed one type of skimming well system, but have not had the funds to conduct a systematic study of various possible systems.

10 January 1969

ON-CAMPUS WATER MANAGEMENT RESEARCH PROPOSAL
CUSUSWASH

I. Department: Agronomy

II. Project Title: Evaluation of Mineral-Water-Ion Equilibria that Relate to Water Management Practices

III. CSU Project Personnel:

A. Senior Resident Faculty Project Leader: W. R. Schmehl
B. Senior Resident Faculty Project Associate: W. T. Franklin
C. Graduate Research Assistant: Mehdi Monadjhemi

IV. Location of Work: Colorado State University, Fort Collins, Colorado

V. Objectives:

1. To determine the mineralogy of sand, silt, and clay fractions of selected sites in West Pakistan.

2. To determine whether sufficient soil mineral dissolution takes place when irrigated with high SAR waters (> 10) to favorably reduce the sodium hazard of the water.

3. To investigate the effects of irrigating with high SAR waters varying in salts on permeabilities of the soils.

VI. Justification:

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 (2). 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 reexamination 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 (2, 5). Other minerals in the sand and silt fractions, such as calcic plagioclases and horneblende, have been reported to undergo significant dissolution and increase the Ca content of the soil solution (11). The activity of Na in soil solutions may even possibly be reduced by the formation of zeolite in strongly alkaline situations (1). 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 adsorbed 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 (10). 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 (6, 7).

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 (11). 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 1/. The data (11) 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 (4).

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 (6). 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.

VII. Plan of Work:

A. Laboratory Phase:

Soil samples at 1-foot intervals to a depth of 4 to 5 feet will be obtained from West Pakistan in areas where intensive on-site water management experiments are being or will be conducted. Gypsum and lime contents will be determined. Gypsum, lime, and organic matter will be removed and the soils fractionated into various sand, silt, and clay sizes. Minerals in the sand and silt fractions will be identified with the petrographic microscope and by x-ray diffraction. Clay-sized minerals will be identified by x-ray diffraction and chemical techniques (9).

The soils will be equilibrated with waters corresponding to the composition of tubewells in the sample area, particularly those with SAR's above 10. Soil solution ionic composition changes, equilibrium salt and sodium levels, physical stability and water transmission properties will be related to well waters with varying ionic composition and specific mineralogical compositions of the soils.

1/ Communication with M. Quayyum, Soil Scientist, Tipton and Kaumbach.

B. Application:

The results will be used to develop more flexible criteria for classifying water by taking specific soil properties into account. The results would be applicable to many arid areas and in particular those in the Indus Plain.

VIII. Cooperators: Personnel and Department(s) Involved

Leader(s) and Degree	Department	Capacity: Participant	Capacity: Advisor
W. R. Schmehl, Ph.D.	Agronomy	X	
W. T. Franklin, M. S.	"	X	
R. S. Whitney, Ph.D.	"		X
A. T. Corey, Ph.D.	Agr. Engineering		X
M. D. Skold, Ph.D.	Agr. Economics		X
M. Monadjhemi, M.S.	Agronomy	X	

IX. Selected References:

1. Baldar, N. A. and L. D. Whittig. 1968. Occurrence and synthesis of soil zeolites. Soil Sci. Soc. Amer. Proc. 32:235-238.

2. Bower, C. A. 1968. Trip and final report on consulting assignment for USAID/Pakistan, Feb. 26-Mar. 15. Mimeographed.

3. Bower, C. A., G. Ogata, and J. M. Tucker. 1968. Sodium hazard of irrigation waters as influenced by leaching fraction and by precipitation or solution of calcium carbonate. Soil Sci. 106:29-35.

4. Clark, R. E. 1967. Recent soil reclamation work. Pakistan J. of Sci. 19:218-226.

5. Franklin, W. T. 1966. Soil gypsum and lime solubility, and equilibration studies with $NaHCO_3$ water. Report to Collaborators (State Reports). U. S. Salinity Laboratory, Riverside, California.

6. McNeal, B. L., D. A. Layfield, W. A. Norvell and J. D. Rhoades. 1968. Factors influencing hydraulic conductivity of soils in the presence of mixed-salt solutions. Soil Sci. Soc. Amer. Proc. 32:187-190.

7. McNeal, B. L. and N. T. Coleman. 1966. Effect of solution composition on soil hydraulic conductivity. Soil Sci. Soc. Amer. Proc. 30:308-312.

8. McNeal, B. L. 1966. Clay mineral variability in some Punjab soils. Soil Sci. 102:53-58.

9. McNeal, B. L. and T. Sansoterra. 1964. Mineralogical examination of arid-land soils. Soil Sci. 97:367-375.

10. Pratt, P. F. and B. L. Grover. 1964. Monovalent-divalent cation-exchange equilibria in soils in relation to organic matter and type of clay. Soil Sci. Soc. Amer. Proc. 28:32-35.

11. Rhoades, J. D., D. B. Kreuger, and M. J. Reid. 1968. The effect of mineral weathering on the sodium hazard of irrigation waters. Soil Sci. Soc. Amer. Proc. 32:643-647.

RESEARCH PROPOSAL

CUSUSWASH Project for Research on Water Management in West Pakistan

I. Department: Political Science

II. Project Title: Organization for Agricultural Development in West Pakistan

III. CSU Project Personnel:
   A. Senior Resident Faculty Director:
      Phillip O. Foss
   B. Senior Resident Faculty Project Associates:
      Charles L. Garrison
      John P. Vloyantes
   C. Resident Research Assistants:
      Four graduate students

IV. Location of Work: Colorado State University, Fort Collins, Colorado

V. Objective: To determine institutional changes essential for optimizing water utilization in order to maximize agricultural production. This research will emphasize the following major dimensions:
   1. To focus on the existing social and governmental institutions and their relationship to water utilization for agricultural production.
   2. To show how various public agencies are involved in the activities of water management for agricultural production, what their role is, how they relate to each other, and their linkages to various non-governmental groups and organizations involved in these processes at the community level.
   3. To investigate the interaction of social groupings with the water bureaucracy in terms of how these groups are affected by and attempt to structure the actions and policies of administrative bodies.

VI. Justification: Agricultural development, like any developmental process, is a progression of events toward systems change. Change in an on-going system places a great deal of stress on the interdependent sectors comprising the system.

Brief of Applied Research in Water Management Proposed for West Pakistan

Department of Agronomy

Dr. Inam-Ul-Haque, Head of Soils, West Pakistan Agricultural University, Lyallpur, and Mr. Nur-Ud-Din, in charge of soils research, Land Reclamation Directorate, Lahore, have both expressed an interest in a cooperative soils-water management research project at their institution. Soil profile samples were taken from two locations on the WPAU research farm and from one location on the research area of the Land Reclamation Directorate. The mineralogy-ionic equilibria study will provide basic soils data needed to evaluate the field studies.

Field experiments will be conducted at the two locations to study the influence of soil properties and water quality on the effective use of the canal and tubewell waters. Variables under study will include (1) irrigation water of varying quality obtained by mixing canal and tubewell waters, (2) plant species, (3) soil amendments, and (4) methods of irrigation. Water quality treatments will be based on local conditions and on CSU campus research; crops to be grown will be those common to the area; gypsum will be used as a soil amendment; and, method of irrigation will include amount of water and the alternate use of good and poor quality water, the latter treatments based on season and stage of crop growth.

Experiments will be conducted on land levelled for optimum water control and fertilized for maximum production. High yielding varieties and good agronomic practices will be followed. Subsequently, fertility variables may be included.

Treatment effects will be evaluated from crop yields, plant composition and changes in the salinity and sodium status of the soil throughout the root zone.

10 January 1969

In other words, the additional input of irrigation water is not solely a problem of technological adaptation. Patterns of behavior are related to present agricultural practices. Plans for technological changes have failed many times because organizational structures have not been effectively evaluated in terms of their ability to facilitate or retard the system changes. The purpose of this research is to analyze the institutional arrangements for water management and to determine needed changes for better water utilization in maximizing agricultural production.

The research includes investigation of the administrative processes as well as components of the social environments and their linkages to the agencies involved in water management. These variables comprise an additional group of factors to be considered in the study of agricultural development. In Pakistan or elsewhere, these processes are not neutral sets of administrative procedures or social practices whose effect can be ignored or assumed without serious investigation.[1] The content and implications of these patterns of human behavior often function as a barrier to planned change or a means of unanticipated change in spite of the goals of individuals and organizations involved.

Agricultural development is a system problem consisting of several interacting factors. Organizational adaptations to innovations such as increased irrigation water is a necessity in terms of complexity of functions (fertilizers, pesticides, transportation and storage facilities) and coordination (facilities at harvest time or pesticides during growing season). These matters are not only problems of effective administration but they are dependent on social acceptance of the formal and informal groups comprising the social environment of the water agencies. Analysis of formal administrative structures must be integrated with the values and behavior of societal elements in order to know the role of these institutions in maximizing agricultural production.

VII. Plan of Work:

1. The analysis of published materials including secondary sources, United Nations and Agency for International Development documents, and Pakistan governmental documents. This analysis will tentatively:
   a. Identify the administrative and social institutions that are relevant to the optimum utilization of water resources for increased agricultural production

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[1] Gustov F. Paponek, Pakistan's Development, (London: Oxford University Press, 1968), pp. 145-183; and Socio-Economic Bench-Mark Survey of Mona Project, (Lyallpur: West Pakistan Agricultural University, 1969).

b. Describe local and national institutions and their interrelationships
c. Evaluate the relative significance of discrete segments of current institutional arrangements as they relate to agricultural production
d. Isolate the patterns of interaction among different types of institutions and between different levels of the system
e. Describe the relationships between important social groupings and government agencies
f. Trace the patterns of recruitment found in the public bureaucracy and relate them to the underlying social structure
g. Measure the probable impact of current institutional arrangements upon the goal of increasing agricultural production by relating the goal to likely sources of support and blockage within the system.

2. The geographic locale of research will be on a specific area yet to be chosen. The area will likely be that of the Mona Project because of the availability of benchmark data, and the likelihood that there will be a significant agricultural and engineering input from other projects in this same CUSUSWASH research program.
3. Use secondary and documentary sources to establish the nature of present organizational linkages between American development agencies and Pakistani agencies involved in the areas of water distribution and agricultural production.
4. Visit West Pakistan to:
   a. Obtain additional documentary data to validate and/or to recast the tentative conclusions drawn from Pakistan and other materials available in the United States
   b. Establish contacts for obtaining data needed to fill in the gaps in the preliminary analysis and for the evaluation of tentative conclusions
   c. Interview Pakistani officials and leaders of American development projects to check validity of conclusions and to obtain information not available in published materials
   d. Arrange for one or more social scientists from West Pakistan Agricultural University to be employed on a full or part-time basis (depending on availability of funds) to aid in the collection and analysis of data.
5. Project activities in other disciplines will be monitored in order to determine if any extensions of administrative services from resulting changes in the system are necessary. Examples of such areas are:
   a. Landleveling: Crop reports have clearly demonstrated that irrigated lands have areas which are either too dry or too wet after application of irrigated water. In the United States, techniques of land leveling have been developed using surveying techniques, staking out the cut and fill, and applying simple

land leveling machinery. Transference of these techniques would make possible effective land-leveling that is relatively simple and inexpensive.

b. Tube Well Management: In many areas of the Punjab, there are two layers of ground water. The Lower layer is water too salty to be useful in irrigation. The upper layer is fresh water needed for irrigation. The water table is close to the ground surface which results in water logging and saline conditions that severely inhibit plant growth. A tube-well technique has been developed for reducing the water table and has been implemented in certain regions of Pakistan. Research is underway to develop techniques of skimming the fresh water off the saline water by means of tube wells. This requires careful management of the following variables: 1) depth of well; 2) rate of pumping (per hour); 3) amount of pumping (number of hours); 4) horizontal spacing of wells; 5) type, size, and length of well screen.

c. Analysis of Soils: Soil samples will be analyzed to specify mineral properties. The major objectives of this research are to improve water quality classification for West Pakistan to include soil properties and additional water characteristics. Findings will be used to quantify various soil and cropping situations for: 1) the proper combinations of tube well and canal waters for maximum effectiveness, and 2) the leaching requirement of irrigation water of varying composition.

6. The preparation of a report which:

a. Identifies and explains the present situation in terms of current institutional arrangements

b. Specifies organizational modifications and adaptations which helped to accomplish recent changes in agricultural practices, such as utilization of fertilizers and new seeds, resulting in large increases in grain and other agricultural production.

c. Advances recommendations for program development that will more effectively utilize current institutional arrangements to maximize the efficiency of aid inputs into the system.

d. Develops recommendations for the shaping of administrative and institutional relationships in a manner more conducive to the efficient absorption of new inputs into the system.

e. Presents a design for deliberate experiments devised to test the utility of alternative models of program development and institutional change which integrate the concepts and findings of all academic disciplines in the Pakistani water research project. Findings from the Political Science and Sociology studies will be analyzed for the purpose of formulating experimental administrative programs and to test techniques for increasing organizational effectiveness in water utilization.

VIII. Integration with Sociology Proposal: The focus of the sociology proposal is on the client groups of the organizations involved in water management. This research will complement the organizational analysis proposed here by the political scientists. Integration of the findings of the two studies will be completed in a final report.

IX. Cooperators: Personnel and Department Involved

Leader(s) and Degree	Department	Capacity Participant	Capacity Advisor
Director:			
Phillip O. Foss, Ph.D.	Political Science	X	
Other Personnel:			
Charles L. Garrison, Ph.D.	Political Science	X	
John P. Vloyantes, Ph.D.	Political Science	X	
Graduate Research Assistants:			
Two	Political Science	X	

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On-Campus Research Proposal

CUSUSWASH Project for Research on Water Management in West Pakistan

I. Department: Economics

II. Project Title: Economic analyses to achieve an efficient allocation of water in Pakistan

III. CSU Project Personnel:
   A. Resident Faculty Project Leader: Melvin D. Skold
   B. Resident Faculty Project Leader: Kenneth C. Nobe
   C. Graduate Research Assistant, Ph. D.: Debebe Worku
   D. Graduate Research Assistant, M.S.: Stanley Hargrove

IV. Location of Work: Colorado State University, Fort Collins, Colorado

V. Objectives:
   A. To analyze data made available through USAID/Lahore on the Crop Cutting Experiments with special reference:
      1. To estimate the response of wheat in the Lyallpur District to water, fertility and other input variables.
      2. To give specific attention to the water input to estimate its value when applied to the wheat crop.
      3. To demonstrate how the information generated from this analysis is needed and useful information to those involved with planning the allocation of water to agriculture, between enterprises on farms, and between farms.
      4. To demonstrate how a policy, such as a high price support for wheat, will affect the amount of water that will be allocated to this enterprise.
      5. And, if the results of the wheat analysis appear fruitful, to secure data for another crop in the Lyallpur District (e.g., sugar cane), to better demonstrate the allocation principles mentioned in subobjectives three and four, above.
   B. To analyze data made available through the Research Director, Agricultural Census of the Government of Pakistan which relates to rice yields-fertility levels and water availability in East Pakistan.
      1. To examine the yield-fertility relations for farmers who do not use supplemental irrigation water.

2. To examine the yield-fertility relations for farmers who utilize supplemental irrigation water.
3. And, to contrast the results of parts B-1 and B-2 in estimating the productivity of supplemental irrigation water.

C. Given the analysis of Objectives A and B, to pose alternative courses of action:
1. With reliable results of analysis under Objective A, to propose further work with the Crop Cutting Experimental data which pertains to other crops and to different locations in the country.
2. With results of analyses under Objective A that do not contain the desired reliability, to pose alternative means of generating data which can provide information to planners such as:
   (a) Field experimental trials which provide control conditions for selected variables
   (b) Field surveys which give careful attention to crop yield-water-fertility relations.
3. Given the results obtained to the analysis for Objective B, to propose further work with the Census data, or to suggest other means of data collection to provide the required information for planning.

VI. Justification: Water allocation over space and between enterprises may be one of the most crucial problems to the development of arid areas. While this proposal does not directly confront the problems of allocating water between alternative uses, e.g., household consumption, industry, and agricultural irrigation, it does focus upon economically efficient allocations within agriculture.

Based on the experience of the economists currently on the Colorado State University faculty who have previous experience in Pakistan, basic input response studies are much needed by planners in Pakistan. These planners require information, which they do not currently have at their disposal, as to the likely consequences and economic feasibility of alternative courses of action. Particular reference is given to the water resource. For example, what are the benefits that can be anticipated from a policy to encourage the development of private tube-wells? The benefits must be weighed against the costs, public and private, incurred by these developments. The value of additional water forthcoming from the tube-wells can be analyzed in the economic framework production response.

Similarly, planners require information about the consequences of various input subsidy and price support schemes. Data are required to evaluate the merits of policies to increase grain production by means of subsidizing the costs of certain key inputs such as fertilizer or improved varieties of seed relative to efforts to encourage production through additional irrigation developments. Or, if the price of wheat is supported, the consequences of this action on the demand for water by the wheat enterprise is needed information. Again, an important part of the data required is that those which is generated through input response studies.

In a recent visit to Pakistan as part of the CSU team, the author of this proposal found that agricultural personnel in that country, Americans and Pakistani, agreed that the research as proposed is research of high priority. Key people with which the research ideas were discussed are: Mr. Tyler Sturdevant, Statistician, SRS, USDA on loan to USAID/Lahore; Dr. Helmer Holje, Chief Economist for Harza Engineering (General Consultant to WAPDA); Dr. Leon Hesser of the AID Mission/West Pakistan; and Dr. Riaz Ahmad Khan, Director Research, Agricultural Census, Government of Pakistan.

This proposal is designed to serve as a first phase to two subsequent stages. A second phase requires the location of an economist in Pakistan as part of a CSU team. This person would (1) work with counterpart Pakistani to pursue the analysis of the Crop Cutting Experiment data and Agricultural Census data, should the results of the on-campus analysis appear that such efforts are of merit, (2) or, the economist would work with his counterparts to establish field research trials involving agronomic-economic cooperation to generate data needed for economic analysis to be useful in policy considerations, (3) or, conduct surveys to obtain data specifically needed for input response analysis.

The third phase would be to utilize the analytical techniques developed, data generated, and knowledge accumulated in educational programs. Knowledge disseminated will be useful to students interested in development, both domestic and foreign, as well as to the Pakistanians in their own educational programs.

Economic analysis of the response of crops to various factors of production is well known. The works of Heady and others are most typical of these contributions. With these studies the methodology has been developed to quantitatively estimate various

economic parameters. The analysis of water-crop yield relations is not very well documented, even though a few studies have appeared in recent years.

In Pakistan, almost no published research exists which makes a systematic economic analysis of factor-product relations. While support for such endeavors has been lacking, many data do exist which could be useful in demonstrating the potential value of such studies to planning authorities. The integration of the methods of analysis of proven value and available Pakistani data into a study to show the usefulness of these types of studies could be very beneficial to planners in Pakistan.

VII. Plan of Work: For Objective A, contacts have been made with people in Pakistan to assist in making the Crop Cutting Experimental data available for our on-campus research. These data are to be obtained through the cooperation of Dr. Leon Hesser and Mr. Tyler Sturdevant, USAID in Pakistan. The analyses will begin with exploring the wheat yield-input level relationships for the Lyallpur District. Special attention will be given to the water input. The analyses will consist of multiple regression techniques to explore the functional dependency of yields of wheat to the levels of various inputs.

The conceptual framework for using this type of analysis to provide information to planners will be set forth. Given satisfactory results to the research analysis, the Crop Cutting Experiment data will be processed through this conceptual framework to demonstrate how such data, which is available, can be used in gaging policy decisions.

The data can be used to demonstrate how, for example, a higher wheat price will affect the demand for inputs in that enterprise. Similarly, with a two product example, one can demonstrate how such information can be used to provide for a more efficient allocation of water between enterprises. In addition, these studies can provide estimates showing the value of alternative amounts of water in agriculture to be used in conjunction with similar estimates of the value of water in other uses.

For Objective B, the Census Survey Data from East Pakistan will be used. These data are to be obtained through Dr. Riaz Khan, Director Research of the Agricultural Census.

Initially, a sample of farmers will be obtained who did not utilize supplemental irrigation. Focus will be on the rice yield-fertilizer level relationships. Subsequent analysis will explore the same relationships for farmers who did use supplemental irrigation. A comparison of the results to these two analyses will provide some information about the increased productivity attributable to supplemental water. This information can be disucssed in a policy context to demonstrate how the benefits of irrigation development versus other policy alternatives can be assessed. Again, the primary analytical techniques will be multiple regression analysis and production economics principles.

Under Objective C, an evaluation will be made of the usefulness of these available data, when analyzed to planners and policy makers. The merits of using these data relative to data generated under field experimental trials for which the levels of certain inputs are carefully controlled will be studied. Discussions of the field experiment approach will include suggestions for the experimental design. With satisfactory results of the analysis of the Crop Cutting data, specific recommendations will be offered to further steps in the analysis of these data. Attention will be given to the priority for information required on the part of the planning authorities.

VIII. Cooperators: Personnel and Department(s) Involved

Leader(s) and Degree	Department	Capacity Participant	Capacity Advisor
Project Leaders:			
Melvin D. Skold, Ph. D.	Economics	X	
Kenneth C. Nobe, Ph. D.	Economics	X	
Worku Debebe, G.R.A. (Ph. D. Candidate)		X	
Stanley Hargrove, G.R.A. (M.S. Candidate)		X	

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File

Relationship of Proposal
for Cooperating Work in West Pakistan
Department of Economics

Cooperation during the on-campus phase will come rpimarily from two sources: (1) Dr. Riaz Ahmad Khan, Director of Research, Agricultural Census, Government of Pakistan, and (2) Mr. Chaudhry Muhammed Afzal Khan, Deputy Secretary (Statistics), Agricultural Department, Government of West Pakistan.

Dr. Riaz will provide data from a survey conducted by the Agricultural Census in irrigated areas of East Pakistan. Dr. Riaz is anxious to have such analyses completed as Colorado State University has proposed but he has not had the opportunity to do so himself. He will assist in analyzing the data and suggesting further work as the project develops. Dr. Riaz has considerable experience in this type of analysis from his previous research.

Mr. Afzal has agreed to provide data from the Crop Cutting Experiments through Mr. Tyler Sturdevant, USAID. Both of these men are anxious to see this type of work begun with the Crop Cutting Experiment data. In fact, given the opportunity, they will develop similar analyses in Pakistan.

19 February 1969

On-Campus Research Proposal

CUSUSWASH Project for Research on Water Management in West Pakistan

I. Department: Civil Engineering

II. Project Title: Optimization of the Conveyance, Delivery and Application of Water to the Farm

III. CSU Project Personnel:
A. Project Leader: E. V. Richardson
B. Associate Project Leader: S. H. Shen
C. Associate Project Leader: Al Mercer
D. Graduate Research Assistant: Khalid Mahmood
E. Graduate Research Assistant: To be assigned

IV. Location of Work: Colorado State University, Fort Collins, Colorado

V. Objectives: To determine the factors which affect the amount of water that can be delivered to the farm and which affect the cost of operating, maintaining and managing the irrigation conveyance system and to study these factors to determine ways of optimizing the amount of water delivered and efficiently utilized on the farm and minimizing costs. The areas to be studied include: (1) the management of the delivery system; (2) the maintenance requirements of the system; (3) water losses due to seepage and associated water-logging; (4) the effectiveness of hydraulic structures for controling the flow and alleviating the silt problem; (5) silt deposition in the canals and on the farm; (6) methods of on-farm application, and; (7) the importance of changes in river behavior in the operation of the irrigation system.

VI. Justification: A considerable part of the water that is diverted from the river for irrigation never reaches the farms because of seepage, evapo-transpiration and management problems. Furthermore, canals and structures fail to operate as intended because of the seidment that is being transported in the canal.

The water lost by seepage and management problems also contributes to the salineazation of the land and ground water. A large portion of the maintenance cost of an irrigation system is attributable to erosion and sedimentation of the streams, canals,

and hydraulic structures. Sedimentation also by decreasing canal capacity decreases the amount of water delivered to the farm and decreases the flexibility of management in scheduling deliveries. The unit cost of water delivered to the farm is, therefore, increased by the foregoing factors.

Poor management of the system results in some farms getting too much water and others not getting enough, water not being available at the most advantageous time for maximum crop production, costly maintenance and excess water loss and seepage problems, and lack of confidence and trust of the farmer in the system.

This study will be concerned with determining (1) the source of the sediment in canals and streams; (2) methods for decreasing and/or ejecting the sediment supplied to the canals by the rivers; (3) the amount of water lost by seepage, evaptranspiration and management problems and methods for decreasing this loss; (4) methods for erosion and sedimentation control at hydraulic structures, farm turnouts on the farm; and (5) methods for more efficient use of water on the farm.

VII. Plan of Work: A laboratory study would be started on problems associated with hydraulic structures for conveyance, delivery and measurement of irrigation water. The first study would be development of easily constructed farm turnouts which are tamper proof and would deliver a predetermined quantity of water over a wide range of upstream and downstream heads.

A study will be initiated into an on-farm application of water. The first step, after a review and compilation of the available literature, would be a pilot study of water application methods (basin, border, furrow, wild flooding), at a reduced scale in a 20' x 80' open flume to determine distribution characteristics for different application techniques and soil conditions. The problem of salt accumulation that occur when furrow irrigation is used in saline soils will be investigated. The results of this pilot study would be used to formulate and stimulate full-scale field tests to be conducted in Pakistan.

A laboratory and field study of canal seepage and water logging of the land will be made. The first study will be to investigate the use of florescent dyes for the measurement and tracing of water seeping from the canals. Studies at Colorado State University indicate that florescent dyes because of their

concentrations can be accurately determined at the part per billion lever, would be an extremely useful tool in seepage studies. Techniques developed would be useful in tube well water supply and drainage studies.

A cooperative study of the silt problems in the Indus Basin will be undertaken with the Water and Power Section of the Pakistan Planning Commission and the University of Peshawar. The changes that will occur in the regime of the rivers (width, depth, slope, etc.) in the area have not been fully assessed. These changes could destroy or require costly remedial action for many of the irrigation and water power projects. The study will assess the extent and location of the sediment problem and make recommendations for minimizing its impact on the rivers and irrigation projects. Most of the work will be in Pakistan (Planning Commission will commit 100,000 rupees). However, on campus studies will be made on certain aggradation and degradation problems for which data is available.

A comprehensive survey and compilation of the literature on hydraulic structures, farm turnouts, control of erosion and sedimentation, on-farm irrigation practice, water measurement and management of irrigation systems will be made. The results of many studies on the above subjects are scattered through the reports of WAPDA, Journal of the Institute of Engineers (Pakistan), Institute of Irrigation Research, Lahore, Tipton and Kalmbach, American Sociaty of Civil Engineers, World Bank, Institute of Civil Engineers (London), American Society of Agricultural Engineers, ARS, etc. The compilation of this material would be of benefit to all water resource planners and agriculturalists working on water problems in underdeveloped countries. The Survey would also aid in planning future research projects on water management.

VIII. Cooperators: The following people will participate in the project as advisors: M. L. Albertson, S. S. Karaki, D. B. Simons of the Civil Engineering Department; N. A. Evans, A. T. Corey, G. Skogerboe of the Agricultural Engineering Department; and E. G. Kruse, H. R. Haise and D. F. Heerman of the Agricultural Research Service.

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Relationship of Proposal
for Cooperating Work in West Pakistan
Civil Engineering

The research will be undertaken with cooperation of the following Pakistanian organizations:

Water and Power Section, Planning Commission of the Government of Pakistan, Islamabad, S. K. Malik, Chief.

Institute of Irrigation, Lahore, Mushtaq Ahmad, Director.

Irrigation Department, WAPDA, University of Peshawar.

15 January 1969