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ANNUAL TECHNICAL REPORT
FISCAL YEAR 1973

IMPROVING CAPACITY OF CUSUSWASH UNIVERSITIES
FOR WATER MANAGEMENT FOR AGRICULTURE

REPORT NUMBER IV

VOLUME I

Submitted by

COUNCIL OF UNITED STATES UNIVERSITIES FOR SOIL AND
WATER DEVELOPMENT IN ARID AND SUB-HUMID AREAS, INC.

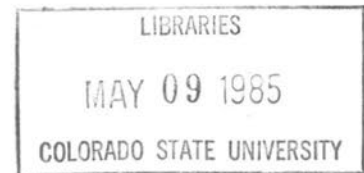
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TABLE OF CONTENTS

	Page
Organization of CUSUSWASH	iii
Preface	v
Part I	
Role of CUSUSWASH	A-1
CUSUSWASH Activities	A-4
Research	A-4
On-Going Research	A-6
Response Capability	A-7
Committee Activities	A-7
New Courses	A-9
Staff Additions	A-10
Student Accomplishments	A-10
Special Activities and Increased Linkages	A-11
CUSUSWASH Transition	A-12
Part II - University of Arizona	B-1
Part III - Colorado State University	C-1
Part IV - Utah State University	D-1

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PREFACE

The impact of the 211(d) grant monies to the three CUSUSWASH universities is real and tangible. This annual report provides an overview on the activities of the report year and clearly indicates that the momentum generated by the stimulus of the 211(d) grand funds is reaching out to the universities and producing a positive cooperation and coordination of activities that will have lasting and far-reaching effects. The report will indicate that many countries are benefiting from the coordinated approach now made possible by and through CUSUSWASH.

The report covers fiscal year 1973 and considers the activities of the following universities:

University of Arizona

Colorado State University

Utah State University

Although the University of California (Davis and Riverside) does not have a 211(d) grant it is a member of CUSUSWASH, and reference will be made to its involvement with the recipient universities.

The report will summarize some of the activities of the universities with 211(d) grants, and the individual reports will be attached for those wishing more detail on the many activities involved with the 211(c) program. For those of us who have been involved with the programs over the years since its inception, it is gratifying to note the progress made to date and to see benefits now accruing to developing

countries from our combined efforts. The future holds further promise of even greater involvement, and it may well be that an even greater effort than has been made in years past will be needed to meet the challenges that now appear before us.

Bruce H. Anderson
Executive Director

ROLE OF CUSUSWASH

The principle concept in the formation of CUSUSWASH is to bring together the major available expertise in the general field of water management. This creates a forum wherein the individual expertise of each of the member universities can be effectively integrated to consider all the elements of the system of water management from the moment that rainfall touches down on the watershed until it is consumed by plants in the field in the production of food. The increasing pressures from many parts of the world to obtain expert help in the development and management of vital water resources validates the need for such a pool and the need to increase this manpower resource so that it can respond more readily.

The formulation of CUSUSWASH in 1967 brought together the talents and expertise of four major universities concerned with water management from the watershed through reservoirs and conveyance systems, deep wells, and underground storage to the final use of water at the farm level for the production of food and fibre. The university presidents of member schools each appointed two trustees to represent their school and to formulate policies and procedures under which the organization would function. This format has remained essentially the same except that the role of secretary has evolved and increased in responsibility to a full time equivalent position of an executive director, responsible to the Board of Trustees.

A system of semi-annual meetings sponsored by CUSUSWASH brings the major expertise of the universities together with the Board of Trustees to compare research programs at each school, identify problems, to

exchange ideas and concepts, and to brainstorm possible new approaches to the solution of water management problems. Researchers are provided opportunity to report techniques, methodologies and results. Question and answer sessions have resulted in changes in programs and modifications of techniques in some programs. The forums and report sessions have been open, frank and on a professional level. The fact that group meetings are not overly large allows active participation from those present and there is no serious inhibition because of large numbers of people wishing to participate but lacking in opportunity.

To further facilitate open exchange of ideas, to generate new thinking, and to facilitate action, CUSUSWASH early established a system of working committees. In the main these have functioned well and have served useful purposes. In some cases the deliberations of these committees have resulted in rather outstanding activities which are now beginning to bear fruit. Without the catalytic pressure of CUSUSWASH it is very doubtful that such activities would have materialized. The semi-annual meetings usually held in January and July of each year provide the opportunity for member universities to meet, committees to convene, reports to be presented and business conducted. Some committees have held additional meetings between the semi-annual sessions in order to complete assignments.

This process of frequent interaction sponsored by CUSUSWASH has produced a positive and cooperative attitude among the scientists and researchers from each school. The individual concerns of each university have in some cases changed to accommodate the broader deeper thinking engendered by interuniversity group interaction. In addition, this interaction within committees and during semi-annual meetings has caused

serious introspection into on-going research programs at individual schools, thus increasing the degree of sophistication of this research. The system has also allowed feedback from research and experience from over-seas projects and engendered a keen sense of appreciation of the problems faced in many countries of the world. This aspect alone is worthy of a great deal of attention.

Another major accomplishment has been the increasing ability of CUSUSWASH members to react collectively to requests for expertise in research and technical assistance in problems of water management. Requests for assistance have come to CUSUSWASH schools not only from AID/Washington and AID Missions, but from outside sources as well. Several countries and international agencies have requested assistance through the Council. The bringing together of a large body of professional expertise produces a confidence that is usually not possible through one school alone. It should be pointed out, however, that the progress to date is still not sufficient, and serious thought needs to be given to ways to augment and increase the capability in water management.

As the Board of Trustees, charged with the overall responsibility of CUSUSWASH, watched the increasing interactions between and within their universities, it was obvious that this effort to integrate activities in research and related activities and to build competency should be continued. The advantages provided by the CUSUSWASH association far outweighed the costs involved in bringing professional groups together. Steps were therefore taken to incorporate the organization and provide management to oversee the increasing activities and responsibilities of CUSUSWASH. Formal incorporation took place September, 1972, and CUSUSWASH now acts as a legal corporate body

and is in a better position to react to requests made upon it. The details of the incorporation of CUSUSWASH are covered in last year's report and will not be repeated here.

The role of CUSUSWASH then has been to stimulate activities, programs and interactions in water management which could not have been achieved in any other way. The progress made to date represents a real beginning. The experience of the past few years provides enough hope and impetus to continue CUSUSWASH and its activities and not to disband it nor let it die. The future will require continued dedication by interested leaders and professional staff to provide a manpower pool capable of responding in some degree to the world's needs in water management. Outside stimulus and some financial backstopping from AID is still essential.

CUSUSWASH ACTIVITIES

This section will consider some of the specific activities carried out during the year to illustrate how the member universities and professional staff have reacted to CUSUSWASH stimulus.

RESEARCH

The Integrated Approaches Committee was established by the Board of Trustees to explore ways and means of integrating the total water system through its many stages to obtain maximum benefits from available water supplies. Sub-committees were established to consider particular problems as they were identified in the main study. A major report is now ready for publication and distribution by the Integrated Approaches Committee. In addition the Irrigation Management Program Committee met during the semi-annual meetings of CUSUSWASH, and in a number of special

meetings called to expedite the discussions, and identified several problem areas of major concern.

Staff members of the committees realizing the need to research these problems prepared proposals based on their deliberations. Research is now under way to obtain answers to the problems identified by the committee action. One problem worthy of study is "Water Production Functions and Predicted Irrigation Programs for Principal Crops as Required for Water Resources Planning and Increased Water Use Efficiency." The nature of the work has multiple benefits in that it will have components carried out at each of the CUSUSWASH schools. An additional major benefit that can come in the future is that such work can readily be expanded to overseas research and add materially to the usefulness and validity of the data. Future CUSUSWASH meetings will deal with the mechanics to incorporate the present campus research programs into the overseas programs whenever possible.

The second research component, identified and conceived through the CUSUSWASH committees considers the question of "Optimizing Crop Production Through Control of Water and Salinity Levels in the Soil." It is complimentary to the Water Production Functions Model and the two programs need to be researched together and properly integrated to achieve the needed data. Again this second component can be extended to overseas research areas. Actually, the more data points that can be added to the system will strengthen rather than weaken the final results. This component will receive further CUSUSWASH study.

It is anticipated that additional material will be forthcoming from the Integrated Approaches Committee report and result in further research activity. The work of the committee has opened new horizons

and will no doubt be used as a permanent committee by CUSUSWASH to brainstorm ideas, identify problem areas and stimulate researchers to explore these areas.

The new exciting dimension of the committee activity will be extending present programs overseas as mentioned above. So many areas of the world can benefit from the work now proposed, and all possible means should be explored to encourage other regions of the world to engage in research to optimize water use efficiencies. The two AID/Washington sponsored regional projects offer a good starting point to initiate a network of research stations on water management, incorporating a study of the question posed above. Such a network can be expanded as opportunities arise.

ON-GOING RESEARCH

As indicated above CUSUSWASH has provided the opportunity for the universities to meet twice each year and report and discuss their progress, problems, results, and future plans on overseas research programs. This continuing dialogue has resulted in changes in program orientation, changes in strategies in the approach to obtaining the cooperation of local agencies, and in modifications of experimental designs. The successes or failures reported by field researchers have stimulated new thinking and dialogue, and discussions have suggested alternative ways to achieve better results.

At times circumstances beyond the control of the field researcher have caused the loss of a year of valuable data. Political changes, lack of monetary support and changing of local personnel have played a part in slowing down or even stopping a research program. Usually, however, the ingenuity of the researcher or the opportunity to discuss

similar problems experienced by his peers has helped solve many problems enabling research to continue and progress to be made.

Not to be overlooked is the value to the researcher in having a forum to which he can report and discuss his problems. The demonstration of interest by his peers in the work he is doing overseas encourages his continuation of effort to overcome the frustrations of working abroad. He learns that others are interested and he is not a forgotten man.

RESPONSE CAPABILITY

Another major reason for the establishment of CUSUSWASH is to be able to respond to requests by AID and cooperating countries for technical assistance and/or consulting help. Each of the participating universities has used monies available to it to augment existing staff and to expand its ability to respond to requests for assistance. The Board of Trustees and the Executive Director have received several requests during the past year to engage in activities associated with water management problems. The Board provides a screening mechanism to consider the merits of the requests and to approve or disapprove further action. Specific requests and overtures have come from five different countries. Each request has been considered on its merits and the interests expressed by the member schools. Some follow-up action is now in process with three countries.

In response to a specific request from AID, CUSUSWASH responded with a team of three scientists to do work in Nigeria. Details can be found in the individual university reports. Also the attachments provide data on the travel of CUSUSWASH personnel to many countries in response to specific requests for consulting help, participation

in technical meetings, presentation of papers, teaching of courses, establishment of new contacts and expanding linkages for future contacts. Many of these have been AID requests while others have come direct from countries themselves, or international agencies.

COMMITTEE ACTIVITIES

Early mention was made of CUSUSWASH committee activity. This will continue to play an important role in promoting the interaction between the staff of member schools. The most recent committee formed to do specific work is the Irrigation Handbook Committee. The idea and arguments to pursue this subject surfaced in a CUSUSWASH meeting early in the year. Initial reaction to the idea of another "Irrigation Handbook" was negative, but the committee members who suggested the subject had discussed the pros and cons in sufficient detail to persuade the Trustees to establish an Irrigation Handbook Committee to explore the present literature and determine if further action should be undertaken by CUSUSWASH. The next year's report will carry the results of the findings. It is quite obvious, however, that this subject would not have been reviewed without the interaction and support from a broad forum of experts through CUSUSWASH. One or two staff members working alone through their own university would have failed to get support and the necessary literature review would not have been done.

Preliminary findings indicate that gaps do exist in information needed for water management procedures. The form in which information exists, its accessibility and understandability for the specific target audiences needs reconsideration.

The CUSUSWASH committee will complete their review and make specific recommendations on future action to bridge the gaps and fulfill the needs for suitable knowledge transfer to the developing world. The

serious drought situations affecting large parts of Africa highlights again the necessity for continuing educational programs at all levels of society to safeguard and beneficially use vital water resources.

As yet, we have not trained enough experts, nor influenced enough governments to seriously support water management programs nor to insure proper collection, development, distribution and beneficial use of water.

NEW COURSES

The generation of new courses or course changes is the prerogative of each member school. Much of the momentum for change, however, is generated in the discussions at CUSUSWASH meetings and committee sessions. This is a natural outgrowth of having access to the thinking of persons interested in the same general subjects, and being able to exchange ideas and interact with them. The following list of new or revised courses can be found by searching through the attached individual reports, but is listed here for convenience

1. Agricultural Planning and Administration in Developing Countries
2. Fertilizer Technology for Irrigated Crops
3. Soil and Water Conservation and Waste Treatment
4. Water Development in Latin America (taught in Spanish)
5. Drainage Principles
6. Drainage Investigations and Design
7. Land Rehabilitation with Special Reference to Sediment
and Flood Control

In addition to specific course additions the affect upon professors who have traveled abroad and been exposed to the problems of the developing world will be to make changes in their course offerings. There are

also other intangible benefits that accrue due to professors exhibiting more patience, showing empathy to the problems of foreign students and helping them to use newly gained knowledge in their back home situations.

STAFF ADDITIONS

Obviously additions to staff for any department or college remains an individual school matter. But again CUSUSWASH can play a catalytic and intermediary role in acting as a clearing house to pass along names of prospective staff members to member schools. The CUSUSWASH office receives many requests from persons looking for employment as a project is completed and his overseas assignment is terminated. This information is available to all member schools. Also, as names of persons come to the attention of individual schools, curriculum vitae can be forwarded to all other schools through the CUSUSWASH office.

This past year has been one of consolidation rather than expansion of personnel. One member school, however, reacting to a need to bolster library support for its water management program added a special librarian. No other new staff have been reported for the year.

STUDENT ACCOMPLISHMENTS

Continued progress and accomplishments are evident during the past year. Interesting details on hydrologic modeling as a means for simulating the hydrologic process as water arrives as precipitation and is used in crop production are found in the university reports. CUSUSWASH has evolved a publication series so that reports are numbered and identified and circulated to member universities and interested parties. Students are also involved in reporting work directly in the semi-annual meetings. This provides them valuable experience beyond

that gained at their home school to exchange ideas and concepts with more experienced personnel.

Many students participating in the on-campus programs have opportunity to work directly in overseas research and do work that leads to continued overseas involvement. The CUSUSWASH office has been instrumental in assisting such students into overseas positions with continuing opportunities for further involvement.

The attached reports indicate that 34 students were involved in graduate programs, reports, and studies during the year. Each of these studies has contributed to the expansion of knowledge and the gathering of data directly related to water management problems. The synthesis and dissemination of this knowledge by CUSUSWASH provides invaluable help in filling the knowledge gaps in which we are presently working. The training of personnel both in the United States and abroad provides an important multiplier effect to increase competence at many levels. Further studies will build upon the work already done thus providing increased opportunity for both local and foreign student involvement.

Hopefully the process of student training both at home and abroad can be continued. The only real hope to dispel ignorance and false notions and concepts about water management in its broadest sense is through a system of continuing education at all levels of society. The nature of the problem is such that constant pressure will be required to eventually break through political and administrative barriers as well as the short supply of available manpower and financial resources to carry on effective work. A continuing education process will assist in maintaining this pressure.

SPECIAL ACTIVITIES AND INCREASED LINKAGES

There is a growing awareness throughout the developing world of the importance of water management for general agricultural uses. This awareness is slowly catalyzing action programs as governments and agencies strive to increase agricultural production. CUSUSWASH personnel are continually making contracts and are requested for special assignments in all parts of the world.

The Food and Agricultural Organization of the United Nations requests personnel for both short-term and long-term involvement. Private organizations seek to hire the expertise developed by the universities. Governmental agencies and developing foreign universities are also interested in having access to competent personnel for consulting and technical assistance.

Contracts in developing countries include all of Central and South America, Iran, Pakistan, Thailand, Turkey, Hungary, several African nations, including Ethiopia, Tanzania, Senegal, Mali, Chad, Niger, and Nigeria. Although work will not be possible everywhere, the contacts made will help to further the cause of water management.

The CUSUSWASH office is in direct contact with many of the agencies and organizations mentioned above. It cannot respond to all the requests that come to it, but does try to maintain constant dialogue with interested persons and organization and to respond where possible.

CUSUSWASH TRANSITION

Previous reports have summarized the development of CUSUSWASH. The Articles of Incorporation and the By-laws have now been duly processed and approved so that CUSUSWASH functions under a legal charter with appropriate by-laws to carry out its activities. The retirement of

William I. Palmer, June 30, 1973, as Executive Director necessitated a new appointment. Dr. Bruce H. Anderson was selected effective July 1, 1973, to be the Executive Director of CUSUSWASH and to manage its affairs. The office will be happy to respond to inquiries and furnish additional information on the activities of CUSUSWASH.

PART II

UNIVERSITY OF ARIZONA

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2457

TABLE OF CONTENTS

	Page
A. Statistical Summary	B-5
B. Narrative Summary	B-5
C. Detailed Report	B-6
I. General Background and Purpose of Grant	B-6
II. Objectives of Grant	B-8
1. Objectives restated	B-8
2. Review of objectives	B-9
III. Accomplishment	B-10
1. Improvement of research capability	B-11
2. Improvement of Teaching Capability	B-14
3. Development of increased consulting competency	B-15
4. Expansion of special activities	B-17
IV. Impact of Grant in Developing Institutional Capabilities	B-18
V. Utilization of Institutional Resources in Development	B-20
VI. Other Resources for Grant- Related Activities	B-21
VII. Next Year's Plan of Work and Anticipated Expenditures	B-21
1. Table I	B-24
2. Table II	B-25
3. Table III	B-26
4. Table IV	B-27

211(d) Annual Report for F.Y. 73

Date August 15, 1973

Title: Optimum Utilization of Water Resources for Agriculture: With Special Emphasis on Systems Analysis of Watershed Management Under Conditions Characteristic of Less Developed Countries.

Grantee: University of Arizona

Director: David B. Thorud

A. Statistical Summary:

Period of Grant:	July 1, 1969	to	May 22, 1974	Amount of Grant	\$350,000
Expenditure for Report Year	\$59,860	Accumulated	\$286,000		
	Anticipated for next year		\$64,000		

B. Narrative Summary

The increased research competency generated by the 211(d) Grant has focused on two general activities, i.e., hydrologic modeling and decision making or resource management techniques. Nine manuscripts have been prepared on such subjects as stochastic precipitation and streamflow models, optimal water use in agriculture, desert strip farming in semiarid areas and decision-making under uncertainty. Two graduate students supported by the Grant obtained advanced degrees last year while a total of seven received degrees during the life of the Grant. Of extreme importance to developing countries is a new research activity initiated during the past year, namely, remote sensing which has a great potential in the identification, appraisal and monitoring a nation's land and water resources.

Increasing the instructional phase is being accomplished through the development of a computer-assisted instruction program in watershed management and in the preparation and modification of courses that have applications for developing countries. A total of six courses have been added or restructured during the life of the project. A computerized information storage and retrieval system on water yield augmentation is under development.

In an effort to expand the consulting capability, linkages are being established with foreign scientists in several Latin American countries, Ethiopia, Iran and Pakistan. To develop these contacts, a Watershed Management Department faculty member visited eight Latin American countries. Another member was part of an AID study team that visited Nigeria to assist with the preparation of pre-feasibility study guidelines for irrigation projects. As a direct outgrowth of the Grant, the Department of Watershed Management has been the recipient of several research contracts in water-related areas. Included are involvement in a Peace Corps' environmental program in Ecuador and Brazil and a cooperative research project with Hungary.

C. Detailed Report

1. General Background and Purpose of Grant

A firmly established concept states that improved water management is an essential element for increasing the agricultural productivity throughout the world. Reports have shown that 60 percent of the world's arable lands are deficient in soil moisture during all or some part of the growing season. A large share of the remainder suffer from floods and lack of drainage.

Water management in agriculture can be viewed as the development, processing, storage, transportation and utilization of a raw material, such as water for increasing food production. Producing a lasting and efficient system for accomplishing this overall objective requires that all segments of water-based activities be integrated into a common plan. Thus, CUSUSWASH has developed a coordinated program in water management for agriculture production.

While Utah State University looks at the practices involving the utilization of water, Colorado State University delves into the problems relating to the storage and transportation of water. At the same time, the University of Arizona is concerned with the develop-

ment, processing and storage of this vital resource, or the watershed management phase of the system.

Watershed management is generally defined as the management of the natural resources of a drainage basin primarily for the production and protection of water supplies and water-based resources, including the control of erosion and floods, and the protection of esthetic values associated with water. The University of Arizona is one of only a few institutions in the world that has attempted to develop a coordinated effort in the management of this important natural resource. A little more than a decade ago, the Department of Watershed Management was established to bring together programs with a common interest in the management of water on the non-cultivated areas, the lands which supply the adjacent agricultural lands with a major portion of its water. Watershed Management is a complex art that is decidedly interdisciplinary in nature. It involves the development and use of hydrologic simulation models, establishing functional relationships between land management methods and hydrologic processes, and also the techniques of systems analysis which seek to integrate the power of quantitative analysis with the concepts of economic theory. With water management systems becoming increasingly complex, so are the procedures which address themselves to the fundamental issue of design and management, that of specifying how men, money and material should be combined

to achieve a larger purpose. This is an area where the Grant is having a large impact, that is, in the area of watershed management with special emphasis on the science and methodology of applying systems analyses techniques to problems of less developed countries.

II. Objectives of the Grant

I. Objectives restated

The University of Arizona through the Department of Watershed Management, in cooperation with supporting departments in the Colleges of Agriculture, Earth Sciences and Engineering contains a nucleus upon which to build an increased competency in research, education and consultation within its area of responsibility, namely, watershed systems. Specifically, the objectives of the University of Arizona program are:

- a. Expand its professional staff in Watershed Management with faculty members who are specifically involved in hydrologic modeling and the utilization of systems analysis techniques in watershed management activities.
- b. Expand the graduate student research training program and activities related to the needs of developing countries.
- c. Expand and modify course offerings concerned with water management in agriculture especially as related to emerging nations.
- d. Expand and initiate special activities such as seminars, exchange programs, institutes, conferences, publications and other programs of interaction which will help establish continuous and effective lines of communication between the University of Arizona and the less developed countries.
- e. Strengthen its capability to serve in advisory and consulting

- capacity through foreign travel and study by faculty members.
- f. Improve its understanding of the type of problems encountered in the less developed countries, including the socio-politico aspects relating to the development and management of watershed systems.

2. Review of Objectives

While the objectives of the Grant have, in general, remained as stated above, certain activities have been emphasized. These activities are listed under the objectives which have been re-grouped as follows:

a. Improvement of Research Capability

The objectives included are:

- (1) Hydrologic Model Building: the development, modification and quantification of relationships that describe the hydrologic processes occurring on watersheds and predict the effects of land management practices on the watershed system.
- (2) Decision-Making Models: the adaptation of relevant management techniques to actual problems encountered in the management of natural resources.

b. Improvement of Teaching Capability

- (1) Computer Assisted Resource Education System (CARES): to instruct in the area of watershed management utilizing systems analysis techniques, computer-based methods are essential not only to reduce the computational burdens, but also to provide the manager with freedom to exercise his creative abilities. The development of a computer-assisted instruction (CAI) program is a logical extension of the

University of Arizona's effort to increase its research and teaching capability.

- (2) Electric Analog Watershed Model: another training aid that is being developed to assist in the instruction of resource management is a Passive Electronic Watershed Model.
- (3) Course Development: new courses have been added and existing ones have been re-structured to incorporate the aims of the Grant.

c. Increase Consulting Competence

Foreign travel and study is the principal activity in which the University of Arizona improves its consulting capability.

d. Expansion of Special Activities

These activities may include the organization of seminars, institutes, conferences, exchange program or other programs that stimulate interaction between the University of Arizona and developing nations. The development of a library which will include bibliographies and abstracts as well as the acquisition of pertinent publications will be a major activity reported in this section.

III. Accomplishment

To meet the objectives of the grant, the University of Arizona has expanded its program of applied research and teaching in the subject matter area of systems analysis in watershed management. With the grant supporting additional faculty members, an enhanced capability for performing consulting services to developing countries has resulted. Criteria for measuring the effectiveness of the University's program are difficult to come by as numbers (additional faculty,

graduate students supported, consulting trips, etc.) are often meaningless. Suffice to say, the University of Arizona has met every known request for technical assistance with professional expertise, is in the process of training competent professionals with an eye towards foreign service, is actively engaged in increasing its circle of influence and stands ready to meet future challenges. The statements that follow are a presentation of the University's accomplishments during the report year, and we suggest that these efforts represent a solid contribution.

1. Improvement of Research Capability

With the ultimate goal to increase the University of Arizona's competency in the management of watershed systems encountered in lesser developed countries, research efforts have centered around two broad categories, e.g., modeling of hydrologic systems and the development of management techniques applicable to water and other natural resources.

a. Modeling Hydrologic Systems

A total of six faculty members in three College of Agriculture Departments (Watershed Management; Soils, Water and Engineering; Agronomy and Plant Genetics) and in the Departments of Hydrology and Water Resources and Systems and Industrial Engineering have been involved in related projects. One subject matter area receiving considerable attention is the development of probabilistic or stochastic models of precipitation and streamflow. A goal here is to improve on methods for extrapolating point source data to areas where data is limited or unavailable.

Managing an irrigation project or similar hydrologic system requires the best estimates of an available water supply and associated risks if the demands are not met.

Another subject area that received attention were projects concerned with maximizing efficiency of water use in both irrigated and rain-fed agriculture. Specific topics included determination of consumptive water-use efficiency for selected crops and development of a rainfall multiplication process for dryland farming in semi-arid regions.

Manuscripts prepared during the current report year include:

"A stochastic snow model to evaluate reservoir operation."

"Desert strip farming: a way to make the desert green."

"Predicting the hydrologic effects of land modifications."

"Optimum control of irrigation water application."

"Steady-state seepage on a hillside."

Out of a total of five graduate students working in this subject matter area and supported by the 211(d) Grant two have completed their objectives. Their efforts have resulted in a Ph.D. dissertation entitled, "Analysis and Application of a Passive Electronic Analog Model to the Hydrologic Regime of a Watershed," and a master's thesis "Parameter Optimization for Simulating Semiarid Watershed Hydrology."

b. Management Techniques

Fundamental to the development and management of a region's land and water resources is a means for identifying, appraising and monitoring these resources and associated environmental process. It is usually accepted that remote sensing has a great potential for becoming an important tool of the resource manager. As a consequence, the Watershed Management Department has initiated the development of a Remote Sensing Laboratory which will be equipped to handle a wide range of activities from routine aerial photo work to automatic data processing for analyzing satellite imagery in a digital format at a much higher resolution than possible with photos.

In progress this past year are two doctoral dissertations that are concerned with the decision-making process in the management of natural resources. One is investigating the use of system analysis to arrive at the optimal investment for watershed development considering ecological and social constraints. Another is looking at the various uncertainties in meteorologic inputs, in input-output relations, and in parameter estimation, to develop a technique that will provide a meaningful transition from inventories to decisions. Decisions developed in this manner will enable the resource manager to base his programs on a quantified interpretation of inventory data.

Two research papers on the use of Bayesian decision analysis were presented during the report year. This effort has implications for the design of water control structures especially those confronted with inadequate hydrologic data, which is often the case in developing nations.

Titles of these papers are:

"Uncertainty in the return period of maximum events: a Bayesian approach."

"A decision-theoretic approach to uncertainty in the return period of maximum flow volumes using rainfall data."

Another paper was prepared that concerned itself with the use of cost-effectiveness methodology to evaluate water resources systems in developing countries. The use of interactive multi-objective decision making under uncertainty was explored in still another research effort.

2. Improvement of Teaching Capability

Increasing the instructional competency of the University of Arizona has been directed towards two activities, developing a computer-oriented instruction program in resource management and in the development of applicable courses.

a. Computer Assisted Instruction (CAI)

Partially supported by the 211(d) program, a doctoral candidate completed his work this year and will be added to the Watershed Management faculty to direct the new Remote Sensing Laboratory. The title of his dissertation is "A CAI Language for Mini-Computers with Sample Dialogue and Problems Relating to Physics and Wildland Hydrology." CAI is ideally suited for training

in the use of systems analysis in watershed management since most of these techniques requires the use of computers. Thus, training is accomplished using a tool that will also be used as an operational device which allows students to gain experience and confidence in the use of computers. Mini-computers are relatively inexpensive and can be used for both research and teaching. Another advantage of CAI is that it is a relatively simple matter to convert from English to a foreign language.

b. Course development

A new course concerned with land rehabilitation is in the process of being prepared. The course deals with water and wind erosion, sedimentation, revegetation and site stabilization. A new graduate student, a Peace Corps Volunteer returned from Iran, is assisting with the preparation of an extensive bibliography on the subject. Topics covered by this course are of material interest to developing countries as erosion is a never-ending battle with the elements. Reducing the sediment load carried by streams is a primary objective of watershed management in many regions of the world.

3. Development of Increased Consulting Competency

The University of Arizona's consulting capability is increased by extending faculty member contacts with counterparts in countries in need of technical assistance and in the actual performance of consulting functions.

A prime example of the former is the five-week trip made to eight Latin American countries by Dr. John L. Thames in the company of Dr. Richard E. Saunier, Environmental Programs Specialist for Latin America with the Peace Corps. Topics discussed with individuals from local agencies, AID Missions, universities, etc. included watershed rehabilitation, water harvesting, ecological impact of urbanization, forestry and fisheries management, and natural resources inventory. Countries visited were Argentina, Chile, Brazil, Columbia, Ecuador, Paraguay, Peru, and Costa Rica.

In addition to the above, contacts have been made with officials in Bolivia, Pakistan, Iran and Ethiopia. Attempts are being made to involve the Watershed Management Department in a seminar or workshop on East African watershed and range programs. It is understood that a recent Ph.D. graduate from Ethiopia and now returned, Gebre H. Zere, will be coordinating these efforts. Under the guidance of the Director General of Soil Conservation and Watershed Management of the Ministry of Agriculture and Natural Resources, Iran, a program has been started to train Iranian students in watershed management and hydrology at the University of Arizona.

As a member of a three-man team of consultants from CUSUSWASH universities, Dr. Martin M. Fogel visited Nigeria to assist in the preparation of guidelines for a pre-feasibility study of a proposed irrigation project. The team visited the Do-Anambra

Rivers area, the site of the proposed development in August and prepared a report for TAB/AGR in November. The report was transmitted to USAID/Nigeria who received the original request for assistance from the Commissioner of Agriculture and Natural Resources of the East Central State of the GON.

4. Expansion of Special Activities

a. Library Development

Putting last year's plans to locate a library within the Department of Watershed Management that will contain reference material pertinent to developing countries into operation, a professionally-trained librarian was added to the staff. Next year she will be full time with support being drawn from three sources, the 211(d) Grant, the new Peace Corps program and the University of Arizona Water Resources Research Center. An important objective of this activity is to develop a computerized reference retrieval system in the subject matter area of watershed management that will be interfaced with the Office of Arid Land Studies Information System.

b. International Symposium

As a cooperative effort, the Departments of Hydrology and Water Resources, Systems and Industrial Engineering, Watershed Management and Mathematics sponsored a symposium endorsed by four international societies. Topics centered around uncertainties in hydrologic and water resource systems. Attendance numbered 150 internationally recognized professionals with a good representation from developing countries.

IV. Impact of Grant in Developing Institutional Capabilities

The 211(d) Institutional Grant has provided the necessary foundation from which it has been possible to entrain other resources into the University of Arizona's watershed management program. A direct outgrowth of the AID grant is the involvement of the Watershed Management Department with the Peace Corps' Environmental Program in Latin America.

Six U.S. universities, including the University of Arizona, will provide technical assistance to at least 10 Latin American countries in watershed management and related environmental programs. Specific topics to be emphasized include air and water pollution; watershed, forest, fisheries and wildlife management; and regional planning. The objectives of the program include (1) assisting Peace Corps Country Directors, their staffs and host institutions in defining specific program objectives for volunteers, (2) providing technical support services for in-country staff in charge of Peace Corps Volunteer environmental programs and (3) reviewing and assessing current technical achievements of Peace Corps watershed and associated environmental programs. At least six faculty members from the Department of Watershed Management and possibly others will be involved in making trips to Brazil and Ecuador, the countries assigned to the University of Arizona.

To meet the objectives of the 211(d) Grant in developing the use of system analysis techniques in watershed management, a multi-disciplinary team involving the Departments of Watershed Management, Hydrology and Water Resources and Systems and Industrial Engineering has been brought together. This relationship has resulted in ob-

taining additional support for related activities. The 1972-73 period was the initial year of operation under a three year grant from the Office of Water Resources Research of the U.S. Department of Interior entitled "Decision Analysis for Watershed Management Alternatives." Another such activity is a National Science Foundation sponsored cooperative research program between the University of Arizona and the Water Resources Center, VIKOZ, of Hungary. The title of the project, a three year program, is "Cooperative Research on Decision-Making Under Uncertainty in Hydrologic and Other Resource Systems."

The increased competency in watershed modeling of hydrologic systems generated by the 211(d) Grant has resulted in the Watershed Management Department receiving additional support from such diverse sources as the U.S. Forest Service, the Arizona Water Resources Resources Research Center, the Salt River Water Users' Association, the Arizona Water Commission, and Peabody Coal Company.

In general, the Grant has been highly instrumental in putting together a group of scientists, engineers and students that is making an impact in the management of natural resources. Not only will the results of these efforts be applicable to developing countries, but to the state of Arizona's problems as well. A rapidly expanding population is placing a continuing strain on Arizona's resources. Solutions to these problems (water shortages, pollution, etc.) can utilize the same techniques being applied to developing countries.

V. Utilization of Institutional Resources in Development

As a member of a three-man team of consultants for CUSUSWASH universities, Dr. Martin M. Fogel of the Department of Watershed Management visited Nigeria to assist in the preparation of guidelines for a pre-feasibility study of a proposed irrigation project. The team visited the Do-Anambra Rivers area, the site of the proposed development in August and prepared a report for TAB/AGR in November. The report was transmitted to USAID/Nigeria who received the original request for assistance from the Commissioner of Agriculture and Natural Resources of the East Central State of the GON.

To effect a transfer of technology, the Department of Hydrology and Water Resources, Systems and Industrial Engineering, Watershed Management and Mathematics jointly sponsored a symposium endorsed by four international societies. Topics centered around uncertainties in hydrologic and water resource systems. Attendance numbered 150 internationally recognized professionals with a good representation from developing countries.

A total of 18 foreign students coming mostly from Africa and Latin America have completed graduate work in the Department of Watershed Management since the beginning of the Grant. Three former Peace Corps Volunteers have returned to the University campus and are doing graduate work in

watershed management. A nearly completed Ph. D. student in watershed hydrology has accepted employment with a private consulting firm and will be working in developing countries.

VI. Other Resources for Grant-Related Activities

The 211(d) Grant, as previously mentioned, has been instrumental in attracting additional support for activities related to the Grant. Contributors have included the U. S. Department of Interior (Bureau of Land Management, Office of Water Resources Research), the U. S. Department of Agriculture (Cooperative State Research Service, Forest Service), the National Science Foundation (International Biological Program, Cooperative Research with Hungary), the Peace Corps, National Aeronautics and Space Administration, Arizona Water Commission, Arizona Water Resources Research Center, and the Peabody Coal Company. As shown in Table I, non 211(d) funding for grant-related activities is nearly double the 211(d) funding.

VII. Next Years Plan of Work and Anticipated Expenditures

It is anticipated that next year will experience a continued shift in emphasis to activities that will increase the University of Arizona's competency to perform consulting service. With additional foreign travel expected as a result of the new Peace Corps program and the cooperative research project with Hungary, opportunities for consulting activities are correspondingly increased. Previous contacts in

such countries as Ethiopia, Iran and Pakistan will be utilized in an expanded effort to produce linkages with developing nations.

VII. Next Years Plan of Work and Anticipated Expenditures

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A new major research activity being planned for next year is in connection with remote sensing. According to a recent AID report (TA/OST 73-17), "Remote sensing now offers a capability for approaching water-resources development and management on a more rational and integrated basis, and also on a regional scale." The report then describes a number of possibilities for its use such as in surveys of water resources, in watershed management and in monitoring surface water resources. In summary, remote sensing presents an efficient and effective means for assessing and monitoring the water resources of developing countries.

To compensate for the increased consulting and remote sensing activities anticipated for the next year, a reduction in the other research areas and in teaching is scheduled. The expenditures, past and projected, are listed in Table I according to activity and in Table II by line items conforming to budget and grant document.

Table I

Distribution of 211(d) Grant Funds (#AID/csd-2457)
and Contributions From Other Sources of Funding

Review Period July 1, 1972 to June 30, 1973

<u>Activity</u>	<u>Period under review</u>	<u>Cumulative Total</u>	<u>Projected next year</u>	<u>Projected to end of Grant</u>	<u>Non 211(d) Funding* Period under re- view</u>
Research					
Hydrologic Modeling	19,000	134,000	21,000	156,000	40,000
Decision Making	9,000	34,000	12,000	46,000	30,000
Remote Sensing	2,000	2,000	4,000	6,000	15,000
Teaching					
Comp. Assisted Instr.	8,000	50,000	4,000	54,000	4,000
Elec. Analog Dev.	1,000	26,000		26,000	
Course Develop.	2,000	4,000	2,000	6,000	12,000
Libraries					
(Incl. Publications)	3,000	7,000	4,000	11,000	2,000
Consultation	8,000	15,000	10,000	25,000	2,000
Other	1,860	3,000	1,000	4,000	2,000
CUSUSWASH	6,000	11,000	6,000	17,000	
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
TOTAL	59,860	286,000	64,000	350,000	107,000

*These figures are our best estimates

Table II

Expenditure Report (Actual and Projected) Under
Institutional Grant #AID/csd-2457Review Period July 1, 1972 to June 30, 1973

	<u>Period under review</u>	<u>Cumul. total</u>	<u>Projected next year</u>	<u>TOTAL</u>
Salaries	19,875	143,469	25,000	168,469
Wages	1,930	24,786	5,000	29,786
Fringe Benefits	<u>2,946</u>	<u>14,668</u>	<u>2,500</u>	<u>17,163</u>
Sub Total	24,751	182,918	32,500	215,418
Stipends ^{1/}	15,658	42,166	11,000	53,166
Travel				
Foreign	4,600	6,635	5,000	11,635
Domestic	2,645	12,226	2,000	14,226
Equipment	3,657	14,059	3,500	17,559
Computer	381	3,558	2,000	5,558
Operations ^{2/}	2,168	13,438	2,000	15,438
CUSUSWASH	<u>6,000</u>	<u>11,000</u>	<u>6,000</u>	<u>17,000</u>
	59,860	286,000	64,000	350,000

^{1/} See Table 3 for detailed breakdown of this category

^{2/} See Table 4 for detailed breakdown of this category

Table III

Expenditure Report Continued Under
Institutional Grant #AID/csd-2457

Review Period July 1, 1972 to June 30, 1973

Students Supported Wholly or ^{1/}in Part by
221(d) Stipends and Salaries⁻

<u>Student</u>	<u>Title</u>	<u>Degree Objective</u>	<u>Level of 211(d) Support</u> (dollars)
Bohren, C. F.	Research Assoc.	Ph.D.	1,662
Tinlin, R. M.	Research Assoc.	Ph.D.	2,353
Foutz, Alan L.	Grad. Asst. in Res.	M.S.	2,676
Morin, G. C.	Grad. Asst. in Res.	M.S.	4,952
Wilhelm, W. W.	Grad. Asst. in Res.	M.S.	<u>4,015</u>
		TOTAL	15,658

^{1/} In addition, a combination of one faculty member, three undergraduates and three graduate students were supported on wages totalling \$1,930.

Table IV

Expenditure Report Continued

Under Institutional Grant #AID/csd-2457

Review Period July 1, 1972 to June 30, 1973

Detailed Breakdown of Operations Expenditures

<u>Category</u>	<u>Amount Expended</u> (dollars)
(1) Maintenance and Repair of Equipment	280
(2) Office, laboratory and field supplies (forms, stationery, computer cards, expendible tools, paint, lumber, small hardware items such as nails and bolts, chemicals, laboratory materials)	1,056
(3) Printing and Audio-visual Services	544
(4) Telephone (long distance calls)	184
(5) Freight charges	0
(6) Subscription	<u>104</u>
TOTAL	2,168

University of Arizona

Fourth Annual Report

List of Publication having significant 211(d) input.

1. Chaemsaithong, K., L. Duckstein and C. Kisiel. 1972. Cost effectiveness of water resources systems in developing countries: Case of the Lower Mekong. Proc. Intl. Symp. on the Planning of Water Resources. Mexico City: Dec. 1972.
2. Davis, D., L. Duckstein, C. Kisiel and M. Fogel. 1972. Uncertainty in the return period of maximum events: A Bayesian approach. Proc. Intl. Symp. on Uncertainties in Hydrologic and Water Resource Systems. Univ. of Ariz., Tucson. Dec. 1972.
3. Davis, D., L. Duckstein, C. Kisiel and M. Fogel. 1973. A decision-theoretic approach to uncertainty in the return period of maximum flow volumes using rainfall data. Proc. UNESCO Symp. on Design of Water Resource Projects with Inadequate Data. Madrid, Spain. June 1973.
4. Duckstein, L., D. Monarchi and C. Kisiel. 1973. Interactive multi-objective decision making under uncertainty. Proc. NATO Conf. on the Role and Effectiveness of Decision Theories in Practice. Luxemburg. Aug. 1973.
5. Fogel, M. M., L. Duckstein and C. C. Kisiel. 1973. A stochastic snow model to evaluate reservoir operation. Paper presented at AGU Natl. Meeting. Washington, D.C. Apr. 1973.
6. Fogel, M. M., L. Duckstein and C. C. Kisiel. 1973. Predicting the hydrologic effect on land modifications. Paper presented at ASAE Natl. Meeting Lexington, Ky. June 1973.
7. Fogel, M. M., L. Duckstein and C. C. Kisiel. 1973. Optimum control or irrigation water application. Proc. IFAC Symp. on Automatic Control of Water Resources Systems. Haifa, Israel. Sept. 1973.
8. Morin, G. C. A. 1973. Desert strip farming: a way to make the desert green. Prog. Agric. in Arizona. (In press).
9. Morin, G. C. A. and A. W. Warrick. 1973. Steady-stage seepage in a hillside. SSSA Proc. 37:346-351. May-June 1973.
10. O'Hayre, A. H. 1972. Parameter optimization for simulating semi-arid watershed hydrology. Unpublished master's thesis. Univ. of Arizona. 74 pp.

11. Rasmussen, W. O. 1973. A CAI language for mini-computers with sample dialogue and problems relating to physics and wildland hydrology. Unpublished Ph.D. dissertation. Univ. of Arizona. 151 pp.
12. Tinlin, R. M. 1972. Analysis and application of a passive electronic analog model to the hydrologic regime of a watershed. Unpublished Ph.D. dissertation. Univ. of Arizona. 109 pp.

PART III

COLORADO STATE UNIVERSITY

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2460

TABLE OF CONTENTS

	Page
A. Statistical Summary	C-4
B. Narrative Summary	C-4
C. Detailed Report	C-7
I. General Background and Purpose of the Grant	C-7
1. Background	C-7
2. Purpose	C-8
II. Objectives of the Grant.	C-9
1. Objectives and Scope	C-9
2. Subject Areas Assigned	C-10
3. Operational Plan.	C-10
4. Review of Objectives	C-11
III. Colorado State University Accomplishments	C-15
1. Accomplishment Criteria	C-19
2. Reporting Year Accomplishments.	C-20
a. Improvement of Faculty and Staff.	C-20
b. Technical Publications	C-26
c. Library Improvement.	C-28
d. Seminars	C-30
e. Research Assistants	C-31
f. Meetings and Travel	C-33
- Foreign Travel	C-34
- U.S. Travel.	C-36
3. Summary of Accumulated Accomplishments	C-37
4. Proportion of Year's Expenditures for each area of Activity.	C-40
IV. Impact of Grant Supported Activities in Developing Institutional Capabilities	C-41
V. Utilization of Institutional Resources in Development. . .	C-47
VI. Other Resources for Grant Related Activities.	C-55
VII. Next Year's Plan of Work and Anticipated Expenditures .	C-58

VIII. Entrainment Activities	C-67
IX. Report of Expenditures	C-69
1. Table I	C-71
2. Table II.	C-72
3. Foreign Travel.	C-73

COLORADO STATE UNIVERSITY 211(d) GRANT ANNUAL REPORT

Title: "Optimum Utilization of Water Resources: With Emphasis on Water Delivery and Removal Systems and Relevant Institutional Building"

Grantee Colorado State University

Director: Dr. Maurice L. Albertson

A. STATISTICAL SUMMARY:

Period of Grant: 23 May 1969 to 22 May 1974

Amount of Grant: \$750,000

Expenditures for Report Year \$185,391 Accumulated \$621,446

Anticipated for next year \$128,554 (Final year of Contract)

B. NARRATIVE SUMMARY:

The area of research assigned to Colorado State University under the 211(d) Grant is entitled, "Optimum Utilization of Water Resources: With Emphasis on Water Delivery and Removal Systems and Relevant Institutional Development". This program involves participation by six departments: Agricultural Engineering, Agronomy, Civil Engineering, Economics, Political Science, and Sociology. Traditionally, engineers and agriculturists working in the areas of water delivery and removal systems have only a limited understanding of the related institutional structure which is required for the successful operation of water systems. Therefore, a primary purpose of this 211(d) Grant program is to develop knowledge, understanding, and ability to overcome these shortcomings by recognizing and understanding the concomitant need to analyze prevailing social systems as they affect water delivery and removal -- including the kinds of institutional changes necessary, the sources of resistance to change, and effective ways of dealing with various forms of social resistance to innovative forms of water delivery and removal. Thus, one of the chief characteristics of the

University's participation in the 211(d) Grant program is its inclusion of social, economic and cultural factors along with engineering, agricultural and other technological considerations -- thereby increasing the capabilities, dimensions of understanding and competence of the University in this assigned area of research.

Because of the complex nature of the physical, financial, and technological constraints placed upon the optimal use of water delivery and removal systems, including relevant institutional structures, the participating disciplines feel that solutions may best be found through a comprehensive interdisciplinary approach. The various departments involved in the Grant program have strengthened and improved their activities with regard to and in support of the Grant objectives through:

- Adding faculty members who have expertise in water delivery and removal.
- Teaching courses involving water delivery and removal systems and related institutional development to students in engineering, agriculture, economics, and the social sciences.
- Guiding the research activities of faculty and research assistants in the area of optimum utilization of water resources.
- Supporting and guiding the research assistants who are interested in optimum utilization of water resources.
- Publication of technical reports.
- Developing linkages throughout the world on common areas of concern.

In general, the six participating departments are increasingly able to meet the requirements of the 211(d) Grant through:

- Close cooperation and coordination of their 211(d) activities with each other.
- A deeper understanding of the role of each department for the theme of the Grant program.
- Establishment by each department of benchmark data and literature applicable to the Grant objectives.

Developing capabilities within each department to respond to water delivery and removal problems through orienting and training students and faculty to the issues of development study of the larger questions of utilizing water and other natural resources for the achievement of planned change.

The Colorado State University accomplishments over the past four years of the Grant program have generated far greater entrainment effects and other benefits than was realized when looking at the program annually in a piece-meal fashion. As a consequence, the net accrued benefits have greatly improved the capability of CSU to achieve planned change and thus has made Colorado State University a better institution for foreign and national students to take up advanced and specialized studies in water delivery and removal systems including relevant institutional development.

The work of the faculty and research assistants in the six participating departments carried on during the reporting year is given in more detail in the following sections of this report. In addition, the four (4) year accumulated benefits, including entrainment effects and linkage growth, are brought into perspective in the Appendices D through K.

C. DETAILED REPORT

I. General Background and Purpose of the Grant

1. Background

Water management has been established as a critical and limiting factor in increasing agricultural productivity throughout the world. This is especially true in the case of developing countries. The need for more efficient use of water to increase agricultural productivity has not only been well stated in many reports and publications, but the necessity of introducing good water management systems is now widely accepted throughout the world. Attaining efficient water use in the United States, particularly in the west, occupies a high level of priority in specific U.S. Government organizations and in public and private water user organizations. The many national and international organizations and institutions in the world today dealing with water use for the purpose of increasing agricultural productivity is ample testimony to its importance in other countries as well.

Recognition of the numerous urgent requests for technical assistance in this field provided the U.S. incentive for the establishment--under United States Title II, Section 211(d) of the Foreign Assistance Act--of the Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas (CUSUSWASH) by four Land-Grant Universities, i. e. Colorado State University, University of Arizona, Utah State University, and the University of California. Accordingly, it can be expected that increasingly high priorities will be given by developing countries located in arid and sub-humid areas of the world to new and improved development of their own water resources.

Water management for agriculture is a complex subject embracing many individual arts and sciences involving such activities as protecting or reclaiming land from excess precipitation or flooding, husbanding or managing soil moisture, optimizing cropping practices to the moisture regime, impoundment of water, distribution and application of irrigation water supplies, coordinated management of watershed areas, and the development and maintenance of institutional capability necessary for support of water-related aspects of agricultural operations.

While all the CUSUSWASH universities have varying capabilities in the water management fields, extending the capacity for international service had to be coordinated, both for sharing research results and for optimum utilization of funding by the Agency for International Development. Based on these concepts and considering existing capabilities and interest of the several universities, Colorado State University was assigned the area of research on optimum utilization of water resources with special emphasis on water delivery and removal systems including relevant institutional development. The following pages depict research and other activities by Colorado State University during the reporting period related to the foregoing assignment involving such topics as:

- Water supply development
- Structures for conveyance
- Delivery and drainage
- Impoundment and storage of water
- Control and measurement of water
- Control of erosion and sedimentation
- Use of wells
- Systems analysis for optimal utilization of water
- Economic allocation of water
- Acquiring and/or developing a concomitant understanding of social systems, culture and process of change to better accomplish a usually difficult and complex task of transferring technology and related institutional building to developing countries.

2. Purpose

The stated purpose of the CSU 211(d) Grant is to improve CSU's level of excellence with respect to planning, development, management and utilization of water resources with special emphasis on water delivery and removal systems and relevant institutional development related to the needs of the developing countries. This purpose is being realized by

increasing CSU's capabilities in the foregoing research areas through:

- Improvement of teaching capability
- Increased research competence
- Increased capacity for consulting and service, and
- Increased involvement in international development programs.

Improving teaching ability, for example, involves not only specific knowledge of the state of technological advancement in foreign countries, but also awareness of their economic, social, cultural and educational conditions. Such knowledge is of great help to the professor in developing new courses, revising and up-dating old courses, teaching, and helping the foreign student to design research work most useful to him when he returns to his country.

During the past 4 years, CSU's competence and capabilities in international service has also greatly increased. CSU could not have reached this level of service ability, for example, as attained in the water management research project in Pakistan, had it not been for the 211(d) Grant program.

II. Objectives of the Grant

The objectives and scope, subject areas, and operational plan of the Grant program are briefly paraphrased below. However, the full text of the Grant Document, as related to the foregoing, may be found in Appendix A of this report.

1. Objectives and Scope

- Improving and expanding professional staff
- Expanding the number of graduate students
- Expanding research programs
- Expanding and improving course offerings
- Expanding special activities such as seminars, exchange programs, institutes, conferences, and publications
- Helping to alleviate the shortage of qualified professional personnel

- Expanding staff and institutional capability to serve in advisory and consulting capacities
- Improving understanding of the nature of the less developed societies
- Exchange of personnel and publications
- Programs of interaction with other groups and individuals
- Establishing linkages and lines of communication between CSU and the less developed countries.

2. Subject Areas Assigned

- Water supply and development
- Water storage
- Water conveyance and control structures
- Water delivery structures
- Water measurement
- Control of erosion and sedimentation
- Development and use of wells
- Drainage components and systems
- Social, political and cultural aspects of institutional development
- Processes of change
- Economic analyses of water systems
- Systems approach to analysis of water development and utilization
- Develop and analyze case studies of water systems.

3. Operational Plan

For the less developed countries:

- Assemble and analyze information on water delivery and removal systems
- Develop research programs which will increase knowledge of methods, techniques, and procedures for optimizing the utilization of water resources
- Increase the breadth and depth of teaching

- Solicit well qualified research assistants from both the U. S. and abroad
- Develop a program of student and faculty exchange
- Expand the library collection
- Plan, initiate and expand an interdisciplinary seminar on development and the interrelationship of the many factors involved in development--especially in the less developed countries.

These objectives, areas of study and operational plans for CSU do not stand by themselves, but they are part of an interlocking effort coordinating equally broad goals of the Water Management Research program and a variety of CUSUSWASH activities. In the schematic illustration, Fig. 1, is shown a general summary of the overlapping goals and objectives of the interrelated programs.

The lists in Fig. 1 not only indicate the interrelationship of goals in the variety of programs associated with the 211(d) Grant, but also serve as a framework for a better evaluation of specific objectives pursued, and of activities undertaken for their implementation.

4. Review of Objectives

With regard to the foregoing stated objectives, Colorado State University feels that these objectives served effectively as guideposts during the past four (4) years with respect to planning, development, management, and utilization of water resources as applied to water delivery and removal systems, and relevant institutional development. However, after several years experience, it has become apparent that the University interprets the Grant document more literally on the whole than do our Washington, D. C. counterparts. For example, the International Interdisciplinary Seminar has been and continues to be conducted on an educational basis with the purpose of stimulating intellectual analyses of a related spectrum of technical, social, economic, political and cultural factors affecting development changes with regard to optimum utilization of water resources including, of course as a part of the total picture, water delivery and removal systems and related institutional development. The six participating disciplines have provided

Fig. 1. INTERRELATIONSHIP OF GOALS*

A. Broad Goals of AID

1. Increased number and level of competence of manpower
2. Interdisciplinary approaches to research
3. Information and knowledge
4. To assist the developing countries

B. 211(d) Grant Goals

- | (In-house) | (Subject Areas) |
|---------------------------------------------------------|------------------------------------------------------------------------|
| 1. Expand professional staff | 1. Water supply and development |
| 2. Expand graduate students | 2. Water Storage |
| 3. Expand research programs | 3. Water conveyance and control structures |
| 4. Expand course offerings | 4. Water delivery structures |
| 5. Expand special activities | 5. Water measurement |
| 6. Expand qualified personnel in international matters | 6. Control of erosion and sedimentation |
| 7. Expand advising and consulting | 7. Development and use of wells |
| 8. Understand nature of LDC's | 8. Drainage components and systems |
| 9. Establish lines of communication between LDC and CSU | 9. Social, political and cultural aspects of institutional development |
| | 10. Processes of change |
| | 11. Economic analyses of water systems |
| | 12. Systems approach to analysis of water development and utilization |
| | 13. Development and analyze case studies of water systems |

C. Water Management Research Program

- | <u>Goals</u> (On-campus) | (Pakistan) |
|--------------------------------------------------------|----------------------------------------|
| 1. Methods of skimming | 1. Land preparation |
| 2. Mineralogical analysis | 2. Use of saline groundwater |
| 3. Conjunctive use of groundwater and surface water | 3. Classification of irrigation waters |
| 4. Farm turnouts | 4. Data limitations |
| 5. Use of saline water | 5. Economic analyses |
| 6. Organization and administration of water management | |
| 7. Acceptance and use of water innovations | |

D. CUSUSWASH (Universities activities) (Council objectives)

- | | |
|-------------------------------------------------|----------------------------------------|
| 1. Determine technical needs of LDC's | 1. Mobilize capabilities of members |
| 2. Determine methods of meeting technical needs | 2. Exchange and communication |
| 3. Determine areas of interest | 3. Provide professional staff |
| 4. Conduct joint activities | 4. Uniform procedures and coordination |
| | 5. Exchange of personnel |
| | 6. Represent common interests |

*Partial list only

the main intellectual stimulus and thrust to the Seminar which in turn has attracted many graduate students and professors from other disciplines who are intrigued not only with the interdisciplinary approach but also with the international character of water management problems. Just as undergraduate and graduate students are required to take courses which in the beginning may be considered by some of them to be unrelated to what they wish to study, so the Seminar Committee feels that discussion must include a fairly wide range of related knowledge before successful transfer of such knowledge can be passed on to graduate students, professors and others. CSU believes that this approach has resulted in marked increase in University competence not only in water delivery and removal systems including relevant institutional development but in adding substantially to the surrounding body of knowledge.

While the foregoing concentrates on the Seminar, there are also criticisms of the participating departments for looking at the 211(d) Grant objectives more broadly than desired by AID/Washington judging from past years comments on annual reports. The Department of Economics, for example, wishes to emphasize the plight of the small farmer and the meager resources he has (water is only one of a number) using 211(d) Grant funds for this purpose. Sociology and Political Science also view the CSU Grant objectives on a broader basis. Yet these disciplines and the others have added much, and will continue to do so, to existing knowledge concerning water delivery and removal systems as well as making valuable new and fresh contributions towards solutions of age old problems of development in the less developed countries.

CSU is quite aware of the project constraints and the limitations of research work and other activities imposed by the Grant objectives and the necessity to remain in-bounds. Nevertheless, it should be noted that a too restricted viewpoint of the objectives tends to turn off the intellectual bombardment of problems which to date have not been solved

and only recently have the Universities been asked for their input. In the light of experience garnered by both AID/Washington and the University during the past four (4) years, including other factors bearing on the foregoing brought on by the changing world, a review of these objectives and possibilities of extending the Contract period might well be considered.

III. Colorado State University Accomplishments

CSU accomplishments in the area of Grant objectives are due essentially to a systematic approach to an area study of water delivery and removal which may be described as a developmental process. Underlying the entire scope and thrust of the 211(d) Grant program are key assumptions concerning the role of water management as a vital element in the total developmental process -- which is a sequential system. Whenever development takes place -- whether it is planned and deliberate or unplanned -- there are certain steps which tend to follow. Such steps, and their sequential nature, are illustrated compactly by the Development Wheel in Fig. 2.* From this diagram it can be seen that development involves various types of resources, broadly classified as physical resources and human resources.

Fig. 2 shows that the manpower resource is motivated by his values and attitudes to take the action and provide the thrust which drives the development wheel. Development is accomplished by his effort and for his benefit. Briefly, the manpower resource acquires and uses information, processes and systems by working through the institutional resources as vehicles to conserve and utilize the natural resources in order to expand the supporting infrastructure, within certain constraints, to produce additional goods and services for his own use and benefit, and to provide greater impetus for driving the development wheel still faster.

Note that there is a variety of linkage mechanisms between various stages or phases of the developmental process, and that this process is a dynamic one with feedback loops among the various subsystems.* Just as in a microscope (mechanism) there are a series of lenses which enables us to see what could not be seen distinctly without it, so there must

* For a more complete presentation of the development process, and the role of research and education for development, see "Research and Education for Development" by Maurice L. Albertson and M. T. Chaudhry, from "Transfer of Water Resources Knowledge" edited by Evan Vlachos, Water Resources Publications, Ft. Collins, Colorado, 1973.

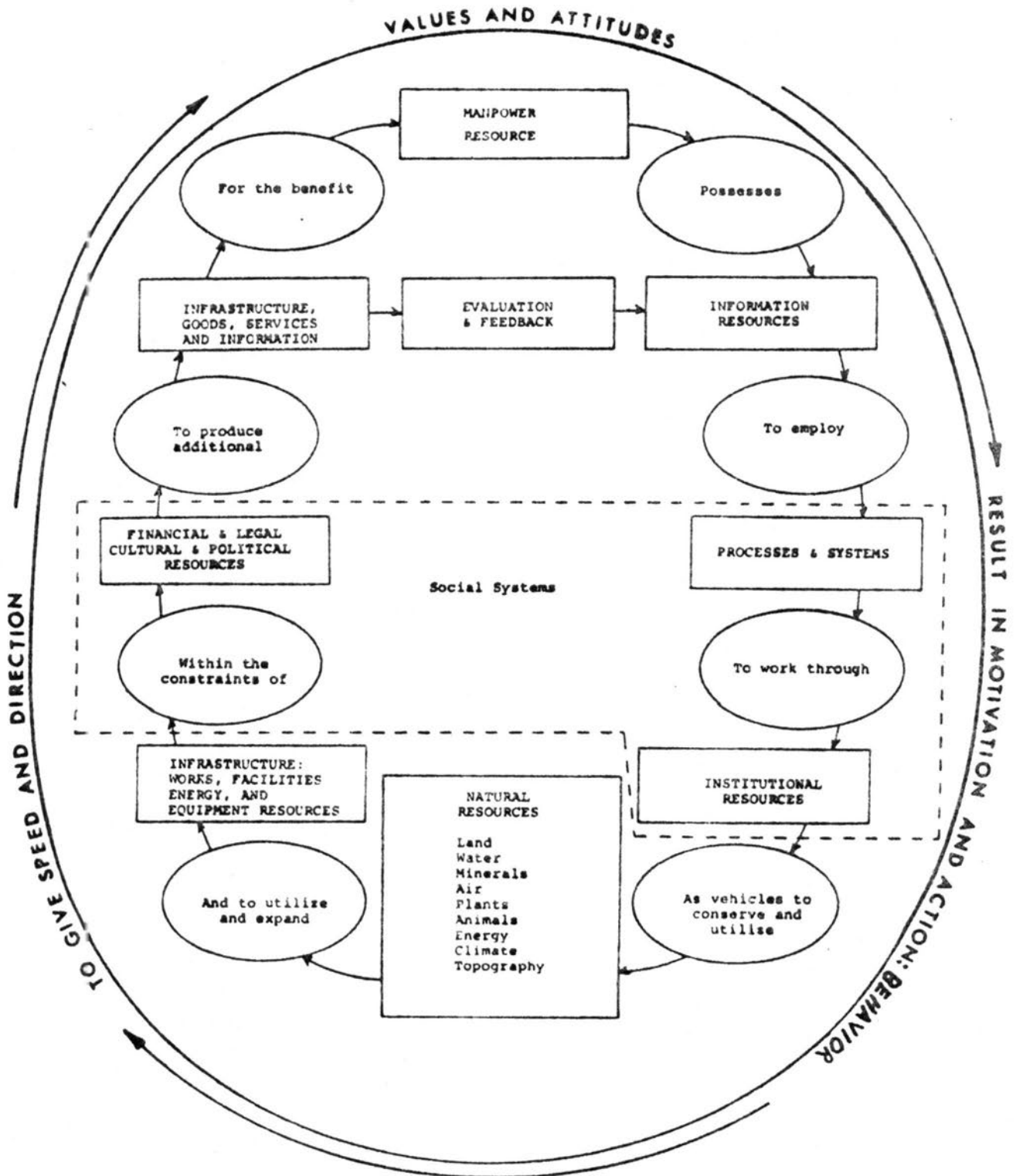
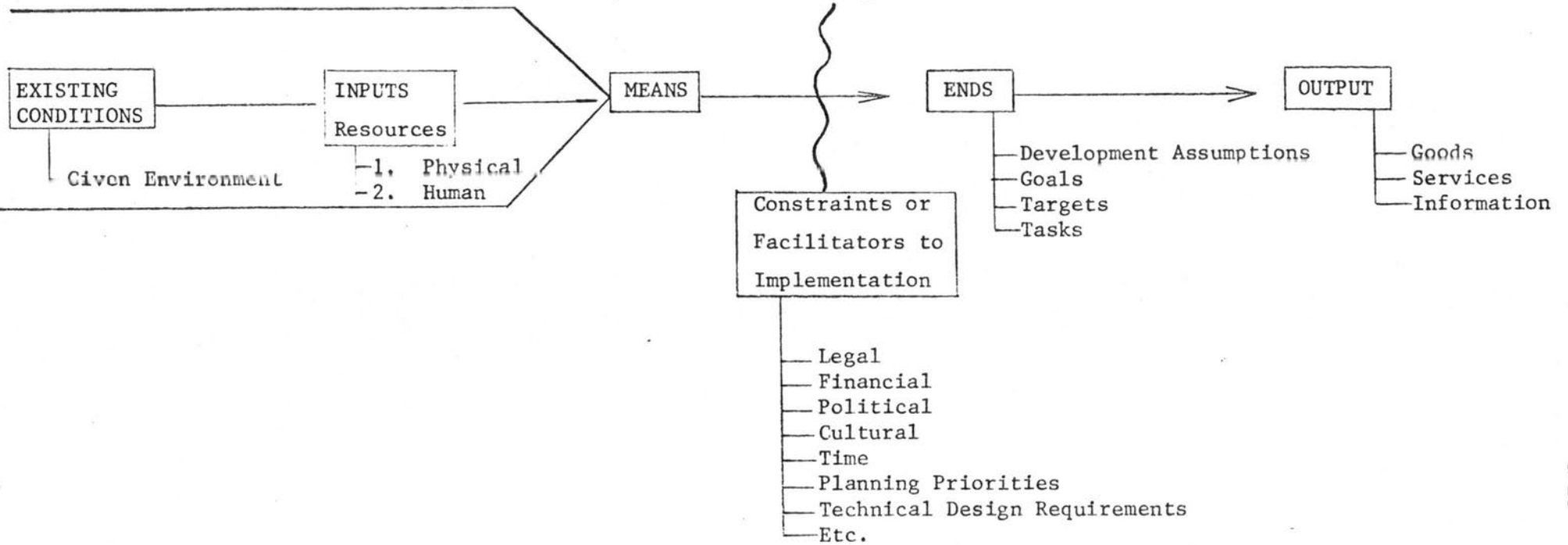


Fig. 2: The development wheel, illustrating the development process. (Adapted from Albertson, 1973 - see footnote page 12)

be a means (mechanism) for focusing on causes of problems. Not knowing the true nature of these causes adversely affects early solutions, rate of progress, and accomplishment--all of which are encompassed in the developmental process and systems approach. In order to present and assess project performance and objectives in a more cogent fashion, it is important to dwell briefly on their overall structuring and operation. CSU has adopted a systems approach to the study and analysis of development. The general orientation with the systems approach is part of the effort to integrate physical and nonphysical dimensions of irrigation systems, provide common vocabulary, and delineate appropriate parameters for interdisciplinary studies. In adopting a systems analysis, CSU views water management as a system operating in a given environment where inputs (physical and nonphysical) processed through the "organization" (the thruput) result in outputs or goals achieved (as infrastructure, goods, information, and services). Fig. 3 summarizes these ideas and provides an abbreviated format of the connecting concepts and dimensions guiding project assessment. Thus, CSU's aim is to generate the kinds of activities that may fulfill the objectives of the Grant, but in such a way as to be able, through appropriate indicators, to evaluate how efficiently and effectively such goals have been reached. Or, in the following succinct summary:

- CSU is providing a systems model
- In order to construct a framework for evaluation
- Which, through the use of appropriate indicators
- Will make possible the measurement and assessment of
 1. Program performance
 2. Specific achievements
- As they relate to general project and development goals.

Fig. 3. A Simplified Version of Systems Dimensions *



INPUTS (Constraints/Facilitators)	THRUPUT (Means)	OUTPUT (Ends, Goals, Objectives)	SIGNIFICANCE (Consequences)
Physical Resources Natural Resources Financial Resources Infrastructure Environment (Physical & Bio.) Human Resources Manpower resources Institutional Information Cultural Political resources Legal resources Social environment	Personnel Campus Field Infrastructure Physical Organizational Rules of Operation	Increased productivity Collective betterment Quality product Increased income Etc. resulting in more Goods Services Information (knowledge)	Indicators or Criteria of Development 1. Growth in economic resources and production. Industrial res. & production Agricultural res. & prod. Infrastructure Etc. 2. Growth in Social Resources Cultural Political res. system -- Values and attitudes Institutions Administration of justice -- Etc. 3. Growth in Manpower Resources Literacy Education Health Training Food Consumption Etc.

* Adapted from "The Development Process" by Maurice L. Albertson.

In completing this brief introduction, CSU would like to emphasize that three key concepts (systems analysis, indicators, evaluation) are not only parts of a concerted approach of all disciplines in the project, but also methodological milestones for identifying causes and corresponding effects and alternative options for more effective water delivery and removal systems.

Having briefly described the setting out of which CSU accomplishments have materialized, the criteria used for measuring successful accomplishment should be examined.

An attempt has been made to look at water delivery and removal as a system, with the various activities described in Section II (Objectives and Scope . . .) interrelated into a total program aimed at a balanced understanding of both the phenomena involved and the planning, design, and operational features which are necessary for success. This is within the framework of the historical and established assignment of CSU -- a Land-Grant Institution -- to provide programs and activities of education, research, and service.

1. Accomplishment Criteria

The criteria used for measuring successful accomplishment include: willingness of faculty to serve short or long terms abroad as advisors or consultants; attendance of all personnel at seminars and conferences; number and relevance of new courses developed, old courses revised and improved, and all courses taught; amount of student advising on water resource development; participation in research activities; service and consulting activities in and/or for developing countries; number and relevance of publications completed; linkages established; entrainment accomplished; and CUSUSWASH activities.

A primary thrust of the CSU program has been the improvement of the manpower resources, the information resources, and the institutional resources stressed in the foregoing pages which are needed for better and more efficient and effective development and utilization of the water resource

within the constraints of other natural resources, and the financial, legal, cultural and political resources (see the Development Wheel, Fig. 2). To this end, efforts have been concentrated on: improvement of faculty and staff, curriculum improvement, technical publication, library improvement, seminars, graduate students, meetings and travel, service, linkages, entrainment, and CUSUSWASH activities.

CSU has taken the position that improvement of faculty and staff can result from both adding new personnel, who already have most or all of the qualifications desired, and improving the knowledge, experience, and ability of existing staff. To this end, nineteen (19) new staff have been added and more than 40 existing staff members have improved their capability as a result of the 211(d) activities. Appendix F is a tabulation of these faculty and staff members.

2. Reporting Year Accomplishments

The six participating departments maintained close coordination with each other during the reporting year and were better able than ever before to meet the requirements of the Grant program and to respond to water delivery and removal problems through training of students and faculty to the issues of development as well as to the larger questions of utilizing water and other natural resources for the achievement of planned change.

a. Improvement of Faculty and Staff

Dr. Alan C. Early was recruited by the Department of Agricultural Engineering to start in September 1973. He will work on international aspects of water delivery and removal systems. His area of specialty focuses on water management in tropical agriculture and will provide new expertise to the University in areas needing further development through teaching, research and consulting and advisory services.

The expertise at the University, fostered and developed by the 211(d) Grant, qualified Dr. William E. Hart to participate as an invited speaker to a conference held at the University of Nigeria, Ibadan, October 23-27, 1972. The title of his paper was, "Prospects for Irrigation in West Africa". The conference was sponsored by the Ford Foundation, the L'Institute de Recherches Agronomiques Tropicales et des Cultures Vivrieres, and the International Institute of Tropical Agriculture. This conference focused on many aspects of irrigation including water delivery and removal systems. Dr. W. Doral Kemper, representing both the Agricultural Engineering and Agronomy Departments, was also present and presented a paper entitled, "Irrigation Agronomy". In this instance, only a small amount of 211(d) Grant funding was utilized to cover travel expenses.

During the report period, Professors Gaylord V. Skogerboe, Wynn R. Walker, and others, produced four (4) papers published in several scientific journals. The titles and authors are given in the following section b, "Publications", and also in more detail in Appendices D and E.

The Department of Agronomy continues to support the agricultural components that are significant to planning and development of irrigation projects. Emphasis continues to be placed on teaching and research that apply to water delivery and removal systems and related institutional development. Competence of the Agronomy staff has been increased by 1) attending and participating in the International Interdisciplinary Seminars sponsored by the 211(d) Grant program, 2) participating in College of Agricultural Sciences Seminars on Foreign Agriculture, and 3) research in water resource development. As a direct result of increasingly greater exposure to domestic and international water delivery and removal systems and related water resources development problems, the staff has been able to include selected examples of such problems in regular course work and has become far more proficient in advising students interested in foreign service.

Dr. John Reuss was in charge of the International Interdisciplinary Seminar for the 1973 winter quarter, which concerned itself mainly with the modeling of water supplies for irrigation projects. Dr. Robert Danielson assisted by discussing agronomic concepts of delivery - removal aspects of a model. The seminar in Foreign Agriculture in the College of Agriculture Sciences was conducted by the Associate Dean, Dr. William Thomas at no cost to the 211(d) Grant Program. However, staff members from the Department of Agronomy who were participants in the International Interdisciplinary Seminar, took primary responsibility in the sessions concerned with water resource development including water delivery and removal systems and relevant institutional development. Finally, research under the direction of Dr. Arnold Klute is being conducted to determine soil physical properties that influence the amount and chemical composition of the drainage water from irrigated land. Two research assistants, Mr. Jacob Dane, supported by 211(d) Grant funds, and Mr. T. K. Glas, supported by OWRR, are working on the project. The effort is interdisciplinary with the Department of Agricultural Engineering.

During the past year, Dr. Daryl B. Simons was chairman of the CUSUSWASH Executive Committee. He contributed much of his time to policy and high level decisions regarding CSU's participation in the 211(d) Grant program. He has been and continues to be a solid supporter of the 211(d) Grant program as well as other international programs at no cost to the Grant. Dr. Maurice L. Albertson, the Director of the Grant program at CSU, spent a great deal of time with the participating faculty in discussing and working out with each department head how best to meet Grant objectives with limited Grant funding. He also gave freely of his time to many research assistants who frequently needed his advice. As Chief of Party of a group of four (4) professors from CSU he gave a paper entitled, "Integrated Approach to Irrigated Agriculture" at an irrigation conference held at Ibadan, Nigeria. The other three (3) members also

also gave papers as indicated under department headings. In addition, he made a number of other valuable contributions to the cause of the 211(d) Grant program described in other sections of this report, thus increasing the entrainment effects of the Grant program. Dr. Everett V. Richardson has assisted in planning and organizing the work of research assistants and in research design supporting Grant objectives. Drs. Albert G. Mercer and Khalid Mahmood have also given their services -- mostly without Grant support -- to research assistants working on some aspects of water delivery or removal systems who are supported by Grant funds.

Last year it was reported that two new faculty members had joined the College of Engineering, Drs. Willis W. Shaner and John W. Labadie. Dr. Shaner continues to teach engineering courses directly related to water delivery and removal systems; developed a new course, "Water Resources Project Planning in the Developing Countries"; gave three seminars in economics of water resources; prepared an outline for the economic portion of a handbook on water resource systems engineering being organized by Dr. Labadie; and advises candidates for the M.S. and Ph.D. degrees. Dr. Labadie is not only working on the handbook, but also continues his work on the development of methodology and models to improve water delivery and allocation. He, like Dr. Shaner, contributes much of his time to planning and supervising the work of research assistants related to water delivery and removal systems and relevant institutional development. Substantial support from 211(d) Grant funding was essential for the initial period required for both men to be absorbed into the University system. Now only nominal Grant funding is required even though both men are contributing as much or more work for the Grant program than ever before. This is another example of the entrainment effect of the Grant program.

The Department of Economics continues to offer a number of graduate and undergraduate courses that are directly supportive of the 211(d) Program at no expense to the project. These courses are in the areas of: agricultural economics, development economics, and water and natural resources economics. These courses have been experiencing increased enrollments of non-economics majors. This fact is explained partially by the increased awareness that the optimal utilization of water resources requires an interdisciplinary, systems approach--a fact that has been emphasized by the International Interdisciplinary Seminar and the 211(d) Program. The 211(d) Grant program provided the opportunity for Dr. George E. Radosevich to become known both at home and abroad as an expert in legal and institutional constraints affecting water resources management in countries throughout the world. He served as a consultant for USAID on a feasibility study of water resources development in Nigeria at no expense to the Grant, and later provided assistance in revising the water laws of Pakistan at the request of USAID. In December 1972, Dr. Radosevich was granted a year's leave from CSU to serve with the United Nations as Economic Affairs Officer, Resources and Transportation Department, Water Resources Division.

Dr. Huntley H. Biggs continued his research efforts on the technological and institutional constraints on resources management including delivery and utilization of water for small farm agricultural improvement in developing countries. He chaired a series of presentations on this subject for the International Interdisciplinary Seminar during the winter quarter 1973. He also went to Guatemala for purposes of consultation with the Minister of Agriculture, and supervise the thesis work of Christopher Dowswell, a research assistant. Dr. Ronald L. Tinnermeier participated in conferences and workshops dealing with the problem of the lack of credit institutions which forms a major constraint affecting the optimal utilization of resources and the introduction of new technologies on small farms. The 211(d) Program was the catalyst for much of his work since it provided sufficient released time for other university responsibilities for the

preparation of papers on small farmer credit institutions. This initial work set the stage for participation in other workshops on small farmer development strategies financed by the Agricultural Development Council and for heavy participation in the AID-Spring Review of Small Farmer Credit in 1973. Dr. Gene C. Wilken, Geography, worked on resources management on small farms including water resources development. It is his belief that there is much to be learned from current management practices on these low energy-using farming operations in devising strategies for increasing agricultural production efficiency. Only a small amount of Grant funds triggered the foregoing activities by these three professors.

Professor Henry P. Caulfield of the Political Science Department has an international reputation in the water resources field. He now teaches both graduate and undergraduate level courses, supervises the work of research assistants, and directs the International Interdisciplinary Seminar on water resources management (see Appendix D). Since joining CSU, he has been involved in numerous consulting assignments on water resources development throughout the world. Though initially heavily supported by Grant funds, he is much less so now as his academic services are being more and more absorbed into the University system.

Dr. Evan C. Vlachos of the Sociology Department has made significant progress in his Department to bring about an understanding and acceptance of the role of the sociologist in an essentially engineering field of water delivery and removal systems. Under his capable leadership, students and faculty have been oriented and trained in the problems of water development and an understanding of how natural resources, and their utilization and limitations affect the rate of development of many nations. Also, Dr. Vlachos is developing the capabilities within the Department to respond to water removal and delivery problems through research into the interface of water and society and an understanding of the dynamic processes involved in the interconnection between water supply, water control, water distribution, water utilization and water reclamation, and through faculty and staff participation in conferences and seminars. Though moderately supported by Grant funds, the entrainment and other effects generated include:

1. Adding a whole new educational dimension in the Sociology Department.

2. Receiving an appointment as a Sociology/Engineering Professor to inject the Sociologist's viewpoints to the Engineer in the field of Water Resources Development and Research.

3. An increasing use of his views, both on and off campus, as a Sociologist on the workability of the interdisciplinary approach to solving development problems. For added details see Appendix F.

b. Technical Publications

Most of these publications were prepared at little or no cost to the Grant program. However, a large part of the publication cost was Grant supported. Appendix B includes abstracts for each of the following reports and theses.

(1) During the reporting year, two (2) 211(d) Grant supported studies were published under CUSUSWASH covers. They are: The Puebla Irrigation Development Project, Publication No. 22 by Dr. H. H. Biggs, Economics Department; and Index for the Eight Near East-South Asia Irrigation Practices Seminars, Publication No. 24 by William Neal and Clifford Stockmyer, Political Science Department.

(2) Also during the reporting year, one (1) 211(d) Grant supported Ph.D. dissertation and three (3) M.S. theses were completed. They are: The Organization of Thai Irrigators, an M.S. thesis by Michael Schiefer, Civil Engineering Department, May 1973; A Laboratory Study of Bed Material Withdrawal in Farm Turnouts, an M.S. thesis by Ata Mohammad Nazar, Civil Engineering Department, May 1973; Optimal Parameter Identification of Nonlinear, Time-Variant Hydrologic System Models, a Ph.D. dissertation by Samuel Tuffuor, Civil Engineering Department, June 1973; and The Problem of Rural-Urban Water Competition, an M.S. thesis by Everett Meyers, Political Science Department, June 1973.

(3) During the reporting year, the following papers supported by 211(d) Grant funding were published in technical journals and acknowledgement made of support from Grant funding: The Green Revolution and Economic Development, by Huntley H. Biggs, Rocky

Mountain Science Society Journal, January 1973; Comparison of Bridge Backwater Relations, by G. V. Skogerboe, J. W. H. Barrett, W. R. Walker and L. H. Austin, Proceedings of ASCE, Journal of the Hydraulics Division, June 1973; Generalized Discharge Relations for Cutthroat Flumes, by G. V. Skogerboe, R. S. Bennett and W. R. Walker, Proceedings of ASCE, Journal of Irrigation and Drainage Division, December 1972; Slope-Discharge Ratings for Cutthroat Flumes, by G. V. Skogerboe, T. Y. Wu, R. S. Bennett and W. R. Walker, Transactions of ASAE, January 1973; Flow Measuring Flume for Wastewater Treatment Plants, by W. R. Walker, G. V. Skogerboe and R. S. Bennett, Journal of Water Pollution Control Federation, March 1973.

(4) The following paper was prepared by George E. Radosevich under partial support from 211(d) Grant funding: Institutional Arrangements for Local Water Control with Particular Reference to Adaptation in Pakistan.

(5) Papers prepared under Grant support and are being edited for possible use in an Irrigation Manual for West Africa are: Integrated Approach to Irrigated Agriculture, by Maurice L. Albertson; Socio-Economic Aspects of Irrigated Agriculture, by Evan Vlachos; Irrigation Agronomy, by W. D. Kemper (not supported by 211(d) Grant); Irrigation Engineering, by W. E. Hart.

(6) Papers prepared under other funding but which would not have been prepared were it not for the CSU 211(d) Grant program: The Impact of Small Farmer Credit in Peru, by Ronald L. Tinnermeier; Technology, Profit and Agricultural Credit, by Ronald L. Tinnermeier.

(7) Still in process are the following theses: An Analysis of the Helmand-Arghandab River Basin Development Program, by Philip A. Hosterman, Civil Engineering Department; Public Investments in Irrigated Agriculture: Mexico 1940-1960, by Larry Caswell, Economics Department.

c. Library Improvement

As reported in the 1971-72 annual report, one of the first steps taken at CSU to improve the cataloging system related to water resources development or management was to move the Project Office Library collection of approximately 1400 publications to the CSU Morgan Library. During the reporting year the following steps were taken to make the library materials more readily available. However, no Grant funds were utilized.

1. In July 1973 a professional librarian was hired and an office established in the Morgan Library for processing these materials;

2. Materials were checked in against a master list. A second "master list" was maintained as a location copy to record the final destination as well as the call numbers of these materials. Order cards were typed for each individual item. These cards were then checked against the CSU card catalogue to establish whether these items were already part of the collection. Titles already in the collection were checked against the shelf list to determine the number of copies held by the library. In cases where the library held only one copy, a second copy (copy 2) was added. If the library held 2 copies, a shelf check was made for missing copies to verify the actual number of copies held. After this was ascertained, remaining additional copies were sent with pertinent cataloging information to the Engineering Research Center reading room. Those materials which could be verified were submitted for original cataloging with suggested classification and subjects.

3. For each title new to the Library, an extra main entry card was created for future bibliographic purposes. Material falling under the category of Government Publications was searched in a similar manner. Those for which a Superintendent of Documents classification number could not be found were held while correspondence with GPO requesting classification could be carried out.

4. Material requiring original cataloging was reported to the National Union Catalog. In many cases, this proved Colorado State University was possibly the only school in the country to hold these titles. This material having been reported may prove a valuable source of information to other schools both in this country and overseas via Inter-Library Loan.

5. Reprints of journal articles were added to a special Engineering Research Center office reprint file in an attempt to keep these materials together. Also conference papers (i. e. pre-published proceedings) were added to the ERC reading room in a special file set up there for that purpose. These conference papers were already represented in the CSU Morgan Library as post-conference published proceedings.

d. Seminars

The International Interdisciplinary Seminar continues to be conducted under the leadership of Professor Henry P. Caulfield, Jr. During the reporting period, he served as Chairman of the Program Committee for the Seminar composed of seven faculty members representing different departments, implemented committee decisions, chaired the meetings, and guided discussion to meaningful conclusions. The Seminar continues to serve as a catalyst for the fusion of ideas on water resource management and the central theme of optimum utilization of water delivery and removal systems and related institutional development. These Seminars have greatly stimulated the thinking and actions of the participating departments, particularly in regard to the relationship of research to objectives of the Grant. Twenty-six presentations were made during the reporting period by the International Interdisciplinary Seminar on Water Resources Management revolving around a central theme, "Optimum utilization of water resources: with emphasis on water delivery and removal systems and relevant institutional development". Most of the presentations were given by CSU faculty and research assistants and the remainder from outside sources. Dr. Huntley H. Biggs served as organizer and coordinator of one series of presentations on Small Farm Agriculture during the winter quarter 1973. This list of presentations is included in the total list of presentations for the reporting period in Appendix C.

One new development included acceptance of a plan for regularizing the Seminar into the academic structure of the University. The attendance at this Seminar for the year was approximately 870. Many attended because of increasing interest created by 211(d) Grant activity. Also many Grant personnel, stimulated in part by the Grant, attended other seminars on related water resources development and management topics both on and off campus at no cost to the Grant.

e. Research Assistants

research assistants received support from 211(d) Grant funds ranging from three to six months' support (6 - 12 months at half-time) for each individual. The nature of studies supported by 211(d) Grant funds were directly related to some phase concerned with optimum utilization of water resources including water delivery and removal systems and related institutional development. All of these research assistants attend the weekly sessions of the International Interdisciplinary Seminar. The research assistants are:

Q. A. Khan, Agricultural Engineering
 Jacob H. Dane, Agronomy
 Ghulam Ahmad, Civil Engineering
 Herbert Blank, Civil Engineering
 S. Janakiram, Civil Engineering
 Frederick Laufer, Civil Engineering
 W. A. Lemma, Civil Engineering
 Rashid Makhdoom, Civil Engineering
 Ata Nazar, Civil Engineering
 Michael C. Schiefer, Civil Engineering
 Samuel Tuffuor, Civil Engineering
 Christopher Dowswell, Economics
 Everett M. Myers, Political Science
 Bailey Wharton, Political Science
 Forrest Deseran, Sociology

As indicated in Section b, Technical Publications, William L. Neal and Clifford Stockmyer, Political Science Department completed the index of the NESAs Irrigation Practices Seminar Proceedings. This was done at the suggestion of Mr. O. L. Mimms of AID/Washington and accomplished under the direction of Garth N. Jones of CSU with support of 211(d) Grant funding. The report was published under a CUSUSWASH cover and provides a detailed alphabetical key to the contents of the eight volumes comprising the published proceedings of these seminars held from 1956 through 1970. Another Political Science Department contribution was an M. S. thesis by Everett Meyers entitled "The Problem of Rural-Urban Water Competition" (Abstracts - Appendix B).

One (1) 211(d) Grant supported Ph. D. dissertation and two (2) M. S. thesis - - from the Civil Engineering Department - were completed during the reporting year. They are:

1. "The Organization of Thai Irrigators" by Michael C. Schiefer. This is an M. S. thesis which examines the problem of organizing Thai farmers for cooperative irrigation in Northeast Thailand and emphasizes the need for social and institutional development for better water delivery and removal efficiencies. See Abstracts - Appendix B.

2. "A Laboratory Study of Bed Material Withdrawal in Farm Turnouts" by Ata Mohammad Nazar. This study concentrated on the phenomenon of bed material withdrawal through a farm turnout. Depth of flow in the flume, discharge in the flume turnout elevation from the concrete bed of the flume, and the discharge through the turnout were the variables whose effect on the variation of sediment discharge through the turnout was determined.

3. "Optimal Parameter Identification of Nonlinear, Time-Variant Hydrologic System Models" by Samuel Tuffuor. This Ph. D. study focused on the important need for investigation of river basin characteristics. One of the major objectives of this study was the development of a hydrologic model for water delivery particularly suited for a developing nation. This dissertation was supported only in small part by 211(d) Grant funds. For further details see Abstracts - Appendix B.

Graduate Research Assistants in Agricultural Engineering co-authored in the following papers published in technical journals: J. W. H. Barrett, "Comparison of Bridge Backwater Relations"; R. S. Bennett, "Generalized Discharge Relations for Cutthroat Flumes"; T. Y. Wu and R. S. Bennett, "Slope-Discharge Ratings for Cutthroat Flumes"; and R. S. Bennett, "Flow Measuring Flume for Wastewater Treatment".

Larry L. Caswell, Department of Economics completed his M. S. thesis entitled, "Public Investments in Irrigated Agriculture in Mexico's Pacific Northwest".

Forrest Deseran of Sociology continued a bibliographic survey as to aspects of water and society and developmental issues related to the general problem of water delivery and removal, collecting data on population problems to be used as case studies for demographic constraints and the understanding of areas affected by proposed projects on water delivery and removal systems, and continuing work on a theoretical scheme integrating demographic data requirements and the interrelationship between population growth and water resource utilization with emphasis on water delivery and removal systems.

In process is an M. S. thesis: Philip A. Hostermann, Civil Engineering, "An Analysis of the Helmand - Arghandab River Basin Development Program". Mr. Hostermann has spent the last year in Afghanistan without 211(d) Grant support. His report focuses on sociological constraints hampering water delivery and removal systems including relevant institutional development within a particular river basin development program. Also, Christopher R. Dowswell, Economics, is working on "An Evaluation of the Irrigation Project for Small Farmers". Here, economic factors affecting a particular use group, i. e. restraints and problems connected with water delivery and disposal systems, are being evaluated in relationship to optimal agricultural production.

f. Meetings and Travel

Attending meetings and conferences abroad stimulates program activity through contact with other scientists, broadening viewpoints, and improving understanding of other cultures and economic and social problems which may inhibit transfer of knowledge. It appears essential that new professors and research assistants be exposed early

to such meetings in order to build interest. Also to allow the more experienced educator to attend meetings, participate, and forge linkages or to travel in a consultant capacity in order to maintain his interest and utilize his technical capacities in international activities. The following briefly describes travel performed in the interest of the 211(d) Grant program.

Foreign Travel

Details of financial support for foreign travel are given in Section IX, part 3, page 70.

Christopher Dowswell traveled to Guatemala City August 21, 1972, to conduct study on problems of small farmers on irrigated lands for his M.S. degree.

Dr. George Radosevich - through contacts made by M. L. Albertson, USAID/Nigeria requested the services of Dr. Radosevich to assist in developing a comprehensive feasibility study of an irrigation development plan for Nigeria. He was on this assignment from August 7 to August 25, 1972.

Dr. Maurice L. Albertson - an international trip October 1 to November 1, 1972, took him to Hawaii where he discussed water institutions in a meeting involving the University of Hawaii and the East West Center, and the potential collaboration of CSU and University of Hawaii in a new water management research program in Vietnam. In Tokyo, at no expense to the Grant, Dr. Albertson attended a regional irrigation seminar sponsored by FAO. From there he went to Thailand, Pakistan and Afghanistan where he was involved in discussion of plans for research involving water delivery and removal systems and educational and research programs. Having been invited to Kenya, he went there to discuss water delivery and removal systems and related institutional development of National Irrigation Plans. Following this, he went to Ibadan to help organize and to attend, by request, a seminar at Ibadan, Nigeria. In addition to Dr. Albertson, the party consisted of Drs. W. Doral Kemper, William E. Hart, and Evan C. Vlachos.

The seminar was sponsored by the International Institute of Tropical Agriculture (IITA), August 23-27, 1972. The main theme of the seminar was, "Prospects for Irrigation in West Africa". Each of those attending the seminar presented papers which were dove-tailed to cover a specific range of subject material and to fit within the theme of the seminar. This material is now being considered for possible use in development of an Irrigation Manual for West Africa. The participation of four CSU professors in this seminar came as a result of Dr. Albertson's attendance (as a representative from CUSUSWASH) of the IITA Soils Consortium Conference held at Ibadan, Nigeria in May 1972. Further linkages developed were: on his return to the U. S., Dr. Evan Vlachos' visit to Israel (at no cost to the Grant) at the request of Dr. Goldberg to see at first hand the national irrigation projects and to lecture and discuss the role of sociology in water resources development. Also, enroute to the States, Dr. Hart stopped in Monrovia, Liberia to discuss with John Osguthorpe, USAID/West Africa Rice Development Association (WARDA), the implementation of their program. Contact was also made with Dean D. Shields, College of Agriculture and Forestry, University of Liberia is an additional part of the linkage program under 211(d) Grant objectives for possible future coordination and assistance.

Dr. Maurice L. Albertson - attended a conference of the SID in Costa Rica regarding rural development and social and political aspects of agrarian reform and their role in promoting social and political development, February 21-25, 1973.

Dr. Huntley H. Biggs - traveled to Guatemala in April 1973 to provide thesis guidance to Mr. Christopher Dowsell, graduate research assistant who was conducting thesis research and a study evaluating the irrigation program for small farms. While there, the Minister of Agriculture inquired into the possibility of CSU providing assistance to the new Institute of Agricultural Sciences in the areas of water resources management for agricultural development as well as graduate programs for Guatemalan students.

U.S. Travel

The following men, well known and qualified in the field of water resources development, conducted seminars at the International Interdisciplinary Seminar held each Wednesday during the academic year within the reporting period. The listed personnel are non-CSU personnel whose travel and other expenses were supported only in small part from 211(d) Grant funds:

Dr. Robert Lindsay - University of Minnesota

Dr. Nathan Buras - Technion, Israel Institute of Technology

Mr. Byron Palmer - Utah State University

Dr. John McNowen - World Bank, Washington D. C.

Dr. A. Alagapan - United Nations, New York

Dr. D. R. Sikka - Secretary for Government Irrigation, State of Madhya Pradesh, India

Dr. Wynn F. Owen - University of Colorado

Dr. John Coulter - Rothamsted Experimental Station, Harpenden, Herts, England

Dr. Garth Jones and George Smith traveled to Logan, August 24-26, 1972 to help finalize the Irrigation Management Program (IMP) report.

Dr. Maurice L. Albertson attended the ASCE, Irrigation and Drainage meeting in Spokane on September 27-29, 1972; also attended the SID meeting in Washington DC on September 30, 1972, to discuss the creation of an Agricultural and Rural Development Section within SID.

Dr. Maurice L. Albertson, George Smith, and Bonnie Frantz attended the CUSUSWASH meeting in San Francisco, January 2-5, 1973.

3. Summary of Accumulated Accomplishments

a. Improvement of Faculty and Staff

One new faculty member was recruited by the Department of Agricultural Engineering. His services will be available beginning September 1973. No 211(d) Grant funds were utilized for this purpose during the reporting year. One new course was developed in water resources development in the Engineering College. All participating departments have improved their courses through increasingly greater exposure to problems of both domestic and international water delivery and removal systems, and through selected samples of such problems in regular course work. The staff members are now far more efficient and effective in advising students in the technological aspects of international water problems.

Effective use of 211(d) Grant funds by all six participating departments provided the incentive and time for research activity, report writing, participating in domestic and international water conferences, graduate student advising, attendance at the International Interdisciplinary Seminars and other relevant seminars, development of linkages, and promoting entrainment effects.

A group of four (4) CSU professors presented keynote papers at a seminar sponsored by the International Institute of Tropical Agriculture (IITA) on the topic, "Prospects for Irrigation in West Africa". The seminar was held at Ibadan, Nigeria in October 1972. Each of these men learned a great deal about problems of irrigation in Africa through active participation at the seminar, and through private discussions. At the same time, valuable linkages were established with professionals from other countries which are continuing through correspondence and exchange of literature and information.

An Economics Professor made several trips abroad which improved his knowledge and understanding of water laws, water user organizations, and constraints and problems on a world-wide basis. On one trip, he served as a consultant for USAID on a feasibility study of water resources development in Nigeria. On another, he provided assistance in revising the water laws of Pakistan at the request of USAID. Other examples of increased staff competence through participation in both domestic and international seminars, conferences and committees are fully described in the foregoing sections of this report.

b. Technical Publications

During the reporting year two (2) Grant supported studies were published under CUSUSWASH covers; one (1) Grant supported (in part) Ph.D. dissertation and three (3) M. S. theses were completed; five (5) papers by staff personnel supported in part by Grant funds were published in technical journals; one (1) completed study under Grant support but not yet published; four (4) papers prepared under Grant support being edited for possible use in an Irrigation manual for West Africa; and two (2) papers prepared under other than Grant funding which could not have been prepared were it not for the Grant program.

c. Library Improvement

As reported in the 1971-72 annual report, the Project Office library collection of approximately 1400 publications was moved to the Morgan Library. During the reporting year, at no cost to the Grant program the following improvements were made: a professional librarian was hired and an office established in the Morgan Library to properly process these materials. During the cataloging and reporting to the National Union Catalog, it was found that CSU was possibly the only school in the country to hold certain titles. About fifty (50) publications were added to the library during the reporting year.

d. Seminars

Twenty six (26) presentations by the International Interdisciplinary Seminar were made. The titles of the seminars together with the names of the speakers and the organizations represented may be found in Appendix B of this report. The Seminar presentations fall under the three (3) general headings as follows:

- (1) Major Constructed Water Development Projects Throughout the World
- (2) Small Farming Problems in Less Developed Countries
- (3) Interdisciplinary Modeling of Water Management Problems

e. Research Assistants

Fifteen research assistants received support from 211(d) Grant funding ranging from three (3) to six (6) months support (6-12 months half time). Three (3) of this number completed M. S. theses and one (1) completed a Ph. D. dissertation. The remainder are in the process of producing theses which may take from one (1) to two (2) years more to complete having just begun their studies. All studies are directed toward making a positive contribution to the body of knowledge surrounding the central theme of the 211(d) Grant program.

4. Proportion of Year's Expenditures Used for Each Area of Activity

The following table contains the same activity areas as appears in Table I, Chapter IX of this report.

	<u>Expenditure</u>	<u>Percent</u>
1. Salaries (Increased teaching competence)	\$ 79,567	43
Stipends (Research assistants)	52,426	29
Travel	16,232	9
Library and Publications	3,604	2
2. *Other (Office expenses)	21,465	11
CUSUSWASH Executive Director's Office Support	12,000	6
Equipment	97	0
TOTAL	<u>\$185,391</u>	<u>100</u>

1. Salaries include \$350.00 consultation fees

2. *Breakdown:

Clerical costs	\$13,305
Office expense (telephone, xeroxing, mailing, supplies, Western Union)	8,160
	<u>\$21,465</u>

IV. Impact of Grant-Supported Activities in Developing Institutional Capabilities

As a direct result of increased faculty competence through 211(d) Grant funding in teaching, research, publications, seminars, conferences and consulting, the faculty and participating departments of CSU can now contribute even more effectively in projects and programs with developing country governments and international organizations in the broad aspects of optimum utilization of water resources development with special emphasis on water delivery and removal systems as well as related institution development.

Regarding these specific areas of increased capabilities, the participating faculty looks at the problem from a broad perspective by gaining a basic understanding of the process of technological change and the relating factors which critically affect the optimal use of water resources. The rationale governing this approach is the necessity of first understanding the basic institutional engineering, social and economic constraints which influence individual decisions, then designing the appropriate water delivery and removal system(s) which will assure an optimal use of water resources for increasing agricultural productivity. Research efforts have indicated that the availability of technology and credit institutions, together with resource management practices, can have an important bearing on the optimal use of water.

The International Interdisciplinary Seminar, has had an important impact on the faculty members and graduate assistants representing the participating disciplines in bringing about a better understanding of optimal development of water resources, particularly in water delivery and removal systems and related institutional development. The International Interdisciplinary Seminar has met for two hours each week throughout the academic year 1972-1973 under the direction of Professor Henry P. Caulfield, Jr., Department of Political Science. Though the terms of reference for the Seminar are quite broad, as

indeed they should be, for encouragement of faculty-student intellectual development, the seminar has been increasingly successful in creating an appreciation among faculty, research assistants, and others of the complex character and the diversity of factors involved -- including engineering, social and political, cultural, biological, and economic -- and thus, of the multidisciplinary and international nature of the problems inherent in increasing agricultural production in the world. As a result, the participating individual acquires a broader background and a basis for better comprehension of the complicated processes involved in successfully establishing in developing countries optimal utilization of water resources including water delivery and removal systems and related institutional structures. Thus, the Seminar has been useful in helping the participating departments to establish basic guidelines for interdisciplinary research activities related to the 211(d) Grant objectives.

More specifically, the Grant has made the following impacts in developing the Department of Agricultural Engineering's capability in the areas of water delivery and removal: increased staff competency -- the department now has increased numbers of staff (such as Professors Kemper, Hart, Clyma, Skogerboe and Walker), who have developed linkages in the developing countries, are aware of problems in developing countries, have an interest in these problems and have significant capability to provide technical assistance for the solution of these problems. Graduate students have been trained who are interested in working in or with the developing countries and have helped to establish linkages in these countries, have worked in developing countries, have significant contacts there and have thus increased CSU's linkages. Courses directly and indirectly related to water delivery and removal and relevant institutional development have been developed (see Appendix G) and are being taught to students and staff from many

departments of the campus. In addition, existing courses have been focused more toward the solutions of problems in developing countries.

Various design manuals have been and are being prepared which can be used to provide needed technology to the developing countries in the field of water delivery and removal systems. The Water Management Technical reports No. 9 "Check-Drop-Energy Dissipator Structures in Irrigation Systems" and No. 19 "Installation and Field Use of Cutthroat Flumes for Water Management" have been well received by numerous engineers based upon return correspondence, as well as comments from foreign engineers and soil scientist participants in the Irrigation Practices Training Course (sponsored by USDA) conducted at CSU each summer who have repeatedly stated the value of these manuals in their work. It is anticipated some of these will be translated into Spanish or other languages to increase their usability. Each of the areas described above have built upon CSU's existing capabilities and the staff and students have become more aware and responsive to the needs in developing countries. Interest has been expressed to the investigators to give short courses in Pakistan and Central America regarding improved water delivery systems. In fact, an advisory mission to Pakistan by Professors Skogerboe and Walker concerning flow measurement and irrigation systems structures is anticipated.

The 211(d) Grant program has created a greater awareness on the part of the Department of Agronomy to the needs of developing countries in the solution of problems in water resource management. It has been responsible, in part, for developing courses designed to inform and train both undergraduate and graduate students for foreign assignments in water resource management especially in water delivery and removal systems, irrigation management, and related institutional development situations. In addition, the Department provides academic

and program advisors for non-degree foreign students enrolled in the International School for Water Resources Environmental Management. The 211(d) program also has increased the competence of CSU staff actively involved as advisors for the CSU/USAID project in Pakistan. For example, the services of Dr. W. R. Schmehl, Dr. W. T. Franklin and Mr. C. W. Robinson were requested by the Mission for consulting and program planning on the water management project during the reporting year.

The 211(d) Grant program has made it possible for the Department of Civil Engineering to: improve faculty and staff capability for advising foreign students in the field of optimum utilization of water resources and more specifically, in water delivery and removal systems and related institutional structures; increase the competence of staff and faculty; developing a greater awareness of the priority needs of developing countries in the solution of water resource management problems, specifically in water delivery and removal systems and related institutional development; improving the design and content of courses for undergraduate and graduate students emphasizing water delivery and removal systems and related institutional structures; and increased number, capabilities and desire of faculty and staff to serve overseas. Grant funding made it possible for a team composed of Drs. M. L. Albertson (team leader), W. Doral Kemper, William Hart, and Evan C. Vlachos, to develop and present papers at an irrigation seminar held in Ibadan, Nigeria last fall. The initial contact with the IITA was made as a result of Dr. Albertson's attendance at the Soils Consortium meeting in Ibadan in May 1972 at which time he was asked to help organize the program and to provide 4 keynote speakers.

The Civil Engineering Department has also made progress on several publications which will be completed during the coming year. New courses have been added in water systems engineering, and linkages have been established with engineers, scientists and public officials in Nigeria, Ivory Coast, Kenya, Uganda, Senegal, Liberia, Tanzania, Afghanistan and Pakistan.

The approach of and the impact on the Department of Economics in the 211(d) Grant program has involved as many young faculty members as possible in research and teaching in the problems of the developing countries, with special focus on understanding the constraints (technological, financial and legal) which influence the optimal use of water resources. Accomplishment of the Grant objectives by faculty members and research assistants has been increasingly realized through a number of activities, including teaching, research, publications, conferences and consulting. For example, due to the broadening and development aspects of the 211(d) Grant program, George E. Radosevich, among other consulting trips taken during the reporting year, was selected by AID/Washington to serve as a legal and economics advisor to assist in preparing a feasibility study of a river basin in Nigeria, Africa. As a direct result of increased faculty competence in these areas through 211(d) Grant funding, the Department of Economics can now participate even more effectively in projects and programs with developing countries. Beginning several years ago, research efforts have gradually been focused more and more on the small farmer. This reflects the conviction that if developmental efforts are to have an impact on the majority of the world's impoverished peoples they must be focused on this group. Currently, it is the technical, financial and legal constraints confronting the small farmer that have largely limited the effectiveness of water delivery and removal systems, and relevant institutional achievement in developing countries. It is anticipated that even greater attention will be given to this problem area in the future by the Economics Department.

The impact of the 211(d) Grant program on the Department of Sociology resulted in the creation of a group within the department entitled, "RDM" (Research in Demography and Modernization), which was established with the explicit purpose of providing a forum and a concrete means for the study of the general problems of the project. This group of faculty members and graduate students (four faculty members contributed time without

211(d) Grant funding) attempted to extend and understand problems of water delivery and removal in the context of a more systematic undertaking of the designing and establishment of a set of data banks related to demography and modernization with emphasis on water delivery and removal; investigation of original surveys and other field studies which may provide the training ground for research assistants in problems of water and development; collection of an initial library and material reflecting aspects of water and the larger questions of both quantity and quality problems in water delivery and removal. Like the other disciplines involved in this 211(d) Grant program, it was early decided that as a first step in studying water delivery and removal systems it was necessary to gain an understanding of the large parameters of problems of water management and organization.

V. Utilization of Institutional Resources in Development

Increasing agricultural productivity throughout the world to a major degree is dependent upon making the proper use of water -- effectivly and efficiently coordinating water use with other agricultural inputs. Since this is a tremendously large and complicated problem, Colorado State University is assigned, through the 211(d) Grant program, the improvement of its competency in optimum utilization of water resources with emphasis on water delivery and removal systems and related institutional development. Six disciplines are actively involved and the International Interdisciplinary Seminar acts as a catalyst for a fusion of coordinated ideas leading to a better understanding of the CSU 211(d) Grant theme.

This interdisciplinary approach leads to connections with all the departments of the University and their personnel participating in the program, and other faculty members and research assistants interested in the general subject, as well as outside institutions, both government and private concerned with various aspects of water resources development. Within the campus, the six participating departments (Agronomy, Agricultural Engineering, Civil Engineering, Economics, Political Science and Sociology) receiving Grant support have developed meaningful ties with each other. Also, ties were continued with CUSUSWASH and during the year contacts, linkages, and communication were established or continued and strengthened with off campus institutions in the United States and abroad. Examples of the utilization of institutional resources in development appear on the following pages.

The importance of water control, including the timing of deliveries and maintaining constant discharges, is well recognized as a necessity for achieving improved irrigation efficiencies. The Department of Agricultural Engineering has long been working on water delivery systems together with other investigators funded from the U.S. Environmental Protection Agency to improve water delivery, farm, and drainage subsystems. This has provided CSU investigators - Professors Gaylord V. Skogerboe and Wynn Walker - with considerable laboratory and field research experience concerned with achieving improved water management practices. Funding from the 211(d) Grant also made it possible for Dr. W. E. Hart to prepare and give a seminar sponsored by the International Institute of Tropical Agriculture in Nigeria concerning irrigated agriculture in tropical and semi-arid regions. While in Nigeria, Dr. Hart visited with a number of African educators, researchers and Government officials resulting in a free flow of information which is continuing by letter communication. Dr. D. B. McWhorter and Professor G. V. Skogerboe taught the Irrigation Practices Short Course under the sponsorship of the USDA. Eighteen participants from around the world had an opportunity to interact with the CSU faculty and to obtain intensive instruction as well as to tour irrigation developments in the Rocky Mountain Region. Though no 211(d) Grant funds were involved, this irrigation course was very supportive of the Grant objectives.

The increased utilization of institutional resources made possible by the 211(d) Grant has permitted the Agronomy Department to make a major contribution to the development of the CSU/AIDcsd 2162 water management research project in Pakistan at no cost to the 211(d) Grant Program, also to permit three Agronomy staff members - Dr. W. R. Schmehl, Dr. W. T. Franklin and C. W. Robinson - to

serve as advisors for the CSU/AID Water Management Project and as water management consultants for other Pakistani institutions. In addition, Dr. R. S. Whitney, Department Head, and Dr. W. T. Franklin were advisors for an Economics project evaluating the impact of the quality of water delivered to an irrigation project based on the economic returns from the crops produced. The results will have general application to problems of irrigation development in developing countries where irrigation water supplies are at low to marginal quality.

Graduate students of the Department of Agricultural Engineering who have chosen to come to CSU, because of interest in development of water delivery and removal systems, and the institutions needed for the development of these systems in their home countries, are as follows (no support from 211(d) excepting one as noted):

<u>Name</u>	<u>Nationality (Citizenship)</u>	<u>MS/Ph. D.</u>	<u>Funding</u>
Zewdie Abate	Ethiopia	Ph. D.	AFGRAD
Robert Chandler	Canada	MS	WMR
Chuntse Cheng	Republic of China	MS	Private
Ken-Tsai Huang	Republic of China	MS	Experiment Station
Qurban Ali Khan	Pakistan	MS	211(d) Grant
Leck Jindasanguan	Thailand	MS	AID
Humberto Lam	Peru	MS	LASPAU
Pongsak Limjaroenrat	Thailand	MS	Private
Mohamad Mahmoodian-Shooshtari	Iran	MS	AFME
Giacomo Paniagua	Nicaragua	MS	AID
Mahmood Shariatmadar-Teleghani	Iran	Ph. D.	WMR
Jose Luis Trava	Mexico	Ph. D.	CNCT Sch.
Ter-Fung Tsao	Republic of China	Ph. D.	Experiment Station
G. S. Vijaya Raghavan	India	Ph. D.	Experiment Station
Jernan Yow	Republic of China	Ph. D.	Experiment Station

Experience gained by the Civil Engineering faculty, staff, and research assistants through participation in the 211(d) Grant program has, over the past several years, noticeably increased this department's competence, ability, and willingness to respond to such requests. Utilization of the institutional resources of the Civil Engineering Department and the University as a whole through 211(d) Grant participation has made it possible to provide competent personnel and persuade University officials to permit the use of University equipment, laboratory facilities, and library facilities for such overseas projects as the AID/csd 2162.

An example of response to overseas requests is the participation of 4 CSU Professors in a seminar sponsored by the International Institute of Tropical Agriculture (IITA) in Ibadan, October 1972, on Prospects for Irrigation in West Africa. The initial contact was made with Dr. Albertson in May 1972 when he was asked to help plan and organize the seminar. Later, he suggested that Utah State University participate, but they were unable to do so.

Another example of responding to an overseas request is the team of CUSUSWASH specialists which went to Nigeria at the request of the AID Agriculture Officer in Lagos, who was following the suggestion made by Dr. Albertson during his visit there in May 1972.

The 211(d) Grant program has stimulated and heightened the Department of Economics' utilization of institutional resources in many ways with very little Grant funding. Following are examples of the utilization of this institution's human resources in development.

As a direct result of Dr. George E. Radosevich's meeting with the leading Spanish authority on water law in the fall of 1972, an International Conference on Water Law will be held in Valencia, Spain during the summer of 1974. Dr. Radosevich will play a major role in that conference. On the same trip, he met with a German lawyer for the United Nations to obtain needed information on the international legal aspects of the Indus Basin project and, in Pakistan, consulted with national and AID officials concerning the need for structuring organizational mechanisms for improving the efficiency of water use in the country at no cost to the Grant program. During late summer of 1972, Dr. Radosevich served as the legal and economics advisor to a special USAID three-man team to Nigeria to assist in the preparation of a feasibility study of the Do-Anambra River Basin, at no expense to the Grant program. At present, Dr. Radosevich is on leave from CSU acting as a United Nations Economic Affairs Officer for the Water Resources Division at the Resources and Transportation Department. His return to CSU next December will add measurably to this institution's utilization capacities in development.

At the request of the Guatemalan Minister of Agriculture, Dr. Huntley H. Biggs went to Guatemala last April under Grant funding to discuss CSU's capabilities in the areas of water resources management for agricultural development. While there, he also provided thesis guidance to Mr. Christopher Dowswell who was conducting his thesis research under Grant funding. In his discussions with the Minister, there was revealed the possibility of a Guatemalan request to CSU for technical assistance to the new Institute of Agricultural Sciences.

The 211(d) Grant program provided no funds but did provide the stimulus for the following type of utilization of institutional resources by encouraging Dr. Ronald L. Tinnermeier to be actively involved in studying and evaluating the experiences of the less-developed countries in promoting agricultural credit institutions to small farmers. First, a paper on small farmer credit was prepared for a workshop on Small Farmer Development Strategies in 1972. As a result of this workshop,

Dr. Tinnermeier then organized a workshop on Small Farmer Credit, financed by the Agricultural Development Council, which provided much of the rationale and the general guidelines for the later, and larger, AID-Spring Review on Small Farmer Credit. Dr. Tinnermeier was also very active in the Spring Review. He prepared a study of the Colombian Bank's small farmer credit activities as one of the some 60 country papers prepared for the Review. Then, he was asked to prepare a paper on credit and technology summarizing the experiences around the world. This paper and some fifteen others served as points of discussion for three-day, regional workshops held in Latin America, Asia, the Middle East, and Africa. Dr. Tinnermeier participated as a resource person in each of those workshops.

The 211(d) Grant program (though no Grant funding was utilized) also inspired Dr. Gene C. Wilken to organize and chair the first session on Peasant Farming ever offered to the Annual National American Association of Geographers in April 1973. This session will now become a part of future annual meetings. During 1972-73, there were a number of students from developing countries enrolled in graduate programs in economics. Typically, the major areas of interest are: water resources economics, agricultural economics, and development economics. The selection of CSU and these courses reflect the growing interest in the economic aspects of water resources management and in other areas supported by the 211(d) Grant. In addition, a number of non-economics students are now taking courses in these areas. Quite a few economics faculty members serve on graduate committees for CSU non-economics graduate students from developing countries. Below is a list of the graduate students enrolled in the graduate program in economics. Each of these students is a candidate for the Masters of Science degree; however, some of them will continue into the Ph. D. program in the future:

<u>NAME</u>	<u>COUNTRY</u>	<u>SPECIALIZATION</u>	<u>FUNDING</u>
Aitell, Tariq	Jordan	Ag. Econ., Stat.	FAO
Chaann, Serewuddh	Cambodia	Econ	Fulbright-Hayes
Kamram, M. Hussain	Afghanistan	Ag. Econ.	Private
Khan, Ahmad Saeed	Pakistan	Ag. Econ. Dev.	211(d)
Khan, Mohammad Jameel	Pakistan	Ag. Econ., Nat. Res., Dev.	211(d)
Mesfin, Mebrahtu	Ethiopia	Ag. Econ., Nat. Res.	USAID
Muttamara, Sumali	Thailand	Ag. Econ.	USAID
Neghassi, Habte Miriam	Ethiopia	Ag. Econ.	AFME - RA
Tekie, Million	Ethiopia	Ag. Econ., Dev., Stat.	USAID
Tiv, Thean Po	Cambodia	Econ.	Fulbright-Hayes
Sarwar, Mohammad	Afghanistan	Dev., Nat. Res.	Private
Satiroglu, Kadir	Turkey	Dev., International	Private
Usman, Mohammad	Afghanistan	Ag. Econ.	Private

The Department of Sociology, through the 211(d) Grant has been provided the opportunity to develop firm ties with the participating departments on campus in the area of optimum utilization of water resources including water delivery and removal systems and particularly in related institutional development activities. During the year, communication was also established with other social scientists working in the field of natural resources, especially water, in such institutions as Michigan State University and Brigham Young University. However, once again, it is imperative to re-emphasize that the general thrust of the utilization of the institutional resources has been one of increasing the general sensitivity for the presence of sociology in the area of water resources rather than of specific task accomplishment. The importance of continuing such sociological activities should not be underestimated.

As a direct result from the accumulated impact of the 211(d) Grant, a number of spin-off activities have been generated. For example:

1. A request by the World Bank as to the interest of CSU in providing expatriate consultants to aid in the preparation of Mexico's National Water Plan. Subsequently, CUSUSWASH became interested and the resources of the Consortia of Universities were offered to the Government of Mexico. As a result, a World Bank official and two highly placed Mexican officials came to the CSU campus and were met by 22 CSU scientists.

2. A letter of intent signed between the University of Coahuila, Saltillo, Mexico, and CUSUSWASH in a collaborative arid zone research and development proposal.

3. As a direct result of Dr. Maurice L. Albertson's trip to Nigeria, May 23-30, and through his contacts with personnel of the International Institute of Tropical Agriculture (IITA) in Ibadan, Colorado State University received an invitation to participate in a seminar sponsored by IITA on Prospects for Irrigation in West Africa. This seminar was held from the 23rd to the 27th of October, 1972. Colorado State University responded by sending to Nigeria, four scientists, Drs. Maurice L. Albertson, W. Doral Kemper, Evan C. Vlachos, and William E. Hart, each of whom presented papers at the seminar. Also, Dr. George Radosevich, at the request of AID Washington was sent to Nigeria to help on the DoAnambra River Basin Study.

4. Development of an outline of principles as a result of a visit by Professor Emanuel Guggino, representing the Polytechnic Foundation of the Mediterranean, Italy, to Colorado State University in the area of water resources -- at no expense to 211(d).

VI. Other Resources for Grant-Related Activities

The Irrigation Practices Training Course was again given at Colorado State University, conducted by Gaylord V. Skogerboe and Wynn R. Walker of the Department of Agricultural Engineering and others. The course is not supported by Grant funds. It is sponsored by USDA and is primarily conducted for foreign engineers and soil scientists. Other resources for Grant-related activities allocated to the Department of Agricultural Engineering include: Irrigation Practices, Return Flow Salinity and Crop Yield -- Environmental Protection Agency; Improvements in Sprinkler Irrigation Systems -- Office of Water Resources Research; Consolidation of Irrigation Systems -- Office of Water Resources Research; Systems of Management for Optimal Water Use -- United States Bureau of Reclamation.

Under the direction of Dr. W. T. Franklin, Department of Agronomy, a cooperative research project between the State Colorado project No. 192 and AID/csd 2162 was conducted to evaluate the effect of water quality and method of irrigation on the salt content of return flows back into the irrigation system. As part of the study a computerized chemical model was formulated for Pakistan conditions. This project will be tested in 1973-74. In addition another project is underway between AID/csd 2162 in cooperation with the State of Colorado project No. 127 to evaluate the influence of soil fertility on plant growth when the crop is irrigated with saline irrigation water. The results so far indicate that some of the detrimental effects of saline return-flow water can be overcome by judicious fertilization.

The participating departments have provided faculty support for an ongoing institute at CSU called the International School of Water Resource-Environmental Management. This school is sponsored by CSU's Department of Civil Engineering to provide one-year training

programs for persons from developing countries. Many of these students take engineering, economics, and sociology courses in water resources development. Faculty from the six participating departments serve in an advisory capacity for a number of these students at no cost to the 211(d) program. Most of the students are funded by such International organizations as: AID, FAO, UNDP, and WHO. Additionally, the Department of Civil Engineering, in cooperation with the Colorado State Experiment Station, is presently doing water research work in the following projects: Irrigation Flow Measurement; Hydraulics; Water Resources Optimization; and Groundwater Resources. Cooperative studies are also undertaken with such organizations as: Bureau of Reclamation; Office of Water Resources Research; and U.S. Geological Survey.

The Department of Economics is heavily involved in funded research dealing with economic aspects of water resources. Many of these projects directly support the areas of concern to the 211(d) Program. Among the general areas of research concern that support the 211(d) Grant Program are: the economics of water quality, systems management for optimum water utilization, legal and economic problems in the consolidation of irrigation systems, water quality, regional use of water resources, and efficiency in on-farm water use. Below is a list of the titles of these projects and the agencies providing funding.

<u>Title</u>	<u>Sponsors</u>
Economic and Institutional Analysis of Water Quality Standards and Management	Experiment Station and Office of Water Resources Research (OWRR)
An Economic Analysis of Water Use in Colorado's Economy	Experiment Station, Colorado Water Conservation Board and OWRR
Economic Analysis of Water Use in Boulder, Larimer and Weld Counties	Bureau of Reclamation, USDI

Consolidation of Irrigation Systems: Economic Aspects	OWRR
Consolidation of Irrigation Systems: Legal Aspects	OWRR
Economic Analysis of On-farm Input Use With Reference to Achieving an Efficient Allocation of Water Use in Pakistan	Agency of International Development, State Department
Systems of Management for Optimum Water Utilization	Bureau of Reclamation, USDI
Finance in Public Water Resource Use and Development	OWRR
Economic Effects of Salinity in the Colorado River	Bureau of Reclamation, USDI
Systems of Management for Optimum Water Utilization	Experiment Station

In addition, Dr. Gene C. Wilken was awarded two research grants for the purposes of studying "Resource Management and Peasant Farming Systems in Middle America" over the next two years. The sources of funding are: the National Science Foundation and the Foreign Area Fellowship Program. Dr Wilken was granted a sabbatical leave from CSU to spend 1973/74 in Mexico. He will return to CSU in 1974 for an additional year to complete his research.

Similar to Economics and the other participating departments, some of the other resources for Grant-related activities in the Political Science Department would include: the Office of Water Resources Research, Resident Instruction Funds and the State of Colorado.

One of the major resources utilized by the Department of Sociology (beyond the immediate funding of graduate students) has been the volunteered time of a number of faculty who were guided by the general interest and concern for the area of water management research. Also extensive use was made of the computer facilities of the University (also no cost to 211(d)) in the context of both training and research in order to develop the general capabilities of graduate students.

VII. Next Year's Plan of Work and Anticipated Expenditures

The fiscal year 1973-74 is intended to consolidate and bring together all of the progress that has been made through the Grant thus far. Specifically, special emphasis is to be placed on publications which will bring out the new information that has been gained during the Grant and to summarize certain existing information which needs to be made readily available; to establish ways for continuing the team activities which are already underway even beyond the end of the Grant; to try to find ways of supporting (beyond the Grant period) the new staff which has been brought to CSU as a result of the Grant; and to round out the research and study activities.

Specific publications which are expected to be produced during this Grant period are:

1. The Ultimate Irrigation Water Supply Potential of the Indus Basin, Pakistan, which is an analysis of the present water delivery system and a projection, using systems analysis of the ultimate potential, using all sources and conveyance systems optimally.
2. Water Resource Management of Small Farms in Developing Countries, which is a collection of 10 papers giving an interdisciplinary approach to the subject.
3. Improving the Water Resources Management Institutions in Pakistan, which will present a summary of existing institutional arrangements, examine the available models, and show how a combination of models might be used to improve the institutional structure in Pakistan.
4. Optimal Conjunctive Use Model for the Indus Basin, which considers the optimal combined use of ground water and surface water to maximize agricultural production.
5. Sediment Problems in Rivers, Canals and Watercourses in the Punjab, which will examine the existing situation and measures which might be taken to improve it.

6. Water Delivery and Removal Systems in the Developing Countries, which will be a volume containing a series of papers relating water supply and conveyance, conjunctive use of ground water and surface water, reuse of excess water, sediment problems, quality control, seepage, and water resource institutions, to improve delivery and removal systems -- all aimed at reducing the cost of irrigation water to the farmer and making it available to him at the time and place and in the quantities that he needs with as little maintenance and operational expense and difficulty for him as possible.

7. Aquifer Recharge for Optimal Conjunctive Use of Surface and Ground Water Resources in Pakistan, which will consider seepage and the lining of canals as well as salinity control and general management of the underground reservoir which has been shown to be much less expensive than reservoirs above ground.

8. Flood Control Measures in Pakistan, which will examine the recent floods, the damage they have caused to water delivery and removal systems, and measures which might be taken to prevent or minimize such damage in the future.

9. Control of Sediment at Farm Turnouts, which will report the results of laboratory and field experiments on methods and designs for controlling the sediment which enters a farm turnout and is deposited in the farmers ditch or field.

10. Development Planning, a book which presents a model on input-output techniques, which can be used to analyze such development problems as: forecasting, optimization, international trade, and technological (this is not supported by 211(d)).

11. Incorporation of Working Capital in Project Analysis, which includes such factors as water application and fertilizers.

12. Underlying Assumptions for the Rate of Return Analysis, which applies to water resources analysis as used by the World Bank.

13. Prospects for Irrigation in West Africa which includes the socio-economic aspects of institutional development for water delivery systems and on-farm irrigation systems.

During the coming year, new courses will be added, such as "Fundamentals of Irrigation and Drainage" which will be taught in the Agricultural Engineering Department for non-engineers such as economists, lawyers, sociologists, agronomists and political scientists. The primary emphasis will be for the expansion and upgrading of existing courses -- especially those which have been added through the help of the 211(d) Grant.

Research will continue and be reported on:

1. water conveyance layout,
2. design and management for small irrigated farms,
3. pumping groundwater overlaid by saline aquifers,
4. small irrigation structures for water delivery and removal,
5. movement and accumulation of salt in the soil and the necessary removal systems,
6. institutional arrangements for water delivery and removal systems,
7. conjunctive use of surface water and groundwater, and
8. techniques for reducing the cost of water to the farmer.

CSU is continuing to expand joint and cooperative activities with the other CUSUSWASH Universities, both in the U. S. and in the developing countries such as Mexico, Iran and Nigeria.

The participating departments' plan of work for next year and anticipated expenditures are as follows:

Dr. William E. Hart, Agricultural Engineering, will direct the research efforts of two graduate students supported by 211(d) Grant funds. One student is Stephen W. Smith, who recently received his B. S. in Agricultural Engineering from New Mexico State University. The other student is Okezie Abarikwu from Nigeria. Dr. Hart met Mr. Abarikwu on his trip to Africa. Both Mr. Smith and Mr. Abarikwu will work on water conveyance designs suitable for distribution to small (1-5 acres) plots on rolling land in Africa as well as a management scheme for the system.

Dr. Alan C. Early, a new recruitment for Agricultural Engineering, will arrive on campus in September and will develop and teach a water conveying, delivery and irrigation course for non-engineers. It is anticipated this course will be popular for sociologists, economists, lawyers, political scientists, and others who are interested in social institutions related to water delivery and conveyance systems.

The design manuals (see CUSUSWASH Water Management Technical Reports No. 9 and 19) have been well received by numerous engineers based upon return correspondence and comments from visiting engineers and foreign students. The world-wide implications of this work are many fold. First, water delivery and measurement problems are areas of specific interest to irrigation planners in the developing countries, and thus, this material has wide general interest and design procedures have been collected into a few presentable sources. Consequently, a potential exists for developing additional useful design manuals, as well as preparing short courses which would facilitate rapid dissemination of project results in other countries. Finally, the principal investigators feel that their technical competence has reached a level where their expertise should now be channeled towards problem evaluation and solution in developing countries.

In order to properly take advantage of previous work and continuing interest, the objective of the coming year is to prepare material on flow measurement, irrigation structures, and the role of water delivery in salinity control for possible short courses and miscellaneous presentations. In addition, as a part of the effort to initiate involvement in developing countries, Mr. Qurban Ali Khan, a Research Assistant, will conclude his study on small irrigation structures used in Pakistan. From this thesis, the specific structures requiring further evaluation will be identified and present designs can be upgraded. Also, anticipated field visits to Pakistan by the investigators will allow the development of realistic designs for Pakistan conditions.

The anticipated man-months and budget are:

	<u>Man-Months</u>	<u>Budget</u>
Staff and Faculty	7.5	\$11,427
Research Assistants	10	<u>7,413</u>
		\$18,840

The Department of Agronomy will continue the research project, "Salt Transport in Soil Systems", under the direction of Dr. Arnold Klute. It is emphasizing the movement and accumulation of salt in the soil as a function of the soil, the quality of water delivered, and the effectiveness of the removal systems. The staff will continue to attend and contribute to the International Interdisciplinary Seminar and Dr. John Reuss will serve on the Planning Committee for the Seminar. Other members of the Agronomy Department will continue to be active in research planning and student training in international water resource management with emphasis on water delivery and removal systems and supply consultants for developing country projects.

The anticipated man-months and budget are:

	<u>Man-Months</u>	<u>Budget</u>
Staff and Faculty	1	\$1,508
Research Assistants	9	<u>5,130</u>
		\$6,638

The Civil Engineering Department has made great progress on several publications which will be completed during the coming year. New courses have been added in water systems engineering, and linkages have been established with engineers, scientists and public officials in Nigeria, Ivory Coast, Uganda, Senegal, Liberia, Tanzania, Botswana, Afghanistan and Pakistan.

As a result of the 211(d) Grant, arrangements were made during the past year to have Dr. Warren A. Hall join the engineering faculty of CSU. He is currently Director of the Office of Water Resources Research in Washington, D. C. and will become a resident member of the CSU faculty in September, 1974. Dr. Hall pioneered the subject of, and has written a book on, Water Resources Systems Engineering -- which is directly related to water delivery and removal systems as well as the institutions involved in the development, utilization, and management of water systems.

The Civil Engineering anticipated man-months and budget are:

	<u>Man-Months</u>	<u>Budget</u>
Staff and faculty	16	\$29,863
Research Assistants	24	<u>13,900</u>
		\$43,763

Only two persons in the Department of Economics will be funded under the 211(d) Program for the coming year: Drs. Biggs and Tinnermeier.

Dr. Huntley H. Biggs will continue to serve as a member on the Planning Committee for the International Interdisciplinary Seminar. He expects to participate and attend these seminars. His major activity will be to serve as editor of a book entitled, "Institutional and Technical Aspects of Resource Management on Small Farms in Developing Countries". In this endeavor, Dr. Biggs will only be partially supported by Grant funds. The book will cover those aspects of water delivery, removal and relevant institutional development in appropriate sequence with other subject material. This book will be a collection of 10 readings, of which Dr. Biggs will contribute two and Dr. Tinnermeier one, by faculty members from agricultural engineering, anthropology, economics, geography, and sociology. The emphasis of the book is on analyzing the institutional and technical constraints that influence the development of a strategy for raising the levels of production on small farms. Dr. Biggs will also be completing work on development planning. This book presents a model, based on input-output techniques, which can be used to analyze such development problems as: forecasting, optimization, international trade and technological change.

Dr. Ronald L. Tinnermeier will continue focusing on small farmer development strategies, with special emphasis on credit and credit institutions and their relationship to the introduction of new water management and other technologies. Water availability has been identified as an important variable for successful small farmer credit programs. On the other hand, further research is needed to more clearly understand the need for credit where new delivery systems, water management techniques, and other practices are introduced. Dr. Tinnermeier will also continue to participate in the International Interdisciplinary Water Seminar this coming year. And, as mentioned above, an article will be prepared for Dr. Biggs' edited work on small farms.

The Economics anticipated man-months and budget are:

	<u>Man Months</u>	<u>Budget</u>
Faculty and staff	4	\$6,795
Research Assistants	1.5	<u>688</u>
		\$7,483

Professor Henry P. Caulfield, Department of Political Science will continue his work in the development, and conduct of the International Interdisciplinary Seminar. He is attempting to obtain full support for the Seminar from sources other than the 211(d) Grant. The Department will also attempt to supplement its support of three graduate research students whose course of studies will focus on the political science aspect of water delivery and removal systems including relevant institutional structures.

The Political Science anticipated man-months and budget are:

	<u>Man Months</u>	<u>Budget</u>
Faculty and staff	2	\$4,996
Research Assistants	3	<u>780</u>
		\$5,776

During the year, the Department of Sociology completed a general cycle of sensitization to both problems of water delivery and removal systems and to the larger questions of the relationship between water and development. Intended for next year, is a more specific writeup of activities reflecting the concern with irrigated agriculture, and especially the component reflecting water delivery and removal systems. As such, a major paper is prepared dealing with socio-economic aspects of irrigated agriculture in order to provide a background document as well as a training device for both faculty and graduate students participating in the program.

The major expenditure for next year involves essentially the time of a faculty member whose purpose will be to write the documents reflecting the general concern with the socio-economic aspects of irrigated agriculture as well as coordinate the nonfunded activities of other faculty members and supervise the work of one research assistant. The research assistant is expected to utilize the theme of relating population growth to problems of water delivery and removal systems. It is believed that this plan will help improve the competence of sociology with relationship to the requirements of the Grant and will also provide for the emergence of capabilities for applied research in this area.

The anticipated Sociology man-months and budget are:

	<u>Man-Months</u>	<u>Budget</u>
Faculty and staff	3	\$5,100
Research Assistants	4.5	<u>2,970</u>
		\$8,070

VIII. Entrainment Activities

The impact of Grant-supported activities in helping to develop and strengthen institutional capabilities, the utilization of these institutional resources in development including other resources for Grant-related activities have all made major advances during the reporting year in coordinated unison. The purpose of the Grant, under Title 211(d) was to increase the University's capability to perform assigned functions in the training of professionals at home as well as from the developing countries in the broad fields making up the developmental process. At CSU the impacts of the Grant program at no cost to the Grant have extended throughout the University, particularly with all activities in connection with international education, development and foreign assistance.

As pointed out previously in an annual report, this process of extending benefits, developing and maintaining interest on-campus in foreign affairs, and increasing the capabilities and accomplishments at the University beyond the prescribed limits of the Grant, may be summed in one word "entrainment." The entrainment effect of the Grant program at CSU cannot be over-estimated. Most of the participant professors are key men in six out of eight colleges of the University. The philosophy of these men, their attitudes and actions have extended downward and upward through many channels to other professors, to graduate and undergraduate students and to administration as well. The net results as seen today have been very beneficial. Far more so than has been indicated in any of the past Grant reports. Last year several of these faculty members brought about a reorganization of the International program at CSU resulting in establishing an Office of International Education, elevating responsibility for strengthening and continuing the International program on-campus to the level of the Academic Vice President. The President himself is Internationally minded -- last year

he spent several weeks at Yugoslavia and in Thailand on technical assistance projects involving educational programs -- and fully supports the International programs on campus.

During the past several decades, CSU has performed many foreign training and advisory services and its competence to successfully complete international technical assistance tasks has measurably improved particularly during the last 5-year period, due, in large part, to the entrainment effects of the 211(d) Grant program. Thus, the Grant program has had and continues to exert a stimulating effect on building and maintaining a strong and stable base for both on campus international affairs and overseas activities.

As a consequence of the greatly increased staff capability and the entrainment effect throughout the university, there has been an increase in support for water resources research from other sources. This is illustrated by the list of some of the new contracts and grants obtained during the period of this 211(d) Grant, see Appendix I. The total number is 64 and the total funding is \$2,192,858. Although a large part of the funding is in engineering, a really significant part of it is in the other departments and colleges which are cooperating in the 211(d) program.

IX. Report of Expenditures

1. The expenditures as shown in Table I and Table II state the expenditures for fiscal year July 1, 1972, through June 30, 1973, the period under review. The amount shown in Expenditures to Date represents the actual amounts spent in each line item since the beginning of the Grant, July 1, 1969. The projected budget for FY 1974 represents the total funds available for the last year of the 5-year Grant period in the 211(d) Grant Program and is outlined in Section VII, Next Year's Plan of Work and Expenditures.

The Report of Expenditures as shown in Table I is as follows:

Line Item I, Teaching, gives the salaries plus the CSU fringe benefits paid to faculty. In many cases a faculty is paid only one or two months salary for such purposes as initiating and teaching a new course or serving as an advisor for a graduate student. This has had the effect of stimulating other programs and research for Grant-related activities at minimal cost with an expanding or entrainment effect.

Line Item II is the amount paid to graduate students for research stipends. A student is required to work at least 20 hours per week in support of his research project, and to qualify for Grant funding. A list of research assistants supported by 211(d) funds for periods from three to six months is given on page 28.

The Line Item III on travel represents all international travel and also travel within the United States. See pages 31 and 70 for details on foreign travel. Some travel support was provided for faculty to attend 211(d) seminars and Grant-related conferences for presentation of papers and increasing their knowledge and competence in the Grant area.

Library and publications expenses, Line Item IV, cover the cost of books purchased out of 211(d) Grant funds requested by the various faculty, staff and graduate research assistants connected with the program in order to improve the CSU and CUSUSWASH library covering

the areas of the research program as outlined in the Grant objectives. These books are catalogued and placed in the CSU Morgan Library for use in all water resources programs and by other disciplines through inter-library loans. Many other libraries can and do draw upon these materials. Also, covered in these expenditures is the cost of printing and publishing the theses and dissertations by graduate students on their research activities including papers and reports by CSU faculty and mailing expenses for these publications.

Line Item V also includes the costs of consultants to support the programs of the Interdisciplinary Seminar. Many consultants served in the capacity at no expense to Grant funds.

With regard to Line Item VI, since the Grant funds have been responsible for spin-offs in other research, there was little need to purchase equipment as most of the equipment was provided by non 211(d) Grant funds.

Line Item VII, Other and Office Expenses, shows the amount spent for clerical assistance for office administration, for the CSU contributed share of the CUSUSWASH Executive Director for administration of the Grant, and for the funds allocated to the three (3) colleges and six (6) departments. Other office expenses cover such items as telephone, miscellaneous office supplies, and xeroxing.

The line items as listed in Table II conform with the budget in the Grant Document, while Table I shows a general distribution of funds in the area of activity.

Table I

Expenditure Report
(Actual and Projected)

Under Institutional Grant AID/csd-2460

Review Period 1 July 1972 to 30 June 1973

(List all Grant-related activities)	Expenditures to Date		Projected Expenditures (Final Year of Contract) FY 1974	Non 211(d) Funding Amount
	Period under Review	1 July 69-30 June 73 Cumulative Total		
I Teaching	79,217	267,261	67,024	97,000
II Research	52,426	166,280	30,881	165,000
III Travel	16,232	59,315	12,000	25,000
IV Libraries and Publications	3,604	23,670	3,397	10,000
V Consultation	350	10,018	1,000	
VI Equipment	97	3,428		50,000
VII *Other	33,465	91,474	14,252	
TOTAL	185,391	621,446	128,554	347,000
*Breakdown on Other Direct Costs:				
Clerical Expense	13,305			
Office Expense (telephone, Xeroxing, mailing, supplies, Western Union)	8,160			
CUSUSWASH Executive Director's Office (CSU contribution)	12,000			
	<u>33,465</u>			

1 September 1973

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Table II

Expenditure Report
(Actual and Projected)

Under Institutional Grant AID/csd-2460

Review Period 1 July 1972 to 30 June 1973

(List all Grant-related activities)	Expenditures to Date		Projected Expenditures (Final year of Contract) FY 1974	Projected Five-Year Total
	Period under Review	1 July 69-30 June 73 Cumulative Total		
Salaries	79,217	267,261	67,024	334,285
Stipends	52,426	166,280	30,881	197,161
Travel	16,232	59,315	12,000	71,315
Equipment	97	3,428	-0-	3,428
*Other (Office Expenses)	33,465	91,474	14,252	105,726
Library and Publications	3,604	23,670	3,397	27,067
Consultation	350	10,018	1,000	11,018
TOTAL	185,391	621,446	128,554	750,000
*Breakdown on Other Direct Costs:				
Clerical expense	13,305			
Office expense (telephone, Xeroxing, mailing, supplies, Western Union)	8,160			
CUSUSWASH Executive Director's Office (CSU contribution)	12,000			
	<u>33,465</u>			

1 September 1973

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FOREIGN TRAVEL

DESCRIPTION

DOLLAR AMOUNT PER TRIP

A brief narrative statement listing the name and title of the individual, purpose and results of the trip, duration and the total amount charged to the Grant including partial funding, is indicated below:

GRA

Christopher Dowswell - 3 months - Guatemala	ticket	none	\$470.00
To establish a research program for an M. S. degree and to gain linkages with the Ministry of Agriculture coordinating this study and activities with USAID.	actual expenses	470.00	

FACULTY

Dr. George Radosevich - 1 month	ticket	914.00	\$1,908.00
Comprehensive feasibility study in the area of irrigation development.	excess baggage actual expenses	283.00 711.00	
Dr. Maurice L. Albertson - Costa Rica	ticket	485.00	\$749.00
Rural Development - Social and Political Aspects of Agrarian Reform and their role in promoting Social and Political Development.	expenses	264.00	

FOREIGN TRAVEL

FACULTY - continued

DOLLAR AMOUNT PER TRIP

Dr. Huntley H. Biggs - 1 week - Guatemala City	ticket	334.00	\$689.00
Thesis research supervision (Christopher Dowswell) and to further strength the linkages of Mr. Dowswell with USAID and Ministry of Agriculture.	expenses	355.00	
Dr. Maurice L. Albertson - Ibadan, Rome	ticket	1,050.00	\$1,802.00
IITA, Nigeria seminar on "Prospects for Irrigation in West Africa". Consult with FAO officials in Rome.	excess		
	baggage	250.00	
	expenses	466.00	
Mr. Evan Vlachos	ticket	1,050.00	\$1,929.00 (partial)
IITA, Nigeria seminar on "Prospects for Irrigation in West Africa". Includes approved linkage stopovers.	excess		
	baggage	250.00	
	expenses	629.00	
Dr. William B. Hart	ticket	1,050.00	\$1,271.00 (partial)
IITA Nigeria seminar on "Prospects for Irrigation in West Africa". Includes approved linkage stopovers.	excess		
	baggage	250.00	
	expenses	1,021.00	
Dr. W. Doral Kemper	-----		\$157.00 (partial)
IITA Nigeria seminar on "Prospects for Irrigation in West Africa".	-----		
	expenses	157.00	
Dr. Maurice L. Albertson - Kabul, Afghanistan	ticket	313.00	\$391.00
Strengthen linkage between CSU/USAID Mission. Follow up with research on the Helmand Valley Project.	expenses	78.00	

PART IV

UTAH STATE UNIVERSITY

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2459

TABLE OF CONTENTS

	Page
STATISTICAL SUMMARY	D-5
NARRATIVE	D-5
DETAILED REPORT	D-6
General Background and Purpose of the Grant	D-6
Objectives of the Grant.	D-7
Objectives Restated	D-7
Review of Objectives	D-8
Accomplishments	D-8
Library Improvement	D-9
Language Training	D-10
Teaching	D-10
Research	D-13
Consulting Services	D-14
Impact of Activities on Institutional Capabilities	D-16
Utilization of Institutional Resources in Development	D-17
Programs	D-17
Consulting	D-18
Foreign	D-18
Irrigation Problems and Practices Short Course	D-19
Summary of Next Year's Plan of Work and Expenditures	D-19
Other Resources for Grant-Related Activities	D-21
Report of Expenditures	D-22
Salaries	D-22
Graduate Trainee Expenses	D-22
Library	D-22
Travel	D-22

LIST OF TABLES

Table		Page
1	Distribution of 211(d) grant funds and contribution from other sources of funding review period July 1, 1972 to June 30, 1973	D-25
2	Actual and anticipated expenditures under Institutional Grant #AID/csd-2459, review period July 1, 1972 to June 30, 1973	D-26
3	Salary support and effort	D-27
4	Graduate trainee expense (Fiscal year 1972-73)	D-28
5	All graduate trained supported by the 211(d) grant	D-29
6	Expenditures for library and publications July 1, 1972 to June 30, 1973	D-31
7	Summary of expenditures by Utah State University in support of on-farm water project	D-32

LIST OF APPENDICES

Appendix		Page
A	Library Report	D-34
B	Publication on "Irrigation System Evaluation and Improvement"	D-37
C	Thesis, Publications, Manuscripts	D-38
D	Abstracts and Summaries	D-41
E	Paper on "Preliminary Examination of the Do-Anambra River Area, East Central, Nigeria"	D-60

DETAILED REPORT

General Background and Purpose of the Grant

The Institutional Grant Program has for its purpose the development of the competence and expertise of U.S. research and educational institutions to deal with critical problems of less developed countries. The Grant Project is expected to have built-in research, training and advisory components. The creation of special capability in a particular area of knowledge must include the relevant technology and the capacity to pass it on to others. The capacity developed by the institution in its field or fields should enable it to do the following:

- a. develop capability in research
- b. develop capability in training; and
- c. put itself in position to provide consulting services

Although it is understood that AID's intention is to require the Grantee to provide ad hoc informal consultant services directly under an institutional development grant, AID would expect, as the need arose, to contract with the University to obtain training and consulting services from the center of competence at the Grantee institution once that center has become sufficiently established to provide such services without disruption to the work of the center. AID expects the Grantee to service, subject to agreement on compensation or other terms and conditions, AID requests for expert personnel to undertake short or long-term consultancies or contract work in the LDCs and to provide research services as requested.

At the time the grant was awarded the Department of Agricultural Engineering and related departments such as Soils and Civil Engineering had many graduate students from foreign countries. The staff and course offerings were not adequate to teach and direct the research of these students.

Utah State University had considerable competence in the areas of irrigation and water management at the time the grant was approved. It was expected that the expanded full-time professional staff, courses of study, library information, and research would enable the University to respond much more adequately than heretofore to requests concerning agricultural related water management problems from such entities as: USAID/Washington, USAID Missions, other state and federal agencies, other

universities, educational groups, foreign governmental agencies, foreign water management institutions, local irrigation and drainage institutions, and farm groups. It was logical to conclude that a Grant would be a natural complement to the research contract AID/csd 2167.

Objectives of the Grant

Objectives Restated

The major objective of the Grant program is to increase and expand the existing competence of Utah State University in the science and technology concerned with "on-farm management" with emphasis on the moisture environment on the farm as related to the special characteristics and problems of the less developed countries. Increased competence will be developed in the teaching and research activities as follows:

1. Expand its full-time professional core staff which will focus its teaching and research activities on the technical disciplines which relate to maintenance of a proper moisture environment on the farm under less developed country conditions. These include irrigation and surface and subsurface drainage. Irrigation and drainage are complex arts requiring the application of the best knowledge of water, soil, climate, and crop sciences and engineering. Existing courses in this area will be re-evaluated and reconstructed as appropriate new graduate courses, special short courses, and seminars will be developed as required.
2. Expand its research in less developed countries to increase the knowledge and understanding of subjects such as water requirements of crops, moisture-fertilizer-crop response, management of irrigated soils, drainage requirements, salinity water quality, movements of water in soils, methods of water application, management of irrigation water, and water-crop-soil system analysis.
3. Expand its total library holdings in irrigation and drainage and related disciplines, especially foreign and international publications, so as to become a center of information on world irrigation and drainage practices.

This increased interrelated teaching and research competence will include, but not be limited to, the following subjects as they relate to problems of the less developed countries:

1. Irrigation Practices. The theory and practice of maintaining the optimum moisture environment for plant growth by irrigation and drainage within the complex physical and institutional systems involved.

2. Drainage Theory and Practices. The investigation, design, and operation of drainage systems to assure the optimum soil-moisture environment and avoid or reduce flooding.
3. Water Resources Systems Simulation Engineering. Simulation of multi-purpose projects to provide adequate service for irrigation, drainage, flood prevention, and other purposes as related to on-farm water management.
4. Irrigation Science Research. The basics of consumptive use, infiltration, water physics, water quality, water-salt-soil interactions, within the framework of "on-farm water management" for maximum efficiency and economic returns.
5. Irrigation Economics. The economics of changing water management practices, costs, and economic efficiency of water utilization including the incremental value of water application and water application systems.

Review of Objectives

The objectives and areas of activities, as originally identified, were broad in scope and general in nature. There appears no particular justification for making major revisions. In the plan for implementation of the program it was anticipated that emphasis on activities would shift. Early emphasis was on identification of staff needs, selection of professions and language training. This was followed by a review of course content, revision and introduction of new courses. Emphasis was also placed on library improvement and expansion. As the goals in these areas have been reached, emphasis has shifted to teaching, conducting research, responding to requests for technical assistance and increasing accessibility of the library holdings. The results from the increase in language competence is becoming evident in the research and consulting accomplishments. There is a constant demand for the services of the staff having the language competence to teach short courses in LDC's.

Accomplishments

In assessing the accomplishments it is difficult to provide specific criteria to be used other than to look at the changes made for the present activities. There must be a general integration of all the components after looking at the specific components and then determining to what extent the increased competence is effectively being used, or in case of research providing new knowledge primarily to be used in solving problems for L.D.C.'s.

We have found the benefits are reflected in the use of our staff having special language competence to teach short courses and participate in seminars, etc. Other benefits are reflected in the new course offerings, a greatly improved library service and somewhat less tangible in the improved professional attitude of the graduate students as well as the staff.

We feel there is adequate evidence that the net effect of the improvements made possible through the Grant Program is that the University is now a much better school for foreign and national students to come to receive special training in the field of irrigation and water management.

Library Improvement

Details of the activities and accomplishments for the current year are given in Appendix A. A review of the program throughout the life of the grant is summarized below.

For the past four years the Agricultural and Irrigation Engineering Department, in cooperation with Merrill Library, has conducted a unique program to expand the existing competence of Utah State University in the field of On-Farm Water Management and related fields. To date the On-Farm Water project has purchased some 1,841 books and developed a vertical file system comprising some 391 titles. All of these titles are in addition to the already existing holdings of the Merrill Library. The project has searched the holdings of other centers of information located on campus. This search for pertinent titles has yielded: 2,000 titles from the Utah Water Resources Research Laboratory; 450 titles from the Agricultural and Irrigation Engineering Department Microfilm Water Law Library; 1,700 titles taken from the Special Collections Sections of Merrill Library; 200 titles on Business Law from the College of Business, and 1,000 titles from the Government Document Section, Merrill Library. All of these titles have been combined in a computerized bibliographic printout, totaling some 13,000 titles. These titles represent the best works, old and new, on the field of On-Farm Water and related areas. This collection covers the United States, and some 60 foreign countries.

As a result of this program many of the Library's documents and archive holdings, which had never been properly indexed or cataloged, have now been correctly cataloged and the holdings are now being used.

The 13,000 titles have been keypunched (91,000 cards) for entry into a computerized bibliography. This bibliographic printout is in the process of being readied for publication in book form. At present, a copy of the

bibliography is housed in the Merrill Library. Use of the bibliography and book materials is open to all students staff and the general public. Students and staff from other schools may obtain materials through inter-library loans or visiting scholar permit procedures.

Language Training

During the last year no new intensive training courses were conducted. A few of the students needing training have used the regular offerings. The staff has gained adequate competence.

Throughout the life of the Grant training program a total of 73 staff, wives and graduate students received training in Spanish. Most completed the advanced course. In the area of water management, 19 of the staff are capable of lecturing in the Spanish language. Three of the staff have competence in Portuguese. This competence is especially valuable to the program and the staff assigned to Latin American countries for research consulting or when teaching short courses or participating in seminars.

All of the U.S. graduate students receiving assistance from the program have obtained language training and of the 14 that completed the program, 7 have accepted work in foreign countries or are employed by companies doing consulting business in foreign countries. One is being cleared to conduct short term investigation for us in El Salvador.

The staff in agriculture and engineering are cooperating in offering a Masters degree program to be taught in LDC's. Most all of the courses will be taught in Spanish.

Teaching

Staff. No new staff members were added during the current year. Those previously engaged were very active in teaching, writing, research and consulting. During the period 211(d) has supported in part acquisition of the following new staff members:

Dr. Jose Alfaro, a promising young irrigation engineer whose native language is Spanish. His services are very much in demand throughout Latin America. (See section on "Consulting")

Dr. E. Joe Middlebrooks, Division Head of the Environmental Engineering Department and distinguished environmental engineer, has given special attention to on-farm water quality problems.

Dr. Chris Lewis, a promising young agricultural economist specializing in agricultural water management.

Mr. Kenneth Bach, an irrigation engineer and teacher with broad international experience. Last month Mr. Bach accepted a two-year assignment for WARDA in Monrovia.

Mr. William L. Palmer, an economist with many years of experience in agricultural water management including serving as Assistant Commissioner, U.S. Bureau of Reclamation, with AID and as head of the agricultural division of a large international consulting firm. Retired June 31, 1973.

Dr. David James, a very competent young specialist in irrigated soils. He is conducting research in El Salvador and Logan. He and a 211(d) student, William Rubink are working on the soil problem in Colombia. Dr. Robert Hill, a promising young civil engineer with considerable farm irrigation design experience. He is teaching irrigation principles and conducting research in systems. At present he is working with the Keller-Peterson model which will be in identifying research needs, in organizing the crop production research program in Water Management.

Dr. Jack Keller, specialist in sprinkler and trickle irrigation, has been associated with the University on a part-time basis for a number of years. Dr. Keller has extensive experience as a consultant in the United States and abroad. The 211(d) grant has permitted us to retain a larger share of Dr. Keller's time, not because of increased funding capability but because of the new opportunity for increased quality that commanded his interest and particularly because of the increased opportunities in the international development arena.

Dr. Larry King was hired concurrently from the Battelle Institute, a general contractor for Atomic Energy Commission at Richland, Washington. Dr. King, though still in his early thirties, had already gained a national reputation both as a theoretician and a practical engineer specializing in the flow of water and solutes through soils. Even though Dr. King was not supported by 211(d) funds, it is very doubtful that the University could have commanded his services without the new strengths and promise implied by the 211(d) recognition.

Dr. James Thomas, a plant scientist, has been given some support to identify dryland grasses that will survive and produce under minimal moisture conditions. Dr. Thomas is fluent in Spanish and has been in Bolivia for four years.

New Courses. In addition to participating in the instructional program, the staff has been involved in the revision of many of the courses and the addition of new courses.

The following are examples of new courses that have been developed within the last year with the assistance of the 211(d) grant:

Agricultural Planning and Administration in Developing Countries.

Fertilizer Technology for Irrigated Crops.

Soil and Water Conservation and Waste Treatment.

Water Development in Latin America (taught in Spanish).

Drainage Principles.

Drainage Investigations and Design.

The staff in agriculture and engineering are cooperating in offering a Masters degree program to be taught in LDC's. Most all of the courses will be taught in Spanish.

Texts and Manuals. Under partial 211(d) sponsorship, John Merriam (of California Polytechnic Institute), Jack Keller and Jose Alfaro have completed the text for a monograph on "Irrigation System Evaluation and Improvements." This will be test-taught during the coming year prior to final revision and publication. Both English and Spanish language editions will be published. A copy is included as Appendix B. Nine chapters of a book have been completed by Jack Keller and A.A. Bishop on surface and sprinkler irrigation. This material is now being classroom-tested. A publishing company is interested in printing this text but no commitments have been made. Dr. Raymond W. Miller, of the Soils and Meteorology Department, has joined Dr. H.B. Peterson and Dr. Komain Unhanand of the Agricultural and Irrigation Engineering Department in writing a monograph on the state-of-the-science pertaining to management of heavy soils. This is now in draft form and is being reviewed. Draft material has been reviewed by Colorado State University, in hopes it may be of use on the Mekong River project. Chris Lewis, Jay C. Andersen, Herbert H. Fullerton, and B.D. Gardner have completed the manuscript for a book, "The Role of Water in Regional Development," under partial support of the 211(d) grant. The manuscript is currently undergoing final editing. The book will total about 250 pages and will be published by the final draft, now under review, of an elementary manual on "Irrigation Fundamentals" to be used primarily for hosrt-course instruction in developing countries.

Research

While our research program relating to development is separately funded by grant AID/csd-2167, the 211(d) program has complemented that program. It has helped prepare researchers by providing additional preparatory training. Much of the research conducted through graduate students supported by the Grant is done on problems of LDC's and directed by or in cooperation with the staff of the research grant. It has been our objective to have the graduate students do their thesis research in at least partial residence, on a research project in a developing country. However, because of logistic problems this has been limited, but all have worked on development problems usually using real field information from on-site research efforts. Typical of research topics studied are:

Analysis of Colombian Precipitation to Estimate Irrigation Requirements.

Effect of Irrigation Frequency on the Average Evapotranspiration for Various Crop-Climate-Soil Systems.

(An) Economic Appraisal of On-Farm Water Management Practice in Developing Countries. A Study of Summer Paddy Rice Production in Guayas River Basin, Ecuador.

Irrigation Design and Management Related to Economics.

Impact on Rural Incomes of Improved Water Management Practices in Milagro County, Ecuador.

Irrigation Water Management in Ecuador.

Evaluation of Wind Effects as Sprinkler Stability and Spacing Criteria (conducted in El Salvador).

A few summary statements illustrate the nature of the Grant research and the findings.

A number of economically advantageous alternatives have been studied in Ecuador and El Salvador. For example, it has been shown that by supplying portable pumps and creating appropriate easements for small channels to reach surface water supplies, the incomes of hundreds of small rice farmers in Ecuador will be greatly enhanced. It was shown that the dairy farmers of Sonsonate area of El Salvador can get adequate supplemental irrigation from underground supplies at much lower costs than they would secure with a proposed surface project.

As an example of short-term field study in response to a critical problem, Dr. D. James and a graduate student, William Rubink, recently

returned from an assignment involving a soils problem in Colombia and have, for the first time, associated this with heavy metal toxicities. Within the past year we have provided experts for AID study teams in Nigeria and Pakistan and for the current Sahelian (Africa) drought study.

Jack Keller, Dean Peterson and Howard Peterson have proposed a systematic approach to optimizing soil and water research programs insuring maximum transferability of information. Combining this with a system of nutritional indexing and analysis for both food products and populations proposed by Garth Hansen of Biochemistry, leads to a suggested methodology for combined regional development of nutritional delivery systems and agricultural potential. This type of development could be more effective than more conventional ones in reaching poorer people especially those outside of the market economy.

It is not possible to summarize in this section the findings of all the research conducted under Grant support. The results are contained in Appendix C, Publications, Thesis and Manuscripts and in Appendix D, Abstracts and Summaries.

Consulting Services.

As a result of the additional qualified manpower provided through 211(d) assistance, the University has been able to make available the services of many highly qualified people for short term assignments; and, in one case, to grant a two-year leave of absence to help strengthen AID's technical staff in Washington. Without 211(d) the University would not have been able to make the temporary services of Dr. Jack Keller, Dr. H.B. Peterson, Dr. J. Paul Riley, Dr. Bruce Anderson, Professor Kenneth Bach, Dr. D. Wynne Thorne, Dr. Dean F. Peterson, Dr. Rex Nielsen, Dr. Glen Stringham, Dr. Jay M. Bagley, Dr. Jose Alfaro and other specialists available for consulting assistance to AID and other international development donors virtually on demand, nor could Dr. A. Alvin Bishop have been spared to serve as an on-farm water management specialist for TAB/AGR. Some specific examples of consulting activities include:

At the time of this writing, the University of Arizona, Colorado State and Utah State have provided a consulting team for CUSUSWASH to spend a month in Manila.

Dr. E. J. Middlebrooks was recently one of the United States representatives at a seminar on "Water Pollution Control in Buenos Aires, Argentina. The seminar was sponsored by OAS and the Republic of

Argentina. Seminar participants were composed of two representatives from each of the American States, a contingency of six engineers from Israel and many of the international organizations and assistance programs, i.e., AID, FAO of UNESCO, Pan. Am. Health Organization, Peace Corps.

Professor J.E. Christiansen and Rex F. Nielsen accepted an invitation to assist AID in Costa Rica. They prepared "A Plan for a Surface Irrigation System for the Taboga Experimental Station."

A three man team from CUSUSWASH went to Nigeria for TAB/AGR in August 1972. Chief of Party was H.B. Peterson from USU. They studied the Do-Anambra River Area for possible irrigation development. The Report "Preliminary Examination of the Do-Anambra Rivera Area, East, Central State, Nigeria" was prepared and is Appendix E. The trip was supported with Grant funds.

Dr. Jose Alfaro, brought to campus mainly by grant funds, has been a frequent participant in a variety of teaching and consulting activities. Recently he has been involved in the following:

1. Where: Santo Domingo, Dominican Republic

Date: January 22-26, 1973

Purpose: To participate in the Symposium on Savanna Soils of the tropics.

Activities: In charge of Water Management section of the Symposium. Presented two papers, one on water requirements for the southeastern region of the Dominican Republic, and the other on the role of water management on agricultural production.

For Whom: This cooperation was requested by Prairie View A&M College, Prairie View, Texas.

2. Where: Port au Prince, Haiti

Date: July 13-20, 1973

Purpose: To teach irrigation short course

Activities: Teaching to graduates from agricultural and civil engineering universities. The subject was irrigation and drainage systems design and management.

For Whom: CIDIAT

3. Where: Merida, Venezuela

Date: July 23 - August 3, 1973

Purpose: To teach sprinkler irrigation

Activities: Teaching sprinkler irrigation to graduate students working for a M.S. degree at the "Universidad de los Andes" in Merida, Venezuela.

For Whom: CIDIAT

Impact of Activities on Institutional Capabilities

The original objectives, simply stated, were to improve the University's competence for teaching, research, and to provide greater resources from which to draw for consulting and technical assistance particularly in LDC's. An interdisciplinary committee was established and it assessed the strength and weaknesses in the associated departments and recommended the most worthwhile improvements to be made. With the needs identified, the program has been directed toward meeting these needs. As a result, we now have an excellent library for students and faculty and also have a staff with experience and technical competence as well as a capability in the use of the Spanish Language.

Consideration was given to the permanence of the improvements. It was recognized that additional competence could be added in the form of new staff and that some staff members could leave resulting in little by way of improvement. If the members developed new courses and prepared needed text books and manuals there would be a permanent improvement evident even when the individuals were no longer on the staff. With this in mind, an emphasis was placed on the preparation of an irrigation text (which is about one-half completed) and a manual on "Irrigation System Evaluation and Improvement" has been completed. These writings have universal use. (A Spanish version of the manual will be prepared for special use in Latin America).

The University has developed a policy of integrating the Grant activities with those of the research contract AID/csd 2167. These two programs now compliment one another. In order to best identify research needs and to select areas of the greatest probable return, considerable effort has gone into the development of a conceptual model which is having an impact on the research done through the contract but influencing other research as well.

Considerable benefit to the irrigation and water management program has resulted from the Grant through its influence on the University. The organization and operation of the library has been improved as a result of the Grant program of library improvement. This change is evident throughout the entire operation and is not at all limited to the "water management" component.

All of the staff that were recruited and supported through the Grant now have support from other funds which is encouraging and indicative of the quality of staff recruited and likelihood by some stable support.

The increase in competence generated by the Grant has resulted from being able to retain some outstanding staff members that would likely otherwise be attracted away.

Much of the research data information, although collected in an LDC is not site specific. For example, work done on the effect of wind on sprinkler design certainly has universal application.

Publications resulting from Grant activities are now being published as a series in conjunction with the Utah Water Research Laboratory. This system greatly enhances the utilization of the material by gaining national and international exposure through the Water Laboratory's mailing lists and library as well as the University's regular channels. Examples of the publications in this series include the Spanish edition of "Medias de Aguas en Canales por Media del Aforador Sin Cuello" por J. F. Alfaro and "Irrigation System Evaluation and Improvement" by John L. Merriam and Jack Keller (Spanish edition by Jose Alfaro). Abstracts of these publications can be found in Appendix D.

Utilization of Institutional Resources in Development

Programs

Inter-American Center for the Integral Development of Land and Water Resources (CIDIAT). The Organization of American States (OAS) with financial support from Venezuela, Colombia and Brazil set up a training program in land and water resources in 1965 which until January 1, 1973 has been administered by Utah State University. During the past two years, in accordance with OAS policy, the program administrator has been progressively turned over to Latin American nationals. USU continues to provide technical staff on request to assist in teaching, course design and presentation. The irrigation short course by Dr. Alfaro was a portion of this program. The preparation of the teaching manual for short courses by Dr. Stringham was also a cooperative effort with CIDIAT training activities.

On-Farm Water Management Research. AID contract csd 2167 with USU provides funds for on-farm water management research in developing countries with Latin America as the designated study area. Since the program was initiated

in June of 1967, staff have carried out collaborative, adaptive research in Brazil, Chile, Colombia, Ecuador and El Salvador with program components including crop water requirements, drainage, water-fertilizer-crop variety inter-action experiments to determine yield response surfaces, water laws, management practices including economic and physical evaluation of management alternatives. Field work in these five countries have been carried out with staff on long term assignments working directly with Host Agency counterparts. Short term projects have taken research staff into ten other Latin American Countries. Much of the research conducted with 211(d) resources has been cooperatively conducted with this contract. Too, the efforts for utilization of information has been jointly developed.

Consulting

As mentioned in previous reports, staff of USU have frequent opportunities to serve as consultants in developing countries in activities not supported by 211(d) or AID research funds.

In Bolivia, USU staff have with USAID mission financing been assisting in an agricultural Sector Analysis, part of which covers irrigated agriculture. Inputs have come from the USU five man team on a long term assignment in Bolivia plus several rural economists sent on short term assignments (Professors Wennergren, Le Baron and Whitaker).

Dr. Bruce Anderson, Director of International Programs was a consultant during the reporting period to the Governments of Brazil on the setting up of an on-farm water management training program at Campina Grande and a proposed Dry Land Farming Program for North East Brazil.

Dr. B. Delworth Gardner, Head of the Department of Economics made a report to the Government of Iran on the pricing of water.

Professor Jay Anderson a Rural Economist was one of a team of consultants sent to Korea by the World Bank to investigate and report on opportunities for World Bank investments in the Agricultural Sector in that country. He reported on the agricultural water resource component.

Foreign

Foreign Students Attracted to USU. During the 1972-73 school year there were 275 full time foreign graduate students from 48 countries on campus of which about 10% were majoring in courses directly related to on-farm water management. At present there are 24 foreign graduate students majoring in irrigation.

Irrigation Problems and Practices Short Course

AID annually sponsors a short course on irrigation problems and practices for professionals from developing countries which USU conducts in collaboration with a number of agencies. The 1972 course, held from June 5 to August 19 was directed by Professor Kenneth Bach and included thirteen students from Brazil and two from El Salvador. The first two weeks of these courses are spent in classroom exercises with the remainder programmed as field inspections of irrigation and drainage works in several of the western states.

The 1973 program which began on June 4 included sixteen students from eleven countries and was under the direction for the first month of Professor Richard Griffin. Subsequently the group was transferred to staff at Colorado State University for further training and field inspections.

Summary of Next Year's Plan of Work and Expenditures

The anticipated expenditures are presented by line items and activities in Tables 1 and 2. There are no plans for major revisions of the program. Changes will be made in the emphasis on the various activities. Teaching of the new and revised courses will be continued with the exception of the intensive language training which has been discontinued. Most of the graduate students and staff now in the program have the needed competence or will obtain the training through the regular courses. This change will result in some reduction of teaching costs.

A greater emphasis will be placed on the research activities. It is planned that the two graduate students in Bolivia, Steve Hammond and Bruce Brown will complete their studies dealing with the basic linear program model of the whole agricultural sector of Bolivia. Mr. Hammond is using the model to determine more efficient ways to produce crops and Mr. Brown is also using the model to predict if certain targets can be achieved. A third graduate student, Gary Glenn will complete his study in the Guayas River Basin, Ecuador on estimates of production functions of rice producers and determining what inputs such as water, crops, etc., will affect values of production and capture the production benefits. During the period of October-January, Grant Hanson will make a study of the costs of alternative irrigation methods in El Salvador.

Considerable effort by Dr. Hill will be directed toward the development of criteria for data collection necessary in order to further develop the model "Strategy for Optimizing Research on Agricultural Systems Involving Water Management." Computer costs for this program are anticipated to increase as the program develops from a conceptual to a mathematical model.

The slide series on sprinkler irrigation has been widely used. It is our plans to develop a similar series on drainage.

Rubink will make greenhouse and laboratory studies on the problem soils from the irrigation plots at Atlantico-3 Colombia. The research team found the soils of the Atlantico 3 area to be highly variable making it impossible to conduct field research on water-fertilizer-crop interactions. Rubink, under the direction of Dr. James, will attempt to further identify the cause of variability and possible treatments for improvement. It now appears that there is some metal toxicity. Dr. James will continue a study on plot size requirements interactions to be used for determining crop production functions. He will also assist in the completion of a manuscript for publication of the results from irrigation studies in Chile. The manuscript is now being revised. The bulletin will be a cooperative effort by Kidman, Stutler, and James entitled "Increasing the Efficiency of Soil Moisture Use for Increased Crop Production."

Dr. Chris Lewis will complete the revision of his manuscript and the book entitled "Regional Growth and Water Resource Investment," is soon to be published by Lexington Books Division of D.C. Heath & Co.

Dr.'s Keller, Alfaro, and Professor Merriam have completed the manuscript on "Irrigation System Evaluation and Improvement" and have it published in draft form. This will be tested in classes and revised for final publication. Dr. Keller will also complete additional chapters of the textbook on irrigation he is preparing for publication.

The manuscript on "Water Management of Heavy Soils" by Raymond Miller, Komain Unhanand and H.B. Peterson will be revised. This is a "state of the art" report on current knowledge on watering and drainage of heavy soils as well as land forming to reduce the water management problems.

The costs for library improvement are expected to decrease as soon as the bibliography is published. This will be a major cost item during the coming year. The effort in obtaining new publications should be limited

to that for the new materials being printed. If a joint bibliography is published by cooperating institutions of CUSUSWASH the costs for publication will be greater than estimated unless other sources of funding are found.

The costs listed in Table 1 as "other" are estimated to increase because it contains such items as travel, and computer time for the research activities which are expected to be considerably greater than during most past years.

Other Resources for Grant-Related Activities

The program activities are carried out in cooperation with the Departments of Agricultural and Irrigation Engineering, Civil and Environmental Engineering and Soils and Biometeorology and Biochemistry. Other administrative units such as the Utah Water Research Laboratory, the Agricultural Experiment Station, and the Merrill Library are intimately involved. The AID research contract AID/csd 2167 is also a valuable component to the 211(d) grant. Each unit has a large program and it would be difficult to record the total magnitude of each. There are, however, some specific examples that are cited. The library reports a contribution of \$13,917.00 for the current year. A grant from the Utah Power and Light Company was provided and has been used to carry on the work of a 211(d) student trainee. Superior Farms Company of California has provided land and equipment for research for two of the trainees working on trickle irrigation research. All of the research conducted in Latin America by the trainees was done in cooperation with AID and the host countries. The Agricultural Experiment Station projects cooperated directly on a project that supplied an identifiable amount of \$10,000 for Dr. Alfaro's research. Professor John Merriam, Department of Agricultural Engineering, University of California, has continued to contribute his services in preparation of the publication "Irrigation System Evaluation and Improvement."

The program made it possible to employ the new faculty members but cooperating units have provided funds for portions of the salaries so that at present the percentage of salary from the Grant varies from about 10 to 50 percent. During the life of the project a major contribution by the University has been the laboratory facilities and administrative supervisors. Dr. D.F. Peterson, Vice President for Research, has not only given administrative assistance but has been active in developing the ideas for the model being used.

Report of Expenditures

Expenditures for the Grants fourth year and accumulated expenditures are presented in Tables 1 and 2. Further detailed listing of expenditures for staff, students, and the library are given in Tables 3, 4, 5, 6, and 7. Travel expenses are presented separately.

Salaries

Staff salaries and effort are reported in Table 3. Salaries have been distributed according to activities whenever possible.

Graduate Trainee Expenses

Expenses for trainee tuition and stipends are presented in Table 4. Expenses for trainee travel are listed under the travel section.

Library

Grant expenditures for the library are presented in Table 6 and the Universities contribution to the library is shown in Table 7.

Travel

Domestic. During the report year \$4,235.33 was expended for travel within the United States. This travel included attendance at the following meetings: ASCE Specialty Conference on Water Management where the previously mentioned model was presented, ASAE Winter Meetings and ASAE Summer Meetings by Jack Keller; the North American Society of Agronomy Meetings by Jose Alfaro where he presented a paper on research needs in LDC's.

Three meetings were held in connection with CUSUSWASH reviews, and program evaluations. Participants from Utah State included: Paul Riley, D.F. Peterson, Richard Jenson, Diane Polchow, Bruce Anderson, Wade Andrews, and H.B. Peterson.

H.B. Peterson also traveled to Washington D.C. to arrange cooperative research under the Grant.

Bob Hill, Tom Young, Grant Hanson and Jose Alfaro traveled to California to conduct research on trickle irrigation as part of the Grant program.

International. International travel under the 211(d) grant amounted to \$8,763.53 during the year. A summary of the individual travel is as follows:

- a. Craig Anderson
 Quito, Ecuador
 May 18 - Sept. 16
 Obligated - \$2,925.00 (Fiscal year 1971-72)
 Paid - \$2,346.10 (Fiscal year 1972-73)

Mr. Anderson, a 211(d) student, collected data in Quito, Ecuador, which was incorporated into his M.S. thesis entitled, "Irrigation Water Management in Ecuador." Mr. Anderson completed his M.S. degree in July, 1973.

- b. David R. Daines
 Rome, Spain
 September 23 - October 5
 Obligated \$1,888.73 - Paid \$1,146.05

He worked with Dr. Radosovich in developing plans for expanded study of Spanish water laws and possible revision on Latin American water law.

- c. H.B. Peterson
 Nigeria
 August 7 - August 25
 Obligated \$1,437.20 Paid - \$1,538.68

Dr. Peterson traveled to Nigeria to prepare guidelines for a pre-feasibility study of a proposed irrigation project along with two other consultants from CUSUSWASH Universities.

- d. William Rubink
 Barranquilla, Colombia
 August 28 - November 25
 Obligated - \$2,061.00 Paid - \$2,067.00

Mr. Rubink traveled to Colombia under the 211(d) graduate trainee program to conduct research on the special problem soils that are non-productive. Mr. Rubink is scheduled to finish his program January, 1973.

e. Bruce Brown

La Paz, Bolivia

July 3 - Present

Obligated - \$2,896.00 Paid to date - \$826.00

Steve Hammond

La Paz, Bolivia

July 3 - Present

Obligated - \$2,896.00 Paid to date - \$826.00

In order to conduct research on economics of water management, Mr. Brown and Mr. Hammond traveled to Bolivia. This research will be incorporated into their M.S. thesis. At the time of this writing Mr. Hammond and Mr. Brown are still in Bolivia. The balance of expense payments will be made upon their return.

Table 1. Distribution of 211(d) grant funds and contributions from other sources of funding*
 review period July 1, 1972 to June 30, 1973

List all grant related activities	211(d) Expenditures				Non 211(d) Funding Amount, 1972-73
	Period Under Review	Cumulative Total	Projected Next Year	Projected to End of Grant	
Research	53,702	183,102	73,500	30,000	**
Teaching	32,235	137,485	42,450	20,500	**
Libraries	16,228	38,078	18,200	2,000	13,917.28
Consultation	5,800	16,658	20,600	9,500	--
Publication	2,685	15,985	25,450	5,100	--
Other	29,537	78,919	3,550	2,023	**
CUSUSWASH	12,000	22,000	12,000	--	1,000
TOTALS	152,187	492,227	188,650	69,123	
GRAND TOTAL	750,000				

* These figures are your best estimates.

** Considerable but difficult to estimate.

Table 2. Actual and anticipated expenditures under Institutional Grant # AID/csd 2459
 review period July 1, 1972 to June 30, 1973

Line Items	Expenditures to Date		Projected Expenditures			TOTALS
	Period Under Review	Cumulative Total	Year			
			5	6	7	
Salaries	\$ 72,701.93	\$285,911.55	\$ 97,550.00	\$24,000.00	\$18,500.00	\$425,961.55
Travel						
Foreign	8,763.53	22,297.85	14,000.00	5,000.00	3,000.00	44,297.85
Domestic	4,235.33	13,651.28	4,600.00	1,000.00	622.55	19,873.83
Equipment	NONE	7,492.67	500.00	NONE	NONE	7,992.67
Stipends, Tuition and Fees	32,491.64	98,171.60	36,550.00	5,000.00	3,000.00	142,721.60
Supplies and Computer Use	17,396.98	28,375.50	18,450.00	3,000.00	1,000.00	50,825.50
Library and Publications	4,598.00	14,327.00	5,000.00	3,000.00	2,000.00	24,327.00
CUSUSWASH	12,000.00	22,000.00	12,000.00	NONE	NONE	34,000.00
TOTALS	\$152,187.41	\$492,227.45	\$188,650.00	\$41,000.00	\$28,122.55	\$750,000.00

Table 3. Salary support and effort

Name	Amount Paid	Man Months
<u>Contract Salaries</u>		
Peterson, Howard B.	\$ 5,341.17	2.40
Middlebrooks, E. J.	3,529.92	1.79
Keller, Jack	7,334.60	4.87
Palmer, Byron C.	2,152.00	1.30
Alfaro, Jose F.	6,843.74	5.05
Bach, W. Kenneth	8,724.77	5.61
McCarty, Dorothy D.	999.84	1.86
Saurey, Maureen E.	849.79	3.86
James, David W.	2,598.38	1.69
Jurinak, Jerome J.	2,142.00	1.15
LeBaron, Allen	1,064.48	.68
Thomas, James H.	4,390.02	3.25
Wennergren, Boyd E.	669.50	.40
Polchow, Diane	3,009.60	9.00
Lewis, W. Chris	8,065.00	5.42
<u>Salary Payroll</u>		
Hill, Robert W.	1,967.92	1.60
Cowan, Peter A.	1,339.27	1.44
Merriam, John L.	1,875.00	1.00
Total Salaries	\$62,897.00	
Wages	3,284.43	
Staff Benefits	6,520.50	
Total Salaries, Wages	\$72,701.93	

Table 4. Graduate trainee expense (Fiscal Year 1972-73)

Name	Stipend	Authorized Tuition	Total
Herbert Paul	600.00	---	600.00
Lee Bailey	1800.00	292.00	2092.00
Richard Chase	300.00	34.00	334.00
Craig Anderson	2564.50	438.00	3002.50
William Rubink	3600.00	478.00	4078.00
Phil Tscheschke	2400.00	292.00	2692.00
Morgan Ely	2207.14	292.00	2499.14
Grant Hanson	3300.00	438.00	3738.00
Richard W. Conn	3600.00	438.00	4038.00
David D. Maxwell	2850.00	438.00	3288.00
Thomas Young	900.00	---	900.00
Steve Hammond	1800.00	292.00	2092.00
Gary Glenn	1800.00	292.00	2092.00
Bruce Brown	900.00	146.00	1046.00
TOTAL	\$28,621.64	\$3,870.00	\$32,491.64

Table 5. All graduate trainees supported by the 211(d) grant

Name	Began Program	Ended Program	Dept. & Degree	Present Status
James E. Hardee	Oct., 1969	April, 1971	AIE-M.S.	Harza Engineering, Stationed in Iran
Thomas L. White	Jan., 1970	July, 1971	Ag. Econ.-M.S.	Army Corp of Engineers, Alaska
Herbert Paul	June, 1970	Sept., 1972	AIE-Ph.D.	CH ₂ M Hill, Consulting Engineers, Redding, California
Mike Moynahan	June, 1970	Jan., 1972	AIE-M.S.	Rainbird Sprinkler Co., Glendora, California, Area Manager for East Division
Lanny R. Ptacek	June, 1970	Jan., 1972	AIE-M.S.	Hawaiian Agronomics, International, Teheran, Iran
Richard Chase	Oct., 1970	Aug., 1972	Plant Sci.-M.S.	continuing education - USU
Lee M. Bailey	June, 1971	Dec., 1972	Ag. Econ.-M.S.	Trainee, Land Bank, Berkeley, California
D. Craig Anderson	June, 1971	March, 1973	Pol. Sci.-M.S.	U.S. Army
Phillip Lloyd	July, 1971	June, 1972	Ag. Econ.-M.S.	U.S. Army
Morgan Ely	Sept., 1971	Feb., 1973	CE-M.S.	Private industry, Connecticut
Phil Tscheschke	Sept., 1971	Feb., 1973	AIE-M.S.	Okokele Sugar Co., Ltd., Kaumakani, Hawaii
Grant Hansen	Jan., 1972	June, 1973	AIE-M.S.	Completed degree, accepted employment with Rainbird Mfg. Co.

Table 5. (continued)

Name	Began Program	Ended Program	Dept. & Degree	Present Status
William Rubink	Sept., 1972		Soils-M.S.	Presently conducting research for M.S. thesis
N. Kent Dittmer	Jan., 1972		AIE-M.S.	Accepted temporary employment at USU
Richard Conn	March, 1972		Soils-M.S.	Presently attending classes and conducting research
David D. Maxwell	Sept., 1972		AIE-M.S.	Presently attending classes and conducting research
Steve Hammond	Jan., 1973		Ag. Econ.-M.S.	Presently attending classes, scheduled to conduct research in So. America, summer & fall, 1973
Gary Glenn	Jan., 1973		Ag. Econ.-M.S.	Presently attending classes, scheduled to conduct research in So. America, summer & fall, 1973
Bruce Brown	April, 1973		Ag. Econ.-M.S.	Presently attending classes, scheduled to conduct research in So. America, summer & fall, 1973

Table 6.
Expenditures for library and publications
July 1, 1972 to June 30, 1973

Salaries	\$3,090.00
Wages	2,000.00
Computer	1,000.00
Publications	2,184.94
Supplies	199.00
Staff Benefits	1,214.54
TOTAL	<u>\$9,688.48</u>

Table 7. Summary of expenditures by Utah State University in support of on-farm water project

Library Materials	
Serials, Abstracts, Indexes	\$ 7,281.00
Personnel	
Orders Processing	
Contractual	400.00
Payroll	200.00
Fund Accounting	
Contractual	800.00
Computer Programming	
Payroll	400.00
Keypunching and Verifying (15,000 cards)	
Payroll	1,250.00
Cataloging	
Contractual	900.00
Payroll	900.00
Supplies	
IBM Cards	100.00
Order Forms	40.00
Misc.	246.28
Processing Costs	
Binding	1,000.00
Computer Time	
Ordering and Processing	400.00
Total of Non 211(d) Funds Expended by Library	\$13,917.28

APPENDIX A
LIBRARY REPORT

LIBRARY REPORT

Introduction

Utah State University began its five year library improvement program in 1969. The department chose improving and increasing the library holdings as a means of increasing its competence in the on-farm water field.

The program was one of three submitted by the University of Arizona, Colorado State University, and Utah State University. Utah State University emphasized the development of its competence in the "on-farm water management field", the University of Arizona in "watershed management", and Colorado State University in "water delivery and removal systems and relevant institutional development". The library activities under the grants to the universities are coordinated through the "Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas" or CUSUSWASH in order to maximize development of competencies and to facilitate usefulness of these competencies to students, staff, AID and other appropriate agencies.

The library program at Utah State University was envisioned in two phases which included:

1. Acquisition of library materials
 - a. Books
 - b. Additional Magazines
 - c. Documents
2. Development of information
 - a. Reference bibliographic collection
 - b. Computer system for retrieval of information
 - c. Cooperative networks for knowledge

Acquisition of Library MaterialsBooks

A continuing search was conducted this year, as in previous years, to locate new, pertinent books being released in the field of on-farm water management. A list of relevant subject headings has been drawn up to help the project staff members locate new book titles for the on-farm water field. The headings are continually used and updated in order to be of value in

determining the selection of material for the library. Information on new book releases was obtained from two sources:

1. Standard magazine and book review guides such as "Agricultural and Engineering" which lists new books released in this field.
2. Richard Abel and Company, which sends us approval slips on both foreign and domestic materials which they feel are pertinent to the subject area.

From these sources a selection and ordering of books which apply to the field on on-farm water management is made.

Vertical File

The acquisition of materials assumed new proportions this year with the establishment of a vertical file system. This system allowed many additional materials to be included because it avoided the problems connected with the library's shelving and cataloging of books. In the past, for instance, bibliographic lists of pamphlets were not reviewed because the materials they listed were considered too small for library cataloging and shelving. This year these lists, one of which contained over 10,000 titles, were reviewed and many pertinent materials from them were ordered for the new vertical file.

A cataloging and indexing system for these vertical file materials had to be devised because the Dewey Decimal system is not generally used for vertical files. The project personnel constructed a system which allows the titles, authors, and subjects to be keypunched for entry into the computerized bibliography, and also provides students and faculty members easy access to material in the vertical file.

Gifts

During the previous year several book contributions were made to the project by professors in the Agricultural and Irrigation Engineering Department. These books are valuable contributions because they are often books which are now out of print but contain excellent subject material. Such books help round out the collection and provide a balance of current and older materials.

Many of the publications selected for the vertical file were sent free of charge to the project. Such materials constitute a valuable source of new and current information and ideas, which may not be available through even the newest book releases.

Aquisitions

During the previous year a total of 16,414 book titles were considered for addition to the on-farm water management library. Of the 16,414 titles considered, 275 books and 391 pamphlets were selected. Many of these publications have been received, catalogued, and are available for use. A large number of titles were rejected because they were fringe area topics, duplicates, or on entirely incorrect subjects. Although the amount of material selected appears to be small, this is the best material available on the subject.

Merrill Library supplemented this selection of books and pamphlets with their subscriptions for periodicals related to the field of on-farm water management. These periodical subscriptions cost the library approximately \$7,000 a year. In addition to the magazines the library maintains an excellent Government Documents Section. It is estimated the 100 to 1,000 government publications are leased yearly which pertain to some part of the on-farm water field.

Additional Holdings

This institution, like many others, contains several centers of information which are not housed in the main library. During this year project personnel sorted out pertinent titles housed in these other centers and devised a method to enter these materials into the computerized bibliography and, at the same time, show where these books can be obtained on campus. Thus the bibliography now contains listings of pertinent materials housed in the Utah Water Research Laboratory, the Special Collections and Government Documents sections, of the Library, the Department of Agricultural and Irrigation Engineering and the Business School Collection (mainly Agricultural Law and Agricultural Economics). The inclusion of these titles serves to make the bibliography a comprehensive listing of all the materials located in the school, rather than just a listing of the materials located in the library proper. These titles also help to insure that all available information relevant to our subject area is listed in the bibliography.

APPENDIX B
"IRRIGATION SYSTEM EVALUATION AND
IMPROVEMENT"

by

John L. Merriam, Jack Keller

(This publication is attached to the report under it's own
separate cover)

THESIS, PUBLICATIONS, MANUSCRIPTS

Computer Simulation for Change in Groundwater Elevation for A...
M.S. Thesis, Civil Engineering, Utah State University, 1973.

Evaluation of Wind Effects on Sprinkler Stability and Spacing Crite...
M.S. Thesis, Agricultural and Irrigation Engineer... Utah State University, 1973.

Hydraulics of Trickle Irrigation Emitters...
M.S. Thesis, Agricultural and Irrigation Engineering, Utah State University, 1973.

Irrigation and Non-Irrigation Alternatives for Reducing Sugar Cane
Transportation Costs in Santa Cruz, Bolivia. Joe M. Kelley. M.S. Thesis,
Agricultural Economics, Utah State University, 1973.

Irrigation Water Management in Ecuador. Craig Anderson. M.A. Thesis,
Political Science, Utah State University, 1973.

APPENDIX C

Sprinkler Performance Prediction When Operated in Unsteady Wind. Thomas
Young. M.S. Thesis, Agricultural and Irrigation Engineering, Utah State
University, 1973.

THESIS, PUBLICATIONS, MANUSCRIPTS

Trickle Irrigation Salinity Patterns as Influenced by Irrigation
Levels and Application Rates. Philip D. Tschaschke. M.S. Thesis,
Agricultural and Irrigation Engineering, Utah State University, 1973.

Theoretical Derivation and Economic Evaluation of the Double Can-
roid and Computer Minimized Cost Methods of Calculating Slopes for Land
Grading. Herbert A. Paul. Ph.D. Dissertation, Agricultural and Irrig-
ation Engineering, Utah State University, 1973.

Medias de Agua en Canales por Medida del Altorador "Sin-Cuello." por
J.F. Alaraz. Agricultural and Irrigation Engineering/Utah Water Research
Laboratory, 211(4)-1, June, 1973.

Appraising the Phosphate Removal Capability of Soil. Frederick G.
Shewans. M.S. Thesis, Agricultural and Irrigation Engineering/Utah Water
Research Laboratory, Utah State University, 211(5)-2, 1973.

(A) Strategy for Optimizing Research on Agricultural Systems Involving
Water Management (Revised Edition). Jack Keller, Dean W. Peterson, R.B.
Peterson. Agricultural and Irrigation Engineering/Utah Water Research
Laboratory, 211(4)-3, July, 1973.

Irrigation System Evaluation and Improvement. John J. Morrison, Jack
Keller. (Special edition by Jose Alaraz). Agricultural and Irrigation
Engineering/Utah Water Research Laboratory, 211(4)-4, July, 1973.

Chemical and Bacteriological Properties of Cattle Feedlot Manure. E.L.
Middlebrooks, Dan Willip. Submitted for publication, Utah Water Research
Laboratory, 1973.

THESIS, PUBLICATIONS, MANUSCRIPTS*

Computer Simulation for Change in Groundwater Elevation for Atlántico-3, Colombia. Morgan Ely, M.S. Thesis, Civil Engineering, Utah State University, 1973.

Evaluation of Wind Effects as Sprinkler Stability and Spacing Criteria. Lanny R. Ptacek. M.S. Thesis. Agricultural and Irrigation Engineering, Utah State University, 1973.

Hydraulics of Trickle Irrigation Emitterlines. Grant Hanson. M.S. Thesis. Agricultural and Irrigation Engineering, Utah State University, 1973.

Irrigation and Non-Irrigation Alternatives for Reducing Sugar Cane Transportation Costs in Santa Cruz, Bolivia. Lee M. Bailey. M.S. Thesis, Agricultural Economics, Utah State University, 1973.

Irrigation Water Management in Ecuador. Craig Anderson. M.A. Thesis, Political Science, Utah State University, 1973.

Sprinkler Performance Prediction When Operated in Unsteady Wind. Thomas Young. M.S. Thesis, Agricultural and Irrigation Engineering, Utah State University, 1973.

Trickle Irrigation Salinity Patterns as Influenced by Irrigation Levels and Application Rates. Philip D. Tscheschke. M.S. Thesis, Agricultural and Irrigation Engineering, Utah State University, 1973.

Theoretical Derivation and Economic Evaluation of the Double Centroid and Computer Minimized Cost Methods of Calculating Slopes for Land Grading. Herbert A. Paul. Ph.D. Dissertation, Agricultural and Irrigation Engineering, Utah State University, 1973.

Medias De Aguas En Canales Por Media Del Aforador "Sin Cuello." por J.F. Alfaro. Agricultural and Irrigation Engineering/Utah Water Research Laboratory. 211(d)-1, June, 1973.

Appraising the Phosphate Removal Capability of Soil. Frederick C. Shewman, H.B. Peterson, Agricultural and Irrigation Engineering/Utah Water Research Laboratory, Utah State University. 211(d)-2, 1973.

(A) Strategy for Optimizing Research on Agricultural Systems Involving Water Management (Revised Edition). Jack Keller, Dean F. Peterson, H.B. Peterson. Agricultural and Irrigation Engineering/Utah Water Research Laboratory, 211(d)-3, July, 1973.

Irrigation System Evaluation and Improvement. John L. Merriam, Jack Keller. (Spanish edition by Jose Alfaro.) Agricultural and Irrigation Engineering/Utah Water Research Laboratory 211(d)-4, July, 1973.

Chemical and Biostimulatory Properties of Cattle Feedlot Runoff. E.J. Middlebrooks, Dan Filip. Submitted for publication, Utah Water Research Laboratory, 1973.

Irrigation Fundamentals by Glen Stringham. An elementary manual to be used primarily for short course instruction in developing countries. This was done in cooperation with CIDIAT.

(A) Plan for a Surface Irrigation System for the Taboga Experiment Station. J.E. Christiansen, Rex F. Nielson. Utah State University, Logan, Utah, April, 1973.

Preliminary Examination of the Do-Anambra River Area, East Central State, Nigeria. H.B. Peterson, Martin M. Fogel, George E. Radosevich. Agency for International Development, United States Department of State, November, 1972.

* Abstracts and Summaries are located in Appendix D.

APPENDIX D
ABSTRACTS AND SUMMARIES

Computer Simulation Change in Groundwater
Elevation for Atlantico-3 Colombia

by

Morgan S. Ely, Master of Science
Utah State University

Major Professor: J. Paul Riley
Department: Civil Engineering

In this study a general computer simulation model of the hydrologic system was applied to three particular problems in a specific geographic area of the Atlantico-3 Project. Three phases of the study was divided as follows:

- A. The effects on groundwater table elevations of a barrier to prevent surface runoff from the northern highlands from entering the study area.
- B. The effects on the groundwater table elevations of varying the densities of native phreatophytes.
- C. An examination of the accumulation, locations, and relative amounts of surface runoff.

Each phase illustrates the kinds of management problems that can be examined by means of the model. The data provided through the use of the model can then be used by the land managers in order to consider alternatives in land use in order to best avoid damage from inadequate drainage.

Evaluation of Wind Effects as Sprinkler Pattern
Stability and Spacing Criteria

Lanny R. Ptacek, Master of Science
Utah State University, 1972

Major Professor and Thesis Director: Dr. Jack Keller
Department: Agricultural and Irrigation Engineering

The purpose of this study was to analyze the wind effects of wind velocity, nozzle size, and pressure upon pattern profiles. To develop a graphical means of presenting various sprinkler spacings expressed as a percentage of the wetted diameter vs. coefficient of uniformity for the various sprinkler pattern shapes, pattern stability indices, spacing ratios, and relative wind directions tested. Single sprinkler can-catch data were analyzed using computer programs to determine the effect of the several factors upon CU and spacing.

The findings indicated that no one wind direction, pattern shape, or spacing consistently produced the highest CU_c values. The total effect of all factors must be considered before optimum system design can be accomplished.

Hydraulics of Trickle Irrigation Emitterlines

Grant R. Hanson, Master of Science
Utah State University, 1973

Thesis Director: Dr. Robert W. Hill

Department: Agricultural and Irrigation Engineering

A study was conducted to investigate the flushing flow characteristics of flushing emitters, the hydraulics of emitterlines under steady flow conditions, and the uniformity of distribution of emitters as influenced by emitter variations and other environmental factors.

The study was composed of three parts:

1. A theoretical analysis employing computer programs.
2. A laboratory analysis of emitterlines.
3. A field analysis of a trickle irrigation system under actual field environmental conditions.

Eight different types of emitters were studied, one non-flushing and seven flushing, and differences between emitters are discussed and recommendations are made concerning the selection of flushing emitters, design of emitterlines, and maintaining maximum efficiency in regards to uniformity of distribution.

Irrigation and Non-Irrigation Alternatives for
Reducing Sugar Cane Transportation Costs in
Santa Cruz, Bolivia

by

Lee M. Bailey, Master of Science
Utah State University, 1973

Major Professor: Dr. E. Boyd Wennergren
Department: Agricultural Economics

The major objective of this study was to investigate various alternatives for lowering the cost of transporting sugar cane in Santa Cruz, Bolivia. These alternatives included both irrigation and non-irrigation possibilities. Production costs for sugar cane were determined by using studies completed by the USAID-Utah State University Study Team, budget studies of Señor Carlos Castro of the Guabirá sugar cane mill in Santa Cruz and a study undertaken by Señor Enrique Comez, a graduate student at Utah State University.

A cane registry commissioned by the National Sugar Cane Commission was used in conjunction with a least-cost transportation model in order to determine a least-cost distribution system for the transport of existing sugar cane production. This model was also used to investigate various alternatives for reducing transportation studies showed that over \$61,000,000 could be saved in transportation costs if "zones of influence" were established for each of the existing mills. Other feasible alternatives were to close the San Auerelio mill and increase the capacity of La Belgica and Guabirá by 25 percent and the development of irrigation projects from rivers in the southern region capable of irrigating 2137 hectares of sugar cane.

Irrigation Water Management in Ecuador

D. Craig Anderson, Master of Arts
Utah State University, 1973

Major Professor: Dr. William Furlong
Department: Political Science

The following thesis describes and analyzes irrigation water management in Ecuador.

One of the primary thesis objectives is to discuss the different private and public administered entities which have irrigation water delivery programs and describe the function and role of each as water management institutions.

Secondly, the thesis investigates and analyzes non-technical variables which influence the actual distribution of irrigation water by those institutions, and the use of water on the farm unit.

The thesis concludes that there are definite recognizable social, political, economic and natural physical factors in Ecuador which are directly associated with programs of irrigation water delivery and use. These non-technical factors play significant roles in determining the success or failure of such programs. They are therefore important variables for development in general.

Sprinkler Performance Prediction When
Operated in Unsteady Wind

by

Thomas J. Young, Master of Science
Utah State University, 1973

Major Professor and Thesis Director: Dr. Jack Keller
Department: Agricultural and Irrigation Engineering

A method was suggested and demonstrated for predicting the field performance of sprinklers operated in unsteady wind conditions from a limited number of single sprinkler tests and a limited amount of wind data. The usefulness of a single sprinkler test is increased by rotating it to any angle, thus enabling it to depict the effects of wind from any direction and resulting in a reduction of the number of tests needed. Wind data is grouped into 45° angle segments and averaged within five mile per hour wind speed intervals.

The method involves synthesizing the effect of unsteady wind on sprinkler water distribution by utilizing a computer to stack a series of sprinkler tests conducted in steady wind. The resulting total stacked test pattern representing the influence of unsteady wind is utilized for predicting the uniformity of water distribution for a sprinkler operated in the wind conditions modeled.

Theoretical Derivation and Economic Evaluation of the
Double Centroid and Computer Minimized Cost Methods
of Calculating Slopes for Land Grading

by

Herbert A. Paul, Doctor of Philosophy
Utah State University, 1973

Major Professor: Dr. Glen E. Stringham
Department: Agricultural and Irrigation Engineering

The Double Centroid and Computer Minimized Cost Methods of calculating slopes for land grading were developed. The Double Centroid Method was based on theory of centroids located in each one-quarter of the field. The cuts and fills balanced in each of these one-quarters. This theoretically reduced the cost of grading, as no soil was moved from one-quarter of the field to another one-quarter. The Computer Minimized Cost Method selected the optimum slope based on the economic parameters of the type of land grading equipment to be used.

The newly derived methods were compared economically with the Least Squares Method, utilizing computers. There was no general economical superiority of the Double Centroid Design over the least Squares Design or vice versa. The Computer Minimized Cost Method was equal to or superior, economically, to the Least Squares Method for all fields. The average savings on 12 fields evaluated was 3.3 percent. The maximum savings was 9.0 percent.

Trickle Irrigation Salinity Patterns as Influenced
by Irrigation Levels and Application Rates

by

Philip D. Tscheschke, Master of Science
Utah State University, 1973

Thesis Director: Dr. Jose F. Alfaro
Department: Agricultural and Irrigation Engineering

An experiment was conducted in a greenhouse using cherry tomatoes to determine the effect which different irrigation treatments have on the distribution of salts and water within the soil profile under trickle irrigation. The four different treatments were: alternate day irrigations 13 percent under, equal to, and 20 percent over the evapotranspiration and daily irrigation equal to the evapotranspiration. The tomatoes were planted in eight lysimeters, which provided one replication of each irrigation treatment used. Two-dimensional contour patterns are reported for both the saturation extract conductivity and soil water potential of the soil profile between two lines of emitters. Differences between irrigation treatments are noted, and recommendations are made concerning the application of the results to the management of trickle irrigation systems.

Medias de Aguas en Canales por
Medio del Aforador "Sin Cuello"

by

J. F. Alfaro

The objective of this publication is to contribute to the technical literature of Latin America with the introduction of the "cuthroat" flume.

The bulletin, written in Spanish, includes the description, development and principles of operation. It also discusses discharge equations, and explains the uses of equations, tables, and nomograms in determining the discharge under free and submerged flow conditions. Recommendations for field installations are also included.

Appraising the Phosphate Removal
Capability of Soil

by

Fredrick C. Shewman, H. B. Peterson

A type of tertiary treatment for removal of phosphate from a effluent is to irrigate an area of land. The degree of treatment obtained will depend upon the soil characteristics and upon the management of the vegetative cover.

A better procedure to evaluate the effect of a given soil type on the removal of phosphate has been developed. The procedure would indicate both the maximum phosphate removal capacity of the soils in an area to be used for irrigation with phosphate laden waters, and the maximum ground water pollution hazard with respect to phosphate that would exist in such an area if no special care was taken in applying the effluent. The phosphate concentrations likely to occur from contamination of groundwater in such a manner could be highly detrimental to a surface water body which received flow from the groundwater.

A test utilizing repeated applications of phosphate was developed which was believed to be superior to the adsorption isotherm approach for determining the maximum P removal capacity of a soil. In addition, soil column tests were made and compared to the repeat application data. The P removal capacity values obtained from the column tests were believed to be best estimates of the least amount of P that would be removed from an effluent by a soil.

The data from both types of tests indicated the possible large differences in P removal capacity which might be encountered depending upon the concentration of P and how the P-laden water was applied.

It was concluded that the maximum P removal capacity of a soil would result from a combination of adsorption of phosphate and precipitation of compounds of phosphorus. From the five Utah Great Basin soils studied, it was found the soil properties most likely correlated with adsorption would be surface area and the related properties, percent clay and cation exchange capacity. The amount and condition of lime present probably influences both

precipitation and adsorption. It was evident that the proper management of effluent application together with proper selection of soil is critical in phosphate removal from water applied to soils.

Key Words: Effluent Phosphate, Removal, Soil, Irrigation.

A Strategy for Optimizing Research on
Agricultural Systems Involving Water Management

by

Jack Keller, Dean F. Peterson, H.B. Peterson

The rationale for a model for optimizing agricultural systems through knowledge transfer is developed and presented. The model attempts to disaggregate the environment into significant components which are also measurable. It uses crop production as the overall integrator of the agricultural system response to the husbandry program imposed at a specific site. The model should aid in organizing available crop data and investigations. It should form a useful outline to guide thought processes involved in research program development and project analysis and provide a framework for a data retrieval system.

Key Words: Water Management, Model, Research, Agricultural Environment, Optimizing, Knowledge Transfer

Irrigation System Evaluation and Improvement

by

John L. Merriam, Jack Keller, Jose F. Alfaro

This second edition of the manual contains detailed procedures for the field evaluation of sprinkler, surface, and trickle irrigation performance and management practices. It contains details such as: a list of equipment needed; step by step instructions for carrying out the field work; sample forms for recording and organizing the field data, and sample studies demonstrating the entire process. It also includes an analysis and recommendations for the actual care studies used.

The introduction deals with the general uniformity, efficiency, and management concepts employed in the evaluation of each system. The sprinkler section covers both simple and full evaluations of regular fixed grid sprinkler systems as well as under tree orchard, center pivot and traveler sprinkler systems. There is a brief section dealing with trickle (or drip) irrigation and a section on basic irrigation. Both the furrow and border irrigation sections contain a simple (short cut) evaluation procedure as well as complete full evaluations.

Key Words: Irrigation, Efficiency, Uniformity, Sprinklers, Trickle, Basin, Border, Furrow, Soil, Moisture, Evaluation

Chemical and Biostimulatory Properties
of Cattle Feedlot Runoff

by

Daniel S. Filip, E.J. Middlebrooks and
Donald B. Procella

Eutrophication and algal nuisance problems have been described many times, but generally specific information on specific sources of nutrients and their biostimulatory characteristics are missing from these accounts. One of the least studied, but perhaps most important, source of nutrients are the small dairy and livestock feedlots located on many of the streams in the rural areas of the country.

Runoff samples (principally snow melt) for algal bioassays and nutrient chemical analysis were collected at two cattle feedlots differing in topography, drainage, and scale of operation. Standard bottle test bioassays and chemical analysis were used so that the data collected in this study would be comparable with that from other studies.

It was found that even though nitrate or phosphate concentrations may be adequate to support algal growth, the nitrogen: phosphorus ratio in runoff water may be a critical factor in determining the biostimulatory effect on receiving waters. Though the N:P ratio may not be optimal for algal growth in runoff itself, dilution and chemical change caused by receiving water may allow for more favorable conditions for algal blooms.

Feedlot runoff was found to be toxic to algal growth but any toxicity indigenous to feed but runoff is likely to be diluted in receiving water sufficiently to permit uninhibited algal growth. The net effect of feedlot runoff on water quality of receiving water is usually detrimental and will substantially increase eutrophication.

IRRIGATION FUNDAMENTALS

by

Glen E. Stringham

Irrigation for food production is a continuing and expanding practice throughout the world. Continued success of irrigation projects and the wise use of the water available is dependent on an understanding of irrigation fundamentals, by water users.

Educational organizations and government agencies throughout the world are working to provide this understanding to the users. To assist in this educational process, a compilation of classroom and field demonstrations has been assembled and demonstration procedures outlined. Demonstrations and the related concepts, dealing with water holding capacity and soil texture; the soil reservoir; infiltration; infiltrometer and soil wetting patterns, are presented.

A Plan for a Surface Irrigation System
for the Taboga Experimental Station - Summary

by

J. E. Christiansen, Rex Nielson

This report is based on a brief trip to Costa Rica by J. E. Christiansen and Rex F. Nielson to provide technical assistance in the planning of an irrigation and drainage system for the Taboga Experimental Station in the Province of Guanacaste. A three-day visit was made to the area, and shorter visits were made to the Experimental Station at Alajuela in the Itiquis Irrigation Project near San Jose, and to the IICA Research Center at Turrialba. The report discusses briefly the climate, soils and crops of the area together with water supply requirements and availability.

A plan for an Irrigation System is presented together with a discussion of many problems pertaining to irrigation. The drainage problem is discussed.

Specifications for equipment needed to construct the system and implement irrigation are included.

Preliminary Examination of the
Do-Anambra Rivers Area, East Central State,
Nigeria - Summary

by

Howard B. Peterson
Martin M. Fogel
George E. Radosevich

In June 1972 USAID/Nigeria received a request from the Commissioner of Agriculture and Natural Resources of the East Central State for assistance in the preparation of guidelines for a pre-feasibility study of a proposed irrigation project, primarily for the growing of rice. This request was transmitted to TAB/AGR who selected a three-man team of consultants from member universities of CUSUSWASH. The team visited the Do-Anambra Rivers Area, the site of the proposed development, in August 1972.

The Do-Anambra Rivers Area, a forest-savannah mosaic, consists of approximately 250,000 acres located in the northwestern section of the East Central State. Approximately 30 percent of this area appears to be suited to irrigated agriculture, if provided with adequate water during dry periods, if protected from floods, and if provided with adequate surface and subsurface drainage. Detailed surveys may indicate additional suitable acreage which would depend in large part on costs of land clearing, pumping and adapted farm irrigation systems. The team noted that while some basic information on soils, vegetation, topography, hydrology, geology, etc. was available, the hydrologic and the available topographic information was not in sufficient detail for a pre-feasibility or reconnaissance type of study of the area's natural resources.

Of major importance within the project area is the 10,500-acre Uzo-Uwani farm settlement scheme initiated in 1962 with substantial financial support by USAID. Prior to the outbreak of hostilities in 1967, approximately one-fourth of the project area was cleared and about ten percent developed for irrigation. The conflict seriously disrupted activities destroying all farm and construction equipment and damaging the irrigation system. The team noted, however, that many settlers have returned to the area and have set up rainfed agricultural operations.

It is recommended that a high priority be given to completing the development of the Uzo-Uwani project. Emphasis should be given to developing the project as a pilot scheme for the entire Do-Anambra Rivers Area to test the practicality of the proposed farm layouts, the administrative and operating procedures and the willingness and ability of the local farmers to adapt to the plan. An experimental farm should also be initiated to assist the farmers with crop selection, water and fertilizer requirements, crop rotations and a host of related problems.

The team has concluded that the Do-Anambra Rivers Area has sufficient potential to warrant initiating a pre-feasibility study of the area. This study should include a basic survey of the area's resources, both natural and human, and the formulation of an overall plan for the development of these resources. The plan should not be limited to a particular crop such as rice, but should take a broad look at other agricultural crops that may be adapted to the area and to the forest and fish potential as well. Modernized rainfed agriculture should also be considered where irrigation is not suitable.

It is recommended that as the first step in the prefeasibility study, aerial photographs be made of the entire area that are of sufficient control for making topographic maps with a 2-foot contour interval. The team further suggests that the use of the latest remote sensing techniques for making aerial surveys be explored. Costs may be reduced over conventional methods in that cloud cover is no problem and added information pertaining to soils, vegetation and even mineral exploration may be obtained with these newer techniques. (Upon returning from their visit to Nigeria, the team has learned that a company engaged in making aerial surveys is currently located in Lagos.)

Concurrent with the aerial surveys, streamflow gaging stations should be established on the major rivers and tributaries of the area.

Following the basic surveys, a 4-man team (engineer, soils scientist, economist and agronomist) could then evaluate the area's resources, formulate plans to develop these resources and present methods and costs for obtaining the detailed, pre-construction feasibility studies.

Incorporated in the basic survey of the pre-feasibility study should be plans to identify and assess the socio-economic factors within the project area. Consideration should be given to establishing a water policy and administrative system as well as a land title recording system.

In addition to the above physical, economic, social and legal studies, an environmental impact study should be included to assess the long-term effects of the proposed plan for developing the area.

APPENDIX E

"PRELIMINARY EXAMINATION OF THE DO-ANAMBRA
RIVER AREA, EAST CENTRAL STATE, NIGERIA"

by

H.B. Peterson, Martin M. Fogel, George E. Radosevich

PRELIMINARY EXAMINATION
OF THE
DO-ANAMBRA RIVERS AREA, EAST CENTRAL STATE, NIGERIA

Prepared for:

Agency for International Development
United States Department of State

By:

CUSUSWASH:
Universities of Arizona,
Colorado State and Utah State

November 1972

CONTENTS

	Page
LETTER OF TRANSMITTAL	D-63
SUMMARY	D-65
INTRODUCTION	D-65
Team Involvement	D-65
Scope of Study	D-65
Previous Investigations	D-66
Local Interest	D-67
DESCRIPTION OF AREA	D-67
Physical Features	D-67
Climate	D-67
Soils, Topography and Drainage	D-70
Water Resources	D-70
Vegetation and Land Use	D-70
Community Facilities	D-71
People	D-71
Land Tenure	D-72
Problems of Area	D-72
FUTURE INVESTIGATION PROGRAM	D-72
Multiple-purpose Development	D-72
Rehabilitation of Uzo-Uwani Pilot Project	D-73
Area Survey	D-74
Feasibility Study Requirements	D-74
Field Engineering	D-74
Geology	D-77
Hydrology	D-77
Land Classification	D-77
Drainage	D-77
Agricultural Economics	D-77
Office Engineering	D-77
Multiple-use Studies	D-78
Financial and Economic Analysis	D-78
Sociological Studies	D-78
Schedule of Investigations	D-78
Personnel Requirements	D-79
CONCLUSIONS AND RECOMMENDATIONS	D-79
REFERENCES	D-82

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In addition to the above physical, economic, social and legal studies, an environmental impact study should be included to assess the long-term effects of the proposed plan for developing the area.

INTRODUCTION

Team Involvement

In June of 1972, the Commissioner of Agriculture and Natural Resources for the East Central State of Nigeria requested the assistance of the United States Agency for International Development (USAID) Mission in Nigeria in the preparation of guidelines for a pre-feasibility study of a major land development project. This request was transmitted through the Food and Agriculture Office of the USAID Mission in Lagos to the Technical Assistance Bureau (TAB) in Washington, D.C. TAB responded favorably by selecting a team of consultants from member universities of CUSUSWASH, a consortium of universities involved in agricultural development and improvement through proper soil and water management. The field study was conducted in August 1972 by the following specialists:

Howard B. Peterson, Agronomist/Chief of Party
Martin M. Fogel, Hydrologist/Agricultural Engineer
George E. Radosevich, Legal Specialist/Economist

Scope of Study

The terminology associated with the development of agricultural projects is as varied as the projects are themselves. To avoid possible confusion, a brief discussion on this matter follows.

Pre-investment studies, pre-feasibility studies, preliminary surveys and reconnaissance surveys are various names given to investigations which may have similar objectives. Reports resulting from such studies generally pertain to developing a comprehensive master plan for the orderly and economic development of an area. Specifically, pre-feasibility or reconnaissance type surveys review existing and proposed developments and determine the practicability of making a detailed study of the area. If a detailed study is recommended then the reconnaissance survey usually prepares an estimate of the type and number of personnel required, the equipment needed, the time required and cost.

In studying the land and water resources of an area, it is necessary to make various related surveys and studies. These include basic engineering surveys, geologic examinations, ground-water surveys, hydrologic surveys and studies, economic analyses and forecasts, estimates of probable costs and benefit studies. Much of this has not been done for the Do-Anambra Rivers Area, at least in sufficient detail for even a reconnaissance-type study. This particular effort, therefore, should precede or be a part of a reconnaissance or pre-feasibility study. The basic objective of such studies is to make a preliminary survey of the area

to determine whether a comprehensive basin-wide study will be justified in view of existing developments, previous studies and the probable future needs for land and water development.

Feasibility investigations are considered pre-construction studies in that it is possible to directly follow them with construction surveys, once the decision is made to build the project and financing is obtained.

Previous Investigations

The Do-Anambra Rivers Area has been under investigation for over 10 years as a potential area for sugar cane production. A study made in 1971 by a team from the Netherlands (Department for International Technical Assistance, Ministry of Foreign Affairs) was the latest investigation. They concluded that most of the survey area was not suitable for large scale sugar cane production because the lands can only be irrigated at relatively high costs. A moderately high pumping lift (approximately 80 feet) and scattered occurrence of suitable soils or that the soils are imperfectly drained to allow proper aeration and adequate root penetration were the reasons presented. A part of the imperfectly to poorly drained soils in the center of the survey area, however, was concluded to be suitable for large scale rice production. Approximately 64,000 acres in continuous stretches could be double-cropped to rice. Furthermore, the Dutch team stated that only a small portion of this area is used for agriculture.

Previous investigations have stated that some 75,000 acres in the southern part of the plain within the 240,000-acre survey area has possibilities for sugar cane production. One of the earlier investigations was done by Tahal Ltd. of Israel who reportedly studied the water resources and sugar cane potential in the East Central State during the early 1960's. These reports were not located by the U. S. team.

While none of the basic surveys (engineering, geologic, soils, hydrologic, etc.) are in sufficient detail for a feasibility study, an available soils survey was deemed adequate for this preliminary examination. The semi-detailed soil and vegetation-land use survey was conducted in 1960 (Obihara et.al., 1964). The mapping was based primarily on fixed interval auger-hole observations along accessible paths through the area and stereoscopic interpretation of aerial photographs (scale 1:25,000) flown in 1959. The soil and vegetation maps were published on a scale of 1:50,000. The team was not able to find the maps prepared on the scale of 1:25,000.

According to the Dutch team topographic maps, scale 1:10,000 with a contour interval of 10 feet and 1:50,000 and a 50-foot interval, are available (Federal Surveys, Nigeria 1964). In either case, topographic detail is not adequate for evaluating the requirements of irrigated agriculture.

Hydrologic and meteorologic data for the area are meager with the former practically non-existent. About three years of water level measurements were taken prior to the outbreak of hostilities. A relationship between water depth

and streamflow has not been firmly established. Precipitation data can be extrapolated from Enugu and Nsukka with a fair degree of reliability.

Local Interest

The Ministry of Agriculture and Natural Resources of the East Central State in Nigeria considers development of the Do-Anambra Rivers Area of utmost importance. A request for technical assistance for a pre-feasibility study of the area has been sent to the Federal Ministry of Economic Development and Reconstruction and the Federal Ministry of Agriculture and Natural Resources. In addition, the ECS Agricultural Commissioner has included in his current budget request funds for rehabilitating the irrigation system of the Uzo-Uwani project, a farm settlement scheme financed in large part by USAID. Portions of the irrigation system were damaged during the recent conflict.

The interest within the political structure of the East Central State is based upon the objectives of the government in developing this project which are directly in line with the national objectives as set forth in the Second National Development Plan, 1970-74, Federal Republic of Nigeria. The primary objective in developing the Do-Anambra Rivers Area is to produce food for an expanding population in a country and state having the highest population density in Africa. A second objective is to increase the standard of living and productive capacity of the people within the region. The third objective concerns the redistribution of population in the East Central State that will come about as a result of developing the project area and providing agriculture and infrastructure labor requirements.

DESCRIPTION OF AREA

Physical Features

The Do-Anambra Rivers Area of approximately 250,000 acres is located in the northwestern corner of the East Central State of the Federal Republic in Nigeria (see Fig. 1). Enugu, the State Capitol, is about 35 miles southeast from the heart of the survey area, while Nsukka, location of the University of Nigeria, is a similar distance to the northeast. Bordering the west is the Anambra River, a major tributary of the Niger River, while the Ezu, Do and Adada Rivers form the southern and eastern boundaries. The area's northern boundary extends nearly to the State line.

Climate

A tropical wet and dry climate with a mean annual rainfall of 66 inches prevails in the area. The wet season extends from April to October with a minor

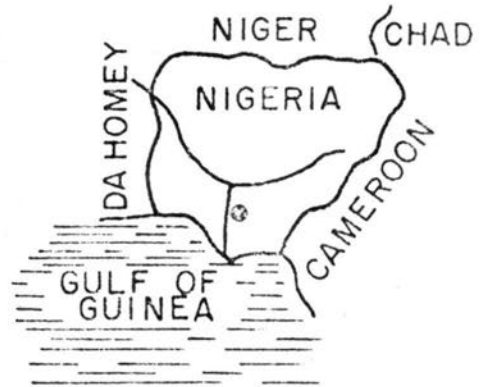
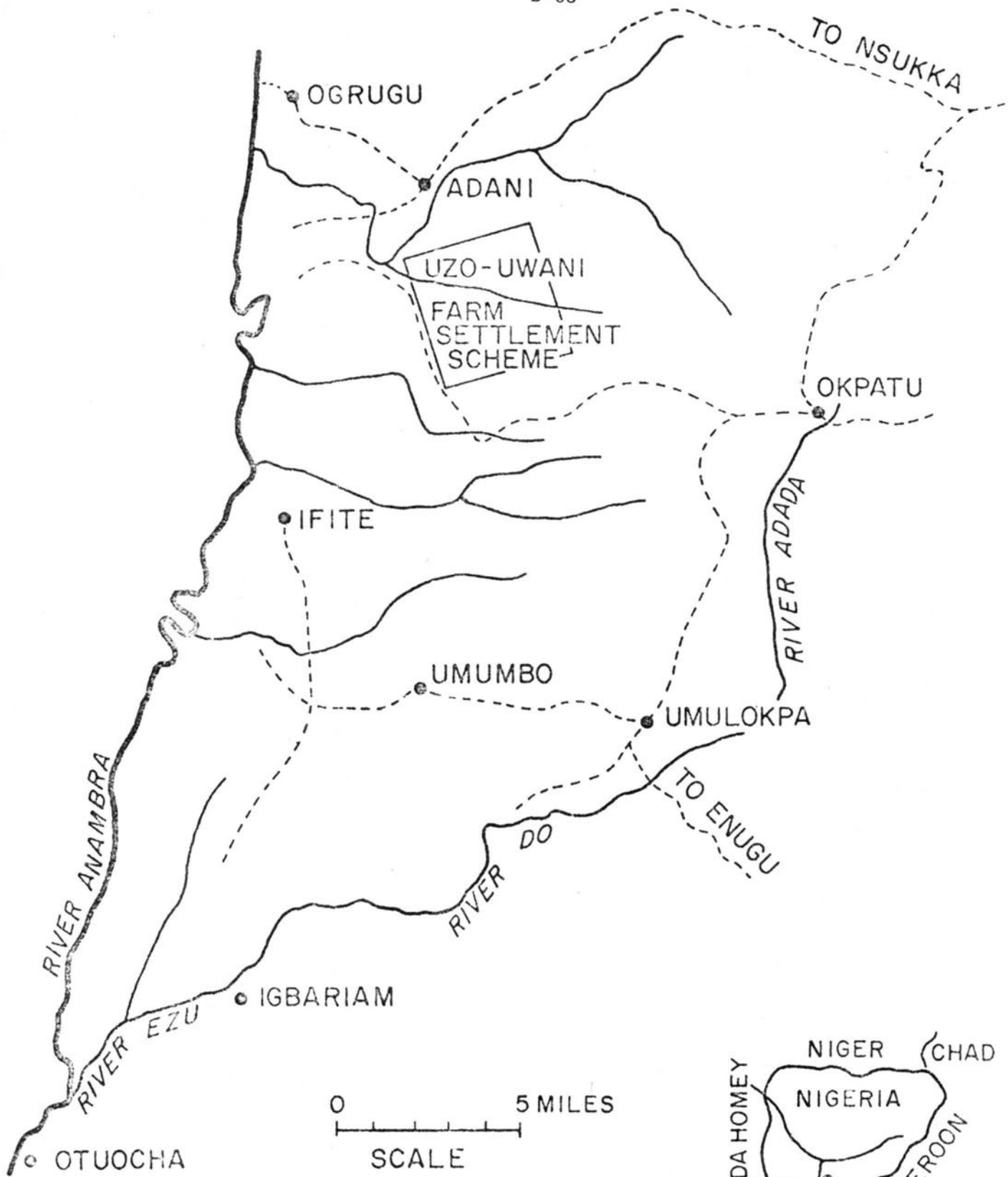


FIG. 1 THE DO-ANAMBRA RIVERS AREA, EAST CENTRAL STATE, NIGERIA

dry period during the August break. There appears to be sufficient variability in the distribution of rainfall during this period to indicate that supplemental irrigation may be of economic benefit. Irrigation would definitely be required for crops grown in the dry season, November to March, as the rainfall total averages out to less than 7 inches for the 5-month period (see Table 1).

The mean monthly temperatures varies between 74°F in August and 82°F in February with the diurnal variations seldom exceeding 20°F. Humidities are generally high (above 50 percent at 1500 hours) except during the northeasterly "Harmattan" which blows intermittently between December and March.

TABLE 1.

Mean Monthly Rainfall and Temperature for Nsukka

	Rainfall, inches	Temperature, °F	
		Max.	Min.
Jan.	0.6	87	71
Feb.	0.9	91	72
Mar.	3.4	90	73
Apr.	5.2	86	71
May	7.9	84	70
June	7.3	82	68
July	9.8	83	68
Aug.	6.9	79	68
Sept.	13.3	80	68
Oct.	8.6	83	68
Nov.	1.7	85	71
Dec.	0.3	87	71
Total	65.9	--	--

Soils, Topography and Drainage

Based on the previously mentioned soils survey of 1960 and the Dutch report of 1971, the area can be classified into the following main subdivisions:

- Uplands: lands with a relatively high elevation (over about 80 feet) above the nearest river water level and/or a rolling to undulating topography. The soils are coarse-textured and are generally well drained. Located along the eastern and western boundaries of the area, these lands comprise a little more than one-fourth of the area.
- Plains: lands with low to moderately high elevation (less than 80 feet) above the nearest river water level and with level to gently undulating topography. The soils are imperfectly to poorly drained being fairly deep, compact and silty. Represents approximately one-half of the area and according to the Dutch report contains most of the land that is suitable for rice irrigation.
- Flood plains: lands along rivers that are level and at an elevation below the seasonal high water level of the river. Soils are deep, clayey and poorly drained; they are basically suitable for rice irrigation if flooding is prevented.

Water Resources

With the area bounded on three sides by relatively major rivers and dissected internally by tributaries, it would appear at first glance that there would be sufficient water to develop the entire area. Since much of the land that may eventually prove to be suitable for irrigation will be at some elevation above the river, pumping rather than direct diversion appears to be the means for diverting the water for irrigation.

If one-fourth of the survey area (about 60,000 acres) is deemed suitable for irrigation, a continuous flow of about 1000 cubic feet per second would be needed during the dry season. The August 1972 flow in the Do and Anambra Rivers was crudely estimated to be 2,000 and 3,000 cfs, respectively. The Dutch team estimated the minimum discharge at 850 and 1450 cfs, respectively. Thus, it appears that there is sufficient water to irrigate most if not all of the suitable lands within the project area.

Vegetation and Land Use

Table 2 shows the percentage of the total area (approximately 400 square miles) that is in various land use and vegetation categories as determined by the 1960 soil survey (Obihara et. al., 1964).

TABLE 2.

Land Use and Vegetation in the Do Anambra Rivers Area

Land Use on Vegetation Category	Percent of Total Area
Dense cultivation	15
Cultivation and fallow	14
Cultivation and fallow, ex-forest	9
Cultivation in Anambra flood plain	6
Borassus palm on flood plain	19
Forest	13
Tree grassland	18
Tree and scrub grassland	6

Community Facilities

In Nigeria, facilities for the transportation and marketing of products can be broken down into three basic conveyance systems: 5,000 miles of navigable rivers; 55,000 miles of roads; and 2,200 miles of railroads. Within the project area, there are no railroads and the roads that lead into the major towns and villages are fair. The principle all-weather road extends from Nsukka to Adani. With the bordering rivers (Anambra, Ezu, Do and Adada) being tributaries of the Niger River and to a large extent navigable, economical transportation to major cities is available.

The extent of utilities and of community services such as hospitals, schools, etc. within the project area were not determined. Enugu, some 35 miles from the center of the project, would have many of such facilities available.

The People

Within the East Central State and the project area, the dominant ethnic group is the Ibo. The Ibo and other groups in southwestern Nigeria generally subscribe to the concepts of competition, personal aggressiveness, and freedom from a rigid class structure. They apparently are willing to accept any type of work that offers the individual an opportunity for personal achievement and advancement towards a better way of life.

Land Tenure

In the general land tenure system of the Ibo people, the land is held by the group of kin, family or clan with a very definite trust responsibility in the living with respect to the proper use of the land. Under the Ibo system of land tenure, three cardinal principles emerge. One, the land ultimately belongs to the community and cannot be alienated from it without the consent of the community. Two, within the community, the individual shall have the security of tenure for the land he requires for his compound, garden and farms. Three, no member of the community shall be without land. A favorable aspect of the project area with respect to land tenure is the low population density which facilitates the role of the government in controlling land use.

Problems of Area

The major technological problems in the development of the area revolve around the suitability of the lands for a sustained type of irrigated agriculture. The soils themselves, more specifically their drainability, appear to be the number one problem that must be resolved. Internal drainage is poor in much of the area and may become worse under unrestricted land leveling that is required for efficient irrigation. Surface drainage relief from heavy rains and flooding would also have to be provided.

The relatively high costs of clearing the land and lifting the water to portions of the area are additional problems that should be considered.

Insofar as institutional problems are concerned, an obstacle to overcome is the constraint imposed by the traditional land tenure system and the lack of legislation and uniform customary law on the allocation and control of water. The constant division and subdivision of land holdings and the scattering of the plots tends to increase the water delivery problems. A corollary problem concerns obtaining new land by farmers although willing and able, financially and physically, to develop the land. With a lack of any formal land registration or deed recording system, land holders must rely on verbal recognition of boundary lines. The land holders are also prevented from using their land as collateral under modern banking practices.

FUTURE INVESTIGATION PROGRAM

Multiple Use Development

The Do Anambra Rivers Area rich in natural resources has the potential for producing a wide range of products useful to man. Management of this area should

be directed not only towards agricultural production but also to forests and fish. To realize the full potential of this area, consideration should be given as early as possible in the development for the possibility of implementing the multiple-use concept in natural resource management.

In competition for the land/or financial resources of the survey area are irrigated agriculture, rainfed agriculture, forestry, fisheries, domestic water supply systems and flood control. The plan that is eventually formulated should present possible solutions to the entire spectrum of problems, if possible, and not just to one segment of the overall development program. Water resources development involves preparing a plan that considers all the alternatives for all the area's potentialities.

Rehabilitation of Uzo-Uwani Farm Settlement Scheme

The Uzo-Uwani farm settlement scheme located in the northern part of the survey area several miles south of the village of Adani was initiated in 1962. USAID designed and financed the scheme and an irrigation system capable of delivering water to 5,000 acres out of a total 10,500 acres in the project. Water for irrigation was supplied from a small river, the Obing. By the fall of 1967, a rockfill diversion dam and canal headgate were constructed, 70 percent of the necessary 7 miles of main canal were completed, 2,500 acres were cleared and about 1,000 acres were developed for irrigation.

Following cessation of hostilities, examination of the area revealed that the roads and buildings in the residential area were generally intact with most of the settlers having returned to the area. While all the farm equipment was damaged, the irrigation system was more fortunate. To deliver water to those units that previously received water, approximately 1/2 to 1 mile of the unlined main canal would have to be repaired, the entire canal cleaned and a gate in the control structure repaired. All of this could be done locally.

The U. S. team strongly recommends that the initial step in the more detailed investigation of the survey area be the restoration of the irrigation system of the Uzo-Uwani farm area to an operational basis to function as a pilot or small-scale example for the entire Do-Anambra Area. Settlement by the people in this demonstration area need not conform to the original intent but should be left to the discretion of local authorities. Within the pilot area, it is suggested that an experimental farm be established to study the cultural practices of growing rice, maize and other food crops suitable to the Do-Anambra Area. As a model for the larger project, the pilot scheme would be in a position to encounter some of the major problems that may arise in the Do-Anambra Area such as the problems of land tenure, acquisition of land, and economic farm size. In addition to studying these sociological problems of developing the Do-Anambra Rivers Area, the pilot scheme should also perform studies to obtain answers to hydrologic, agronomic and management problems.

Area Survey

As mentioned earlier, a reconnaissance or pre-feasibility study of the entire Do-Anambra Rivers Area should be made before more detailed studies are initiated on any particular phase or stage of development. The reconnaissance study should (1) inventory all the resources and (2) develop a framework plan for optimum use of these resources. This study should be more comprehensive than the 1971 Dutch report or any other previous investigation made in the area. It should be in sufficient detail to be reasonably sure that an overall plan close to the optimum has been developed.

In making pre-feasibility studies of an area, it is essential that accurate aerial surveys be available. For reconnaissance studies of this type, a scale of 1:25,000 with a 10-foot contour interval should be adequate. If sufficient control is obtained, the photographs may be blown up to 1:5,000 and utilized for the detailed investigations. It is recommended that the use of the latest remote sensing techniques be investigated, as cloud cover presents no problem. Also, these techniques often obtain additional information on soils, vegetation and minerals at little extra cost.

The proposed plan may be of a general nature such as the overall water resources development that includes an irrigation system, flood control, domestic water supply and a fishery project, for example. The overall plan may be accomplished in stages with the first being the development of an irrigation system for rice production on a portion of the area, say 20,000 acres. This alternative for the southern part of the area is seen as a possibility in Figure 2. Subsequent stages would then be plans to develop additional areas to the north. Figure 3 illustrates possible pump diversion locations for irrigating all of the suitable lands within the Do-Anambra Rivers Area.

Feasibility Study Requirements

Feasibility studies should be prepared in sufficient detail to determine the economic and financial feasibility of the project and to be the basis for a firm project plan. It should be possible to proceed directly to construction surveys as soon as the decision has been made to build the project and financing is available.

The following is a suggested checklist of work, comprehensive but not necessarily complete, that should be performed during the feasibility investigations:

1. Field Engineering
 - a. Topography of the project service area on a scale of 1:4,800, with a contour interval of 2 feet. This work could probably be done best by aerial photogrammetric methods.
 - b. Topography of sites of project features, at scales and contour intervals appropriate for each site.
 - c. Alinement surveys of canal lines, drains, levees, and channel improvements.

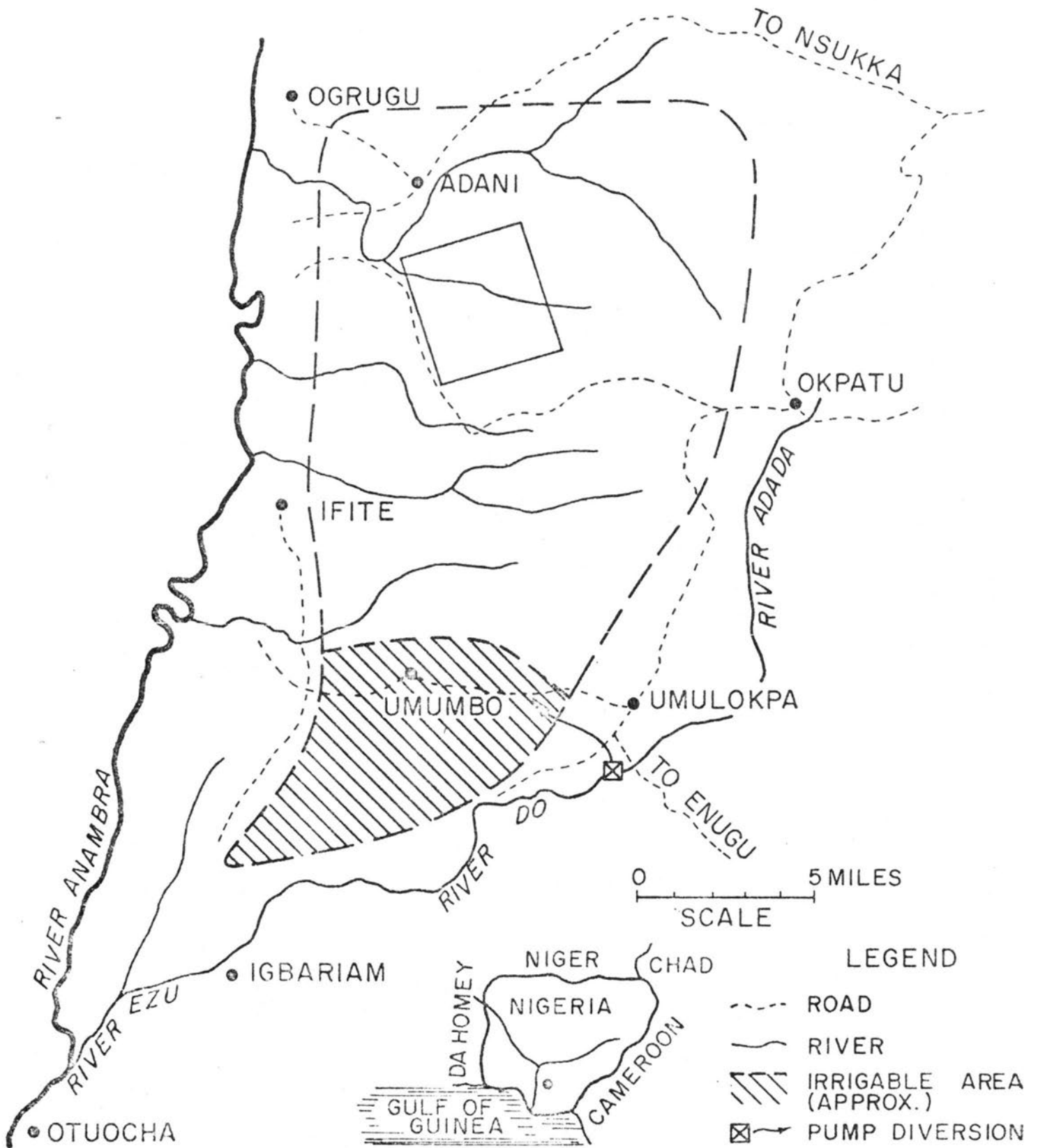


FIG. 2 ALTERNATIVE FOR PUMP DIVERSION TO IRRIGATE APPROX. 20,000 ACRES

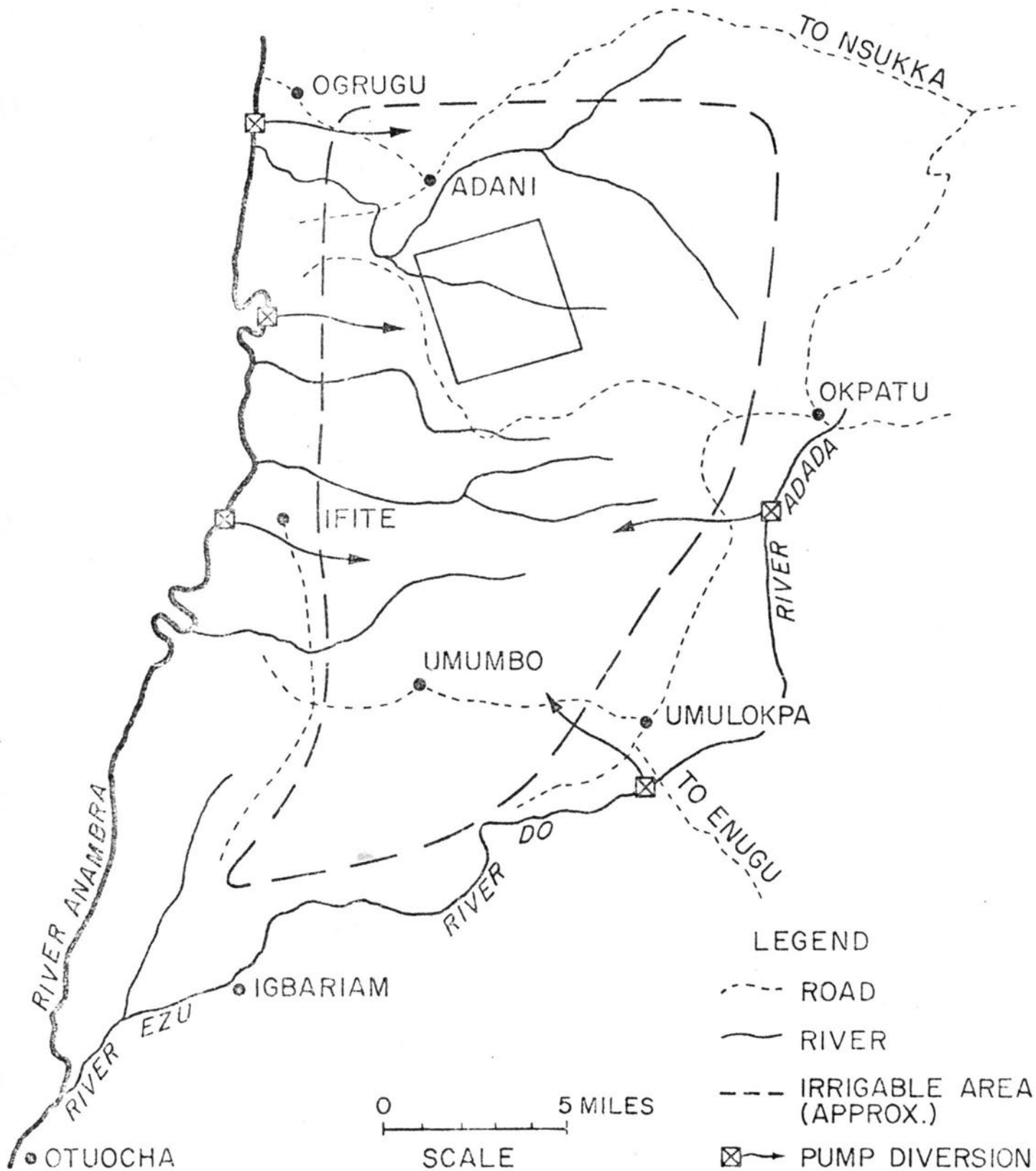


FIG. 3 POSSIBLE PUMP DIVERSIONS TO IRRIGATE DO-ANAMBRA RIVERS AREA

2. Geology
 - a. Regional geologic studies
 - b. Geologic studies of project works including, as appropriate: mapping of surface geology; foundation exploration, including drilling; exploration for and testing of construction materials.
3. Hydrology
 - a. Determine available surface water supply in area. Since streamflow records are essentially non-existent, the Nigerian Government should immediately establish (or in a few cases re-establish) streamgaging stations on the major rivers and its tributaries. This would include but not be limited to gaging
 - (1) the Anambra at Ogrugu and Otuocha
 - (2) the Do at Umulokpa
 - (3) the Ezu at Igbariam
 - (4) and the tributaries, the Obing, the Okpu and the Iyiakwa.
 - b. Make flood control studies that would
 - (1) estimate flood control magnitudes
 - (2) estimate flood damages
 - (3) select flood control plan
 - (4) estimate flood control benefits
 - c. Studies of water requirements of crops expected to be grown in the area.
 - d. Ground water studies, coordinated with subsurface drainage investigations.
 - e. Analyses of quality of water supplies.
4. Land Classification
 - a. Detailed classification of project lands, based on standards that correlate economic and physical factors relating costs and returns of production under irrigation farming.
5. Drainage
 - a. Necessary studies to determine the need for subsurface drainage. These should include deep borings to determine characteristics of subsoils, observations of ground water and field permeability tests.
6. Agricultural Economic Studies
 - a. Basic irrigation and agronomic data would be obtained from studies on the pilot scheme.
 - b. Studies of marketing, transporting, and processing various crops and livestock expected to be produced on the project.
 - c. Economics of controlled livestock production.
 - d. Family farm income requirements.
 - e. Labor requirements--both family and hired--per farm unit and for various crops.
 - f. Farm budget studies.
 - g. Estimates of project benefits.
 - h. Estimates of payment capacity of irrigators.
7. Office Engineering
 - a. Designs of project features.
 - b. Estimates of construction cost, including land preparation, on-farm works, and permanent operating facilities.
 - c. Estimates of project operation, maintenance, and replacement costs, including all administrative costs.

8. Multiple-use Studies
 - a. Domestic water supply.
 - b. Forestry potential.
 - c. Fisheries.
9. Financial and Economic Analysis
 - a. Determination of benefit-cost ratios for project justification.
 - b. Allocation of project costs to appropriate purposes.
 - c. Determination of requirements for project repayment.
10. Sociological Studies
 - a. Present land tenure.
 - b. Land acquisition problems.
 - c. Removal of homes and unharvested crops.
 - d. Resettlement studies--homes, villages, schools, and other community buildings, etc.
 3. Infrastructure required to accommodate changes brought about or necessitated by project--transportation, processing, financing, education, government, structure, etc.

Schedule of Investigations

A preliminary estimate is that about 5 years should be allowed for the feasibility investigations of the Do-Anambra Rivers Area. This would include about 2 years for the inventory of resources and plan formulations (reconnaissance or pre-feasibility study) and 3 years for the detailed studies themselves.

It would be desirable that the pilot scheme be in operation for a few years before the agricultural economic studies are completed. A possible time table for accomplishing the various phases leading up to the construction of the proposed project is shown in the following approximate schedule:

	Year				
	1	2	3	4	5
Rehabilitate Uzo-Uwani irrigation system	x				
Complete Uzo-Uwani pilot scheme	x	x			
Pilot scheme in operation		x	x	x	x
Inventory resources	x	x			
Formulation of plans		x			
Feasibility study			x	x	x

Personnel Requirements

A 4 man team for a period not to exceed 90 days should be adequate for making the reconnaissance appraisal of the Do-Anambra River Area. An engineer, an agricultural economist, a soils scientist and an agronomist would probably make up the team. A forester and a fishery specialist may be needed for a brief period. The reconnaissance team should be scheduled following completion of the aerial photographic survey. A rough estimate of the cost of the reconnaissance team and the aerial surveys including the processing and plotting of the topographic maps is in the general area of \$125,000. This estimate will depend in large part on the techniques and the detail of the aerial survey, on the availability of information and on the team requirements. It does not include making any other extensive basic surveys pertaining to the soils, geology, hydrology, etc. It is assumed that other than streamflow measurements, sufficient information exists for the pre-feasibility or reconnaissance study. The reconnaissance team should obtain information on methods and costs for the necessary detailed investigations.

For the detailed investigations, a much larger team would be necessary. This would in all probability include one or two project engineers, a geologist, several field and design engineers, a draftsman, two or three hydrologists, two field soil scientists, a drainage engineer, an agricultural economist, a sociologist, one or two administrative officers, a report writer, stenographers and clerks and a local survey crew and laborers. The exact number of the above personnel would be ascertained by the reconnaissance appraisal.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations given in this report are the result of a limited field examination of the Do-Anambra Rivers Area, a review of available information and discussions with key personnel in the Ministry of Agriculture and Natural Resources of the East Central State.

Although the team encountered difficulty in traversing much of the survey area because of damaged bridges, there was sufficient evidence to indicate that the area has a definite potential for being developed into a major food producing region. The development, however, would probably be on the costly side. A major portion of the area will require extensive clearing of existing vegetation prior to any land forming for irrigation. Flood protection may be required for some of the more productive sections such as for rice. A pumping lift of approximately 100 feet would be required to divert water on to parts of the area. Nevertheless, the team concludes that

- (1) a basic survey of the resources, both natural and human, of the Do-Anambra Rivers Area, is definitely warranted.

- (2) the formulation of an overall plan for the development of these resources be initiated.

Studies that are conducted along these two lines are essentially of the reconnaissance or pre-feasibility type.

In inventorying the area, the first step should be obtaining a set of aerial photographs on a scale of at least 1:25,000 with a contour interval of 10 feet for the entire Do-Anambra Rivers Area. Since the detailed feasibility investigations will require topographic maps with a 2-foot contour interval, it may be possible to obtain the 1:25,000 photos with sufficient control so that they may be blown up to a 1:5,000 scale and utilized to obtain an adequate contour interval for topographic mapping.

The reconnaissance would be better scheduled after the maps have been obtained to be of value to them during their pre-feasibility study. Also, logical boundaries within the total area should be selected for programming the basic surveys in the event limited financial support is available.

Prior to or at least concurrent with the resources survey and plan formulation studies, the team recommends that the Uzo-Uwani irrigation system be restored to operational status. The team also suggests that this project function primarily as a pilot scheme for the development of the entire area rather than as a farm settlement scheme as was formerly the case.

The establishment of a water resources use policy and necessary institutions for administration and enforcement is suggested. The state water policy should be designed toward a resources orientation as opposed to the traditional sectorial or use-orientation in order to optimize through integration or combination the available resources. The substantive water law provisions of the code should refer to the allocation, distribution and utilization of surface and sub-surface waters, the rights of the water users, provisions with respect to both quantity and quality aspects of the resource.

In the water laws, other aspects to concentrate on are: (1) who owns the water and who determines the rights, duties and liabilities of individual water users; (2) who administers the diversions, awards the rights to diverts, and assures continuation of these rights; (3) the basis of the right to use water whether upon capital investment and beneficial use or some other criteria; (4) who shall enforce the water laws, whether it is an administrative body or the courts.

It is recommended, that in addition to establishing a water policy and an administrative system, that water organizations at various levels also be designed and implemented.

The design and implementation of an integrated approach to natural resources and human resources utilization is suggested. The preparation of an East Central State resources development plan should be undertaken with the purpose to provide

a broad, conceptual framework for the orderly, efficient development and management of the state's natural resources in conjunction with meeting the national objectives of food production, redistribution of people, and improving the general well-being of all the State's inhabitants.

A major recommendation is that a land title recording system be designed specifically for the conditions existing in the East Central State. The proposed project should serve as a catalyst for land reformation. Such a land title recording system should encourage the consolidation of holdings into economic units but would not preclude individual or communal ownership. It should also encourage the concept of "undivided interest" in land held by the youngest sons to permit or entice them to find employment elsewhere while allowing the eldest son or one who desires to remain on the farm the right to purchase over time the interest of the non-residing owners.

In addition to the economic, legal, social and physical-technical studies to be conducted in the inventory and assessment of resources, it is highly recommended that a study of the effect of the proposed project on the surrounding environment be conducted. Certain international funding agencies require an environmental impact study. To include it within the initial request would demonstrate a concern for long-range effects and planning as well as provide the basis for an opportunity cost evaluation.

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