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FISCAL YEAR 1972

IMPROVING CAPACITY OF CUSUSWASH UNIVERSITIES FOR WATER MANAGEMENT FOR AGRICULTURE

REPORT NUMBER III

VOLUME I

Submitted by

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

May 1973

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ORGANIZATION OF
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FOR SOIL AND WATER DEVELOPMENT IN
ARID AND SUB-HUMID AREAS, INC.
(CUSUSWASH)

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PREFACE

This constitutes the annual report of the three 211(d) grant recipient member universities of the Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas, Inc. (CUSUSWASH) for the fiscal year 1972. The grantee universities are:

University of Arizona	Contract AID/csd 2457
Colorado State University	Contract AID/csd 2460
Utah State University	Contract AID/csd 2459

The purpose of the grants is to enhance the competence of these universities in the field of water management for agriculture. The programs were initiated July 1, 1969.

CUSUSWASH was designed to facilitate the expeditious exchange of views and information, the joint undertaking of projects or programs that might tax the capacity of any member university standing alone, for joint planning and review of accomplishments under assigned programs and for coordinated leadership for the inter-university aspects of these programs.

Besides the three grant recipient universities listed above, the University of California is also a fully accredited member of CUSUSWASH.

The preparation and submittal of the FY 1972 annual report has been delayed for a period of months because of a change of procedure initiated by AID/Washington. Earlier in the year AID requested the grant recipient member universities of CUSUSWASH to submit draft copies of their annual reports covering their assigned portions of the "optimum utilization of water resources for agriculture" so that the reports could be reviewed in the Office of the Associate Assistant Administrator in Washington, D. C. prior to their being finalized. The Washington review produced many

helpful suggestions for the revision of individual annual technical reports. These suggestions led to major or minor revisions in all reports with the result that the final revisions did not reach the office of the Executive Director until mid May. It was determined that it would be unprofitable to proceed with finalizing a covering document until the report from each of the grantee member universities was at hand.

In the preparation of this year's report, a separate discussion of the accomplishments of the grantee institutions is presented somewhat along the lines that guided the submittal of the annual report for the previous two years. Additionally, the activities of CUSUSWASH as such have been given far greater coverage in this report than in previous years. The discussion of CUSUSWASH activities also covers a period extending into the first part of calendar year 1973.

211(d) Grants and CUSUSWASH

It is essential that the relationship between CUSUSWASH and its grantee member universities and operations of both as they relate to 211(d) grants be understood. As far as the grant recipient university members of CUSUSWASH are concerned, the grant agreements between them and AID govern all operations under the grant. CUSUSWASH as such was organized prior to receipt of any of the grants. The objectives of its founding, however, were essentially those sought by the grants. As far as the grants go, CUSUSWASH functions entirely as a facilitating mechanism. There is no conflict between the purposes of CUSUSWASH and the aims and objectives of the grants and no attempt is made by CUSUSWASH to take over any of the responsibilities of any part of or function of any grant.

SUMMARY

The activities of the three grant recipient member universities of the Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas, Inc. (CUSUSWASH) are covered in this report of CUSUSWASH. The University of Arizona, Colorado State University and Utah State University are recipients of grants under Section 211(d) of the Foreign Assistance Act. The fourth member university, the University of California, has no 211(d) grant in the field of water management but is active in that field under other auspice and is a highly important and respected member of the consortium.

Each of the four CUSUSWASH universities has been active for upwards of a century in providing leadership in "water management for agriculture" and all have been active in technical assistance programs both on their campuses and throughout the developing world. The impact of grant funds has operated to improve and enhance this attained level of excellence at the grantee universities and has operated significantly to increase their capability for overseas service in the technical areas of primary concern to them. The University of California continues to add to its tremendous stature in international assistance through contracts with the Ford Foundation and others.

Increased teaching competence is shared by 17 departments in the three grantee universities. During the last year (FY 1972) the teaching programs have been strengthened. Nine new courses have been added and ten have been overhauled and refurbished. Seven new staff members of high distinction and competence have been added in part with 211(d) funding.

Material progress has been made in increasing both the depth and utility of library collections partially with grant funds. Forty-one technical reports and at least one manual have been issued and the preparation of additional reports, textbooks, manuals and monographs are now underway. Forty-four graduate students were supported wholly or in part with grant funds.

The competence of member universities in language fields has been advanced and consideration is being given to offering several basic water development and management courses in at least two languages at member universities. At Utah State one course, Water Development in Latin America, was offered in Spanish during the past year. Some of the teaching aids that have been prepared are already available in two languages and are readily susceptible to additional translations. All member universities are prepared to counsel with students from the developing countries in their own tongues as the need arises.

New staff members are heavily engaged in research. Among the programs receiving attention as they relate to water management for agriculture are hydrologic decision making, systems analyses, development of stocastic models of preciptation as stream flow, water use, drainage and irrigation structures, computer assisted resource education systems, political science, sociology and public administration.

The consulting capability has been increased and additional linkages with developing countries have been established through trips undertaken for 211(d) and other purposes and through visits of agricultural and water leaders to the campuses of member universities.

Inter-university programs on publications, seminars and student faculty interchange are being actively developed by the Council.

The Annual Technical Reports of the 211(d) grantee member universities of CUSUSWASH are made a part of this annual report. They are regarded as the best source of information regarding the operations of individual grantee universities under 211(d) grant programs.

ACCOMPLISHMENTS OF CUSUSWASH INSTITUTIONS

DURING FY 1972

If the first and second years' operations under the grants were to be characterized by any one single term, it would have to be known as the years of initiation. The availability of funds under the grants during these years made possible recruiting of key personnel, the addition of new courses, strengthening of the bibliographic resources and the undertaking of essential work in some instances long deferred, and in fulfulling cherished aims of the member universities. Additional progress in all of these areas has occurred during the report year.

As far as the challenges and objectives of the member universities are concerned, they remain essentially unchanged. Basically, these objectives anticipate increasing the institutional capability for international service in the following areas:

1. Improvement of teaching capability
2. Development of increased research competence
3. Development of increased capacity for consulting and service
4. Increased involvement in international programs

Each of these objectives, if they are to be attained, require increased technical competence and capability, a greater number of qualified professionals who can be marshaled in the solution of any given problem or set of problems or in gaining increased strength and an increased understanding of the problems of developing countries and their programs, resources and objectives. The increased capacity of the CUSUSWASH institutions, however, is greater than the portion that is specifically financed by 211(d) funds. These funds do have a leavening effect that has

initiatives across the board. Related research programs, new courses, language training, library acquisitions, area studies and collections have reached a new high level because of 211(d) interest and support.

The increased capacity of CUSUSWASH institutions is reflected in many areas. It is evident in terms of enlarged and more comprehensive curricula and in an expanded staff of highly qualified professionals. It is apparent in increased research competence, increased consulting services performed and expanded graduate student training programs. It is demonstrated in expanded library collections and in the organization of this material to make it more accessible to researchers, students and staff alike. It is measured in a constantly increasing flow of manuals, technical reports, teaching materials and aids, and in a more active program of collecting and analyzing of information relating to developing countries. It is evidenced also in improved attitudes, increased interest in languages and language training and is sharpening programs covering information exchange with developing countries.

The progress reports recorded earlier evidenced variation with the individual initiative and institution and covered the spectrum from "less than hoped for" to "significant," but in the case of each initiative a start had been made.

If a single term were sought to characterize the current year's operation under the grants, it would probably be "consolidation." The programs initiated during the first years were continued. In some instances they were expanded. In other cases they are undergoing review and adjustment to make them work more smoothly and effectively. The Consortium and its member institutions have:

1. Probed and are continuing to probe the capacity of their creation CUSUSWASH to see if it can be of real help in attaining the reasonable development objectives of the member institutions.

2. Incorporated CUSUSWASH to make it more responsive to observed needs.

3. Brought going programs as they are carried out by the grantee member universities and by CUSUSWASH more nearly into the focus of the development objectives of the 211(d) grants and the rationale that prompted the establishment of CUSUSWASH.

INCREASING RESEARCH COMPETENCE

The competence of grantee universities to undertake and accomplish meaningful research, particularly in the international sphere, has been materially enhanced by the availability of 211(d) funds. During FY 1972 these funds have been available to support many independent projects and a total of 41 graduate students working on them. They have aided in securing new professional staff to guide individual research efforts and have supported staff travel to development countries through which a greater perception of research potentials and requirements has been gained.

Colorado State University

The large research capability of Colorado State University has been measurably enhanced by the grant of 211(d) funds. In Ag Engineering, the research effort continues in control and measurement of water in conveyance channels. The departments of agronomy, sociology and anthropology, geology and political science continue research projects underway or programs that will lead to research projects.

In all seven graduate research assistants have benefited from grant funds. These GRA's attend the International Interdisciplinary Seminars and participate in both leadership of the meetings as well as discussions. Some have participated in the field trip, some in weekly project leader's meetings, and all received faculty consultation and guidance on an interdisciplinary basis with regard to research programs and projects, course offerings and special activities on problems and needs of the less developed countries.

Utah State

Results from the research program previously initiated are only now becoming evident. Considerable time has elapsed between the time when staff additions were considered, new members added, as well as graduate students selected and trained and projects selected. Evidence of research accomplishments are now becoming increasingly apparent. Much of the information gained is now in the prepublication or "in press" stage or in theses.

The large coordinated program of research in the field of on-farm water management includes work sponsored by the Utah Agricultural Experiment Station, the Environmental Protection Agency, the Office of Water Resources Research and AID Research contract AID/csd 2167 as well as that supported directly from 211(d).

As teaching competence and library resources have increased, so has research capability. Each new staff member is expected to assume some research responsibility and each graduate student supported by the grant is engaged in research. At least a part of this research is conducted in one of the Latin American countries. In all, 16 graduate students have been supported at least in part by the grant. During the past year five masters theses and one doctorial dissertation have been completed. Research covered by these theses and other projects still underway has led to preparation and submission of many separate reports.

University of Arizona

At the University of Arizona the increased research competency in the utilization of systems analysis techniques has been channeled into two general activities. Hydrologic model building is one while modeling the decision-making process itself is the other. Simulation of a watershed's behavior as a means for determining the effect of man's intervention is an

important aspect in water resources decision making. Projects under the hydrologic modeling activity which involve six faculty members include:

Development of stochastic models of precipitation and streamflow.

Computer simulation of the hydrologic behavior of watersheds.

Runoff farming in semi-arid areas.

Water use efficiency of selected crops.

The above projects are inputs into the management activity which is devoted to developing decision making models for the optimal utilization of a watershed's resources.

The research programs at the member universities continue largely in the completion of programs initiated in previous years.

Linkage

The subject of linkage is discussed in the reports of the member universities and based on these reports and their individual judgments, several hundred important contacts have been established throughout the world to link the resources of the member universities with the problems and programs for water management for agriculture in the developing world.

Of the dozens of linkage examples accruing from a better and broader staff, which in turn is traceable at least in part to 211(d) grants, a few examples may be helpful here.

The distinguished scientists and educators who make up the Board of Trustees of CUSUSWASH have traveled extensively throughout the year and have met many important people in their travels. In turn they have been visited by important persons from abroad, thus strengthening old ties and making new ones to closely link the member universities with the developing nation the world around.

Trips made abroad by faculty and staff in connection with regularly 211(d) supported activities has produced added linkage with the developing countries.

Dr. Maurice Albertson of Colorado State and William I. Palmer of Utah State are members of the Executive Committee of the United States Committee on Irrigation, Drainage and Flood Control. Many other staff members are also members of ICID. Thus a measure of linkage is established with the many thousands of members of ICID who are the leaders in water resource development and management fields in more than 60 nations of the world affiliated with the International Commission on Irrigation, Drainage and Flood Control.

INCREASING THE TEACHING CAPABILITY

The availability of 211(d) funds continues to contribute significantly toward building increased teaching capability at the grantee universities in their assigned areas of interest. The curriculum of each of the universities has been broadened, new courses have been added and, where indicated, many courses in the curriculum encountered in developing countries have been overhauled, updated and improved to give them greater relevancy as regards problems. New teaching and research staff has been placed under contract and many graduate students have been brought to the university campuses for graduate training in development subjects.

Seven completely new courses were included in the curricula of grantee universities with assistance from 211(d) funds--one at the University of Arizona and three each at Colorado State and Utah State, with one of these courses, "Water Development in Latin America," taught in the Spanish language. Additionally, major revisions were made on nine courses offered--one at the University of Arizona and eight at Colorado State. In part because of the entrainment effect of the 211(d) grant, but with no direct contribution from the grant, four water oriented courses were added to the curriculum at Colorado State. Virtually all water related courses given at the grantee universities have been reviewed and revised since the advent of the 211(d) grant in an attempt to enhance their relevancy to problems in developing countries. While some of this cost has been borne by the 211(d) grant, a major portion of it represents entrainment.

Many additional courses other than those discussed above have been added or revised at the three grantee universities during the first years of the grant, and the leavening or entrainment process is everywhere

evident in course development. You add a course which may be keyed to the problems of a few developing countries and end up by revising and modernizing the entire curriculum.

INCREASED CONSULTING CAPABILITY

Major progress has been recorded in the actual consulting assignments filled as well as in increasing the competence of staff to initiate consulting efforts. Consulting assignments abroad have been performed by staff members from all grant recipient universities. This has been made possible in part at least by increasing the depth and competence of the staffs of these institutions by the availability of 211(d) money.

ENTRAINMENT

Under Title 211(d), grants have been made to universities and colleges to increase their 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. The total investment has not been large. The impacts of this investment, however, have been great and have extended throughout the entire staffs of the universities and throughout their entire operations in connection with international development and foreign assistance. This process of extending benefits, capabilities and accomplishments beyond the basic grant in this report is termed "entrainment."

The evidence of entrainment is readily apparent in many areas. The quantifying of entrainment benefits, however, is more difficult to do. As of this point in time few precise measures are available and the challenges to quantify rather than describe entrainment values looms large and must be a continuing effort.

The impact of the 211(d) grants to the grantee members of CUSUSWASH are described in the case of six major areas of interest. In describing these it should be noted that it is difficult, if not impossible, to draw a sharp line between contributions made directly by the university and those that came through investment of 211(d) funds. The significant fact is that the total capability and competence of the grantee universities has been increased by a much greater amount than the amount the grant would make possible standing alone.

Building of Staff

The availability of grant funds to supplement those that would have been regularly budgeted for the employment of staff obviously makes it possible to bring to the campuses additional staff members. Under the 211(d) grants highly qualified staff members have been added at all three of the grantee universities. Moreover, the availability of even relatively small amounts of grant funds tends to invite the universities "to go the additional mile" and invest any additional funds that they can possibly find to round out and improve the total staff.

As the total staff is increased, additional activities can be undertaken. It is obvious that staff over and above the number needed to carry out the programs and directives of the Boards of Regents and the State Legislature does not and cannot exist in any depth. Accordingly, as a general proposition, if new efforts are to be undertaken, the staff must be supplemented or other activities curtailed. Grant funds have made it possible to supplement existing or foundation staff capability by the simple expedient of adding new staff members.

Staff Capability, Balance and Utilization

The entrainment phenomenon is perhaps most evident in the improvement of staff capability, balance and utilization. Grant recipient members of CUSUSWASH have benefited in this matter. Benefits accrue in the following specific instances:

1. The addition of carefully selected, potentially highly valuable junior staff members can often free up the time of senior staff members so that they can make increasing portions of their time available for teaching, research and other grant-associated activities.

2. By supplying an administrative assistant from grant funds, it is frequently possible for deans, department heads and other senior staff to transfer administrative chores and burdens now reposing with them, thus making it possible for them to spend more time in teaching, counseling, supervising research or performing other grant-associated activities.

3. The careful selection of a single key professional may add greatly to the stature and balance of a staff and thereby increase the potential of the entire staff. The addition of such a key man complemented by existing staff may also open up new avenues to be explored in research programs that were previously inaccessible.

4. The availability of the additional cash provided by the grant supplements university resources to a point where individual key expertise can be recruited to bring to the campus the skills required. To do this may require the input of only limited amounts of grant money to supplement regular departmental budgets. Moreover, the grant itself tends to attract the desired individuals by providing the challenge and assurance of funding of a reasonable program.

Teaching

The availability of supplementary financing through 211(d) grants has enabled the member universities to provide improved teaching facilities and devise new methods of teaching. The impact of these developments extends far beyond those staff members most directly concerned with the increasing competence in water management and will extend far beyond the term of the grant.

The development of improved methods and facilities draws deeply upon not only assigned new staff members, but also upon the ideas, suggestions

and efforts of the basic or original staff. The facilities and systems evolved, moreover, will have a lasting effect on both domestic and international programs of member universities that will continue long after the expiration of the grant. The development of a computer oriented instruction program known as CARES, Computer Assisted Resources Educational System, developed at the University of Arizona with the program of mathematical modeling and other devices and services essential to it, can be called upon for a great variety of services to accelerate and make effective methods of information dissemination in any language the world over.

Colorado State has developed an excellent interdisciplinary seminar to bring social and physical sciences to bear in proper mix in water management for agriculture programs. Use of this interdiciplinary seminar format is now being considered for use at the University of Arizona and Utah State University. They are also developing sound movies, photographic slides and other visual aids that can be employed by the entire staff as opportunity is presented.

Utah State is advancing its work in the use of visual aids. At year's end a series of 116 slides on sprinkler irrigation with a taped narrative was completed. These are available in the Spanish language as well as in English.

All three universities are working to increase or improve technical information and to make it widely available through presentation of technial papers, professional publications, books, textbooks, monographs or articles.

The entrainment effect is operating and in each case is significant because "seed capital" made available in relatively small amounts stimulates individual staff members who are paid largely from university funds to

extend and improve their knowledge and effectiveness in this broad field of international development.

Acquisition of Library Materials

Perhaps the most lasting values accruing from monies that come to CUSUSWASH universities because of 211(d) grants is found in the strengthening and enlargement of the universities' libraries in making them more accessible and readily usable. In this area entrainment is graphically represented. At Utah State University, for example, the investment of $17,600 in 211(d) money has been overmatched by an investment of $20,470 during FY 1972 from regular library money. At Arizona and Colorado like entrainment is apparent.

The chance to add to library holdings by the judicious use of 211(d) money tends to invite dedication of regular university funds in amounts greater than either the grant budget or the regular budget. Grant monies thus tend to bring the logical and reasonable aims of the library within the realm of the attainable and to stimulate the additional inputs from regular funds while this condition exists. The quality of the libraries is enhanced with the addition of each purchased book.

The challenge of making library holdings more accessible and usable for the patron has resulted in development of various extremely convenient and usable bibliographies and is now leading to installment of rapid retrieval systems.

Two other examples of entrainment are evident in the library programs of the member universities. These are:

1. Hundreds of important publications accrue to grantee libraries as gifts simply because requests are being sent to donors under an active library program.

2. Experience to date indicates that thousands of valuable works are being made accessible and usable by finding and organizing "fugitive material" existing in special collections, archives and other separately maintained places.

Ability to Conduct Research in Assigned Areas

It is axiomatic that the greater the depth and strength of staff available for research activities and the greater the wealth of bibliographic material available, the greater is the university's ability to undertake meaningful research projects and programs; the greater also the number of areas or fields into which this research effort can be directed.

In all, 44 research graduate assistants were aided as a result of the AID grants. Their exposure to proven technical direction by outstanding scientists assures a continuity of competence and research ability at the CUSUSWASH universities. Many projects were carried out in the international setting and a larger number are underway on the campuses of member universities.

Travel

A level of entrainment is exercised on the entire staff of grantee universities by the judicious use of both domestic and international travel. The domestic travel enables the individual staff members to attend conferences and symposia and participate in all forms of information exchange in this country, while international travel makes possible for the top professionals to become the eyes and ears of the university in

assigned areas of interest and to bring back information on specific subjects of interest and cultural observations needed in the total training effort. The product of both U.S. and international travel in net is to bring back vast amounts of scholarly information to illuminate and edify staff members and students who remained at home.

Throughout last year many domestic and international trips were made by CUSUSWASH university members to participate in meetings, conventions, conferences, etc. in the U.S. and abroad. Many of these trips would not have been made had it not been for the 211(d) program; yet, the percentage of the total cost of travel actually borne by the 211(d) budget remained relatively small.

CUSUSWASH DISCUSSED

The Council for United States Universities for Soil and Water Development in Arid and Sub-Humid Areas, Inc. (CUSUSWASH) came into being in 1967 in recognition of the mutuality of major interests and the inherent strengths and opportunities possessed by great universities working together. In 1969 three of the four received grants from AID under Section 211(d) of the Foreign Assistance Act of 1961. The purposes for which the grants were given and the objectives for which CUSUSWASH was created were and are virtually the same. CUSUSWASH has emerged as a force in increasing the achievements of the grantee universities under the grants. Accordingly, in addition to the accomplishments of the universities themselves in attaining grant objectives, some of the operations of CUSUSWASH are here reported. These are reported under the following headings:

Increased Gains Expected in Tying the Grant Recipient Universities Together

Development of a Coordinated CUSUSWASH Program

Accomplishments of CUSUSWASH

Liaison with Other Consortia and Developmental Agencies

CUSUSWASH Incorporated

Office of the Executive Secretary/Director

Meeting the Costs of Operating CUSUSWASH

Added Linkage Attained

INCREASED GAINS EXPECTED IN TYING THE GRANT RECIPIENT UNIVERSITIES TOGETHER

While each university member of CUSUSWASH has a recognized capacity for working alone on various technical assistance projects, a strong conviction was and is held that the sum of the expertise possessed by the staffs of the four member universities if added together would be far greater than that of any single university standing alone; and contrary to mathematical law, the total competence of CUSUSWASH would be greater than the sum of its parts. It being further held that tying the universities together for purposes of (1) exchange of information in all its forms (2) systematic discussions of individual problems among professionals engaged in similar or related efforts for the benefit of all (3) rotation of responsibilities in the conduct of seminars and (4) the utilization of other methods of achieving unified competence, would result in significant gains in the case of all of the member universities.

The CUSUSWASH format provides a convenient method for the pooling of resources for the joint undertaking of projects and programs which might be beyond the capacity of any individual member to undertake alone. It at the same time assures each university its right to maintain individuality and identity.

Under the following topics specific examples of gains achieved are discussed:

Face-to-Face Disciplinary Discussions

During the last fiscal year two large, semi-annual CUSUSWASH meetings were held which brought a total of 88 top executives, staff members and

graduate research assistants from the four CUSUSWASH universities and AID/Washington together. These meetings were structured to encourage a free exchange of ideas at both the inter-university and interdisciplinary levels and have led to greater understanding among the CUSUSWASH members regarding the individual university responsibilities, programs, aspirations, potentials and capabilities.

In the CUSUSWASH mechanism, opportunity is also available for the organization of committees, task forces and working groups to undertake and deal with common problems regardless of the disciplines involved, and several such special subject matter meetings were held in 1972. Through these forums a free exchange of information on complex subjects, programs and problems has been realized and, in turn, it has been possible to assemble the essential competence from the staffs of member universities to solve problems or devise procedures for solving them. The mechanism, moreover, provided opportunity for a continuing dialogue among the deans, department heads, faculty and research specialists at any time and on any subject. The frequency of such discussions is increasing.

During the last year a number of special seminars have been held at Tucson, Fort Collins and Logan in which visiting professors from other member universities participated.

Information Exchange

Aside from the exchange of views at seminars and major and minor meetings, opportunity to exchange information is offered through an active publications program. The printing of technical reports, theses, monographs and other writings are coordinated by the CUSUSWASH committee on Acqusitions, Storage, Retrieval and Distribution. The use of

microfiche, microfilm, television, visual aids, coordinated voice and slide recordings in the dissemination and exchange of information is being made and increased use of these media is being considered.

The joint sponsorship of all of these means of information collection and dissemination through the stimulus of CUSUSWASH appears to have gained momentum during the years.

When the Publications Committee was created, opportunity to improve both the depth and the utility of the bibliographic resources available at grantee universities led to the appointment of special committees to take the library related segments of the work originally assigned to that Committee. During the July 8 and 9, 1972 CUSUSWASH meetings in Logan, a Library Committee was appointed to accelerate and sharpen the exchange of information on holdings of the libraries of the member universities. This Committee met with the Board of Trustees in Fort Collins in July 1972. Substantial progress has been made by each of the universities over the past year in bringing into the library "fugitive material" held in private collections, individual and departmental collections, but university owned, which has existed in each of the campuses without its being available for use by library patrons.

Committee on Integrated Approaches to Water Management Problems

The Committee on Integrated Approaches to Water Management Problems, previously appointed on an ad hoc basis, was given continuing status during the July 1971 meeting. It is currently working actively in developing ways of improving and coordinating technical efforts. A

subcommittee of the Committee, known as the Irrigation Management Program (IMP) has produced a highly creditable proposal titled "Soil and Water Management in Irrigated Regions," which will soon be published. From it will come several proposals for highly important research in the broad field of water management for agriculture.

DEVELOPMENT OF A COORDINATED CUSUSWASH PROGRAM

Efficient water use in crop and livestock production is imperative in meeting the world's reasonable agricultural goals and needs. Despite significant developments in improved crop species such as short stem wheats, improved corn and the so-called miracle rice, the world by and large has not been able to emerge from the shadows of impending famine. This is especially true in the case of the developing countries. The importance of water in the mix of agricultural inputs necessary to increase agricultural productivity is well known. It has been recognized by every major governmental institution in this country from the White House and the Congress through the Bureaus of Agriculture and Interior and the Agency for International Development that are directly concerned with the problem. Attaining efficient water use, moreover, occupies a position of high priority in the programs of the Food and Agricultural Organization of the United Nations and in the programs of other developmental agencies the world around.

In 1967 four major western universities with a cumulative total of over 400 years of successful experience in grappling with the problems of inadequate rainfall and short water supply banned together under a broad charter agreement to create the Council of United States Universities for Soil and Water Development in Arid and Sub-Humid Areas (CUSUSWASH). Subsequent to the establishment of CUSUSWASH, the University of Arizona, Colorado State University and Utah State University received grants under Title II of Section 211(d) of the Foreign Assistance Act. The University

of California, although not a grant recipient, participates in the activities of the Council as a regular member. It also is active in international programs funded under the Ford Foundation and other grants.

The establishment of CUSUSWASH and the initiation of programs under Section 211(d) constitutes a logical extension of the U.S. land grant university system to the problems of international assistance. The expertise of the American land grant universities is widely recognized as a major source of strength in meeting man's ever-growing needs for food and other agricultural products throughout the world. Historically, these universities have participated in the international assistance programs since these programs formally began following World War II. Even prior to formal entry of this country into the field of organized foreign assistance the land grant universities were active in training thousands of foreign nationals on their U.S. campuses in the subjects now grouped under the heading of Water Management for Agriculture. Since adopting by the United States of foreign assistance as a major instrument of international policy, the land grant universities have continued to serve in marshaling U.S. technical know-how and providing the major source of trained professionals to carry out agricultural assistance programs. The land grant university has also been the model for university creation and development in many of the developing countries.

The CUSUSWASH universities' activities in water management for agricultural production began a century ago and much that is known and has been placed into practice in this broad field has been developed at their research stations. These institutions also have shared to the extent of their financial capacity in the increasing task of international development. As in the case with other U.S. universities, attainment of their

full potential for international service has been somewhat thwarted because of limited state support for international activities and irregular and uncertain support from other sources. This deficiency has been well recognized by the universities, the Congress and the Agency for International Development, who have been concerned about improving the effectiveness of technical assistance.

Section 211(d) of the Foreign Assistance Act, as revised in 1966, was passed as a result of these concerns. This section provides that the Agency for International Development (AID) can support "research and educational institutions for the purpose of strengthening their capacity to carry out programs concerned with economic and social development of the less developed countries."

The organization of CUSUSWASH coupled with grants under Section 211(d) have furthered the areas of joint university-federal government approach to strengthening the capacity of the nation for research and education in the area of water management for agriculture. Considering technical assistance efforts determined to be of national interest, the program has evolved a broad scope in its planning and initiation by the universities in consultation with AID within the agreed upon goals.

Delineation of Responsibility

Water management for agriculture is a complex art embracing or impinging upon many individual arts and sciences. It involves protecting or reclaiming land from excess precipitation or flooding, husbanding and managing soil moisture, optimizing cropping practices to the moisture regime, impoundment, 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 apsects of agricultural operations. The art of transferring technology and of assisting in the related institutional building in the developing countries is also a difficult and complex one which must be merged with the technical arts of water management.

Discussions of how the CUSUSWASH universities might increase their joint capacities to provide resources for agricultural water management began January 31, 1967, at Davis, California. In the interim, prior to initiation of the 211(d) grants, on July 1, 1969, three formal meetings of the Council and one informal meeting of representatives in Washington, D. C. formalized the Council's Charter and Agreement and its organization. Other accomplishments during this period included:

1. development of the objectives and philosophy of the consortium
2. developing an operational procedure for the Consortium
3. conceptualizing the program and assignment or responsibility
4. assistance in preparing specific university proposals
5. interchange of ideas at the university operation level
6. development of plans to implement some specific inter-university activities.

The universities recognized from the beginning that joint cooperation and planning with the federal government was essential in order that programs would be meaningful to technical assistance. Planning and implementation has proceeded with representatives of AID in a spirit of mutual cooperation.

All the CUSUSWASH universities have considerable existing capability and teach some courses in most water management fields. Their students desire and need broad backgrounds that include some exposure to most of them. Extending capacity for <u>international</u> service in all relevant

subjects at each university, however, would be inefficient and wasteful. Rather, leadership responsibility should be identified in each case so that the results may be shared by all. Research is a necessary and important element of all graduate education. In the context of the technical assistance, like teaching, it has two dimensions also: the technical one and the one of extension. While separately administered and reported, complementary research programs based in developing countries are essential to the 211(d) program.

Implementation of programs for all of the topics which are included in the art of water management for agricultural production is not immediately possible. Priorities have been considered and choices have been made. Time is not adequate to go through the decades of agricultural evolution that have led to the present level of technology in the more developed countries. Based on these concepts and considering existing capability and interest of the several universities, assignments were made as follows:

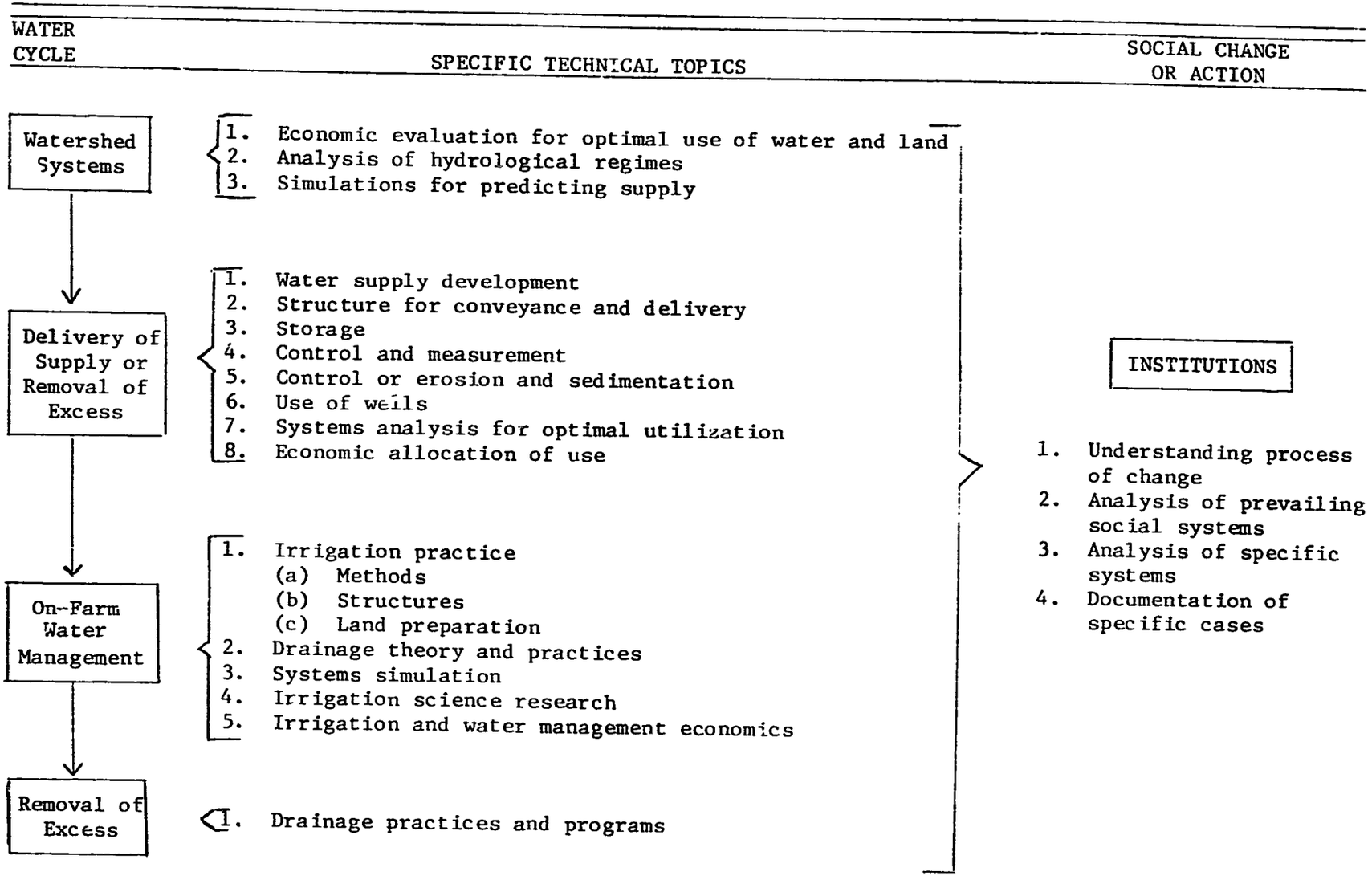
University of Arizona: Watershed management with special emphasis on the science and methodology of applying systems analysis techniques to problems of less developed countries.

Colorado State University: Optimum utilization of water resources: with special emphasis on water delivery and removal systems and relevant institutional development.

Utah State University: On-farm water management for increased agricultural production.

Figure 1 shows systematically how these assignments relate to management of the physical water cycle for use in agriculture. The University of Arizona has responsibility in the first box, shown in the

Figure 1. System Diagram of CUSUSWASH 211(d) Program as Implemented 1969/72



first column; Colorado State University has responsibility for the second and the fourth; and Utah State University for the third. The second column identifies specific technical topics and the third column considers institutions.

Clearly, interactions between the various elements of the water management system are essential. Knowledge of on-farm water needs is essential in order to properly design water delivery and removal systems; likewise, a knowledge of watershed characteristics and a mechanism for predicting water production from them is necessary both to the design of delivery and removal systems and to optimize the use of available water supplies on the farm. Adequate institutional facilities impinges at all three levels; without these institutions neither optimal watershed management, operation of delivery and removal systems, nor management of water once it reaches the farm can be very efficient. Operational coordination by CUSUSWASH has been designed to make sure that products of increased capability flow freely among the several institutions, and to provide mechanisms whereby personnel, consulting advice and know-how desirable for planning and operating the program may be drawn from the common pool. This requires that CUSUSWASH continue both advanced planning and evaluation, and development of specific mechanisms of communication and exchange. Throughout FY 1972 consideration was given to the possibility of increasing the CUSUSWASH capability in attaining all objectives through basic changes in its organization and structure. The search continues.

CUSUSWASH's conceptual plans called for increased capability in "soil and water management for increased crop production and water use" by the University of California. The importance of this input into the system

seems self-evident and the 211(d) recipient universities look forward to adding that capability.

ACCOMPLISHMENTS OF CUSUSWASH

The history of CUSUSWASH, dating back to April 1967, has been characterized by a growing awareness of the tremendous potential possessed by the Consortium and its member universities in providing the technical and professional leadership to the developing nations of the world in the broad field of water for agriculture. Dating from the summer of 1971 the following points are indicative of this trend:

1. CUSUSWASH Opens Formal Office. During the July 1971 meeting the programs of the individual universities and the Consortium were reviewed in detail and the past recommendation that a formal CUSUSWASH office be established and an Executive Secretary appointed was acted upon. The office was established in Rooms 403-5 of the Eccles Business Building on the campus of Utah State University with William I. Palmer named as Executive Secretary. Later in September the office personnel complement was completed with the addition of Mrs. Diane England as secretary to the Executive Secretary.

At the same meeting an ad hoc committee consisting of Dean Peterson (USU), Chairman; Maurice Albertson (CSU); Bruce Anderson (USU); James Officer (UA); Daryl Simons (CSU) and William Palmer (Executive Director) was given the assignment to conduct a review of the accomplishments of CUSUSWASH up to that time and develop recommendations as to how the organization should be modified or adjusted to increase the capability and effectiveness of the Council in meeting its aims and objectives. The committee was also to review development programs then in operation and assess the strengths and weaknesses of the Council for working with

development programs and interests. A series of meetings of the committee was held. These culminated the writing of a report which recommended among other things the incorporation of CUSUSWASH. This led to the preparation of the Articles of Incorporation and Bylaws by the Executive Director. (The details of the July 1971 meeting have been previously reported.)

2. Draft Articles of Incorporation and Bylaws Approved. The winter semi-annual meeting of the Consortium was held in Tucson on January 10-11, 1972, at the invitation of the University of Arizona. Draft copies of the Articles of Incorporation and Bylaws were presented to the Executive Committee of CUSUSWASH and were given tentative approval. The job of the Executive Secretary was reviewed and upon motion by Dean Peterson and second by Maurice Albertson, the Executive Secretary's position was changed to that of Executive Director and to the position were added additional assignments. The position was continued on a half-time basis. All of the on-going programs of the universities were reviewed as were the operations of CUSUSWASH.

3. CUSUSWASH Submits First Proposal. On March 28, 1972, responsive to RFP No. 10, CUSUSWASH assembled an excellent team of world renown specialists and submitted a proposal to AID covering work in Nepal in Agricultural Education Planning. This was submitted after incorporation had become a virtual certainty but before the papers had actually been filed. Had CUSUSWASH been successful in this endeavor the actual business items would probably have been handled through the contracting offices of one of the member universities. This, however, rates as the first independent CUSUSWASH proposal to be prepared and submitted.

4. CUSUSWASH Joins Utah State in Submitting Project Proposal. The summer semi-annual meeting at the invitation of Colorado State University

was held in Fort Collins on July 6 and 7, 1972. This meeting brought together the Board of Trustees, the Grant Directors Committee, two representatives of the Consortium on Soils of the Tropics, the entire Library Committee and four representatives from AID. It inaugurated an experiment calling for an in-depth discussion of joint problems of the member universities by the Board of Trustees as handled by a subject matter committee. In this instance the Library Committee discussed its library problems and proposed programs and recommendations for the consideration of the Board.

Viewed from any possible position, the meeting was a successful one. The various members of the Library Committee returned to their work with renewed interest and vigor and with a better understanding of the potential of their assignment.

During the meeting the office of the Executive Director was changed from half time to full time and an adequate budget covering the increased cost was adopted.

6. CUSUSWASH Library Grant Application Submitted. On August 21, 1972, as a logical outgrowth of the Fort Collins meeting of July 1972 and the special meeting of the Library Committee held at that time, with due recognition of the desire and need to multiply the bibliographic resources available to the CUSUSWASH institutions, a proposal was drafted and submitted to AID/Washington requesting a grant of $557,425 to fund a joint library improvement program to be carried out over a four year period. The money requested was to be spent through CUSUSWASH at the four member universities. Under this proposal a modest acquisition program of new publications was envisioned with the main emphasis placed on the development of a rapid retrieval system which in turn called for preparation of a union bibliography of the holdings of all four

universities. Library holdings at all three 211(d) grantee institutions are acceptable in the broad portion of work under the water management for agriculture assignment given to them. Nevertheless, significant advantage would accrue to them by providing them access to the bibliographic resources of the University of California. The University of California would gain in like manner. The proposition of providing all the member universities access to the bibliographic resources of all four member universities is exciting and would net out to multiply by several times the technical bibliographic resources available at any campus. More particularly, it would facilitate by mechanical means the use by staff, graduate students and researchers alike of the entire bibliographic resources of all four universities.

7. CUSUSWASH Incorporated. On September 8, 1972, the Articles of Incorporation for CUSUSWASH were filed with the Secretary of State of Utah under the non-profit corporation statutes of the State of Utah, and as of that date CUSUSWASH became a fully incorporated entity empowered to undertake virtually any training, land and water planning, development or management assignment anywhere in the United States or throughout the world.

8. AID Inquires as to the Ability of CUSUSWASH to Provide Technical Assistance. On September 21, 1972, Mr. Hyde G. Buller of AID/Washington inquired regarding the interest of CUSUSWASH in helping meet the Algerian request for two civil engineers specializing in silo construction, five engineers specializing in refrigeration, five engineers specializing in the use of pasture lands and the development of small irrigation projects, two architects and two agricultural economists. By telephone Buller was advised that the Consortium had the capability of providing the technical assistance and was keenly interested in doing so. Subsequently we were

advised that additional information would be forthcoming after the program developed, which to date has not arrived.

9. Foreign Assistance Contacts Made Throughout World. Throughout the latter part of calendar year 1972 CUSUSWASH was in contact with FAO/Rome. This culminated in an invitation being extended to the Executive Director to attend the Seminar on Water Management and Control for Agriculture held in Japan from October 2-14, 1972, and providing an unexcelled opportunity for the story of CUSUSWASH to be told to the representatives of 24 countries. Subsequent to the seminar, the Executive Director met with agricultural leaders and discussed developmental problems in the Far East and Middle East countries who were represented at the seminar. He also visited Iran for lengthy discussions with governmental and private entities on possible contributions of CUSUSWASH to the developmental programs of that country. He also met with FAO leaders in Rome on possible technical needs of FAO that could be met from the resources of the Consortium.

10. IMP Proposal Developed. During the special meeting of the Integrated Approaches Committee in Salt Lake City on August 29-30, 1971, the Irrigation Management Program Subcommittee was appointed to consider a broad subject matter assignment involving mathematical modeling of hydrologic, water management and other problems and the development of a master proposal covering computer analysis of the agricultural sector of any developing economy. Dr. J. Paul Riley was appointed Chairman of the subcommittee with Wade Andrews, Wayne Clyma, Del Fangmeier, Warren Hall, James Luthin, Martin Massengale and George Smith as committee members.

11. First CUSUSWASH Contract Signed. As an offshoot to the activities of the IMP Subcommittee, CUSUSWASH undertook negotiations with

the Escuela Superior de Agricultura "Antonio Narro" of the University of Coahuila, in Saltillo, Mexico and developed a frame of cooperation between that University and CUSUSWASH, which subsequently was finalized in a Memorandum of Agreement signed on November 15, 1972, Arnoldo Villarreal and Gabriel Murrillo P. and George Smith signing for Daryl Simons and George Olson signing for William I. Palmer. This instituted the first contract executed between CUSUSWASH and an international client in the developmental area. Under this agreement exchange of staff and students, conduct of research in Mexico and other activities were envisioned with the University of Coahuila "Antonio Narro" adopting a budget of $104,000 and CUSUSWASH pledging to seek funding in an amount of $78,625. The significant achievement of this contract was a recognition of potential for services in training between a foreign government which would be available at the CUSUSWASH universities.

12. Information Brochure. In July 1972 an infomration brochure on CUSUSWASH was issued. It filled only the most elemental needs of the Council at the time. Almost simultaneously with its issuance preparation of a new enlarged version was initiated. Progress on this revised and enlarged brochure has been slowed, however, because of the rapidity of developments on member university campuses having import on CUSUSWASH as well as those accruing within CUSUSWASH itself.

13. Joint Venture. CUSUSWASH has been approached several times by U.S. consultants to ascertain interest in joint venturing of various developmental proposals and in each instance positive assurance has been given as to the qualifications, interest and willingness of the Corporation.

14. Providing Technical Assistance to Developing Countries Through Third Party Contract. At several times during the year TransCentury

Corporation of Washington, D. C. inquired as to the ability and interest of the Consortium in providing technical help to serve in various African assignments. The job requests were circulated to the member universities and when no interested persons were found, the Executive Director recruited several people from the outside whose names were submitted to TransCentury. Two of these transmitted to TransCentury were in turn nominated by TransCentury to the friendly governments in Africa. To date neither has been appointed.

With incorporation in 1972 the foundation upon which an ever ascending competence and capability in the broad area of water for agriculture can be built without further adjustment to the corporate structure. Through deliberations of the Board of Trustees the basic architecture of the superstructure has taken shape. The Board has considered vaious types and kinds of work in which it might have interest and has delineated broad subject areas in which it feels CUSUSWASH has great capability of service. Progress has been made in recruiting highly qualified individuals from outside of the university who can be called on to take on specialized assignments for the Consortium. The potential of the organization is limitless and the basic organization is already established. Success or failure would appear now to be determined largely by how well the Corporation is managed and how well the members support it. Minor discouragement and frustration, of course, will continue to plague the efforts of the organization and these must be met and dealt with for what they are. CUSUSWASH, however, would appear to be healthy and capable of providing great service at home and abroad in achieving the reasonable objectives of this country's domestic and foreign policy regarding development.

LIAISON WITH OTHER CONSORTIA AND DEVELOPMENTAL AGENCIES

In addition to the more or less continuous exchange of letters, telephone calls and visits with members of the staff of AID, CUSUSWASH keeps the lines of communication open with other developmental groups and agencies. Among these are the following, which are listed only as examples:

Consortium on Soils of the Tropics. Because of the obvious overlap between assignments given CUSUSWASH and the Soils Consortium, the need to understand each others programs, priorities, projects and modus operandi was recognized at once. CUSUSWASH has appointed a liaison officer and an alternate liaison officer to keep the Soils Consortium informed of CUSUSWASH programs and to find out what the Consortium on Soils of the Tropics is doing in areas of interest to CUSUSWASH. A representative of CUSUSWASH, Dr. Maurice Albertson, attended the meeting of the International Institute of Tropical Agriculture in Nigeria on May 22-25, 1972, and representatives of the Soils Consortium have met with Trustees of CUSUSWASH at every semi-annual meeting of the Consortium since the summer of 1971. Dr. Stanley Buol attended the January 1972 meeting which was held in Fort Collins. A systematic program of coordinating the efforts of the two consortia has been adopted and is working well. As a continuing part of this cordial exchange of information, Dr. Kirkwood spent several days in Logan getting acquainted with the library and other phases of the 211(d) programs as they are being carried out at Utah State University.

Other Consortia. Letters have been exchanged and some highly preliminary discussions have been held with groups like the Indian, MUCIA,

Border States and other consortia, but arrangements for organized follow-up have not been concluded.

IBRD, IBD, ABD. Fairly frequent visits have been logged with the representatives of these banks by members of the Board of Trustees of CUSUSWASH and the Executive Director and, notably, by Chairman Daryl Simons. One project involving CUSUSWASH is still being negotiated with IBRD personnel.

FAO. Inquiry was made by FAO during the year as to the ability and interest of CUSUSWASH to provide individuals and teams to FAO to assist in its far-flung developmental programs. Reply was made on the affirmative and CUSUSWASH is now registered with the Contracts Division of that organization.

CUSUSWASH INCORPORATED

Since its founding the potential of CUSUSWASH has been considered more and more in terms of its viability as a tool in attaining not only the laudatory aims of attaining greater cooperation between member universities having many common interests, but also of meeting other objectives of the grants and in providing service in many additional areas--some not yet fully defined. If CUSUSWASH were to attain its full potential in terms of attaining optimum utilization of water for agriculture or in any other broad area in which it had or could develop competence, there was an apparent need to give it more authority to act as an independent agent. To this end incorporation was considered and decided upon. On September 8, 1972, the Articles of Incorporation were filed with the Secretary of State for Utah as a non-profit corporation. On that date CUSUSWASH became an incorporation entity with broad latitude to undertake any program assignments meeting the approval of the Board of Trustees of the Consortium.

With regard to the purposes of the organization, Article III of the Articles of Incorporation provide the following:

> This Corporation is organized as a non-profit corporation, and the purposes for which the corporation is organized are:
>
> A. To provide means by which the members may effectively discuss philosophy and objectives and exchange of information which would enhance their common goals in development of arid and sub-humid agriculture; and cooperate in developing educational programs, credit and non-credit courses, seminars, conferences, visiting lectureships, etc., especially in developing countries.
>
> B. To provide professional staff capability for preliminary assessments of programs and institution-to-institution relationships in order to facilitate development of specific programs in developing countries, to improve coordination among programs, and to enhance their technical excellence.

C. To assist in the development of uniform administrative procedures and provide coordinative assistance among the members regarding educational offering and contractual grant programs.

D. To represent and assist the members on common items of interest before AID, the IBRD, IDB, ADB, Ford or Rockefeller Foundation, other international credit or developmental bodies and the countries as agreed upon in furtherance of the programs of the Corporation and its member universities.

E. To receive, hold and administer gifts and grants, including property, both real and personal, and to enter into contracts with the United States Governmental agencies, private foundations, universities, especially member universities, corporations, developing countries and individuals for the advancement of any of the purposes for which this corporation is formed, and to make gifts and grants of contract or salary payments or otherwise compensate therefore.

F. To seek ways to mobilize the respective capabilities and strengths of the member universities in order to provide the most effective programs to meet their objectives.

G. To strengthen and enrich academic and technical programs of institutions of higher education, especially those of member universities in various fields related to soil and water management, both on their respective campuses and in other countries and to promote and encourage the exchange of information between institutions of higher education, including member universities, with a view toward inter-relating and improving their respective campuses and international activities programs.

H. To increase and disseminate knowledge and understanding concerning the strategy of cross-cultural education, and concerning significant economic, social and educational problems in less developed countries, particularly as they relate to the programs of the Council and its member universities.

I. To provide a mechanism for possible exchange of students, staff or graduate credit among the members in relevant disciplinary areas where this is desirable.

J. No part of the activities of the Corporation shall be carrying on propaganda or attempting to influence legislation, and the corporation shall not participate in, or intervene in (including the publication or distribution of statements) any political campaign on behalf of any candidate for public office or political party, either in the United States or in a developing country.

K. Notwithstanding any other provisions of these articles, the corporation shall not conduct or carry on any activities not permitted to be conducted or carried on by an organization excempt under Section 501 (c) of the Internal Revenue Code Annotated, 1953, and any regulations relating to these codes as they may now exist or as they may hereafter be amended, or by an organization, contributions to which are deductible under Section 170 (c) (2) of the Internal Revenue Code and such regulations as they now exist or as they may hereafter be amended.

Thus, CUSUSWASH has gained identity as an organization legally able to bind the tremendous resources of the four member universities together in the performance of appropriate assignments as approved by the Board.

OFFICE OF THE EXECUTIVE SECRETARY/DIRECTOR

As reported in the FY 1971 report, the university members of CUSUSWASH voted for the establishment of the Office of the Executive Secretary of CUSUSWASH. On July 8 the screening of the prospective candidates for the position of Executive Secretary was completed and Mr. William I. Palmer was selected and installed as the Council's first Executive Secretary on a half-time basis. Headquarters were established in Logan, Utah with the office housed in Rooms 403 and 405 of the Eccles Business Building.

A budget of $25,000 was subscribed by grantee universities from 211(d) funds with the concurrence and support of AID/Washington to cover the cost of the first year's operation. The office continued to function on a half-time basis throughout the year. Mrs. Diane England continued to serve as secretary to the Executive Secretary.

At the end of the first year's operation of the office (June 30, 1972), approximately $7,000 of the original subscribed amount remained on deposit at Utah State University. By action of the Grant Directors of the member universities and the Board of Trustees this money was made available to help meet the budget for the next fiscal period.

The title of the Executive Secretary was changed to Executive Director in January 1972 with the assignment continued on a half-time basis. In July 1972 the responsibilities of the office were increased and the job of Executive Director made full time.

MEETING THE COSTS OF OPERATING CUSUSWASH

Under the Articles of Incorporation and Bylaws adopted by the Council, funds for the operation of CUSUSWASH, including the office of the Executive Director, will come from three basic sources:

1. Membership dues. Each member institution is required to pay an annual membership fee of $1,000.

2. Fees and commissions earned by CUSUSWASH in connection with its contract operations.

3. Subscriptions from member universities to pay for work undertaken by CUSUSWASH for the benefit of the member universities and to help underwrite other costs of CUSUSWASH. These subscriptions, however, cannot be assessed or in any way imposed upon the member universities, but must be negotiated.

During the first year of operation of the office of the Executive Secretary/Director the entire funding came from the latter source. The budget adopted during the Fort Collins meeting anticipated utilizing dues, fees and commissions in meeting the adopted budget for expanded activities of the office. The long-range goal of CUSUSWASH, however, has been and still remains making their operations sufficiently self-supporting that subscriptions of any kind will not need to be negotiated in future years.

ADDITIONAL LINKAGE ATTAINED

With more time available and more travel and other funds available the Executive Director in quest of professionals of high merit and broad training and experience, by personal call, letters and telephone calls, as many as 150 to 200 were located and recruited as stand-by experts who could be called on to handle difficult and involved assignments for CUSUSWASH or its member universities in almost any kind of assignment any place in the world. This linkage with the professional community is a great asset and will become more important as the member universities expand their developmental role.

In similar manner, many of this country's great credit, engineering, developmental and consulting organizations have been visited to ascertain where university and CUSUSWASH resources might be pooled with those of the visited agencies and groups in helping to meet this country's developmental objectives. Many persons have participated in this effort and the linkages thus established are invaluable in carrying out the programs of CUSUSWASH and its member universities.

PART II

UNIVERSITY OF ARIZONA

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2457

May 1972

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211(d) Annual Report

Date April 17, 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 June 30, 1974 Amount of Grant $330,000
Expenditures for Report Year $76,620 Accumulated $230,922
Anticipated for next year $67,300

B. Narrative Summary:

The University of Arizona's overall competency in the area of watershed management utilizing systems analysis as applied to developing countries has been materially strengthened by the 211(d) Grant. As a member of a consortium of U.S. universities dedicated to providing assistance for increasing world food production through optimum utilization of water resources for agriculture, the University of Arizona has concentrated its activities on those concerned with the source of the water supply. Operators of water resource systems are faced with increasingly difficult decisions to overcome the physical, economic and social problems which characterizes man's never-ending battle against aridity, flood, drouth and pollution. The planners and designers of water resource systems must often choose among

a number of alternative plans for location and design of water control structures, operation of water management systems and institutional arrangements for effecting an acceptable plan. Systems analysis techniques with its inherent computer-based methods are employed as an aid in the decision-making process as it combines quantitative analysis and economic concepts into system design and evaluation. Involved in these techniques are predictions and testing to suggest objectives and possible courses of action.

To be in a better position for providing assistance to emerging nations in developing and operating water supply systems for agriculture, the University of Arizona has expanded its program of applied research and teaching in the area of systems analysis in watershed management.

The increased research competency in the utilization of systems analysis techniques has been channeled into two general activities. Hydrologic model building is one while modeling the decision-making process itself is the other. Simulation of a watershed's behavior as a means for determining the effect of man's intervention is an important aspect in water resources decision making. Projects under the hydrologic modeling activity which involve six faculty members include:

Development of stochastic models of precipitation and streamflow.

Computer simulation of the hydrologic behavior of watersheds.

Runoff farming in semi-arid areas.

Water use efficiency of selected crops.

The above projects are inputs into the management activity which is devoted to developing decision-making models for the optimal utilization of a watershed's resources.

A total of four graduate students have obtained their master's degrees (two this past year) working on the above projects. In addition, two doctoral candidates should complete their dissertations within the forthcoming year.

The enhanced instructional phase of the program has the dual function of training U.S. students interested in the development of emerging nations and the development of teaching aids for all students. Three new courses in World Soils, in Hydrologic Modeling and in Environmental Quality and Agriculture have been added, the latter this past year, to those that have been applicable to developing countries.

Since inception of the 211(d) Grant, considerable effort has been directed towards the development of a computer-oriented instruction facility (CARES: Computer Assisted Resource Educational System) and an Electric Analog Watershed Model. Computer-assisted instruction (CAI) is ideally suited for this activity because of the computer requirements of many systems analysis techniques. Thus, instruction is conducted using the very same device as is employed in an operational situation. The Electric Analog Watershed Model facilitates training as students can "visualize" the hydrologic response of watersheds. Two graduate students have been instrumental in developing these training aids and

should finish their dissertations within the next year. With the 211(d) Grant supporting approximately two faculty man-years in the area of systems analysis in watershed management, additional opportunities for providing consulting services to developing countries are available. Some six faculty members (three in the Watershed Management Dept.) consulted on Grant-related activities in Latin America and Near East countries.

Plans have been made to locate within the Department of Watershed Management a library that will contain information pertaining to developing countries. Bibliographies and abstracts have been prepared on specific subjects, such as the one accomplished last year on snow hydrology. In cooperation with other University departments (Hydrology and Water Resources and Systems and Industrial Engineering), the Watershed Management Department is involved in the planning for an international symposium on Uncertainties in Hydrologic and Water Resource Systems to be held next year on the University of Arizona campus.

The Grant has stimulated an awareness on the problems of developing countries within the College of Agriculture. Students, both foreign and U.S. with an interest in foreign relations, have been attracted to the program.

In most cases, the research supported by the Grant will have direct applications to developing countries. The models being developed to describe the hydrologic and decision-making processes have as their goal, the optimum utilization of water resources for agriculture. These models are of the universal type in that their only requirement for making them usable in developing countries is an estimate of parameters obtained from an appraisal of local conditions. Since knowledge so gained must be transferred to be of value, a mechanism for accomplishing this is the international symposium such as the one being planned to be held next year on the University of Arizona campus. The development of special instructional techniques for training and the dissemination of information of complex water management systems is also relevant to developing countries. Finally, U.S. students can focus their attentions on the classes of problems found in developing countries with the aid of a library of readily available information that pertains to these countries.

Cooperation with departments outside the College of Agriculture has also increased the University's capability of involving other faculty members in Grant-related activities. These activities were instrumental in obtaining additional support such as from the Office of Water Resources Research, the U.S. Forest Service and the Bureau of Land Management.

To increase linkages with other countries, plans were made for a faculty member to visit several South American countries to examine first-hand watershed management problems and situations and to establish contacts with foreign scientists working on these problems.

C. Detailed Report

I. 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, 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 development, 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 decidely 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

1. 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

1. Improvement of Research Capability

a. Hydrologic Model Building

During the past year, support in this area was given to one doctoral and three master's degree candidates. The subject of their projects are:

Development of an overland flow hydrologic model for semi-arid watersheds.

Optimizing parameters in hydrologic models.

Determination of consumptive water-use efficiency for selected crops.

Development of a rainfall multiplication process for dryland farming in semi-arid areas.

There are six faculty members in three College of Agriculture Departments (Watershed Management, Soils, Water and Engineering and Agronomy and Plant Genetics) that are involved in the above activity whose related projects include:

Development of stochastic models of precipitation and runoff.

Prediction of snowpack water balance by means of a seasonal energy balance.

Remote sensing of hydrologic parameters.

Development and testing of transpiration retardants.

Papers prepared on the above subjects during the 1972 year include:

A stochastic model of runoff-producing rainfall for summer type storms.

Elevation effects on rainfall: a stochastic model.

Analysis of ephemeral flow in aridlands.

Choosing hydrologic models for changing watersheds.

An event-based stochastic model of winter rainfall.

Antitranspirant effects on the transpiration and physiology of tamarisk.

Two theoretical models of radiation heat transfer between forest trees and snowpacks.

b. Decision-Making Models

The Grant supported one doctoral dissertation in the 1972 fiscal year dealing with the subject--Optimizing production of range resources through systems analyses on operations research techniques. Completion of this work is anticipated next year.

Dr. Lucien Duckstein of the Systems and Industrial Engineering Dept. was supported by the Grant for one month to consult with

various faculty members on the use of systems analysis techniques in natural resource management. He also presented two lectures on this subject at a Bureau of Land Management short course, a two-week instructional program held annually at the University of Arizona by the Department of Watershed Management.

The following are papers presented this past year that pertain to this activity:

Evaluation of the effects of water yield management.

Systems Analysis: a decision-making tool for arid land development.

2. Improving Teaching Capability

a. CARES

Partial support was granted to two students working in the field of developing a computer-oriented instruction program, the second year for this activity. One, a doctoral candidate, is working on a computer language for use with this system. The other has just completed an M.S. in which he prepared a professional paper which presents four lessons of computer-assisted instruction (CAI) designed to introduce the concepts and utility of linear programming.

To assist such projects as the above, Grant funds have been expended towards developing a completely interfaced hydrologic

data acquisition-analysis system. The small computer utilized in this system was used in the above CAI program. In addition to the computer, the facility includes software and hardware for working with live telemetered data and has provisions for rapid recall of data and programs from a magnetic tape library. While primarily intended for improving teaching methods, the facility can also be used for research. This particular activity has been a major effort since initiation of the Grant.

b. Electronic Analog Model of a Watershed

The development of a direct passive electrical analog model of a watershed has essentially been completed by a doctoral candidate supported with Grant funds. All that remains is Graduate College acceptance of the final copy of the dissertation entitled, "Analysis and Application of a Passive Electronic Analog Model to the Hydrologic Regime of a Watershed".

A representative of the Food and Agricultural Organization (FAO) of the United Nations has expressed interest in this model as a teaching and research device.

c. Course Development

This past year the services of Dr. Lucien Duckstein were used to help reorganize a course entitled, "Advanced Watershed Management." Incorporated in the course are such techniques as linear and dynamic programming, simulation devices, sensitivity analysis and

other concepts that are involved in the investigation of a broad range of alternatives and in consideration of the economic and social constraints of natural resources management system.

The College of Agriculture has added a new course, "Environmental Quality and Agriculture", which deals in large part with world food production requirements and problems. Like the above course, it will be offered for the first time in the following fiscal year. This course has direct implications of a current topic of concern to developing countries. The development and management of water resources to increase food production is a major effort in many emerging nations. While the environment for producing more food is greatly enhanced by such projects, these efforts can also have deleterious effects on other parts of the environment. A striking example is the Aswan Dam in Egypt. Linked to this project has been the increased incidence of a dread disease and a reduction of fish production in the Mediterranean Sea.

In the first two years of the Grant, a review of all water-related courses in the College of Agriculture was made in an attempt to increase their relevancy to problems encountered in

developing countries. Two new courses were added, one dealing with world soils and the other with the hydrologic modeling of natural watersheds. Several other courses were revised to incorporate the objectives of the Grant.

3. Development of Increased Consulting Competance

The University of Arizona continues to encourage faculty members to serve in an advisory or consulting capacity to developing countries. Dr. E. L. Smith, formerly supported under 211(d), has been designated as Chief of Party of the University's AID Mission Program in Northeast Brazil. Also spending time in Brazil consulting with University of Ceara personnel was Dr. P R. Ogden, Professor of Range Management. Dr. Martin Fogel attended a CENTO Seminar in Agricultural Aspects of Arid and Semi-Arid Zones held in Tehran, Iran. He presented a paper on the use of systems analysis in agricultural management.

4. Expansion of Special Activities

a. Library Development

Plans have been made to locate a library within the Department of Watershed Management that will contain information pertinent to developing countries. The library will be organized by a professional librarian and will be maintained indefinitely. It will have a computer access capability compatible with the computer retrieval system being developed by the Office of Arid Land Studies

in conjunction with the University Library. As part of this effort last year, an expanded bibliography on snow hydrology and management was prepared. In previous years, abstracts were obtained in such subject matter areas pertaining to arid watersheds as range management, climatology, hydrology, water quality and irrigation. These categories constitute the basis for developing mathematical models to determine streamflow, soil moisture content, salt accumulation or a variety of other parameters that characterize watershed processes. A bibliography on one of these processes, interception, was also prepared in past years.

b. International Symposium

The Department of Watershed Management is cooperating with the Departments of Hydrology and Water Resources, Systems and Industrial Engineering and Mathematics in sponsoring an International Symposium on Uncertainties in Hydrologic and Water Resource Systems. It has been endorsed by four international societies as well as leading American organizations.

IV. Impact of Grant in Developing Institutional Capabilities

The approach to solving the problems of water management in agriculture must be integrated to consider all policy levels from the system planner to the controller and finally to the user. Watershed Management for the most part, relates to the first two phases. It is concerned with such

specific technical topics as economic evaluation for optimal use of water and land, analysis of hydrologic regimes, and simulations for predicting the water supply. To assist the planner and operator of watershed systems in utilizing the more sophisticated but generally accepted techniques requires the development of procedures that will aid him in understanding these techniques. Computer-assisted instruction (CAI) is a tool that can be used for training in natural resources management.

Procedures for its utilization are currently being developed within the Department of Watershed Management. As a result of this activity, interest in CAI has expanded to other University departments, Geosciences, Physics and Education.

The development of systems analysis or operations research techniques in the field of watershed management has provided the opportunity for collaboration with other University departments, namely Systems and Industrial Engineering and Hydrology and Water Resources. These multidisciplinary efforts have resulted in the University receiving a three-year grant from the U.S. Department of Interior for studying decision-making processes in natural resources management..

The Grant has stimulated an awareness within the College of Agriculture of the agricultural problems that developing countries are facing. It has helped attract students with an interest in international relations

such as two former Peace Corps members now graduate students in the Department of Watershed Management. These students are considered prime candidates for this program; they have the experience of working with the watershed management problems in developing nations, they are proficient with at least one foreign language, and they have a high technical capability. With further training, they should become excellent candidates for further foreign service. We hope to obtain more students with this kind of background.

With its increased competency in watershed modelling of hydrologic systems, the Watershed Management Department has received financial support from the Arizona Water Commission and the U.S. Forest Service.

V. Utilization of Institutional Resources in Development

The University of Arizona has made a concerted effort in providing faculty time, office space, library facilities, equipment, materials, etc., to meet the objectives of the Grant. Most of the faculty associated with the program are state supported.

Three faculty members from the Department of Watershed Management (B. N. Freeman, P. R. Ogden and E. L. Smith) made two visits to a new livestock and range experimental station in northern Mexico. They were consulted on the implications of adopting various land use management practices.

Since the inception of the Grant, a total of 16 foreign students have completed work in the Watershed Management Department, with 9 coming from emerging African nations and 7 from Latin American countries. Several U.S. students have enlisted in the Peace Corps while two former members have enrolled in the department for graduate work.

The College of Agriculture continues to be heavily engaged in development through its USAID/Brazil contract.

VI. Other Resources for Grant-Related Activities

A major input in the University's program in Watershed Management is the National Science Foundation supported International Biological Program (IBP) - Analysis of Ecosystems. This organization has contributed to the hydrologic data acquisition - analysis system which includes CARES. Another large contributor to Grant-related activities in the USDA through its Hatch, Regional Research and Forest Service programs. The first two programs are involved in the development of specific watershed and precipitation models, while the Forest Service projects are concerned with the installation of experimental watersheds to validate watershed models.

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

While no new activities are planned for the 1972-73 year, there will be some shifting of emphasis. It is planned that consulting activities will increase as will special activities including library development and

co-sponsoring an international symposium. A reduction in research and teaching activities, primarily in connection with the nearly completed electric analog watershed model, will compensate for the expanded activities.

Table I

Distribution of 211 (d) Grant Funds and Contributions From Other Sources of Funding*

Review Period July 1, 1971 to June 30, 1972

List of all grant related activities	211 (d) Expenditures				Non 211 (d) Funding Amount- Period Under Review
	Period Under Review	Cumulative Total	Projected Next Year	Projected to end of Grant	
Research					
Hydrologic Modeling	32,000	115,000	20,500	160,000	35,000
Decision Making	9,000	25,000	12,000	45,000	15,000
Teaching					
Computer Assisted Inst.	16,000	42,000	10,000	59,000	5,000
Electrical AnalogDev.	8,000	25,000	2,000	27,000	4,000
Course Development	1,000	2,000	3,000	6,000	15,000
Libraries	2,000	4,000	3,000	10,000	2,000
Consultation	3,000	7,000	10,000	22,000	1,000
Other	620	1,140	800	4,000	2,000
CUSUSWASH	5,000	5,000	6,000	17,000	
Publication (incl. Above)					
TOTAL	76,620	226,140	67,300	350,000	79,000

*These figures are our best estimates

Table II

Expenditure Report

(Actual and Projected)

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

	Expenditures to Date		Projected expenditures		Total
	Period Under Review	Cumulative Total	Year 4	Year 5	
Salaries	37,265	123,599	23,000	25,000	171,599
Wages	7,090	20,535	10,000	3,060	33,595
Fringe Benefits	3,800	12,463	2,300	2,500	17,263
Sub Total	48,155	156,597	35,300	30,560	222,457
Stipends 1/	13,513	29,366	10,000	8,000	47,366
Travel					
Foreign 2/	415	3,035	6,000	5,000	14,035
Domestic	3,090	9,711	3,000	1,000	13,711
Equipment	3,880	10,559	3,500	3,500	17,559
Computer	410	1,858	2,000	1,000	4,858
Operations 3/	2,157	10,014	1,500	1,500	13,014
CUSUSWASH	5,000	5,000	6,000	6,000	17,000
TOTAL	76,620	226,140	67,300	56,560	350,000

1/ See Table 3 for detailed breakdown of this category.

2/ B. N. Freeman, P. R. Ogden and E. L. Smith trips to Mexico to evaluate and consult with Mexican resource managers on range watershed conditions.

3/ See Table 4 for detailed breakdown of this category.

Table III

Expenditure Report Continued

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

Students Supported Wholly or in Part
by 211(d) Stipends and Salaries[1/]

Student	Title	Degree Objective	Level of 211(d) Support (dollars)
Bartlett, L.T.	Instructor-Research Assoc.	Ph.D.	2000
Rasmussen, W.O.	Grad. Assoc.	Ph.D.	1200
Tinlin, R.M.	Instructor-Research Assoc.	Ph.D.	9600
Welch, T.G.	Grad. Assoc.	Ph.D.	2100
Cunningham, R.O.	Grad. Assist.	M.S.	1750
Morin, G.C.A.	Grad. Assist.	M.S.	3300
Wilhelm, W.W.	Grad. Assist.	M.S.	3600
		Total	23550

1/ In addition, a combination of four undergraduates and graduate students were supported on wages totalling $2,210.

Table IV

Expenditure Report Continued

Under Institutional Grant #AID/csd - 2457

Review Period July 1, 1971 to June 30, 1972

Detailed Breakdown of Operations Expenditure.

	Category	Amount Expended (dollars)
(1)	Maintenance and Repair of Equipment	119
(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)	1203
(3)	Painting and Audio-visual Services	135
(4)	Telephone (long distance calls)	160
(5)	Freight charges	20
(6)	Equipment rental (typewriter, equipment for field watershed installations)	510
(7)	Subscription	10
	Total	2157

Abstracts of Publications Related to 211(d) Grant Activities

1. Point Rainfall Frequencies in Convective Storms

ABSTRACT

An exponential relation was developed to describe the spatial distribution of convective storm rainfall in southwestern United States. Given that a storm center has occurred, a geometric distribution was used to describe the frequencies of point rainfall depths. A Poisson distribution was assumed to represent the probability of at least one storm center occurring over a given area a specified number of times during a season. Assuming that the two probability distributions are independent and uncorrelated, maximal and minimal distributions of point rainfall depths were derived. The minimal distribution indicates that with a very high certainty a single rain gage will miss at least one convective storm a year. When compared with frequencies determined from long-term historical records, the maximal distribution exhibits a similar mean, a greater variance, and lower recurrence intervals for the higher rainfall depths.

REFERENCE. Fogel, Martin M. and Lucien Duckstein. Point rainfall frequencies in convective storms. Water Resources Res. 5(6):1229-1237. 1969.

2. A Passive Direct Electric Analog of a Watershed

ABSTRACT

A passive electric analog has been developed that has a direct physical correspondence to the processes taking place on a typical watershed. The usual procedure in surface water electronic analog models is the use of active elements such as operational amplifiers or in the case of surface water routing models, R-C networks coupled with slow speed switching devices. Modern technology has made available numerous semiconductor elements which allow us to build passive electric analogs that modify an electrical input function in manner of marked similarity to the way rainfall input is modified by the watershed storage parameters as it traverses through the watershed.

The model discussed in this paper is designed as an instructive tool for student or scientist in investigating the use of electrical components in analog modeling; and also serves as an excellent means of studying most of the major hydrologic processes of a watershed and their interrelationships.

REFERENCE. Tinlin, R. M. and J. L. Thames. A passive direct electric analog of a watershed. Paper presented in Amer. Geophys. Union Sect. of Hydrol. Fall National Meeting, San Francisco, December 1969.

3. Prediction of Convective Storm Runoff in Semiarid Regions

ABSTRACT

Analysis of 14 years of data taken on the Atterbury Experimental Watershed located near Tucson, Arizona, USA has led to a procedure for predicting semiarid basin runoff from convective storms. The record event for small catchments is usually the result of these localized, high-intensity, short-duration storms.

A general runoff equation was developed based on the mass curves of infiltration and runoff. The relationship included a runoff coefficient defined as the ratio of runoff to effective rainfall (storm total less initial abstractions). Multiple regression techniques indicated that for very small areas (less than two square kilometers), this coefficient remains essentially constant for a given basin. However, for catchments ranging in size up to 20 or 25 square kilometers, additional information can be obtained by characterizing the time distribution of storm rainfall.

Using the storm's maximum 15-minute intensity as the time distribution parameter, it was shown that the runoff coefficient was a function of this parameter. Thus, the probability of equalling or exceeding a given volume of runoff is an event that can be determined by a joint probability. The results from a previously developed model that describes the spatial distribution and frequency of occurrence of convective storm rainfall were combined with the frequency distribution of the storm's intensity to define the joint probability function.

An extreme-value distribution was found to adequately describe the annual maximum series of runoff volumes. Using selected return periods, results from this analysis were compared to runoff predicted from rainfall data. The comparison was favorable, especially for the longer return periods.

Antecedent rainfall and the location of the point of maximum rainfall on the relatively small watersheds had no significant effect, statistically, on runoff.

REFERENCE. Fogel, Martin M. and Lucien Duckstein, Prediction of convective storm runoff in semiarid regions. Int. Assoc. Sci. Hydrol. Pub. No. 96:465-478. 1970.

4. Computerized Hydrologic Data Acquisition System - A Facility for Upgrading Instruction in Watershed Management

ABSTRACT

Technological explosion, population expansion, urban sprawl, changing patterns of land and water use and increasing emphasis on environmental quality control are presenting vast new challenges to natural resource scientists and land managers. To successfully meet these challenges, colleges and universities need to produce graduates with new kinds of training and skills. Land managers of the future must have a wide understanding and have a technical training much better than ever before. Familiarity with the computer, for example, is no longer so much an advantage as a necessity. Similarly, skill in interpreting remote satellite data for land management purposes may be required in the very near future. Accordingly, the Department of Watershed Management in the College of Agriculture of the University of Arizona has an extensive program of upgrading its curriculum and improving teaching methods. The purpose of this paper is to describe a teaching-research facility which provides an innovation in instruction techniques for one facet of the program.

The facility is a completely interfaced hydrologic data acquisition processing system. It goes somewhat beyond the definition of SCI and CDI as described by Borden.[1] In addition to a small, laboratory computer and the services of a remote time shared terminal to the large CDC 6400 computer, the facility also includes both software and hardware for working with live telemetered data. Provisions are also made for the rapid recall of past data from a magnetic tape library.

REFERENCE. Thames, J. L. and R. M. Tinlin. Computerized hydrologic data acquisition system - a facility for upgrading instruction in watershed management. J. Natl. Assoc. of Coll. and Teachers in Agric. 14(1):3-4. 1970.

5. A Computer Automated System for Hydrologic Data Acquisition and Analysis

ABSTRACT

This report discusses a state-of-the-art computer controlled telemetered data acquisition system operated by the Department of Watershed Management, University of Arizona for the past two years. The purpose of the system is to provide an accurate time and space history of the variations of hydrometeorological parameters.

A computer is incorporated into the system which processes the raw data on-line, producing finished answers in any format desired. It also affords the user total control of the data taking process--varying the sample rate in relation to input changes, real time, etc. All output is recorded on tape but may also be displayed on a teleprinter for visual inspection.

The system consists of the computer controlled central station on campus with software for data reduction and analysis, a VHF and landline telemetry link, and two remote field stations within a radius of 40 miles. The field stations consist of an array of hydrometeorological sensors, a memory unit, signal conditioning unit, and telemetry transmitter.

The central station 8-K-16bit digital computer is the heart of the system. Accessory central station equipment consists of a teleprinter, digital clock, magnetic tape unit, and the radio and landline communications links.

REFERENCE. Thames, J. L. and R. M. Tinlin. A computerized automated system for hydrologic data acquisition and analysis. Proc. Int. Symp. on Hydrometry, Koblenz, September 1970.

6. Systems Analysis in Natural Resources Management

ABSTRACT

This paper discusses the applications of systems analysis as a tool for decision making in the management of natural resources. The use of systems analysis in decision making is briefly discussed and contrasted with the empiracism used by natural resource managers. By using this technique, a meaningful transition from inventories to decisions is provided which enables the manager to base his programs on a quantified interpretation of basic inventory data. The technique brings together the past knowledge and experience of managers and scientists as well as economics, physical relationships of the natural systems and the ecological and social constraints. An example of a decision making model which employs a combination of linear and dynamic programming is presented. The example, although simplified by assumptions, illustrates the determination of optimal investment for watershed development, considering the distributed nature of model parameters.

REFERENCE. Bartlett, E. T. Systems analysis in natural resources management. 1971 New Mexico Water Conference, New Mexico State Univ., Las Cruces, New Mex., March 1971.

7. Space - Time Validation of a Thunderstorm Rainfall Model

ABSTRACT

A probability model for predicting the occurrence and magnitude of thunderstorm rainfall developed in the southwestern United States was tested in the metropolitan Chicago area with reasonable success, especially for the moderate to the extreme runoff-producing events. The model requires the estimation of two parameters, the mean number of events per year and the conditional probability of rain given that an event has occurred. To tie in the data from more than

one gage in an area, an event can be defined in several ways, such as the areal mean rainfall exceeding 0.50 inch and at least one gage receiving more than 1.0 inch. This type of definition allows both of the model parameters to be obtained from daily warm-season rainfall records. Regardless of the definition used a Poisson distribution adequately described the number of events per season. A negative binomial distribution was derived as representing the frequency density function for rainfall where several gages are employed in defining a storm. Chicago data fit both distributions very well at events with relatively high return periods. The results indicate the possibility of using the model on a regional basis where limited amount of data may be used to estimate parameters for extensive areas. (KEY WORDS: thunderstorm rainfall model; frequency analysis; probability distributions; parameter estimation)

REFERENCE. Fogel, M. M., L. Duckstein and C. C. Kisiel. Space - time validation of a thunderstorm rainfall model. Water Resources Bul. 7(2):309-316. 1971.

8. Antitranspirant Effects on the Transpiration and Physiology of Tamarisk

ABSTRACT

Five-stamen tamarisk, an important phreatophyte in the southwestern United States, is difficult to eradicate for water salvage. There also is increasing opposition to its eradication because this species provides cover for wildlife and greenery in the environment. The application of nontoxic antitranspirant sprays to reduce tamarisk transpiration may be an alternative to eradication. We tested several antitranspirants, including a combination of the monomethyl and monoglyceryl esters of n-decenylsuccinic acid (MDSA-GDSA), 8-hydroxyquinoline sulfate (8-HQS), and phenylmercuric acetate (PMA), on tamarisk in greenhouse and field environments. PMA was toxic at a concentration of 0.001 M and was therefore not considered in the evaluation described below. The effects of MDSA-GDSA and 8-HQS on transpiration, growth, net photosynthesis, dark respiration, relative stomatal apertures, chlorophyll and protein contents, and foliage

temperature were evaluated. Transpiration rates of plants treated with MDSA-GDSA and 8-HQS were 25-35% less than those of control plants for 20 days in the greenhouse and for at least 5 days in the field. Growth was reduced for 2-3 weeks, and net photosynthesis for less than 1 week. The other physiological factors were not changed substantially. Foliage temperatures increased 2°-3°C for 3 days following treatment in the field. Further study for possible management application is suggested.

REFERENCE. Brooks, Kenneth B. and David B. Thorud. Antitranspirant effects on the transpiration and physiology of tamarisk. Water Resources Res. 7(3):499-510. 1971.

9. Analysis of Ephemeral Flow in Aridlands

ABSTRACT

A framework has been presented for the analysis and modeling of streamflows in aridlands. The basic event series of streamflows as observed in nature is found to be more informative than monthly and annual series. The frequency of occurrence of summer and winter events at the Tucson Arroyo gaging station are described, respectively, by a negative binomial distribution and a geometric distribution. Meteorologically this result is explained in terms of the temporal and spatial independence of summer thunderstorms and the persistence of winter cyclonic storms. The negative binomial distribution also describes the duration of flow per event in both winter and summer.

Meriting further exploration in the study of ephemeral flows but not considered herein are the following: (1) Zero-crossing theory (30); (2) theory of forecasting (4); (3) extreme value theory for a random number of random variables (34); (4) multivariate time series models to allow for inclusion of other causal variables

that influence flow prediction; (5) a decision-theoretic approach to estimation of parameters in deterministic and stochastic models (8); and (6) the study of time series of ground-water level fluctuations in wells adjacent to aridland channels periodically recharging the unconfined aquifer.

REFERENCE. Kisiel, C. C., L. Duckstein and M. M. Fogel. Analysis of ephemeral flow in aridlands. J. Hydraul. Div., ASCE, 97(HY10):1699-1717. 1971.

10. Evaluating the Effects of Water Yield Management

ABSTRACT

Research that presents the quantitative analysis of watershed management practices to increase water yields is reviewed. A methodology is suggested for evaluating these practices in light of the entire water supply, storage and delivery system. The procedure includes utilizing a synthetic time series of precipitation as input into a watershed model with streamflow and sediment yields as outputs. A storage - yield function is used to obtain the net yield increase for a given storage reservoir system.

REFERENCE. Fogel, Martin M. Evaluating effects of water yield management. Proc. Third Mt. Symp. for Hydrol. Prof. , Purdue Univ. June 1971.

11. Systems Analysis: A Decision-Making Tool for Arid Land Development

ABSTRACT

Systems analysis is a tool that can permit a view of the entire problem. It takes into account means and ends, choices and alternatives. It makes use of prediction and advanced testing to suggest objectives and courses of

action. It provides a method for more thorough consideration of alternatives.

Systems analysis may be viewed as a formalization of interactions. It contains few new concepts; it makes use of newly developed tools. Its application is by no means restricted to the planning of large-scale water resource management schemes. It can have a significant role in the decision-making processes of individual farmers.

While systems analysis may be a powerful tool, the tools of operations research as applied to water resources systems can only assist the decision-making process. In addition, by itself systems analysis is useless; a knowledge of water resources systems is essential. The purpose of this discussion is to take a brief look at selected examples in which some form of systems analysis may be used to advantage.

REFERENCE. Fogel, Martin M. Systems analysis: a decision-making tool for arid land development. CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones, Tehran, September 1971.

12. A Stochastic Model of Runoff-Producing Rainfall for Summer Type Storms

ABSTRACT

Modification of watersheds occurs either through natural processes, such as erosion, or human influences, such as urbanization. In either case the rainfall input must be properly modeled before the runoff output can be predicted as the modifications take place. The paper considers runoff-producing summer precipitation of short duration and high spatial variability as an intermittent stochastic phenomenon. The probability distribution of seasonal total point or areal rainfall is obtained by convoluting a Poisson number of events with a geometric or negative binomial probability of rainfall amount. Close agreement with the experimental data is found. Next the probability of various combinations of rainfall amounts, given the seasonal total and the number of events, is computed. With these

results, the theoretical seasonal water yield distribution can be obtained by using a simple rainfall-runoff relationship, such as the Soil Conservation Service formula. The possibility of using regional input parameters to study the distribution of the output of poorly gaged small watersheds is discussed. In particular, extreme total flows can be computed.

REFERENCE. Duckstein, Lucien, Martin M. Fogel and Chester C. Kisiel. A stochastic model of runoff-producing rainfall for summer type storms. Water Resources Res. 8(2): 410-421. 1972.

13. Choosing Hydrologic Models for Management of Changing Watersheds

ABSTRACT

Changes in the hydrologic behavior of watersheds can be voluntary, indirect, inadvertent or in any combination. Many of these changes will require environmental impact statements to reflect both beneficial and adverse effects. Man-made changes are planned to meet a particular goal. To choose the most appropriate hydrologic model for predicting these modifications, the standardized cost-effectiveness analysis is recommended. In this methodology, the following steps are included: definition of goals, identification of specifications for realization of goals, development of alternative models to achieve goals, establish measures of effectiveness for evaluation of alternative models, determine capabilities and analyze merits of models and perform sensitivity analysis on goals, specifications and measures of effectiveness. For predicting changes on ungaged watersheds, many hydrologic models encounter calibration, validation or extrapolation problems. It is possible, however, to obtain an approximation of these changes with the use of simple models of the rainfall-runoff process. Two such models are compared in determining the effect of urbanization on the return period of a flood of given magnitude.

REFERENCE. Fogel, Martin M., Lucien Duckstein and Chester C. Kisiel. Choosing hydrologic models for management of changing watersheds. Proc. Amer. Water Res. Assoc. Symp., Watersheds in Transition, Ft. Collins, June 1972.

14. Elevation Effects on Rainfall: A Stochastic Model

ABSTRACT

The variation in point precipitation with elevation is investigated using an event-based stochastic model of thunderstorm rainfall and empirical data. Parameters of the model correspond to the number of events per unit of time and the depth of rainfall per event. An increase in precipitation with elevation may be due to an increase in the number of events, in the amount of rainfall per event or to some combination of both possibilities. The distribution of the number of events per season is assumed to be a Poisson variate while the distribution of point rainfall depths may be taken as geometric. The summation of a random number of random variables is used to represent seasonal point precipitation. Assuming that the two parameters of the model increase linearly with elevation, then total seasonal rainfall increases as a quadratic polynomial with elevation. The use of the model allows one to obtain the return period of storm rainfall of a given magnitude despite a short historical record. An independent set of data was used to verify the procedure.

REFERENCE. Duckstein, Lucien, Martin M. Fogel and John L. Thames. Elevation effects on rainfall: a stochastic model. Paper accepted for publication in J. of Hydrology, 1972.

15. Two Theoretical Models of Radiation Heat Transfer Between Forest Trees and Snowpacks

ABSTRACT

Two simple theoretical models have been developed to describe the effect of forest cover on radiation transfer to a snowpack.

Model 1, which describes the effect of varying canopy

closure on the net radiation received by an interior snowpack, suggests that the net radiation may increase or decrease monotonically as the canopy closure increases from zero to 100%, or may exhibit a maximum at a non-zero canopy closure depending upon whether or not certain conditions are satisfied. These conditions involve the values of the albedos and radiant fluxes. This perhaps surprising result was due to the combined effect of long-wave radiation emitted from the canopy to the snowpack and multiple reflections of solar radiation between the snowpack and canopy.

Model 2 predicts the spatial variation of the long-wave radiation flux from the bole and crown of an individual tree to the surrounding snowpack. This model may partially explain melt rates which appear to be higher near the boles of trees than at more distant points. Calculations with assumed data showed an intensification of the long-wave radiation flux to the snowpack as the bole is approached. According to this model, a horizontal snow surface receives negligible amounts of long-wave radiation from the tree at distances from the bole that are greater than two to three times the crown radius.

REFERENCE. Bohren, Craig C and David B. Thorud. Two theoretical models of radiation heat transfer between forest trees and snowpacks. Agric. Meteor. (in press) 1972.

16. Development of Management Guidelines for Increasing Snowpack Water Yields from Ponderosa Pine Forests in Arizona

ABSTRACT

Snowmelt on the Salt-Verde River Basin in Arizona yields a major portion (possibly 50 percent or more) of the annual surface runoff that supplies six reservoirs. These reservoirs provide municipal, industrial, and agricultural water for the Phoenix metropolitan and nearby areas. About 30 percent of

the Basin (2 1/2 million acres) is within the ponderosa pine forest zone, where much of the snowmelt runoff originates. Therefore, initial work in the development of forest management guidelines for increasing snowpack water yields is concentrated in this zone. These guidelines, to be effective, must be developed in a context that considers the constraints imposed by management objectives involving the other products and uses (e.g., timber, forage, wildlife, recreation opportunities, etc.) of the land.

REFERENCE. Thorud, David B. and Peter F. Ffolliott. Development of management guidelines for increasing snowpack water yields from ponderosa pine forests in Arizona. Proc. Am. Water Resource Assoc. Symp., Watersheds in Transition, Ft. Collins, 1972.

APPENDIX B

PUBLICATIONS ANNEX

UNIVERSITY OF ARIZONA

3 rd ANNUAL REPORT

(Having Significant 211 (d) input)

October 31, 1972

1. Fish, E. B. and E. L. Smith. 1971. Remote sensing for inventory of desert shrub vegetation in southeastern Arizona. Paper presented at Annual Meeting of Rocky Mt. Sec. AAAS and Ariz. Acad. Sci., Phoenix, Ariz.

2. Fish, E. B. and E. L. Smith. 1971. Application of remote sensing for watershed inventories. Paper presented at ARETS Symposium on applied Remote Sensing of Earth Resources. Tucson, Ariz.

*3. Fogel, M. M. and L. Duckstein. 1969. Point rainfall frequencies in convective storms. Water Resources Research. (December, 1969) pp. 1229-1237.

*4. Fogel, M. M. 1969. The effect of storm rainfall variability on runoff from small semiarid watersheds. Trans. Am. Soc. Agric. Eng., 12 (Nov.-Dec., 1969) pp. 808-812.

5. Fogel, Martin M. and L. Duckstein. 1970. Prediction of convective storm runoff in semi-arid regions. Proceedings Symposium on Representative and Experimental Watersheds, International Association of Scientific Hydrology, New Zealand, Publication No.96, 465-478.

6. Fogel, Martin M., L. Duckstein and C. C. Kisiel. 1971. Space-time validation of a thunderstorm rainfall model. Water Resources Bulletin 7(2): 309-316.

7. Fogel, Martin M., C. C. Kisiel, L. Duckstein. 1971. Analysis of ephemeral flow in arid lands. J. Hyd. Div., Proc. Am. Soc. Civ. Eng. 97(HY10): 1699-1717.

8. Fogel, Martin M., L. Duckstein, C. C. Kisiel. 1971. A stochastic model of runoff-producing rainfall for summer type storms. Paper presented at 52nd Annual Meeting, AGU Washington, D.C. Accepted for publication in Water Resources Research.

9. Fogel, Martin M. 1971. Evaluating the effects of water yield management. Paper presented at Third International Seminar for Hydrology Professors, IHD, Purdue Univ., Lafayette, Indiana.

10. Fogel, Martin M. 1971. Systems analysis: A decision-making tool for arid land development. Paper presented at the CENTO Seminar on Agricultural Aspects of Arid and Semi-arid Zones, Tehran, Iran.

11. Fogel, Martin M., L. Duckstrin, C. C. Kisiel, 1972. Choosing hydrologic models for management of changing watersheds. Proc. National Symposium on Watersheds in Transition, Fort Collins, Colo. June 1972.

12. King, David A. 1972. Towards more effective natural resources planning. Paper presented at 37th North American Wildlife and Natural Resources Conference, Mexico City.

13. Matlock, W. G. and P. R. Davis. 1970. Desert strip Farming: A modified dry farming method using rainfall multiplication. Paper presented at Annual Meeting American Society of Agricultural Engineers, Minneapolis, Minnesota.

14. Thames, J. L. and J. H. Kitchen. 1969. Application of a computer model to a desert watershed, Prog. Agric. in Arizona, 21(1): 12-19.

15. Tinlin, R. and J. L. Thames. 1969. A direct passive electrical analog model of a watershed. Abstract, annual meeting of American Geophysical Union, San Francisco. (Not available) (See Professional Paper-Tinlin).

16. Thames, J. L. and R. Tinlin. 1970. A computer a tomated hydrologic data acquisition system. Proceedings, International Symposium on Hydrometry. Koblenze, Germany.

17. Thames, J. L. and R. Tinlin. 1970. Computerized hydrologic data acquisition system: a facility for up-grading instruction in watershed management. Journal, National Association of Colleges and Teachers in Agriculture, 24(1): 3-5.

18. Thorud, David B., E. S. Simpson, I. Friedman. 1970. Distinguishing seasonal recharge to groundwater by deuterium analysis in southern Arizona. Proc., Reading Symposium. International Assoc. of Scientific Hydrology. p. 112-121.

19. Thorud, David B., R. S. Cunningham. 1971. Antitranspirants: a possible alternative to the eradication of saltcedar thickets. Proc. New Mexico Water Conference, Las Cruces, New Mexico, pp. 101-109.

20. Thorud, David B., P. F. Ffolliott. 1971. Progress in developing forest management guidelines for increasing snowpack water yields. Hydrology and Water Resources in Arizona and the Southwest. Proc. of American Water Resources Assoc. (Ariz. Section) and the Arizona Academy of Science (Hydrology Section) pp 291-300.

21. Thorud, David B., K. N. Brooks. Antitranpirant effects on the transpiration and physiology of tamarisk. Water Resources Research 7(3): 499-510.

22. Thourd, David B., P. F. Ffolliott. 1972. Use of forest attributes in snowpack inventory-prediction relationships. Jour. Soil and Water Conservation. In press.

23. Zwolinski, Malcolm J. 1971. "Effects of Fire on Water Infiltration Rates in a Ponderosa Pine Stand". Proceedings, Arizona Academy of Science and Arizona Section, AWRA. April 22-23, 1971, Tempe, Arizona. pp. 107-112.

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* Not supported initially by 211(d), but closely related to subsequent 211(d) activities.

PART III

COLORADO STATE UNIVERSITY

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2460

May 1972

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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 23 May 1974

Amount of Grant: $750,000

Expenditures for Report Year $195,074 Accumulated $436,056

Anticipated for next year $171,444

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." The Colorado State University's activity in the 211(d) Grant 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 little or no understanding of, or concern for, the related institutional structure which is required today for the successful operation of water systems. A primary purpose of the 211(d) Grant program is to overcome these shortcomings by recognizing the concomitant need to analyze prevailing social systems as they affect water delivery and removal systems including the kinds of institutional changes necessary, the sources of resistance to change, and effective ways of dealing with

social resistance. 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 and 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. Each of the participating departments has looked to the International Interdisciplinary Seminar for guidance in relating research activities to the Grant objectives. The Seminar reviews and discusses a related spectrum of technical, social, economic, political and cultural factors affecting developmental changes in order to bring about a better understanding of the processes involved with regard to optimum utilization of water resources including water delivery and removal systems and related institutional development. More specifically, the departments have strengthened and improved research 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 including water delivery and removal systems and related institutional development; supporting graduate research assistants who are interested in optimum utilization of water resources; publication of technical reports; and developing linkages.

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; by deeper understanding of the role of each department to the theme of the Grant program;

through establishment by each department of benchmark data and literature applicable to the Grant objectives; and by 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 and to the larger questions of utilizing water and other natural resources for the achievement of planned change. In the following pages, Colorado State University accomplishments are discussed, including the details of the impact of Grant-supported activities in developing institutional capabilities, utilization of institutional resources in development, other resources for Grant-related activities, and next year's plan of work.

C. DETAILED REPORT

1. General Background and Purpose of the Grant

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. 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. 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 activities by Colorado State University during the reporting period related to the above 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 and economic allocation of water; also 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.

II. Objectives of the Grant

1. Objectives Restated

With the funds from the 211(d) Grant, Colorado State University is improving its 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. Specifically, the objectives and scope of the CSU 211(d) Grant Project, as stipulated in the Grant Document, are as follows:

a. Improving and expanding its professional staff in the various departments of the University which are now involved in water resource activities related to the needs of the less developed countries.

b. Expanding its number of graduate students in the departments interested in the less developed countries.

c. Expanding its departmental research programs and activities related to the needs of the less developed countries.

d. Expanding its course offerings in these departments--including interdisciplinary courses--which are related to the less developed countries.

e. Expanding special activities and initiating new ones in the United States and abroad which are related to research, teaching, and service, e.g. seminars, exchange programs, institutes, conferences, and publications which are concerned with the less developed countries.

f. Helping to alleviate the critical shortage of qualified professional personnel with international interests, experience, and expertise, and with cross-cultural insights.

g. Expanding its capability to serve in advisory and consulting capacities to various individuals, government agencies, industries, business, and other organizations having an interest in activities abroad.

h. Improving its understanding of the nature of the less developed societies, and finding ways and means of assisting them to resolve crucial problems relating to water resources development and management.

i. Developing an exchange of personnel and publications, and other programs of interaction, which will help to establish steady and effective lines of communication between Colorado State University and the less developed countries.

In addition, the CSU 211(d) Grant Document specifically lists the following area subjects:

a. Development of water supplies from various sources.

b. Conveyance, delivery, and drainage of water in open and closed conduits including rivers, canals, irrigation ditches, tunnels, and pipelines.

c. Storage and use of water in reservoirs, both above and below ground.

d. Control and measurement of water in storage and water being conveyed either for delivery or for removal (drainage).

e. Control of erosion and sedimentation with respect to delivery, removal, and storage.

f. Use of wells as a source of water or for storage of water underground.

g. Use of systems engineering for development of optimum solutions to problems of water resources utilization.

h. Understanding social, economic, political, and cultural factors in technological change, and the processes of developmental change.

i. Analysis of prevailing social systems, their structural-functional characteristics within specific less developed countries to determine:

(1) The kinds of structural changes necessary for maximizing water resource development and management, including the use of necessary new inputs.

(2) The sources of resistance to these necessary changes.

(3) Effective ways of dealing with social resistance.

j. To analyze specific organizational and administrative structures for agricultural development in specific less developed countries to determine needed changes for better water utilization in maximizing agricultural production.

k. To conduct economic analyses, including input response studies and including the analysis of delivery and removal systems, to achieve efficient and economic allocation of water for agricultural purposes in selected areas of the less developed countries.

l. By use of systems analysis, develop case studies analyzing and documenting the above relationships in selected areas of the less developed countries for instructional research and training purposes in a multidisciplinary setting.

Also, the CSU 211(d) Grant Document spells out specifically the operational plan as follows:

a. Assemble and analyze existing information on water delivery and removal systems related to the less developed countries.

b. Assemble and analyze existing information on development of institutions relevant to optimum utilization of water resources in the less developed countries.

c. Prepare plans for additional research programs which will increase the knowledge of methods, techniques, and procedures for optimizing the utilization of water resources in the less developed countries.

d. Increase the breadth and depth of teaching and educational materials for the subjects of this proposal and for the situations in various less developed countries.

e. Solicit especially well qualified graduate research assistants, from both the United States and the less developed countries, who expect to work in some aspect of international development upon completion of their training.

f. Expand the library collection, especially with respect to the problems of the less developed countries.

g. Develop a program of student and faculty exchange with certain less developed countries.

h. 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.

i. Conduct short courses, institutes, seminars, and other activities to stimulate other personnel to become more deeply and actively involved, and to help in continuing education for those already involved in various aspects of international development.

2. Review of Objectives

After several years of experience, Colorado State University feels that these objectives serve effectively as guideposts and are indispensible with respect to planning, development, management, and utilization of water resources as applied to water delivery and removal systems, and relevant institutional building.

III. Colorado State University Accomplishments

The boundaries of research work carried on by the faculty and research assistants in the 211(d) Grant program during the reporting period has been determined by the 211(d) Grant objectives assigned to Colorado State University, i.e. Optimum Utilization of Water Resources: With Emphasis on Water Delivery and Removal Systems and Relevant Institutional Development. With this context in mind, the work of the faculty and research assistants in the six participating departments is described below in two parts as follows:

1. Relationship of Research to Objectives

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. Each of the participating departments has looked to the International Interdisciplinary Seminar for guidance in relating research activities to the Grant objectives. The Seminar reviews and discusses a related spectrum of technical, social, economic, political and cultural factors affecting developmental changes in order to bring about a better understanding of the processes involved with regard to optimum utilization of water resources including water delivery and removal systems and related institutional development.

In addition, participating departments at CSU continue to look to the creative work performance of CUSUSWASH Committees such as IMP (Irrigation Management Program) which has made great progress working through the broad spectrum of interdisciplinary approach for finding solutions to the many facets of water management development including water delivery and removal systems and related institutional development. More specifically, the departments have strengthened and improved research activities with regard to and in support of the Grant objectives through:

a. Adding faculty members who have expertise in water delivery and removal, have experience in developing countries and have a

strong interest in continued work with developing countries. Civil Engineering has hired two new, experienced faculty members and Agricultural Engineering is supporting one new staff member, two of whom have had extensive experience in developing countries.

b. Teaching courses involving water delivery and removal systems and related institutional structures to students in engineering, agriculture, economics, and the social sciences. Four courses have been developed and eight courses revised due to increased knowledge gained in part through the 211(d) Grant program at little or no cost to the Grant program. Such courses have and continue to greatly broaden the knowledge and interest of faculty and students in developing countries.

c. Guiding the research activities of faculty and research assistants to increased knowledge of and/or solutions to problems in the area of optimum utilization of water resources including water delivery and removal systems and related institutional development. For example, the Agricultural Engineering Department has concentrated this year on collecting and developing water measurement technology to be used in water delivery and removal studies. In most countries, including the U.S.A. in some cases, water measurement of delivery systems and drainage return flow is poorly done or nonexistent. To knowledgeably analyze, improve or modify delivery and removal systems water measurement is absolutely necessary.

d. Supporting research assistants who are interested in optimum utilization of water resources; desire to work in water delivery and removal area want to understand more thoroughly how to put into effect related institutional structures; and who have a deep interest in developing countries.

e. Publication of technical reports and papers, and developing design manuals on water delivery and removal systems and related institutional development considered to be of high priority by developing countries.

f. Developing linkages by faculty, staff, and research assistants at CSU with faculty and staff of other universities, government

officials, officials of private companies, institutions, and individuals in developing countries.

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; by deeper understanding of the role of each department to the theme of the Grant program; through establishment by each department of benchmark data and literature applicable to the Grant objectives; and by 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 and to the larger questions of utilizing water and other natural resources for the achievement of planned change.

2. Accomplishments

a. Increased Teaching Competence

Dr. Wayne Clyma, Department of Agricultural Engineering, was supported by 211(d) Grant funds for six months. His primary interests are in water delivery and removal problems. He has had overseas experience in Ethiopia and is interested in further overseas activities. Dr. Clyma worked effectively on on-campus research in water delivery and removal systems, participated with the Department of Agronomy in the Interdisciplinary Seminar. Dr. Clyma has become fully integrated into the CSU faculty and program and has made plans to spend two years in Pakistan as part of the CSU team there. Following this tour, he will return to the CSU campus.

Two new faculty members joined the College of Engineering at Colorado State University. They are Dr. Willis W. Shaner and Dr. John W. Labadie, and are supported in part by 211(d) Grant funds. Dr. Shaner is teaching engineering courses directly related to water delivery and removal systems. Dr. Labadie is working on the development of methodology and models to improve water delivery and allocation. Both men have contributed much of their time to planning and supervising

graduate assistants performing research work related to water delivery and removal systems.

Two new courses have been developed and taught by the Department of Agricultural Engineering as a result of the 211(d) Grant. AE 555, Irrigation Structures, by Professor G. V. Skogerboe, which deals specifically with water delivery systems. This course was taken by 25 Agricultural and Civil Engineering students. AE 483, Irrigation Practices in Developing Coun' 's, by Dr. Wayne Clyma, was taken by 15 faculty and staff from nonengin..ering fields who benefited from a better understanding of water delivery and removal problems in developing countries.

One new course was added to the University curriculum in the Department of Political Science, GS 797, International Interdisciplinary Seminar in Water Resources Management. The course includes studies in the area of water delivery and removal systems. This course is a direct result of the International Interdisciplinary Seminar conducted by Professor Henry P. Caulfield. The work involved in establishing this course was partially supported by 211(d) funds. No 211(d) funds are involved in support of the course itself. Four additional new courses were added in this department, at no cost to 211(d), which are indirectly related to the Grant objectives and were added due to increased knowledge and interest gained in part through the 211(d) Grant program.

Eight courses in the Department of Economics were revised, at no cost to the 211(d) Grant program, by Drs. H. H. Biggs, G. C. Wilken and J. S. Krebs of the department. The revisions were made based on information obtained from the International Interdisciplinary Seminar and on 211(d) Grant-related activities.

The Department of Agricultural Engineering has developed, published and distributed to numerous irrigation organizations throughout the world during 1971, the design manual, "Check-Drop-Energy Dissipator Structures in Irrigation Systems." Another design manual, "Installation and Field Use of Cutthroat Flumes for Water Management" was prepared this year, but has not yet been distributed. Preparation and publication of these design manuals were partially supported by 211(d) Grant funds.

b. Improved Training of Staff; Entrainment Effects

The 211(d) Grant funds have provided the following faculty members of the Department of Economics the opportunity for research, writing, participation in the International Interdisciplinary Seminar, and graduate student advising in the application of economics, law, and institutional development to optimum utilization of water resources with emphasis on water delivery and removal systems and related institutional development. Dr. George E. Radosevich has become quite extensively involved with the special legal and institutional constraints affecting water resource management practices not just in the U.S. where he has worked in the past, but also in many other countries of the world, particularly Pakistan. During 1972-73 Dr. Radosevich will be working at the United Nations in this problem area. Dr. Huntley H. Biggs has been concerned with the problems of technological change and institutional relationships in the context of small farm agriculture and its relationship to optimum utilization of water resources. He has published two articles on the subject and written a technical report on the Puebla Project in Mexico. These presentations dealing with the delivery and utilization of water for development of small farm agriculture may be published in an edited form as evidence of CSU's enhanced competence in this area. Dr. Ronald L. Tinnermeier has been able to participate in professional conferences dealing with the problems of credit institutions for small farmers to promote better utilization of water resources and to offer consulting services to international agencies engaged in these activities, such as the Agricultural Development Council, at no cost to the 211(d) program. Dr. Terutomo Ozawa has been studying institutions and the problem of transferring and introducing new technologies in water resources development. He also serves as a consultant to the United Nations and the World Bank at no cost to the 211(d) program.

Dr. John Reuss and other staff members of the Department of Agronomy have assisted in introducing agronomic concepts

concerned with modeling supplies and delivery of irrigation water in the International Interdisciplinary Seminar and into other seminars and courses. Dr. Reuss, with foreign experience in Nigeria, and two post-doctoral fellows from Pakistan and Iran have been involved with considerable success in obtaining the interest of and training other staff and students in the optimum utilization of water resources and emphasizing water delivery and removal. In addition, the 211(d) Grant has stimulated the development of an undergraduate major entitled, "Foreign Service in Agronomy." Also, awareness of the need for foreign agricultural assistance has stimulated the College of Agricultural Sciences to have an annual undergraduate seminar entitled, "Seminar in Foreign Agriculture." Agronomy staff associated with the 211(d) project contribute each year to presentations and discussions at no cost to the Grant.

The Agronomy Department has a small group of foreign students from the developing countries. They are encouraged to participate in the International Interdisciplinary Seminar, in other seminars involving developing countries, and they serve as additional resource persons used in training CSU staff and students in the development of water resources, especially in optimum utilization of water resources and related water delivery and removal systems.

The same kind of improved staff and student training resulting in increased interest and capabilities, including entrainment effects, may be applied to each of the other participating departments.

c. Publication of Technical Reports

Six Colorado State University CUSUSWASH reports were prepared and published under the 211(d) Grant program. They were:

1. Width Constriction in Open Channels, by J. W. Hugh Barrett, Agricultural Engineering

2. Cutthroat Flume Discharge Relations, by Ray S. Bennett, Agricultural Engineering

3. Culverts as Flow Measuring Devices, by Va-son Boonkird, Agricultural Engineering

4. Installation and Field Use of Cutthroat Flumes for Water Management, by G. V. Skogerboe, Ray S. Bennett, and Wynn R. Walker, Agricultural Engineering

5. Dualism in Mexican Agricultural Development: Irrigation Development and the Puebla Project, by Huntley H. Biggs, Economics

6. The Puebla Project: Progress and Problems, by Huntley H. Biggs, Economics

The Appendix contains copies of these reports.

During the reporting year five M.S. research studies were completed. These studies were partially supported by 211(d) Grant funds and were directed toward research on some aspect of optimum utilization of water resources including water delivery and removal systems and related institutional development. The completed M.S. studies are:

1. Effect of Settlement on Flume Ratings, by Tsu-Yang Wu, Agricultural Engineering, page 49.

2. Width Constriction in Open Channels, by J. W. Hugh Barrett, Agricultural Engineering, page 50.

3. Culverts as Flow Measuring Devices, by Va-son Boonkird, Agricultural Engineering, page 51.

4. Cutthroat Flume Discharge Relations, by Ray S. Bennett, Agricultural Engineering, page 52.

5. A Systematic Approach to the Water Supply of a Large Area, by Alain Deredec, Civil Engineering.

Available abstracts, 1-4, are in Appendix A (page 48) of this report.

In process are the following theses:

1. An Analysis of the Helmand-Arghandab River Basin Development Program, by Philip A. Hosterman, Civil Engineering.

2. Water Resource Project Planning: A Conceptual Framework for Analyzing Social Action, Michael Schiefer, Civil Engineering.

3. Public Investments in Irrigated Agriculture: Mexico, 1940-1960, by Larry Caswell, Economics.

d. Library Improvement

Dr. Garth N. Jones, Political Science Department, headed a special task force consisting of members of participating departments and university librarians to strengthen the present system of identification, acquisition, storage, and retrieval of information and data in the area of water resources, particularly on the water delivery and removal systems component. In addition, he worked with library personnel at Utah State University on ways and means of integrating water resources information on a more systematic and modern storage and retrieval basis between the two universities. As one of the first steps taken at CSU to improve the cataloging system directly and/or indirectly related to water resources development or management, the Project Office moved its library collection, approximately 1400 publications, to the CSU Morgan Library.

e. Seminars

The International Interdisciplinary Seminar is conducted under the leadership of Professor Henry P. Caulfield, Jr. He also served as Chairman of the Program Committee for the Seminar composed of seven faculty members, implements committee decisions, chairs the meetings, and guides discussion to meaningful conclusions. The Seminar serves 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-eight presentations were made during the reporting period by the International Interdisciplinary Seminar on Water Resources Management using as 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 graduate research assistants and the remainder from outside sources. 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 840.

Many project 211(d) 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. Brief subject material descriptions including the names of the speakers and titles of the talks are given in the Annex.

f. Research Assistants (GRA's)

Seventeen research assistants received support from 211(d) Grant funds ranging from three to six months' support 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 are required to attend the weekly sessions of the International Interdisciplinary Seminar. The research assistants are:

James Barrett, Agricultural Engineering
Ray S. Bennett, Agricultural Engineering
Jacob H. Dane, Agronomy
Ghulam Ahmad, Civil Engineering
Alain Deredec, Civil Engineering
Philip A. Hosterman, Civil Engineering
W. A. Lemma, Civil Engineering
Rashid Makhdoom, Civil Engineering
Helena Mbele-Mbong, Civil Engineering
Michael C. Schiefer, Civil Engineering
Christopher Dowswell, Economics
Tiffin D. Harris, Economics
John M. Fly, Political Science
Everett Myers, Political Science
William Neal, Political Science
Calliope Boudara, Sociology
Forrest Deseran, Sociology

As shown in Section c., Publications, J. W. Hugh Barrett completed a study on "Width Constriction in Open Channels, Ray S. Bennett completed a study on "Cutthroat Flume Discharge Relations," and Alain Deredec completed a study on the subject, "A Systematic Approach to the Water Supply of a Large Area." Near completion are a study, "Analysis of the Helmand-Arghandab River Basin Development," by Philip A. Hosterman, and a study, "Water Resource Project Planning: A Conceptual Framework for Analyzing Social Action," by Michael Schiefer. These studies not only include but emphasize water delivery and removal systems as contributions to general studies in the area of optimum utilization of water resources. In the area of graduate research assistant supervision, the pattern of economics' involvement has followed a similar pattern of beginning with a broad approach and narrowing focus onto the institutional structures related to water management problems of small farmers. Larry Caswell was concerned with institutions related to irrigation development in the northwest region of Mexico. Chris Dowswell is currently in Guatemala where he has been involved in analyzing specific organizational and administrative structures needed for better water delivery and removal systems in maximizing agricultural production. The remaining graduate research assistants are still in various stages of thesis development. For example: Calliope Boudara and Forrest Deseran of Sociology are continuing 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.

g. Meetings and Travel

Two interuniversity (CUSUSWASH) meetings were held, one at the University of Arizona (Tucson) and the other at Colorado State University (Fort Collins). Since the subject material discussed at these meetings covered both 211(d) Grant and the CUSUSWASH overseas Contracts, the travel and meeting costs are appropriately divided.

Six CUSUSWASH Committee Meetings were held at one or another of the Consortia Universities. Grant funding was provided for CSU participants. Two international trips were supported by 211(d) Grant funds and one was partially supported.

3. Summary of Accumulated Accomplishments

a. Increased Teaching Competence

Two new faculty members joined the College of Engineering, Dr. Willis W. Shaner and Dr. John W. Labadie. Two new courses were developed in the Department of Agricultural Engineering and taught by Professor G. V. Skogerboe and Dr. Wayne Clyma. One new course was added to the University curriculum in the Department of Political Science, and four courses added at no cost to the 211(d) Grant. Eight courses in the Department were revised due to increased knowledge gained in part through the 211(d) Grant program at little or no cost to the Grant program. Developed and distributed throughout the world the design manual, "Check-Drop-Energy Dissipator Structures in Irrigation Systems". Another design manual published but not distributed, Installation and Field Use of Cutthroat Flumes for Water Management". See abstracts in Appendix A.

b. Improved Training of Staff; Entrainment Effects

Greatly improved and more effective use of 211(d) Grant funds by all six participating departments providing time for research, writing, participation in the International Interdisciplinary Seminar, travel, developing linkages at and participation in professional conferences, graduate student advising, and promoting entrainment

affects in the field of optimum utilization of water resources: with emphasis on water delivery and removal system(s) and related institutional development.

c. Publication of Technical Reports

Six Colorado State University CUSUSWASH reports were prepared and published under the 211(d) Grant program; five M.S. research theses. Abstracts for most of these reports and studies may be found in Appendix A.

d. Library Improvement

Members of the six participating departments together with two university librarians strengthened the present library system particularly in the area of water delivery and removal systems. During the reporting year, 52 new publication purchases were made from non-211(d) Grant funds. At the end of the fiscal year, the project office moved its library collection, approximately 1400 publications, to the CSU Morgan Library as a first step in improving the availability of reference material on water delivery and removal systems.

e. Seminars

Twenty-eight presentations were made during the reporting period, greatly stimulating the thinking of the participating departments, particularly in relationship of research to objectives of the Grant.

f. Graduate Research Assistants (GRA's)

Seventeen research assistants received support from 211(d) Grant funding ranging from three months to six months support. Five of this number completed M.S. theses. The remainder are in the process of producing theses which may take from one to two years longer to complete, having just begun their studies. All studies are directed toward some aspect of 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, page 46.

	Expenditure	Percent
Salaries (Increased teaching competence)	$ 84,594	43
Stipends (Graduate research assistants)	59,695	30
Travel	13,188	7
Library and Publications	13,060	7
*Other (Office expenses)	14,537	8
CUSUSWASH Executive Director's Office Support	10,000	5
Total	$195,074	100

*Breakdown:

Clerical costs	$ 9,073
Office expense	$ 5,464
(telephone, Xeroxing, mailing, supplies, Western Union)	$14,537

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 participating departments of CSU can now participate even more heavily in projects and programs with developing country governments and international institutions 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 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 a major 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 to related institutional development. The International Interdisciplinary Seminar has met for two hours each week throughout the academic year 1971-1972 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, Professor Caulfield has been increasingly successful in creating an

appreciation among faculty, graduate 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 through optimal utilization of water resources. 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 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.

The Grant has made the following specific 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 (Skogerboe, Walker, Clyma) 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 who have helped to establish linkages in these countries, who work in developing countries, who have significant contacts there and increase CSU's linkages. Courses directly and indirectly related to water delivery and removal and relevant institutional development have been developed and are being taught to students and staff from many parts 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 and relevant institutional development.

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.

The 211(d) Grant program has created a greater awareness of the needs of developing countries in the solution of problems in water resource management on the part of the Department of Agronomy. 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. The program has improved staff capability for advising the increasing number of U.S. and foreign students coming to our Department to study in the various program areas such as delivery and removal systems, irrigation management, and related institutional development situations. 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, three trips to Pakistan in 1971-72 were requested by the Mission for consulting and program planning on the water management project.

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 by adding to the staff Drs. Shaner and Labadie; 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.

The approach of and the impact on the Department of Economics in the 211(d) Grant program has been to involve 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 have been increasingly realized through a number of activities, including teaching, research, publications, conferences and consulting. 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 heavily 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 removal and delivery systems 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; instigation of original surveys and other field studies which may provide the training ground

for graduate students 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 larger 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--effectively 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. The Seminar, under the leadership of Professor Henry P. Caulfield, has had and continues to exert a great deal of influence through its 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. The competence of Colorado State University in the above stated Grant theme has greatly improved its utilization of such institutional resources through the activities of the Seminar. 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. Elsewhere, ties were also 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 below.

The following utilization of institutional resources in development was made by the Department of Agricultural Engineering: Dr. W. E. Hart made a trip to Nigeria to help give a seminar at the International Institute of Tropical Agriculture. He has spent considerable time

preparing the seminar dealing with irrigation development and problems in this region in the work. Dr. Hart is well able to focus on these topics because of his experience in irrigated agriculture in tropical and semi-arid regions. While in Nigeria, Dr. Hart visited with a number of African educators, researchers and Government officials, thereby gaining additional knowledge and experience in water delivery and removal systems. Professor G. V. Skogerboe and Dr. D. B. McWhorter, also of the Department of Agricultural Engineering, organized and taught the Irrigation Practices Short Course under the sponsorship of the USDA. Thirty participants from all over the world came to CSU to interact with our faculty and to obtain some intensive instruction and tour irrigation developments in the Rocky Mountain Region. This short course (60 days) was very supportive of the 211(d) Grant objectives and dovetailed into CSU's overall program (no 211(d) funds involved). A design manual prepared during fiscal year 1971 was distributed this fiscal year to numerous irrigation organizations throughout the world. The title of this manual is "Check-Drop-Energy Dissipator Structures in Irrigation Systems" (partially funded by 211(d), abstract page 53). Another design manual, "Installation and Field Use of Cutthroat Flumes for Water Measurement," was prepared this year, but has not yet been distributed (partially funded). Numerous letters have been received regarding the first design manual, with statements being made regarding the usefulness of such a report in the actual design of structures. After developing an awareness of specific design problems in any particular irrigated region, the possibility of presenting a short course on designing irrigation distribution systems, as well as the role of such systems in improved water management and consequent agricultural productivity, should be undertaken.

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/AID/csd 2162 water management research project in Pakistan at no cost to the 211(d) Grant Program, also to permit one Agronomy staff member to serve as a

consultant for the USBR during the year on the Pamong Irrigation Project in Thailand, again at no cost to the 211(d) Grant.

Many members of the Civil Engineering faculty are asked each year to serve as advisors and consultants to various foreign governments, and various industries and organizations (such as the World Bank) on problems of water delivery and removal. Experience gained by 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 of 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. Brief examples of the department's response to overseas requests are: Dr. Maurice L. Albertson's participation in a seminar sponsored by the International Institute of Tropical Agriculture (IITA) in Ibadan on Prospects for Irrigation in West Africa; and Dr. Albert G. Mercer's participation with the National Science Foundation (no 211(d) funds involved) regarding the new link-canal study in collaboration with the Mona project in Pakistan.

The participation of CSU in the 211(d) Grant program has heightened the visibility of the Department of Economics in the area of water resources management, especially in optimal utilization of water resources, water delivery and removal systems, and related institutional development. An increasing number of foreign students have selected CSU to pursue a graduate degree in water resources economics, related economic development as well as agricultural development including investigating through research, ways and means of increased food production through optimal utilization of water resources. Examples of the utilization of institutional resources by faculty members are: Dr. George Radosevich, an Assistant Professor of Economics, holds a Doctor of Jurisprudence as well as a Master of Agriculture in economics. His special area of

interest is in water law and the legal constraints which affect the optimal use of water resources. In part with the support of 211(d) funding, he responded to a request from AID to travel to Europe and Southeast Asia for the purpose of gathering information and material for the USAID/Pakistan Water Law Project. This trip was completed in the summer of 1971. In April, 1972, he was requested by USAID/Mission Pakistan and Afghanistan to travel to Pakistan, Afghanistan, Iran, Israel, and Italy to gain information regarding water management through legal controls. During the summer of 1972, Dr. Radosevich served as the legal and economics adviser to a special USAID three-man team to Nigeria, Africa, to assist in the preparation of a request for a feasibility study of the Do-Anambra River Basin. Dr. Huntley H. Biggs has worked on the problems of technological change with regard to small farm agriculture and its relation to optimum utilization of water resources institutional development, and published two articles on the subjects including a technical report on the Puebla Project in Mexico. Dr. Ronald L. Finnermeier participated in many conferences during the year dealing with problems of credit institutions for small farmers to promote better utilization of water resources. Dr. Terutomo Ozawa continued his studies on institutions and the problem of transferring and introducing new technologies in water resources development. In addition, examples of the utilization of institutional resources by graduate students are: Larry Caswell concerned with institutions related to irrigation development in northwest Mexico; and Chris Dowswell involved in analyzing specific organization and administrative structures needed for better water delivery and removal systems in maximizing agricultural production.

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 places 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 to be held from the 23rd to the 27th of October, 1972. Colorado State University will respond by sending to Nigeria four scientists, Drs. Maurice L. Albertson, W. Doral Kemper, Evan C. Vlachos, and William E. Hart to Nigeria who will present papers at the seminar. Also, Dr. George Radosevich will be sent to Nigeria to help on the Do-Anambra 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.

Dr. Garth N. Jones, Department of Political Science, has been engaged in many 211(d) Grant supported activities as well as generating many spin-off activities related to 211(d) Grant objectives. Some of these spin-off activities, not 211(d) funded, are:

1. Participation as a member of the water development workshop program of the Agricultural Development Council (ADC).

2. Presented a paper on December 23, 1970 to East-West Center senior scholars on "Emerging Conceptions and Patterns of Development Assistance".

3. Participated in sessions sponsored by AID on irrigation systems and development.

4. Assisted in course revision and development of new courses.

VI. Other Resources For Grant-Related Activities

All of the participating departments have reported that contributions in time to the training of students in the field of optimum utilization of water resources with emphasis on water delivery and removal systems and related institutional development are two to three times the 211(d) Grant funds for salaries. Also, all departments list the AID Research Contract AID/csd 2162 as a valuable resource for the 211(d) Grant.

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.

A dual effort research program under the Department of Agronomy is being developed through the combined funding from 211(d) and from OWRR to study the interactions of water and salt movement in soil profiles. The proposed research relates to the quality of water in return flows. This information will be useful in the design and management of irrigation water delivery and removal systems. Staff has been obtained and research will begin immediately.

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. Dr. Albert G. Mercer, at no cost to the 211(d) Grant, submitted to the National Science Foundation a proposal for collaboration with WAPDA, Pakistan, to increase food production in waterlogged and saline areas.

Currently, the major source of funding for Grant-related activity in the Department of Economics is provided by the Agency for

International Development through CUSUSWASH in support of a water Management Program in Pakistan. The central focus of this program is "On-Farm Water Management." Dr. Gene Wilken, at no cost to the 211(d) Grant, is attempting to develop a research program through the National Science Foundation. This research program was to be concerned with "Resource Management and Native Farming Systems in East Africa." It is expected that a number of additional research programs will be submitted to funding agencies in the coming year dealing with problems of water resources and agricultural development in the developing countries.

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 Department of Agricultural Engineering will continue to utilize research results in preparing at least one design manual during fiscal year 1973. In addition, the total research effort to date will be assimilated into the compilation of information on irrigation structures which had been collected at an earlier date. This will allow another upgrading of the course material for AE 555, "Irrigation Structures." Mr. Qurban Ali Khan, a graduate research assistant, attended the Irrigation Practices Training Course conducted by CSU during the summer of 1971. This course was sponsored by AID. He is presently on leave from the Directorate of Agricultural Engineering at Lyallpur, Pakistan. He will undertake a study on small irrigation structures for water delivery and control used in Pakistan, and the information being utilized in designing such structures. This information will be compared with the existing material collected by the department to determine: Which structures have adequate design information and which have inadequate design information. Also, CSU collected information will be used to improve design information or to obtain additional needed design information

The anticipated budget and expenditures are:

	Man Months	Budget
Staff and faculty	3	5,244
Graduate research assistants	10	5,000
		10,244

The Department of Agronomy will activate a new research project, "Salt Transport in Soil Systems," under the direction of Dr. Arnold Klute and Dr. W. T. Franklin. It will emphasize the movement and accumulation of salt in the soil as a function of 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.

The anticipated budget and expenditures are:

	Man Months	Budget
Staff and faculty	2	2,365
Graduate research assistants	9	5,040
		7,405

211(d) funds this coming year will be used by the Department of Civil Engineering primarily to obtain new Civil Engineering personnel to increase staff resources in optimum utilization of water resources--particularly in water delivery and removal systems and relevant institutional development. The department is supporting two new faculty, Drs. W. Shaner and J. Labadie. They are being supported six and four months, respectively, by 211(d) Grant funds.

Dr. Shaner has been hired by the College of Engineering to broaden its water management program to include water delivery and removal systems and related institutional development. He has had extensive foreign experience both in South America and in Africa. His experience and knowledge of these areas will strengthen the teaching of the water delivery and removal systems programs of the Engineering College and of the University. Dr. Shaner will take part in the Water Management Seminars, work with Dr. Albertson in developing optimum utilization of water resources programs in Africa, East Asia and South American, and will be available for short or long term assignments on specific water delivery and removal problems. Dr. Labadie was hired in the water resources program of the Civil Engineering Department. He is working on improvement of water delivery and removal systems courses, the development of methodology and models to improve water delivery and removal. In addition to the new staff, the 211(d) Grant monies will be used for support of Drs. M. L. Albertson (2 months), E. V. Richardson (1 month), H. J. Morel-Seytoux (1/2 month), and A. G. Mercer (1/2 month) in order that they might have time to guide and plan research and the work of graduate assistants on water delivery and removal studies, take part in the International Interdisciplinary Seminar, to correspond, advise and work with

CUSU SWASH officials, and other 211(d) Grant affairs involving the United Nations, World Bank, foreign governments and universities (foreign and U.S.). The 211(d) Grant to improve the competence of Colorado State University in optimum utilization of water resources, especially in the field of water delivery and removal systems including relevant institutional structures, will allow the following graduate research assistants to continue their studies: W. A. Lemma, Michael Schiefer, and Rashid A. Makhdoom.

The anticipated budget and expenditures are:

	Man Months	Budget
Staff and faculty	14	30,380
Graduate research assistants	36	21,900
		52,280

Dr. Huntley H. Biggs, Department of Economics, will continue to: take an active part in the International Interdisciplinary Seminar including service on the Planning Committee for the Seminar as representative from Economics; act as chairman of a seminar series on a selected topic concerned with constraints affecting optimum use of water resources with emphasis on water delivery and removal systems and relevant institutional development; continue research in the field of employment and technology that was initiated under 211(d) during 1971-72 related to water development and removal systems and essential institutional structures; advise graduate research assistants funded under 211(d), supervise theses of Larry Caswell and Chris Dowswell; continue interest in investigating the impact of increasing production of small farms on general economic development using the Puebla Project area of Mexico as a case study and tying these studies in with water delivery and removal systems. Dr. Terutomo Ozawa will participate regularly in the International Interdisciplinary Seminar and continue with his input on international transfer of technology in the field of optimum utilization of water resources, water delivery and removal systems and related institutional development.

Dr. Ronald Tinnermeier will continue to increase professional competence in water delivery and removal systems and to carry out research on the economics of agricultural development with special emphasis on subsistence agriculture as affected by water delivery and removal problems; continue looking at supervised agricultural credit institutions for small farmers. The introduction and use of new water management delivery and removal techniques along with other complementary inputs almost always requires additional capital. Few research results are available suggesting how credit institutions can best be extended to small farmers to acquire such inputs; and to seek additional resources to complement Grant-related activities. Dr. Gene C. Wilken will continue attendance and participation in the Seminar on optimum utilization of water resources emphasizing water delivery and removal systems and related institutional development; continue research and preparation of reports: Ecologic Aspects of Native Farming Systems, including perception, modification, and optimum utilization of water resources, use of water delivery and removal systems and related institutional development including the cultural aspects of underdeveloped areas. Dr. J. Stuart [illegible]bs will continue attendance and participation in the 211(d) International Interdisciplinary Seminar on optimum utilization of water resources emphasizing water delivery and removal systems and related institutional development; and begin research on a modest scale on the effects of agrarian reform upon agricultural production, focused primarily on Chile including effect of reform on water delivery and removal and results upon agricultural production.

The anticipated budget and expenditures are:

	Man Months	Budget
Faculty and staff	7	10,579
Graduate research assistants	6	3,300
		13,879

Professor Henry P. Caulfield, Department of Political Science, will continue his work in the development, direction and conduct of the Interdisciplinary Seminar. The Department will attempt to supplement

its support of four 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 anticipated man months and bduget are:

	Man Months	Budget
Faculty and staff	6	9,385
Graduate research assistants	18	9,720
		19,105

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 two research assistants. The research assistants are 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 man months and budget are:

	Man Months	Budget
Faculty and staff	3	6,228
Graduate research assistants	12	5,400
		11,628

VIII. Other

The utilization of institutional resources not related directly to water delivery or removal systems and not supported by 211(d) Grant funds generated by participating department faculty members but showing the entrainment effect of the Grant includes the following examples:

1. During August, 1971, Dr. Ronald L. Tinnermeier presented a paper on supervised agricultural credit programs in developing countries for the Agricultural Policy Seminar in Washington, D. C. He also presented a second paper dealing with supervised agricultural credit for the Seminar on Development Strategies for Small Farmers sponsored by Ohio State University and the Research and Training Network of the Agricultural Development Council, Columbus, Ohio, in September, 1971. As a result of the Ohio seminar, Dr. Tinnermeier was also asked to organize a workshop to analyze specifically agricultural credit requirements for small farmers. This seminar was completed in April, 1972. Dr. Tinnermeier has been invited to participate in the USAID Annual Spring Review concerned with Agricultural Credit for Small Farmers in developing countries to be held in 1973. Beginning in June 1972, a resident economist from CSU, Dr. Jerry Eckert, has been assigned to participate in the project as a member of CSU's field party in Pakistan. The major thrust of the research effort will be to formulate a technical package which is relevant to the needs of the small farmers in that country. During 1971-72, there were a number of students from developing countries enrolled in a graduate program 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.

Name	Country	Specialization	Funding
Acquah, Benjamin Kojo	Ghana	Ag Econ Nat Res Dev	USAID
AlTell, Tariq	Jordan	Ag Econ Statistics	FAO
Khan, Mohammad Jameel	Pakistan	Ag Econ Nat Res Dev	211(d)
Khan, Ahmad Saeed	Pakistan	Ag Econ Dev	211(d)
Lee, Sun-Jong	Korea	Ag Econ Nat Res	USAID
Mesfin, Mebrahtu	Ethiopia	Ag Econ Nat Res	USAID
Tekie, Million	Ethiopia	Ag Econ Dev Stat	USAID
Reyes, Pedro	Peru	Ag Econ Dev	
Sarwar, Mohammad	Afghanistan	Dev Nat Res	
Satiroglu, Kadir	Turkey	Dev International	
Sumali, Muttamara	Thailand	Ag Econ	USAID
Weng, Yueh-Shya	Taiwan	Ag Econ	

2. Graduate students of the Department of Agricultural Engineering who have chosen to come to CSU because of interest in institutional development work in the area of water delivery and removal systems are as follows: (no support from 211(d) excepting two as noted)

Zewdie Abate	Ethiopia
Chuntse Chang	China
Ken Tsai Huang	China
Jindasanguan Leck	Thailand
Qurban Ali Khan	Pakistan *
Mohamad Mahmoodian-Shoostari	Iran
Habte Neghassi	Ethiopia *
Mahmood Shariatmadar-Taleghani	Iran
James Taylor	USA

* Supported in part by the 211(d) Grant program.

3. 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 and 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.

IX. Report of Expenditures

1. The expenditures as shown in Table I and Table II state the expenditures for fiscal year July 1, 1971, through June 30, 1972, 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 '73 represents the total funds allocated to the six departments involved in the 211(d) Grant Program. The projected budget for FY '74 is outlined in Section VII, Next Year's Plan of Work and Anticipated 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 the purpose of 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 I also includes the costs of consultants to support the programs of the Interdisciplinary Seminar. Some consultants served in this capacity at no expense to Grant funds.

Line Item II is the amount paid to graduate students for 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 Graduate Research Assistants supported by 211(d) funds for periods from three to six months is given on page 17.

The Line Item III on travel represents all international travel and also travel within the United States. See page 47 for 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. 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.

With regard to Line Item V, since the Grant funds have been responsible for spin-offs in other research, there was no need to purchase equipment as most of the equipment was provided by non-211(d) Grant funds.

Line Item VI, Other and Office Expenses, shows the amount spent for clerical assistance for the CSU contributed share of the CUSUSWASH Executive Director for administration of the Grant, and for the funds allocated to the various departments. Other office expenses cover 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.

2.

Table I

Expenditure Report
(Actual and Projected)

Under Institutional Grant AID/csd-2460

Review Period 1 July 1971 to 30 June 1972

(List all Grant-related activities)	Expenditures to Date: Period under Review	Expenditures to Date: 1 July 69 - 30 June 72 Cumulative Total	Projected expenditures: FY '73	Projected expenditures: FY '74	Non 211(d) Funding Amount
I Teaching	$84,594	$198,012	$68,500	$53,500	$ 96,800
II Research	59,695	113,555	68,500	53,500	165,000
III Travel	13,188	43,083	17,500	18,500	20,000
IV Libraries and Publications	13,060	20,066	4,000	5,000	10,000
V Equipment	--	3,331	2,000	1,000	55,000
VI *Other	24,537	58,009	10,944	11,000	
TOTAL	$195,074	$436,056	171,444	142,500	$346,800
*Breakdown on Other Direct Costs:					
Clerical expense	9,073				
Office expense (telephone, Xeroxing, mailing, supplies, Western Union)	5,464				
CUSUSWASH Executive Director's Office (CSU contribution)	10,000				
	$24,537				

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3.

Table II

Expenditure Report
(Actual and Projected)

Under Institutional Grant AID/csd-2460

Review Period 1 July 1971 to 30 June 1972

(List all Grant-related activities)	Expenditures to Date: Period under Review	Expenditures to Date: 1 July 69 - 30 June 72 Cumulative Total	Projected expenditures: FY '73	Projected expenditures: FY '74	Projected Five-Year Total
Salaries	$84,594	$198,012	$68,500	$53,500	$320,012
Stipends	59,695	113,555	68,500	53,500	235,555
Travel	13,188	43,083	17,500	18,500	79,083
Equipment	--	3,331	2,000	1,000	6,331
Other (Office Expenses)	24,537	58,009	10,944	11,000	83,498
Library and Publications	13,060	20,066	4,000	5,000	25,521
TOTAL	$195,074	$436,056	171,444	142,500	$750,000

*Breakdown on Other Direct Costs:

Clerical expense	9,073
Office expense (telephone, Xeroxing, mailing, supplies, Western Union)	5,464
CUSUSWASH Executive Director's Office (CSU contribution)	10,000
	$24,537

11 April 1973
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4. **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. IF PARTIAL FUNDING WAS CHARGED TO THE GRANT, THIS SHOULD BE INDICATED.				
GRA	Philip A. Hostermann - Kabul, Afghanistan - 2 months To study the Helmand River Valley and other water resources in Afghanistan in relation to CSU Institutional Grant.	ticket actual expenses	1,545.18 548.04	$2,093.22	
Faculty	Dr. Maurice L. Albertson - Bulgaria, Nigeria - 1 month To attend the ICID Executive Council To attend the Soils Consortium in Ibadan as a representative of CUSUSWASH.	ticket (partial) expenses	802.40 582.00	$1,384.40	(partial)
Faculty	Dr. Huntley H. Biggs - Mexico City - 10 days To conduct research activities connected with water resources that are related to the objectives of the 211(d) Institutional Grant	Ticket expenses (actual)	209.00 238.86	$447.86	

APPENDIX A

Appendix A contains the following abstracts:

1. Effect of Settlement on Flume Ratings
2. Width Constrictions in Open Channels
3. Culverts as Flow Measuring Devices
4. Cutthroat Flume Discharge Relations
5. Check-Drop-Energy Dissipator Structures in Irrigation Systems

ABSTRACT

EFFECT OF SETTLEMENT ON FLUME RATINGS

Frequently, flow measuring flumes placed in unlined channels settle at the flume exit because of the scouring action of the high velocity flow leaving the flume. Usually, this settlement condition goes uncorrected in the field. A more satisfactory solution to the problem would be in evaluating the effect of this settlement upon the discharge rating of the flume.

Four cutthroat flumes were selected for hydraulic testing in the laboratory. These flumes had been previously rated with the flume floor horizontal. In this study, hydraulic data were collected under both free flow and submerged flow conditions for each flume at various degrees of flume floor slope.

The experimental results show that there is a very definite effect upon the discharge rating of a flume due to settlement. The amount of correction increases as the tilt angle increases. Also, the amount of correction increases as the flume length is increased.

Tsu-Uang Wu
Agricultural Engineering Department
Colorado State University
Fort Collins, Colorado 80521
August, 1971

ABSTRACT

WIDTH CONSTRICTIONS IN OPEN CHANNELS

The purpose of this study is to compare the existing methods of calculating the backwater due to, or discharge through, a constriction in an open channel, and to show how these methods are but particular expressions of a more general submerged flow equation.

An extensive literature review has been made describing the analyses leading to the current methods of computation. The application of these methods of computation has been described. The derivation and application of the submerged flow equation to these methods has also been described.

The equations of Kindsvater, Carter and Tracy; Liu, Bradley and Plate; and the Bureau of Public Roads, have each been expressed in the form of a submerged flow equation, with data generated from the equations plotted in terms of the submerged flow parameters. The relation of the Froude number to the submerged flow analysis is then shown.

Application of the submerged flow equation, as presented in this work, is considerably simpler than previous methods. Also, more accurate results were obtained when the equation was applied to data collected from model studies. However, the submerged flow analysis has not been proven in prototype application.

J. W. Hugh Barrett
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Colorado State University
Fort Collins, Colorado 80521
November, 1971

ABSTRACT

CULVERTS AS FLOW MEASURING DEVICES

Culverts are encountered throughout irrigation systems. Many of these culverts operate under free surface flow conditions. Usually, the flow depths in the culvert are governed by downstream flow conditions. This particular flow condition can be described as free surface outlet control. Only an approximate solution for determining discharge has been available for this situation.

A 12 inch diameter corrugated metal pipe has been used in the laboratory to test the validity of the submerged flow analysis employed with flow measuring flumes and weirs in describing free surface outlet control in culverts. Various slopes and culvert lengths were studied.

This study has shown that discharge ratings under free surface outlet control flow conditions can be developed. Such ratings can be related to the discharge relationships for inlet control and submerged outlet control. Thus, culverts can be used as flow measurement structures in irrigation systems.

Va-son Boonkird
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Colorado State University
Fort Collins, Colorado 80521
February, 1972

ABSTRACT

CUTTHROAT FLUME DISCHARGE RELATIONS

The purpose of this study is to rate a group of cutthroat flumes which have the same geometric shape. Because of geometric similarity, the behavior of all flumes which are dimensionally similar to those tested should be capable of being predicted within a degree of accuracy suited for field use.

Twelve flumes were used in this study, all of which have the same shape. Three flume lengths were used, namely, 1.5 feet, 3 feet, and 4.5 feet, with four different throat widths for each length. In addition, the flume sizes were selected so as to permit correlation with the initial cutthroat flume studies (28), wherein a flume length of 9 feet, and throat widths varying from 1 foot to 6 feet, were studied.

The hydraulic data were collected under both free flow and submerged flow conditions. The method of submerged flow analysis reported by Skogerboe, Hyatt, and Eggleston (29) was utilized in developing the rating curves for the cutthroat flumes. This method of analysis was performed while the data were being collected.

An outstanding feature of the cutthroat flume is that generalized discharge rating curves can be easily developed.

ABSTRACT

CHECK-DROP-ENERGY DISSIPATOR STRUCTURES
IN IRRIGATION SYSTEMS

There is a large volume of available literature regarding small energy dissipator structures. Existing publications present basic information for particular types of structures. This information has been compiled in order to present present-day available design information. Also, research topics are delineated which would further assist the development of adequate design criteria.

Skogerboe, Gaylord V., Venus T. Somoray, and Wynn R. Walker. CHECK-DROP-ENERGY DISSIPATOR STRUCTURES IN IRRIGATION SYSTEMS. Report to United States Agency for International Development, Contract No. AID/csd-2460. Water Management Technical Report No. 9. AER 70-71GVS-VTS-WRW4, Agricultural Engineering Dept., College of Engineering, Colorado State University, Fort Collins, Colorado. May 1971.

KEYWORDS - baffles, drops (structures), hydraulic design, *hydraulic structures, *open channel flow, overfalls, riprap, stilling basins.

APPENDIX B

Further information on the 211(d) Grant supported program of the International Interdisciplinary Seminar is provided in Appendix B and is presented in two parts:

1. The Three Types of Presentations
2. Titles of Presentations

Appendix B

1971-1972 Report on the 211(d) Grant Supported Program of the International Interdisciplinary Seminar in Water Resources Management

The general plan for conduct of the Seminar in 1971-1972 called for three types of presentations:

1. Theories of Modernization and Development of Less Developed Countries. A multidisciplinary faculty-student group under the leadership of Dr. Huntley Biggs, Assistant Professor of Economics, developed a series of presentations under the general heading with particular emphasis upon the role of technology in developmental change related to institutional development affecting optimum utilization of water resources: with emphasis on water delivery and removal systems.
2. Review of the Comprehensive Framework Study of the Platte-Niobrara Subbasin. This study is a part of the larger "Comprehensive Framework Study of the Missouri River Basin" (one of eleven such large studies now underway or recently completed in the United States) that has been recently completed by the Missouri Basin Inter-Agency Committee which is composed of representatives of the several Federal departments and agencies and of the States that are concerned. A multidisciplinary faculty-student group under the leadership of Dr. Albert Mercer, Associate Professor of Civil Engineering, undertook review of the Platte-Niobrara reports and prepared papers for presentation to the seminar. Criteria used to guide the review related: (a) to the appropriateness of the study design, the professional competence exhibited in conduct of the study, and the usefullness of the results in terms of the abilities and needs of the United States; (b) to the usefulness of such an approach to planning water and related land resources use in less developed countries; and (c) from these reviews what conclusions or lessons might be drawn regarding water delivery and removal systems and related institutional development necessities.
3. Interdisciplinary Modeling of Water Management Problems. Emphasis in the development of papers presented to the seminar was placed on rigorous construction of interdisciplinary models. This approach,

which was undertaken under the leadership of Dr. John Reuss, Associate Professor of Agronomy, resulted in a series of presentations relating to optimal timing of the delivery of irrigation water and in one presentation on the conjunctive use of ground and surface water in irrigation.

In implementation of this general plan, the following presentations were made:

1. Theories of Modernization and Development of Less-Developed Countries

   a. Perspectives on Development: Problems of Definitions and Concepts, Dr. Huntley Biggs, Assistant Professor of Economics; Dr. David M. Freeman, Assistant Professor of Sociology and Anthropology; Robert F. Schmidt, Classroom Assistant, Political Science.

   b. Classical Models of Economic Development, Dr. Huntley Biggs, Assistant Professor of Economics.

   c. A Sociological View of Technology in Development, Dr. David M. Freeman, Assistant Professor of Sociology and Anthropology.

   d. Organizational Requirements for the Development and Application of Technology, Dr. Garth N. Jones, Professor of Political Science; Robert F. Schmidt, Classroom Assistant, Political Science.

   e. Information and Misinformation on Models for Decision Making, Dr. David M. Freeman, Assistant Professor of Sociology and Anthropology.

   f. Some Ecological Aspects of Technological Change, Dr. Gene Wilken, Associate Professor of Geography.

   g. Factors Conducive to Transferring Technologies: The Viewpoint of Developed Countries, Dr. Terutomo Ozawa, Associate Professor of Economics.

   h. The Appropriateness of Technological Transfers: The Viewpoint of the Developing Countries, Dr. Huntley Biggs, Assistant Professor of Economics.

2. Review of the Comprehensive Framework Study of the Platte-Niobrara Subbasin.

   a. The High Policy of Comprehensive Multiple Purpose River Basin Planning in the United States. Professor Henry P. Caulfield, Jr., Department of Political Science.

   b. The Framework Study of the Missouri River Basin with Special Reference to the Platte-Niobrara Subbasin.

      (1) Overall Analysis Planning, Conduct and Results of Framework Study. Mr. Gus Karabotsus, Chief, Planning Division, Missouri River Basin Division, Army Corps of Engineers Omaha, Nebraska.

      (2) Fish, Wildlife and Outdoor Recreation Aspects. Emanuel Laucks, Bureau of Outdoor Recreation, Denver.

      (3) Irrigation Aspects Plus State Role in Study. Mr. James Owen, Assistant Executive Secretary Soil and Water Conservation Commission, State of Nebraska, Lincoln.

   c. An Overall Appraisal of the Comprehensive Framework Study, Platte-Niobrara Subbasin. Michael C. Schiefer, Graduate Student, Department of Civil Engineering.

   d. Framework Study, Platte-Niobrara Subbasin--Analysis of Surface and Groundwater Hydrology. Cathy Kraeger, Graduate Student, Department of Civil Engineering; and Dr. Albert G. Mercer, Associate Professor of Civil Engineering.

   e. Framework Study, Platte-Niobrara Subbasin--Use of Economic and Population Projections. Dr. Robert A. Young, Associate Professor of Economics, Colorado State University.

   f. Framework Study, Platte-Niobrara Subbasin--Analysis of Agricultural, Municipal, and Industrial Water Needs. Dr. Robert A. Young, Associate Professor of Economics, Colorado State University; and Dr. Raymond Anderson, Research Economist, Economics Research Service, USDA, Fort Collins.

g. Framework Study, Platte-Niobrara Subbasin--Analysis of Fish, Wildlife and Recreation Aspects. Dr. Howard Alden, Department of Outdoor Recreation, College of Forestry and Natural Resources; and Dr. James Bailey, Department of Fishery and Wildlife Biology College of Forestry and Natural Resources.

h. Framework Study, Platte-Niobrara Subbasin: Critique of Plan Formulation and Overall Plan in Terms of Professional Standards and Utility in United States and Less Developed Countries. Panel of faculty members and graduate students.

i. North Atlantic Framework Study (For Comparison to Platte-Niobrara Subbasin Study). Harry Schwarz, Senior Planner, North Atlantic Division, Army Corps of Engineers, New York City. Discussants: Dr. Albert G. Mercer, Associate Professor of Civil Engineering; Dr. Burnell Held, Professor of Recreation Resources and Economics; Dr. Robert A. Young, Associate Professor of Economics.

3. Interdisciplinary Modeling of Water Management Problems

a. A Program for Water and Soil Management in Irrigated Regions. Dr. Wayne Clyma, Associate Professor of Agricultural Engineering; George L. Smith, Associate Professor of Civil Engineering. Discussants: Dr. David M. Freeman, Assistant Professor of Sociology and Anthropology.

b. The Effects of Varying Levels of Water Availability on Crop Response. Habte Mariam Neghassi, Graduate Student from Ethiopia in Agricultural Engineering; Dr. V. J. Bidwell, Research Associate from New Zealand, Department of Civil Engineering. Discussants: Dr. John O. Reuss, Associate Professor of Agronomy; Dr. Raymond L. Anderson, Economist, Economic Research Service, USDA; and Dr. H. J. Morel-Seytoux, Associate Professor of Civil Engineering.

c. The Effects of Water Distribution Rules on the Economic Returns from Irrigation. Dr. Raymond L. Anderson, Economist, Economic Research Service, USDA. Discussants: Dr. Robert E. Danielson, Professor of Agronomy, Dr. Wayne Clyma, Associate Professor of Agricultural Engineering; and Dr. John O. Reuss, Associate Professor of Agronomy.

d. Plant Responses to Water Stress and Possible Modeling Approaches. Dr. John O. Reuss, Associate Professor of Agronomy; Dr. Robert E. Danielson, Professor of Agronomy.

e. An Improved Model for Optimal Timing of Irrigation. Habte Mariam Neghassi, Graduate Student in Agricultural Engineering. Discussants: Dr. Vincent Bidwell, Research Associate, Department of Civil Engineering; Dr. Robert Young, Associate Professor of Economics; Dr. John O. Reuss, Associate Professor of Agronomy.

f. Criteria for Conjunctive Operation of Ground and Surface Waters. Dr. H. J. Morel-Seytoux, Associate Professor of Civil Engineering; and Dr. Robert A. Young, Associate Professor of Economics. Discussants: George E. Radosevich, Instructor, College of Business; and Research Associate, Legal Specialist, Department of Economics; and Henry P. Caulfield, Jr., Department of Political Science.

In addition to the foregoing seminar presentations in accord with the general plan for the year, the following five presentations were also made.

1. The Search for Social Goals in Natural Resource Development--From the Viewpoint of an Engineer[1]. Dr. Dean F. Peterson, Dean College of Engineering, Utah State University.

2. The Search for Social Goals in Natural Resources Development--From the Viewpoint of a Social Scientist[1]. Henry P. Caulfield, Jr., Department of Political Science.

[1] These presentations were to a joint session of the International Interdisciplinary Seminar on Water Resources Management and the Seminar on Fluid Mechanics, College of Engineering, Colorado State University.

3. Pakistan's Agricultural Growth--Its Lessons and Some Unanswered Questions, Dr. Jerry B. Eckert, former Agricultural Planning Advisor for The Ford Foundation, Pakistan.
4. Political Unrest and Economic Development in Latin America--A Personal Experience, Dr. Claude L. Fly, Soil Scientist from Fort Collins.
5. A Methodology For Evaluation of Soil Productivity Potential for Uruguay, Dr. Claude L. Fly.

No multidisciplinary field trip was undertaken like those of the previous two years to the Balsas River Basin, Mexico. It was tentatively decided that such trips if they involve return trips to the same location should probably be conducted every two years.

Seminar Program Planned for 1972-1973

The general plan developed by the Program Committee for conduct of the International Interdisciplinary Seminar on Water Resources Management in 1972-1973 calls for seminar presentations falling under the following three general headings:

1. Small Farming Problems in Less Developed Countries
   Because much irrigated farming in less developed countries is on small farms and promises to remain so, attention will be focused upon the factors that are critical in making such small farms economically, socially and politically viable.
2. Major Constructed Water Development Projects Throughout the World--Evaluation of their Planning Procedures Experience During Construction, and Operations and Effects to the Present. Emphasis in this series will be placed upon learning from apparent past mistakes. Also, efforts will be made to discern whether there is any difference in "mistake-making" if the projects are planned by public agencies in a country, by private engineering firms of the country or foreign, or by university planning teams.
3. Interdisciplinary Modeling of Water Management Problems--This part of the program will continue the emphasis upon modeling in previous years. The topics to be covered during the coming year have not yet been selected.

PART IV

UTAH STATE UNIVERSITY

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2459

May 1972

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ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd -2459

Title: Optimum Utilization of Water for Agriculture with Emphasis on "On-Farm Water Management."

Grantee: Utah State University

Director: H. B. Peterson

NARRATIVE SUMMARY

During the year, 17 staff members and graduate students received intensive training in Spanish. A total of 73 staff, wives, and graduate students received training. Most completed the advanced course. In the area of water management there are 19 of the staff that are capable of lecturing in Spanish. 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.

During the report year the project added more than 500 new titles to the computerized bibliography. It established a vertical file of over 400 pamphlets. Materials were gathered from all the water resource centers. The on-farm water library program accomplishments during the first three years include: a comprehensive check of the library card catalogue for relevant titles; a comprehensive bibliographic search; a

computerized printout (currently 8,000 entries) of library holdings; the acquisition of approximately 4,000 books and non-book materials, and the establishment of an approval book buying program with the Richard Abel, and Baker & Taylor Companies.

Two new staff members were added this report year. A total of six new members have been added to the program. All receive some support from sources other than the grant. Each is engaged in some teaching and research. Three new courses were added during the current year. The one on water development in Latin America is attended by staff and graduate students and all lectures and discussions are in Spanish. Each year of the grant three or four new courses have been introduced but more significantly many more courses were revised under the supervision of a special committee. With the employment of a new staff or specialists and the addition and revision of courses, the offerings at the University are the best ever. New teaching materials have been prepared for use in the courses and in seminars and short courses. A slide series of 116 entries with the narrative in English and Spanish has been taped and widely used. A text on irrigation is being written. Five of the completed chapters are being used in classes. At least ten foreign students are presently taking advantage of the offerings in the program.

With the addition of staff and the support of graduate students by the grant it has been possible to greatly expand the research. During the report year, 14 publications, manuscripts and theses were completed. The research program is now developed to a point where the productivity will become more evident. A total of 19 studies has been reported. Five of the graduate students have completed their research studies. The impact and benefits from the research are expected to be realized in the near future.

The staff has responded nineteen times to requests for consulting assistance during the year. For the life of the grant 20 of the staff have responded to a total of 64 requests for assistance.

DETAILED REPORT

General Background and Purpose of the Grant

For many years Utah State University has had an active expanding program of education and research in irrigation science and related fields such as Civil Engineering, Soil Science, and economic and social aspects of water resource management and development. The capacity of the University for research, teaching, and service on the problems of irrigation and drainage has been continually increased and strengthened. Utah State University authors were among the first to publish textbooks on the various aspects of irrigation and water management. Leadership in the field has continued with the publishing of such texts as Irrigation Principles and Practices and Irrigated Soils, both books having been issued in several languages. In recent years this experience and competence has been directed toward the special characteristics and problems of the less developed countries.

At the time the grant was awarded, the Department of Agricultural and Irrigation Engineering had many graduate students from foreign countries. The staff was not adequate to direct the research of these students. The requests for irrigation, drainage, and soil salinity consultants was greater than could be provided by the University.

It was felt that Utah State University had considerable competence in these areas and an expanded full-time professional staff, courses of study, library information, and research would enable the University to respond much more adequately 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, and local irrigation and drainage institutions. It was certain to also strengthen the research program carried out under AID/csd research contract 2167.

Because irrigation agriculture is concentrated in relatively few states,

special U. S. competence in irrigation water management is limited to a few U. S. universities. However, irrigation is of extreme importance to the agriculture of a large proportion of the less developed countries. Therefore, the increased competence in water management under less developed country conditions to be created through the Grant would be of a central importance to optimum agricultural development in many less developed countries of all the major continents of the world.

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 water 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 an identification of staff needs and selection of professions. 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.

Accomplishments

In assessing the accomplishments made during the first three years of the Grant program it became evident that the benefits have been considerably greater than the summation of the components. The benefits are reflected in the new course offerings, a greatly improved library service available to students and staff, a favorable influence on the professional attitude of graduate students and staff and an increase in their competence and confidence. The net effort of the improvement program is that Utah State University is now a much better institution for foreign and national students to come for specialized training in the field of on-farm management. The research component of the program increases the competence of the students and staff while providing new knowledge to be used in the solution of water problems throughout the world.

Language Training

The University and cooperating agencies have found it to be essential for those involved in technical assistance, to be able to communicate in the language of the cooperating country. The emphasis of the Utah State University research program has been on Latin American problems. It therefore was deemed necessary to have a staff capable of using the Spanish language.

During the first year of the grant, partial support to an intensive Spanish Training Program was provided. Instruction was given four hours a day, five days a week, for three consecutive quarters. A total of 17 people participated in the program with eleven completing the second level course.

The second year of the program 39 persons participated in either the beginning, intermediate or advanced training session.

Language training requirements were at a minimum during the third year and only 15 persons attended the sessions. Two elementary levels and one intermediate level were taught. Instruction was provided by Viva Lynn, Jamie Johnson, and Sara Hargreaves.

The staff and student need for language training was at its highest level during the first three years of the program. Most of the staff and all of the students in the program now have considerable competence in Spanish and it is anticipated there will be little need for an intensive training program.

Library

During the past year the On-Farm Water Project has added over 500 new titles to the already existing titles in the computerized bibliography. The project has begun to enter fugitive materials (Water Laboratory Library, Richard's Collection, Archives, etc.) and the U. S. Government documents into the bibliography. A vertical file has been established which contains pamphlets. Materials have also been gathered from all of the Water Resources Centers in the United States for entry into the library and the bibliography. The bibliography was checked against the shelf to insure the presence of the materials listed therein. This bibliography is being readied for publication in a book form and will contain approximately 13,000 entries. A brochure on the water management library was prepared.

The On-Farm Water accomplishments during the first three years include: a comprehensive check of the library card catalogue for relevant titles; a comprehensive bibliographic search; a computerized printout (currently 8,000 entries) of library holdings; the acquisition of approximately 4,000 books and non-book materials, and the establishment of an approval book buying program with the Richard Abel, and Baker & Taylor Companies.

The Department of Agricultural and Irrigation Engineering has collected and maintains a specialized library concerned with water rights and water law in Central and South American countries. It contains microfilm cards or microfiche and includes more than 450 books totalling 30,000 pages. This holding is unique in the fact that it is one of the most comprehensive water law microfilm libraries available in the U. S. or South American countries. Many of the books are otherwise available only in South America or government libraries. The first three years have also seen the development of a better communications system between inter-library personnel

and the personnel working on library projects at other CUSUSWASH centers. A more detailed library report is in appendix A.

Teaching

New Staff. Three new staff members were employed during the year. Dr. Robert Hill is a joint employee in the Department of Civil Engineering and Agricultural and Irrigation Engineering. He is also obligated with the Utah Water Research Laboratory. Dr. Chris Lewis is a new member in the Department of Economics. Dr. Jose Alfaro, an irrigation engineer from South America, was trained in the United States and has acquired citizenship. He is especially prepared to advise and instruct the many students from Latin America and has been very effective when lecturing to the students in short courses.

A total of six new staff members have been employed during the last three years and are now partially supported by Grant funds.

New Courses. Three new courses were added during the year. These are: Soil and Water Conservation and Agricultural Waste Treatment; Fertilizer Technology for Irrigated Crops; and Water Development in Latin America. In the latter class all presentations and discussions are conducted in Spanish.

Teaching Materials. A series of 116 slides on sprinkler irrigation with a taped narrature was completed. One set was prepared in English and one in Spanish. These series have been used extensively on campus and in short courses in Central and South America. A series on drainage has also been initiated.

Dr. Keller has completed five chapters for the text on irrigation. John Merriam, Jack Keller and Jose Alfaro have completed a draft of the manuscript for a tin on Irrigation System Evaluation and Improvement. When completed, a Spanish version of the bulletin will also be prepared.

A manuscript in Spanish has been prepared on the use of cut throat flumes. This is work done in cooperation with Colorado State University.

A "State of the Art" report on Watering and Dewatering Heavy Soils

is being prepared. This will be of value in teaching as well as in research. It is particularly applicable in many parts of the world where there are large acreages of relatively unproductive wet soils. These are often too wet during the rainy season and need irrigation during the dry periods.

Research

Results from the research program are only now becoming evident. Considerable time has elapsed between the period when staff additions were considered, new members added, as well as graduate students selected and trained, and some evidence of research accomplishments. Much of the information gained is now in the prepublication or "in press" stage, or in theses.

There is considerable research underway. As an example, Dr. James, brought into the program with 211(d) funds, has completed some research as indicated in the attached list of publications, but also has considerable research underway. An AID sponsored graduate student of his is working on a problem entitled "The Effect of Time and Rate of Application of Nitrogen on the Yield of Mexican Wheat," Mr. Rubink a 211(d) graduate is scheduled to go to Colombia where he will conduct his research on problems of soil variability that have been found to hamper field research. Mr. Gonzales, member of the faculty, National University, Palmira, Colombia, is conducting research for his thesis in Colombia under the direction of Dr. James.

Considerable research emphasis has been devoted toward solving some of the problems. Hunter and James devised a technique where they used an acquatic plant, Duckweed, as an indicator of nutrient content of waters in streams and lakes. They found that often nitrogen and phosphorus were not the limiting elements for acquatic weed growth but that iron or manganese were limiting. They also concluded that removal of phosphorus from water or prevention of its imput many will prevent excess algal growth by making phosphorus limiting. Shewman and Peterson studied the removal of phosphorus by soils and devised a method for predicting the phosphorus removal capacity of soils.

In Central America and in much of northern South America the climate permits the growth of acquatic plants throughout the year. In the U. S. this problem exists throughout the growing season. Weed growth along and in irrigation canals, storage ponds, and drainage ditches create barriers to water movement. When the growth is treated and killed, it causes the depletion of oxygen leading to fish kill and foul odors of the rotting organic matter.

Richard Chase and John Evans in El Salvador studied the effects of selected herbicides on perennial grasses and water pollution under tropical high rainfall conditions.

Mr. Herbert Paul has completed his research and a thesis is being typed. A copy of his abstract is being included. His study was prompted by his experiences in Latin America where large earth moving equipment was not readily available or very costly and a minimum of earth moving was desired when preparing land for irrigation.

A list of the publications and reports resulting from the 211(d) program is presented as appendix B. Appendix C contains the abstracts. Copies of thesis and published papers have been submitted to AID.

Impact of Activities on Institutional Capabilities

The general objective in using the grant resources was to make the University a better place for students to study, increase the research capability and provide greater competence on which to draw when requests are received for consultants or other technical assistance. An advisory committee with membership from different disciplines decided that these goals could best be met by increasing the library holdings and by increasing the competence of the library staff. It was also thought that improvement would result from selection of some new staff members in areas of the greatest weakness and needs and in providing additional training of present staff. It was also though that new competence for teaching, research and consulting should be generated. For these reasons the graduate student program was initiated. Students could be trained and given experiences in research, use

of the language as well as conduct some of the research under Latin American conditions. The training of staff and students in the use of the Spanish language was considered essential to the success of the research training and consulting program in Latin America.

In 1971 a "water resources planning seminar with special emphasis on developing countries" was held on campus. Dr. A. Wiener served as the leader. Much of the seminar was developed around his new book, The Role of Water in Development, an attempt was made to evaluate the success of the program. The only concrete response was from Dr. Keller of our staff who was impressed and thought the experience was most worthwhile. A copy of his evaluation of the seminar is given in appendix D.

We feel that as a direct result of the Grant, the University is a much better place to study and conduct research. It is familiar with the problems of their countries. Its staff has the technical and language capabilities to respond to requests for assistance.

Some indirect benefits have been realized as a result of the Grant. Some are rather intangible such as the increased cooperation among members of different departments and disciplines. Another is the general support by the University and its attention and investment of resources that would not have been directed to the Water Management Program. The University contributed, during the report year, $20,470 toward the Water Management Library and $10,749 for a pressure water system on the experimental drainage farm where many of the foreign as well as domestic students conduct much of their research.

Results from most of the research on water are not site specific and can be used anywhere. For example, the research done in El Salvador on the effect of wind on sprinkler patterns yielded useful information for in the U.S. or anywhere sprinklers are used under windy conditions. The same is true of the results of research on water quality such as that by Middlebrooks, Shewman, Peterson, Hunter, James and Chase.

The study by Keller, Peterson, and Peterson on "A Strategy for Optomizing Research on Agricultural Systems Involving Water Management",

was conducted in an attempt to better identify research needs and select those studies that would yield results with broad application. A copy is appendix E.

Utilization of Institutional Resources in Development Programs

On-Farm Water Management Research. A major program has been in progress since June of 1968 (AID contract csd 2167) which is designed to increase agricultural production in Latin America and elsewhere through adoptive research in on-farm water management problems. Long term staff have been stationed in Brazil, Chile, Colombia, Ecuador, and El Salvador and short term visits have been made to ten other Latin American countries. Program components include crop-water requirements, drainage, water-fertilizer, inter-action, water law, management techniques, economics of irrigated agriculture. This is currently funded at about $550,000 per year.

Inter American Center for Integral Development of Land and Water Resources. This is funded by the governments of Brazil, Colombia, and Venezuela at about $600,000 per year.

This program administered by USU is designed to train professionals in most of the disciplines directly related to land and water resources development. It has a strong on-farm water management component. Practically all of the course work and related research is carried out in Latin America. During the reporting period, courses were presented in ten countries.

Consulting

A fairly continous flow of staff to and from developing countries is mentioned elsewhere in the report.

Professor Keller was a distinquished guest lecture in the Israel Institute of Technology at Haifa, Israel. He also traveled to Greece and Senegal on consulting assignments concerned with irrigated pastures and

sugar development.

Dean D. F. Peterson is a member of AID's RAC Committee and is currently advising the Canadian government on their program to locate an international irrigation research center in some developing country.

Bruce H. Anderson assisted in the design of an Irrigation Graduate Program in the University of Ceara at Campina Grande, Brazil.

Ronda Christiansen, Darwin Nelsen, Boyd Westerfield, Allen Jones, and Morris Whittaker of the Economics Department participated in three short courses in Bolivia on the economics of irrigated farming - OAS and AID.

Jose Alfaro directed a short course in Guatemala on Operation and Maintenance of Irrigation Projects.

George Hargreaves was a consultant to UN Development Council World Meteorological Organizations in Costa Rica and Honduras and AID in Bolivia on matters dealing primarily with irrigation feasibility studies and crop water requirements.

Jerald E. Christiansen was a consultant in Argentina for the design of a drainage system at a large irrigation project near Santiago del Estera for a private firm - Latinoconsult. He also visited Guatemala together with Dr. E. C. Olsen to advise on the requirements for a feasibility study for a new irrigation project - AID mission request. He visited Panama to advise on problems of irrigation of community gardens - AID mission request.

Leon Huber was in Chile to present a short course on hydrologic model simulation - OAS sponsored.

Richard Griffin traveled to Nicaragua to assist in a short course on irrigation methods - AID and OAS sponsored.

Raymond W. Miller visited Venezuela and Bolivia to participate in OAS training courses and irrigated soils.

Kenneth Bach visited Thailand and Korea to participate in FAO and AID sponsored seminars in Water Management and to advise the governments in Water Management and irrigation and drainage matters.

Komain Unhanand visited Langkok, Thailand to assist in the design of a major water distribution system.

Howard B. Peterson traveled to Turkey, Pakistan, and Iran to organize and conduct a Seminar on the "Agricultural Aspects of Arid and Semi-arid Zones", for CENTO (Central Treaty Organizations).

Foreign

Foreign Students Attracted to USU. Just under 10% of the 260 foreign graduate students attending USU are majoring in courses directly related to on-farm water management. The remainder are enrolled in 41 different departments. Only the department of Civil Engineering, with approximately 12% of the foreign graduate students, has a higher enrollment. Many of these are taking water management course work as a minor subject. The on-farm water management graduates come from 14 foreign countries.

Use Made of USU Generated Research

The Government of Ecuador has used the material prepared by our Professor David R. Daines in rewriting their water laws.

Chilean corn production in the Aconcagua Valley doubled.

The Christiansen-Hargreaves method for determining crop water requirements in the tropics where data is limited, found much wider use because of its publication in technical journals, the foreign students using it and their research contracts.

Several research stations in El Salvador and Brazil began water-fertilizer interaction experiments for the first time.

Some wet lands in Colombia were drained by mole plows developed at USU on a pilot scale.

Graduates Engaged in Developmental Work

Over the past several years, all of our graduates in water management have found employment in either government, teaching or private industry. A check of their last employment record indicates that nearly all are associated with organizations that have foreign or international interests.

Other Resources [illegible]

The program activities are carried out in cooperation with three different departments: the Utah Water Research Laboratory, the Agricultural Experiment Station, and the Library. The AID research contract AID/csd 2167 is also a valuable resource for the 211(d) grant. Each administrative unit has a large program and it would be meaningless to record the total magnitude of each. There are, however, some specific examples that are sited. The library reports a contribution of $20,470. A grant of $4,000 from the Utah Power and Light Company was provided and is being used to carry on the work of a 211(d) student trainee. Superior Farms Company of California provided land and equipment for research for two of the 211(d) trainees. 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. Professor John Merriam, Department of Agricultural Engineering, University of California, contributed a month of his services in preparation of a publication being jointly prepared.

The program made it possible to employ six new faculty members. The cooperating units have provided funds for salaries so that at present the percentage of salary from 211(d) grant varies from about 9 to 56 percent.

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 new programs. The major 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 will be discontinued. The graduate students and staff now have the needed competence. This change will result in a reduction of teaching costs. There is a further reduction in teaching costs because there will be less expense for development of new courses.

A greater emphasis will be placed on the research activities. It is planned that two graduate students will go to El Salvador to study. Grant Hanson will study filtration of water for trickle systems. The main purpose of the proposed study is to investigate the clogging effects vs. type of water used in a trickle or drip irrigation system. In a non-flushing type of trickle irrigation system, the performance of the system is dependent upon the quality of the filtration of the water. If the water is sufficiently filtered, clogging of the emitters or drippers will not occur. It is proposed to study the different sources of irrigation water in the area in order to determine the criteria which must be met to provide adequate filtration for each type of water. Tests will also be run on a trickle or drip irrigation system, employing both new and used lines, in order to study the effects of time on uniformity, variation, and clogging in a system.

Phil Tschesche will make an irrigation design study for tickle irrigation systems. It has been shown by many studies that the trickle method of irrigation is a successful method of irrigating many crops. When installing such a system for the farmer, however, the designer is faced with the problem of how far apart the drippers should be placed to adequately wet the soil for the growing plants. To he' answer this question more study needs to be done on evaluating the amount of soil wetted by an individual dripper or a line of drippers under different flow rates and different irrigation intervals. He proposes to study the influence that application rate and length of application time for various tropic soil types found in the area on the movement of water in the soil, or more specifically the volume of soil wetted by a dripper. It is possible that an easy field technique may be devised to evaluate the volume of soil wetted, and therefore, make it possible fo the designer to quickly determine the volume of soil wetted for a given dripper discharge and application time for a particular soil.

Craig Anderson will complete a study in Ecuador on the organization and function of canal user associations. Lee Bailey and Dr. LeBaron will study water management costs and relocating and shifting traditional crops that are being displaced by cotton in the Santa Cruz area of Bolivia. William

Rubink will spend about three months in Colombia working with the CIAT staff on contract USAID/csd-2167. They have 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 identify the cause of variability and possible treatments for improvement. Dr. James will continue a study on plot size requirements interactions to be used in 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 bulletin will be a cooperative effort by Kidman, Stutler, and James entitled "Increasing the Efficiency of Soil Moisture Use for Increased Crop Production."

Dr. Riley and Morgan Ely plan to prepare a model of the Atlantico 3 project of Colombia in order to provide alternative solutions of the drainage and salinity problems of the area.

Dr. Chris Lewis will spend approximately six man months on a project dealing with the role of water development in regional development. It is expected that through his efforts a manuscript for a book on the subject will be prepared.

Dr's. Keller, Alfaro, and Professor Merriam will complete the manuscript on "Irrigation System Evaluation and Improvement" and have it published. An edition in Spanish will be prepared and published. Dr. Keller will also complete several chapters of the textbook he is preparing for publication.

The costs for library improvement are expected to decrease slightly. Less labor will be required to complete the inventory of on campus holdings. The effort in obtaining new publications should be limited to 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 greatly increase.

The costs listed under consultation result from meeting requests for staff to cooperate and participate in seminars and short courses such as the AID sponsored seminars in water management and those sponsored by the soils consortium. An example, Dr. Alfaro will in January 1973, participate in a program in the Dominican Republic in cooperation with Prairieview University and the University of the Dominican Republic.

Report of Expenditures

The expenditures for the third year and the accumulated expenditures are shown in Tables 1 and 2. Further detailed listings for staff and students are recorded in Tables 3 and 4. Expenses for domestic and international travel are presented separately.

Salaries

The salaries and percentage of effort of staff and supporting services are shown in Table 3. An attempt was made to distribute the salaries according to activities as indicated in column two of Table 1.

Graduate Trainee Expense

The expenses for stipends and tuition are indicated in Table 4 with the exception of travel and supplies. All travel expenses are indicated under the section on travel. Status of the various trainees is indicated in Table 5.

Library

The approximate expenditure for the library is shown in Table 6. The contributions by the university are detailed in Table 7.

Travel

Domestic. During the 1971-72 fiscal year, $5,112.84 was expended for travel within the United States. This travel included attendance at the following meetings: The Rocky Mountain Irrigation Equipment Exposition, attended by Dr. Glen E. Stringham; The Irrigation and Drainage Specialty

Conference, attended by Dr. A. A. Bishop and the annual Winter Meetings of the American Society of Agricultural Engineers attended by Michael D. Moynahan, a 211(d) graduate student who presented a paper at the meetings.

Dr. Larry G. King traveled to California and Washington to study drainage and current research programs and to gather material for a manuscript on drainage. Professor J. E. Christiansen traveled to California to attend committee meetings on water quality and irrigation return flow in order to evaluate new trends in drainage techniques.

Four meetings were held in connection with CUSUSWASH reviews and program evaluations. Utah State participants in those meetings were Calvin Clyde, Dean F. Peterson, W. I. Palmer, J. P. Riley, Wade Andrews, Bruce Anderson, Howard B. Peterson and Byron Palmer. In addition, one discussion program between USU and CSU was held and attended by Calvin Clyde, Leon Huber, and Alton King; and one annual 211(d) program review was also held in Washington attended by Howard B. Peterson, Dean F. Peterson, Bruce H. Anderson, and Byron Palmer. Dr. J. Paul Riley also made four separate trips in order to finalize research programs and confer with other CUSUSWASH teams.

International. International travel under the 211(d) grant totaled $11,969.72. A summary of the travel is as follows:

a. David Daines
   Quito, Ecuador to Logan
   May 31 to June 18, 1971
   Obligated - $1,800 Paid - $1,430

In June 1972, Dr. Daines returned to Logan in order to participate in a Water Resources Planning Seminar. Dr. Daines was featured as a key speaker in connection with recent developments in water resources in Latin America. The funds for this trip were obligated in 1971, but not paid out until this fiscal year.

b. Lanny Ptacek
   San Salvador, El Salvador
   July 7 - Oct. 7
   Obligated - $1,800 Paid $1,430

In order to conduct sprinkler irrigation research, Mr. Ptacek and Michael D. Moynahan traveled to El Salvador to conduct a series of experiments. This research was incorporated into the student's thesis currently nearing completion.

c. Mike Moynahan
San Salvador, El Salvador
July 7 - October 7
Obligated - $2,700 Paid $2,535

As previously described, Mr. Moynahan's research was incorporated into an M.S. thesis, "The Use of Sprinkler Profiles to Predict Field Performance". Mr. Moynahan received his M.S. Degree June 1972.

d. Phillip Lloyd
Quito, Ecuador
August 8 - October 15
Obligated-$1,741.50 Paid $1,751.09

A 211(d) supported graduate student, Mr. Lloyd traveled to Quito, Ecuador in order to collect data for the completion of his M.S. thesis, "Impact on Rural Incomes of Improved Water Management Practices in Milagro County, Ecuador". Mr. Lloyd received his Master of Arts Degree in Agricultural Economics in June of 1972.

e. Richard Chase
San Salvador, El Salvador
June 25 - September 25
Obligated - $2,304.20 Paid - $1,699.80

As a 211(d) graduate student, Mr. Chase, traveled to El Salvador in order to conduct research on water pollution and weed control.

* f. Jack Keller
Israel
September 6 - September 13
Obligated - $565.00 Paid-$387.00

Dr. Keller and an associate Dr. R. J. Hanks, attended the International Experts Panel on Drip and Automatic Irrigation. As a result of this panel, Dr. Keller and Dr. Hanks co-authored two papers concerning drip irrigation; "What About Drip Irrigation" and "Drip Irrigation".

* g. R. J. Hanks
Israel
September 6 - September 13
Obligated - $192.00 Paid - $70.00

Following his attendance at the International Symposium on Soil and Water Physics, Dr. Hanks remained in Israel under sponsorship of 211(d) funds in order to attend the International Experts Panel on Drip and Automatic Irrigation.

* h. A.A. Bishop
Mexico
November 7 - November 14
Obligated - $890.74 Paid - $468.74

Dr. Bishop traveled to Mexico City to attend the First Latin American Seminar on Systematic Evaluation of Land and Water Resources. The Seminar was organized and conducted by FAO and evaluated the soil and water resources of the countries involved.

i. Rick Chase
San Salvador, El Salvador
April 1 - April 15
Obligated - $697.60 Paid - $671.70

Mr. Chase returned to El Salvador to evaluate the effects of treatments made in August. This research resulted in the thesis "Effects of Selected Herbicides on Perennial Grasses and Water Pollution Under Tropical High Rainfall Conditions." Mr. Chase completed his M.S. program in August of 1972.

j. John Evans
San Salvador
April 1 - April 15
Obligated - $681.00 Paid - $603.31

Dr. Evans traveled to El Salvador with Rick Chase to help evaluate the results of Mr. Chase's experiments and to make recommendations to the host country concerning aquatic weed control in irrigation canals.

k. Craig Anderson
Quito, Ecuador
May 18 - Present
Obligated - $2,925.00 Paid - $594.50

Mr. Anderson, a 211(d) graduate student, is now in Quito, Ecuador conducting research concerning the organization and function of the Canal Users Assocation in Ecuador. This research is part of his Master's program in Political Science.

1. Lee M. Bailey
   Santa Cruz, Bolivia
   June 15 - Present
   Obligated - $2,400.91 Paid - $1,570.63

Mr. Bailey traveled to Bolivia under the 211(d) trainee program. He is studying the water management costs and relocating and shifting traditional crops that are being displaced by cotton in the Santa Cruz area. This study will be incorporated into his Master's thesis.

* see trip report, Appendix F.

Table 1. Distribution of 211(d) grant funds and contributions from other sources of funding * review period July 1, 1971 to June 30, 1972

List all grant related activities		211(d) Expenditures			Non 211(d) Funding Amount Review Year
	Period Under Review	Cumulative Total	Projected Next Year	Projected to End of Grant	
Research	65, 500	129, 400	83, 500	89, 400	**
Teaching	52, 000	105, 250	37, 800	51, 300	**
Libraries	17, 600	21, 850	13, 950	23, 000	20, 470. 78
Consultation	6, 200	10, 858	5, 875	9, 700	
Publications	900	13, 300	10, 300	11, 200	
Other	22, 924	49, 382	16, 575	45, 360	10, 749. 00
CUSUSWASH	10, 000	10, 000	12, 000	0	
TOTAL	175, 124	340, 040	180, 000	229, 960	
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, 1971 to June 30, 1972

Line Items	Expenditures to Date		Projected Expenditures				TOTALS
	Period Under Review	Cumulative Total	Year 4	Year 5	Year 6	Year 7	
Salaries	$ 98,212.83	$213,209.62	$ 95,500	$ 90,500	$20,000	$15,000	$434,209.62
Travel							
Foreign	11,969.79	13,534.32	15,000	16,000	5,000	3,000	52,534.32
Domestic	5,112.84	9,415.95	5,000	4,000	1,000	960	20,375.95
Equipment	NONE	7,492.67	500	NONE	NONE	NONE	7,992.67
Stipends, Tuition and Fees	37,555.46	65,679.96	39,000	35,000	5,000	3,000	147,679.96
Supplies and Computer Use	9,615.02	10,978.52	10,000	11,000	3,000	1,000	35,978.52
Library and Publications	2,658.54	9,729.00	3,000	2,500	2,000	2,000	19,229.00
CUSUSWASH	10,000.00	10,000.00	12,000	10,000	NONE	NONE	32,000.00
TOTALS	$175,124.48	$340,040.04	$180,000	$169,000	$36,000	$24,960	$750,000.00

Table 3. Salary support and percentage of effort

Name	Amount Paid	Man Months	Percentage of Support
Palmer, William I.	$1,788.82	1.0	8.33
Keller, Jack	6,155.00	3 3/4	31.33
Middlebrooks, E. J.	3,605.00	2	16.82
Jurinak, Jerome J.	2,000.00	1 1/8	9.4
Shewman, Fred	1,000,00	2	---
Lewis, Chris	1,474.00	1	100.00
Bishop, A. Alvin	2,250.00	1 1/16	8.85
Lynn, Viva Lee	4,000.00	4 1/2	37.49
LeBaron, Allen	4,053.96	2 3/4	23.33
James, David W.	7,316.00	5 1/8	43.03
Wood, Diane	377.76	1 1/8	9.83
Douglas, Dorothy	4,250.00	8 1/2	70.83
Peterson, Howard B.	12,000.00	5 7/8	49.18
Stringham, Glen E.	1,512.00	1	11.10
Broderick, Carla	1,182.24	.5	56.95
Palmer, Byron C.	6,739.56	4 3/8	56.00
Alfaro, Jose F.	8,608.80	6 3/4	56.00
Miller, Ray	4,254.00	3	25.00
Bernstein, Gay	856.09	2 5/8	21.54
Bach, Ken	8,705.00	6	48.95
Total Salaries	$81,128.33		
Wages	8,536.19		
Staff Benefits	8,548.31		
Total Salaries, Wages	$98,212.83		

Table 4. Graduate trainee expense (Fiscal Year 1971-72)

Name	Stipend	Tuition	Total
Michael D. Moynaham	2012.96	135	2147.96
Herbert Paul	3600.00	584	4184.00
Lanny R. Ptacek	18.00	53.50	1853.50
Richard Chase	3600.00	438	4038.00
Lee M. Bailey	3600.00	438	4038.00
D. Craig Anderson	3600.00	438	4038.00
Phillip Lloyd	2100.00	---	2100.00
William Rubink	2750.00	544	3294.00
Phil Tscheschke	2750.00	518	3268.00
Morgan Ely	3000.00	438	3438.00
Kent N. Dittmer	1500.00	292	1792.00
Grant R. Hansen	1800.00	372	2172.00
Richard W. Conn	900.00	292	1192.00
TOTAL	33,012.96	4,542.50	37,555.46

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

Name	Began Prog.	End Prog.	Dept. & Degree	Present Status
James Elmer Hardee	Oct. 1969	April 1971	AIE - MS	now employed Harza Engineering and stationed in Iran
Thomas Lloyd White	Jan. 1970	July 1971	Ag. Econ. -MS	now employed Army Corp. of Engineers, Alaska
Herbert Paul	June 1970	Sept. 1972	AIE - PHD	hired by CH_2M, Consulting Eng. Redding, Calif. to begin Oct. 1972
Mike Moynahan	June 1970	Jan. 1972	AIE - MS	employed by Rainbird Sprinkler Co. Glendora, California
Lanny R. Ptacek	June 1970	Jan. 1972	AIE - MS	employed by Soil Conservation Service, Dickinson, No. Dakota
Richard Chase	Oct. 1970	August 1972	Plnt. Sci. -MS	continuing education - USU
Lee M. Bailey	June 1971		Ag. Econ. -MS	presently conducting research in Bolivia
D. Craig Anderson	June 1971		Pol. Sci. -MS	presently conducting research in Ecuador
Phillip Lloyd	July 1971	June 1972	Ag. Econ. MS	now with U. S. Army
Morgan Ely	Sept. 1971		Civil Eng. PHD	presently attending classes
Phil Tscheschike	Sept. 1971		AIE - MS	scheduled to travel to El Salvador in October for research
Grant Hansen	Jan. 1972		AIE - MS	scheduled to travel to El Salvador in October for research
William Rubink	Sept. 1972		Soils - MS	scheduled to travel to Colombia in September
N. Kent Dittmer	Jan. 1972		AIE - MS	accepted temporary employment at USU
Richard Conn	March 1972		Soils - MS	attending classes and conducting research
David D. Maxwell	Sept 1972		AIE - MS	to begin program Fall Quarter.

Table 6. Expenditures for library and publications July 1, 1971 to June 30, 1972

Salaries	$9,126.42
Wages	3,510.80
Staff Benefits	1,214.54
Computer	1,089.70
Publications	2,658.54
Total	$17,600.00

Table 7. Summary of expenditures by Utah State University in support of on-farm water project 211(d)

Library Materials	
Serials, Abstracts, Indexes	$7,281.00
Personnel	
Orders Processing	
Contractual	1,800.00
Payroll	400.00
Fund Accounting	
Contractual	800.00
Computer Programming	
Payroll	900.00
Keypunching and Verifying (3,200 cards)	
Contractual	1,000.00
Payroll	250.00
Cataloging	
Contractual	1,800.00
Payroll	2,200.00
Supplies	
IBM Cards	42.00
Order Forms	120.00
Misc.	246.28
Processing Costs	
Binding Serials and Books	3,231.50
Computer Time	
Ordering and Processing	400.00
Total of Non 211(d) Funds Expended by Library	$20,470.78

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 Materials

A. Selection Policy

1. Subject Headings

When the project began in 1969 a list of subject headings relevant to the on-farm water field was constructed. These headings helped the project staff members to locate pertinent book titles for the on-farm water field. These headings continue to be used and updated in order to be of value in determining the selection of material for the library.

2. Standard Book Orders

The project continually conducts a search of all possible sources which might contain book titles of relevance to the on-farm water field. Subject headings (see previous paragraph) aid in determining the relevance of a book title to our field. When a relevant title is located the information is recorded on an order card. The order card is then checked against the card catalog, book history, and the open order report (this lists all books that have been ordered but not received to that date) to ascertain if the book has been ordered previously. After the cards have been allowed to accumulate for a period, they are given to the Department of Agricultural and Irrigation Engineering for final selection and approval. Therefore, the selection system is two prong. A basic selection, along subject headings, is made by the library assistant hired by the staff of the project. Additional selection and illimination is made by an authority on the field in the Agricultural and Irrigation Engineering Department. After the final selection has been made the book information is typed on a computerized form, key punched, and sent to a jobber for purchase.

3. Approval Books

a. Richard Abel and Company

The Richard Abel Company was selected as the on-farm water approval system because they job foreign books. There are many worthwhile books on the project field that are published in England, France,

Germany, Israel, India, and even Russia. Many of the approval slips received from Richard Abel have been English or other foreign publishers. Richard Abel has been a good source for locating foreign books in the project field.

The Richard Abel Company was given a profile of the on-farm water management needs, arranged by subject area. The profile was entered into a computer at Richard Abel and Company, then if a book entry matches our profile a set of approval slips is sent to the Library Assistant for the project. The approval slips are then given to the Agricultural and Irrigation Engineering Department for selection. After notifying the company as to which titles are desired, the books are sent to the project where they are judged for their content value, type of printing, binding, and the author of the book (i. e. is the author an authority in this subject area, if so - book should probably be purchased).

b. Baker and Taylor

Baker and Taylor is the Merrill Library approval system. The Merrill Library sent a profile to Baker and Taylor outlining the library's book needs, and the on-farm water profile was included. Baker and Taylor sends books to the library once a week. These books are displayed in a selection room on the library's fourth floor. The books are judged for content value, type of print, type of binding, as well as the author.

The Baker and Taylor Company will continue to supply the library (the library requested them to do so) with approval books dealing with on-farm water, after the five year program has ended. From the books sent for approval, the library will select books which are on the on-farm water subject line. Thus, there will be a continual updating of materials by the library after the grant money has expired.

4. National Technical Information Service

The National Technical Information Service publishes Research Reports issued by various universities and colleges (and other institutions, i. e. Rand Corporation) whose research work was funded by the government.

These reports constitute an important source of information in the project's field, and the on-farm water project has begun (during the last year) a program of search for pertinent materials listed within these catalogues. Reports from this source are selected according to the descriptions provided in the catalogue as well as the brief abstract also given in the catalogue.

5. Government Documents

Last year the decision was made by project personnel not to include the Government Documents into the on-farm water bibliography. The decision was reached due to the time and effort required to include the documents (some dating back to the 1800's) was too immense and therefore prohibitive. Project leaders have, in retrospect, reaccessed the decision and have decided to include the documents on a limited basis. The Merrill Library is a depository for all Government Documents; this means the library receives all documents published. These documents are not always listed in the Government's Catalogue of Monthly Publications (this catalogue only lists a portion of the U. S. Government Documents issued every month). This consideration plus an excellent depository library prompted the decision to enter the documents for the last five years into the bibliography.

After making the decision to include the documents, a monumental task began. The Merrill Library established a computer printout of all the government documents received within the last two years. The library has provided the on-farm water project with a program whereby a person needs only to type the documents call number on a slip of paper, have it key punched, and the information will then be lifted from a documents computer tape onto our bibliography. Additionally, a search of the stacks has begun so that pertinent government documents over two years old can be included into the bibliography. The Government Documents Stacks cover an area of three floors, and date back to the 1800's. Including all possible relevant documents from the 1800's to date was an impossible task. The project leaders decided in favor of including only documents since 1962 in

the bibliography. The government usually updates most of its publications periodically, so information is not lost due to the age of the document. The project also left the option open to the library assistant (since the stacks have to be searched anyway) to include any documents the assistant considers relevant which date back further than ten years into the bibliography.

B. Acquisitions

During the previous year a total of 3,390 book titles were considered for addition to the on-farm water management library. Of the 3,390 books considered, 568 were chosen as suitable for purchase. Many of the publications have been received, catalogued, and are available for use. Additionally the project personnel have received many excellent free publications. These publications are checked against the card catalogue to see if a copy was received previously. If the publication is new it is sent to the binding service to receive a hardback cover (if necessary). The publication is then catalogued and put on the shelf for patron use.

The project personnel decided to order fifteen magazines in the project subject area. In addition to project purchases the library subscribed to or renewed subscriptions for 1066 periodicals relating to our subject area. The periodicals cost the University over $6,600 a year.

The Merrill Library, as stated previously, receives all of the government documents published. This saves the project personnel from having to purchase government documents pertaining to the on-farm water field. This is one of the several ways in which the library has been of service to the project. An estimated 100-1,000 government publications are released yearly which pertain to some area in the on-farm water field.

Desirable book titles which are out-of-print are microfilmed by the Library of Congress Photoduplication Service. Many technical books are printed only once, and when sold out are not reprinted. If the books are listed in the National Union Catalogue the books are in the Library of Congress holdings and can be microfilmed. The measure of success depends

on the willingness of the publisher to relinquish his copyright.

Additional Holdings

A. Utah Water Research Lab

Utah State University has an excellent water research lab affiliated with it. The water research lab on campus contains a library that is separate from the Merrill Library (the water lab holdings are not indexed in the Merrill Library card catalogue). The water lab's library has many holdings that would be worthwhile additions to the on-farm water bibliography. Due to these factors the on-farm project personnel has decided to include those books and reports pertinent to the on-farm water project in the bibliography.

B. Agricultural and Irrigation Engineering Department Library.

The Agricultural and Irrigation Engineering Department has a small library for the department. Any holdings in this library (not already present in the Merrill Library) will be included within the on-farm water bibliography. This procedure entails making a list of the Agricultural and Irrigation Engineering Library holdings and comparing them with the bibliography. Materials not listed in the bibliography will be added.

Problem Areas

A. Richard Abel Approval Plan

There are always a few problem areas connected with any project. Perhaps the project's biggest problem has been the Richard Abel Approval system. The profile on on-farm water sent to the company was not entered in its entirety into Richard Abel's computer. Some of the subject areas entered were too broad for the project field (i.e. pollution, water and air or ecology - marine). Many of the approval slips sent to the project deal with air pollution, ocean pollution, or marine ecology. These are not areas relevant to the project field. There are other subject areas relevant to our

field that were completely omitted from entry into the Richard Abel computer. During the last year the percent of approval books selected was only 12.6%. The low rate of acceptance is due to the large number of approval slips sent which did not pertain to the project field.

The project is now in the process of redoing the Richard Abel profile. The on-farm water project is trying to delete all irrelevant materials, and to stress materials in the subject area. When this profile is completed the on-farm water project expects much better, more relevant service from the Richard Abel Approval Plan.

B. Computer Printout

The computer printout is a useful source of information, but not a source readily available to all interested particis. The bulk and the costs of obtaining a computerized bibliography rule out making the bibliography available in its present form to interested parties. The bibliography is difficult for the students of the Utah State Campus to use because costs prohibit more than three copies being available. The copies can not be checked out of the library since they are needed for use by the project personnel.

These considerations make it a necessity to have the bibliography reproduced in a bound form for general distribution. The cost of having the bibliography reproduced in a bound form is not overly prohibitive and the bibliography would become several times more useful that it is in its present state.

Advancements

A. On-farm water started an approval book buying plan with Richard Abel and Company. The idea of an approval book buying plan originated in the "Suggestions" section of last year's report.

B. Government Documents are being included in the on-farm water bibliography. After reconsidering the project's earlier decision, it was decided to include the documents.

C. The books listed in the on-farm bibliography are being checked against the books on the library shelf. If some books are missing or lost, replacement books will be ordered, if possible.

D. Government funded college research reports are being included in the on-farm water bibliography.

E. Order cards for book titles, rejected in previous years, have been reviewed. This is another suggestion included in last year's report. The rejected book cards are to be held for a one year period and then reviewed.

F. The on-farm water management project has started a deposit account with the Library of Congress Photoduplication Service. The purpose of this account is to have worthy out-of-print book titles microfilmed for addition to the on-farm water non-book collection. (Suggestions in report made last year).

G. A brochure was issued which briefly explained the on-farm water project and its holdings. The brochure is included in the appendix.

H. The project secured library privileges for visiting students and faculty in the project area. The privileges are equivalent to those offered the students and faculty of Utah State University. (See Appendix)

I. The project continued the search for new book and non-book titles, and ordered titles pertinent to the on-farm water field.

New and Continuing Suggestions

A. Continue inclusion of the Government Documents into the bibliography.

B. Continue and improve the Richard Abel approval buying plan.

C. Continue the search for new materials, particularly reports issued by other Universities and Colleges. (Soft Documents)

D. Rapid Retrieval System. Discuss and explore the possibility of an RRS with the other libraries in CUSUSWASH.

E. Continue the search for and addition of Research Reports into the bibliography.

F. Add the holdings of the Utah Water Research Lab into the bibliography.

G. Begin a vertical file system for the small pamphlets and papers which can not be maintained on the shelf.

H. Continue checking the bibliography against the books on the shelf.

I. Arrange to have books on the on-farm water subject line, which have been ordered by other departments, brought to the projects attention. Although the project did not pay for these books they should be entered into the project's bibliography if they are relevant to the field.

J. Move toward better coordination and cooperation between the libraries involved in the CUSUWASH project.

K. Continue to review the rejected book order cards at least once a year.

L. Add the holdings of the Agricultural and Irrigation Engineering Department Library into the project bibliography.

M. Investigate ways of providing the project's bibliography to the public in bound form. A computer printout does not make the bibliography readily available to a wide range of people at the present time. In a photoproduced bound form the bibliography would become more usuable for all interested parties concerned.

APPENDIX B

PUBLICATIONS

PUBLICATIONS

* Agricultural Contribution to Water Quality Deterioration, R.A. Gearheart, E.J. Middlebrooks, D.B. Porcella. Water Users Workshop, USU Extension, 1972.

* Biostimulation and Algal Growth Kinetics of Wastewater, E.J. Middlebrooks, et. al. Journal of Water Pollution Control Federation, Washington, D.C., March, 1971.

* Analysis of Colombian Precipitation to Estimate Irrigation Requirements. Jim Hardee. M.S. Thesis, Ag. & Irrig. Engineering, Utah State University, 1971

* (A) Draft Research Plan Prepared by the Ad Hoc Committee Relating to the Irrigation Management Program (IMP) of CUSUSWASH. Utah State University; University of Arizona; University of California, Colorado State University, July 5, 1972

* Duckweed as an Indicator of Nutrient Relations in Lakes and Streams. D.W. James, Richard Hunter. Proc. 22nd Annual Fertilizer Conf. Pac. N.W., Bozeman, 1971.

* Effect of Irrigation Frequency on the Average Evapotranspiration for Various Crop-Climate-Soil Systems. A.L. Norero, J. Keller, J. Ashcroft. accepted for publication, ASAE Proceedings, 1972.

* Effects of Selected Herbicides on Perennial Grasses and Water Pollution Under Tropical High Rainfall Conditions. Richard L. Chase. M.S. Thesis, Plant Science, Utah State University, 1972

* (An) Economic Appraisal of On-Farm Water Management Practice in Developing Countries. A Study of Summer Paddy Rice Production in Guayas River Basin, Ecuador. Thomas L. White, M.S. Thesis, Agricultural Economics, Utah State University, 1971.

* Irrigation Design and Management Related to Economics. J. Keller, J.P. Riley, R.J. Hanks. Paper presented to the Irrigation and Drainage Division Specialty Conference ASCE, Spokane, Washington, Sept. 26-28, 1972.

* Impact on Rural Incomes of Improved Water Management Practices in Milagro County, Ecuador. Phillip H. Lloyd. M.S. Thesis, Agricultural Economics, Utah State University, 1972

* Phophate Content of Great Basin Ground Waters and Methods for Appraising their Contamination Potential. Fredrick Charles Shewman. Ph.D. Dissertation, Civil Engineering, Utah State University, 1971

Problemas y Practicas de Riego Curso Breve, Utah State University (Brochure prepared in Spanish announcing Irrigation short course)

* Sprinkler Profile Analysis to Predict Field Performance. J. Keller, M. D. Moynahan, L. R. Ptacek. Paper presented at the 1971 Winter Meetings, ASAE

* A Strategy for Optimizing Research on Agricultural Systems Involving Water Management. J. Keller, D. F. Peterson, H. B. Peterson. Prepared for presentation at the Irrigation and Drainage Specialty Conference, ASCE, September, 1972.

* Use of Sprinkler Profiles to Predict Field Performance. Michael D. Moynahan. M. S. Thesis, Agricultural and Irrigation Engineering, Utah State University, 1972.

Utah State University Water Management Library. Brochure prepared by Ag. & Irrig. Eng. Dept. announcing library holdings, 1972.

* What About Drip Irrigation. J. Keller, R. J. Hanks.

* See Appendix C for abstracts.

APPENDIX C

ABSTRACTS OF PUBLICATIONS

ABSTRACT

Agricultural Contribution to Water
Quality Deterioriation

by

R. A. Gearheart, E. J. Middlebrooks,
D. B. Porcella

The research identifies the pollutants from agriculture such as sediments organic wastes, nutrients, and pesticides and considers the means of entry into the water system. The problems of salinity control in irrigation waters per se were not considered. The more salient management techniques necessary to reduce water quality deterioration due to agricultural activities are enumerated.

Analysis of Colombian Precipitation to
Estimate Irrigation Requirements

by

James E. Hardee, Master of Science
Utah State University, 1971

Major Professor: Dr. H. Peterson
Department: Agricultural and Irrigation Engineering

Monthly and annual distributions of precipitation were analyzed for a 103-year record station. A gamma probability distribution with maximum likelihood estimates of the parameters gave the best fit.

For 97 stations throughout Colombia a computer program was written to calculate 13 probability levels of precipitation using the gamma distribution. Potential evapotranspiration was calculated from climatic data at 43 of these stations using the Christiansen and Hargreaves formula. The difference between potential evapotranspiration and five probability levels of precipitation was calculated as an index of irrigation requirements.

Biostimulation and Algal Growth Kinetics of Wastewater*

by

E. J. Middlebrooks, D. B. Porcella, E. A. Pearson,
P. H. McGauhey, and G. A. Rohlich

An investigation was made of the biostimulatory characteristics and algal growth potential of wastewater effluents and surface runoff in Lake Tahoe. Specific parameters studied were the maximum growth rate and the maximum cell concentration for waters that have undergone various degrees of treatment. Growth rates increased linearly with total nitrogen, and algal growth approached a maximum rate at an initial total phosphorus concentration of 50 μg/l. All types of wastewater effluents apparently are toxic to algal growth in the assay used, and deviations from the expected growth response predicted by nitrogen and phosphorus concentrations could be caused by the presence of toxicants. All effluents could be expected to increase the algal productivity of Lake Tahoe.

*Journal of Water Pollution Control Federation, 43, 454 (1971).

ABSTRACT

DERIVATION AND EVALUATION OF THE DOUBLE CENTROID METHOD OF LAND GRADING CALCULATIONS FOR DETERMING THE MOST ECONOMICAL IRRIGATION SLOPES.

by

Herbert A. Paul

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.

An economic comparison of the newly derived methods to the Least Squares Method was made, utilizing computers. There was no general superiority, economically, of the Double Centroid design to the Least Squares design or vice versa. The Computer Minimized Cost Method is equal to or superior, economically, to the Least Squares Method for all fields. The average saving on 12 fields evaluated was 3.3%. The maximum savings was 9.0%.

ABSTRACT

A Draft Research Plan Prepared by the Ad Hod Committee
Relating to the Irrigation Management Program (IMP)
of Cususwash
by
Utah State University, University of Arizona,
University of California, and Colorado State University

The table of contents that follows gives an indication of the material covered and the accomplishments. The material is not adoptable to concentrating in an abstract.

Introduction

Program Justification, Objectives, and Procedures

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B. Objectives
C. Framework for the analysis
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The Elements of the Problem

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A. Research
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Duckweed as an Indicator of Nutrient Relations in Lakes and Streams*

by

Richard Hunter and D. W. James

Duckweed (Lemna minor) was evaluated as an agent for bioassaying nutrient composition of waters. One objective was to develop a sensitive test were elemental concentrations range to below one part per million in waters. Waters tested included samples from important lakes and streams in Utah. Duckweed was cultured in the collected waters in a growth chamber under controlled light and temperature.

With no exception, duckweed did not reproduce in natural waters unless the nutrient composition was augmented artificially. Lakes and reservoirs tended to be most deficient in N and P and streams tended to be most deficient in Fe and Mn. There were several exceptions to this generalization.

Addition of either N, P, Fe, or Mn alone created a secondary deficiency in one or more elements. A high growth rate of duckweed occurred when the waters were treated with all four of these elements. An even larger growth rate occurred when the natural waters were treated with the complete array of fifteen nutrients. None of the tests with any or all nutrients in the natural waters approached Hoaglands standard culture solution in terms of the rate of growth or total dry matter produced.

It was concluded first that duckweed can have considerable utility as a bioassay for nutrients in waters. Secondly, the lakes and streams sampled in Utah are very deficient in several nutrient elements. The performance of duckweed under the conditions of this experiment needs now to be correlated with eutrophication levels in drainage and polluted waters.

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*Paper presented at the 22nd Annual Fertilizer Conference of the Pacific North West, Bozeman, Montana, July 1971.

An Economic Appraisal of On-Farm Water Management Practices in Developing Countries: A Study of Summer Rice Production in Guayas River Basin, Ecuador

by

Thomas L. White, Master of Arts
Utah State University, 1971

Thesis Director: Dr. Jay C. Andersen
Department: Economics

The primary objective of this study was to examine rice production methods, with special emphasis on irrigation-water management practices used by producers from all levels of management in the Guayas River Basin, Ecuador. To do this, rice producers were divided into four categories on the basis of the level of mechanization of their operation, use of purchased inputs, and the level of invetment in irrigation facilities and general management practices. The levels of investment in irrigation facilities ranged from 7,000 to 500 sucres per hectare, and mechanization of production varied from almost total use of machinery for cultivation operations to no machinery at all. Similar variations were noted in regards to yields which ranged from 100 quintals of hulled rice to just 22 quintals per hectare.

The efficiency of irrigation-water use presented some problems and could only be calculated for two management levels, I and II; these were found to be low in relation to results found in other areas. This efficiency was defined as being the ratio of the amount of water beneficially used to the amount of water delivered to the farm.

In order to compare the profitability of rice production and investments in machinery and land development, the internal rate of return criterion was used. This rate of return is that rate which equates the flow of net benefits to the flow of net investment for a project over its expected economic life. The streams of benefits were estimated from the costs and

returns budgets and the investments stream from the costs of land developments and initial machinery costs, together with expected maintenance and replacement costs of headgates and other water control structures. These rates varied from almost 80 percent for production under management level I, 17.6 percent for management level II, to losses (negative returns---these were not calculated) for management levels III and IV.

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

by

A. L. Norero, Jack Keller, G. Ashcroft

A formula was developed and tested describing the relationship between evapotranspiration and soil moisture as affected by irrigation frequency, taking into account various effects of the interacting crop-climate-soil systems. This new knowledge is particularly important when considering the development and management of automatic and conventional irrigation systems.

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*Paper presented at the Winter Meetings of the American Society of Agricultural Engineers and recently accepted for publication in the Proceedings of the ASAE.

Effects of Selected Herbicides on Perennial Grasses
and Water Pollution Under Tropical,
High Rainfall Conditions

by

Richard L. Chase, Master of Science
Utah State University, 1972

Major Professor: Dr. John O. Evans
Department: Plant Science

The following herbicides were evaluated for their effect on perennial grasses and water pollution in El Salvador, Central America: MSMA (monosodium methanearsonate), DSMA (disdoium methanearsonate), cacodylic acid (hydroxydimethylarsine oxide), paraquat (1, 1'-dmethyl 4, 4'-bipyridinium ion), dalapon (2, 2-dichloropropionic acid), amitrole (3-amino-s-triazole), atrazine (2-chloro-4-(ethylamino)-6-(isoprophylamino)-s-triazine), diuron (3-(3, 4-dichlorophenyl)-1, 1-dimethylurea), and karbutilate (m-(3, 3-dimethylureido) phenyl-t-butylcarbamate). The herbicides were sprayed on drainage channels at different dosage levels. Some plots received one application, others received two, and still others received three applications.

All herbicides except atrazine effectively controlled perennial grasses. Cacodylic acid was the most effective contact chemical, with dosage levels of 7 and 10 kg/ha achieving 77 percent control of the grasses after two applications. Four and 6 kg/ha of amitrole produced 67 percent during the same period, but control of amitrole then increased while control of cacodylic acid decreased.

After three applications, 5 kg/ha of MSMA yielded 88 percent control. MSMA was more effective than DSMA or dalapon. No significant increase in control was obtained by alternating dalapon and organic arsenicals.

A single application of 12 kg/ha of diuron and karbutilate effectively controlled perennial grasses for 6 weeks.

During the dry season, a single application of MSMA at 6 kg/ha each yielded over 70 percent control after 8 days.

Water samples were taken during rainstorms that occurred shortly after application of diuron was 1.8 ppm. Samples containing MSMA and cacodylic acid were analyzed for arsenic, and in no case was the concentration greater than .5 ppm. These low concentrations likely would not be hazardous to crops, animals, or fish.

ABSTRACT

IMPACT ON RURAL INCOMES OF IMPROVED WATER MANAGEMENT PRACTICES IN MILAGRO COUNTY, ECUADOR

by

Phillip H. Lloyd, Master of Arts
Utah State University, 1972

Major Professor: Dr. Allen LeBaron
Department: Agricultural Economics

Farm budgets based on survey data are used to calculate the net revenue for average irrigated and unirrigated farms for four tenure classes on the Milagro irrigation project, Ecuador. Differences in net revenues between irrigated and unirrigated farms within each tenure class are assumed to be the return to investment in irrigation capital, assuming homogeneity of all other production factors.

The internal rate of return is calculated on investment in irrigation capital assuming returns to such an investment are the difference in net revenues between irrigated and unirrigated farms. Investment in such capital is found to be highly profitable assuming the opportunity cost of capital is 12 per cent. However, small size farms (minifundios) are relatively more profitable than larger farms.

Also, the pure economic profit (rent) accruing to each hectare of land is determined. This is done by finding the water tariff that causes the internal rate of return to fall to 12 per cent and subtracting the current water tariff per hectar (S/.200) from the maximum tariff. The difference is rent per hectare, which is greater for small farms than larger ones. However, when the total land area by tenure class is considered, larger farms capture the greatest share of the economic rent from the project.

Irrigation Design and Management Related to Economics*

by

Jack Keller, J. Paul Riley and R. John Hanks

Various factors associated with an irrigation system affect both the costs and the production levels of the irrigation crop. The link between the hydrologic and the economic systems is the production function. Based on this linkage, a conceptual method is proposed for combining various irrigation factors into a unified procedure for optimizing the design and management of irrigation systems.

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*Paper presented to the Irrigation and Drainage Division Specialty Conference, ASCE, Spokane, Washington, September 26, 1972.

Phosphate Content of Great Basin Ground Waters
and Methods for Appraising Their Contamination Potential

by

Frederick Charles Shewman, Doctor of Philosophy
Utah State University, 1971

Major Professor: Dr. Howard B. Peterson
Department: Civil Engineering

The study was made to determine the feasibility of using polluted water effluent for irrigation and/or the renovation of waters by irrigation with evaluation of ground water pollution potential. The phosphate content status of the ground waters was investigated. A theoretically expected phosphate concentration was determined. Soils were selected and their phosphorus disposal capacities were determined by column and repeat treatment testing methods. A program was developed for computing a soil's maximum phosphorus disposal capacity by utilizing data from the repeat treatment test.

Analyses of 183 ground water samples showed a range in orthophosphate content of from 0.00 to 0.93 mg/l as P, with a mean concentration of 0.027 mg/l as P. These data were used along with solubility theory calculations to establish an approximate level of orthophosphate concentrations which might be expected to exist in average ground waters of the Great Basin. It appeared that the closest approximation to natural orthophosphate concentrations in these ground waters could be made by assuming a solubility equilibrium existed with the calcium phosphate hydroxyapatite. Combining this information with the most severe conditions found with respect to ionic strength and calcium concentration in the ground water, any concentration above about 0.2 mg/l as P would probably indicate that either sample contamination or actual pollution of the ground water had occurred. This information and approach should prove useful in the future for detecting pollution or establihsing quality standards in a given geologic

area.

Five soils were selected as representatives of some of the various potentially irrigable types. These were studied in order to develop the best testing procedures to indicate both the maximum phosphorus disposal capacity of the soils in an area to be used for land disposal of phosphorus laden waters, and the maximum ground water pollution hazard that existed in such an area if no special care was taken in applying the effluent. The Langmuir adsorption isotherm approach for determining a soil's phosphorus disposal capacity was discussed and data was presented which apparently eliminated it for this purpose.

A repeat treatment test was developed which was shown to be superior to the adsorption isotherm approach for determining the maximum phosphorus disposal capacity of a soil. Data from this test were used in conjunction with a computer-solved soil model to obtain numerical values of the maximum phosphorus disposal capacity of any given soil profile.

Soil column tests were made and compared to the repeat treatment data. The data from the two types of tests indicated the possible large differences in phosphorus disposal capacity which might be encountered depending upon the concentration of phosphorus and how the phosphorus laden irrigation water was applied. The phosphorus disposal capacity values obtained from the column tests were found to be estimates of the least amount of phosphorus that would be removed from an effluent by a soil.

It was concluded from a consideration of all the data that the maximum phosphorus disposal capacity of a soil would result from a combination of adsorption of phosphate and precipitation of compounds of phosphorus. 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 adsorption and precipitation. It was evident that the phosphorus concentration of the water and the method of application greatly affect the amount of phosphorus

fixation by any given soil. Periodic applications of waters would result in less ground water pollution.

The Phosphase Removal Capability of Soils

by*

Fred Shewman and H. B. Peterson

Five soils were selected as representives of some of the important irrigable types in the Great Basin. These were studied in order to develop a testing procedure to indicate both the maximum phosphate removal capacity of the soils in an area to be used for irrigation with phosphorus laden waters, and the maximum ground water pollution hazard that would exist in such an area if no special care was taken in applying the effluent or polluted waters.

A repeat treatment test was developed which was believed to be superior to the adsorption isotherm approach for determing the maximum P removal capacity of a soil. Soil column tests were made and compared to the repeat treatment data. The P 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 the two 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 irrigation water was applied.

It was concluded from a consideration of all the data that the maximum P removal capacity of a soil would result from a combination of adsorption of phosphate and precipitation of compounds of phosphorus. 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 P removal from water applied to soils.

* Abstract of a manuscript prepared for publication.

Sprinkler Profile Analysis to Predict Field Performance*

by

Jack Keller, M. D. Moynahan, L. R. Ptacek

A method is presented and successfully tested for predicting the field performance of sprinklers for a variety of steady state wind conditions from a limited number of single sprinkler tests. The method utilizes the concept of the shift in the center of gravity of the test pattern to characterize wind and the slope of the sprinkler profile under low winds to characterize the sprinkler.

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*Paper presented at the 1971 Winter Meetings of the American Society of Agricultural Engineers, Sherman House, Chicago, Illinois. December 7-10, 1971.

ABSTRACT

A Strategy for Optimizing Research on
Agricultural Systems Involving Water Management
by
Jack Keller, D.F. Peterson, and H.B. Peterson

Optimal cropping systems are highly site-specific. That this has been recognized is demonstrated by the acceptance of extensive field trials as a basis for project design and for providing the necessary extension-type information needed in initial developments or in changing agricultural patterns, both in the advanced and the developing countries. However, a consideration of transferable information using a systematic model should permit greatly increased efficiency of field trials and should help identify *in situ* opportunities which may not be apparent on an *ad hoc* basis. This paper proposes a concept for such a model and attempts to demonstrate its use through specific applications. Like all such models, it must be regarded as a "straw man" which will need continual refinement and development.

The single overreaching factor relevant to transfer of information and technology for any crop system can be characterized as agricultural environment. Recognizing this, the model then presents a basis for describing the environment by identifying, through disaggregation, factors and descriptors which are significant to the transfer process in agriculture. The environmental vector is considered to be comprised of three basic dimensions: physical and biological, institutional, and economic. A second level of disaggregation identifies the major descriptors under each of the three dimensions. At a third level the measurable components of each descriptor are listed. Thus one has, under the "physical and biological" dimension, the descriptors "climate" "soil", etc. One measurable component of climate is temperature; another is humidity, etc. Temperature regime may be quantitatively described by such indicators as daily high, daily low, frost-free period, degree days, hourly variation, monthly average, etc.

Transfer can be made in terms of specific crop or crop systems. Thus, for each site-related environmental vector there are large numbers of potential crops or crop systems. These systems are described by "indicators" such as germination, rapid growth, flowering, fruiting harvest, etc., which can be related to environmental parameters. In order to optimize, one needs to know the quality of the transfer function, the potential action programs which might be taken in order to modify the environment, and the quality of the expected response, i.e., whether it is optimal, good, fair, poor, failure or unknown.

If adequate measurements are made in site-specific field trials under different environmental conditions, specific points in the model space can be delineated. With even a few such points the geometry of the model space can begin to be understood with the result that more valid transfer interpolations can be made. As additional data are collected the model can be improved as well as its geographical scope.

The application of this model should be useful in organizing research efforts to minimize the number of site-specific studies necessary and to identify areas of basic research needs. The potential for optimizing research efforts to fill in the model space by utilizing transferable information and conducting site-specific field trials only to bridge critical areas is perhaps the most important contribution of the model. Furthermore, the model should afford a useful framework for the cataloging and retrieval of research information from a data bank.

The model does not include evaluation of social goals or objectives, e.g., maximum food production, maximum national income, income distribution, etc. Given such an objective or some agreed-upon mix of objectives, however, the model, hopefully, would lead to improvement in the strategy for research culminating in an improved program of action to accomplish that objective.

The Use of Sprinkler Profiles to Predict
Field Performance

by

Michael D. Moynahan, Master of Science
Utah State University, 1972

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

A method was developed and successfully tested for predicting the field performance of sprinklers for a variety of steady state wind conditions from a limited number of single sprinkler tests. Three basic geometric profile shapes were investigated.

The method utilizes the shift in the center of mass of the single sprinkler pattern to characterize wind speed. Values of UC versus spacing along the main as a percentage of the effective diameter, 100 Sm/D_e, were plotted for a sprinkler spacing on the lateral of 3% of D_e. From these plots, called "basic UC curves," functional relationships were developed to predict the field performance of a particular sprinkler nozzle pressure combination under a variety of steady state wind conditions from a knowledge of the zero wind basic UC curve for that combination. Although much of the research was conducted in El Salvador, the results are applicable any place windy conditions exist.

ABSTRACT

What About Drip Irrigation

by

J. Keller and R. J. Hanks

Farm Home Science

Volume 92

1972

The basic concept of the system was presented. An evaluation of the advantages and disadvantages of drip method of irrigation was made.

Recommendations were made for the design and operation of such systems as well as the costs involved. Consideration was given to pressure of the systems, kind of drippers, filtering, pipe selection, and to the installations.

APPENDIX D

REPORT ON "WATER RESOURCES PLANNING SEMINAR"

UTAH STATE UNIVERSITY · LOGAN, UTAH 84321

COLLEGE OF ENGINEERING

DEPARTMENT OF
AGRICULTURAL
AND IRRIGATION
ENGINEERING

May 10, 1972

Dean D. F. Peterson
College of Engineering
Utah State University
Logan, Utah

Dear Dean:

This is a delayed report on the "Water Resources Planning Seminar" conducted mostly by Dr. Aaron Wiener here at Utah State University between June 7-18, 1971. In short, I thoroughly enjoyed the Seminar and even now after almost a year has past, find myself re-thinking discussions and moments which occurred during the Seminar.

Dr. Wiener is a most unusual and extremely brilliant man. He expended a tremendous amount of energy lecturing for several hours and leading discussions for several more hours every day. About half the members of the group were very vocal during the discussions, participating and enjoying the Seminar immensely.

I would imagine, however, that the discussions were at such a level that at least half of the participants were not quite certain what the Seminar was really about. The key to enjoying the discussion was probably one's complete participation in the reading assignments and lectures coupled with a certain level of personal maturity and sufficient experiences to relate to the subject at hand.

We utilized Dr. Wiener's text for reading assignments and the lectures followed the reading assignments quite closely. This happened to be my first intensive formal exposure to water resource and irrigation planning and know that it filled a void in my learning. I had intended to only continue through the course if I felt it worthwhile. Once I started, I was so interested I put everything aside. I found myself reading the assignments dilligently and seldom missing a moment of lecture or discussion. As you know, this was not a part of my school assignment and I attended mostly on non-contract time. Knowing me, I am certain you can realize I would not have continued attending if I didn't feel the time was well spent.

I was somewhat disappointed that more of the Utah State University staff did not find time to fully participate in the program. Those who did not attend missed an opportunity to develop a close association with Dr. Wiener, who is undoubtedly one of the world's outstanding intellects in the field of water resource development.

Very truly yours,

Jack

Jack Keller
Associate Professor

dsw

APPENDIX E

PAPER ON

A STRATEGY FOR OPTIMIZING RESEARCH ON

ON AGRICULTURAL SYSTEMS INVOLVING WATER MANAGEMENT

A STRATEGY FOR OPTIMIZING RESEARCH ON AGRICULTURAL SYSTEMS INVOLVING WATER MANAGEMENT 1/

Jack Keller, M. ASCE, D. F. Peterson, F. ASCE, and H. B. Peterson 2/

Optimal cropping systems are highly site-specific. That this has been recognized is demonstrated by the acceptance of extensive field trials as a basis for project design and for providing the extension-type information needed in ititial developments or in changing agricultural patterns, both in advanced and developing countries. However, a consideration of transferable information using a systematic model should permit greater efficiency in the selection of both applied and basic research as well as in the design of agricultural development programs involving water management.

Presently, both the design of programs of research and of agricultural development are based primarily on expert judgment. In forming their judgments, experts draw on a reservoir of physical, biological and economic information gained by study and experience. The quality of the judgment made depends on the accessibility of information stored in the literature or in an expert's brain, and on the skill with which he weighs and synthesizes that information. The writers advance the suggestion that a computerized model which could predict crop production functions for changing environmental conditions could greatly enhance the efficiency of the expert. Such a model could have both information storage and processing as well as optimization characteristics. The model could also help guide the processes of

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1/ Paper submitted at the Irrigation and Drainage Specialty Conference - American Society of Civil Engineers, Spokane, Washington. Sept. 26-28, 1972.

2/ Associate Professor, Department of Agriculture and Irrigation Engineering; Dean, College of Engineering; and Head, Department of Agriculture and Irrigation Engineering, Utah State University, Logan, Utah.

characterizing the agricultural environment.

In a sense, the model might be regarded as a sophisticated analogue of a hypothetical expert possessing all or most of the relevant information. Certain thought processes apparently must commonly be used by engineers and scientists in characterizing the environment, selecting research, and choosing potential action programs in the water management field. Little attention has been given to verbalizing these thought processes. Without being verbalized these are somewhat obscure and perhaps even the investigators who possess certain capabilities for making decisions in this area would be at a loss if called upon to describe the rationales for their actions. Verbalization of these thought processes is the first step in formulating the desired model.

The Model Rationale

Agriculture requires the superposition of biological production resources (culturable genetic materials, both plant and animal) upon an existing or to be modified set of environmental components. Biological production resources may be subdivided into various crops (or animals); these can further be subdivided into various plant varieties (or breeds). Each crop system will have varying physical a. biological environmental conditions necessary for acceptable levels of production.

The model attempts to disaggregate the environment into significant components which are also measurable. Crop growth is viewed as having a number of intermediate production stages or indicators which will show a given response to each of the environmental components and a compounded

response to combinations of them with the ultimate production being the overall integrater of crop growth.

Many of the environmental components are not fixed. They can be altered by various potential action programs or crop husbandry practices. Amoung the most important husbandry programs are irrigation and drainage. In turn, the selection of and success with crop programs is dependent upon the knowledge and ability to transfer information. The transfer process involves relating known environmental components and expected responses as affected by achievable husbandry programs to new environmental situations. The transfer process must also involve the techniques of catigorizing the agricultural environment and optimizing the action programs needed to improve it. Biological production resources are not fixed either, but may be altered by plant and animal breeding programs both to improve quantity and quality of crops and to adapt to differing environmental components.

The model may thus be thought of as the interaction of two variable multi-dimensional vectors: agricultural environment, $\bar{E}$, and production materials, $\bar{M}$. The output vector is the response, $\bar{R}$, ; i.e., $\bar{R} = \bar{E} \times \bar{M}$. In the general model, $\bar{R}$ may be any designated objective. In the crop production model $\bar{R}$ becomes the crop response $\bar{R}_c$. The agricultural environment $\bar{E}$ reduces to $\bar{E}_i$, the intimate plant environment and $\bar{M}$ is the plant material.

Environmental Disaggregation - The single overarching factor relevant to transfer of information and technology can be described as agricultural environment. Agricultural environment may be disaggregated into

four general frameworks which are subdivided into various relevant descriptors, each with a number of measurable components as presented in Table 1.

The concept of the frameworks was taken from Barlowe 3/ who suggested a threefold framework in which land economics could be encompassed. The three frameworks suggested by Barlowe are the physical and biological framework, the institutional framework, and the economic framework. These he defined as follows:

> Briefly stated, the physical and biological framework is concerned with the natural environment in which man finds himself and with the nature and characteristics of the various resources with which he must work. The physical and biological factors involved in this framework provide the physical support, the site, and the raw materials for various activities. At the same time they provide not only the inanimate resources of the earth but also the vegetative, bacterial, insect, fish, animal and human resources that both help and hinder man in his use of land.
>
> The institutional framework is concerned with the role man's cultural environment and the forces social and collective action play in influencing his behavior as an individual and as a member of his family, his various groups, and his community. It is concerned with the impact of cultural attitudes, custom and tradition, habitual ways of thinking and doing things, legal arrangements, government programs, religious beliefs, and other similar factors upon man-to-man and man-to-land behavior. Among its many facets, it also involves the effect of personal and household considerations -- an individual's nonmonetary goals or his family obligations--upon one's decisions as a business operator.
>
> The economic framework is concerned with the operation of our price system as it affects each individual in his attempt to make profitable use of his land-resource base. This framework deals with man's tendency to maximize his returns. It is concerned with the effect that economic concepts such as value, costs, returns, and profits have upon his allocation and distribution of land resources and upon his use of these resources for production and consumption purposes.

3/ Raleigh Barlowe, Land Resource Economics, Prentice Hall Publishing Company Inc., England Cliffs, N.J., 1958.

In dealing with crop systems, the physical and biological framework must be divided into two groups of factors: The intimate physical and biological site conditions which form the immediate environment surrounding the plants in the field and the external physical and biological resources upon which the plant husbandry practices must depend. The successful application of these resources and the procurement of additional necessary resources for the husbandry of the crop system is dependent on the institutional and economic frameworks. As shown in Table 1, a second level of disaggregation identifies the major descriptors which are significant to the information transfer process related to crop husbandry and productivity. At a third level of dissaggregation, the pertinent measurable components of each descriptor are listed (as will be presented later).

Crop Response - Crop production is the overall integrator of the agricultural system response to the husbandry program imposed at a specific site. Transfer must be made in terms of specific crop varieties or crop systems. For each site-related environmental vector, there are large numbers of potential crop systems utilizing various plant materials. The failure or success of each plant material and the necessary husbandry programs can best be described at various production stages or indicator points which are related to the intimate plant environment.

Once the intimate plant environment has been defined, each measurable component of the environment can be looked upon in terms of its effect on various production indicator points related to the crop. The crop production indicator points selected are planting opportunity, germination, early and rapid growth, flowering, fruiting, ripening, and harvest opportunity, as

Table 1. Condensed Summary Model for Optimizing Comprehensive Agricultural Systems Involving Water Management

INTIMATE PLANT ENVIRONMENTAL VECTOR				PLANT MATERIAL VECTOR		
FRAMEWORK	DESCRIPTOR	MEASURABLE COMPONENTS	HUSBANDRY PROGRAMS	PRODUCTION INDICATOR	KNOWLEDGE TRANSFER	EXPECTED RESPONSE
I PHYSICAL AND BIOLOGICAL SITE CONDITIONS	CLIMATE SOIL SOIL MOISTURE FERTILITY PESTS		CULTURAL PRACTICES SCHEDULING IRRIGATION DRAINAGE FERTILIZE PESTICIDES ⋮ PLANT MATERIAL	PLANTING GERMINATION EARLY GROWTH RAPID GROWTH FLOWERING FRUITING RIPENING HARVEST	EXPLICIT OBJECTIVE SUBJECTIVE UNKNOWN NONE ⋮ INADEQUATE	OPTIMUM GOOD FAIR POOR FAIL UNKNOWN
ALTERED AND INTEGRATED PLANT ENVIRONMENT				PRODUCTION		UNITS
EXTERNAL ENVIRONMENTAL VECTOR				HUSBANDRY PROGRAM VECTOR		
FRAMEWORK	DESCRIPTOR	MEASURABLE COMPONENTS	ACTION PROGRAMS	HUSBANDRY INDICATOR	EXPERIENCE TRANSFER	EXPECTED QUALITY
II PHYSICAL AND BIOLOGICAL RESOURCES	HUMAN WATER ENERGY CHEMICAL		ENGINEERING DEVELOPMENT EDUCATION EXTENSION ENFORCEMENT ENLIGHTENMENT INFRASTRUCTURE INCENTIVES SUPPORTS ETC.	CULTURAL PRACTICES IRRIGATION DRAINAGE FERTILITY PROGRAM PEST CONTROL LOGGING AND SCHEDULING PLANT MATERIAL	EXPLICIT OBJECTIVE SUBJECTIVE UNKNOWN NONE ⋮ INADEQUATE	OPTIMUM GOOD FAIR POOR FAIL UNKNOWN
III INSTITUTIONAL	LEGAL EDUCATIONAL RESEARCH FINANCIAL					
IV ECONOMIC	INCENTIVES FACTOR MARKETS PRODUCT MARKETS			PROGRAM PRODUCTION		COSTS RETURNS

shown in Table 1. Each intimate environmental component has some effect at one or more of these indicator points.

In order to optimize, one needs to know the existing plant environment, the quality of transfer, the potential husbandry program which might be taken in order to modify the environment and the quality of the expected response, i.e., whether it is optimal, good, fair, poor, failure or unknown, as shown in Table 1.

Various qualities of knowledge transfer exist, as indicated in Table 1. This column is not necessary to the model, but is included to give some qualification as to the nature of transfer. Sometimes explicit relationships or formulas which allow definite predictions are available. More often the expert is confined to objective reasoning where only some data points or a mix of data and theory are available to provide a basis for information transfer. Simple interpolations or functions such as the empirical consumptive-use equations are examples. Often knowledge transfer capability is completely subjective and dependent totally upon experience and judgment. There also exist classes of knowledge transfer which could be considered as unknown, where it is not known if one exists and the explicit case of none, where it is known that no transfer is possible.

The class of transfer considered as inadequate may be used as a qualifier to the above transfer qualifiers. It may also be used to depict an inadequate categorization of the environment due to either insufficient data or insufficient knowledge of methods of categorization.

Husbandry Programs - As far as the external environment is concerned the meaningful response is the ability to develop the physical and biological resources necessary for the husbandry programs directly related to crop production. For example, irrigation is a potential husbandry program which may affect the total crop environment of almost every crop at each growth indicator point. On the other hand, the ability to effectively irrigate can be greatly affected by the resources available and the institutional or economic environmental components dealing with water resources, water law and water costs. Obviously, certain action programs are available which can modify the external environment to enhance the possibility of achieving the desired husbandry program. Water resources can be developed, laws changed or enforced, and economic incentives altered. The above process is outlined in the lower portion of Table 1.

Formulation and Use of the Model

Crop production is responsive directly only to the intimate physical and biological site conditions. The external environmental sub-vectors are relevant only as they impact on this one, through husbandry; i.e., $\overline{E}_i = f(\overline{E}_N, \overline{E}_R, \overline{E}_E, \overline{E}_S, \overline{H})$ where $\overline{E}_i$ represents the intimate plant environment which is linked to the natural existing site biological and physical environment $\overline{E}_N$, the external physical and biological resources $\overline{E}_R$, the economic component $\overline{E}_E$, the institutional component $\overline{E}_S$ and the husbandry programs $\overline{H}$. It is through $\overline{H}$ that $\overline{E}_N$ is altered to $\overline{E}_i$, i.e., $\overline{E}_i = \overline{E}_N \times \overline{H}$.

This relationship is pictorially dipicted in Figure 1.

At this point the intimate physical-biological-crop response components of an overall model can be partitioned off from the social and husbandry components. Table 1 has been expanded to give finer resolution to the important environmental descriptors and action programs associated with optimizing agricultural systems involving water management. Furthermore, the important measurable components of these environmental descriptors have been delineated. A portion of this expanded sub-model is presented in Table 2. In its simplest form, the sub-model would simply be a data bank partitioned by crops and capable of making interpolations or extrapolations as environmental factors are varied. To take this first step, crop production data under different environmental conditions should be collected in standardized form. All of the pertinent environmental factors should be measured. As a beginning, this could be done to develop data banks for major crops such as wheat, maize and rice.

One advantage of the disaggregation of Table 2 is that it represents an attempt to be comprehensive. All of the environmental factors should be accounted for or catigorized at both experimental sites and contemplated development sites. Neglect of any single factor could prevent transferability of information from the research side and unanticipated difficulties and perhaps even failure on the development side. It would be far better to have a few experimental data points for which the environmental descriptors are measured.

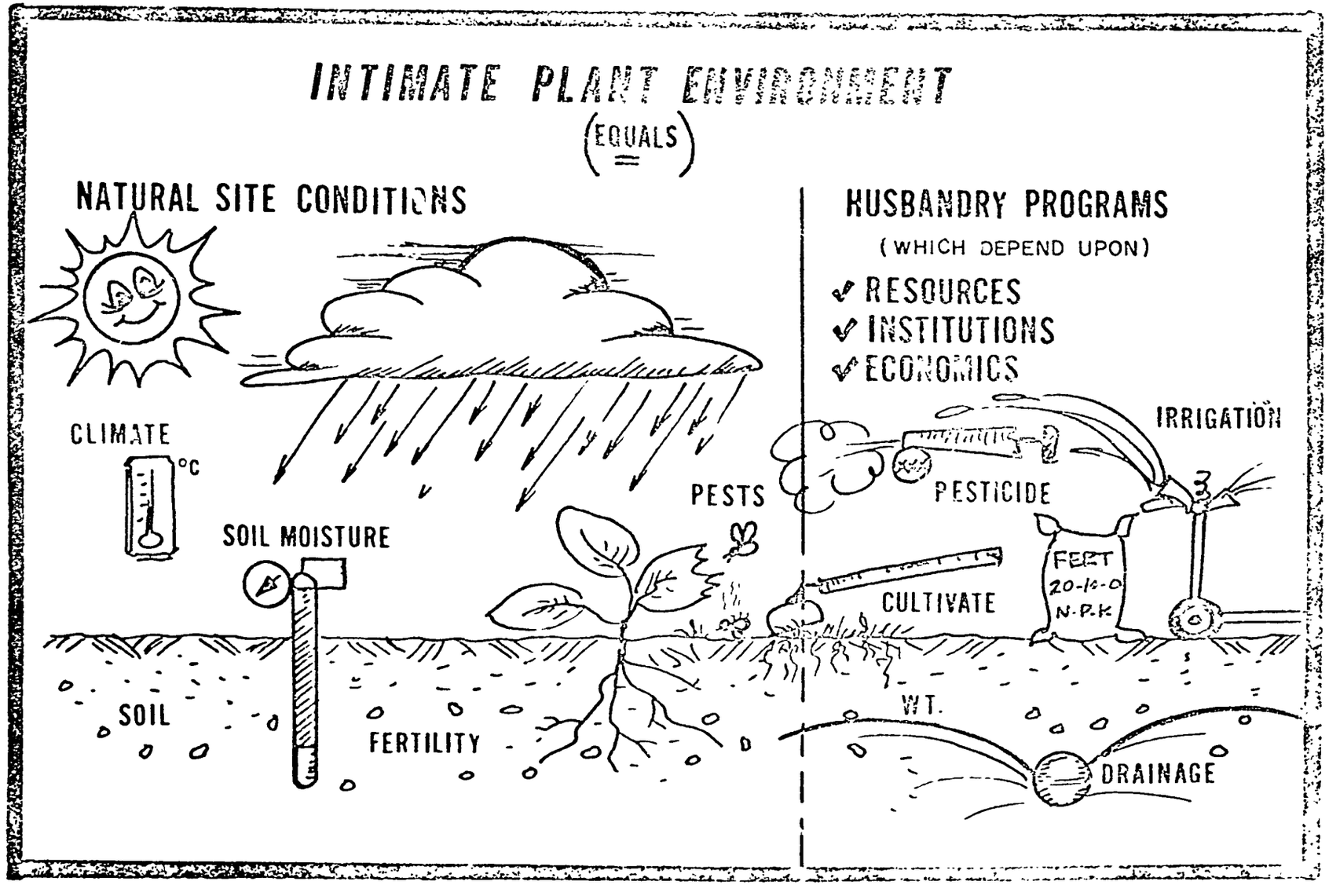

Figure 1. The intimate plant environment vector.

Table 2. Intimate Physical and Biological Site Conditions Portion of Model for Optimizing Comprehensive Research and Action programs on Agricultural Systems Involving Water Management

INTIMATE PLANT ENVIRONMENTAL VECTOR			PLANT MATERIAL VECTOR		
DESCRIPTOR	MEASURABLE COMPONENTS	POTENTIAL HUSBANDRY PROGRAMS	PRODUCTION INDICATOR	KNOWLEDGE PRAISE FUNCTION	EXPECTED RESPONSE
CLIMATE	TEMPERATURE Daily High Daily Low Frost Free Period Degree Days Hourly Variation Monthly Average HUMIDITY Daily High Daily Low Monthly Average RAIN Daily History Monthly Average Intensity Probability LIGHT Daily Intensity Day Length WIND, HAIL, SNOW History Probability	CULTURAL PRACTICES PLANTING DATE IRRIGATION SHADING Cover Crop Inter-plant CULTIVATION TRANSPLANTING SPECIAL HARVEST WIND BREAKS SUPPORT HOUSING LIGHTING NEW PLANT MATERIAL	PLANTING GERMINATION EARLY GROWTH RAPID GROWTH FLOWERING FRUITING RIPENING HARVEST	EXPLICIT OBJECTIVE SUBJECTIVE INADEQUATE UNKNOWN NONE	OPTIMUM GOOD FAIR POOR FAIL UNKNOWN
SOIL	TEXTURE PROFILE Surface Sub-surface Profile STRUCTURE PROFILE Surface Profile INFILTRATION CAPACITY PERMEABILITY SALINITY pH CHEMISTRY ORGANIC CONTENT BACTERIA TEMPERATURE TOPOGRAPHY	CULTURAL PRACTICES PLOWING SUB SOILING CULTIVATION RECLAMATION AMENDMENTS PLANTING DATE IRRIGATION DRAINAGE COVER CROP CROP ROTATION MANURING NEW PLANT MATERIAL			
SOILMOISTURE	QUANTITY PROFILE Surface 0 - 30 cm 30 - 60 cm 60 - 90 cm 90 + cm POTENTIAL PROFILE SALINITY PROFILE	CULTURAL PRACTICES IRRIGATION DRAINAGE CULTIVATION MULCHING COVER CROP AMENDMENTS PLANTING DATE CLIMATE MODIFICATION NEW PLANT MATERIAL			
FERTILITY	NATURAL PROFILE Nitrogen Phosphorus Potassium Trace EXCHANGE ION TIE-UP RESIDUAL HOLDING CAPACITY	CULTURAL PRACTICES FERTILIZE MANURING CROP ROTATION ADDITIVES CULTIVATION IRRIGATION DRAINAGE COVER CROPS NEW PLANT MATERIAL			
PESTS	FUNGUS INSECTS NEMATODES WORMS & SNAILS POLLUTANTS BIRDS ANIMALS RODENTS WEEDS	CULTURAL PRACTICES PLANTING DATE PESTICIDES MECHANICAL IRRIGATION DRAINAGE CULTIVATION NEW PLANT MATERIAL			
ALTERED AND INTEGRATED			PRODUCTION		UNITS

The writers developed this paper in the context of discussions of water management programs for developing countries, thus world-wide data are contemplated. As the model is developed, basic physical and biological relationships may be utilized to simplify and refine the response surface in lieu of simple interpolations.

Plant Breeding - The possibility of developing new plant materials always presents the opportunity to improve production over that which might be expected using different varieties--existing or to be created. How to build this factor into the predictive model is troublesome. At first, within any one basic crop, productivity data might focus on the optimal variety at the test site with the thought that breeding or varietal selection could result in similar optimization at a new site. This approach would need to be used with caution. There would still probably have to be manual review or screening of variety limitations and potentials by crop geneticists for each prediction.

Interaction - This is implied in the model where various indicators or potential action programs or environmental components are cross referenced. For example, interaction is implied between soil moisture and fertility, since it is given as a potential husbandry program for each of these.

Knowledge Transfer - The need for the transfer of knowledge is implicit in the model. Without such an ability, the desired environmental site conditions obtainable through husbandry programs, the selection and application of these husbandry programs, and the expected production indicator responses could not be predicted.

Comprehensive Evaluation

The sub-model would provide predicted production functions for alternative choices of crop systems and husbandry as prerequisites to economic and social evaluation. The resource, institutional and economic frameworks provide the qualitative and quantitative measures of the costs of inputs and the values of the expected responses. A summary of the total evaluation of the agricultural system is presented in Table 3. However, the only quantitative evaluation contemplated is economic, wherein the cost of the husbandry and action programs can be compared to the total economic value of the crop production and action programs to the farm unit or the region. Several operations - research type techniques have been devised for optimizing economic returns given certain levels of resource and marketing constraints. See, for example, Windsor and Chow 4/.

The "social" and "environmental" statements dealing with costs and benefits are, for the most part, qualitative, but some considerations of these categories may be imposed quantitatively on the evaluation in the form of constraints. Social and environmental consequences are important, however, in providing policy makers with the information necessary to make comprehensive decisions.

Application of the Model

The two important vectors operative at the production level are thus the intimate plant environmental vector depicted by the disaggregated

4/ Windsor, J. S., and Chow, V. T., "Model for farm irrigation in humid areas," Journal of the Irrigation and Drainage Division, ASCE, Vol. 97, No. IR3, Sept., 1971.

Table 3. Comprehensive Evaluation of Agricultural Systems as a Basis for the Decision Process

ASPECT	COSTS TO REGION	BENEFITS TO REGION
Economic Balance	Monitary cost of action and husbandry programs.	Monitary value of production and support programs.
Social Statement	Social cost of action programs to the region.	Social benefits of action programs and production.
Environmental Statement	Environmental costs of development programs.	Environmental value of the action programs.
TOTAL	Comprehensive political decision by policymakers.	

measurable components as altered by husbandry programs and the biological production (plant) material vector imposed upon it. The action is two-fold: a husbandry program is imposed on the site environment to make it more hospitable, and this modified intimate environment is imposed upon the plant material.

The availability and quality of the husbandry programs depends upon the external environment which may, in turn, have been modified by some action program. Figure 2 shows a flow diagram of the model process and points out the importance of knowledge transfer.

The response of the plant material to this modified site environment is checked at a number of production indicator stages, and ultimately the expected productivity is estimated. The disaggregation of production into a number of production indicator points or stages is important in systematically selecting potential modifications to the husbandry program and estimating productivity.

Plant materials which have low production expectations at the given environmental site under reasonable husbandry programs are discarded in favor of more promising plant materials. The selection process is continued to the conclusion of the optimization process. This process implies that there is a data bank, the environment is characterized, the knowledge of applying husbandry programs and crop response expectations are transferable from one to another environment.

Agricultural Engineering - In general, agricultural engineering technology is transferable. For example, irrigation system design parameters

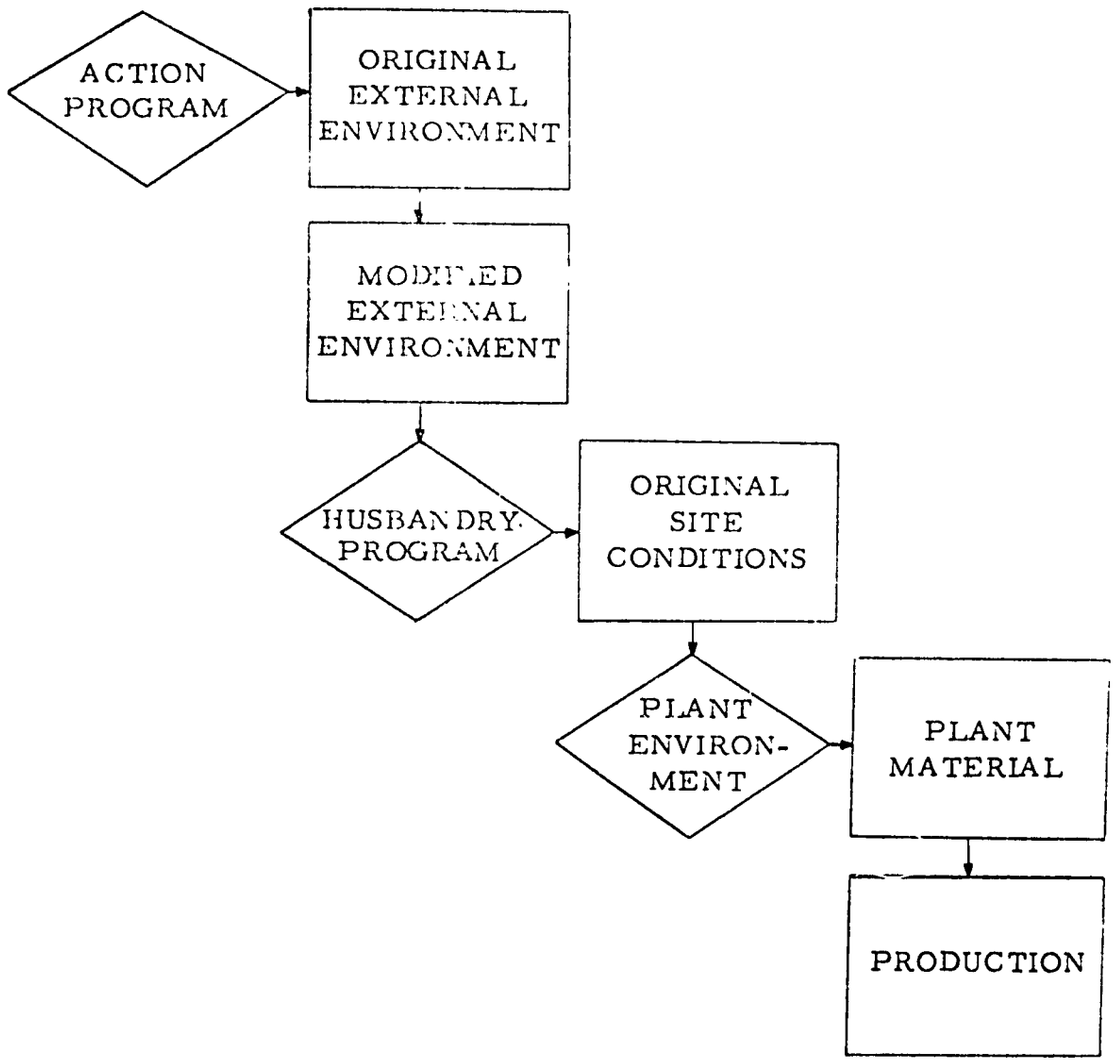

Figure 2. Flow Diagram of Model - Knowledge Transfer is Implicit At All Arrows

including details such as the expected sprinkler performance in wind can be estimated if the environment has been adequately characterized and sufficient sprinkler performance data is available. The reason for inadequate estimates results either from insufficient wind records or insufficient sprinkler performance data. Sprinklers should not be tested at the project site if it is more convenient or economical to adequately characterize the wind and use sprinkler test data which is already available.

The effective application of engineering technology to achieve practical husbandry programs implies that the desired alteration of the natural site environment is known. The technological processes required in the husbandry program which are best suited within a given set of external environmental restraints can be selected from the technological data bank. Thus test site operations are only needed for the final on-site fine-tuning and demonstration of the operating programs. For example, within various environmental restraint circumstances the following technology is transferable; irrigation, drainage, and cullivation methods; fertilizer and pesticide application methods; and planting, thinning, and harvesting processes.

Plant Requirements & Responses - Much of the information regarding the intimate environmental requirements of specific crops and varieties and expected responses to site conditions is transferable. Two sets of data are required before this information can be applied:

1) The existing site environment must be categorized

2) The achievable husbandry programs and resulting plant environ-

environment conditions must be estimated.

The information transfer process breaks down if either the "categorization" of the expected plant environment or the "data bank" of plant needs is inadequate.

An obvious example of applying the model as a check list for crop and varietal selection is:

a) Bananas fail in freezing climates - the temperatures in Alaska are well below freezing much of the year - no reasonable husbandry program other than green houses could alter the temperatures sufficiently to create a hospitable environment for bananas in Alaska - failure of bananas can be expected.

A more subtle application is:

b) In parts of South America it would be desireable to grow corn under irrigation during the dry season. (Since there is little cloud cover, dry season corn should do better than wet season corn). Many say corn doesn't do well during the dry season because of experience with planting the wet season varieties for a dry season crop. The problem results from temperatures being too high during the dry season for pollinization of wet season varieties. If the model had been applied, more suitable dry season varieties which would pollinate at higher temperatures might have been selected and been successful.

Characterizing the Environment - The detail study of many aspects which characterize the environment does not need to be carried out on or near the site. It is often most efficient to bring the component under study to an established laboratory rather than bring the laboratory to the site. This is especially true when highly sophisticated techniques are involved. The model will help pinpoint the most efficient strategy for characterizing the environment.

Optimizing Research - Much of the basic information necessary for optimizing agricultural systems can be obtained from data already available

in the literature. This is possible since much of the information required is transferable.

If adequate measurements are made in site-specific field trials under different environmental conditions, specific points in the model space can be delineated. With even a few such points the geometry of the model space can begin to be understood with the result that more valid transfer interpolations can be made. As additional data are collected the resolution of the model can be improved as well as its geographical scope.

The application of this model should be most useful in organizing research efforts to minimize the number of site-specific studies necessary. The potential for optimizing research efforts to fill in the model space by utilizing transferable information, using the more sophisticated research facilities efffectively, and conducting site-specific field trials only to bridge critical areas is perhaps the most important contribution of the model. Furthermore, the model should afford a useful framework for the cataloging and retrieval of research information from a data bank.

Much information dealing with soil-water-plant-climate relationships is transferable. However, it is not unusual to find field research being conducted to determine crop response where it could easily have been predicted if the environment had been adequately characterized. For example, is it unnecessary to grow: (a) cotton to find that the growing season is too short, (b) rice to find that the temperatures are too cool, (c) orange trees to find out it freezes, (d) alfalfa to determine optimum moisture requirements, etc., (e) wheat to find it is too wet to harvest

at the proper time, etc. On the other hand site specific research is necessary to determine: (a) Varietal disease susceptability, (b) Interactions between climate-moisture-pest controls for various plant materials, etc.

Conclusion -

Hopefully, this model will aid in setting up and guide the activities of investigating teams. Too often proposed projects are viewed by "teams of experts" who go no further than measuring a number of environmental components. This may be a worthy and necessary effort, however, the ultimate success of projects depends on the level of knowledge transfer capability. The real and most unique experts are not the technicians who measure the environmental parameters, but the few engineers and scientists who are capable of optimizing the agricultural system through knowledge transfer. The model disclosed herein should help in organizing and defining the necessary processes.

In addition to forming a useful outline to guide the thought processes involved in research program development and project analysis, the model could form the framework for a data retrieval system. It is being proposed that the work be extended in an effort to make the model more complete and to form a world data bank for at least one important grain or fiber crop.

APPENDIX F

TRIP REPORTS

A. A. Bishop to Mexico

R. J. Hanks to Israel

J. Keller to Israel

APPENDIX F

TRIP REPORT

A. A. Bishop to Mexico - November 8-14, 1971

I participated in the First Latin American Seminar on Systematic Evaluation of Land and Water Resources held in Mexico City during the period November 8-14, 1971. The attached documents consisting of the official program, the conclusions and recommendations, a list of the participants and copies of the papers distributed at the seminar indicate the scope of the seminar. Only a few of the seminar were translated into English, and these are attached along with the original Spanish version of the paper. You will note that this seminar was organized and conducted by FAO and their influence was very strong in the seminar. This is evidenced both in the personnel invited to present official papers at the seminar and also in the general nature of the conclusions and recommendations.

The meeting was attended by representatives from over 20 Latin American nations and the USA and UK were also represented as well as a number of technical personnel from the FAO and UNDC. The seminar was very well planned and organized. The program was followed very closely with the presentation of the prepared paper and this was followed by a discussion. Most all of the countries represented participated in the discussions at one time or another and there was a considerable amount of time devoted to discussions which, in general, made the sessions run beyond their scheduled times. As is the case with most all seminars, the principal objective is to provide an opportunity for an exchange of ideas and information. This was an extremely successful seminar in this regard.

The emphasis was heavily weighted towards the evaluation of the soil resources although the water resources did receive some emphasis. Most all of the countries reported their methods of classifying soils for agriculture purposes and indicated their progress and plans for the future.

The seminar included two field trips. One on Wednesday, November 10, and the second into Guadalajara on November 13. The principal objective of the field trip was to allow the participants to examine the various soils pro-

files in the agricultural lands of Mexico. The visits on Wednesday were principally in the area surrounding Mexico City and those on Saturday, of course, were concerned with the areas in and around Guadelajara. Of particular interest to me was the Wednesday visit where I saw the sewage water from Mexico City being used for the irrigation of the agricultural lands. It was reported that the "black water " the sewage water of Mexico City is used primarily for the irrigation of alfalfa and pasture lands although grain, sorghum, corn, and some of the other crops were also being irrigated with sewage water. I did not observe the use of any sprinkler irrigation in this area and inquired as to why the sprinklers were not used. The answers were that in general it was too expensive and was not popular in that area. However, they did indicate that farther north, I presume by the United States border, that sprinklers were in wide use.

The second seminar was planned for 1974 prior to the 12th Regional FAO Conference for Latin America. The second seminar proposes to examine the progress made concerning the conclusions and recommendations of the first seminar. The conclusions and recommendations have been translated by SCS in Washington, D. C. These were the first documents in the set obtained at the seminar. I would suggest that all of these papers be bound together in one set and circulated to the interested staff at Utah State and maintained in the file for future reference regarding our Latin American research.

LIST OF TECHNICAL PAPERS, REPORTS COLLECTED IN MEXICO

Alphabetical listing according to titles

1. Approach and Parameters for Evaluating Suitability of Land for Irrigated Agriculture.
   Charles W. Houghton, Technical Officer (Irrigation)
   Land and Water Development Division

* 2. Aumento de la Productividad Agricola atraves de los Trabajos de Conservación de Suelos
   Juan A. Comerma, Ingeniero Agronomo Expecialista en Suelos del CIDIAT, Venezuela
   Alfredo Rivas Larralde, Ingeniero Agronomo Jefe de la División de Conservación de Suelos y Aguas del MAC, Venezuela
   Jaime Soriano, Ingeniero Agronomo de la División de Conservación de Suelos y Aguas del MAC, Venezuela
   (Spanish)

* 3. Conclusions
   First Latin American Seminar on the Systematic Evaluation of Land and Water Resources
   (both Spanish and English)

* 4. Cooperación y aporte internacional a Proyecto Regional LAT 70/32 Evaluación Sistematica de los Recursos de Tierras y Aguas Programa de Trabajo para 1972-1974
   (Spanish)

* 5. Discurso de Bienvenida a Los Participantes
   El Señor Ingeniero Leandro Rovirosa Wade, Secretario de Recursos Hidraulicos.
   (Spanish)

* 6. Lista de Documentos, (Documents List)
   (Spanish and English)

* 7. Ensayos de Suelos en Relación con las Recomendaciones de Manejo y la Evaluación Regional
   Robert Cate, Professor No. Carolina State Univ. International Soil Testing Project, Brasilia, Brasil
   (Spanish)

8. Estudios y Projectos, S.A. y Aerofotogrametria, S.A.
   Congreso Nacional de la Ciencia del Suelo
   Obrero Mundial 115
   Mexico 12, D.F.
   (Spanish)

* 9. Estudios Regionales sobre Recursos de Suelos: Mapas de Suelos de America Latina preparado por FAO UNESCO
Klaas Jan Beek, FAO (Santiago)
Charles Wright
(Spanish)

* 10. Evaluación de las Practicas de Manejo de Suelos en los Programas Regionales de Producción de Cultivos
R.J. Laird, Centro Internacional de Mejoramiento de Maiz y Trigo, Mexico
(Spanish and English)

* 11. Evaluación de Tierras para la Planificación del Uso Agricola - Un Método Ecológico
Klaas Jan Beek, FAO (Santiago)
Jacob Bennema, Universidad Agricola Estatal, Wageningen (Holanda)

* 12. Examen de los Métodos de Levantimiento de Suelos en America Latina
A. Van Wambeke, Rijksuniversiteit Gent (Belgica)
(Spanish)

* 13. Fe de Erratas
(hand written document, Spanish)

14. Guideline for the Preparation of Feasibility Studies for Irrigation and Drainage Projects
FAO IBRD Cooperative Programme
Eome, December 1970

* 15. Increase of Agricultural Productivity Through Soil Conservation
J.A. Comerma, CIDIAT (Venezuela)
A. Rivas Larralde, MAC (Venezuela)
J. Soriano, MAC (Venezuela)

16. Ingenieria Hidraulica en Mexico
Dirección de Agrologia
Informe de Actividades
Este Sobretiro Corresponde al No. 1 Vol.
1971 De La Revista Ingeniera Hidraulica
(Spanish)

* 17. International Cooperation and Contribution to LAT 70/32 Programme of Work 1972-74.

* 18. La Administración de Aguas y Los Organismos Para su Control en America Latina
J.A. Sagardoy, Oficial Tecnico en Instituciones para el Riego
Servicio de Recursos y Fomento de Aguas, Dirección de Fomento de Tierras y Aguas FAO, Roma

* 19. "La fertilidad, condición del suelo más limitante para la agricultura en America Latina. Referencia especial al programa de fertilizantes de FAO y su posible aportación a la evaluación de los recursos regionales."
Juan de la Vega, FAO (Rio de Janeiro)
(Spanish)

* 20. La Fertilidad de los Suelos en Relación con la Silvicultura en Cuba
Dr. Abdul Bari Awan, Expecialista de Suelos Forestales y Fertilizantes
(Spanish)

* 21. Land Reclamation by Irrigation and Drainage in the Peruvian Coast
Julio Lostao E., Cendret (Peru)

* 22. Lista Provisional de Participantes
(Spanish)

* 23. Mapa de Interpretación de Imagenes de Radar
(Spanish)

* 24. Manejo de Cuencias Prevención y control de la contiminación del agua
I Ing. Cesar Buenrostro Hernandez Secretaria de Recursos Hidraulicos
(Spanish)

* 25. Métodologia Para el Informe du un Estudio Agrologico Detallado
Secretaria de Recursos Hidraulicos Jefatura de Irrigación y
Control de Rios dirección de agrologia.
Publicación Num. 2
Mexico, D.F., Mayo 1970

* 26. Métodos y Parameteros para la evaluación de las tierras según su aptitud para la agricultura de regadio
Charles W. Houghton, Oficial Tecnico (Riegos, Dirección de Fomento de Tierras y Aguas, FAO-NACIONES UNIDAS
(Spanish)

* 27. Naturaleza y objectivos del Proyecto LAT 70/32
Klaas Jan Beek, FAO (Santiago)
(Spanish)

* 28. Necesidades de una Evaluación de los Recursos de Tierras y Aguas en Relación con la Reforma Agraria y Colonización
Ernest Feder, FAO (Santiago)
Sebald Manger-Cats FAO (Guatemala)
(Spanish)

* 30. Organismos Internacionales de Naciones Unidas
(Spanish)

* 31. Programme
Centrol de Convenciones, Reforma 445, Mexico City 5, Mexico

* 32. Progreso en Lavantamientos de Suelos y su Aplicación en Latinoamerica
R. Costa de Lemos, FAO (Santiago)

* 33. Recuperación de Tierras Mediante el Riego y Drenaje en la Costa del Peru
Julio Lostao E., CENDRET (Peru)

34. Regional Seminar on Systematic Evaluation of Land and Water Resources
Document of the Office of Regional Development Organization of American States, Washington, D.C.
Mexico D.F.,November 8-14, 1971

35. Requisitos de los Estudios de Evaluación de Recursos de Tierras y Aguas con fines de Inversión.
Programa de Cooperación FAO BIRF
(Spanish)

* 36. Rol del Desarrollo de Recursos de Aguas en la Futura producción Agricola en America Latina
Kazuki Takamiya, FAO (Santiago)
(Spanish)

37. Secretaria de Recursos Hidraulicos, Dirección General de Pequeña Irrigación
Plan Nacional de Pequeña Irrigación
(Spanish)

* 38. Soil Data Processing as an Aid to Regional Land Use Planning
Soil Resources, Development and Conservation Service, FAO

* 39. Soil Fertility in Relation with Silviculture in Cuba
Abdul Bari Awan, FAO (Havanna, Cuba)

* 40. Soil Testing in Relation to Management Recommendations and Regional Evaluation
Robert Cate, Professor No. Carolina State University, International Soil Testing Project, Brasilia, Brazil

* 41. Statement made by Dr. Angelo A. De Tuddo,
Country represetative and senior agricultural adivser on behalf of the Director General of FAO, Dr. Addeke H. Boerma, (opening address) Seminar, Mexico City, 8 November, 1971
(Spanish and English)

* 42. Una Investigación sobre la Utilidad de las Imagences de Radar en la Clasificación de Tierras
E. Nieuwenhuis, Centro Interamericano de Fotointerpretación Bogota, Colombia

* published by the First FAO UNDP Latin American Seminar on Systematic Land and Water Resource Evaluation, held in Mexico, D.F., Mexico, November 8 to 14, 1971.

TRIP REPORT

R. J. Hanks to Israel - August 29 - September 10, 1971

I left Logan on August 22 and traveled to Baltimore, Maryland to consult with Dr. Doral Kemper who is joining staff of Colorado State University. On August 24 I left Baltimore, arriving in Israel on the 25th. August 28 and 29 were spent with the Soil Physics Group at the Volcani Institute of Agricultural Research at Bet Dagan, Israel.

Dr. Eshel Bresler, a Ph.D. graduate of Colorado State University and a co-worker of mine on a couple of papers, is head of the soil physics group. They are quite active in pursuing the development of models for soil water flow including water extraction by roots and simultaneous salt flow. Bresler has extended the on-dimensional model we used earlier to the three dimensional flow case from a point source. He has a couple of papers coming out on this --I have reprints and the references are listed in the appendix. This has particular importance to the new practice of "drip irrigation" causing so much excitement in Israel and other parts of the world. More will be said about this later.

Bresler had very limited contact with the IBP group in Israel, headed by Evenari. However, at the Volcani Institute I spent considerable time with Dr. Gerald Stanhill, head of the meteorological section there. He had had more contact with the IBP group apparently being in on some of the planning. He said that "IBP was dead" in Israel as far as he knew. He said, that there should be a report out soon if it had not already been published on "Survey of Arid Land Research in Israel" edited by Gideon Orshan of the Botany Department, Hebrew University, Jerusalem. I intend to request a copy. Stanhill also told of some very interesting work done by someone in Israel (he thought Orshan) where he found that transpiration could be measured with good accuracy by weighing cut leaves for loss of weight.

Also at the Volcani Institute I discussed work that is being done jointly by Dr. Amos Hadas, in the soil physics group, and Dr. Marcel Fuchs of

the meteorology group, on soil heat flow. They are using some good soil heat flow plates that seem better than any available commercially. They also have been involved in computing soil heat flow from a minimum of measurements knowing soil properties. They have been using rather sophisticated analyses (La Place Transforms and Fourier Analyses) for their solution.

The International Symposium on Soil Physics and Technology started on August 29 with an opening ceremony. A list of the papers given is enclosed in the appendix. As expected most of the papers were rather routine. Probably the most interesting exchange resulted from the assertion by several people (Rawlins, Zaslavisky and Rawitz) that dramatic increases in plant growth result if the soil water content can be kept near saturation. This was of only theoretical importance until the inventions of the drip irrigation system. Moreover the adherants to this idea claim it is possible to increase plant growth without any increase in transpiration. Stanhill pointed out that most of the studies on which these conclusions are drawn were laboratory type research and failed to be verified in the field. A lively and inconclusive exchange resulted. In my opinion it seems that both points of view may be right depending on what you call plant growth and what plant you are talking about. If you are interested in total dry matter growth you may have an entirely different situation from growth of grain or fruit or a tuber.

Stanhill gave a paper where he tried to evaluate the progress in micrometeorology. He concluded it had been very costly in view of the results received. He thought that there was a real need of some system of making the data collected in the past generally available so the same data would not have to be collected again. Several people rose to the occasion and disagreed with Stanhill citing the same analysis would show most research or endeavor to to be of little value (the Vietnam war, soils research, plant research, TV etc, were all examples cited) and that comparative analyses need be done before we all quit . Stanhill claimed all of this didn't change his basic argument.

A paper by H. Taylor, giving a summary of the results of many root studies at his lab, showed root extraction patterns to be highly dependent on the age of the plant and the soil water status. This would say our root model may need to be more complicated to account for root growth with time. However, his studies were essentially laboratory type on annual plants.

W.R. Gardner, of Wisconsin, gave a "state of the art" paper on the last day in which he strongly advocated research tied to field research, particularly paying attention to plant factors. He noted a need for work having application to wide and diverse areas such as watersheds. There was no disagreement in principle but much in practice.

The Symposium lasted four days---August 30 to September 2---after which there were three days of study tours.

I met Dr. Marvin Twersky (soil-plant relation man) and Mr. Dov Mills (ecology-meteorologist) from the Negev Institute of Desert Research at Beersheva during the symposium. Through them I attempted to contact Eveneri, head of the IBP group in Israel. He is head of the Botany Department at Hebrew University but has been spending a good deal of his time at his desert research site at Avdat in the Negev Desert. At any rate I made arrangements to meet Eveneri at Avdat on September 2 but he never showed up while we were there. I understand that his wife had been ill of late which may be the reason he didn't show. At any rate we toured the Avdat site where some German plant physiologists are working. These people are well acquainted with Martin Caldwell and are using the same experimental set up to study CO_2 assimilation and transpiration on natural desert plants. They are also comparing the natural plants with those in Eveneris water harvesting area apricots. They have about $200,000 worth of equipment on the site.

The Avdat site is a very interesting one because it is situated in an ancient area where the people had a flourishing city about 2000 years ago. They constructed "water harvesting" areas where the runoff water from a large area of land was concentrated in a relatively small area. Eveneri has reconstructed several of these sites and is actually farming

them. He is evaluating orchards, field crops, and range plants for suitability under desert conditions. He is making measurements of water yield from various runoff areas etc. The rainfall here is very low, about 10 cm or so, each year but comes during the winter months. The ancient people removed rock from the runoff area to increase runoff. Eveneris "farm" looked quite impressive. A green spot in very barren area. The results of his research are in a book recently published by Harvard University Press, ("The Neger-Challenge Desert" $15)

Eveneri has apparently had some social problems with tourists, especially Israeli soldiers, with vandalism. Consequently, he has fenced the area and probably contributed to my not seeing Eveneri.

The "International Experts Panel on Drip and Automatic Irrigation" started at Herzila on September 3. There are many people throughout the world very excited about this system among which are some promoters and revolutionaries (self styled).

Briefly the system involves the use of a "dripper" or "trickle" valve at various intervals installed in a plastic pipe connected to water under pressure. The "drippers" deliver water at 2 to 8 liters per hour which is much less than the conventional furrow or sprinkler methods. What this system water can be applied nearly continuously. This allows a portion of the root zone to be at a water content continuously higher than field capacity. This would supposedly allow use of salty water unsuited for the conventional furrow or sprinkler systems. Where rows are wide, such as orchards, grapes etc., the water can be placed near the plant roots in the row without wetting all of the surface. Thus the trickle system would allow for water savings compared to a sprinkler system where the entire soil surface is wetted. Another advantage of the trickle system is the reduction of weed growth between wide rows by eliminating water from getting to this area. This allows for machinery and people to move easily between rows at all times to spray, etc.

The disadvantages of the trickle system are cost, need for very good water filtration and difficulties when the system is used for leaching purposes. The high cost results from the need for so many tricklers. The tricklers are fairly simple and are being mass produced at about 25¢ each. In an orchard with rows 5 meters apart they were using one trickle per meter of row or 2000 tricklers per hectare at a cost of $500 for tricklers alone. The cost of the plastic pipe connecting the tricklers and filtration system would add another $200 or so to this cost. The use of tricklers for crops like corn or potatoes with rows 1 meter or so would be very expensive.

Since the trickler system requires that water be delivered at a very slow rate there has been a lot of development work in the design of the drippers. With low flows most drippers have very small orifices which are easily plugged by any dirt etc. in the lines. Thus, the need for very good filtration. The most successful design appears to be one with relatively large oriface with a long length. A lot of engineering has gone into these tricklers. It would appear there are many that are available that do not work well.

Leaching of salts is a necessity of any irrigation system. In some areas rainfall is sufficient for this purpose. However, in many areas where rainfall is small leaching must be done with the irrigation system. The capacity of the "drippers" are so low that it would appear impossible to leach adequately with this system. Thus, another system such as gravity or sprinkler irrigation must be available, together with the water, for leaching. Some people are advocating that leaching is not necessary over the entire soil but only near the dripper lines allowing salt to pile up between the rows indefinitely.

From the papers that were given and the field trips I came to the following conclusions:

1. Trickler irrigation is feasible under certain conditions--crops must have a high economic value and/or the row spacing must be wide. Thus, they are being used in orchards with wide rows and high economic yield. They are also being used for such relatively narrow row crops as eggplant, peppers, and strawberries with apparent economic success. They have been tested with tomatoes with good increases in yield but

doesn't appear to be economically feasible. Attempts to "beat" the economics by moving the trickler lines have been tried but do not appear to be successful.

2. Trickler irrigation may show yield increases compared to conventional systems on many crops because of better soil water control. It did not appear to me that the advantage of keeping soil water content above field capacity was definitely shown, in the field, to increase yields compared to keeping the water content at or just below field capacity. This needs further research. I'm sure the results will be highly crop dependent. However, it appears that the same result can be accomplished with frequent short sprinkler irrigation.

3. The trickler system has decided advantages over sprinklers where salty water is used--because the salty water is kept off the leaves and the soil water potential is kept higher. The problem of salt distribution and removal under the trickle system has not really been studied and may cause disaster in the future.

4. The convenience of not wetting the entire soil surface and no runoff from the trickler system is a decided advantage. In the field trip it appeared that the farmers were largely influenced by this factor.

5. The eonomic and cultural situation in Israel is so different from the rest of the world that it is next to impossible to draw conclusions valid to another country from their situation. The water in Israel is delivered to the farmer in a high pressure pipline. Most of the farms using trickle irrigation were communal farms-kibbutzim-with highly mechanized and advanced agriculture. The people running these farms seem to be exceedingly eager to try anything new. The climate and market situation of Israel is much like Southern California where many high income crops can be grown. The entire country is organized and bureaucratized so that little surplus food is grown. Agriculture is considered to be the most important "industry" in Israel. There are many subsidies in the cost of water and other agricultural activities. Many of the kibbutzim were established for security purposes (on the borders and in the desert) and are surely subsidized. It is possible to spend your military obligations in these border kibbutzum.

6. The Israelis are very generous hosts. They went all out to treat us well. They subsidized many of the tours which were a mixture of business and "Tourist" type tours. They like to manage you and your time and make all kinds of decisions on what is good for you. They are almost overwhelmed with educated people. I was informed that there were about 100 Extension people having to do with irrigation in Israel (compared to 2 in Utah).

APPENDIX

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Wadleigh, Cecil H. 1970. Cultural advancement and land use. A paper presented at the Nineteenth Annual Meeting, Agricultural Research Institute, Arlington, Virginia. October 13-14

Wadleigh, Cecil H. 1970. Nitrate. A paper presented before the Maine Association of Soil and Water Conservation District Supervisors' Summer Meeting, Waterville, Main, July 30-31, 1970

Wadleigh, Cecil H. 1971. Land runoff and eutrophication. A paper presented before the 1971 Annual Meeting of Western Society of Soil Science, Laramie, Wyoming, June 16-18

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Wadleigh, C.H. and R.S. Dyal. 1970. A paper presented before the 56th Mid-Year Meeting of Chemical Specialties Manufacturers Association, Chicago, Illinois, May 20.

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COLLEGE OF ENGINEERING

DEPARTMENT OF
AGRICULTURAL
AND IRRIGATION
ENGINEERING

May 11, 1972

MEMORANDUM

To: Howard B. Peterson

From: Jack Keller

Subject: International Experts Panel on Irrigation held in Israel between September 6-13, 1971

Attending the "International Experts Panel on Irrigation" was quite an experience. The conference was carried out in a Seminar fashion and for the most part dealt with drip or trickle irrigation. Attached are copies of the general program of the conference with a list of the participants who attended or were supposed to have attended the conference. Actually, a number of the listed participants did not attend but I assume they had indicated an interest.

I will not discuss all of the papers presented at the conference since we were informed that the Conference proceedings would be published. Most of the papers presented, however, were available as handouts and I have them in my files. Upon receiving the proceedings I will include them with this report and make them available for general departmental use.

The conference was not on a particularly high level and many of the papers were more the product of observations (which weren't always unbiased) rather than reasonable field research activities. However, I did obtain a much better general idea about drip irrigation and, since returning from the conference have authored (along with John Hanks) two papers concerning the generalities discussed at the conference. These papers are: "What About Drip Irrigation", by Jack Keller and R. J. Hanks. This paper was published in the Utah Farmer and gives a general laymen's type concept of the subject of drip irrigation and its general applicability for conditions in Utah. The second paper is entitled, "Drip Irrigation" by R. J. Hanks and Jack Keller. This paper has been submitted for publication in Utah Science. This paper is somewhat general in nature, however, it covers more technically specific information involving the use of drip irrigation and applications in Utah.

Copies of these manuscripts are also attached to this report.

The previously mentioned papers, along with the conference proceedings, present a very good prospective of the value of the conference to me. While attending the conference I met and became acquainted with Dr. David Karmeli of the Agricultural Engineering Department at the Technion in Haifa. Through this acquaintance I have been invited to be a Guest Professor at the Technion for the summer of 1972 during which time I will be studying drip irrigation in Israel. I also plan to study irrigation in general throughout Israel along with liquid waste disposal on irrigated lands.

I have found Israel is a most enjoyable place to visit since the people are such wonderful hosts. I do not believe, however, their irrigation facilities are appropriate for many other parts of the world. The Israelis have many technicians in the field of irrigation and have the problem of having competing technicians trying to play the role of learned engineers. This is not to say they are lacking individuals with very high quality credentials and great potential. The problem arises, however, with the numerous specialists who have tried to promote and export narrow approaches in a world of broad needs.

Attachments

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