

AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523
BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

BTW 37

1. SUBJECT CLASSIFICATION	A. PRIMARY Serials	Y-AP10-0000-0000	
	B. SECONDARY Agriculture--Water resources and management		
2. TITLE AND SUBTITLE Optimum utilization of water resources for agriculture with special emphasis on systems analysis of watershed management; annual technical report, 1972/1973			
3. AUTHOR(S) (101) Ariz. Univ. Dept. of Watershed Management			
4. DOCUMENT DATE 1973	5. NUMBER OF PAGES 29p.	6. ARC NUMBER ARC 333.91.A719	
7. REFERENCE ORGANIZATION NAME AND ADDRESS Ariz.			
8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publisher, Availability) (Activity summary)			
9. ABSTRACT			

10. CONTROL NUMBER PN-AAC-290	11. PRICE OF DOCUMENT
12. DESCRIPTORS Watersheds	13. PROJECT NUMBER
	14. CONTRACT NUMBER CSD-2457 211(d)
	15. TYPE OF DOCUMENT

CSD-2457 211(d)
PN-AAC-290

PART II

UNIVERSITY OF ARIZONA

ANNUAL TECHNICAL REPORT 211(d) PROJECT

AID/csd 2457

TABLE OF CONTENTS

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

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

Date August 15, 1973

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

Grantee: University of Arizona

Director: David B. Thorud

A. Statistical Summary:

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

B. Narrative Summary

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

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

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

C. Detailed Report

1. General Background and Purpose of Grant

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

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

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

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

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

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

II. Objectives of the Grant

I. Objectives restated

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

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

- capacity through foreign travel and study by faculty members.
- f. Improve its understanding of the type of problems encountered in the less developed countries, including the socio-political 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.

Increase Consulting Competence

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

Expansion of Special Activities

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

III. Accomplishment

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

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

1. Improvement of Research Capability

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

a. Modeling Hydrologic Systems

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

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

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

Manuscripts prepared during the current report year include:

"A stochastic snow model to evaluate reservoir operation."

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

"Predicting the hydrologic effects of land modifications."

"Optimum control of irrigation water application."

"Steady-state seepage on a hillside."

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

b. Management Techniques

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

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

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

Titles of these papers are:

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

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

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

2. Improvement of Teaching Capability

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

a. Computer Assisted Instruction (CAI)

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

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

Course development

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

3. Development of Increased Consulting Competency

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

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

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

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

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

4. Expansion of Special Activities

a. Library Development

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

b. International Symposium

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

IV. Impact of Grant in Developing Institutional Capabilities

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

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

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

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

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

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

V. Utilization of Institutional Resources in Development

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

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

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

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

VI. Other Resources for Grant-Related Activities

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

VII. Next Years Plan of Work and Anticipated Expenditures

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

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

VII. Next Years Plan of Work and Anticipated Expenditures

It is anticipated that next year will experience a continued shift in emphasis to activities that will increase the University of Arizona's competency to perform consulting service. With additional foreign travel expected as a result of the new Peace Corps program and the cooperative research project with Hungary, opportunities for consulting activities are correspondingly increased. Previous contacts in such countries as Ethiopia, Iran and Pakistan will be utilized in an expanded effort to produce linkages with developing nations.

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

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

Table I
Distribution of 211(d) Grant Funds (#AID/csd-2457)
and Contributions From Other Sources of Funding
Review Period July 1, 1972 to June 30, 1973

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

*These figures are our best estimates

Table II

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

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

^{1/} See Table 3 for detailed breakdown of this category^{2/} See Table 4 for detailed breakdown of this category

Table III

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

Review Period July 1, 1972 to June 30, 1973

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

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

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

Table IV
Expenditure Report Continued
Under Institutional Grant #AID/csd-2457
Review Period July 1, 1972 to June 30, 1973
Detailed Breakdown of Operations Expenditures

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

University of Arizona

Fourth Annual Report

List of Publication having significant 211(d) input.

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

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