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9. ABSTRACT

This final report is a brief overview of the major activities and results of research on the needs for water control and delivery system in Brazil, Chile, Colombia, Ecuador, El Salvador, Guatemala, and Peru. The details of the study are reported in the technical and annual progress reports listed in the Appendix. This document is mainly colored photographs showing various aspects of the research. Crop yield was studied as a function of water application, timing and amount, fertilizer use, planting density and other variables. Techniques for minimizing the deleterious effects on crops of excess surface and subsurface water have been developed. There is increased production of corn in Chile and rice in Colombia. Brazil has several operating irrigated research stations in the Sao Francisco Valley. Guatemala and Peru are beginning to develop irrigation programs. All of Latin America now has access to once unavailable data, water laws, institutions, methods, costs of alternative water management strategies, improved salinity control and drainage techniques, and better tools for estimating crop water requirements. It is expected that this research in Latin America will be applicable in other regions having similar conditions.

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

FINAL REPORT

Contract AID/ta-c-1103
Utah State University
April, 1977

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INTRODUCTION

In June, 1968, a contract for on-farm water management research was awarded by the Technical Assistance Bureau of the United States Agency for International Development to Utah State University. The general objective was to increase food production in the arid and sub-humid lands of less developed countries through the improvement of water management practices and their integration with other good management practices.

Research objectives and programs have included the development of farming practices which optimize the use of rain and irrigation within specific climate, soils, economic infrastructure and social constraints. This has required research on developing country needs for water control and delivery systems.

Crop yield as a function of water application, timing and amount, fertilizer use, planting density and other variables have been studied. New techniques have been developed for minimizing the deleterious effects on crops of excess surface and subsurface water and poor water quality.

Institutional constraints to effective on-farm water management have been identified and are resulting in changes in laws and operating policies.

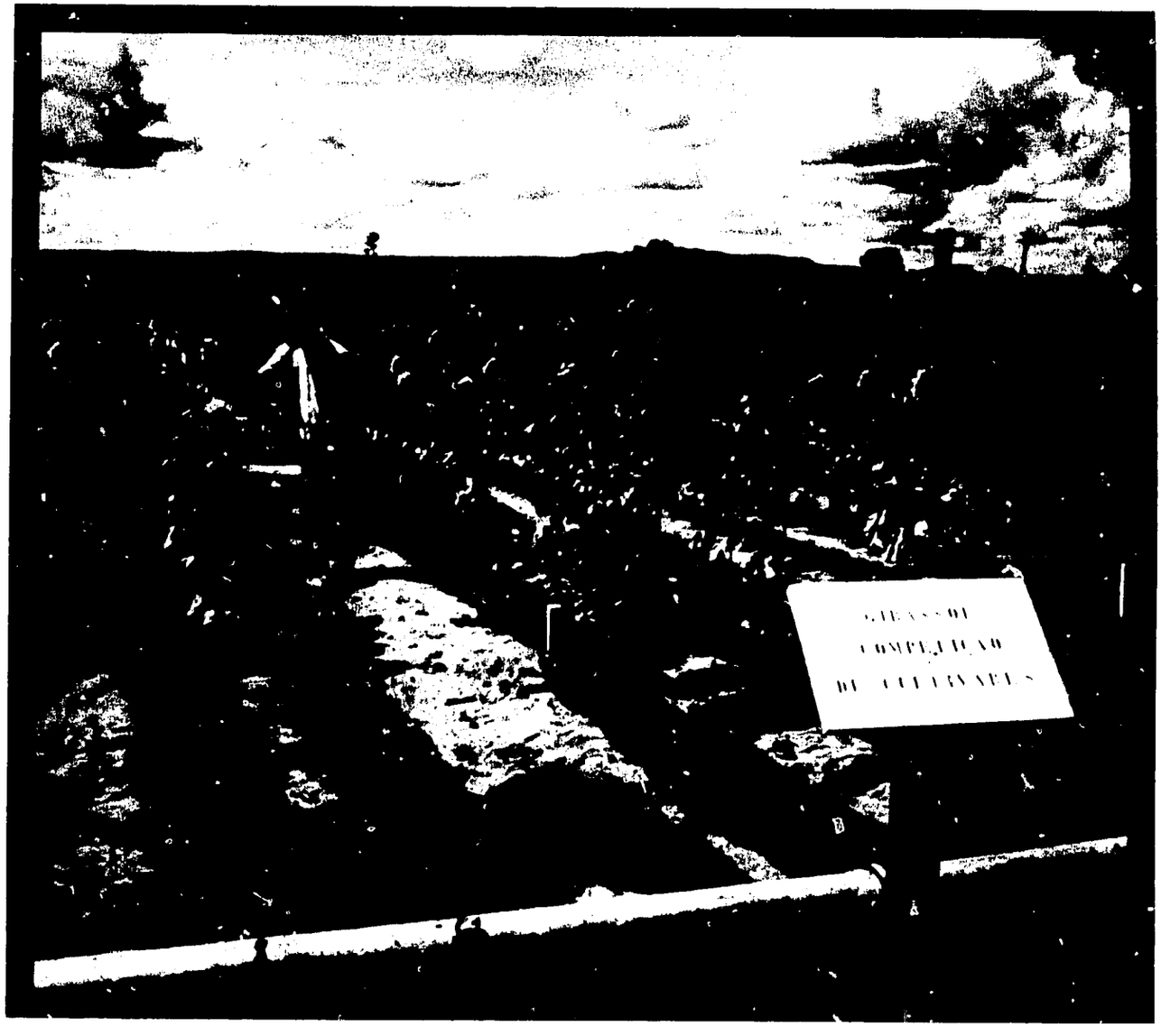
Through seminars, short courses, and constant interaction between USU researchers and national collaborators, the capability of national researchers, extension agents, farmers and others in agriculturally related occupations (lawyers, legislators, computer programmers, hydrologists) has been significantly expanded.

Latin America was selected as the primary research area with the expectation that much of the research would be applicable in other regions having similar conditions.

All of the field programs have been executed by USU through the USAID Missions in collaboration with national research and extension agencies and have, therefore, been related to the high priority needs of Brazil, Chile, Colombia, Ecuador, El Salvador, Guatemala, and Peru. USU researchers worked on the program in these countries for two years or more. Bolivia, Costa Rica, Honduras, Nicaragua, Panama and Venezuela have also collaborated to a lesser extent, in several areas of the research, especially that related to crop water requirements.

This final report has been designed to provide a brief overview of the major activity and results. Details have been reported in the many technical and annual progress reports listed in Appendix II.

Appendices Ia and Ib list the principal researchers and administrators associated with the contract.



BRAZIL

Photo 1

This plot of sunflowers at PIRAPORA is being irrigated with gated pipe supplied by the project.

Variety and water-fertilizer interaction experiments similar to this one are now being run exclusively by Brazilian researchers. The newly installed stations are studying over forty crop species for possible use on nine new irrigation projects totaling over 600,000 hectares.

Photo 2

Professor Austin (R) discusses with Brazilian engineers the operation of a temporary water intake from the São Francisco River which will provide water for research plots.

Stations at Formoso, Pirapora, and São Desiderio began operating in 1973. Their major objectives were to provide the thousands of new farmers who are moving into the valley with data on crop varieties best suited to irrigated agriculture and to demonstrate good farming practices.

Photo 3

Professor Gilbert (3rd from left) poses with a group of Brazilian agronomists in front of a tomato experiment plot. Part of the plot demonstrated the value of one supplemental irrigation during a fifteen-day dry period which occurred during the rainy season. The irrigated plots yielded nearly 38 metric tons per hectare while those not irrigated had zero yield.

Photo 4

Professor Austin helps install the first water supply lateral at the Saõ Desiderio station. Initial tests established infiltration rates and soil water holding capacities.

Photo 5

Professor Kidman and an EMBRAPA agronomist discuss water application rates on corn plots at the Mandacaru Research Station near Petrolina.

These vertisols (a soil type) are underlain at 1.5 meters with an impermeable layer of paragneiss and require careful control of water to avoid waterlogging and salt build-up.

Photo 6

A Brazilian engineer sets a measuring flume which is part of a furrow irrigation experiment.
Devices such as these are essential for gathering desirable flow rates for specific soils and lengths of furrows.

Photo 7

This picture was taken on the Formoso Research Station site prior to its construction in 1971. It depicts the vegetation which had to be cleared before farming could begin.

BRAZIL RESULTS

1. Three new research and demonstration stations in the São Francisco Valley were put into operation. Three others near Petrolina were reorganized.

2. Existing water management research in the Northeast was evaluated. A center for directing and coordinating this valuable information was established by the Ministry of Agriculture's research department (EMBRAPA) at Petrolina. This was done at the recommendation of USU.

3. Water management practices for over forty crops were developed for new irrigated areas for a variety of soils.

4. The entire Northeast was zoned on the basis of rainfall adequacies for crop production using a moisture availability index (MAI). This index is the ratio of dependable precipitation to potential evapotranspiration.

5. Several seminars, workshops, short courses, informal field and office training were given for officials of SUVALE (São Francisco River Development Agency), EMBRAPA, SUDENE (Northeast Development Agency) and DNOCS (National Drought Control Agency).

CHILE

Photo 8

A Chilean extension supervisor demonstrates the results of different treatments of water and fertilizer on corn to a group of local farmers. The effects can be seen by viewing the relative size of harvest from each plot.

By modest adjustments to their traditional farming practices, yields were doubled.

Photo 9

Professors Stutler (L) and Kidman check the soil moisture in a corn research plot on the El Castillo Farm. To develop improved crop management strategies, data concerning water and fertilizer application and water loss from the soil is needed.

Photo 10

Two National University students assist in measuring water leading to an orchard near Santiago. Excess water was being applied at the upper end while trees at the lower end were suffering from water deficiency. By rearranging the furrows through the orchard, infiltration was made uniform.

CHILEAN RESULTS

1. Farmers growing irrigated corn in the Aconcagua Valley were able to double yields by combining these methods:
   a. Furrow irrigating rather than flood irrigating
   b. Conserving spring moisture by better seedbed preparation
   c. Adjusting fertilizer application rates (sometimes downward)
   d. Adjusting planting rates, and
   e. Incorporating crop residue in the soil surface to increase infiltration rates.

2. Soils were classified according to moisture holding capacities in order to develop drought proofing specifications. These were primarily related to encouraging early spring irrigation where water storage reservoirs were inadequate.

3. Excellent dissemination of corn results was achieved through seminars, field trips, and extensive national press coverage.

4. Orchard irrigation techniques were adjusted to improve infiltration, hence higher yields.

COLOMBIA

Photo 11

On the Atlantico III Project near Barranquilla, officials of INCORA (The National Agrarian Reform Agency) installed a project-supplied perforated flexible plastic drain line through an orange grove under Professor Olsen's supervision. This project was originally a brackish swamp with much of its 25,000 hectares below sea level.

In addition to the subsurface drainage experiments, surface drainage and leaching plots yielded information for controlling the water table. A technique of water table control by computer simulation was also developed for this project by Professor Paul Riley.

COLOMBIA RESULTS

1. The research plots established that most of the soils on the Atlantico III project were not and possibly could not be made very productive for any crop but inundated rice. The likely cause of the problem is excessive amounts of trace elements in the soil. This discovery has caused a major shift in existing and projected farming patterns in the project and underscores the need to produce field data on crop yield potentials before investing heavily in irrigation infrastructure.

2. It was shown that surface grading to eliminate ponding of water can be a better alternative to the installation of subsurface drains, especially where the topography is relatively flat.

ECUADOR

Photo 12

An Ecuadorian water users organization meeting — informal, frank, and friendly. The newly established water organization effectively delivers water to its members.

Photo 13

A regional Water Law Seminar was held in Quito, Ecuador, in January, 1974. The purpose was to review the implications of the comparative *Water Law Digest* prepared by project worker Dr. David R. Daines (upper left) and Dr. Gonzalo Falconi of the Ecuderian Ministry of Hydraulic Works (INERHI). Twenty-five legislators and water law experts from Argentina, Bolivia, Chile, Colombia, Ecuador, and the USA attended.

Water Law and Institutions Information

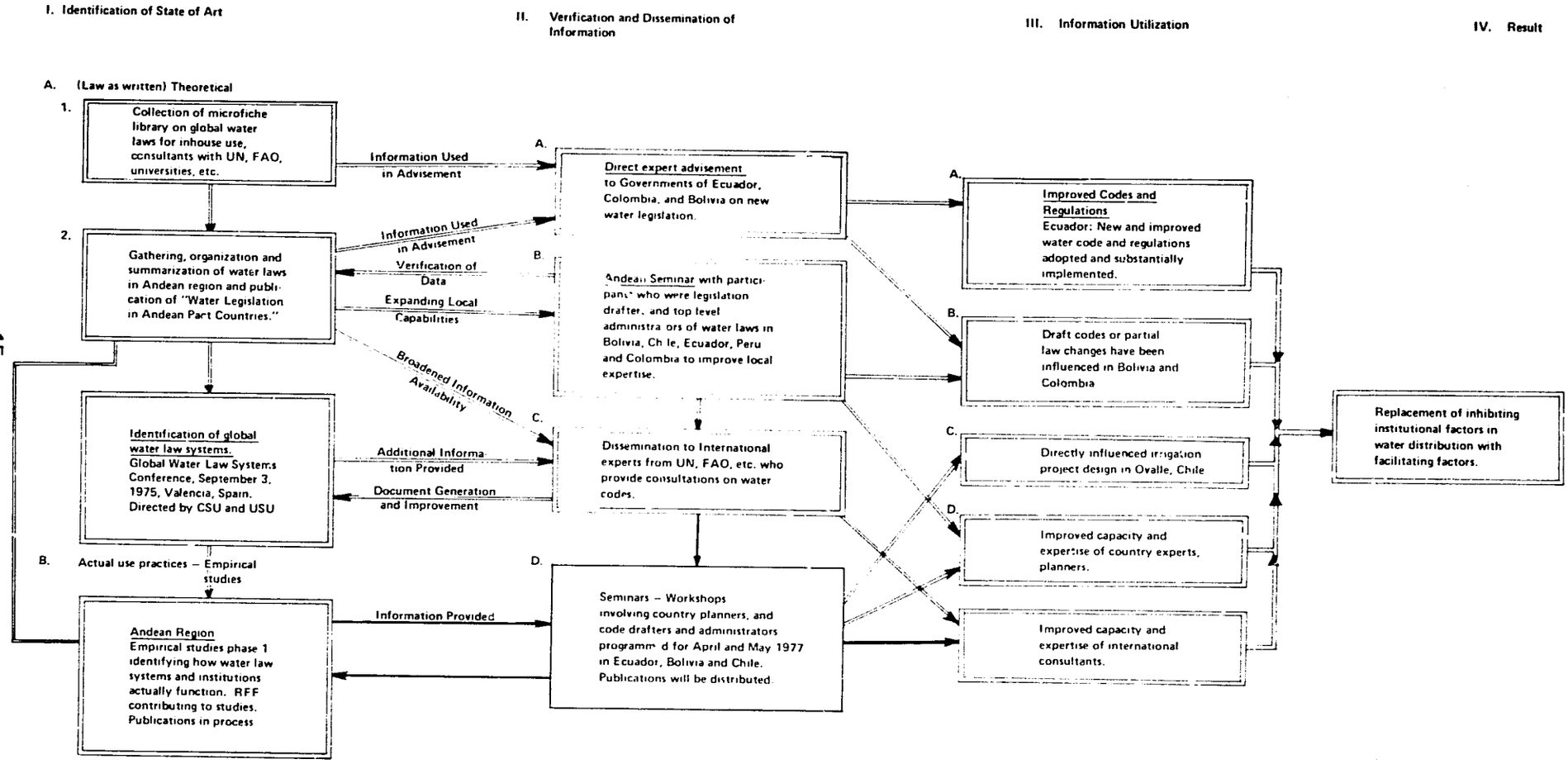
Network and Linkages

Page illustrates the interrelationships of components comprising the water law program under the supervision of Dr. David R. Daines. These include:

I. Identification of the state of the art
II. Verification and dissemination of information
III. Information utilization
IV. Results

WATER LAW AND INSTITUTIONS

INFORMATION NETWORK AND LINKAGES



ECUADOR RESULTS

1. The Comparative *Water Law Digest* provides summaries of legislation in Bolivia, Chile, Colombia, and Ecuador. This study is now a standard reference text, having been distributed on request to several hundred users.

2. A four-country water user organization survey, done by researcher Craig Anderson has resulted in seminars scheduled in Chile, Bolivia, and Ecuador. These seminars will provide a forum for discussion of the data collected in the field surveys.

   Following the seminars, a report with conclusions of the water management studies will be published.

3. Studies by Dr. Allen LeBaron in Ecuador indicated that for rice production in Ecuador's Guayas Basin, the highest returns on investment by the farmer came at an intermediate level of farm improvement.

ELSALVADOR

Photo 14

Professors Fullerton (left) and Stutler inspect a water-fertilizer treatment on Sorghum plots. Data is being collected on crop varieties, irrigation and fertilizer requirements, optimum planting dates, and insect and disease control techniques for those crops which produce well under irrigation.

Photo 15

Irrigated corn plots at the San Andres Experimental Station, El Salvador, showed the effect of various levels of water and fertilizer application. The selection of an appropriate water-fertilizer level is determined by their combined effect on yield, the cost of applying various amounts of water and fertilizer, and the value of the crop.

Photo 16

Photos 16 and 17 show two recent experimental designs for determining combined water-fertilizer effects. Photo 16 shows a corn plot receiving water from a line of sprinklers located near the center of the field (seen near the left side of photograph). The amount of water applied on the right was decreased.

Photo 17

Two USU researchers are standing near a single sprinkler head in an experimental rice plot. The six wedges (in the circular area) each have a different fertilizer treatment. The amount of water received decreases with the distance of the crop from the sprinkler head.

EL SALVADOR RESULTS

1. Irrigated management technologies have been developed for corn, rice, sorghum, pangola grass, and tomatoes in the newly created irrigation districts of the Zapotitan Valley and Atiocoyo and the older established Sonsonate area.

2. Extension bulletins in Spanish were prepared for employees of the National Agricultural Extension Agency (CENTA) and the Irrigation Research Department (DGRD) on several water management topics.

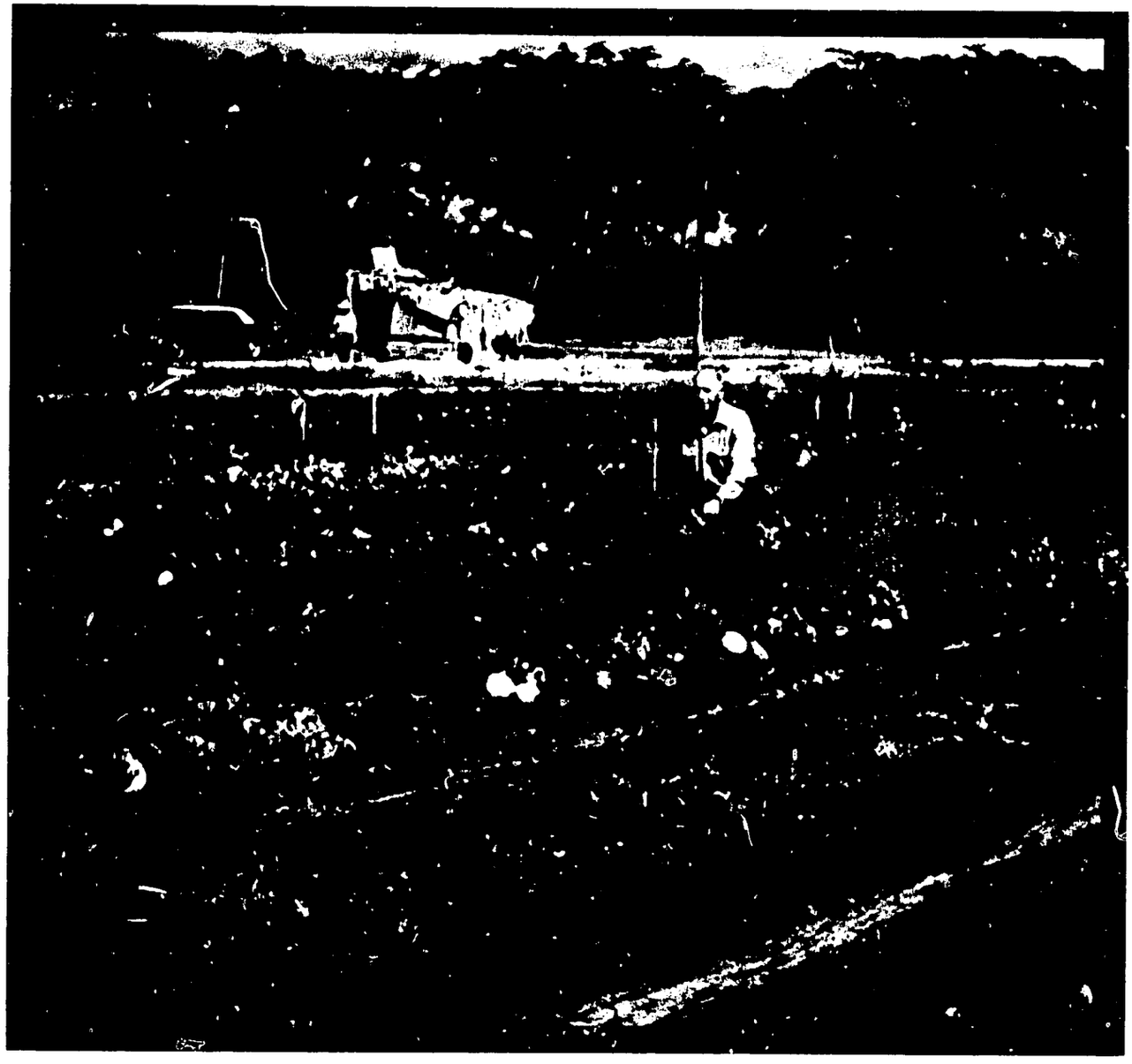
3. CENTA and DGRD staff and technical students at the National Agricultural School at San Andres have received training in water management techniques through three formal seminars, on-the-job training, and curriculum improvement assistance at the technical school.

4. Drainage problems on the new project area near San Andres were solved.

5. Herbicide studies for aquatic weed control in the canals and drainage ditches in the Zapotitan Valley were conducted and recommendations prepared.

6. A study of the economics of alternative irrigation strategies for pangola grass pastures in the Sonsanote area resulted in recommendations which have been put to use by a number of dairy cattle farmers.

7. Comparative studies of sprinkler, drip, and furrow irrigation methods now permit farmers to select the best methods of irrigation based on El Salvador's climate, soils, and economic conditions. These studies included cost estimates and water application efficiencies with special attention given in the Zapotitan Valley to the effect of wind on sprinkler operation and yield vs application method.



GUATEMALA

Photo 18

Dr. Embry examines melon experimental plots on the Oasis Research Station in the Zacapa Valley, Guatemala. This study was in collaboration with the Guatemala Institute of Agricultural Science and Technology (ICTA). Since irrigation is fairly new in this country, treatments to determine length of run for furrow irrigation, frequency of irrigation, size of stream, and effect of slope were imposed on: melons, cantaloupes, tomatoes, chili, onions, garlic, okra, and corn. Recently fertilizer treatments have been added.

Photo 19
Pretty . . . but barren. A typical landscape in Guatemala.

Photo 20
Research project director Dr. Bishop and resident researcher Dr. Embry look over irrigated corn demonstration plots. These plots are directly across the fence from the scene in photo 19 and demonstrate what proper irrigation and farming methods can do.

Photo 21

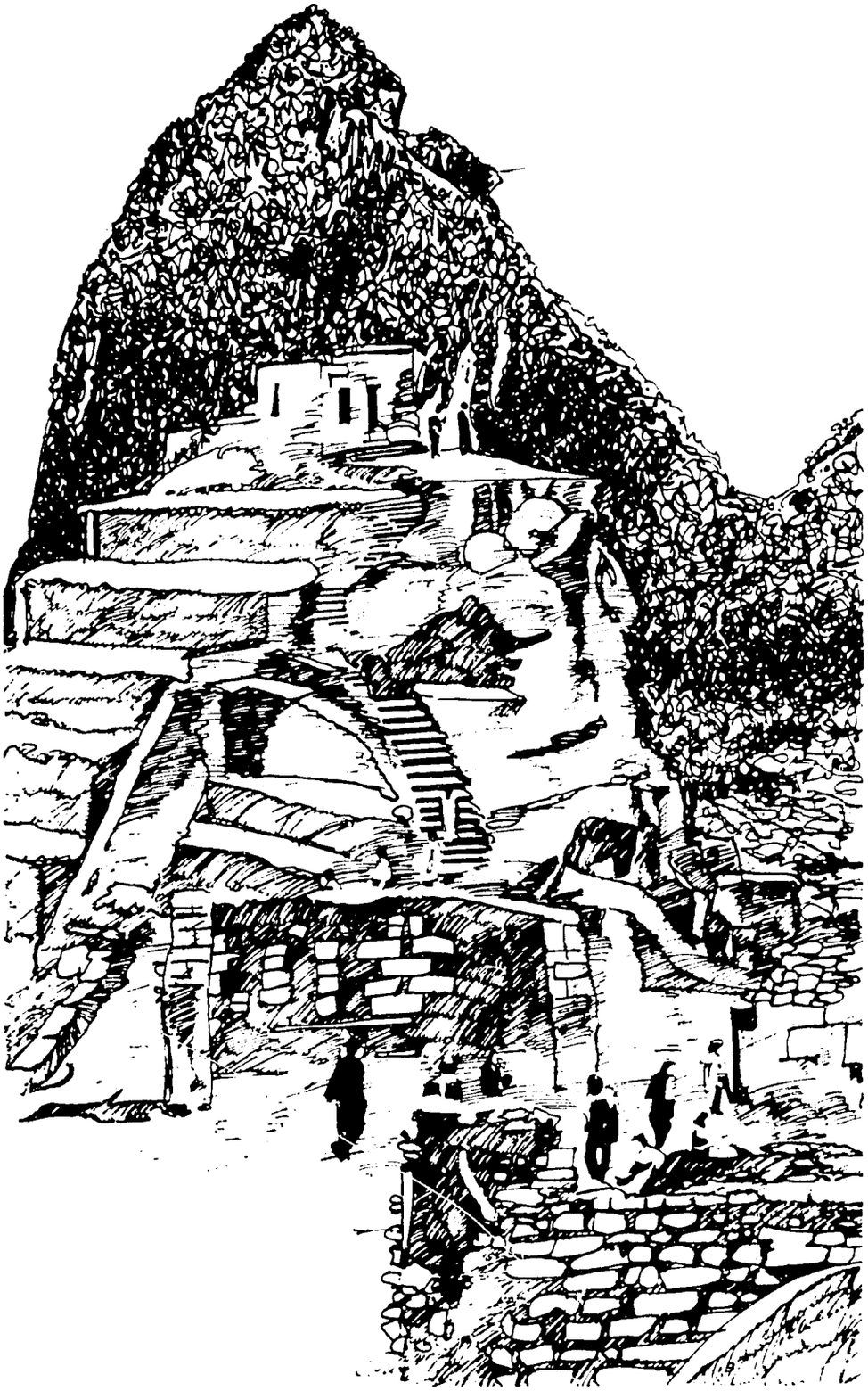
Dr. Embry (left) and counterpart collect soil samples on a new irrigation project in Guatemala. Irrigation methods had to be tailored to low infiltration rates possibly due to the high sodium in the soil.

GUATEMALA RESULTS

1. Irrigated crop technology was developed at both research and demonstration level for melons, cantaloupes, tomatoes, chili onions, garlic, okra, and corn.

2. Blossom-end rot in tomatoes and melons was linked with low infiltration rates.

3. Treatments of gypsum, green manuring, and chisel plowing were shown to improve infiltration rates. (Gypsum application is feasible only where there are hammer mills available.)



PERU

Dr. Olsen began research with the General Water Directorate (DGA) of the Ministry of the Agriculture in April 1975. The primary research in Peru has been to: find economic solutions to long-standing drainage problems; determine crop water requirements throughout the country, especially in areas under investigation for new irrigation projects; and evaluate the relative merits of alternative water application methods.

PERU RESULTS

1. Peruvian researchers were trained in the use of drip irrigation systems for more precise control of applied water. Control and measurement of soil water has received high priority because of the vast amount of land which can be irrigated and because of the capability of Peruvian researchers to effectively carry out field research. This is especially true at the International Potato Center (CIP) at La Molina. The proximity of the DGA research plots to those at the CIP station has generated several collaborative studies.

   CIP and DGA-USU are researching irrigated potato yield during the dry hot summer on the Peruvian coast.

2. One irrigation research team composed of Professors Olsen and Kidman, an agronomist from the University of Arkansas, and four agricultural engineers from the National Agrarian University at La Molina are responsible for the development of a national irrigation research program. Research and demonstration sites have recently been put into operation in the coastal zone near Canete in collaboration with a local technical agricultural school. In preparation for an $11 million dollar USAID loan to Peru for the improvement of small irrigation systems in the Sierra, two demonstration sites have been installed near Cajamarca and Huancayo.

CAMPUS BASED PROGRAMS SUPPORTING FIELD RESEARCH

Climate and Moisture Adequacy Program

Objectives

The traditional methods used for estimating water requirements are inadequate for general use in tropical areas. This resulted from insufficient available data and difficulties encountered in calibrating various methods for the large variety of climatic conditions encountered. An early objective consisted of research to estimate water requirements that would have universal applicability, be sufficiently precise and accurate, and require a minimum of climatic or weather data.

It is commonly known that moisture excesses or deficits adversely effect crop production, but the degree of adverse effect needed further quantification. A study was undertaken by professors Christiansen and Hargreaves to develop means of classifying moisture excesses and deficits with respect to degree or severity and to develop meaningful relationships to yields, production, and the economics of crop production.

Once basic relationships were found, statistical procedures were developed for estimating or defining conditions, training technicians, conducting seminars, publishing technical papers and reports. In addition, other necessary steps were taken for advertising the methodology.

Accomplishments

A procedure was developed for estimating potential evapotranspiration and crop vegetative water requirements. This procedure requires temperature and radiation data. Temperature can be estimated from latitude and elevation. Radiation is either measured or is estimated from sunshine hours. A method was developed for estimating sunshine hours from relative humidity. Considerable missing humidity data can be approximated from similar locations (locations having similar rainfall, elevation and latitude). A start was made for developing equations for water requirements from latitude and elevation. Preliminary results are most favorable.

Use of the Gamma distribution for rainfall probabilities of occurrence was used to calculate probabilities for a large number of locations in countries in Latin America and Africa and to develop relationships and equations for estimating probabilities from mean precipitation.

The concept of a moisture availability index (equal to the 75 percent probability of precipitation occurrence divided by the potential evapotranspiration) was developed and used to numerically define moisture deficits and excesses and to classify climates for agricultural use potential. This index was used for zoning large areas (all of Northeast Brazil, for example) and has been used by other individuals and organizations for crop adaptability zoning.

Moisture availability and moisture adequacy were related to crop production for several crops. Comparisons were made between fertilized and nonfertilized moisture adequacy production functions. The procedures developed have been further amplified by other individuals and organizations.

The climatic descriptions and moisture indices developed are being used by AID's central American Regional Organization (ROCAP) and the International Research Center in Costa Rica (ICCA) throughout Central America for developing packages of cropping practices and for agricultural technology transfer.

Photo 22
Extensionists in El Salvador learn how to read the evaporation from an evaporation pan. They were then instructed by Professor Griffin on how to use this data to compute potential and crop evapotranspiration.

World Water for Agriculture

A publication, *Water Requirements Manual for Irrigated Crops and Rainfed Agriculture,* was prepared which summarizes water requirements, rainfall probabilities, climatic variables and moisture availability indices for 30 year climatic records.

Crop Production Program

In most of Latin America and in many other developing nations, governments and farmers do not have the background for evaluating the potential of irrigated agriculture. With new crop varieties and technologies being developed at an accelerating rate, there is need to shorten the expensive field plot trial method of evaluation. By carrying out a relatively small number of field trials in as few as seven reference climate sites, sufficient data can be collected to intelligently predict yields under most other climatic conditions. This will substantially cut down the time and expense of field trials and focus the limited resources of research agencies on those varieties which have been carefully screened by predictive techniques.

Drs. Robert Hill and Howard Peterson of USU in collaboration with Dr. Les Leiniger of Lincoln, Nebraska, Dr. David Johnson from University of Missouri, Columbia, and Dr. Robert Shaw of Iowa State

University are attempting to express yield as a function of various components of the intimate crop environment. A number of private seed and irrigation equipment companies have expanded interest and provided very helpful comments.

This collaborative effort has been funded jointly by the contractor, CSU and USU 211-d grants, and the collaborating institutions. Major emphasis has been with corn and soybeans.

Other individuals and institutions are developing predictive techniques for a wide variety of other crops; i.e., wheat, peanuts, cotton, rice. This has raised the issue of how to select efficient mixes, planting dates, and management strategies for specific farmers. Conceptually, it is not difficult to select a "best" combination of crops from a large number of alternatives available even to a very small scale (subsistance) farmer. If he can specify his objectives, a crop mix, planting dates, and management strategy can be determined based on a library of crop models, weather, cost, and price data. Professor Palmer has developed a simulation program which produces for a given farm, an efficient set of mixes and planting dates. Selection of a particular mix from this efficient set will depend on the farmer's attitude toward risk. A high risk averter will select a mix with low risk and lower return than other efficient mixes.

Mole Plow Program

The mole plow draws a small tunnel or drain approximately 18 to 24 inches below the surface of the ground. Its purpose is to quickly lower the soil moisture to field capacity. This facilitates early working of the land after the rainy season and leaching (control of salts) in the root zone.

Although mole drains have been in use for over a century, there are little design data available. Dr. Unhanand and his students developed improved designs in order to increase drain life and minimize power costs. Their work included double and single mole plow designs of several sizes and shapes, energy requirements, and mole life when drawn at various soil moisture levels. One study included a vibration variable.

Economic Program

In conjunction with the physical and institutional water management research, Dr. Allen LeBaron and his students collected economic data in South and Central America. His activities were designed first to determine what costs and benefits were associated with agricultural water management. With these data he was able to evaluate various levels of water management control to determine what would bring the greatest return at a given risk to farmers. Cost date on all irrigation alternatives studies in El Salvador, Brazil, Chile, Colombia, and Ecuador were collected and have been used by government agencies in their decisions on whether to go to flood, furrow, sprinkler, or trickle irrigation systems on their irrigated development projects.

SUMMARY AND CONCLUSION

Large scale use of agriculural water management technology in Latin America is just beginning. In contrast with other developing areas where major irrigation works have been in operation for many years, Latin America's needs are not so much a redirection of an existing technology as a need for a completely new approach to farming. With the exception of the Chilean corn fields, most of the work undertaken was related to early efforts to introduce irrigated agriculture.

In terms of costs and benefits of this project it is estimated that the costs have more than been recovered in the increased production of corn in Chile and rice in Colombia. On Colombia's Atlantico III project, farmers and INCORA would very likely have tried for several more years to grow diversified crops had it not been for Olsen's and Fullerton's work identifing rice as having by far the greatest return potential.

When Professor Griffin arrived in El Salvador, farmers in the new Zapotitan Valley project were not taking advantage of their irrigation systems. Therefore, the extension and research technicians provided specific answers to most of the problems which were causing stagnation to this area.

Brazil now has several operating irrigated research stations in the Sao Francisco Valley and research and extension personnel are rapidly becoming water experts.

Guatemala is starting to develop irrigation, and Peru has been able to move into poorly developed mountain valleys with an ambitious, vigorous irrigation program.

All of Latin America now has access to once unavailable data, water laws, institutions, methods, costs of alternative water management strategies, improved salinity control and drainage techniques, and better tools for estimating crop water requirements and classifying regions according to their precipitation probabilities and agricultural water needs.

Techniques have been developed for minimizing the high cost of introducing new crops and cropping patterns into newly developed lands. All of this has been done in collaboration with local research and extension people who have been intensively involved.

Utah State University has benefited greatly from this program through an increased knowledge by its staff of the many problems faced by countries trying to improve the quality of life of their rural poor. Perhaps the best criteria of accomplishment lie in the attitudes of the researchers and AID missions as this program draws to a close. In spite of a number of physical hardships and personal risks, all of the staff have felt disappointment in the termination of the program. As one put it, "just when big payoffs were starting to show."

Photo 25
One wing of the Engineering Building, Utah State University, which houses the Irrigation Engineering Department.

THE USU RESEARCHERS

During the nine year duration of this contract, twenty-one faculty researchers made major contributions. Ten were assigned for periods of two or more years to field stations, the rest provided specialized support through field visits and campus based research.

At this time all the staff with the exception of Professors Austin, Gilbert, Unhanand, and Christiansen (retired) are still with the University. Most have continuing international commitments.

Major contributions to the success of the project were made by host country researchers and administrators who were highly motivated and anxious to work very closely with the contractors' staff. Misunderstandings because of language barriers were few, due to major efforts of the USU staff in learning Spanish and Portuguese.

Several USU graduate students also made significant contributions. Over thirty graduate theses by foreign students on subject areas directly related to the contract were produced from 1968 to 1977.

Appendix 1a

RESIDENT STAFF WHO WORKED FOR TWO OR MORE YEARS IN A LATIN AMERICAN COUNTRY

D. Craig Anderson
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Ecuador
- Contract Related Specialty:
  - Irrigation Institutions

Lloyd C. Austin
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Brazil
- Contract Related Specialty:
  - Civil and Agricultural Engineering

David R. Daines
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Ecuador
- Contract Related Specialty:
  - Water Law, Irrigation Institutions

Bertis L. Embry
- Department Affiliation:
  - Electrical Engineering
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Guatemala
- Contract Related Specialty:
  - Irrigation and Drainage Engineering

Thomas W. Fullerton
- Department Affiliation:
  - Soils and Biometeorology
- Country of Assignment:
  - Colombia and El Salvador
- Contract Related Specialty:
  - Agronomy, Soil Fertility, Aquatic Weed Control

Norris Gilbert
- Department Affiliation:
  - Soils and Biometeorology
- Country of Assignment:
  - Brazil
- Contract Related Specialty:
  - Agronomy, Soil Fertility

Richard E. Griffin
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - El Salvador
- Contract Related Specialty:
  - Agronomy, Soil Fertility

Don C. Kidman
- Department Affiliation:
  - Soils and Biometeorology
- Country of Assignment:
  - Chile, El Salvador, Brazil, Peru
- Contract Related Specialty:
  - Agronomy, Soil Fertility

Edwin C. Olsen, III
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Colombia, Peru
- Contract Related Specialty:
  - Civil Engineering, Irrigation and Drainage

R. Kern Stutler
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Country of Assignment:
  - Chile, El Salvador
- Contract Related Specialty:
  - Irrigation and Drainage Engineering

Appendix 1b

STAFF WHO FILLED SHORT TERM LATIN AMERICAN ASSIGNMENTS AND CARRIED OUT ON-CAMPUS RESEARCH

Bruce H. Anderson
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Contract Related Specialty:
  - Administration, Irrigation and Drainage Engineering

A. Alvin Bishop
- Department Affiliation:
  - Agricultural and Irrigation Engineering
- Contract Related Specialty:
  - Project Administration, Irrigation and Drainage Engineering

Jerald E. Christiansen
Department Affiliation:
Agricultural and Irrigation Engineering
Contract Related Specialty:
Irrigation, Drainage, Crop Water Requirements

George H. Hargreaves
Department Affiliation:
Agricultural and Irrigation Engineering
Contract Related Specialty:
Crop Water Requirements, Climatic Zoning

David W. James
Department Affiliation:
Soils and Biometeorology
Contract Related Specialty:
Administration, Soil Chemistry

Allen D. LeBaron
Department Affiliation:
Economics
Contract Related Specialty:
Resource Economics, Water Resources

Rex F. Nielson
Department Affiliation:
Soils and Biometeorology
Contract Related Specialty:
Agronomy, Soils, Field Plot Research Systems

Byron C. Palmer
Department Affiliation:
Agricultural and Irrigation Engineering
Contract Related Specialty:
Project Administration, Irrigation Engineering, Crop Yield Forecasting

Howard B. Peterson
Department Affiliation:
Agricultural and Irrigation Engineering
Contract Related Specialty:
Administration, Water Quality, Soils, Irrigation

J. Paul Riley
Department Affiliation:
Civil and Environmental Engineering
Contract Related Specialty:
Simulation of Hydrologic Processes

Komain Unhanand
Department Affiliation:
Agricultural and Irrigation Engineering
Contract Related Specialty:
Civil Irrigation and Drainage Irrigation

Appendix 2

CONTRACT GENERATED PUBLICATIONS

1971 Christiansen, J. E. and George H. Hargreaves, *Irrigation Requirements and Climatic Evaluation for Venezuela,* Utah State University, Logan, Utah, 1971.

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