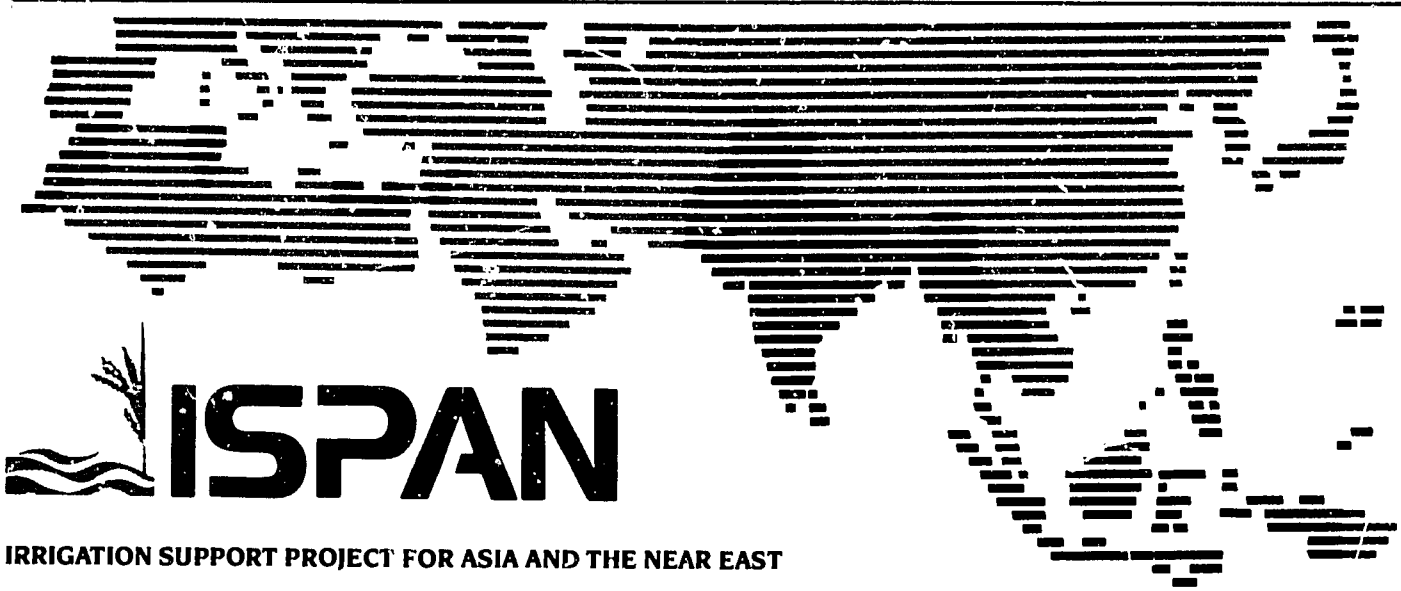
U.S.-FINANCED IRRIGATION AND DRAINAGE RESEARCH:

APPLICATIONS FOR DEVELOPING COUNTRIES

March 1992

ISPAN Report No. 44



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ISPAN Report No. 44

U.S.-FINANCED IRRIGATION AND DRAINAGE RESEARCH: APPLICATIONS FOR DEVELOPING COUNTRIES

Prepared for the Asia Bureau
and the Near East Bureau
under ISPAN Activity No. 671B

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CONTENTS

FIGURES

Acronyms

AES	Agricultural Extension Service
A.I.D.	U.S. Agency for International Development
ARS	Agricultural Research Service
ASAE	American Society of Agricultural Engineers
ASCE	American Society of Civil Engineers
CAST	Council on Agricultural Science and Technology
CES	Cooperative Extension Service
CRIS	Current Research Information System
CSRS	Cooperative State Research Service
ICID	International Commission on Irrigation and Drainage
IMTP	Irrigation Management and Training Project
ISPAN	Irrigation Support Project for Asia and the Near East
NACD	National Association of Soil and Water Conservation Districts
SAES	State Agricultural Experiment Stations
SCS	Soil Conservation Service
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USDI	U.S. Department of Interior

USGS	U.S. Geological Survey
WRRI	Water Resources Research Institute

Two-Letter State Abbreviations

AL	Alabama	LA	Louisiana	OH	Ohio
AK	Alaska	ME	Maine	OK	Oklahoma
AZ	Arizona	MD	Maryland	OR	Oregon
AR	Arkansas	MA	Massachusetts	PA	Pennsylvania
CA	California	MI	Michigan	RI	Rhode Island
CO	Colorado	MN	Minnesota	SC	South Carolina
CT	Connecticut	MS	Mississippi	SD	South Dakota
DE	Delaware	MO	Missouri	TN	Tennessee
FL	Florida	MT	Montana	TX	Texas
GA	Georgia	NE	Nebraska	UT	Utah
HI	Hawaii	NV	Nevada	VT	Vermont
ID	Idaho	NH	New Hampshire	VA	Virginia
IL	Illinois	NJ	New Jersey	WA	Washington
IN	Indiana	NM	New Mexico	WV	West Virginia
IA	Iowa	NY	New York	WI	Wisconsin
KS	Kansas	NC	North Carolina	WY	Wyoming
KY	Kentucky	ND	North Dakota		

Executive Summary

In 1987, the International Commission on Irrigation and Drainage (ICID) requested World Bank assistance for an assessment study of present irrigation research in the world. As part of this study, the World Bank asked the U.S. Agency for International Development (A.I.D.) to prepare a country report on U.S. irrigation and drainage research. This report was prepared by consultants associated with the Irrigation Support Project for Asia and the Near East (ISPAN), an A.I.D.-sponsored project dealing with water resources and irrigation. The report reviews research on domestic problems and analyzes the relevance of the research to irrigation problems in developing countries.

From 1939 until 1978, the area of irrigated land in the United States increased by an average of 2.7 percent per annum from 7.3 million hectares to 20.4 million hectares. During the 1980s the rate of growth of irrigation was negative and an estimated 1.6 million hectares of irrigated production was ceased due to increased competition for water supplies, declining groundwater levels, increasing energy costs, environmental constraints, and low farm prices. The degree of cutback in irrigated area differs by region. However, many states are now projecting expansion in irrigated areas over the 1990s.

The major federally funded organizations doing research on irrigation are the Agricultural Research Service and the Cooperative State Research Service under the U.S. Department of Agriculture, the U.S. Geological Survey, and the U.S. Bureau of Reclamation under the U.S. Department of Interior. At state level, the state agricultural experiment stations, the state Water Resources Research Institutes, and the state departments of water resources fund conduct research on irrigation. Of special relevance to developing countries is A.I.D. research-related assistance to 14 irrigation projects in 11 countries.

In addition, private firms carry out research on irrigation, for example development of equipment for irrigation, or technologies for water application such as drip, micro-jet, and sprinkler. Private research is completely market oriented. Although this research is a significant portion of the overall mix of research conducted in the United States, it has not been possible to quantify the financial expenditures of the private sector. In contrast, research by private firms in developing countries is virtually nonexistent.

This paper categorizes irrigation activities of major public research organizations in the United States. Categories are used that correspond with those from previous ICID and World Bank papers and other country reports. Most of the irrigation projects are associated with irrigation agronomy, which accounted for more than a third of the

projects surveyed. These projects, which seek to improve agricultural production, use a broad approach and consider interrelated aspects of crop cultivation, of which irrigation is but one. Next in number of projects are those dealing with environmental aspects. Federal and state governments increasingly stress the importance of a healthy environment. Other major categories of research projects include: system control, performance assessment, on-farm application, and hydrology.

No single approach is used to formulate research programs or encourage coordination among the agencies and universities conducting irrigation research. Federal agency programs are generally developed in response to needs identified by a wide range of user organizations. Federal research programs tend to address national concerns. Research undertaken by state-level universities and institutes addresses local conditions.

Because of marked economic and social differences between the United States and developing countries, applied and local research conducted in the United States may not relate directly to other countries. However, techniques used and analysis patterns followed do have relevance. Federal efforts in research, augmented by strong local and applied research, constitute a comprehensive framework for irrigation research which may be a model for other countries.

Chapter 1

Introduction

Production levels of many irrigation projects in developing countries fall below those of industrial countries. The reasons for this disparity are many and are the subject of continual investigation. The International Commission on Irrigation and Drainage (ICID), noting a relative stagnation in the progress of irrigation technology in developing countries, believes that research is imperative for sustained technological advancement (World Bank, ICID, 1989).

In order to enhance irrigation research in developing countries, the ICID International Executive Council in September 1987 asked the ICID president to explore the possibilities for international support of a special program to improve such research. This led to a request for assistance from the World Bank, which, with the ICID, decided to undertake an assessment study of present irrigation research in the world. As part of this study, the World Bank asked the U.S. Agency for International Development (A.I.D.) to produce a country report that would: (a) review domestic U.S. research on irrigation, and (b) analyze the relevance of this research for developing countries.

Chapter 2

Irrigation and Drainage in the United States

Irrigation development in the United States began during the latter part of the 19th century in the arid and mountainous areas, followed by new irrigation development in semi-arid and humid areas around the early 1900s. By 1939, 7.3 million hectares were irrigated, gradually increasing to 13.5 million in 1959 and up to 20.4 million in 1978 (Figure 1, and Table 1)[1]. The 19-year trend between 1959 and 1978 shows a better than 2 percent annual increase in area irrigated. During the 1980s, there was a slight decline in certain states in area irrigated mainly due to increased competition for scarce water supplies, declining groundwater levels and increased pumping lifts, and increased energy costs. Texas is the state showing the largest decline, on the order of 1.0 million ha. The decrease in irrigated area is mainly due to declining water table levels and well yields in the large Ogallala Aquifer (Figure 2).

California has experienced a 10 percent decline in irrigated area during the 1980s due to a series of droughts and to increased competition for existing supply. Another example of declining groundwater levels can be found in Arizona, where new groundwater-management laws have been enacted to reduce agricultural water use (Thompson, 1987).

On the other hand, irrigated area in Nebraska has increased to about 3.0 million in 1990. In Nebraska, much of the water used for irrigation also comes from the Ogallala Aquifer. Irrigation expansion started later in Nebraska and Kansas than in Texas. From the mid-1960s to 1978, the irrigated area increased in Nebraska as large numbers of center pivots were used to irrigate land otherwise not suited for surface irrigation. Vast quantities of readily available groundwater from the Ogallala Aquifer were a key factor influencing this development (Jensen, 1990).

Environmental problems and increasing competition from urban areas and industry have also caused a decline in the amount of irrigated area (Thompson, 1989). In California,

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[1] Based on data of the Census of Agriculture, summarized by U.S. Department of Commerce (1983, 1986), Solley et al. (1988), Lea (1985), Pavellis (1965), and the American Society of Civil Engineers (1986). Irrigated area before and after 1978 has a slightly different base.

Table 1

Irrigated Land for Each State

	1959	1969	1978	1987
	(thousand hectares)			
CALIFORNIA	2,993	2,930	3,442	3,074
NEBRASKA	841	1,156	2,300	2,299
TEXAS	2,289	2,788	2,811	1,728
IDAHO	1,043	1,117	1,406	1,303
COLORADO	1,087	1,172	1,389	1,220
KANSAS	308	616	1,087	997
MONTANA	759	745	838	808
ARKANSAS	288	409	681	974
OREGON	560	615	761	667
WYOMING	595	616	673	614
WASHINGTON	408	495	663	615
FLORIDA	168	552	801	657
UTAH	430	415	473	470
ARIZONA	466	477	484	370
NEVADA	220	305	357	315
NEW MEXICO	296	333	361	291
LOUISIANA	196	284	276	262
OKLAHOMA	80	212	244	193
OTHER	426	633	1,330	1,915
UNITED STATES	13,453	15,870	20,377	18,772

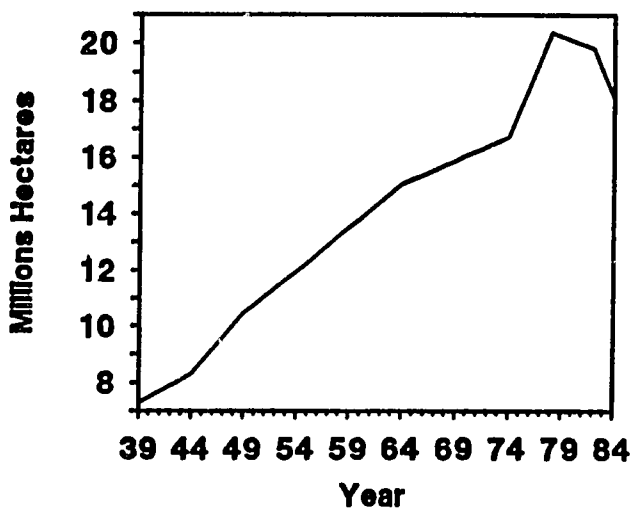

Figure 1

U.S. Irrigated Area from 1939 through 1984

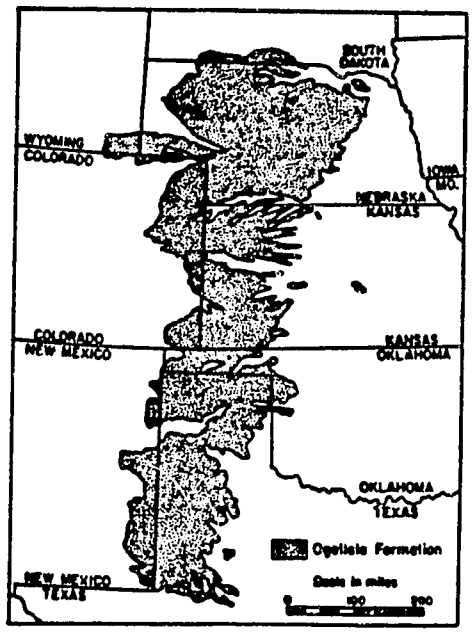

Figure 2

Generalized Distribution of the Ogallala Formation
(Based on available published maps)

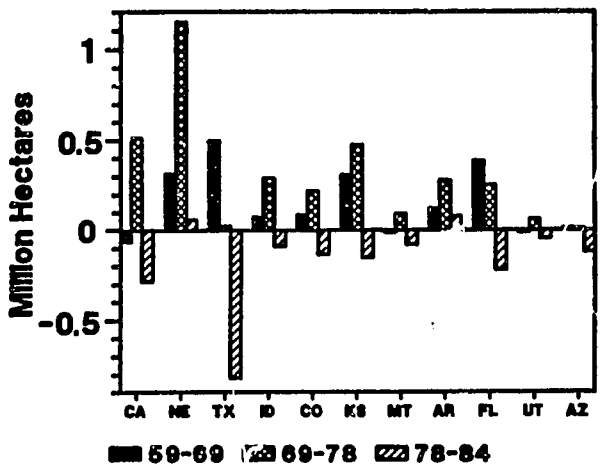

Figure 3

Expansion and Decline of Irrigated Area from 1959 through 1984

constraints have been placed upon the disposal of drainage water containing high salinity or toxic levels of selenium. This, together with the transfer of water from irrigation to other uses, caused the amount of irrigated area to drop by 0.4 million ha from 1978 to 1987 (Figure 3). In Florida, preservation of the Everglades has caused a decline of 0.15 million hectares.

Major legislation in the United States during the 1960s, 1970s, and 1980s placed restrictions on converting wetlands to croplands and, therefore, current drainage programs involve improving drainage of *existing* croplands (American Society of Civil Engineers, 1986, 1989). Thus, do current economic conditions and environmental constraints force landowners to improve production on existing lands rather than annex other lands for agriculture? For example, subsurface drainage systems have been installed in much of the farmland in the humid midwestern and eastern states to remove excess water, enabling timely planting and harvesting of crops and enhancing the root environment, which, in turn, increases crop production. In arid irrigated areas, the main purpose of drainage is to control the water table level and maintain a salt balance in the soil. In 1985, an estimated 44.5 million hectares of land benefitted from drainage systems (U.S. Department of Agriculture, 1987), about 70 percent of the drained land in crops, 12 percent in pasture, 16 percent in woodland, and 2 percent in miscellaneous uses.

Chapter 3

Research Organizations and Domestic Programs

Irrigation and drainage research is carried out by private companies and by universities at the federal, state, and local level. At the federal level, the U.S. Departments of Agriculture (USDA) and Interior (USDI) have the largest components of irrigation and drainage research. The USDA is involved through the Agricultural Research Service (ARS) and the Cooperative State Research Service (CSRS). The USDI has formed a technical Interbureau Task Group, chaired by the U.S. Geological Survey (USGS), which also includes the Bureaus of Reclamation (USBR) and Indian Affairs plus the Fish and Wildlife Service. The task group is to recommend a comprehensive plan for reviewing irrigation drainage concerns.

State research is implemented mostly through the public universities, which also receive funds from the federal government, industry, nonprofit foundations, and private contributions. Some irrigation- and drainage-related research is conducted by the private sector.

3.1 Federally Funded Research

3.1.1 Agricultural Research Service

The ARS focuses its research on the most critical national problems of the U.S. food and agriculture sector that fall within the scope of ARS capabilities, resources, and mission. Research resources are allocated to ARS laboratories and field locations to address high-priority national problems with emphasis on using interdisciplinary teams (Jensen, 1983, 1984).

Current (1990) ARS research related to irrigation and drainage is concentrated in a soil and water conservation program amounting to $60 million per year. Within this program, research is conducted to improve soil and water management, irrigation, and conservation practices; to protect natural resources from harmful effects of soil, air, and water pollutants and to minimize certain agricultural pollution problems; and to determine the relation of soil types and water to plant, animal, and human nutrition (U.S. Government, 1989). Research needs are updated at three- or six-year intervals. A second program area involves the integration of program areas such as soil and water conservation, plant and animal productivity, commodity conversion and delivery, and human nutrition.

Major ARS laboratories and field units conducting irrigation research include the U.S. Water Conservation Laboratory, Phoenix, AZ; U.S. Salinity Laboratory, Riverside, CA; Water Management Laboratory, Fresno, CA; Irrigation and Drainage Research Unit, Fort Collins, CO; Soil and Water Management Research Unit, Kimberly, ID; Coastal Plains Soil and Water Conservation Research Center, Florence, SC; and Conservation and Production Research Laboratory, Bushland, TX.

Information on all ARS-funded research projects is entered into the USDA Current Research Information System (CRIS), which the ARS uses as a tool for planning, resource allocation, monitoring, reporting research results, and also as a general research information database. Appendix I lists the 48 ongoing ARS research projects.

3.1.2 Cooperative State Research Service

The CSRS irrigation and drainage research underway relates directly to priorities established by the Joint Council on Food and Agricultural Sciences. Established by Congress in 1977, the Joint Council works to improve the planning and coordination of research, extension, and higher education within the public and private sectors, as well as to relate the federal budgeting process to the overall functioning of the system. The council's 32 members represent producers and industry, state and federal agencies, and institutions. Annually, the Joint Council prepares a list of priorities for research, extension, and higher education that is submitted to the Secretary of Agriculture. Current research priorities emphasize the following three areas: profitable, sustainable food and fiber agriculture; conservation and protection of natural resources and the environment; and global competitiveness of the U.S. food and fiber system.

The CSRS administers federally funded agricultural research conducted at the State Agricultural Experiment Stations (SAES) and other colleges and institutions. Research proposals are first reviewed and approved by the SAES directors, who forward approved proposals to CSRS for funding.

3.1.3 U.S. Bureau of Reclamation

The research program of the USBR supports the agency's major water-resource management operations in the western United States. Its five major research program areas include environmental restoration and enhancement, water supply alternatives, resource optimization, new methods and materials, and power systems. Within these program areas, projects include aquatic plant control in canals; maintenance of open-

channel conveyance systems including flexible and earth linings; sealants, subsidence, and seepage; closed conduit systems including plastic pipe; subsurface drainage systems including drain envelopes; irrigation-well design including screens, gravel packs, and construction; water management; and water requirements.

USBR engineers and scientists conduct in-house research at the Bureau's Research and Laboratory Services Division in Denver and at certain field offices. Some projects are contracted to outside research organizations.

3.1.4 U.S. Geological Survey

USGS provides basic scientific data and information concerning water, land, and mineral resources. Irrigation-related research and irrigation drainage studies take place at the Branch of Regional Research in Menlo Park, CA and at various field locations. At five-year intervals, the USGS provides estimates of water use in the United States (Solley et al., 1988).

The USGS administers two federal grant programs, the Water Resources Research Institute (WRRI) Program and the Water Resources Research Grant Program, both falling under the Water Resources Research Act of 1984, which encourages research aimed at groundwater quality and management, water resource management, and climate-hydrologic cycle interactions. The WRRI Program provides equal funding to each of 54 state and territorial WRRIs on a specified matching basis, currently two nonfederal dollars to each federal dollar. These WRRIs select and fund projects according to state and regional priorities and management criteria (for projects, see Appendix I). The Water Resources Research Grant Program provides research grants to universities, research organizations, and qualified individuals on a one-to-one matching basis, each year requesting research proposals for research in areas of particular interest.

3.2 State-Funded Research

State Agricultural Experiment Stations at land grant universities in each state receive state support in addition to federal funds. Research projects are funded according to established priorities and available resources. Some state organizations, such as departments of water resources and state engineering offices, may also contract for irrigation-related research. State-funded projects are reviewed by the CSRS, then entered into the CRIS for information and coordination purposes.

3.3 University Research

Most universities receive state and federal funds that fall within some of the categories mentioned previously. The Hatch funds, a principal funding source for university agricultural research, are administered through the CSRS. Other federal research funds are obtained on a competitive basis. Also supporting university-level research are contributions from industry, private individuals, and nonprofit foundations.

3.4 Private Research

Most producers of irrigation materials are affiliated with a trade organization called the Irrigation Association, which yearly organizes a conference focusing on a specific theme such as the environment (Power, 1988). Material presented at these conferences covers commercial products, materials, and services. Much attention is given to pumps, well construction, sprinkler installation design and control, and drip irrigation. Because most of the findings are considered to be trade secrets, this type of research is difficult to analyze, although it can be inferred that private research is very important for the development of new techniques in the United States. A major part of the U.S. domestic research is privately funded, in contrast to research in developing countries, which is nearly all paid for by the governments.

Chapter 4

Research Activities

4.1 Categories of Domestic Research

This chapter notes important findings and peculiarities relating research performed in the United States to needs abroad. Recent irrigation activities of major U.S. research organizations have been categorized. The categories shown in Figure 4 and Table 2 correspond with those from previous ICID and World Bank papers (ICID, 1988) and those from other countries[2].

The relative importance of each of the various research categories cannot be judged by the number of projects in each. One reason is that many projects fit more than one category. Also, it was not possible to include irrigation research projects executed by organizations such as the USBR and the various state water agencies. Thus, Table 2 is only a partial listing.

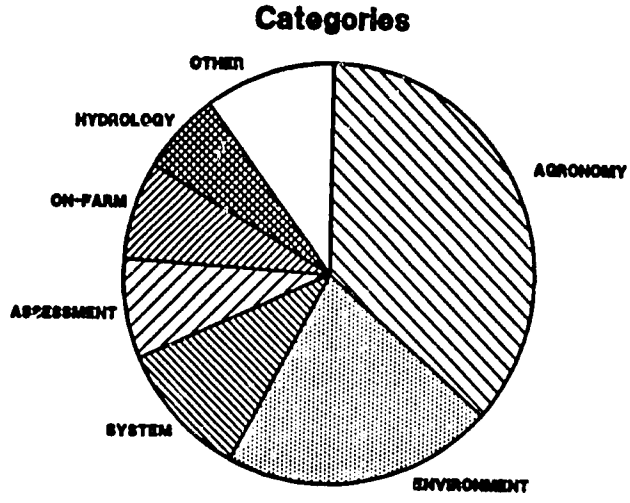

Figure 4

Distribution of Research Projects

[2] India, United Kingdom, France, Indonesia.

Table 2

Number of Research Projects Currently Funded

	Water Resources Research Institute	Agricultural Extension Service	Cooperative State Research Service	Agricultural Research Service	TOTAL
Irrigation Agronomy	3	42	82	24	151
Environment	60	2	21	4	87
System Control	8	11	14	9	42
Performance Assessment	7	2	21	1	31
On-Farm Application	0	3	26	2	31
Hydrology	25	1	0	0	26
Other	23	2	8	8	41
Total	126	63	172	48	409

ARS, CSRS, and SAES activities were collected by means of an on-line search in the USDA CRIS, which contains the following information for every research project: title, investigators, location, sponsor, CRIS-codes, objectives, approach, keywords, progress, and publications. Research activities were then categorized based on all information.

WRRI projects come from a list containing only title, investigators, and location; thus, selection and classification of these activities were based mainly upon the project titles. Because no comprehensive database exists for research undertaken by private companies or by the USBR, no quantitative analysis can be done of this research; there is, however, some qualitative information available. In the following category overview, private and USBR research is mentioned if it appears especially relevant to the category.

4.1.1 Irrigation Agronomy

Almost all projects are funded by CSRS, SAES, and ARS institutes (see Table 2). As the general purpose of these projects is to improve agricultural production, many of them look at interrelated aspects of crop cultivation, such as fertilizer application, plant pathology, and soil characteristics. Irrigation is often only one aspect considered. Many of the projects can be compared with the farming systems research from developing countries.

In 19 percent of the cases, irrigation was a major sideline of another agronomic specialization. In 47 percent of the projects, irrigation was an important aspect of the whole cropping system, as in "Influence of Production Practices on Yield and Grain Quality of Maize and Winter Wheat," at the University of Nebraska (Lincoln), and "Soil Fertility, Plant Nutrition, and Irrigation Management," at Montana State University (Bozeman). Projects with irrigation as the major research component, comprising 31 percent of the projects in the agronomy category, mainly studied plant/soil/water relationships. Examples of this type are "Analysis of Penman Equation Wind Function and Crop Water Requirement," at Oregon State University (Corvallis), and "Models, Physics, and Physiology of Soil-Plant Water Transport, Irrigation, and Stress Control," Agricultural Research Service (Fort Collins, CO).

4.1.2 Environment

Current federal and state policies give emphasis to the importance of a healthy environment. Agencies are willing to fund research. However, the environmental problems addressed differ from those in developing countries, which face such challenges as salinization, waterlogging, and waterborne diseases (ICID, 1988). In industrial countries, contamination of ground and surface water by agricultural chemicals is of concern.

Salinity-related research in the United States occurs mainly at the U.S. Salinity Laboratory (Riverside, CA), where researchers study fundamental processes associated with salinity problems and often include mathematical modeling in their activities (see "Measurement and Modeling of Water, Salt, and Energy Movement through Soil"). The lab also conducts other environmental research, especially on selenium contamination, a significant problem in California.

Most other projects in this category study the effects of pesticides and nitrogen on ground and surface water, e.g., "Agricultural Impacts on Stream Water Quality," at Oklahoma

State University, and "Agricultural Utilization of Waste Materials to Reduce Pesticide Movement to Groundwater in Sandy Coarse-Textured Soils," at the University of Illinois. Traditional solute-movement models have only limited validity here, especially in relation to pesticides. This is why more fundamental research is found under *Environment* than under other categories, although site-specific research can also be found. Fundamental research, in this case, tends to focus on transport mechanisms, whereas applied research is directed toward pesticide and nitrogen management. The idea is to reduce the use of agrochemicals by adapting different cultivation practices (see the interstate projects, "Integrated Irrigation Water and Nitrogen Management to Sustain Ground Water Quality and Quantity," and "Impact of Soil Macropores on Water and Chemical Transport to Ground Water Through the Vadose Zone," at the University of Minnesota). An example of site-specific research would be "Nitrogen Leaching Losses for Corn Produced on Soils in the Chesapeake Bay Area as Influenced by Selected Best Management Practices," at the Virginia Polytechnic Institute.

Projects from other categories often have an environmental component. For example, many of the regional "Trickle Irrigation in Humid Regions" projects, categorized under *On-Farm Application*, have a large environmental component. This also holds true for many *Agronomy* projects which study, among other things, the relationship between irrigation practices and leaching of agrochemicals.

4.1.3 System Control

This category (11 percent of total) includes research on high-tech applications, such as remote sensing techniques and computer models, e.g., "Surface Irrigation Control and Decision Support Systems," at Utah State University, and "Appraisal and Enhancement of Computer-Aided Management of Irrigation Water Distribution," at Colorado State University. Modeling and system control are often closely intertwined in such projects, and it is, therefore, hard to distinguish between these two categories. For purposes of this study, the main distinguishing criterion was whether the research was directly aimed at field application; if so, it was categorized under *System Control*. Some projects even bridge the entire process—from assessment of the present situation to implementation of a newly developed system, as in "Development, Simulation, and Evaluation of Irrigation Practices for Arkansas Agriculture," at the University of Arkansas.

Over 70 percent of the projects in this category, however, include general irrigation management practices, as do "Integrated Systems to Coordinate Irrigation Canal Deliveries with Farm Water Management in Arid Areas," at the Agricultural Research Service Station in Phoenix, AZ, and "Integrating the Soil-Plant-Atmosphere System for

Irrigation Scheduling," at the University of California (Davis). There are no projects concerning hydraulic control structures; the ARS decided, in 1983, to deemphasize this line of research (Jensen, 1983).

4.1.4 Performance Assessment

Most research projects listed in this category are economic evaluations of irrigation systems, such as "Economics of Uncertain Water Supplies for Irrigation," at the University of Nebraska (Lincoln), or deal with legal and policy issues, e.g., "Enforcing the Arizona Groundwater Management Act: Implications for Agricultural and Industrial Development," at the University of Arizona.

To a lesser degree, social issues in performance assessment are studied. At least two projects include social assessment: "On Managing Texas Rural Water Supply Systems: A Socioeconomic Analysis and Quality Evaluation," at East Texas State University, and the interstate project "Socioeconomic Dimensions of Technological Change, Natural Resource Use, and Agricultural Structure."

A more interdisciplinary approach is taken in the regional project "Water Management and Conservation in Western Irrigated Agriculture," whose objectives are to develop and evaluate alternative on-farm irrigation technologies and management strategies; to assess the state, regional, and national economic impacts of alternative irrigation technologies and management strategies; and to formulate and evaluate alternative legal-institutional frameworks for water allocation.

Research is currently lacking on evaluation procedures for irrigation system performance. The few procedures available, such as the "Rapid Evaluation Technique," developed at Colorado State University, have often been applied, but seldom systematically evaluated. Although the development of well-tested assessment techniques is an urgent need of developing countries (Svendsen, 1987; Abernethy and Pierce, 1987; ICID, 1988), U.S. techniques are generally invalid for developing countries because of the different economic, social, and legal framework in which the irrigation systems are operating. If, however, only technical issues are involved, assessment procedures developed in the United States may be applicable.

4.1.5 On-Farm Application

Within this category, 18 of 31 projects are part of the regional research project, "Trickle Irrigation in Humid Regions" and are mainly conducted in the southeastern states, especially Florida. The objectives of these projects are to determine scheduling and amount of irrigation in relation to soil wetting and plant growth needs; effectively deliver nutrients and pesticides through trickle irrigation systems; and assess the costs, returns, and profitability of trickle irrigation on selected crops in humid regions. Of the remaining projects, the majority also focus on trickle irrigation.

Private research concentrates on this category, as manufacturers of center pivots and trickle installations invest in the development of new equipment and techniques. Many presentations made at Irrigation Association conferences relate to the design and management of pressurized irrigation systems (Irrigation Association, 1985, 1986, 1987, 1988).

4.1.6 Hydrology

This research category is a traditional topic funded by WRRI (Table 2), with most research comprising local application and refinement of existing mathematical models, e.g., "Estimation of Low Flows in Small Ungaged Watersheds via Correlation with Concurrent Flows in Gaged Watersheds and Regional Analysis," by the University of New Hampshire, and "Estimation of Leakage between Aquifers of the Las Vegas Valley," by the University of Nevada. Such research barely considers the development of new hydrologic models, which the respective universities carry out with funding outside of the WRRI.

4.1.7 Other

The remaining categories (i.e., sediment, models, modernization, drainage, farmers's role, groundwater, meteorology, maintenance, traditional systems, wastewater, consolidation, construction, and pressurized systems) cover 41 projects. The absence of some categories (consolidation, construction, low-pressure systems) reveals that these topics are not of current interest.

Sediment-related research, especially in erosion control, is important in the United States. The Soil Conservation Service (SCS) of the USDA is the main federal institution for implementing this program. Research is carried out by the ARS, the SCS research

agency. ARS has made a great effort to develop a new national erosion model, but few projects have dealt with irrigation-related erosion.

Models and modernization research are among the more important of the small categories, and some projects falling within the larger categories also have a model or modernization component. Assessment research is often followed by or aimed at modernization of existing schemes; for example, the objective of "Evaluation of Alternatives in Soil and Water Management Practices in Southeast Kansas" is "to determine optimum soil and water management practices." Models are often related to system control because computer modeling is an important management tool (see "Crop Model-Based Farm Management Decision Aids" at Texas A&M University).

Drainage research is undertaken by the same institutions that conduct irrigation research. The volume of drainage research undertaken is actually much larger than presented here because only drainage research related to irrigation is mentioned. In the eastern part of the United States, supplemental irrigation by subsurface drains is growing in importance and a topic of much active research.

The *farmers' role* is rarely part of the irrigation research agenda in the United States. Detailed information about farmers' practices is gathered in the four-year Census on Agriculture conducted by the Economic Research Service of the U.S. Department of Commerce. Much U.S. irrigation involves pressurized systems, which do not generally require participation among farmers. This is one way that the circumstances of U.S. farmers differ from those of farmers in developing countries. Other differences may be seen in the U.S. farmers' quest for high profitability, their relatively easy access to capital, and their high labor costs. Farmers in developing countries, by contrast, seek subsistence, avoid risk, and deal with low labor costs and low capital availability.

Research into *groundwater use*, without reference to environmental issues, is rare. Much fundamental research on such use has already been performed, and efforts are now concentrated on refining existing techniques. The USBR does some research on well design including screens, gravel packs, and construction. Monitoring of aquifers and groundwater levels are part of the USGS routine, providing data for policymakers and researchers. Many private enterprises build wells, and their research concentrates on the optimization of water pumps. The State of California has an innovative program ("the Kern River Bank") in which an 8,000 ha parcel is managed to investigate ways to accelerate groundwater recharge.

Meteorology, highly developed in the United States, is the subject of much research. However, the Federal Weather Bureau and local and state meteorological institutes were

not included in the study because meteorology would be pertinent to this report only if, for example, weather forecasts were a part of a water management system. Thus, the relatively few projects included in this study category do not indicate the amount of research in this area.

Maintenance of U.S. irrigation systems is usually not a problem because the techniques to maintain a surface irrigation system differ little from the maintenance of other large infrastructures, and the technical knowledge is readily available. Good maintenance is part of sound economic management. Maintenance of pressurized systems is done either by the farmers themselves or by the firms that installed the systems. Micro-irrigation is sensitive to maintenance because such systems are easily clogged. Ongoing private research on trickle irrigation includes the development of "maintenance-free" installations.

Traditional systems are usually thought of as small systems constructed with locally available materials using locally developed techniques. Often praised for their sustainability and studied for their heuristic value, such systems are in almost all cases, farmer-owned and managed. Although no ancient traditional irrigation schemes exist in the United States, there are many farmer-owned irrigation systems. Such systems have not yet been the subject of systematic study, and it will be interesting to investigate them because they function well.

Wastewater reuse research, funded by many WRRIs, usually deals only with urban wastewater and, for this reason, was not relevant to this report. Only one project dealt specifically with the reuse of wastewater for irrigation.

Consolidation was beyond the mission of the research organizations listed here; therefore, no such projects were included.

As was the case with maintenance, *construction* in the United States needs no special attention (aside from large dams); most information on how to build an irrigation system is already available. Within this category, the contrast between the United States and developing countries is great, as there is little use of manual labor in the U.S. because building in concrete and working with machines are highly specialized jobs. Improvement of existing construction techniques is mostly done by manufacturers and university civil engineering departments. New construction techniques, such as the lining of canals under water and building rolled concrete dams, have been major USBR activities.

Research on *low-pressurized* systems is mainly undertaken by manufacturers of irrigation installations, and the scope of this research is unknown.

4.2 A.I.D.-Sponsored Projects

The purpose of this report is to give an overview of domestic irrigation research. Such an overview would be incomplete without mention of A.I.D.-financed irrigation research conducted in and for other countries. A.I.D. administers the U.S. Government's assistance program in other countries. Much of the assistance focus has been on rural development in developing countries. Since irrigation is such an important and costly component in rural development programs in many countries, a large proportion of A.I.D.'s financial support has gone to irrigation. Because A.I.D.'s support addresses development priorities, irrigation research is carried out in parallel with financial support for irrigation rehabilitation and purchase of equipment.

With strategic purpose, A.I.D. has sought to direct significant irrigation funding into institution building ("software") components. Funding is designed to complement and help shape the type of lending which other bilateral and multilateral donors give to the sector.

Irrigation research sponsored by A.I.D. is concerned with entire portions of irrigation systems and with the functioning of the system as a whole, and not on detached components. Research is concerned with the functioning of irrigation systems from conveyance canals to on-farm water applications, from management of government agencies to organization of farmer water users. Here, research cannot be done under controlled conditions, rather it is the behavior of the system that defines the conditions and the research which must be done. Because of the broad nature of this line of inquiry, interdisciplinary teams are frequently used as the dominant irrigation research mode. Because work is done not on experiment stations, but rather in active irrigation systems, the work undertaken has been labeled as "action" research.

The research categories shown in Table 2 are another way to categorize A.I.D.'s research projects in developing countries. We find, however, that A.I.D. research differs from research conducted in the United States in the following ways:

- A.I.D.'s irrigation research overseas has studied the functioning of entire irrigation systems, emphasizing:
  - Performance monitoring, with particular attention to upgrading the performance of irrigation projects which function below expectation. The criteria use to gauge irrigation performance have been shifted from production, during the post-green-revolution

period, to issues of equity and reliability of irrigation supplies today.

- ☐ System maintenance aspects, particularly issues of deferred maintenance and strategies to induce irrigation system managers and governments to place added emphasis on maintenance.
- ☐ Policy aspects related to irrigation, in particular, valuation of water and collection of water fees, and more recently, privatization of irrigation systems and services.
- ☐ Human/sociological aspects, particularly issues such as formation of water user groups.

- In contrast to A.I.D.'s research overseas, domestic irrigation research has focused on component parts of the system. The research agenda has emphasized:

  - ☐ Engineering technologies, for example, public- and private-sponsored research to develop materials and equipment for drip, micro-jet, center pivot, and surge irrigation.
  - ☐ Irrigation agronomy.
  - ☐ Environmental aspects related to irrigation such as Best Management Practices, and reduction of drainage effluent.

A.I.D.-sponsored research findings have enhanced understanding of development issues and constraints, and have helped guide current and future programs in irrigation. Three examples of past A.I.D.-sponsored research serve to illustrate the type of projects carried out and their impact upon development programs.

During the late 1970s, A.I.D. support to Pakistan was focused on *performance monitoring* of watercourses (tertiary canals). A.I.D. researchers found that conveyance losses in these canals were up to 40 percent, an amount far larger than previously documented. Research findings led to creation of agencies within the Government of Pakistan (the On-Farm Water Management Directorates) to make improvements in watercourses. The program of improvements is being supported to this day by the World Bank and the Asian Development Bank which will each fund the third tranche of On-Farm Water Management Projects in 1992.

In contrast to a focus on large-scale irrigation development, the emphasis during the 1980s by the U.S. Government was on small farmers. A.I.D.-sponsored irrigation research was directed to *small scale irrigation* works, such as Sederhana and the Small

Scale Irrigation Management Project in Indonesia, and the Hill Areas Land and Water Development Project in Himachal Pradesh, India. Research showed that benefits from support to small-scale irrigation could be significant. As a result, country agencies have geared up to service the small-scale irrigation sectors in various countries, and donors are responding with support to small-scale irrigation development throughout the world.

A.I.D.-sponsored action research in the Dominican Republic has supported *privatization (turnover) of irrigation facilities and services* from the government to organized irrigation associations. The research documented the critical importance of: (1) renovation of facilities prior to turnover; (2) creation of federated groups of water users into irrigation associations; and (3) support from the highest levels of government and from the government irrigation agency to allow change to proceed. Publicity from the Dominican project and from other A.I.D.-supported irrigation research projects in Honduras, Nepal, and Sri Lanka are helping to define a future line of donor support to irrigation which will include increased emphasis on privatization of irrigation facilities and services.

A.I.D.'s support to irrigation and the findings generated by it have benefitted more than 25 countries. While helpful to direct recipients, individual projects lacked a way to capture what was learned. In response, the Water Management Synthesis Projects (1977 to 1988) were created to capture and disseminate action research findings to be used to address similar situations in other countries. Currently, ISPAN continues this mandate. Soon to be initiated is another A.I.D.-funded irrigation project, the Agricultural Water Resources Management Project (AWRM) which will fund irrigation research for selected countries in Africa and Latin America.

Present A.I.D.-sponsored irrigation projects are shown in Table 3. The following paragraphs describe highlights of these projects.

The Irrigation Support Project for Asia and the Near East (ISPAN) helps synthesize the learning from A.I.D.-sponsored projects throughout the world. ISPAN provides assistance in irrigation engineering, agriculture, and social science disciplines to A.I.D. missions. The project has four components: technical assistance to A.I.D. missions, projects, and regional institutions throughout Asia and the Near East; training and technology transfer; research or applied studies; and support to the development of regional irrigation institutions. ISPAN is supporting applied irrigation research (policy) studies in Sri Lanka and flood action planning for Bangladesh, in addition to more limited assistance in ten other countries.

Table 3

A.I.D.-Supported Irrigation Projects with Research Components

COUNTRY	PROJECT TITLE	YEARS	FUNDING ($m)
Asia and Near East	Irrigation Support Project for Asia and the Near East (ISPAN)	1987-92	20.1
Africa and Latin America	Agricultural Water Resources Management Project (AWRM)	1992-97	Not yet funded
Dominican Republic	On-Farm Water Management Project	1983-92	12
Egypt	Irrigation Management Systems Project	1981-95	340
Honduras	Irrigation Development Project	1986-93	22
India	1) Hill Areas Land and Water Development Project 2) Madhya Pradesh Minor IP 3) Maharashtra Minor IP 4) Water Resources Management and Training Project	1984-92 1983-92 1984-92 1983-92	42 46 50 51
Indonesia	Small-Scale Irrigation Management Project (SSIMP)	1987-94	50
Morocco	Water and Soil Resource Conservation Project	1992-97	est. 17
Nepal	Irrigation Management Project (IMP)	1985-94	9
Pakistan	Second Irrigation Systems Management Project (ISM II)	1988-93	150
Philippines	Accelerated Agricultural Production Project (AARP)	1986-92	30
Senegal	Southern Zone Water Management Project (SZWMP)	1990-96	18
Sri Lanka	Mahaweli Agriculture and Rural Development/Mahaweli Downstream Support Projects (MARD/MDS)	1988-93	29

The Agricultural Water Resources Management Project (AWRM) is a project that will work on water management research innovations in three to four pilot countries in Africa and the Americas. Slated to begin in 1992, the project seeks to demonstrate technologies and strengthen host-country capabilities for more effective agricultural water resource development, management, and use.

Farmers in the Dominican Republic have accepted responsibility for management and maintenance of two large irrigation systems near Azua and Santiago. A.I.D. support was used to rehabilitate portions of the systems. Action research was instrumental to help form water user associations and irrigation districts, and to improve on-farm agricultural productivity. Farmers take an active role in maintenance, and they have paid higher water service fees for district-level operations and maintenance activities. Farmer-administered irrigation districts are a departure from strongly paternalistic modes characteristic of the past. This marks a change toward irrigation system privatization which is relevant to many countries in the world.

With ten components implemented over 14 years, the Irrigation Management Systems Project in Egypt is a $340 million A.I.D. investment. The bulk of the funding goes for irrigation system improvements, structural replacement, preventive maintenance, data collection and analysis, planning for and new project preparation, and survey and mapping. Approximately $27 million is earmarked for a Water Research Center (WRC). Funding for the WRC component is to strengthen the Ministry of Public Works and Water Resources in activities to control, use, and develop Egypt's water resources; provide answers to key policy issues in the irrigation sector; and develop the long-term capabilities of the center and its 11 institutes.

In Honduras, the Irrigation Development Project provides assistance for small-scale irrigation development in three regions of the country. The project is providing funding for: (1) irrigation system design and construction; (2) on-farm extension related to water management and improved agricultural practices; (3) credit for production and for irrigation system construction; and (4) strengthening of local public and private institutions to plan and implement irrigation activities.

Four irrigation projects in India currently receive support from A.I.D.: (1) The Hill Areas Land and Water Development Project (Himachal Pradesh) focuses on small-scale irrigation works. The objective has been to increase irrigation efficiencies and to expand the area under irrigation. The research component involves support for agro-economic studies by local universities; (2) The Madhya Pradesh Minor Irrigation Project funds design and construction of approximately 50 small-scale irrigation schemes. These are used to test and demonstrate participatory innovations in design, construction, and

operations. In addition, 200 demonstration watercourse commands have been constructed to disseminate new technologies and on-farm infrastructure; (3) The Maharashtra Minor Irrigation Project funds construction or rehabilitation of approximately 100 small-scale irrigation schemes. The project promotes research through funding of special studies; for example, water scheduling, pilot activities in system management, and on-farm irrigation; (4) The Water Resources Management and Training Project helped establish Water and Land Management Institutes as training centers for India's future water resource planners. The project opens linkages between U.S. and Indian research institutions and provides funding for action research on improved design, water resource planning, and on-farm irrigation management.

The Small-Scale Irrigation Management Project assists the Government of Indonesia in implementing activities in small-scale irrigation technologies, management of provincial public works, and improved beneficiary participation. The project works in the drier outer islands of Indonesia, developing nontraditional (sprinkler and drip technologies as well as surface systems) approaches to irrigation design, construction, operations, and maintenance. Applied research deals with policy concerns, such as decentralized decisionmaking and expanding the role of the private sector in groundwater development.

The Irrigation Management Project in Nepal strengthens the Department of Irrigation (DOI) capacity to implement participatory approaches to irrigation management. Support is being provided to create an in-house training institute and a systems management branch within the Planning, Design, and Research Division of the DOI. The branch does monitoring and evaluation, and implements pilot and applied research studies. The project has supported farmer-managed irrigation and the turnover of management functions from the government to water user organizations.

Slated to begin in 1992, the Water and Soil Resource Conservation Project in Morocco will improve resource use efficiency and sustainability of resource productivity on the Tadla irrigation perimeter. The project will improve main system management, institute the country's first integrated water quality and agrochemical loading monitoring system, identify and test on-farm resource management technologies, assist in the turnover to irrigation associations of the tertiary network, and stimulate the development of private services and cooperative enterprises. On one of the largest (142,000 ha) and oldest (1937) perimeters in the country, the project will serve as a model for similar transformation of other large-scale irrigation perimeters.

With support from A.I.D., IBRD, and the Government of the Netherlands, Pakistan's Second Irrigation System Management Project (ISM II) is providing approximately $150 million for civil works (primarily rehabilitation of distributary channels, drainage

systems, and barrage gates), technical assistance, and training. Objectives are to: (a) provide a more equitable and reliable water supply in the irrigation conveyance system; (b) reduce crop losses by improving the drainage systems; and (c) strengthen the capabilities of the Provincial Irrigation Departments to carry out O&M functions. ISM II channels $2 million in support to the International Irrigation Management Institute, Pakistan to be used specifically for research.

In the Philippines, the Accelerated Agricultural Production Project provides support to both agriculture and irrigation. NGOs and universities are carrying out policy-oriented irrigation studies dealing with farmer participation and water user fees. Assistance for farmer organization has been a main component of the project.

The Southern Zone Water Management Project in Senegal is providing assistance for reclamation of over 15,000 ha in the Casamance Zone. Simple dams, dikes, and other flood mitigation works are being installed to protect and reclaim salinized lands. The project's applied research component supports national research agencies to help them devise appropriate soil and water management practices for implementation by farmers. An environmental monitoring component tracks resource changes in the Casamance.

The Mahaweli Downstream Support and Mahaweli Agriculture and Rural Development projects in Sri Lanka combine construction of tertiary irrigation infrastructure with adaptive research, farmer organization, extension, and marketing. The projects address six main challenges to integrated development in Mahaweli System B: (1) improved supervision of the construction of infrastructure needed for irrigation, transport, settlement, and provision of supporting services; (2) improved management of the Mahaweli water distribution systems to increase water supply reliability, reduce O&M costs, and improve the effectiveness of the systems' irrigation authority and farmer organizations; (3) preparation and implementation of an O&M plan that is participatory, farmer-operated, locally financed and cost-effective; (4) diversification of the cropping pattern from double cropping of rice to increased dry season production of higher value crops; (5) mitigation of drainage problems and difficult soil conditions that impede production of crops requiring a nonsaturated root zone; and (6) establishment of backward linkages to input suppliers and forward linkages to markets and processors through private sector initiatives.

Chapter 5

Formulating and Coordinating Research Programs

5.1 Identifying and Prioritizing Needs

No single countrywide approach is used to formulate research programs or to coordinate research. Within a federal agency, programs generally are developed in response to needs identified by a wide range of user organizations. For example, the ARS responds to irrigation- and drainage-related research needs identified by the National Association of Soil and Water Conservation Districts (NACD). Nearly every state has an NACD organization with a research committee; these committees interact with research institutions within the state and formulate research-needs statements and recommendations. Such recommendations are then considered at NACD's national level, and the resulting consensus resolutions are forwarded to federal and state research organizations and to the appropriate congressional appropriations committees.

Several professional societies, of which the most relevant are the American Society of Civil Engineers (ASCE) and the American Society of Agricultural Engineers (ASAE), have committees that asses research needs and identify high-priority subjects, which are disseminated to various research organizations. For example, the American Society of Civil Engineers recently published research needs identified by technical committees of the Irrigation and Drainage Division (ASCE, 1989). Professional societies sometimes conduct comprehensive assessments of ongoing irrigation and drainage research programs, involving identification of high-priority research objectives; summaries of funds being invested in research programs by federal and state organizations; and discussion of national and regional problems and issues, human resources assigned to various research programs regionally and nationally, and improved technology to be expected from proposed research programs (ASCE, 1986). Some societies organize and sponsor special presentations to U.S. congressional appropriations committees and federal agriculture research leaders. An organization whose members are professional societies is the Council on Agricultural Science and Technology (CAST), which periodically prepares documents discussing subjects that are of current high interest. For example, a CAST task force recently prepared a publication on effective use of water in irrigated agriculture (CAST, 1988).

In some cases, Congress may earmark funds from federal agency budgets for specific areas of research identified by various commodity or natural resources organizations. In

other cases, funds for research programs administered by federal agencies my be provided on a competitive grants basis.

Typically, federal and state research organizations meet with client groups at least once a year to discuss research needs and programs. Periodically, research programs at individual laboratories are reviewed in-depth by teams made up of internal national staff scientists, external research specialists, and user group representatives. These reviewers prepare a report with recommendations for program and staff changes. Research leaders and administrators consider the recommendations and implement actions that redirect financial, physical, and human resources to those projects deemed of highest priority with regard to available resources and their relative importance to the user groups or clients.

The USBR research program is formulated and coordinated by the Chief of the Research and Laboratory Services Division in Denver. Research focuses on problems and needs associated with the USBR's water-resource management. A five-year strategic plan is the basis for research in five major technical areas, each guided by its own plan.

The USDA Soil Conservation Service is the main federal agency providing technical soil and water management assistance to farmers. Periodically the SCS updates and publishes high-priority research needs identified by its regional technical service centers and state technical staffs.

A special place is taken by private research, which is market-oriented and, thus, very sensitive to demands from the field. Companies often integrate market and technical research with the promotion carried out by sales representatives in close contact with the farmers. These representatives not only promote products, but also asses their customers' needs, relaying farmer requests and market data to the research division, where the information is incorporated into the development of new products. Continuous feedback to and from the field ensures a demand for the innovated merchandise.

5.2 Coordinating Research Efforts

Of the various mechanisms used to coordinate research activities between federal and state agencies and universities, most successful are the regional research committees uniting representatives from the SAES, federal and state agencies, and various commodity and natural resources user groups. At five-year intervals, each committee reviews and discusses regional agricultural research needs and produces a document summarizing its recommendations. These documents are used by federal and state organizations in planning new research programs and developing their annual budgets.

The CSRS also funds some regional research projects in which researchers from universities in the region submit component research proposals. State and university researchers, whose projects have been approved and funded, usually meet once a year with ARS researchers, as well as with ARS and CSRS staff scientists, to summarize, discuss, and exchange technical results. Examples of regional projects are "Trickle Irrigation in Humid Regions" and "Irrigation in the Western States" (see Chapter 4, Research Activities).

Chapter 6

Dissemination of Research Results

6.1 Research Organizations

Research organizations disseminate findings in two ways: by publishing papers in peer-reviewed scientific and engineering journals (most often) or by presenting papers at professional society meetings or conferences. Journal papers take a variety of forms, from in-depth reviews of research literature to special reports on a particular subject. When major advances are made, news releases may announce the discovery or achievement prior to formal technical presentation. Research scientists and engineers also contribute to chapters in monographs or books on subjects within their area of expertise.

6.2 Extension Service

In the United States, the USDA Cooperative Extension Service (CES) transfers new technology developed through research to the farming communities. Through its offices at each of the land grant universities and at some major agricultural laboratories, the CES prepares special, easy-to-understand publications and sponsors local workshops and field days on special subjects. CES specialists participate in research planning and review conferences, providing feedback from the farming community on problems that may require research.

6.3 Professional Societies

A large amount of research literature in the United States comes from professional societies of research scientists and engineers, whose members frequently belong to several such societies. These societies sponsor technical sessions and special symposia that enable researchers and research users to discuss problems on which research is needed or being conducted. (The number of international issues addressed on these occasions is rather limited.)

6.4 Trade Associations and Private Companies

Functioning much like professional societies, trade associations draw their membership from industry suppliers and manufacturers and commercial distributors of technical products and services. The Irrigation Association and the Land Drainage Contractors are two active trade associations involved with irrigation and drainage problems. These associations meet annually and sponsor technical programs, frequently inviting researchers and extension specialists to participate in their technical sessions.

As noted, sales representatives play an important role in disseminating the results of private research. In marketing the newly developed products, they explain how the merchandise can meet the specific needs of individual farmers. In addition, the sales representatives will bring farmers in contact with the firm's engineers if technical questions arise. Facilitating a two-way process, the representatives not only provide product information to the farmers, but also transfer the farmers' market demands back to the company.

Chapter 7

Financing

U.S. irrigation and drainage research is funded by a variety of sources, and many projects may be jointly funded from both public and private sectors. The main source of funds varies with the research organization involved: for example, federal laboratories receive mainly federal funds, while state laboratories, experiment stations, and universities are often funded from a combination of private and public sources (the public funds being federal, state, or perhaps both).

In 1989, the total budget of the Agricultural Research Service was US $560 million, of which about $60 million was appropriated for research on soil and water conservation and $215 million for research on plant sciences. From 1988 to 1989, soil and water research gained $6 million, which was proposed to finance research to improve groundwater quality and the effects of ozone depletion (U.S. Government, 1989).

The Cooperative State Research Service had a total fund of $262 million for 1989. Of this amount, $155 million was spent on projects financed under the Hatch Act, which finances projects at one designated university in each state. The CSRS projects listed under *Research Activities* are financed under the Hatch Act on a formula basis: for every federal dollar, one nonfederal dollar must be invested in the research. The matching funds usually come from the state in which the university is located.

The Water Resources Research Act of 1984 appropriates $60 million annually for research related to the nation's water resources. Of this amount, $10 million is distributed in grants to the Water Resources Research Institute of each state, every dollar to be matched by two nonfederal dollars. Another $40 million is given in competitive grants using a one-to-one match of federal and nonfederal funds. This same act authorizes a grant program of $10 million for technology development, using a flexible matching requirement that may vary from case to case (U.S. Congress, 1984a,b).

Chapter 8

Relevance of U.S. Irrigation Research to Developing Country Needs

8.1 Research Needs of Developing Countries

In April 1987, a colloquium held in Wallingford, England, addressed Third World irrigation research needs, eventually identifying (through a postconference questionnaire) high-priority topics: performance data, water scarcity, performance criteria, health, measuring devices, erosion and sedimentation, sustainability, crop breeding, efficiency of water use, performance monitoring, and saline soil. The questionnaire had originally included 43 topics, none of which the respondents placed in a "low importance" category and to which they added 75 more, indicating typical difficulties encountered in establishing research priorities.

At a World Bank-sponsored workshop on "Technological and Institutional Innovation in Irrigation," participants discussed irrigation and drainage research needs and priorities in great detail and noted that establishing research needs was easy enough, setting research *priorities* was much more difficult (Le Moigne et al., 1989). Priorities are usually based on situation-specific conditions that depend on the mission of the research organizations, the resources required, and the needs of the research users.

Svendsen (1987) describes the "on-farm water management" research projects of the past years, which have underscored the need for interdisciplinary studies and produced research accordingly. It is important to look at higher management levels, as well, and take into account the functioning of the complete system. Larger systems (2,000 ha or more), with substantial government involvement, play a central role in irrigation development, and main system management appears to be of foremost importance. Based upon current realities, such as high world food-supply levels, declining irrigation investments, debt-repayment problems, low system efficiencies, and a rising concern about sustainability, Svendsen suggests a new research agenda that expands the traditional field of inquiry of irrigation engineers to include such issues as developing effective planning techniques, establishing managerial measures for performance improvement, and designing irrigation systems for manageability.

Here it is interesting to look at what U.S. irrigation engineers can contribute to research in developing countries. From a system perspective, there is a great need for performance measurement that considers factors like equitable water allocation and regularity of water deliveries (Svendsen, 1987; Abernethy and Pierce, 1987). Thus, new

concepts such as Levine's Relative Water Supply[3] must be developed to facilitate comparison of different projects. This, in turn, requires new research methods and adaptation of existing methodologies. As irrigation engineering increasingly becomes an international affair (Power, 1988), U.S. engineers must give these issues more thought if they want to remain leaders in irrigation technology development.

8.2 Conclusions Concerning the Domestic Research Activities

Svendsen (1987) describes three related characteristics of U.S. irrigation research, which can also be traced in this report's list of projects: 1) heavy emphasis on water management and plant/soil/water relationships at the farm level; 2) absence of research on system management; and 3) research on field water application that is dominated by technology development. He argues that this is logical only for research in the U.S., where water resources are fully allocated, labor is expensive, energy costs are rising, and farms are large. The situation in developing countries is completely different, with many small holders, low labor costs, and low capital availability.

The relevance of domestic U.S. research for developing countries is open to question because irrigation projects are heavily influenced by local and country socio-economic settings. Therefore, U.S. research which has the most direct usefulness for developing countries is that which is fundamental in nature. Examples of this type of research are topics such as plant/water/soil relationships, solute movement, and salinity research.

Research priorities for all organizations discussed here are established at local and state levels. Federal research funding ensures that regional and nationwide problems are addressed. State-sponsored SAES research, especially, deals with problems of local relevance. However, federally sponsored research is also, in most cases, relevant to the region in which the centers are located. Technologies developed by private research, for example irrigation equipment, are aimed at specific markets required by American farmers.

Localized research emphasizing problem-solving enables research groups to address needs observed in the field. Although carrying the risk of redundancy, frequent workshops and congresses, along with an excellent publication network, reduce this risk. The overall impression is that the local, applied approach has many more advantages than disadvantages. The structure of irrigation research in the United States cannot readily be introduced in developing countries. However, local research efforts and their relative

[3] Ratio between water supply and water demand (Levine, 1982).

success, is an engine behind U.S. agricultural production gains and environmental quality, suggest that more local and applied research projects, together with improved networking and information exchange, may be a way to improve research in developing countries.

Appendix A

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Appendix B

List of Research Topics

ST	TITLE	LOCATION	INVESTIGATORS
CATEGORY 1: HYDROLOGY			
AZ	A STATE-OF-KNOWLEDGE ASSESSMENT OF THE PROCESSES INVOLVED IN A UNIFIED HYDROLOGIC FLOW MODEL	UNIVERSITY OF ARIZONA	BURAS N; RASMUSSEN W; EVANS D
SD	BLACK HILLS WATER RESOURCES MODEL	SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY	PROPSON T; RAHN P; DAVIS A; DRISCOLL D
NM	CHARACTERIZATION OF DEEP SALINE AQUIFERS IN THE ROSWELL BASIN OF NEW MEXICO FROM LITHOLOGIC ANALYSIS AND GEOPHYSICAL WELL LOGS	NEW MEXICO INSTITUTE OF MINING & TECHN	MACMILLAN J; GROSS G
WY	CHARACTERIZATION OF MECHANICS, RATES, WATER QUALITIES, AND SEASONAL VARIATIONS ASSOCIATED WITH GROUND WATER RECHARGE IN THE UPLAND ZONES OF TYPICAL WYOMING FORELAND AND THRUST	UNIVERSITY OF WYOMING	HUNTOON P
FL	DETERMINING SOIL-WATER SEASONAL MOVEMENT	UNIVERSITY OF FLORIDA	COLLINS M; BROWN R
AZ	DEVELOPMENT OF A MODEL FOR AUTOMATED FLASH FLOOD FORECASTING IN ARID WATERSHEDS	UNIVERSITY OF ARIZONA	SOROOSHIAN S
WY	DEVELOPMENT, MANAGEMENT AND CONSERVATION OF WATER RESOURCES	UNIV OF WYOMING LARAMIE	JACOBS J J; HELD L J
UT	DYNAMIC ANALYSIS OF HYDROLOGIC SYSTEMS IN THE MOUNTAINS AND LOWLANDS OF CLOSED BASINS	UTAH STATE UNIVERSITY	DUFFY C
OR	EFFECTS OF RIPARIAN VEGETATION ON GROUNDWATER HYDROLOGY AND THE ANNUAL HYDROGRAPH OF RANGELAND STREAMS	OREGON STATE UNIVERSITY	BESCHTA R; CHILDS S; BARBER J
NH	ESTIMATION OF LOW FLOWS IN SMALL UNGAGED WATERSHEDS VIA CORRELATION WITH CONCURRENT FLOWS IN GAGED WATERSHEDS AND REGIONAL ANALYSIS	UNIVERSITY OF NEW HAMPSHIRE	DINGMAN S
NV	ESTIMATION OF LEAKAGE BETWEEN AQUIFERS OF THE LAS VEGAS VALLEY, NEVADA	UNIVERSITY OF NEVADA	MIZELL S; HESS J; POHLMANN K; BROTHERS K
MI	HYDROGEOLOGICAL AND HYDROGEOCHEMICAL CHARACTERIZATION AND IMPLICATION FOR CONSUMPTIVE USE OF A LARGE GLACIAL-DRIFT AQUIFER SYSTEM IN SOUTHWEST MICHIGAN	WESTERN MICHIGAN UNIVERSITY	STRAW W; KEHEW A; WALLACE R
MI	HYDROGEOLOGY OF PONNPEI	UNIVERSITY OF HAWAII	PETERSON F; MINK J
SC	HYDROGEOLOGY OF UNSATURATED PIEDMONT SAPROLITE	CLEMSON UNIVERSITY	WHITE R; LOGON J
OK	HYDROLOGIC MODELLING THROUGH THE INTEGRATION OF REMOTELY SENSED DATA IN A GEOGRAPHIC INFORMATION SYSTEM	OKLAHOMA STATE UNIVERSITY	VITEK J; GREGORY M
GU	LOSS OF FRESHWATER FROM AQUIFER AND STORM WATER DISCHARGE TO THE COASTAL ZONE OF GUAM	UNIVERSITY OF GUAM	MATSON E
IN	MEASUREMENT OF RECHARGE RATES AND GROUNDWATER VELOCITIES BY TRITIUM AND CARBON-14 ANALYSES IN THE WASBASH RIVER AQUIFERS	PURDUE UNIVERSITY	FRITZ S; LEAP D
KY	MODELLING MASS TRANSPORT IN AQUIFERS: THE DISTRIBUTED SOURCE PROBLEM	UNIVERSITY OF KENTUCKY	SERRANO S
CA	PHYSICS-BASED STOCHASTIC DESCRIPTION OF OVERLAND FLOWS DUE TO EXCESS APPLIED IRRIGATION WATER OVER AN INFILTRATING AGRICULTURAL REGION	UNIVERSITY OF CALIFORNIA	KAVVAS M
ID	PRELIMINARY EVALUATION OF GROUNDWATER INFLOW TO COEUR D'ALENE LAKE FROM THE COEUR D'ALENE RIVER VALLEY	UNIVERSITY OF IDAHO	RALSTON D; SPRENKE K
KY	REGIONALIZATION OF FLOOD DATA USING PROBABILITY DISTRIBUTIONS AND THEIR PARAMETERS	UNIVERSITY OF LOUISVILLE	BHASKAR N; O'CONNOR C

ST	TITLE	LOCATION	INVESTIGATORS
NV	RELATIVE AGE DATING OF GROUNDWATER: A COMPARISON OF THE FLUOROCARBON METHOD TO THE TRITIUM METHOD	UNIVERSITY OF NEVADA	MILLER G; SERTIC K; MILLER M; HEIDKER J
ID	RESEARCH AND FRACTURE FLOW MODEL STUDY FOR THE BOISE POINT FRONT LOW TEMPERATURE GEOTHERMAL GROUNDWATER MANAGEMENT AREA	BOISE STATE UNIVERSITY	WAAG C; WOOD S
KS	STREAM FLOODWAVE PROPAGATION THROUGH THE GREAT BEND ALLUVIAL AQUIFER: A SIGNIFICANT RECHARGE AND STREAM-AQUIFER INTERACTION MECHANISM?	UNIVERSITY OF KANSAS	SOPHOCLEOUS M
MN	SUBSURFACE FLOW BETWEEN UPLAND AND WETLAND SYSTEMS	UNIVERSITY OF MINNESOTA	BROOKS K
ID	UNCERTAINTY AND SENSITIVITY ANALYSES OF PARAMETERS IN A REGIONAL GROUNDWATER FLOW AND RECHARGE MODEL	UNIVERSITY OF IDAHO	BROCKWAY C

CATEGORY 2: METEOROLOGY

HI	DROUGHT IN HAWAII	UNIVERSITY OF HAWAI AT MANOA	GIAMBELLUCA T
NC	MICROCLIMATE MODIFICATION AND USE IN PREDICTION OF AGRICULTURAL SYSTEMS	NORTH CAROLINA STATE UNIV RALEIGH	PERRY K B
VI	PREDICTING RAINFALL VARIABILITY FOR WATER RESOURCES MANAGEMENT IN THE U.S. VIRGIN ISLANDS	UNIVERSITY OF VIRGIN ISLANDS	MILLS F; INIAMA E; KRISHNA H

CATEGORY 3: IRRIGATION AGRONOMY

CA	ACID STRESS ON CROPS UNDER LOW VOLUME IRRIGATION	UNIV OF CALIFORNIA DAVIS	ZASOSKI R J; BURAU R G; DAHLGREN R A
LA	AGRONOMIC RESEARCH WITH GRAIN SORGHUM FOR NORTHEAST LOUISIANA	NE LOUISIANA AGRIC EXPT STA ST JOSEPH	MILAM M R
OR	AGRONOMIC PRACTICES FOR CROP PRODUCTION IN NORTHEAST OREGON	PO BOX 370 PENDLETON	SMILER R.W.; HANE D C
OH	AN EVALUATION OF WATER TABLE MANAGEMENT AS A BMP AFFECTING WATER QUALITY	OHIO STATE UNIV COLUMBUS	WARD A D; KRETCHMAN D W; LOGAN T J
OR	ANALYSIS OF PENMAN EQUATION WIND FUNCTION AND CROP WATER REQUIREMENT ESTIMATES	OREGON STATE UNIV CORVALLIS	CUENCA R H
FL	BIOLOGY AND MANAGEMENT OF NEMATODES AFFECTING VEGETABLE CROPS	UNIVERSITY OF FLORIDA BRADENTON	OVERMAN A J
LA	BREEDING AND CULTURE OF VEGETABLE CROPS FOR COMMERCIAL PRODUCTION IN LOUISIANA	CALHOUN RESEARCH STATION CALHOUN	LANCASTER D M; JOHNSON C E
PA	CALCIUM-RELATED DISORDERS OF APPLES AS AFFECTED BY CULTURAL TREATMENTS	PENNSYLVANIA STATE UNIVERSITY	GREENE G M; SMITH C B

ST	TITLE	LOCATION	INVESTIGATORS
HI	COFFEE-NUTRITION AND IRRIGATION	UNIV OF HAWAII HONOLULU	KOBAYASHI K D; NAGAO M A
OH	CONTROL OF ORNAMENTAL PLANT DISEASES: A SYSTEMS MANAGEMENT APPROACH	OHIO STATE UNIV WOOSTER	POWELL C C
KS	CROP PRODUCTION IN STRESSFUL ENVIRONMENT	KANSAS STATE UNIV MANHATTAN	KANEMASU E T; KIRKHAM M B; STONE L R
MO	CROP PRODUCTION/SOIL FERTILITY: MAXIMIZING CROP PRODUCTION EFFICIENCIES IN S. E. MISSOURI	UNIVERSITY OF MISSOURI COLUMBIA	TRACY P W
MT	CROP WATER REQUIREMENTS	MONTANA STATE UNIVERSITY BOZEMAN	WESTESEN G L
ND	CROP PRODUCTION ON THE GLACIAL DRIFT PRAIRIES OF NORTH DAKOTA	CARRINGTON AGRIC EXPT STATION CARRINGTON	SCHATZ B G; GARDNER J C
UT	CROP AND PHREATOPHYTE WATER USE IN IRRIGATION SYSTEMS MANAGEMENT	UTAH STATE UNIVERSITY LOGAN	HILL R W; ALLEN R G
WA	CROP PRODUCTION VERSUS IRRIGATION WATER APPLIED FUNCTIONS FOR WASHINGTON	WASHINGTON STATE UNIVERSITY	JAMES L
MS	CROPPING SYSTEMS AND MANAGEMENT PRACTICES TO ENHANCE FARM INCOME IN THE DELTA OF MISSISSIPPI	PO BOX 197 STONEVILLE	TUPPER G R; PRINGLE H C; PENNINGTON D A
AZ	CULTURAL AND WATER MANAGEMENT FOR NEW AND ALTERNATIVE AGRICULTURAL CROPS	AGRICULTURAL RESEARCH SERVICE PHOENIX	NAKAYAMA F S; BUCKS D A; ALLEN S C
OK	CULTURAL AND MANAGEMENT EFFCTS ON YIELD COMPONENTS OF WARM-SEASON GRASSES AND LEGUMES	AGRICULTURAL RESEARCH SERVICE STILLWATER	KINDLER D
OR	DETERMINATION OF CROP WATER REQUIREMENTS IN THE EBRO VALLEY	OREGON STATE UNIV CORVALLIS	CUENCA R H
WA	DEVELOP WEED MANAGEMENT STRATEGIES IN IRRIGATED HORTICULTURAL CROPS	AGRICULTURAL RESEARCH SERVICE PROSSER	BOYDSTON R A
ID	DEVELOPING IMPROVED FORAGE MANAGEMENT SYSTEMS IN IDAHO	UNIV OF IDAHO MOSCOW	HALL M H
HI	DEVELOPMENT OF CHEMICAL CONTROL MEASURES FOR PLANT PARASITIC NEMATODES ON PINEAPPLES	UNIV OF HAWAII HONOLULU	APT W J; CASWELL E P
MT	DEVELOPMENT OF NEW AND IMPROVED CROPS FOR WATER CONSERVATION IN ARID LANDS	MONTANA STATE UNIVERSITY BOZEMAN	SCHAEFFER J R; SMITH C W
TX	DEVELOPMENT OF NEW AND IMPROVED CROPS FOR WATER CONSERVATION IN ARID LANDS	TEXAS A&M UNIVERSITY PECOS	MOORE J
TX	DEVELOPMENT OF INTEGRATED MANAGEMENT SYSTEMS FOR PRODUCING COTTON MORE EFFICIENTLY	AGRICULTURAL RESEARCH SERVICE WESLACO	NAMKEN L N; NEILMAN M D
MN	DISEASES OF WHEAT	UNIV OF MINNESOTA ST PAUL	WILCOXSON R D; KOMMEDAHL T; BISSONNETTE H
OK	DOUBLE-CROPPING SOYBEANS UNDER RAINFED AND IRRIGATED CONDITIONS IN THE SOUTHERN GREAT PLAINS	OKLAHOMA STATE UNIVERSITY STILLWATER	CRABTREE R J; EDWARDS L H; SMITH E L
TX	DROUGHT TOLERANT LANDSCAPE PLANTS FOR THE CHIHUAHUAN DESERT AREA	TEXAS A&M UNIV EL PASO	TIPTON J L

ST	TITLE	LOCATION	INVESTIGATORS
OH	EFFECT OF HIGH TEMPERATURE STRESS ON THE SURVIVAL RATE OF ANNUAL BLUEGRASS BIOTYPES	OHIO STATE UNIV WOOSTER	DANNEBERGER T K
TX	EFFECT OF IRRIGATION ON DEVELOPMENT OF SEEDLINGS OF PECAN BREEDING PROGRAM	TEXAS A&M UNIV COLLEGE STATION	THOMPSON T E; HUNTER R E; STOREY J B
AR	EFFECTS OF SOIL WATER STRESSES ON SOYBEANS GROWN ON CLAYEY SOILS	UNIV OF ARKANSAS FAYETTEVILLE	SCOTT H D; FERGUSON J A; STUTTE C A
GA	EFFICIENT FERTILIZER AND IRRIGATION MANAGEMENT FOR VEGETABLE PRODUCTION	GEORGIA AGRIC EXPT STATION EXPERIMENT	BEVERLY R B
AR	ENHANCEMENT OF SOYBEAN YIELD POTENTIAL BY IMPROVING PRODUCTION SYSTEMS	UNIV OF ARKANSAS FAYETTEVILLE	OLIVER L R; BACON R K; TALBERT R E
NV	ENHANCEMENT OF THE SOUTHERN NEVADA WATER CONSERVATION RESEARCH PROGRAM	UNIVERSITY OF NEVADA RENO	DEVITT D A; MORRIS R L
FL	ENVIRONMENTAL PHYSIOLOGICAL LIMITATIONS TO INCREASED EFFICIENCY IN CROP PRODUCTION	AGRICULTURAL RESEARCH SERVICE GAINESVILLE	SINCLAIR T R
WA	ENVIRONMENTAL FACTORS AND MANAGEMENT PRACTICES AS THEY INFLUENCE CROP PHYSIOLOGY AND COLD HARDINESS	WASHINGTON STATE UNIVERSITY PROSSER	WAMPLE R L
SC	ESTABLISHMENT AND MANAGEMENT OF FORAGE CROPS UNDER STRESSES OF ENVIRONMENT AND BIOTIC ORIGIN	CLEMSON UNIVERSITY CLEMSON	STRINGER W C; RICE J S; CROSS D L
GU	EVALUATION OF DIFFERENT CULTURAL METHODS FOR PRODUCTION OF ORNAMENTAL PLANTS IN GUAM	UNIVERSITY OF GUAM UGO STATION MANGILAO	MCCONNELL J
LA	EVALUATION OF VARIETIES, CROPPING SYSTEMS, NITROGEN FERTILIZATION AND IRRIGATION FOR COTTON PRODUCTION	NE LOUISIANA AGRIC EXPT STA ST JOSEPH	BOQUET D J; BREITENBECK G A
MD	EVALUATION OF VEGETABLE VARIETIES & MODERN CULTURAL PRACTICES TO MAXIMIZE LAND USE ON SMALL FARMS	BELTSVILLE AGR RES CENTER BELTSVILLE	BARKSDALE T H; CANTELO W W; GOTH R W
NE	EVALUATION OF COMPLEMENTARY FORAGE SYSTEM	UNIVERSITY OF NEBRASKA LINCOLN	NICHOLS J T
NM	EVALUATION OF GRAPE CULTIVARS AND CULTURAL PRACTICES IN NEW MEXICO	NEW MEXICO STATE UNIV LAS CRUCES	HOOKS R F; CORGAN J N
OK	EVALUATION OF COTTON VARIETIES FOR OKLAHOMA	OKLAHOMA STATE UNIVERSITY STILLWATER	VERHALEN L M; THACKER R W; HOOPER D W
WY	EVALUATION OF ADAPTATION AND PRODUCTION OF SMALL GRAIN VARIETIES WITHIN CROPPING SYSTEMS IN COOPERAT	UNIV OF WYOMING LARAMIE	KRALL J; LAUER J
OK	FERTILITY AND CULTURAL MANAGEMENT OF VEGETABLES IN SOUTHEASTERN OKLAHOMA	OKLAHOMA STATE UNIVERSITY STILLWATER	ROBERTS B W
TX	FERTILIZER AND INTERRELATED RESPONSES OF SOILS AND CROPS GROWN ON THE TEXAS HIGH PLAINS	RT 3 BOX 219 LUBBOCK	ONKEN A B; NESMITH D M
GA	FIELD CROP INSECT CONTROL VIA MGT INPUTS DELIVERED IN IRRIGATION WATER & BY CONVL.APPLICATION METHOD	AGRICULTURAL RESEARCH SERVICE TIFTON	GROSS H R; YOUNG J R; SUMNER H R
NM	FIELD ANALYSIS OF THE ROLE OF THREE-DIMENSIONAL MOISTURE FLOW IN GROUND-WATER RECHARGE AND EVAPOTRANSPIRATION	NEW MEXICO INSTITUTE OF MINING & TECHN	STEPHENS D
MT	FORAGE CROPS FOR EASTERN MONTANA	PO BOX 1109 SIDNEY	BERGMAN J W; ECKHOFF J L A

ST	TITLE	LOCATION	INVESTIGATORS
MT	FORAGE CROP PRODUCTION AND QUALITY	MONTANA STATE UNIVERSITY KALISPELL	WELTY L E
AR	FRUIT AND NUT TESTING BREEDING AND SPECIAL PRACTICES	UNIV OF ARKANSAS FAYETTEVILLE	MOORE J N; ROM R C
MS	GROWTH AND DEVELOPMENT OF FLORICULTURAL CROPS	MISSISSIPPI STATE UNIVERSITY	NEWMAN S E
LA	HOST PLANT RESISTANCE IN COTTON TO INSECTS, MITES, NEMATODES AND DISEASE	LOUISIANA STATE UNIV BATON ROUGE	GRAVES J B
CO	IDENTIFY AND QUANTIFY PLANT-SOIL AND BIOLOGICAL N-FIXATION PROCESSES TO INCREASE N-USE EFFICIENCY	AGRICULTURAL RESEARCH SERVICE FORT COLLINS	PORTER L K; NORSTADT F A; HUNTER W J
MN	IDENTIFY & MANAGE WATER & CHEMICAL SINKS IN CONSERVATION PRODUCTION SYSTEMS	AGRICULTURAL RESEARCH SERVICE MORRIS	REICOSKY D C; OLNESS A E; WESTGATE M E
CO	IMPROVEMENT OF QUALITY AND PERFORMANCE OF COLORADO WHEAT	COLORADO STATE UNIV FORT COLLINS	QUICK J S
KS	IMPROVEMENT OF CROP PLANTS FOR SOUTHWEST KANSAS	KANSAS STATE UNIVERSITY GARDEN CITY	WITT M
LA	IMPROVEMENT OF COTTON PRODUCTION ON ACID, DROUGHT PRONE SOILS	LOUISIANA STATE UNIV BATON ROUGE	KENNEDY C W; JONES J E
AZ	IMPROVING ALFALFA SALT TOLERANCE VIA A VERTICAL INTEGRATION OF BIOTECHNOLOGY AND PLANT BREEDING STRATEGIES	UNIVERSITY OF ARIZONA	DOBRENZ A; GOLDSTEIN A; MCCOY T; SMITH S
OR	IMPROVING THE EFFICIENCY OF IRRIGATED FORAGE CROP PRODUCTION IN CENTRAL OREGON	PO BOX 246 REDMOND	NELSON J L; HANNAWAY D; BALLERSTEDT P J
OR	IMPROVING ROW CROP PRODUCTION BY IDENTIFYING SUPERIOR VARIETIES AND CULTURAL METHODS	595 ONION AVENUE ONTARIO	STANGER C E; ISHIDA J
CA	INFLUENCE OF ENVIRONMENTAL STRESSES ON DEVELOPMENT AND IMPACT OF PHYTOPHTHORA ROOT ROT	UNIV OF CALIFORNIA DAVIS	DUNIWAY J M
GA	INFLUENCE OF DROUGHT/TRAFFIC STRESSES AND MANAGEMENT ON TURFGRASS GROWTH AND WATER RELATIONS	GEORGIA AGRIC EXPT STATION EXPERIMENT	CARROW R N
NE	INFLUENCE OF PRODUCTION PRACTICES ON YIELD AND GRAIN QUALITY OF MAIZE AND WINTER WHEAT	UNIVERSITY OF NEBRASKA LINCOLN	MASON S C
MS	INTEGRATE EQUIPMENT, WEED CONTROL & CULTURAL PRACTICES INTO EFFICIENT CROP PRODUCTION SYSTEMS	AGRICULTURAL RESEARCH SERVICE STONEVILLE	WILLIFORD J R; SMITH L A; WESLEY R A
CA	INTEGRATED SYSTEMS FOR BED-GROWN PERENNIALS, EMPHASIS STRAWBERRIES	UNIV OF CALIFORNIA DAVIS	VOTH V; BRINGHURST R S
HI	INTEGRATED PEST MANAGEMENT FOR PINEAPPLE DISEASES	UNIV OF HAWAII HONOLULU	ROHRBACH K G; YUEN J E
OR	INTEGRATED PRODUCTION SYSTEMS FOR ORNAMENTAL PLANTS	OREGON STATE UNIV CORVALLIS	GREEN J L
TX	INTEGRATED RESEARCH PROGRAM FOR GUAYULE IN TEXAS	TEXAS A&M UNIVERSITY PECOS	MOORE J; WAGNER J; FOSTER M
CA	INTEGRATIVE PHYSIOLOGY OF CROP PRODUCTION SYSTEMS	UNIV OF CALIFORNIA DAVIS	LOOMIS R S

ST	TITLE	LOCATION	INVESTIGATORS
IA	INTERACTIONS OF MOISTURE STRESS, HOST PLANT GENOTYPE, AND SEVERITY OF BSR OF SOYBEANS	AGRICULTURAL RESEARCH SERVICE AMES	TACHIBANA H
IA	IOWA VEGETABLE CROP PRODUCTION - MISSOURI RIVER VALLEY	IOWA STATE UNIV AMES	HALL C W; DEBUCHANANNE D
CO	IRRIGATION, DRAINAGE AND TILLAGE PRACTICES FOR ENHANCED AGRICULTURAL PROFITABILITY	COLORADO STATE UNIV FORT COLLINS	EARLY A C; AYERS P D; ISRAELI I
DE	IRRIGATION MANAGEMENT OF FIELD AND VEGETABLE CROPS	UNIV OF DELAWARE NEWARK	RITTER W F SCA; RBOROUGH R W; WILLIAMS T H
GA	IRRIGATION STUDIES WITH SELECTED VEGETABLE CROPS	FORT VALLEY STATE COLLEGE FORT VALLEY	SINGH B P
ID	IRRIGATION MANAGEMENT AND CULTURAL PRACTICES TO IMPROVE POTATO TUBER QUALITY PARAMETERS	AGRICULTURAL RESEARCH SERVICE KIMBERLY	WESTERMANN D T; SOJKA R E; KINCAID D C
IA	IRRIGATION AND FERTILIZER EFFICIENCY FOR PROCESSING POTATOES	IOWA STATE UNIV AMES	TABER H G; LAWSON V; DEBUCHA-NANNE D
KS	IRRIGATION EXPERIMENT FIELD, SCANDIA, KANSAS	KANSAS STATE UNIV MANHATTAN	RANEY R J; THIERSTEIN G E
AL	LEACHING, ACCUMULATION AND PLANT AVAILABILITY OF BORON IN ACID ULTISOLS	AUBURN UNIV AUBURN	ODOM J W
LA	LOUISIANA STATE SOIL TESTING LABORATORY	LOUISIANA STATE UNIV BATON ROUGE	KOVAR J; HENDERSON R E; SEDBERRY J E JR
CA	LYSIMETER STUDY OF WATER REQUIREMENTS FOR PERENNIAL CROPS	UNIV OF CALIFORNIA BERKELEY	HOFFMAN G J; PHENE C J; JOHNSON R S
CA	MANAGEMENT PRACTICES FOR IMPROVED EFFICIENCY OF COTTON PRODUCTION	UNIV OF CALIFORNIA DAVIS	KERBY T A
NY	MANAGEMENT OF INSECT PESTS OF BEAN FOLIAGE AND PODS	N Y AGRICULTURE EXPT STATION GENEVA	ECKENRODE C J
TN	MANAGEMENT STRATEGIES FOR CONTROL OF VEGETABLE DISEASES IN TENNESSEE	UNIVERSITY OF TEN-NESSEE KNOXVILLE	CANADAY C H
CO	MANAGING PLANT SPECIES FOR MEADOW IMPROVEMENT	COLORADO STATE UNIV FORT COLLINS	SIEMER E G
CA	MEASUREMENT AND MODELING OF WATER, SALT, AND ENERGY MOVEMENT THROUGH SOIL	UNIVERSITY OF CALIFOR-NIA RIVERSIDE	JURY W A; STOLZY L H; SPENCER W F
MI	MINERAL NUTRITION OF MICHIGAN FRUIT CROPS	MICHIGAN STATE UNIV EAST LANSING	HANSON E J
MT	MISCELLANEOUS RESEARCH IN AGRICULTURAL ENGINEERING	MONTANA STATE UNIVER-SITY BOZEMAN	LARSEN W E; HANSON T L
MI	MODELING CROP RESPONSES & ENVIRONMENTAL FACTORS RELATED TO SHORTAGE & EXCESSES OF WATER	MICHIGAN STATE UNIV EAST LANSING	RITCHIE J
NE	MODELING WATER USE AND GROWTH OF PLANTS	UNIVERSITY OF NEBRASKA LINCOLN	NORMAN J M
CO	MODELS, PHYSICS, AND PHYSIOLOGY OF SOIL-PLANT WATER TRANSPORT, IRRIGATION AND STRESS CONTROL	AGRICULTURAL RESEARCH SERVICE FORT COLLINS	FISCUS E L

ST	TITLE	LOCATION	INVESTIGATORS
OH	N RESPONSE IN SOYBEANS GROWN UNDER A SUBIRRIGATION/DRAINAGE SYSTEM	AGRICULTURAL RESEARCH SERVICE WOOSTER	COOPER RL
GA	NEMATODE AND INTEGRATED PEST MANAGEMENT SYSTEMS FOR THE SOUTHEASTERN COASTAL PLAIN	AGRICULTURAL RESEARCH SERVICE TIFTON	JOHNSON A W
AR	NITROGEN UTILIZATION IN SELECTED GRASS/LEGUME MIXTURES	UNIV OF ARKANSAS FAYETTEVILLE	SABBE W E; WEST C P
AR	NITROGEN FERTILIZER MANAGEMENT AND CULTURAL PRACTICES FOR WHEAT, GRAIN SORGHUM, AND CORN	NORTHEAST BRANCH STATION KEISER	MASCAGNI H J; SABBE W E
AZ	NITROGEN REQUIREMENTS OF CROPS GROWN UNDER DIFFERENT MOISTURE REGIMES	UNIV OF ARIZONA TUCSON	GARDNER B R; TUCKER T C; ROTH R L
MI	OPTIMIZATION OF THE ROOT ZONE ENVIRONMENT IN GREENHOUSE CROP PRODUCTION	MICHIGAN STATE UNIV EAST LANSING	BIERNBAUM J A
OR	OPTIMIZING VEGETABLE CROP PRODUCTION	OREGON STATE UNIV CORVALLIS	MACK H J
TX	OPTIMIZING SOIL NUTRIENT STATUS FOR BEST WATER USE UNDER DRYLAND, IRRIGATION, AND LIMITED IRRIGATION	AGRICULTURAL RESEARCH SERVICE BUSHLAND	ECK H V; JONES O R
WA	ORCHARD FACTORS IN STONE FRUIT QUALITY	WASHINGTON STATE UNIVERSITY PROSSER	PROEBSTING E L; PATTERSON M E; PATTERSON M E
LA	ORNAMENTAL PLANT PRODUCTION RESEARCH	HAMMOND RESEARCH STATION HAMMOND	BROWN W L
VA	PEANUT PROD. EFFICIENCY IMPROVED THRU TILLAGE SYSTEMS, SOIL & WATER MANAGEMENT AND PEST CONTROL	AGRICULTURAL RESEARCH SERVICE SUFFOLK	WRIGHT F S; ADAMSEN F J; PORTER D M
TX	PECAN GROWTH AND DEVELOPMENT, IN RELATION TO WATER STRESS AND DYNAMICS	PO BOX 292 STEPHENVILLE	WORTHINGTON J W; MCFARLAND M J; LASSWELL J L
OR	PHYSICAL TESTING OF SOILS	OREGON STATE UNIV CORVALLIS	WARKENTIN B P
MS	PHYSIOLOGICAL, PATHOLOGICAL, ENVIRONMENTAL AND CULTURAL STUDIES OF SELECTED LANDSCAPE PLANTS	SOUTH MISS BR EXPERIMENT ST POPLARVILLE	LAICHE A J JR; SPENCER J A; NEWMAN S E
AZ	PINK BOLLWORM POPULATION DYNAMICS AND RELATION TO OTHER COTTON INSECT SPECIES	AGRICULTURAL RESEARCH SERVICE PHOENIX	HENNEBRRY T J; AKEY D H; TBD
ID	PLANT AND SOIL TEST CALIBRATION FOR IRRIGATED CROPS IN SOUTHERN IDAHO	UNIV OF IDAHO MOSCOW	BROWN B D
VA	PLANT WATER STRESS MONITORING AND CONTROL	VIRGINIA POLY INST BLACKSBURG	BYLER R K
MS	PRODUCTION AND PROCESSING RESEARCH FOR NON-FERMENTED PRODUCTS OF MUSCADINE GRAPES	MISSISSIPPI STATE UNIV	AMMERMAN G R; HEGWOOD C P; VINE R P
OR	PRODUCTION AND MANAGEMENT OF NURSERY PLANTS	15210 NE MILEY RD AURORA	TICKNOR R L
VT	PROPAGATION AND EVALUATION OF ORNAMENTAL WOODY PLANTS FOR THE NORTHEASTERN U.S.	UNIVERSITY OF VERMONT BURLINGTON	PELLETT N E
CA	QUANTIFICATION OF WATER AND SOLUTE TRANSPORT MECHANISMS IN ROOT AND VADOSE ZONES	AGRICULTURAL RESEARCH SERVICE RIVERSIDE	DALTON F N; VAN GENUCHTEN R; SHOUSE P J

ST	TITLE	LOCATION	INVESTIGATORS
OR	RANGE LIVESTOCK NUTRITION AND MANAGEMENT	STAR RT. 1-4.5 HWY 205 BURNS	VAVRA M; RALEIGH R J; TURNER H A
CO	ROOT ROT OF WHEAT: RESISTANCE, YIELD LOSS, AND DISEASE CONTROL	COLORADO STATE UNIV FORT COLLINS	HILL J P
CA	SALT AND WATER FLUXES THROUGH SOIL-PLANT SYSTEMS	UNIVERSITY OF CALIFORNIA RIVERSIDE	VAN GENUCHTEN R; JURY W A
KS	SANDYLAND EXPERIMENT FIELD	KANSAS STATE UNIV MANHATTAN	TENEYCK G R; GREENLAND R C
ID	SELECTION AND CHARACTERIZATION OF DROUGHT TOLERANT POTATO GERMPLASM	UNIV OF IDAHO MOSCOW	STARK J C; DWELLE R B; PAVEK J J
GA	SIMULATION OF CROP ROOT RESPONSE TO SOIL WATER AND SOIL STRENGTH	GEORGIA COASTAL PLAIN EXPT STA TIFTON	HOOK J E; THREADGILL E D
MT	SMALL GRAIN PRODUCTION FOR EASTERN MONTANA	PO BOX 1109 SIDNEY	ECKHOFF J L A; BERGMAN J W
OR	SMALL FRUIT AND VEGETABLE CROP CULTIVARS AND THEIR PRODUCTION REQUIREMENTS IN SOUTHERN OREGON	569 HANLEY ROAD MEDFORD	SUGAR D; SUGAR D
AZ	SOIL THERMAL RESPONSES TO SURFACE CONFIGURATION, IRRIGATION, AND MICROMETEOROLOGICAL FACTORS	UNIV OF ARIZONA TUCSON	MATTHIAS A D
IL	SOIL AND CROP MANAGEMENT PRACTICES FOR SOUTHWEST ILLINOIS SOIL ASSOCIATIONS (4 AND 34)	1301 WEST GREGORY DRIVE URBANA	BOONE L V; RAINES G A
MT	SOIL FERTILITY, PLANT NUTRITION, AND IRRIGATION MANAGEMENT	MONTANA STATE UNIVERSITY BOZEMAN	ENGEL R E
OR	SOIL AND IRRIGATION MANAGEMENT EFFECTS ON POTATO PRODUCTION AND QUALITY	595 ONION AVENUE ONTARIO	SHOCK C C; STIEBER T; ELDREDGE
OR	SOIL AND IRRIGATION MANAGEMENT EFFECTS ON POTATO PRODUCTION AND QUALITY	OREGON STATE UNIV CORVALLIS	KOONG L J; SHOCK C C; STIEBER
NE	SORGHUM & CORN BREEDING & CORN, SORGHUM, & WHEAT VARIETY EVAL. UNDERCENTRAL NE ENVIRONMENT CONDITION	UNIVERSITY OF NEBRASKA LINCOLN	NORDQUIST P T
LA	SOYBEAN PRODUCTION RESEARCH FOR THE LOESSIAL TERRACE SOILS OF NORTHEAST LOUISIANA	NE LOUISIANA AGRIC EXPT STA ST JOSEPH	HUTCHINSON R L
LA	STUDIES OF CULTIVAR, ADAPTATION AND CULTURAL PRACTICES WITH PECANS	LOUISIANA STATE UNIV BATON ROUGE	BOUDREAUX J
CO	STUDY THE PHYSICS AND DEVELOP THEORY OF INFILTRATION FOR IMPROVED IRRIGATION	COLORADO STATE UNIV FORT COLLINS	AYERS P; HEERMAN D F
MT	SUGARBEET PRODUCTION FOR EASTERN MONTANA	EASTERN MONTANA AGRIC EXPT STA SIDNEY	BERGMAN J W; ECKHOFF J L A
LA	SURVIVAL AND GROWTH OF TWO SOURCES OF FERTILIZED AND IRRIGATED VIRGINIA PINE IN A NORTH LOUISIANA CH	LOUISIANA TECH UNIVERSITY RUSTON	ROWELL C E
IA	THE EFFECT OF WATER TABLE MANAGEMENT ON PRODUCTIVITY AND WATER QUALITY	IOWA STATE UNIV AMES	KANWAR R S; BAKER J L; FENTON T E
WA	THE BIOLOGY AND CONTROL OF ECONOMICALLY-IMPORTANT POTATO PATHOGENS	WASHINGTON STATE UNIVERSITY PROSSER	EASTON G D; MARTIN M W; ROBERTS S
CO	TURFGRASS WATER USE & VARIETAL EVALUATIONS	COLORADO STATE UNIV FORT COLLINS	KOSKI A J

ST	TITLE	LOCATION	INVESTIGATORS
IN	TURFGRASS CULTURE AND MANAGEMENT SYSTEMS	PURDUE UNIVERSITY WEST LAFAYETTE	THROSSELL C S
TN	VARIATION IN SOIL SOLUTION COMPOSITION IN FIELD ENVIRONMENTS	UNIVERSITY OF TENNESSEE KNOXVILLE	WOLT J D
OR	VARIETAL DEVELOPMENT AND CROP, SOIL AND WATER MANAGEMENT FOR IRRIGATED CEREALS IN CENTRAL OREGON	PO BOX 246 REDMOND	CROWE F
OR	VARIETY EVALUATION AND MANAGEMENT OF CEREALS AND FORAGES FOR EASTERN OREGON	595 ONION AVENUE ONTARIO	SHOCK C C; BURNETT C R
TX	VEGETABLE PRODUCTION AND HORTICULTURAL PRACTICES UNDER ARIDCONDITIONS	TEXAS A&M UNIV EL PASO	TAYLOR R M; FENN L B; MIYAMOTO S
TX	VEGETABLE PRODUCTION AND EVALUATION IN EAST TEXAS	TEXAS A&M UNIV OVERTON	PATERSON D R
WA	VITICULTURAL, ENOLOGICAL, AND ECONOMIC ASPECTS OF WINE GRAPE PRODUCTION IN WASHINGTON	WASHINGTON STATE UNIVERSITY PULLMAN	FOLWELL R J; NAGEL C; SPAYD S
CA	WATER MANAGEMENT ON SLOWLY PERMEABLE SOILS	UNIV OF CALIFORNIA DAVIS	GRIMES D W
GA	WATER MANAGEMENT OF PEACH AND PECAN TREES	GEORGIA AGRIC EXPT STATION EXPERIMENT	DANIELL J W
GA	WATER AND NUTRIENT MANAGEMENT TECHNOLOGY IN MULTIPLE-CROP VEGETABLES	GEORGIA COASTAL PLAIN EXPT STA TIFTON	SMITTLE D A
LA	WATER MANAGEMENT FOR VEGETABLES, FRUITS AND ORNAMENTALS IN LOUISIANA	LOUISIANA STATE UNIV BATON ROUGE	EDLING R J; BRACY R P
OH	WATER MANAGEMENT AND CROP ROTATIONS FOR VEGETABLE CROPS	OHIO STATE UNIV WOOSTER	KRETCHMAN D W; WARD A; FAUSEY N R
TX	WATER, NUTRIENT AND SALINITY MANAGEMENT FOR SUSTAINED MAXIMUM YIELDS IN THE LOWER RIO GRANDE VALLEY	2415 EAST HIGHWAY 83 WESLACO	BOGLE C R
GA	WEED BIOLOGY, ECOLOGY, MGMT SYSTEMS AND HERBICIDE APPLICATION TECH. ON COASTAL PLAIN IRRIGATED CROPS	AGRICULTURAL RESEARCH SERVICE TIFTON	DOWLER C C
NE	WEED CONTROL SYSTEMS FOR WESTERN NEBRASKA IRRIGATED CROPS AND RANGELAND	UNIVERSITY OF NEBRASKA LINCOLN	WILSON R G
WA	WEED CONTROL RESEARCH IN IRRIGATED HORTICULTURAL AND SPECIALTY CROPS	WASHINGTON STATE UNIVERSITY PROSSER	BOYDSTON R A; OGG A G

ST	TITLE	LOCATION	INVESTIGATORS	10
CATEGORY 4: ON-FARM APPLICATION				
CO	DESIGN CRITERIA & INTEGRATED MANAGEMENT TECHNOLOGY FOR SURFACE AND CENTER PIVOT IRRIGATION SYSTEMS	AGRICULTURAL RESEARCH SERVICE FORT COLLINS	HEERMANN D F; DUKE H R; BAUSCH W C	
AZ	EVAPOTRANSPIRATION FROM DRIP IRRIGATED COTTON	UNIV OF ARIZONA TUCSON	GAY L W	
NE	IRRIGATION AND FARMSTEAD ELECTRICAL DEMANDS, LOAD MANAGEMENT AND SAFETY	UNIVERSITY OF NEBRASKA LINCOLN	STETSON L E	
CO	MANAGEMENT SYSTEMS FOR LIMITED SUPPLEMENTAL IRRIGATED AGRICULTURE IN THE CENTRAL GREAT PLAINS	AGRICULTURAL RESEARCH SERVICE AKRON	HALVORSON A D; ANDERSON R L; HINKLE S E	
HI	MATCHING DRIP-IRRIGATION SYSTEM DESIGN AND OPERATION TO SOIL HYDRAULIC PROPERTIES	UNIV OF HAWAII HONOLULU	GREEN R; WU I	
VT	MOVEMENT OF WATER AND CHEMICALS APPLIED TO CORN AND PEANUT USING SUBSURFACE MICRO-IRRIGATION	TIDEWATER AGRIC EXPT STATION SUFFOLK	POWELL N L	
AZ	NITROGEN AND WATER USE EFFICIENCY WITH DRIP IRRIGATION FOR VEGETABLE PRODUCTION	UNIV OF ARIZONA TUCSON	TUCKER T C; STROEHLEIN J L; DOERGE T A	
GA	PRODUCTION SYSTEMS FOR PEACHES GROWN UNDER CENTER-PIVOT IRRIGATION	GEORGIA COASTAL PLAIN EXPT STA TIFTON	EVERT D R	
NE	SOIL AND WATER CONSERVATION PRACTICES FOR SPRINKLER IRRIGATION IN NORTHEAST NEBRASKA	UNIVERSITY OF NEBRASKA LINCOLN	KRANZ W L	
GA	SPRINKLER VS DRIP IRRIGATION IN THE PRODUCTION OF FRESH MARKET CUCUMBER IN CENTRAL GEORGIA	FORT VALLEY STATE COLLEGE FORT VALLEY	MAHOTIERE S; CARTER J	
KS	SUSTAINING IRRIGATED AGRICULTURE IN KANSAS WITH DRIP IRRIGATION	KANSAS STATE UNIV MANHATTAN	LAMM F; MANGES H; ROGERS D	
AZ	TRICKLE IRRIGATION AND CONTROLLED TRAFFIC	UNIV OF ARIZONA TUCSON	COATES W E; LARSON D L; YITAYEW M	
TX	TRICKLE IRRIGATION AND FERTILIZATION OF YOUNG CITRUS ORCHARDS	TEXAS A&M UNIV COLLEGE STATION	SWIETLIK D; BOGLE C R	
AL	TRICKLE IRRIGATION IN HUMID REGIONS	AUBURN UNIV AUBURN	AMLING H J	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIV OF FLORIDA GAINESVILLE	LOCASCIO S J	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIV OF FLORIDA GAINESVILLE	SMAJSTRLA A G; ZAZUETA F S; BURGESS D H	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIV OF FLORIDA GAINESVILLE	PREVATT J W	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIVERSITY OF FLORIDA BRADENTON	OVERMAN A J; STANLEY C D; CSIZINSZKY A A	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIVERSITY OF FLORIDA LAKE ALFRED	KOO R C J; PARSONS L R	
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIVERSITY OF FLORIDA HOMESTEAD	ORTH P G	

ST	TITLE	LOCATION	INVESTIGATORS
FL	TRICKLE IRRIGATION IN HUMID REGIONS	ROUTE 3 BOX 4370 QUINCY	RHOADS F M; OLSON S M
FL	TRICKLE IRRIGATION IN HUMID REGIONS	UNIV OF FLORIDA DOVER	ALBREGTS E E
GA	TRICKLE IRRIGATION IN HUMID REGIONS	UNIVERSITY OF GEORGIA ATHENS	CHESNESS J L; COUVILLION G A
LA	TRICKLE IRRIGATION IN HUMID REGIONS	LOUISIANA STATE UNIV BATON ROUGE	EDLING R J
MI	TRICKLE IRRIGATION IN HUMID REGIONS	MICHIGAN STATE UNIV EAST LANSING	BRALTS V; KESNER C; FLORE J
OH	TRICKLE IRRIGATION IN HUMID REGIONS	OHIO STATE UNIV WOOSTER	FUNT R C
PR	TRICKLE IRRIGATION IN HUMID REGIONS	UNIV OF PUERTO RICO (MAYAGUEZ) RIO PIEDRAS	GOYAL M R; RIVERA L; GUADALUPE R
SC	TRICKLE IRRIGATION IN HUMID REGIONS	CLEMSON UNIVERSITY CLEMSON	COSTON D C; AITKEN J B; LIGON J T
TX	TRICKLE IRRIGATION IN HUMID REGIONS	TEXAS A&M UNIV COLLEGE STATION	MCFARLAND M J; WORTHINGTON J W; BOGLE C R
VA	TRICKLE IRRIGATION IN HUMID REGIONS	VIRGINIA POLY INST BLACKSBURG	MOSTAGHIMI S
GA	TRICKLE IRRIGATION WETTED SOIL VOLUME REQUIREMENTS FOR PEACH TREES	UNIVERSITY OF GEORGIA ATHENS	CHESNESS J L; COUVILLION G A; MCLENDON B D

CATEGORY 5: SYSTEM CONTROL

CO	ADAPTIVE CONTROL OF SURFACE IRRIGATION SYSTEMS	COLORADO STATE UNIV FORT COLLINS	PODMORE T H; AYERS P D; ISRAELI I
NY	AGRICULTURAL DEVELOPMENT AND IRRIGATION MANAGEMENT IN NEPAL	CORNELL UNIVERSITY ITHACA	UPHOFF N T; ZUIDEMA L W; BARKER R
OR	AGRICULTURAL EXPERIMENT STATION LONG DISTANCE RESEARCH NETWORK (LODRN)	OREGON STATE UNIV CORVALLIS	CROFT B A
CO	ALTERNATIVE TECHNOLOGY FOR MANAGEMENT OF CROP WATER AND GASEOUS SUPPLY	COLORADO STATE UNIV FORT COLLINS	MOORE D D III
CO	APPRAISAL AND ENHANCEMENT OF COMPUTER-AIDED MANAGEMENT OF IRRIGATION WATER DISTRIBUTION	COLORADO STATE UNIV FORT COLLINS	NELSON J D
ND	BEST MANAGEMENT PRACTICES FOR IMPROVED IRRIGATION AND FERTILIZER NITROGEN USE EFFICIENCIES	NORTH DAKOTA STATE UNIV FARGO	STEGMAN E C; KNIGHTON R E; PRUNTY L D
TX	CROP MODEL-BASED FARM MANAGEMENT DECISION AIDS	TEXAS A&M UNIVERSITY TEMPLE	STOCKLE C; ROSENTHAL W D; JACKSON B J

ST	TITLE	LOCATION	INVESTIGATORS	12
CO	DECISION SUPPORT SYSTEMS FOR IRRIGATION MANAGEMENT	COLORADO STATE UNIV FORT COLLINS	LOFTIS J C; ISRAELI I; OAD R	
AR	DEVELOPMENT, SIMULATION AND EVALUATION OF IRRIGATION PRACTICES FOR ARKANSAS AGRICULTURE	UNIV OF ARKANSAS FAYETTEVILLE	FERGUSON J A; COSTELLO T A	
CO	EFFICIENT ESTIMATION OF WATER SUPPLY AUGMENTATION NEEDS IN REAL TIME ALLOCATION OPERATIONS	COLORADO STATE UNIVERSITY	MOREL-SEYTOUX H J	
KS	EFFICIENT IRRIGATION AND DRAINAGE SYSTEMS	KANSAS STATE UNIV MANHATTAN	MANGES H L	
TX	EFFICIENT WATER UTILIZATION THROUGH MANAGEMENT AND ENGINEERING DESIGN	RT 3 BOX 219 LUBBOCK	LYLE W M; BORDOVSKY J D	
IL	ELECTRONIC CONTROLS AND ELECTRIC EQUIPMENT FOR FARM PRODUCTION	1301 WEST GREGORY DRIVE URBANA	BUCK M L; SPAHR S L; DAY D L	
MS	EVALUATION AND DEVELOPMENT OF WATER RESOURCES MANAGEMENT STRATEGIES FOR DROUGHT/EMERGENCY CONDITIONS	MISSISSIPPI STATE UNIVERSITY	TRUAX D	
MT	EVALUATION OF POROUS CUP LYSIMETERS	MONTANA COLL OF MINERAL SCIENCE & TECHN	SONDEREGGER J; HARRISON B	
WA	EXPERT SYSTEM FOR DROUGHT MANAGEMENT PLANNING IN WASHINGTON	UNIVERSITY OF WASHINGTON	PALMER R	
OK	IMPROVED WATER MANAGEMENT WITH WIDE-SPACED BAND IRRIGATION	OKLAHOMA STATE UNIVERSITY STILLWATER	STONE J F; REEVES H E; ELLIOTT R L	
AR	IMPROVING IRRIGATION SCHEDULING AND WATER USE EFFICIENCY IN COTTON	UNIVERSITY OF ARKANSAS	OOSTERHUIS D	
OK	INCORPORATION OF RISK IN DESIGNING WATER RESOURCES FACILITIES	OKLAHOMA STATE UNIVERSITY	HANN C; WILSON B	
AZ	INTEGRATED SYSTEMS TO COORDINATE IRRIGATION CANAL DELIVERIES WITH FARM WATER MANAGEMENT IN ARID AREA	AGRICULTURAL RESEARCH SERVICE PHOENIX	REPLOGLE J A; DEDRICK A R; BUCKS D A	
ND	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	NORTH DAKOTA STATE UNIV FARGO	STEGMAN E C; NELSON W C	
CA	INTEGRATING THE SOIL-PLANT-ATMOSPHERE SYSTEM FOR IRRIGATION SCHEDULING	UNIV OF CALIFORNIA DAVIS	GRIMES D W	
ND	IRRIGATED CROP PRODUCTION PRACTICES	NORTH DAKOTA STATE UNIVERSITY CARRINGTON	ALBUS W L; GARDNER J C	
AZ	IRRIGATION SCHEDULING USING PLANT, SOIL AND CLIMATIC SENSOR SYSTEMS	UNIV OF ARIZONA TUCSON	FANGMEIER D D; SLACK D L; YITAYEW M	
SC	IRRIGATION MANAGEMENT FOR INCREASED PROFITABILITY IN THE SOUTHEASTERN COASTAL PLAIN	AGRICULTURAL RESEARCH SERVICE FLORENCE	CAMP C R; SADLER E J; HUNT P G	
CA	IRRIGATION WATER MANAGEMENT TO CONTROL WATER AND SOLUTE STRESSES	AGRICULTURAL RESEARCH SERVICE FRESNO	PHENE C J; HOFFMAN G J; MIGHTINGALE H I	
ID	IRRIGATION SCHEDULING & SOIL AND WATER MANAGEMENT TO MINIMIZE PLANT STRESS & IMPROVE EFFICIENCY	AGRICULTURAL RESEARCH SERVICE KIMBERLY	WRIGHT J L; SOJKA R E; BROWN M J	
ID	IRRIGATION WATER SUPPLY, MANAGEMENT, AND CONSERVATION	UNIV OF IDAHO MOSCOW	BROCKWAY C E; BUSCH J R	
ND	IRRIGATION MANAGEMENT IN THE NORTH DAKOTA DRIFT PRAIRIE	CARRINGTON AGRIC EXPT STATION CARRINGTON	MEYER R F; GARNDER J C	

ST	TITLE	LOCATION	INVESTIGATORS
NY	IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST (ISPAN)	CORNELL UNIVERSITY ITHACA	COWARD E W; WALTER M; BARKER R
KS	MANAGEMENT OF THE KANSAS RIVER BASIN: A SYSTEMS APPROACH	UNIVERSITY OF KANSAS	YU Y; POGGE E; MANOUTCHEHR M
CA	OPTIMAL CONJUNCTIVE USE MODE FOR MANAGING WATER SUPPLY SYSTEMS	HUMBOLDT STATE UNIVERSITY	WILLIS R; FINNEY B; MCKEE M
MS	PRODUCTION SYSTEMS AND WATER MANAGEMENT FOR SOY- BEANS IN THE LOWER MISSISSIPPI VALLEY	AGRICULTURAL RESEARCH SERVICE STONEVILLE	HEATHERLY L G
WA	RADIO TELEMETRY CONTROL SYSTEM FOR IRRIGATION VALVES	2635 151ST PLACE NE REDMOND	MURREY L
FL	ROOT-ZONE WATER MANAGEMENT FOR MINIMIZING PLANT STRESS IN HIGH WATER TABLE SOILS	AGRICULTURAL RESEARCH SERVICE GAINESVILLE	ALLEN L H JR
MN	SAND PLAIN RESEARCH FARM OPERATIONS	UNIV OF MINNESOTA ST PAUL	BERGSRUD F G; BARNES D K; MALZER D M
UT	SURFACE IRRIGATION CONTROL AND DECISION SUPPORT SYSTEMS	UTAH STATE UNIVERSITY LOGAN	WALKER W R
ID	SYSTEMS AND MANAGEMENT TO CLEAN AND APPLY IRRIGA- TION WATER EFFICIENTLY AND AT OPTIMUM COSTS	AGRICULTURAL RESEARCH SERVICE KIMBERLY	HUMPHERYS A S; KINCAID D C; TROUT T J
DC	WATER USE AND CONSERVATION POLICY	1301 NEW YORK AVENUE NW WASHINGTON	HORNER J
NE	WATER CONSERVATION PRACTICES FOR IRRIGATED AGRICULTURE IN SOUTH CENTRAL NEBRASKA	UNIV OF NEBRASKA CLAY CENTER	EISENHAUER D E
NJ	WATER REQUIREMENT AND IRRIGATION SCHEDULING OF THE CULTIVATED HIGHBUSH BLUEBERRY	RUTGERS UNIVERSITY PO BOX 231 NEW BRUNSWICK	ECK P
SC	WATER TABLE MANAGEMENT SYSTEMS IN THE HUMID SOUTHEAST	AGRICULTURAL RESEARCH SERVICE FLORENCE	DOTY C W; PARSONS J E; SADLER E J
SC	WATER MANAGEMENT WITH IRRIGATION IN SOUTHEASTERN COASTAL PLAINS	AGRICULTURAL RESEARCH SERVICE FLORENCE	CAMP C R; SADLER E J; KASPER-BAUER M J
TX	WATER MANAGEMENT FOR RICE, SOYBEANS AND ALTERNATE CROPS IN THE GULF COAST AREA	ROUTE 7, BOX 999 BEAUMONT	MCCAULEY G N

CATEGORY 6: MODELLING

UT	A REMOTE SENSING AND COMPUTER MODELING TECHNIQUE FOR ESTIMATING TEMPORALLY AND SPATIALLY DEPENDENT SUBSURFACE WATERSHED SOIL-MOISTURE CONDITIONS	UTAH STATE UNIVERSITY	GUNDERSON R; RILEY J
MA	DEVELOPMENT OF A WATER SUPPLY DECISION-MAKING MODEL INCORPORATING THE LONG-RUN COST OF WATER	UNIVERSITY OF MASSA-CHUSETTS	MALE J; STEVENS T; WILLIS C; DALE D
MS	GROUND WATER MODELS FOR THE HATTIESBURG AND LAUREL, MISSISSIPPI REGIONS	UNIVERSITY OF SOUTHERN MISSISSIPPI	PATRICK D
CO	IMPROVED METHODS FOR MODELING CONJUNCTIVE MANAGEMENT OF SURFACE AND GROUND WATER	COLORADO SCHOOL OF MINES	POETER E; KRAEGER-ROVEY C

ST	TITLE	LOCATION	INVESTIGATORS	14
OK	IRRIGATION DECISION MAKING BASED ON RISK ANALYSIS AND CROP GROWTH SIMULATION	OKLAHOMA STATE UNIVERSITY STILLWATER	ELLIOTT R L	
PA	LINKING HYDROLOGIC/WATER QUALITY MODELS WITH A GEOGRAPHIC INFORMATION SYSTEM	PENNSYLVANIA STATE UNIVERSITY	PETERSEN G	
PR	MICROPROCESSOR-BASED WATER RESOURCES REQUIREMENTS SIMULATION ANALYSIS	UNIVERSITY OF PUERTO RICO	VASQUEZ-ESPINOSA R; PAGAN-TRINIDAD I	
TX	SIMULATION OF THE NON-POINT SOURCES RUNOFF PROCESS	SOUTHERN METHODIST UNIVERSITY	COLLINS M	

CATEGORY 7: GROUNDWATER UTILIZATION

NE	CONSERVE GROUNDWATER QUALITY AND CONTROL ENERGY COSTS FOR CENTRAL PLAINS IRRIGATED AGRICULTURE	AGRICULTURAL RESEARCH SERVICE LINCOLN	STETSON L E; SCHEPERS J S; POWER J F	
NE	DEVELOPMENT OF A DECISION SUPPORT SYSTEM TO AID DECISION MAKERS EVALUATING GROUNDWATER TRANSFER	UNIVERSITY OF NEBRASKA	BLEED A; BOGARDI I; WOLDT W	
TX	INTEGRATED ALTERNATIVE ENERGY SYSTEMS FOR IRRIGATION PUMPING	AGRICULTURAL RESEARCH SERVICE BUSHLAND	CLARK R N	

CATEGORY 8: SEDIMENT-RELATED RESEARCH

GU	A STUDY OF SOIL ERODIBILITY FACTORS FOR GUAM WATERSHEDS	UNIVERSITY OF GUAM	KHOSROWPANAH S	
AK	ASSESSMENT OF STREAMFLOW SEDIMENT TRANSPORT FOR ENGINEERING PROJECTS	UNIVERSITY OF ALASKA FAIRBANKS	CARLSON R	
ID	CONSERVATION TILLAGE AND CROP SEQUENCES TO REDUCE EROSION AND IMPROVE SOIL CHEMICAL CONDITIONS	AGRICULTURAL RESEARCH SERVICE KIMBERLY	CARTER D L; MASSEE T W; ROBBINS C W	
MS	DEVELOPMENT OF AGRICULTURAL SEDIMENT AND TRANSPORT MODELS THROUGH STREAMS AND LAKES	UNIVERSITY OF MISSISSIPPI	PRASAD S; DELEEUW S	
GA	GUIDELINES FOR DEVELOPMENT OF WATERSHED PROTECTION PROGRAMS IN GEORGIA	UNIVERSITY OF GEORGIA	COOLEY J; COWIE G	
DC	IMPACT OF EROSION AND SEDIMENTATION ON THE WATER QUALITY OF THE ESTUARINE PORTION OF THE ANACOSTIA RIVER	UNIVERSITY OF THE DISTRICT OF COLUMBIA	CHANG F; WATT M; VENKATAIAH S	
TN	MODELING EROSION AND THE EFFECTS OF AGRICULTURAL PEST MANAGEMENT PRACTICES ON A WEST TENNESSEE WATERSHED	MEMPHIS STATE UNIVERSITY	MOORE L; SMITH R	
MD	SEDIMENT SOURCES, STORAGE, AND FLUX RATES IN THE UPPER SOUTH RIVER ESTUARY, MARYLAND	UNIVERSITY OF MARYLAND	MARCUS W; KEARNEY M	
MT	SEDIMENT REDUCTION BY LIVESTOCK GRAZING MANAGEMENT	MONTANA STATE UNIVERSITY	MARLOW C	
TX	SEDIMENT TRANSPORT INTO TEXAS BAYS	UNIVERSITY OF TEXAS AT AUSTIN	HOLLEY E	

ST	TITLE	LOCATION	INVESTIGATORS
CATEGORY 10: DRAINAGE			
MN	AGRICULTURAL DRAINAGE PRACTICES FOR IMPROVED WATER RESOURCE MANAGEMENT IN MINNESOTA	UNIV OF MINNESOTA ST PAUL	BERGSRUD F G; WRIGHT J A; NIEBER J L
MD	DESIGN AND PERFORMANCE OF COMBINED DRAINAGE-SUBIRRIGATION SYSTEMS FOR MARYLAND SOILS	UNIV OF MARYLAND COLLEGE PARK	HILL R L; SHIRMOHAMMADI A; MULFORD R
CA	EVALUATION OF EVAPORATION PONDS FOR SALINE DRAINAGE WATERS	UNIVERSITY OF CALIFORNIA	TANJI K
CA	EVALUATION AND MANAGEMENT OF DRAIN WATER EVAPORATION PONDS	UNIV OF CALIFORNIA DAVIS	GRISMER M E; TANJI K K
IA	WATER MANAGEMENT SYSTEMS TO IMPROVE AGRICULTURAL DRAINAGE PRACTICES IN IOWA	IOWA STATE UNIV AMES	KANWAR R S; BAKER J L; MARLEY S J
CATEGORY 11: MAINTENANCE			
CA	INFLUENCE OF ENVIRONMENTAL AND BIOLOGICAL FACTORS ON LIFE CYCLE STAGES FOR AQUATIC WEED SPECIES	AGRICULTURAL RESEARCH SERVICE DAVIS	ANDERSON L W J; SPENCER D F
CATEGORY 12: ENVIRONMENT			
IL	AGRICULTURAL UTILIZATION OF WASTE MATERIALS TO REDUCE PESTICIDE MOVEMENT TO GROUNDWATER IN SANDY COARSE-TEXTURED SOILS	UNIVERSITY OF ILLINOIS	BICKI T; HINESLY T
OK	AGRICULTURAL IMPACTS ON STREAM WATER QUALITY	OKLAHOMA STATE UNIVERSITY	TOETZ D
NM	ALLUVIAL AQUIFER HETEROGENEITIES IN THE RIO GRANDE VALLEY: IMPLICATIONS FOR GROUNDWATER CONTAMINATION	NEW MEXICO TECH	PHILLIPS F
OK	AN EVALUATION OF THE UNCERTAINTIES ASSOCIATED WITH PESTICIDE TRANSPORT TO GROUNDWATER AS WELL AS WITH CURRENT ASSESSMENT TECHNIQUES	OKLAHOMA STATE UNIVERSITY	MCTERNAN W; SMETHEN D
NE	APPLICATION OF EXPERT-SYSTEMS TECHNOLOGY TO THE DRASTIC GROUNDWATER-VULNERABILITY MODEL	UNIVERSITY OF NEBRASKA	RUNDQUIST D; LI R
WI	APPLICATION OF GROUND PENETRATING RADAR TO DEFINE RECHARGE AREAS FOR THE MANAGEMENT OF AGRICHEMICALS	UNIVERSITY OF WISCONSIN-EXTENSION	ANDERSON M; WANG H; BRADBURY K
DE	ASSESSMENT OF THE IMPACT OF NUTRIENT AND HERBICIDE LEACHING ON GROUNDWATER QUALITY IN DELAWARE	UNIV OF DELAWARE NEWARK	SIMS J T
CO	BIOLOGICAL DENITRIFICATION OF POLLUTED GROUNDWATER	UNIVERSITY OF COLORADO	SILVERSTEIN J; COOK N

ST	TITLE	LOCATION	INVESTIGATORS
OK	CAUSE AND EFFECT OF RAPID CHANGES IN SHALLOW GROUND-WATER QUALITY	OKLAHOMA STATE UNIVERSITY	PETTYJOHN W
NC	CHARACTERIZATION OF SOILS AND SAPROLITES FROM THE PIEDMONT REGION FOR WASTE DISPOSAL PURPOSES	NORTH CAROLINA STATE UNIVERSITY	AMOOZEGAR A; VEPRASKAS M
TN	CHARACTERIZATION OF PESTICIDE MIGRATION IN THE UNSATURATED ZONE	MEMPHIS STATE UNIVERSITY	KLAINE S
CA	CHEMICAL PROCESSES GOVERNING SOIL SALINITY AND ITS EFFECTS ON SOIL-WATER-PLANT SYSTEMS	AGRICULTURAL RESEARCH SERVICE RIVERSIDE	SUAREZ D L; GOLDBERG S R; RHOADES J D
CA	COLORADO RIVER SALINITY CONTROL	AGRICULTURAL RESEARCH SERVICE RIVERSIDE	RHOADES J D; SUAREZ D L; SNOUSE P J
MD	COMPARATIVE WATER QUALITY OF IMPACTS OF STANDARD AGRICHEMICAL-INTENSIVE AND ALTERNATIVE LOW-INPUT FARMING SYSTEMS	UNIVERSITY OF MARYLAND	WEIL R
IN	CONTRIBUTION OF SUBSOIL AND AQUIFER MICROORGANISMS TO GROUNDWATER QUALITY	PURDUE UNIVERSITY	TURCO R; KONOPKA A
ID	DEVELOPING AN INTEGRATED MODEL FOR EVALUATING THE ECONOMIC AND ECOLOGIC EFFECTS OF REDUCING NON-POINT POLLUTION IN A PALOUSE WATERSHED	UNIVERSITY OF IDAHO	PRATO T; BRUSVEN M
KS	DEVELOPMENT OF EMPIRICAL MODELS FOR THE EFFECTS OF CADMIUM, LEAD, MANGANESE, AND ZINC ON RESIDENT BIOTA IN THE SHORT CREEK- EMPIRE LAKE AQUATIC SYSTEM, CHEROKEE CO, KANSAS	UNIVERSITY OF KANSAS	FERRINGTON L
ND	DEVELOPMENT OF A HIGHLY SENSITIVE AND SELECTIVE ANALYTICAL METHOD FOR MONITORING HERBICIDES IN GROUNDWATER	NORTH DAKOTA STATE UNIVERSITY	TALLMAN D
NE	DEVELOPMENT AND EVALUATION OF IMPROVED METHODS OF MEASURING CHEMICAL LEACHING	UNIVERSITY OF NEBRASKA	MARTIN D; GILLEY J
NE	DISSIPATION AND BIOAVAILABILITY OF HERBICIDES AND OTHER PESTICIDES IN SOIL	UNIVERSITY OF NEBRASKA LINCOLN	SHEA P J
MS	EFFECT OF FLOODING ON ECOLOGY OF GREEN-TREE RESERVOIRS	MISSISSIPPI STATE UNIVERSITY	KARR B; LEOPOLD B; HODGES J; KAMINISKI R
VA	EFFECTIVENESS AND IMPACTS OF AGRICULTURAL BMPS APPLICABLE TO VIRGINIA: A COMPREHENSIVE ASSESSMENT	VIRGINIA POLYTECHNIC INSTITUTE	HEATWOLE; DILLAHA; MOSTAGHIMI; KRAMER; GIVENS
OH	EFFECTS OF COMPLEXATION OF SOLUBLE HUMIC SUBSTANCES ON THE AQUEOUS TRANSPORT AND CHEMISTRY OF PESTICIDES	THE OHIO STATE UNIVERSITY	TRAINA S; LOGAN T
RI	EVALUATING PLANTS FOR NUTRIENT RETENTION IN VEGETATIVE BUFFER STRIPS	UNIVERSITY OF RHODE ISLAND	HULL R
MO	FIELD EVALUATION OF TERMITICIDE MOVEMENT	UNIVERSITY OF MISSOURI	PEYTON R
MO	FIELD EVALUATION AND MODEL CALIBRATION FOR AGRICULTURAL PESTICIDE TRANSPORT TO GROUNDWATER	UNIVERSITY OF MISSOURI	ANDERSON S
IL	GEOSTATISTICAL ANALYSIS OF REGIONAL NON-POINT GROUND-WATER CONTAMINATION	ILLINOIS STATE WATER SURVEY	SHAFER J; WEHRMANN H
ID	GROUNDWATER CONTAMINATION FROM AGRICULTURALLY APPLIED PESTICIDES	UNIVERSITY OF IDAHO	MORRA M
NE	GROUNDWATER CONTAMINATION CONTROL: MONITORING AND DESIGN	UNIVERSITY OF NEBRASKA	BOGARDI I
MN	HERBICIDE MANAGEMENT TECHNIQUES TO REDUCE GROUND- AND SURFACE WATER CONTAMINATION	UNIVERSITY OF MINNESOTA	EBERLEIN C; KOSKINEN W; YOUNG R; PORCELLA F

ST	TITLE	LOCATION	INVESTIGATORS
KS	HYDROGEOCHEMISTRY OF THE DAKOTA AQUIFER IN WESTERN KANSAS	KANSAS STATE UNIVERSITY	CHAUDURI S
GA	HYDROLOGIC/WATER QUALITY MODELLING OF SEDIMENT AND CHEMICAL MOVEMENT .	GEORGIA COASTAL PLAIN EXPT STA TIFTON	THOMAS D L
MN	IMPACT OF SOIL MACROPORES ON WATER AND CHEMICAL TRANSPORT TO GROUND WATER THROUGH THE VADOSE ZONE	UNIVERSITY OF MINNESOTA	NIEBER J; MOORE I
OK	IMPACT OF AGRICULTURAL PRODUCTION PRACTICES ON GROUNDWATER QUANTITY AND QUALITY IN WESTERN OKLAHOMA	OKLAHOMA STATE UNIVERSITY STILLWATER	MAPP H P; BERNARDO D J
TX	IMPROVING SALINITY & IRRICATION MANAGEMENT FOR EFFICIENT CROP PRODUCTION IN FAR WEST TEXAS	TEXAS A&M UNIV COLLEGE STATION	MIYAMOTO S
ND	INFLUENCE OF IRRIGATION ON THE MOVEMENT OF THE INSECTICIDES, CARBOFURAN AND TERBUFOS, THROUGH A SANDY LOAM SOIL TO UNDERLYING GROUNDWATER	NORTH DAKOTA STATE UNIVERSITY	WEISS M; FLEEKER J; PRUNTY L
AZ	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAINT GROUNDWATER QUALITY AND QUANTITY	UNIV OF ARIZONA TUCSON	SLACK D C; FANGMEIER D D
IL	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	1301 WEST GREGORY DRIVE URBANA	KONYHA K D; DRABLOS C J W; EWING L
IN	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	PURDUE UNIVERSITY WEST LAFAYETTE	WHEATON R Z
KS	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY & QUANTITY	KANSAS STATE UNIV MANHATTAN	STONE L R
MI	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	MICHIGAN STATE UNIV EAST LANSING	LOUDON T; RITCHIE J; BRALTS V
NE	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	UNIVERSITY OF NEBRASKA LINCOLN	MARTIN D L; WATTS D G
WI	INTEGRATED IRRIGATION WATER AND NITROGEN MANAGEMENT TO SUSTAIN GROUND WATER QUALITY AND QUANTITY	UNIV OF WISCONSIN MADISON	MASSIE L R; BUBENZER G D
CA	IRRIGATION MANAGEMENT FOR CONTROLLING SALTS AND POTENTIALLY TOXIC ELEMENTS	AGRICULTURAL RESEARCH SERVICE FRESNO	AYARS J E; HUTMACHER R B; HOFFMAN G J
CA	IRRIGATION MANAGEMENT UNDER SALINE CONDITIONS	UNIVERSITY OF CALIFORNIA RIVERSIDE	LETEY J; STOLZY L H
IL	IRRIGATION FOR OPTIMUM CROP PRODUCTION AND GROUNDWATER PROTECTION IN ILLINOIS	1301 WEST GREGORY DRIVE URBANA	SIMMONS F W; BOAST C W; DUNKER R E
KS	LEACHING OF ATRAZINE AND NITRATE THROUGH SOIL AND INTO GROUNDWATER	KANSAS STATE UNIVERSITY	SCHWAB A; TENEYCK G
WA	LEACHING OF LEAD ABD ARSENIC IN SOILS CONTAMINATED WITH LEAD ARSENATE PESTICIDE RESIDUES	WASHINGTON STATE UNIVERSITY	PERYEA F
IL	MANAGEMENT AND DEVELOPMENT OF AQUATIC HABITAT IN AGRICULTURAL DRAINAGE SYSTEMS	UNIVERSITY OF ILLINOIS	HERRICKS E
VT	MANAGEMENT OF NITROGEN FERTILIZER AND MANURE FOR CORN PRODUCTION TO REDUCE THE POTENTIAL FOR NITRATE LEACHING INTO GROUNDWATER	UNIVERSITY OF VERMONT	JOKELA W
WA	MANAGEMENT OF GROUND WATER CONTAMINATION IN WASHINGTON'S COLUMBIA BASIN	WASHINGTON STATE UNIVERSITY	MULLA D

ST	TITLE	LOCATION	INVESTIGATORS	18
CA	MICROBIAL MECHANISMS OF SELENATE REDUCTION FOR REMOVAL OF SELENIUM FROM AGRICULTURAL DRAINAGE WATER	UNIV OF CALIFORNIA DAVIS	MACY J M	
RI	MICROBIAL PROCESSES CONTROLLING THE FATE OF NITROGEN IN VEGETATIVE BUFFER STRIPS	UNIVERSITY OF RHODE ISLAND	GROFFMAN P; SULLIVAN W; LEMUNYON J	
AR	MINIMIZING THE POTENTIAL FOR GROUNDWATER CONTAMINATION FROM AGRICULTURAL POINT SOURCES	UNIVERSITY OF ARKANSAS	LAVY T; MATTICE J	
VA	MODELING EFFECTS OF AGRICULTURAL PRACTICES ON NITRATE CONTAMINATION OF GROUND AND SURFACE WATER	VIRGINIA POLYTECHNIC INSTITUTE	PARKER J; KATYOL A; BAKER J	
ND	MOVEMENT OF CHEMICALS THROUGH SOILS	NORTH DAKOTA STATE UNIV FARGO	PRUNTY L D; MONTGOMERY B R; KNIGHTON R E	
VA	NITROGEN LEACHING LOSSES FOR CORN PRODUCED ON SOILS IN THE CHESAPEAKE BAY AREA AS INFLUENCED BY SELECTED BMP	VIRGINIA POLYTECHNIC INSTITUTE	RENEAU; MARTENS; HAGEDORN; SIMPSON; HAWKINS	
MI	NUTRIENT MANAGEMENT IN CONSERVATION TILLAGE TO IMPROVE PRODUCTIVITY AND ENVIRONMENTAL QUALITY	MICHIGAN STATE UNIV EAST LANSING	ELLIS B	
ND	NUTRIENT MANAGEMENT IN CONSERVATION TILLAGE TO IMPROVE PRODUCTIVITY AND ENVIRONMENTAL QUALITY	NORTH DAKOTA STATE UNIV FARGO	GOOS R J; PRUNTY L D	
WA	PEST MANAGEMENT OF IRRIGATED CROPS	WASHINGTON STATE UNIVERSITY PROSSER	JOHNSON D A	
CA	PESTICIDE TRANSPORT AS RELATED TO QUALITY OF SURFACE AND GROUNDWATERS IN IRRIGATED AREAS	AGRICULTURAL RESEARCH SERVICE RIVERSIDE	SPENCER W F; YATES S R	
MN	PESTICIDE METABOLITES IN MINNESOTA GROUNDWATER	UNIVERSITY OF MINNESOTA	SWACKHAMER D	
WA	PHYSICOCHEMICAL BASIS FOR MANAGING SALT-AFFECTED SOILS AND WATER	WASHINGTON STATE UNIVERSITY PULLMAN	HARSH J B	
UT	PHYSIOCHEMICAL BASIS FOR MANAGING SALT-AFFECTED SOILS AND WATER	UTAH STATE UNIVERSITY LOGAN	JURINAK, J J; HANKS, R J; DUDLEY, L M	
UT	PLANNING SUSTAINED GROUNDWATER YIELD WITH CONTAMINANT MANAGEMENT	UTAH STATE UNIVERSITY	PERALTA R; TURNER K	
MD	POTENTIAL FOR RESTORATION OF SUBMERGED AQUATIC VEGETATION IN UPPER CHESAPEAKE BAY WITH FORTY PERCENT REDUCTION OF NUTRIENT INPUTS	UNIVERSITY OF MARYLAND	KEMP W	
WI	POTENTIAL GROUNDWATER IMPACTS FROM MANAGEMENT TECHNIQUES DESIGNED TO ABATE NON-POINT POLLUTANTS TO SURFACE WATERS	UNIVERSITY OF WISCONSIN-MADISON	CHESTERS G; SIMSIMAN G	
NE	REDUCING NITRATE-N LOSSES TO GROUNDWATER BY IMPROVING FIELD SAMPLING ACCURACY OF NITRATE-N	UNIVERSITY OF NEBRASKA	HERGERT G; ANDERSON F; SHAPIRO C; FERGUSON R	
AL	REMOVAL OF PESTICIDES FROM SURFACE AND GROUND WATER	UNIVERSITY OF ALABAMA	ATWOOD J	
NE	RETENTION OF TOXIC ORGANICS AS RELATED TO SOIL SERIES AND SOIL MAPPING UNIT	UNIVERSITY OF NEBRASKA	MCCALLISTER D; LEWIS D; SHEA P	
WA	RETENTION OF PESTICIDES BY ALLUVIAL SOILS IN WESTERN WASHINGTON	WASHINGTON STATE UNIVERSITY	COGGER C; GETZIN L; BRISTOW P	
DC	SALINITY AND DRAINAGE IMPACTS OF IRRIGATION	1301 NEW YORK AVENUE NW WASHINGTON	HOSTETLER J	
SD	SITE AND MANAGEMENT EFFECTS ON AGRICULTURAL CHEMICAL LEACHING	SOUTH DAKOTA STATE UNIVERSITY	RICKERL D; GELDERMAN R; LEMME G	

ST	TITLE	LOCATION	INVESTIGATORS
			19
ND	STATUS OF WETLANDS IN NORTH DAKOTA	NORTH DAKOTA STATE UNIVERSITY	LEITCH J
RI	STOCHASTIC STUDY OF THE NATURAL FLUSHING OF CONTAMINANTS FROM AQUIFERS	UNIVERSITY OF RHODE ISLAND	HU S; CHANG C
CO	SURFACE AND GROUND WATER POLLUTION POTENTIAL FROM HERBICIDE USE IN COLORADO AGRICULTURE	COLORADO STATE UNIVERSITY	LOFTIS; DURNFORD; DALE; BUTTERS; WORKMAN
IL	TABLE EFFECTS ON MOVEMENT OF AGRICULTURAL CHEMICALS TO GROUNDWATER IN ILLINOIS	UNIVERSITY OF ILLINOIS	SIMMONS F; LIEBL R; BOAST C
FL	THE EFFECT OF ON-FARM AGRICULTURAL PRACTICES IN EAA ORGANIC SOILS ON PHOSPHORUS & NITROGEN TRANSPORT	UNIV OF FLORIDA GAINESVILLE	BOTTCHER A B; IZUNO F T
FL	THE EFFECT OF ON-FARM AGRICULTURAL PRACTICES IN EAA ORGANIC SOILS ON PHOSPHORUS & NITROGEN TRANSPORT	UNIV OF FLORIDA BELLEGLADE	IZUNO F T; PORTER P S; SANCHEZ C A
ME	THE EFFECTIVENESS OF BUFFER STRIPS TO PROTECT WATER QUALITY	UNIVERSITY OF MAINE	ROCK C
MN	THE IMPACT OF SETTLEMENT AND AGRICULTURE UPON THE EVOLUTION OF PRAIRIE LAKES IN MINNESOTA, WITH PARTICULAR REFERENCE TO BLOOMS OF BLUE-GREEN ALGAE	UNIVERSITY OF MINNESOTA	GORHAM E
ND	TOXICOLOGICAL EVALUATION OF POTENTIAL GROUNDWATER CONTAMINATION IN AGRICULTURAL AREAS	NORTH DAKOTA STATE UNIVERSITY	CHATURVEDI A; PADMANABHAN G
IA	TRANSFORMATION, FATE, AND TRANSPORT OF NITROGEN IN AGRICULTURAL STREAMS	IOWA STATE UNIVERSITY	BACHMANN R; CRUMPTON W
WY	TRANSFORMATION AND PLANT UPTAKE OF SELENIUM BY SOIL MICROORGANISMS	UNIVERSITY OF WYOMING	WILLIAMS S
MO	TRANSPORT OF NITRATES IN THE MISSOURI RIVER VALLEY LOESS DEPOSITS	UNIVERSITY OF MISSOURI	BLANCHARD P
WY	UNCERTAINTY ANALYSIS OF WATER QUALITY MODELS AND ITS APPLICATIONS TO RISK ASSESSMENT AND MANAGEMENT	UNIVERSITY OF WYOMING	TUNG Y; SMITH S
MN	WATER QUALITY MODELING: TERRAIN ANALYSIS AND THE AGRICULTURAL NON-POINT SOURCE POLLUTION (AGNPS) MODEL	UNIVERSITY OF MINNESOTA	MOORE I
TN	WATER-BORNE OFF-SITE MANAGEMENT OF AN AGRICULTURAL HERBICIDE AS AFFECTED BY TILLAGE AND HERBICIDE APPLICATION PRACTICES	THE UNIVERSITY OF TENNESSEE	MOTE C; SHELTON C; TOMPKINS F

CATEGORY 13: FARMERS' ROLE

MS	FARMER'S PERCEPTION AND USE OF SOIL AND WATER CONSERVATION TECHNOLOGIES	MISSISSIPPI STATE UNIVERSITY	ANDERSON B
ME	QUANTIFYING LONG RUN AGRICULTURAL RISKS AND EVALUATING FARMER RESPONSE TO RISK	UNIVERSITY OF MAINE ORONO	HARRA M
NM	TRADING CONSERVED WATER: A PROPOSAL TO STUDY MARKET INCENTIVES FOR AGRICULTURAL CONSERVATION	UNIVERSITY OF NEW MEXICO	NUNN S

ST	TITLE	LOCATION	INVESTIGATORS
	CATEGORY 15: WASTE WATER REUSE		
AZ	BACTERIAL PATHOGENS AND INDICATORS IN WASTEWATER/REUSE FOR FOOD CROP IRRIGATION	UNIV OF ARIZONA TUCSON	SINCLAIR N A
	CATEGORY 16: PERFORMANCE ASSESSMENT		
MT	AGGREGATE PRODUCTION ECONOMICS, RESOURCE ECONOMICS AND TECHNOLOGICAL CHANGE	MONTANA STATE UNIVERSITY BOZEMAN	ANTLE J M; BEATTIE B R; CAPALBO S M
MS	AN ECONOMIC EVALUATION OF COTTON IRRIGATION IN THE DELTA AREA OF MISSISSIPPI	PO BOX 197 STONEVILLE	HAMILL J G; COOKE F; NEILL S W
MT	ECONOMIC VALUES OF INSTREAM FLOWS	UNIVERSITY OF MONTANA	DUFFIELD J
NE	ECONOMICS OF UNCERTAIN WATER SUPPLIES FOR IRRIGATION	UNIVERSITY OF NEBRASKA LINCOLN	BAKER M E; HELMERS G A
AL	EFFICIENT UTILIZATION OF WATER FROM RAINFALL AND IRRIGATION IN SOUTHEASTERN CROPPING ENVIRONMENTS	AUBURN UNIV AUBURN	ROCHESTER E W; HATCH L U
AZ	ENFORCING THE ARIZONA GROUNDWATER MANAGEMENT ACT: IMPLICATIONS FOR AGRICULTURAL AND INDUSTRIAL DEVELOPMENT	UNIVERSITY OF ARIZONA	CORY D; HINKS R
HI	EVALUATION AND ANALYSIS OF THE 1987 HAWAII WATER CODE	UNIVERSITY OF HAWAII	CHANG W
KS	EVALUATION OF ALTERNATIVES IN SOIL AND WATER MANAGEMENT PRACTICES IN SOUTHEAST KANSAS	KANSAS STATE UNIVERSITY PARSONS	SWEENEY D W
SD	FIELD EVALUATION OF A SUBSURFACE IRRIGATION/DRAINAGE SYSTEM IN A LACUSTRINE SOIL OF THE NORTHERN GREAT PLAINS	SOUTH DAKOTA STATE UNIVERSITY	BECK D; CARLSON C; DEBOER D
AZ	IRRIGATION SYSTEMS FOR ARID LANDS	UNIV OF ARIZONA TUCSON	HART W; YITAYEW M; FANGMEIER D
CA	IRRIGATION EFFICIENCY & REGIONAL SUBSURFACE DRAIN FLOW ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY	AGRICULTURAL RESEARCH SERVICE FRESNO	HOFFMAN G J; AYARS J E
MI	MACROECONOMIC IMPACTS ON WATER RESOURCES SYSTEMS OF THE NORTHERN MARIANA ISLANDS	UNIVERSITY OF HAWAII	YAMAUCHI H
TX	ON MANAGING TEXAS RURAL WATER SUPPLY SYSTEMS: A SOCIOECONOMIC ANALYSIS AND QUALITY EVALUATION	EAST TEXAS STATE UNIVERSITY	SINGH R; ELLERBROCK M; KUSHLAN J
DC	PRODUCTION RESPONSE, YIELD ANALYSIS, AND RESOURCE ALLOCATION	1301 NEW YORK AVENUE NW WASHINGTON	COOKE F; STARBIRD I
IA	SOCIOECONOMIC DIMENSIONS OF TECHNOLOGICAL CHANGE, NATURAL RESOURCE USE AND AGRICULTURAL STRUCTURE	IOWA STATE UNIV AMES	KORSCHING P F
LA	SOCIOECONOMIC DIMENSIONS OF TECHNOLOGICAL CHANGE, NATURAL RESOURCE USE AND AGRICULTURE STRUCTURE	LOUISIANA STATE UNIV BATON ROUGE	JENKINS Q A L; OHLENDORF G W
PR	SOCIOECONOMIC DIMENSIONS OF TECHNOLOGICAL CHANGE, NATURAL RESOURCE USE AND AGRICULTURAL STRUCTURE	UNIV OF PUERTO RICO (MAYAGUEZ) RIO PIEDRAS	CARRO V; DROZ E

ST	TITLE	LOCATION	INVESTIGATORS
TX	SOCIOECONOMIC DIMENSIONS OF TECHNOLOGICAL CHANGES, NATURAL RESOURCE USE & AGRICULTURAL STRUCTURE	TEXAS A&M UNIV COLLEGE STATION	ALBRECHT D
CA	SURFACE IRRIGATION SYSTEM EVALUATION AND MODELING UNDER VARIABLE SOIL CONDITIONS	UNIV OF CALIFORNIA DAVIS	WALLENDER W W
IA	THE ADOPTION OF MODERN IRRIGATION TECHNOLOGY AND ITS IMPLICATIONS FOR ENVIRONMENTAL AND RESOURCE POL	IOWA STATE UNIV AMES	HERRIGES J A
OR	THE WORKABILITY OF WATER MARKETS: ECONOMICS AND LEGAL ALTERNATIVES AND CONSEQUENCES	OREGON STATE UNIVERSITY	BERGLAND O; OBERMILLER F; LOVETT R
AZ	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UNIV OF ARIZONA TUCSON	SALIBA B; YITAYEW M
CA	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UNIV OF CALIFORNIA DAVIS	WALLENDER W W
HI	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UNIV OF HAWAII HONOLULU	GOPALAKRISHNAN C
NM	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	NEW MEXICO STATE UNIV LAS CRUCES	LANSFORD R R; MCGUCKIN J T; HARPER W M
OK	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	OKLAHOMA STATE UNIVERSITY STILLWATER	NELSON J R
OR	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	OREGON STATE UNIV CORVALLIS	CUENCA R H
TN	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UNIVERSITY OF TENNESSEE KNOXVILLE	HUFFAKER R G
TX	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	TAMU RES & EXPERIMENT CENTER AMARILLO	HARMAN W L; LACEWELL R W
UT	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UTAH STATE UNIVERSITY LOGAN	HANKS R J
WA	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	WASHINGTON STATE UNIVERSITY PULLMAN	WHITTLESEY N; WANDSCHNEIDER P; JAMES L
WY	WATER MANAGEMENT AND CONSERVATION IN WESTERN IRRIGATED AGRICULTURE	UNIV OF WYOMING LARAMIE	JACOBS J J; HELD L J

CATEGORY 17: REHABILITATION AND MODERNIZATION

CO	CHARACTERIZE, PREDICT AND MANAGE INFILTRATION FOR MORE EFFICIENT IRRIGATION	AGRICULTURAL RESEARCH SERVICE FORT COLLINS	HEERMANN D F; KRUSE E G; DUKE H R
ID	CONTROLLING INTAKE TO IMPROVE IRRIGATION WATER DISTRIBUTION AND REDUCE NITRATE LEACHING	AGRICULTURAL RESEARCH SERVICE KIMBERLY	TROUT T J; BROWN M J; VACANT
WA	DEVELOP CROP SIMULATION MODELS FOR THE CROPPING SYSTEMS IN THE PACIFIC NORTHWEST	AGRICULTURAL RESEARCH SERVICE PROSSER	HODGES T

ST	TITLE	LOCATION	INVESTIGATORS	22
KS	IMPROVEMENTS IN IRRIGATED WATER MANAGEMENT FOR THE CENTRAL GREAT PLAINS	KANSAS STATE UNIV MANHATTAN	LAMM F	
TX	IRRIGATION SYSTEMS AND MANAGEMENT FOR EFFICIENT WATER USE--SOUTHERN PLAINS	AGRICULTURAL RESEARCH SERVICE BUSHLAND	HOWELL T A; ALLEN R R; MUSICK J T	
NE	RENOVATION AND IMPROVEMENT OF NEBRASKA RANGE AND PASTURE	UNIVERSITY OF NEBRASKA LINCOLN	WALLER S	

CATEGORY 18: TRADITIONAL AND SMALL-SCALE SCHEMES

HI	WATER MANAGEMENT IN PRE-CONTACT HAWAII	KAPIOLANI COMMUNITY COLLEGE	FRANCO R