Agricultural Water Management Technologies, Institutions and Policies Affecting Economic Viability and Environmental Quality.

Table of Contents

Project Number
W-190

Project Title
Agricultural water management technologies, institutions and policies affecting economic viability and environmental quality.

Duration
Five years; 1 October, 1999 to 30 September, 2004

Statement of the Problem
The rapidly changing configuration of water use in the American West in recent years has resulted in a number of economic, environmental, and institutional problems with profound impacts on irrigated agriculture. The purpose of this project is to identify, examine, and evaluate the multiple impacts of these challenges on western irrigated agriculture, help develop viable mechanisms to effectively address them, and thus contribute toward informed water policy formulation.

Justification
As new problems associated with water management emerge, the need to devise dynamic new approaches for solving them takes on added importance and urgency. Examples of such emerging areas of concern include climate change and its impact on irrigated agriculture, increasing demand for water transfer from agriculture to environmental and urban uses, impacts of animal waste management from concentrated animal feeding operations (CAFO's) on water quality, precision agriculture and the effects of site-specific management on water conservation and quality, contingent water marketing, and new approaches (e.g. game theory) to conflict resolution among competing water uses and users. The proposed revision of this regional project is a concerted effort to address these emerging concerns in innovative ways.

The consequences of water management and policy decisions are frequently difficult or impossible to predict because of the many complex interactions between technological, institutional, and economic factors. Extensive research has been done on the individual factors and their effect on economic and environmental outcomes. In addition, many models have been constructed which attempt to account for the myriad interactions that may occur that effect such outcomes. Past work by this regional project has focused on model development. Little work has been done, however, on the application of such models to evaluate and quantify the interactions, or to direct the development of sound integrated research to verify and corroborate model predictions. In addition, the difficulty in applying existing models is the lack of complete on-farm or regional data appropriate for input to them. The focus of this revision is to treat these unaddressed needs.

Current and Related Research
In this proposal to revise this regional project, a slightly different angle has been taken on the preparation of this section. Much of the related work in the topic areas covered by the objectives of this proposal, has been, or currently is being, conducted by the members of this highly successful project. The past work, of course, has been carefully discussed in the critical review

section in the appendix of this document. A discussion of other related work is accomplished through a careful consideration of the objectives of other regional projects around the nation that compliment and support the work that this project proposes to undertake.

A search was made on the Internet information sites for each of the four Regional Associations of Agricultural Experiment Stations. All regional projects that had objectives that related to the work proposed by this project were reviewed. In this section of the proposal, related regional projects are identified, their objectives listed, and a discussion of how this proposed project will support on-going work around the nation, is provided. It is the intent of this project to hold, where possible, joint technical sessions with these related regional projects to facilitate coordinated research of mutual benefit.

<u>Related Research in the Western Region</u>
There are several western regional projects that are related to the work proposed by this project as follows:

W-082 - Pesticides and Other Toxic Organics in Soil and Their Potential for Groundwater and Surface Water Contamination.

The objectives of this project are:
1. Characterize mechanisms and quantify processes by which pesticides and other toxic organics interact with soil and water systems.
2. Evaluate models and data describing transport and transformation of pesticides and other toxic organics under field conditions to improve modeling and experimental methodologies.
3. Develop management strategies and tools to reduce soil and groundwater contamination from pesticides and other toxic substances.

This project is centered around a modeling effort, much the same as the work proposed under this project in objective 2. The differences being that W-082 is specifically focused on pesticide contamination of water resources, which is only one aspect of the overall quality of water that the proposed project must consider in the "big picture" analysis of the impacts of water management.

Coordination with this project in formulating and sharing databases in the modeling efforts at the different scales indicated will be investigated. Our proposed project will also support any efforts to assess the economic impacts of pesticide and other organic contaminants that W-082 may be interested in pursuing.

W-128 - Micro-Irrigation: Management Practices to Sustain Water Quality and Agricultural Productivity

The objectives of this project are:
1. Development of micro-irrigation system BMP's to sustain crop production and minimize water application and water quality degradation.
2. Carry out field evaluations of BMP's for crop production and water quality degradation control using micro-irrigation systems

3. Develop an expert system and models for chemical management practices using micro-irrigation systems.
4. Assess the economics of BMP's developed for micro-irrigation systems.

This W-128 project is of narrower focus than the proposed project, but includes some common goals, particularly regarding objective four above. It should be noted that many of the individuals working on the existing W-190 project (which this proposal revises), are also members of the W-128 project, and regularly lend their expertise to the evaluation of the general economic and environmental impacts of water management that the proposed project is focused on. It is expected that the relationship between these projects will continue in light of the need to project system/field-level research to basin- and regional-scale questions.

W-133 - Benefits and Costs of Resource Policies Affecting Public and Private Land

The objectives of this project are:
1. Valuing changes in recreational access.
2. Calculating benefits and costs of agro-environmental policies.
3. Evaluating benefits transfer for groundwater quality programs.
4. Valuing ecosystem management of forests and watersheds.

Again, this project is much broader in scope than the proposed project. Commonality with the proposed project falls primarily in objective 2 above. The participants in the proposed project would be able to lend support in the area of technical, rather than economic, expertise in evaluating policies. Some coordination, perhaps by way of a joint annual meeting, would be desirable between W-133 and the proposed project.

W-170 - Chemistry and Bio-Availability of Waste Constituents in Soils

The objectives of this project are to:
1. Characterize trace element chemistry in soil and waste to predict plant uptake and movement of trace elements in soils.
2. Determine the chemistry of nutrients in organic wastes and the bio-availability and mobility of soil-applied organic chemicals.
3. Characterize trace element chemistry in contaminated soils and evaluate the effects of soil remediation on trace element chemistry, bio-availability and mobility.

The W-170 project should be a tremendous support in obtaining the data for input to the models that the proposed project will be using. There is a need for input at the field-level for soil hydraulic properties and chemical movement parameters (particularly for conservative salts and nitrogen) that impact basin-scale evaluations of return flow quantity and quality. We will look to W-170 to provide much of that support in our proposed efforts.

W-183 - Improvement of Rural and Agricultural Sample Survey Methods

The objectives of this project are:
1. To test procedures and develop conceptual models for reducing measurement error in self-administered mail surveys and telephone interviews.
2. To model the effects of response categories and question order on relations (co-variances) among variables.
3. To test procedures and develop conceptual models of the effects of cognitive and motivational factors on non-response errors in mail and telephone surveys.
4. To integrate and disseminate the results of the experiments for survey practitioners.

One of the tools that the economists in our proposed project have, and will continue to use (especially in proposed objectives 1 and 3) is the survey. The guidance that the W-183 project can provide in this area will be invaluable.

W-184 - Biogeochemistry & Management of Salts & Potentially Toxic Trace Elements in Arid-Zone Soils, Sediments and Waters

The objectives of this project are to:
1. Quantify the biogeochemistry of salts and potentially toxic trace elements in soils, sediments, and waters of arid and semi-arid environments.
2. Revise and refine existing models that integrate hydrodynamics, solute transport, and salt and trace element biogeochemistry in soil and shallow ground water.
3. Evaluate and extend practical management practices, strategies, and systems that reduce the deleterious effects of salts and potentially toxic trace elements in irrigated agroecosystems.

The W-184 project is the best source of technical data for model parameters on the movement of salts and other chemicals through the soils and groundwater of the Western Region. As with W-170, we will look to this project for assistance in the formulation of up-to-date input databases for our proposed modeling efforts. In addition, the management practices that the W-184 project will study and develop will be among those that the proposed project will evaluate for economic viability (see proposed objective 1.3). Given the prospect for significant cooperation, we will try to set up a joint annual meeting with this project in the coming five-year project period.

W-192 - Rural Communities and Public Lands in the West: Impacts and Alternatives

The objectives of this project are to:
1. Evaluate economic models and methodology currently available in Western States to analyze public land issues. Existing methodology will be incorporated into objectives 2, 3, 4, and 5 when appropriate.
2. Develop intra-state agricultural sector enterprise budgets for firm-level analysis and to improve input-output databases.
3. Compile primary and secondary databases for regional, state, sub-state and/or county

input-output and SAM models.

4. Develop computable general equilibrium models from input-output and SAM accounts with special attention given to the treatment of environmental and non-market goods in these models.
5. Estimate the economic impacts of alternative public land management policies using the database and methods of objectives 3 and 4.
6. Assess the social impacts of public land policies on selected communities and households in western states.

The W-192 project is very broad in scope. Our proposed project deals with the impacts of water management on economic viability and environmental quality. However, much of the broader aspects of the agricultural economic analyses that the W-192 project will study, will be important to our proposed effort, particularly as embodied in objectives 2 and 3 of the W-192 project. Enterprise budgets are important to our analyses of how changes in water management can affect the input-output of an operation. We will look to the W-192 project for guidance in this area of expertise.

Related research in other regions

S-273 -- The Impact of Ag. Systems on Surface and Ground Water Quality.

The objectives of this project are to:

1. Modify, improve and evaluate under a variety of land uses and geographic areas existing hydrologic/chemical/sediment models incorporating biotic and economic components.
2. Develop new and improved systems to integrate existing data sources to enhance the applications of the comprehensive models.
3. Collect and assemble comprehensive data bases necessary for model development and evaluation.

Though this project is not in our region, it is a potential source for assistance in the development of sound model databases. We will consult with this project for any assistance that can be provided in this area.

The last two projects that are involved in research related to the proposed project are S-283 and NCR-180. Both projects are involved in Precision or Site-Specific Agriculture. Their objectives are as follows:

S-283 -- Develop and Assess Precision Farming Technology and its Economic and Environmental Impacts

1. Adapt and develop sensors and data acquisition technologies for precision farming.
2. Adapt, develop, and assess methodology and equipment for variable-rate control of inputs to precision farming systems.
3. Develop methodologies and analytical tools for optimum utilization of inputs in precision farming systems.
4. Assess the economic and environmental effects of precision farming.

NCR-180 -- Site Specific Management

1. Review recent and current knowledge and application technology with respect to site specific management.
2. Outline research that will enable evaluation of agronomic practices for site specific crop management relative to the economic and environmental consequences of its adoption.
3. Identify development and technology transfer needs, participate in training of extension specialists and industry consultants, and incorporate the use of rapid information transfer technologies.
4. Facilitate coordinated research on site specific management among participating states, in the. North Central Region and throughout North America.

One of the emerging technologies that the proposed project must consider is that of Precision Agriculture and Variable Rate Application Technology. It has the potential for significantly changing the way agriculture is performed and will have direct affects on water management and agricultural enterprise viability. The W-190 project (which this proposal revises) has had interaction with individuals from these regional projects in the past, to explore where our project might assist in the economic evaluation and modeling applications of/to Precision Agriculture. The interaction has been very helpful in the past, particularly in identifying the economic and water management issues associated with site-specific management. Joint annual meetings are certainly desirable with these two projects where possible.

Objectives
The proposed project will pursue the stated problem through the following three objectives:

1. Evaluate the farm-level economic and environmental implications of alternative resource-conserving irrigation technology and water management systems.

2. Apply alternative methodologies to evaluate economic, environmental and social impacts of potential technology, policy, and institutional changes affecting water resources for irrigated agriculture.

3. Evaluate alternative institutions and policies for resolving competing agricultural and environmental water demands.

Each of these objectives is detailed below, with the discussion identifying research activities for each objective, interaction between objectives, as well as a discussion of the procedures and expected outcomes associated with each objective.

Objective 1:

Evaluate the farm-level economic and environmental implications of alternative resource-conserving irrigation technology and water management systems.

This objective focuses on the assessment of farm-level economic and environmental outcomes under integrated systems of alternative irrigation technologies and resource management strategies. The research involves experimentation and demonstration of alternative irrigation production systems combined with farm-level economic analysis. Research will address the farm-level profitability and environmental benefits of precision-farming techniques in irrigated agriculture, the onfarm economics of using best-management practices (BMPs) for water quality goals, and the impact of alternative irrigation production systems on farm economic risks. Results from Objective 1 research will help explain the implications of irrigation technology and water management change regarding agricultural water use, its potential impacts on water quality, its potential contribution to water-resource reallocation, and the profitability of alternative irrigation systems at the farm level. Further, research for this objective will also investigate the factors that limit or facilitate farmer adoption of irrigation technology, as well as assess the likely effectiveness of alternative technology/water management transfer mechanisms.

Research activities contributing to Objective 1 will:

1.1. Evaluate the farm-level profitability and environmental tradeoffs associated with integrated irrigation production systems involving irrigation, fertilization, pest management, and cropping strategies and practices.

1.2. Evaluate the implications of alternative irrigation production systems on economic risk of the farm, and devise strategies for risk management.

1.3. Evaluate the potential net impact of on-farm water conservation practices on the hydrologic system=s water balance, and their implications for water quality goals.

1.4. Identify the socio-economic factors that affect the adoption and implementation of alternative irrigation production technologies and water management options.

Research results for Objective 1 will contribute both directly and indirectly to Objectives 2 and 3. Policy and institutional analyses based on more aggregate economic approaches generally endogenize micro (farm-level) assumptions within the economic framework, either through their definition of regional production technologies and/or the resource environment, as well as through restrictions on output and/or input substitution possibilities. Research activities 1.1, 1.2, and 1.3 will help to characterize both unique regional production and resource environments for Objectives 2 and 3 economic frameworks. Results from these activities will also help define the potential for alternative levels of irrigation technology change when evaluating alternative policy/institutional changes. Research activities 1.3 and 1.4 will provide Objective 2 research with a basis for improving regionally unique characterizations of hydrologic adjustments to farm-level water conservation. These activities will also assist in adapting policy/institutional mechanisms to reflect differential regional hydrologic and socio-economic environments.

Procedures

1.1. The USDA-ARS Water Management Research Unit in Ft. Collins, Colorado, will lead a large interdisciplinary effort evaluating the potential for precision farming techniques to contribute to profitability and environmental protection in irrigated settings in the western U.S.

This effort will be the continuation of two years of intensive sampling and data collection on two sites in northeastern Colorado. Spatially referenced crop yield, soil properties, water application, and pest occurrence will continue to be collected. Water and nutrient treatments are currently being devised in response to patterns identified through statistical analysis of the baseline data. These variable treatments will be applied along side appropriate controlled treatments to evaluate the potential impacts of site-specific, integrated irrigation-management techniques.

1.1. Colorado State University will be conducting field trials to evaluate the effectiveness of best management practices (BMPs) applied to irrigated agriculture and designed to control water quality. Western states, particularly Colorado, have legislatively mandated that BMPs be voluntarily adopted by farmers. The expediency to educate growers on their irrigation management options required that most published BMPs be based largely on heuristic data and generalized scientific evidence, and have not been evaluated rigorously for their effectiveness in specific settings (for examples of educational materials, see Waskom et al., 1994 and Cardon et al., 1997). This effort is designed to evaluate BMPs for irrigated agriculture in an integrated manner to test their impacts in specific regions and to identify similarities and differences in BMP effectiveness between regions within states. Among the specific issues to be evaluated are conjunctive irrigation & nitrogen management tools (including surge irrigation, LEPA irrigation, chemigation, irrigation scheduling, in-season nutrient status testing, timing of nutrient applications), waste management strategies, and salinity/drainage management methods.

1.2. Texas A&M, and the Texas Agricultural Experiment Station (TAES) will contribute to evaluating the implications of alternative irrigation production systems on economic risk of the farm. This work will focus on estimating outcomes of cropping systems under different irrigation technologies and water management approaches. Frequency distributions of yields and financial measures such as profit and cash flow will be determined for each alternative evaluated.

1.2. The USDA Water Management Research Unit and Colorado State University will extend the analysis of precision application and management techniques to address the element of risk for irrigated agriculture. As techniques are applied to more precisely provide a given amount of water and nutrient inputs to specific areas within the field, the importance of risk becomes much greater. In field-wide applications, farmers often apply inputs to ensure that the large majority of the field area receives at least a given level of the input. As a result of nonuniform requirements, much of the field receives more input than necessary. While this Aover application@ can result in detrimental environmental effects, it does reduce the variability in yield. The approach will be to explicitly model the variability within fields and simulate the response under different scenarios of variable-rate input application. Simulation results will be compared to experimental data from the sites as it becomes available.

1.3. Colorado State University and the University of California at Davis, will be conducting research to evaluate the net impact of onfarm water conservation practices on hydrologic system water balance and their water quality implications. As shifts in water allocations are considered in most river basins, the importance of understanding the ultimate impact of onfarm water conservation becomes paramount. The approach will be to apply mathematical models to estimate onfarm water use and farm production as a function of regional water allocation policies.

1.4. Colorado State University and the USDA-ERS will conduct detailed surveys of irrigation management and technology adoption. In Colorado, data has already been collected through both mail and in-person surveys to determine the extent of technology adoption and the factors affecting producers= decisions in irrigation implementation and management. Statistical analysis will be applied to examine specific questions of how producers determine the timing and quantity of irrigation applications. Producer response will be compared with extension and research program activities to evaluate the effectiveness of various technology transfer mechanisms. (The work from Colorado will serve as a template for region-wide surveys to be sent out under the lead of the USDA-ERS.)

<u>Expected Outcomes</u>

1.1. The effort spearheaded by the USDA-ARS Water Management Research Unit in Ft. Collins, Colorado, will advance the knowledge of the role of small-scale site specificity in interactions among farm-managed inputs. The information gained will be immediately applicable in production agriculture having impacts on both farm profits and environmental sustainability. The results of this effort will be communicated largely through extension field days, popular press and mass media, and professional journals and meetings.

1.1. Colorado State University=s evaluation of BMPs will result in information applicable in fine tuning current BMPs to local conditions. These findings potentially will impact farm profit, environmental integrity, and effectiveness of government policy. Public demonstration sites, field days and local workshops, extension bulletin/manuals, and legislative guidance (white) papers will be the primary communicative pieces.

1.1. Both data and research results for 1.1 research activities will also help define integrated irrigation production technologies for Objective 2 and 3 economic frameworks.

1.2. The work coordinated by Texas A&M and TAES in generating income distributions and evaluating the implications of alternative production systems on economic risk, will advance practical knowledge by developing strategies for risk management. The information generated will be critical input for higher-order modeling efforts on profitability, risk management, and environmental quality under Objective 2 research. The primary communication methods of results from this work will be through professional journals and meetings.

1.2. The work of the USDA-ARS, Ft. Collins, and Colorado State University on precision farming will result in the advancement of practical knowledge by developing sound economic evaluation of such practices on farm risk management. The primary communication medium will be professional journals and meetings.

1.3. The work by Colorado State University and the University of California at Davis on the evaluation of BMP and onfarm water conservation practices on the hydrologic system=s water balance and water quality, will contribute to the knowledge on changes in patterns of water use and irrigation return flows. Research results will also serve as important supporting input to basin-wide modeling efforts of water supply and ultimate water quality impacts in Objective 2.

Results also will provide supporting data for regional resource constraint adjustments across policy and institutional changes for Objectives 2 and 3. Results for this research will be disseminated in professional journals and meetings, and in state/local policy direction documents and educational materials.

1.4. The work of Colorado State University and the USDA-ERS will advance the science and practical knowledge base of irrigation technology adoption and its adjustment process by identifying the socio-economic factors that affect adoption and the implementation of alternative technology transfer mechanisms. The identification of such factors will be critical in technology transfer efforts at all levels. Research results will also provide important information in establishing policy relevant options for alternative conservation policy choices involving farm-level irrigation technical change under Objective 2 research. The primary vehicles of communication will be professional journals and meeting proceedings.

Objective 2:

Apply alternative methodologies to evaluate economic, environmental, and social impacts of potential technology, policy, and institutional changes affecting water resources for irrigated agriculture.

Competition for scarce water resources in the west continues to increase. Meeting new water demands for urban and recreational growth, the Endangered Species Act, and for water quality goals for human and ecological health, as well as demands for Native American and rural economy development, will require assessments of economic tradeoffs of reallocating scarce supplies among competing water users. Agriculture, the largest consumptive user of western water supplies, is a principal stakeholder in policy, regulatory, and institutional changes needed to address water conservation and reallocation issues. Research and extension addressing these issues will evaluate the economic and resource use impacts on agriculture, benefits to water quality, and benefits of enhanced water supplies for ecological habitat as well as for rural economy development.

Water policy and institutional change may encourage water resource conservation, regulate its use, and/or promote its exchange. All three broad policy perspectives, particularly when change involves an integrated policy focus, generate resource availability for competing demands. In addition, policy change that encourages farm-level conservation may not only enhance farm profitability, but increased farm-level input-use efficiency (for both water and chemical inputs) will generally also enhance surface and groundwater quality. These impacts are also likely to contribute to other human health, ecological, and environmental goals. Changes in resource and environmental policies and institutions then, may not only impact agriculture, but will also likely occur to promote both resource-use efficiency and to enhance or create public-sector goods.

To address these issues, objective two research will apply, integrate, and validate models of agricultural production, hydrology, and regional economy impacts. Research will make use of both static and dynamic modeling frameworks to assess economic, conservation, hydrologic, and water quality tradeoffs of conservation-incentive, regulatory, and institutional water policy changes. Modeling approaches will emphasize measuring producer and regional resource, output, and water management and technology adjustments in response to policy and institutional changes, as well as the impact these changes have on resource opportunity values to agriculture and agricultural economic conditions. Research will address both the private and social (public) costs and benefits of alternative policy and institutional changes.

Research activities contributing to Objective 2 will:

2.1 Evaluate the economic implications of water policy change using integrated models of agricultural production, hydrology, and regional economy impacts;

2.2 Identify and evaluate the economic and reallocation tradeoffs of alternative water transfer institutions, including the use of alternative water marketing, banking, and pricing structures;

2.3 Assess the economics of conservation versus regulatory water policy approaches designed to promote water reallocation and environmental policy goals;

2.4 Evaluate the economics and water quality implications of policies designed to reduce nonpoint-source pollution;

2.5 Examine the impact of farm structure on the economics of water policy change (and vise-versa); and

2.6 Assess the potential impacts of climate change on water supply, agricultural production, and on the economics and conservation/reallocation goals of water policy and institutional change.

Both data and research results from Objective 1 research will help identify the production technology and resource environments characterized within alternative economic modeling frameworks for Objective 2 research activities. Objective 2 research will benefit from Objective 1 research assessing farm-level integrated irrigation production systems (precision farming technologies) and irrigation BMPs to characterize aggregate, farm-relevant production technologies within primal-dual static, dynamic, and game-theoretic modeling approaches. Objective 2 research will also use Objective 1 research results to differentiate the implementation of water policy choices consistent with unique regional technology and resource environments. (For example, the significant declines in aquifer water tables of the southern High Plains have induced more water-conserving irrigation technology adoption, relative to other regions. Therefore, for this region, conservation water policy will likely need to place greater emphasis on water management to increase irrigation efficiencies for water quality goals.) Objective 2 research will also use the alternative characterizations of institutional water transfer mechanisms developed under Objective 3 research to conduct comparative economic analyses across water policy, regulatory, and institutional changes. Objective 2 research results also will serve to supplement the economic analyses of Objective 3 research. That is, minimum willingness-to-accept values for alternative policies estimated under Objective 2 research will provide the basis to evaluate the costs to agriculture in Objective 3 benefit-cost analyses of reallocating water resources to meet nonagricultural demands.

Procedures

Alternative economic research methodologies (direct and indirect) will be used to evaluate both private and public costs and benefits of water resource-related policy and institutional changes. Direct approaches will integrate hydrologic modeling results with agricultural production and regional economy models. Direct approaches will also adapt and extend models of irrigation technical change, and primal-dual, restricted-equilibrium programming-optimization models to evaluate the impact of alternative conservation and regulatory water policy choices across regional resource and institutional environments. Indirect approaches will adapt dynamic optimal-control and indirect profit-maximization models to evaluate the economic and water quality impacts of farm-level water management and technology adjustments designed to reduce non-point source pollution. Differential game theory will also be applied to assess the impacts of alternative producer irrigation strategies consistent with maximizing producer benefits when producers account for the risks associated with their neighbor=s behavior. The research for Objective 2 will apply these methodologies at both the farm- and regional-level to capture producer behavioral response to change. Research will also look at the impact climate change is likely to have on water supplies for agriculture, producer output substitutions, regional production shifts, and the implications these changes will have on the agricultural economic impacts of water conservation and reallocation policy changes.

More specifically, research activities for Objective 2 will involve the following procedures.

2.1 Most river basins are extremely complex, in part because of the physical interactions between river, aquifer- and water-management systems, and in part because of the institutions governing water allocation among users and uses. Given this setting, a multi-disciplinary research perspective using an integrated economic/hydrologic modeling approach will be used to evaluate both economic and subsequent aquifer and streamflow impacts of policy change altering water diversions and/or withdrawals. The research will seek to identify the most desirable policy alternatives that serve competing water demands while minimizing the impacts on hydrologically-vested interests.

This research will integrate a system of economic and hydrologic models by extending, refining and integrating existing models of hydrology, irrigation management, irrigated agricultural production, hydroelectric generation, and regional economics. As a case study, researchers at the University of Idaho, Washington State University, and Oregon State University will conduct research linking ModSim, a Bureau of Reclamation (BoR) model of the hydrology of the southern Idaho Snake River basin, to an economic optimization model that evaluates farmer response to alternative levels of water supply, and to IMPLAN, an input-output regional economic impact model. This integrated modeling system will be used to assess the economic, as well as the water quantity and quality impacts of policy changes anticipated for management of the upper Snake River, including policies to aid the recovery of endangered salmon stocks within the basin.

2.2 To achieve goals for water reallocation in the West, it will be necessary to amend current water allocation institutions. Traditional institutional allocation schemes are based heavily on State water-rights law -- dominated in the West by the doctrine of prior appropriation -- which ignores the relative economic value of competing water demands. Western water allocations are also heavily influenced by the governance and water management responsibilities of the BoR, of which both are believed to impede western irrigation water conservation and the ability to reallocate scarce water resources to competing demands.

New economic institutional arrangements, including the use of alternative water market and banking structures, and water pricing schemes will be needed to achieve economic efficiency of water allocation among competing demands, as well as promote the ecological health of western river systems, reduce human health risks, and to satisfy outstanding Native American water claims. This research will examine the economic and reallocation tradeoffs across new and traditional institutional water allocations. The research, involving participants from Washington State University, University of Idaho, and the University of Nevada-Reno, will emphasize the impact of unique regional characteristics affecting participation in new institutional arrangements, as well as their regional comparative-economic advantages. For example, in the upper Snake River, allocation of storage water is a critical issue. This regional characteristic may lead to a distinction between water marketing and water banking as a viable institutional change for the region. In regions where water storage is limited, water banking is likely to be a relatively less important issue. In addition, the University of Hawaii plans to continue its research on sector-specific water demand, with special reference to water transfers from agricultural to environmental and visitor-industry uses. This research will examine the role of water markets and pricing and their effect on water transfers.

2.3 Water policy change may contribute to Federal and State resource, environmental, and social policy goals by inducing irrigated agriculture to conserve water, or by imposing regulatory restrictions on either agricultural water supplies or production practices. Conservation-incentive policy can consist of institutional reforms that encourage producers to consider the opportunity value of water resources for other than agriculture, as well as resource-efficiency policies that generally alter the direct marginal cost of water within agriculture. Policies adopted through institutional reforms may include alternative water market structures, expanded BoR water management authority, as well as defined conserved-water property rights. Alternatively, resource-efficiency policies may induce conservation through increased BoR water prices or alternative pricing structures, or through conservation subsidies designed to encourage onfarm and off-farm irrigation technical change. Regulatory policy, however, may impose quantity-based restrictions on agriculture=s use of surface or groundwater supplies, or it may require increased use-efficiency through best-management-practices. This research will examine the economic and conservation tradeoffs across conservation versus regulatory policy options, as well as their policy implications across regions. The research, involving Washington State University, University of Idaho, and the Economic Research Service, USDA, will adapt or extend the interregional, programming-optimization, production-economic models developed under W-190 to evaluate policy tradeoffs.

Research at the University of Nevada-Reno will also develop or adapt economic models to evaluate the impact of alternative irrigation district water-pricing structures, and assess the economics of alternative district-level conservation plans. Particular attention will be devoted to addressing the economic tradeoffs of alternative district-level water-pricing structures within the context of Federally-mandated water conservation plans for irrigation districts receiving BoR-supplied water. For example, volumetric water-pricing is regarded as a critical BoR best-management practice (BMP), whereas incentive pricing, such as a tiered block-pricing structure, is regarded as an exemptible BMP. Many irrigation districts with BoR water delivery contracts are working on developing a water-pricing structure, as well as plans for water conservation, measurement, and the efficient use of water. Examining the economics of district-level pricing structures and conservation plans will provide for improved management of BoR-supplied water resources.

2.4 Agricultural-based nonpoint-source pollution contributes to water quality problems for industrial and recreational use, and for human and ecological health. Regulations, through diversion reductions or best-management practices, taxes, cropland retirement, and technical assistance programs are the general policy perspectives used to address agricultural nonpoint-source pollution problems. Research at the Economic Research Service (ERS), USDA, and the University of Nebraska-Lincoln, will examine the economics of alternative policy choices designed to enhance public water quality goals. With Congress establishing the Environmental Quality Incentive Program , as part of the 1996 Farm Act, ERS will give particular research emphasis to evaluating the economics of a conservation cost-share policy perspective designed to reduce nonpoint-source pollution. Using a dynamic, indirect profit-maximization approach that accounts for the nonjoint production character between crop output and nonpoint pollution, this research will recognize both the economic and environmental characteristics of the producer production decision process. Using differential game theory, research at the University of Nebraska-Lincoln will assess the economic impacts of alternative producer water management strategies when producers account for the risks associated with their neighbor-s behavior.

2.5 Alternative water policy options are known to alter the economic-opportunity value of conserved water to agriculture differently, and thereby result in a different agricultural response across policy choices. Resource opportunity values to agriculture change because producer resource and output substitution responses differ across policy choices. Regional production models using dual cost/profit function approaches have demonstrated this result theoretically and empirically. However, regional models are less able to identify the differences in producer responses to policy change across farm size. Resource availability, economies of size, financial stability, and output substitution possibilities will all affect the ability of farms of different size to respond to policy change. Research at the Economic Research Service, USDA, will investigate the use of USDA NASS/ERS farm-level data from the Agricultural Resource Management System (ARMS) to establish micro and regional economic models (using a normalized, primal-dual, restricted-equilibrium optimization approach) to evaluate: a) the influence of regional farm structure and farm production technology differences on the economics of irrigated agriculture; and b) the effect farm structure has on the economics of alternative regulatory and conservation policy choices.

2.6 Preliminary results from global climate change research suggest that it could have significant effects on western irrigated agriculture. Precipitation amounts and timing may change, as may the mix of snow and rainfall, which may affect the ability of reservoirs to store runoff, while higher temperatures will affect the length of the growing season and crop evapotranspiration. Several of the modeling frameworks developed under W-190 will be useful in exploring the potential impacts of global climate change on western irrigated agriculture. For example, research at the University of Idaho proposes to use a ModSim model of the Snake River basin hydrology to explore how predicted changes in the amount and timing of water supplies and irrigation demands would affect the allocation and adequacy of water in the basin. Results can then be used in conjunction with the models being developed at Washington State University that show how farmers respond to varying levels of water supply to demonstrate the possible economic effects of climate change on irrigated agriculture in southern Idaho, as well as the effects on instream flows and hydropower generation.

<u>Expected Outcomes</u>

2.1 Research results will benefit regulatory agencies, policy makers, water resource users, and the general public by developing and providing knowledge and analytical methods that will result in better management and use of scarce water resources. The type of information the research will produce are quantitative changes in river flow, reservoir storage, aquifer recharge and discharge, cropping patterns in irrigated agriculture, irrigation management practices and technologies, the quality of excess applied water, hydroelectric power production, and the impacts of these changes on the region's economy. This information will improve policy makers ability to assess tradeoffs between enhancing instream flows and the policy's impacts on a region's hydrology and its regional economy. Research results will be reported in both professional journals and extension outreach reports.

2.2 This research will report the economic and conservation tradeoffs of alternative water transfer institutional arrangements, as well as their unique regional characteristics. Emphasis will be given to the regional comparative advantages of alternative institutional policy perspectives. Research results will be reported in both professional journals and extension outreach reports.

2.3 This research will report on the comparative economic and conservation tradeoffs of conservation-incentive versus regulatory water policy change. In addition, research on irrigation district-level water pricing and conservation plans will report results in terms of a farmer's ability to pay, revenues to an irrigation district, the cost of water deliveries, and the overall economic efficiency of water resource use within irrigation districts. Results will be reported in both professional journals and extension outreach reports.

2.4 This research will evaluate both the private and social (public) economic costs and benefits of irrigation technology adoption and its effect on groundwater nitrate contamination levels, as well as evaluate the optimal government cost-shares needed to encourage pollution-reducing irrigation production technologies and practices. The research will also report on the impact producer risks preferences associated with alternative producer resource-management practices have on the economics of irrigated agriculture. Research results will be reported in both professional journals and extension outreach reports.

2.5 For this research, emphasis will be given to reporting on the effect farm structure has on the opportunity value of conserved water to agriculture, thereby providing public-policy decision makers information on agriculture's minimum willingness-to-accept policy change across policy choices. Results will be reported in both professional journals and extension outreach reports.

2.6 This research will compare economic impacts of water policy change, with and without climate change, providing useful information to assess the impact of climate change on the economics of water policy change, and the ability to refocus watershed-based, reservoir management. Research results will be reported in both professional journals and extension outreach reports.

Objective 3:

Evaluate alternative institutions and policies for resolving competing agricultural and environmental water demands.

Irrigated agriculture accounts for about 90% of the water consumed in the West. Agricultural water rights are based on the prior appropriation doctrine underpinning western water law. The doctrine grants a user's right to a person diverting previously unappropriated public water to a beneficial private use. The priority of the right is based on the date of first diversion and use. Consequently, water is allocated during shortages to completely satisfy the most senior rights first, and to partially satisfy more junior rights as the water supply permits. Agriculture perfected the most senior rights over the last century, and the security of these rights has been strengthened by protectionist legislation in a number of states.

Most would agree that the prior appropriation doctrine was highly successful in promoting the rapid development of the West over the previous century. However, the doctrine's strength in securing water rights to traditionally productive uses can render it inflexible in allocating water to competing environmental uses which have been largely unprotected under the doctrine's traditional application. Specifically, the doctrine generally prohibits an appropriator from engaging in any use that infringes on the rights of another. Since a water transfer from one user to another can impair the appropriative rights of a user not involved in the transfer, many state water codes require the proponent of a water transfer to demonstrate that no such impairment will occur as a condition of approval. The burden of such a showing has been identified as a major reason that water markets have not developed more extensively in the Western States.

Despite the doctrine's inflexibility in providing for water transfers in general, the economic and legal pressures to transfer water to environmental uses are increasing. The economic pressure mounts as economists demonstrate that the marginal value of water in many environmental uses exceeds that in agricultural use. The legal pressure mounts as environmental uses are increasingly protected by the public trust doctrine (a common law doctrine protecting public resources from private harm and predating the prior appropriation doctrine) and federal environmental statutes.

Objective 3 is concerned with crafting water institutions that facilitate water transfers while protecting the historic appropriative water rights of current users, and developing institutions to resolve conflicts among user groups that arise as water is transferred from one use to another. Findings from Objective 1 will assist in crafting institutional and policy mechanisms that will fully reflect and be responsive to regional hydrologic and socio-economic differences. Results from Objective 2 will be used to identify opportunities for improved resource allocation and to provide justification for institutional change. A regional approach will require communication among researchers in different states since legal and institutional arrangements vary widely in the western region.

Research activities contributing to Objective 3 will:

3.1 Evaluate potential water markets by quantifying environmental benefits of instream flow using newly-generated information on the relative economic value of water in environmental and agricultural uses.

3.2 Evaluate alternative laws, institutions, and mechanisms, current as well as potential, to promote agricultural water conservation using strategies such as raising irrigation water prices and increasing on-farm irrigation efficiencies.

3.3 Evaluate economic, environmental and social impacts of technology, regulation, and institutional changes associated with regional water resource issues.

3.4 Evaluate the effects of drought on agriculture, and the Federal role in water market development to mitigate drought conditions using a contingent market approach.

3.5 Evaluate alternative strategies for resolving water use conflicts among multiple stakeholders which will include litigation, market acquisitions, policy reforms, and changes in public resource management, including dam reoperations.

Procedures

3.1 Three procedures will be used to quantify the dollar value or "shadow price" of water in environmental uses: (1) Estimate the demand for environmental uses of water based on recreationists' travel behavior to rivers and reservoirs with varying quantities of water. From this demand curve, the visitors' willingness to pay (WTP) can be calculated and compared to the cost of purchasing small quantities of water from farmers; (2) Estimate a dollar value for environmental uses of water by comparing property prices of parcels adjacent to streams with adequate instream flow versus those with either poor instream flow or contaminated agricultural return flows; and (3) Employ a survey-based approach asking individuals how their recreation behavior would change with increased instream flows and fish populations. Such surveys will be conducted on the Platte and Snake Rivers to estimate the environmental benefits of water and endangered fish recovery. Colorado State University and the University of Idaho will take the lead in this effort.

3.2 Analytical techniques from mathematical economics, hydrology, and law will be employed to evaluate the theoretical rationale and justification for expecting that the various policy mechanisms listed in the objective statement will result in actual water conservation in irrigated agriculture. Washington State University and the University of Hawaii will be conducting research along these lines.

3.3 Cointegrated maximum likelihood time-series methods will be used to test for long-run relationships between water use and economic indicators such as employment in agriculture and total employment in farming regions of California.

3.4 A case study approach will be used to evaluate whether the adoption of contingent water markets can lead to enhanced environmental quality in periods of drought and to reduced production risk for farmers.

3.5 Cost/benefit analysis and game-theoretic approaches will be used to compare the desirability of various voluntary measures (such as water purchases) and involuntary mechanisms (such as court orders) to resolve water conflicts. Research at the University of Arizona, University of Hawaii and the University of Nevada will examine ongoing and potential water use conflicts involving multiple stakeholders and evaluate the efficacy of alternative conflict resolution strategies.

Expected Outcomes

3.1 The research will result in improved methodology for valuing environmental water benefits, and will provide policy-makers with currently unavailable data for regulating instream flows in the Platte and Snake River basins. The research will be communicated through refereed journals and outreach publications.

3.2 The research will advance knowledge concerning the hydro-economic impacts of encouraging irrigators to increase their on-farm irrigation efficiency, and of increasing the prices charged for water deliveries. The research will also aid policy-makers in deciding whether to incorporate such measures in state and federal water statutes and regulations. The research findings will be reported in refereed journals and outreach publications.

3.3 The research will provide policy-makers with a valuable empirical tool for predicting state-wide water use based on its statistical relationship with various state-reported economic indicators. The research will be communicated in refereed journals and outreach publications.

3.4 The research will augment theoretical work on contingent water marketing with case study results showing how the concept might actually be implemented. This information will be valuable to state and federal governments deciding whether to encourage contingent marketing to achieve public objectives such as increasing instream flow for fish and wildlife. The research results will be communicated in refereed journals, conference presentations, and outreach publications.

3.5 The research will demonstrate to policy-makers how state and federal water policies can be revised to better prevent, manage and resolve disputes. The research will be communicated in refereed journals, outreach publications and other appropriate outlets.

Organization
The technical committee for this project will be organized as follows:

Chair
Vice-chair (chair elect)
Secretary (vice-chair elect)

Each year a new secretary will be elected by the project participants. The positions will rotate upward year to year from Secretary to Chair. The Chair is responsible for the organization of the annual meeting the year he/she is serving, and is ultimately responsible for submission of the annual report as assisted by the Vice-chair and Secretary. At times, the technical committee may choose to organize ad-hoc sub committees for various purposes such as proposal writing, special annual meeting events (e.g., field trips), etc

W-190 Agricultural water management technologies, institutions and policies affecting economic viability and environmental quality.

Signatures.

Administrative Advisor — Date: 9/1/99

ADMINISTRATIVE ADVISOR — DATE: 9/1/99

CHAIR, REGIONAL ASSOCIATION OF DIRECTORS — Date: 9/10/1999

Administrator, CSREES — Date

References

Waskom, R.M., G.E. Cardon, M. Crookston. 1994. Best Management Practices for Irrigated Agriculture: A Guide for Colorado Producers. Colorado Water Resources Research Institute Completion Report #184.

G.E. Cardon, R.M. Waskom, A.Y. Ali, and J.K Alldredge. 1997.

PROJECT LEADERS

Name	State	Agency	Specialization
Adams, R.	OR		Agricultural Economics
Colby, B.	AZ		Resource Economics
Berck, P.	CA-B		Resource Economics
Grismer, M.	CA-D		Agricultural Engineering
Bali, K.M.	CA-D		Agricultural Engineering
Cardon, G.	CO		Agronomy
Gopalakrishnan, C.	HI		Resource Economics
Hamilton, J.R.	ID		Agricultural Economics
Narayanan, R.	NV		Resource Economics
Harman, W.L.	TX		Agricultural Economics
Mapp, H.	OK		Agricultural Economics
Michelson, A.	TX		Agricultural Economics
Huffaker, R.G.	WA		Agricultural Economics/Law
Lacewell, R.	TX		Agricultural Economics
Perry, G.	OR		Agricultural Economics
Schaible, G.	DC	ERS/RED	Agricultural Economics
Supalla, R.	NE		Agricultural Economics
Ward, F.	NM		Agricultural Economics
Other Cooperators			
Buchleiter, G.	CO	ARS	Agricultural Engineering
Heerman, D.	CO	ARS	Agricultural Engineering
Duke, H.	CO	ARS	Agricultural Engineering
Bausch, W.	CO	ARS	Agricultural Engineering
Wiles. L.	CO	ARS	Weed Science
Gollehon, N.	DC	ERS/RED	Agricultural Economics
Caswell, M.	DC	ERS/RED	Agricultural Economics
Martin, D	NE		Agricultural Engineering

RESOURCES PAGE

PARTICIPANT		OBJECTIVES			RESOURCES			PERCENT TIME		
		1	2	3	SY	PY	TY	RES	EXT	TEACH
Arizona										
Bonnie Colby				X	0.20			80		20
California										
Peter Berck		X	X	X	0.10			70		30
Mark Grismer		X	X		0.05					
K.M. Bali		X	X		0.10		0.04			
Colorado										
Grant Cardon		X			0.50			75		25
Hawaii										
C. Gopalakrishnan				X	0.50			100		
Idaho										
Joel R. Hamilton			X		0.25			100		
Nevada										
Rangesan Narayanan			X		0.50			60	40	
Texas										
Wyatte J. Harman		X	X	X	0.10			100		
Washington										
Ray G. Huffaker				X	0.10			75		25
ARS - Colorado										
Gerald Buchleiter		X			0.30			100		
Dale Heerman	X			0.20			100			
Harold Duke		X			0.10			100		
Walter Bausch	X			0.10			100			
Lori Wiles		X			0.10			100		
ERS/RTD - Washington										
Margriet Caswell		X	X	X	0.10			100		
Glenn Schaible			X	X	0.10			100		
Noel Gollehon	X		X	0.20			100			

A Critical Review of Work Under the W-190 Regional Research Project:

Water Conservation, Competition and Quality in Western Irrigated Agriculture (1994 to 1999)

Project Overview

The W-190 regional research project entitled "Water Conservation, Competition and Quality in Western Irrigated Agriculture" was established in 1994 to address major issues in water resource management in the American West. Under the three broad themes of conservation, competition and quality, a large number of specific problems were identified, examined and studied by researchers from individual states. These include the conservation effects of water pricing and water law, conservation technologies and policies, the changing configuration of water use, competition among uses and users, the third party effects of water transfer, non-point source pollution, public health and recreational impacts of water pollution, recreational demand for water, institutional dimensions of water allocation and management, the politics of water in the American West, and Western water laws in transition. Thus, research accomplished under this project showed significant diversity and range, while at the same time focusing on the projects three themes.

During the 1994-99 period, W-190 attracted participation from thirteen states. (Although Wyoming is one of these states, its participation was limited to a short period at the very beginning of this project). Also involved from the outset were researchers from ARS and ERS (Table 1). As expected, there has been some turnover of participating scientists due to changes in faculty assignments, retirements, resignations and changes in individual research interests.

A total of 34 researchers have been directly involved in this project in the course of the review period. The group consisted of 25 agricultural/resource economists, 6 agricultural/irrigation engineers, and three agronomists (Table 1). Researchers from the three disciplines have worked on many collaborative projects.

A review of research accomplished during the 1994-99 period, under each of the three objectives, is presented in the next section.

Research Accomplishments

A summary of research accomplishments, by objective and state, is presented in this section in order to document project productivity and to show the diversity and range of topics that have been addressed under the W-190 regional project.

Objective 1: Develop and assess technologies and management strategies for their potential to conserve water, improve water quality and enhance profitability in irrigated agriculture.

Significant research has been carried out under this objective, although the bulk of it was done in relatively few states: California, Colorado, Nebraska and Texas. Research focused on all three areas of concern - water conservation, water quality and productivity of irrigated agriculture. While some studies dealt primarily with new technologies, others focused on innovative management strategies.

Research conducted in California studied the influence of field-characteristic data on producer irrigation technology choices in San Joaquin Valley using a discrete-choice, multinomial logit model of producer field-level technology adoption decisions. This research examined the influence of ten independent field characteristics on a producer's field technology decision -- field size, field slope, soil permeability, water price, water source and crop choice (citrus crop, deciduous crop, grape vineyard, or truck crop).

Work done in Colorado has addressed many issues involved in irrigation technology and management. These include: a research project developed by eighteen ARS and University researchers to better understand the various interactions between production factors causing spatial variation in yield under irrigated conditions; a project dealing with spatially and temporally varied water and chemical application; and work on a user-friendly evaluation model for performance of center-pivot systems.

Nebraska's work involved the development of strategies and technologies for reducing nitrate pollution of groundwater and on methodologies for evaluating management options. The potential of precision farming in reducing nitrate pollution of ground water was also examined as part of the research.

In Texas, research at the farm level focused on water quality and irrigated agricultural productivity. In an effort to analyze feedlot supply/demand conditions for 90+ feedlots in the Texas High Plains, many options regarding crop yields and water quality inferences of using various rates of livestock manure for crop fertilizer were developed by simulation modeling with EPIC, a daily time-step crop growth simulation model. These yield /manure responses were utilized as inputs to a large spatial transportation model to optimize manure use and to analyze the supply/demand conditions for manure at each of the feedlots in the region.

Objective 2: Develop and evaluate means for meeting state, regional, and national policy goals for water supply, allocation, and quality under available and emerging technologies and management strategies.

There was considerable research activity under this objective, with virtually all states participating in work contributing to its goals. Water supply, water allocation and water quality figured prominently in the research efforts. A recurrent theme in research conducted under this objective had to do with the economic and environmental tradeoffs of policy instruments. Water markets, water pricing and water transfer received special attention in the study of water supply and allocation issues.

Work in California focused on water quality and water trading. Under the former, research measured and assessed the impact of salinity standards in the Colorado basin. The analysis combined a stochastic differential specification of salinity loads with regionally calibrated Cobb-Douglas models of irrigated agriculture. Under the latter, research assessed the effects of water trading that occurred in 1991 on two local California farm communities. The analysis used all aspects of social measurement to evaluate results from surveys of local opinion and economic impact. Colorado did studies on water transfer and nonmarket valuation of river restoration. One study evaluated the opportunity costs to agriculture, or the direct foregone economic benefits of agriculture-to-urban water transfers what have occurred along the Colorado Front Range for water from the Colorado Canal. Another study examined the total nonmarket economic value of restoring the Elwha River (in Washington state) and its fisheries for residents of the county, state, and nation.

Water conservation, water supply and water transfer were the concerns of research done in Hawaii. The conservation effects of irrigation and residential water pricing were examined using regression analysis as part of this work. A detailed analysis of water demand in the agricultural, residential, visitor industry and commercial and industrial sectors of Hawaii was completed. The possibilities for water transfer from agricultural to nonagricultural uses were also studied.

New Mexico research addressed issues pertaining to optimal reservoir/instream-flow water management and reservoir recreational use values. One study examined economically efficient management of scarce water resources for a multiple-use, basinwide reservoir/instream flow management system for New Mexico's Rio Chama River Basin using an economic optimization model. Another study evaluated the effect changing reservoir levels have on the marginal recreational value of water for ten Corps of Engineer reservoirs in the Corps' Sacramento, California District.

In Indiana, farm economic and environmental tradeoffs of alternative Midwestern cropping systems were studied through an integration of research results from biophysical, simulation models within a multi-attribute, utility maximizing economic framework.

Idaho research addressed the economic and hydrologic implications of the proposals to aid the recovery of endangered salmon in the Snake River Basin. Partly funded by a USDA/NRI grant, the research was conducted in collaboration with Washington state. Research focused on linking models of irrigation behavior to models of river and aquifer response to estimate the economic impacts of alternative policy actions in the upper Snake.

Research in Oregon evaluated the welfare effects on recreational anglers of alternative Salmon allocation policies designed to meet Native American treaty rights along the Willamette River spring chinook fishery. Welfare analysis was conducted using a discrete-choice random utility model coupled with a Poisson trip frequency model.

In Oklahoma, research developed an empirical framework for quantifying the impacts of government commodity program provisions (crop target prices and ARP rates) on cropping patterns and the resulting impacts on nitrogen losses in runoff and leaching in the High Plains region (overlying the Ogallala aquifer). The empirical framework integrated site-specific information on soils, climate, cropping systems, and production practices to evaluate nitrate water contamination potential for each of 12 multi-county High Plains subregions.

Policy options for inducing agricultural producers to adopt practices which reduce nitrate pollution of groundwater were the main focus of Nebraska's research. Three studies were completed, one of them an aggregate LP analysis which examined the tradeoffs from nitrogen taxes and nitrate pollution constraints for the Central Platte Valley in Nebraska.

In Texas, research examined the economics of alternative farm-level environmental policies designed to reduce nitrate pollution in the Seymore aquifer of north-central Texas. This research used a risk-sensitive, farm-level optimization model which integrated information on crop yield and the percolation of nitrates to the aquifer into an economic optimization model through yield and nitrate percolation responses. Policies were evaluated for both risk-neutral and risk-averse farm-decision environments.

Water conservation and water transfer were the major themes Washington researchers worked on under this objective. A joint research project involving Washington State University, University of Nebraska-Scottsbluff and New Mexico State University investigated the adoption and implementation of conservation prices and rate structures by irrigation districts. A second joint research project by WSU and NMSU studied the effectiveness of residential water conservation programs in the Southwestern United States. A third research project assessed water banking policies in the upper Snake river in Southern Idaho; quantified the effect of land allocation, soil quality and water price on the demand for irrigation technology; and examined the potential of water transfers for environmental uses in Washington state.

Research in Nevada evaluated economic impacts of three different water transfer actions. The first study involved evaluating the economic impacts of the Truckee River Operating Agreement. The second study estimated the economic impacts of the water acquisition program for wetlands administered by the U.S. Fish and Wildlife Service. The third study examined the economic feasibility of alternative water management strategies for the Walker River Basin to improve the declining water level of Walker Lake.

Significant research contributions were made by researchers from ERS, USDA. This included the completion of model development on the Western Agricultural Water Analysis (WAWA) model designed to evaluate production, producer surplus, and water use impacts, as well as interregional flow implications of alternative conservation-incentive/regulatory water policies. The model structure was established for the 17 Western States, but calibrated now for the Pacific Northwest. A second study evaluated selected regulatory and conservation-incentive water policy choices for the Pacific Northwest (Oregon, Idaho and Washington). Using the WAWA model, the study evaluated production, water use, and producer welfare impacts of alternative water policies. A third study, using econometric applications of limited-dependent variable methods, evaluated the role of water price across alternative behavioral models for irrigated agriculture across four multi-state Western regions, and for irrigation water use in the Central Plains.

Objective 3: Evaluate alternative laws, institutions, and mechanisms developed to promote and implement state, regional and national policies for water quality and supply allocation.

Most states have been involved to some degree in research pertaining to this objective. Issues addressed include the role of institutions in shaping water policy, water laws and their impact on ownership and allocation of water, and water use conflicts and strategies for their resolution.

Arizona and New Mexico in joint research addressed institutional issues associated with water allocation in each state. Research examined the economic benefits of enhanced and more reliable instream flows, and the likely effectiveness of market transactions vis--vis administrative or judicial water reallocations to ensure adequate water for instream recreation and wildlife needs. The upper Rio Grande river reach at the Colorado/New Mexico border also involved interstate allocation issues and water transfers from agriculture to instream uses.

Work in California focused on institutional change in water resource property rights. Research extended previous work on the issue of malleable property rights in natural resources. This research recognized that even if gains from trade are evident, water-resource property rights have not endured institutional change according to some smooth marginal adjustment process. This institutional-change issue was examined by developing a simple theoretical model the stochastic dynamic evolution of water demand and supply in California; and using the model to explain qualitative properties of the delay in the switch to a market-based water-supply system in California.

Research in Hawaii dealt with water use conflicts and allocation of water under conjunctive use. As part of work on the first theme, two case studies were completed, one on Oahu and the other on the island of Molokai. The major issues emerged as native people's water rights, sustaining bio-ecosystems, recycling and future urban development. Conflict resolution measures examined included negotiation, arbitration, judicial processes, water pricing, quotas, and conditional permits. Research on allocation of water under conjunctive use included analysis of technology choice and land quality issues. A model for urban-agricultural water allocation that included desalination of sea water was developed.

Nebraska focused on institutional arrangements for addressing the consequences of water quality problems for consumers. As part of this work, the ability of 439 rural communities in Nebraska to pay for sewer and water services was evaluated. Research was also done on the conjunctive management of ground and surface water.

Researchers from Texas A&M, New Mexico State University and Colorado State University examined how water management institutions in their respective states could adjust operational strategies to cope with droughts. The study grant was awarded through the Western Region of the National Institutes for Water Resources USGS. The research, among other things developed realistic drought scenarios for the region, and did economic simulations to identify monetary damages associated with specific drought scenarios. Legal-institutional measures that water managers can use to deal with droughts were also identified.

The water conservation/reallocation challenge posed by Western Water Law was the major thrust of research in Washington. Three water-related institutional concerns were examined: (1) the usefulness of the prior appropriation water law in reallocating water to growing demands for environmental and public (nonmarket) uses; (2) the institutional, technological and hydrologic complexities and interrelationships associated with water "conservation" programs and water markets; (3) and the merits, shortcomings and role of the public trust doctrine as an institutional means to protect the public's interest in water allocation decisions.

Specific Accomplishments

Some examples of specific accomplishments are given below.

1. California researchers from Berkeley and Davis jointly designed an electronic, water-market communication system to be used by irrigators in the Westlands District of the Central Valley of California.

2. Colorado researchers, in cooperation with Coors Brewing Company, completed a comprehensive educational document on irrigated barley management practices in the state.

3. Using simulation modeling with EPIC, Texas developed many options regarding crop yields and water quality inferences of using various rates of livestock manure for crop fertilizer for 90+ feedlots in the Texas High Plains.

4. Research in Oklahoma developed an empirical framework for quantifying the impacts government commodity program provisions (crop target prices and ARP rates) on cropping patterns, and the resulting impacts on nitrogen losses in runoff and leaching in the High Plains Region overlying the Ogallala Aquifer.

5. Research in New Mexico developed regional recreation demand models and tested them for interchangeability across Army Corps of Engineer reservoirs in Arkansas, California and Tennessee/Kentucky.

Project Productivity and Impact: Further Comments

It should be clear from the above review that this regional project was highly productive and that it encompassed research on a diverse array of related issues. The project has been a successful effort as judged by the substantial number of publications dealing with many aspects of water resource management in the Western region, and the interdisciplinary cooperation it fostered among economists, engineers and other scientists.

The impact of this project goes far beyond the impressive number of publications that it has generated. Other measures of project impact include conference presentations, collaborative research with federal and state agencies involved in water management, expert testimony on water problems at important public hearings, serving on important committees on water policy, and other activities. In all these endeavors, the record of this regional project is impressive. Examples include: presentations at annual meetings of the American Agricultural Economics Association,Western Agricultural Economics Association, American Society of Agricultural Engineers, American Water Resources Association and the International Water and Resource Economics Consortium; research collaboration with U.S. Geological Survey, Bureau of Reclamation, and Army Corps of Engineers as well as state agencies; and service by a technical committee member as one of eight economists for the Northwest Power Planning Council.

A major achievement of the regional project is the projected publication next year of a special issue of the International Journal of Water Resource Development, a leading interdisciplinary journal in the water resources field, devoted exclusively to papers written by W-190 members on project-related research. Two members of this regional committee, Gopalakrishnan and Huffaker, will serve as the guest editors of this special issue on "Water Resource Management in the American West." Work on this effort is progressing very well: we expect the special issue to feature about 10 to 12 papers (all peer reviewed) written by the W-190 technical committee members. The publication of the special issue will provide a singular opportunity to showcase our work to an international audience and significantly increase the impact of our research.

Degree of Achievement of Objectives

As should be evident from the above review, the project has made considerable progress under all three objectives leading in many instances to new lines of inquiry. Under objective 1, work on agricultural technology at the farm level has advanced our understanding of the linkages among technology, water conservation, and water quality. Under objective 2, farm level data generated under objective 1 provided useful input for modeling the impacts of technological change on water markets and pricing. Much progress was also made in assessing the economic and environmental tradeoffs of policy instruments. Under objective 3, much headway has been made in analyzing the role of law and institutions in shaping water policy. Considerable work was done on new approaches to conflict resolution among uses and users of water. Thus research completed under the three objectives during the review period has produced significant new knowledge and new insights.

Areas Needing Further Investigation

The major research themes under the three objectives are evolving. Research completed under the three objectives during the review period have unmasked a number of new areas for further research. Examples of such emerging areas of concern include climate change and its impact on irrigated agriculture, increasing demand for water transfer from agriculture to environmental and urban uses, animal waste management from concentrated animal feeding operatives (CAPO), precision agriculture and the effects of site-specific management, contingent water marketing, and new approaches (e.g. game theory) to conflict resolution among competing water uses and users. Project extension will contribute significantly toward addressing these issues of vital concern to water resource management in the Western U.S.

Table 1: W-190 Project Participants by State and Areas of Specialization

UNIVERSITY OF ARIZONA	
James C. Wade	Agricultural Economics
Bonnie Colby	Resource Economics
UNIVERSITY OF CALIFORNIA, DAVIS	
Peter Berck	Resource Economics
W. Michael Hanemann	Resource Economics
David Zilberman	Resource Economics
Richard Howitt	Resource Economics
COLORADO STATE UNIVERSITY	
Grant Cardon	Agronomy
Israel Broner	Irrigation Engineering
UNIVERSITY OF HAWAII	
C. Gopalakrishnan	Resource Economics
UNIVERSITY OF IDAHO	
Joel R. Hamilton	Resource Economics
UNIVERSITY OF NEBRASKA	
Raymond J. Supalla	Agricultural Economics
Derrel L. Martin	Agricultural Economics
UNIVERSITY OF NEVADA	
Rangesan Narayanan	Resource Economics
NEW MEXICO STATE UNIVERSITY	
Frank Ward	Agricultural Economics
Robert R. Lansford	Agricultural Economics
OKLAHOMA STATE UNIVERSITY	
Harry P. Mapp	Agricultural Economics
OREGON STATE UNIVERSITY	
Gregory M. Perry	Agricultural Economics
Richard M. Adams	Agricultural Economics
PURDUE UNIVERSITY	
John G. Lee	Agricultural Economics

TEXAS A&M	
Ronald D. Lacewell	Agricultural Economics
Wyatte L. Harman	Agricultural Economics
Ray H. Griggs	Agricultural Engineering
Thomas H. Marek	Agronomy
WASHINGTON STATE UNIVERSITY	
Norman K. Whittlesey	Agricultural Economics
Ray G. Huffaker	Resource Economics
Ari Michelson	Resource Economics
UNIVERSITY OF WYOMING	
James J. Jacobs	Resource Economics
Larry J. Held	Agricultural Economics
ARS/AERC - COLORADO	
Dale F. Heermann	Agricultural Engineering
Harold R. Duke	Agricultural Engineering
Gerald W. Buchleiter	Agricultural Engineering
ERS/RTD - WASHINGTON	
Glenn Schaible	Agricultural Economics
Michael Moore	Resource Economics
Noel Gollehon	Agricultural Economics

W-190 PRINCIPAL PUBLICATIONS (1994-1999)

W-190 research accomplishments for the period 1994-99 include 13 abstracts in professional journals, a book review, 5 published popular reports, 19 Master's theses and Ph.D. dissertations, and 80 professional presentations. In addition, W-190 research accomplishments include the following list of 144 principal publications (including professional journal articles, book chapters, and reports).

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