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Irrigation Management Research Needs in an Era of Changing Water Use Priorities[1]

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The Issue

With growing competition for water, increased environmental constraints and a weak economic picture for agriculture, there has been growing concern about the future of the irrigation industry in both the western United States and the prairie provinces of Canada. In this paper I argue that irrigation research is a major reason the industry has successfully weathered troubled times in the past and that a properly focused research program can also be very helpful in addressing future challenges. I further argue, however, that the research programs in both the United States and Canada must be refocused if we are to effectively and efficiently meet these challenges.

Implications and Conclusions

Both the U.S. and Canadian irrigation research programs now place greater emphasis on technical irrigation issues than would seem warranted in terms of the most critical challenges facing the industry. The challenges facing the industry are primarily at the level of public policy rather than at the level of the firm. What is needed is not simply to do more economics and less technical research, however; instead, we need an economics research program with a quite different emphasis from what we have seen in recent years.

If the irrigation industry is to thrive in ways that are consistent with maximizing social welfare, means must be found to compete more effectively with non-market demands for water and to provide for an allocation of water to its highest-value uses. As water shortages develop, the need is not for additional traditional studies of ways to increase the value of irrigation water, but rather for more work toward understanding non-market demands. Current estimates of non-market demand may be off by an order of magnitude, whereas improved irrigation management can at best affect irrigation water values by a few dollars per acre-foot. To the extent that current policies and institutions exaggerate non-market demands, much is to be gained by improved knowledge of these values and by development of new policies that would more accurately reflect such demands.

Perhaps most importantly, successfully addressing the evolving water use priorities in both countries is likely to require major changes in how economists conceptualize this resource management issue. The profit-maximizing, market-failure paradigm of neoclassical economics must be modified or replaced, because it does not reflect the reality of how agricultural producers behave and often leads to erroneous public policy recommendations. Irrigation efficiency concepts must be expanded to incorporate hydrologic interdependence between all users of a common water supply. Finally, our failure to adequately integrate ecological risk and economic considerations in a comprehensive resource management theory has resulted in a great deal of ineffective resource planning. These conceptual problems must be addressed before economists, lawyers and policy makers can hope to balance competing water interests in a socially optimal way.

Introduction

Sustaining an irrigation industry has presented a challenge to mankind ever since the first primitive canals were constructed in Asia and Central America (Reisner, 1993). Throughout history experts and prognosticators have often expressed concern about the future of irrigation, only to be proven wrong as the ingenuity of man met the challenge (Rogers and Fredrich, 2003). Irrigation opportunities that were temporarily lost to salinity problems have been restored in many cases due to the development of more salt-tolerant crops (Tanji, 1990). Urban demands in water-short areas have usually been met without significant reductions in irrigated acres as furrow irrigation replaced flood irrigation, gated pipe distribution systems replaced siphon tubes and, later, sprinklers replaced furrow irrigation. Changes such as these reflect the tremendous roles that research and development, education and management have played in sustaining the irrigation industry.

The challenges associated with growing needs and changing priorities continue. About 25 years ago the U.S. Department of Commerce invested $6.0 million in a study of the future of irrigation in the Ogallala region, which includes much of the Central Plains from Texas to South Dakota (High Plains Association, 1982). Although this study put to rest for a couple of decades the then prevalent expectation that declining groundwater levels and rising energy prices would mean economic ruin for the irrigation sector, concerns about the future of irrigation in this region and others resurfaced again in a more general way in the 1990s. In the late 1990s the Council of Agricultural Research and Technology (CAST) and the U.S. National Academy of Sciences (NAS) conducted independent studies of the future of irrigation in the United States. A recent study published by Agriculture and Agri-Food Canada addressed the future of irrigation in Canada, reflecting concerns similar to those in the western United States (Hoppe, 2000).

The recent CAST and NAS studies of the U.S. irrigation industry and the Hoppe study of the irrigation potential in western Canada draw mixed conclusions about the future of the irrigation industry. The NAS study concludes that " … the future of irrigation depends on our ability to find ways to use this tool in a manner that continues to provide important benefits but with fewer and more acceptable environmental and economic costs" (National Research Council, 1996). More specifically, the investigators came to the following nine conclusions:

1) It is likely that total irrigated acres will decline, but that the value of irrigated production will remain about the same because of shifts to higher-value crops;
2) Given changing societal values and increasing competition for water, the amount of water dedicated to agricultural irrigation will decline;
3) The economic forces driving irrigated agriculture increasingly will be determined by our ability to compete in global markets;
4) Crop support prices will decrease and the cost of water supplies and environmental compliance will increase;
5) Producers of some crops, particularly higher-value crops such as vegetables, will face greater competition from foreign producers;
6) The irrigation industry will need to play a larger role in technology development and dissemination as the federal government trims its support for these activities;
7) The pressures for greater efficiency will increase and will require the development and transfer of new technology;
8) Some portion of the water now in agricultural use will over time be shifted to satisfy environmental goals; and
9) Irrigation emerged as an individual and collective effort at the watershed level and in many important respects its future will be determined in the local watershed.

The CAST study drew very similar conclusions, although they placed more emphasis on local area differences, with some areas growing while others declined (CAST, 1996).

Table 1 Irrigation Activity in the United States and Canada

Western United States[a]	
Irrigated area (ha.)	17,418,742
Irrigated crops	
corn	22.0%
alfalfa	16.6%
other hay	7.5%
cotton	8.6%
other	45.3%
Irrigation system	
centre pivot sprinklers	35%
gravity systems	49%
other	16%
Water source	
ground water	32%
surface water	68%
Canada, prairie provinces [b]	
Irrigated area (ha.)	636,168
Irrigated crops	
cereals	36.0%
foraging	41.1%
oilseeds	11.2%
other	11.7%
Irrigation system	
sprinklers	73%
other	27%
Water source [c]	
ground water	26%
surface water	74%

[a] 1997 Census of Agriculture, Farm and Ranch Irrigation Survey.
[b] From Hoppe, Terrie. 2000. *The Potential for Irrigation Expansion in Western Canada*. Regina: Prairie Farm Rehabilitation Administration. Most estimates reflect 1996 data.
[c] Computation assumes all district irrigation land is irrigated with surface water and all other land with groundwater.

The Hoppe study of the potential for irrigated growth in western Canada painted a quite different picture, reflecting a more abundant water supply and an irrigation industry that is less mature. Hoppe found a potential for 78,180 additional hectares in Alberta, 250,000 in Manitoba, and between 50,000 and 1,500,000 in Saskatchewan depending on the feasibility of dam construction. He noted that this physical potential is constrained, however, by environmental concerns, competing water uses and economic constraints, which is consistent with what is being experienced in the western United States.

There are currently 17 million hectares under irrigation in the 17 western states, representing 27 percent of all cropland in the region and 72 percent of the value of all crop production (table 1). In the Canadian prairie provinces there are 640,000 hectares under irrigation, accounting for 2.3 percent of total cropland. Although the amount of irrigated acreage in the western United States has fluctuated around a relatively flat long-term trend since the late 1970s, and the amount in western Canada is growing at a modest rate, some local areas, especially in the Southern High Plains, have experienced significant declines (CAST, 1996). Localized declines are often significant because much of the irrigation activity in both countries is located in sparsely populated regions where agriculture is an important part of the regional economic base, with few economic development prospects if irrigation were to decline; however, concern about the industry is not limited to the local areas which have experienced or may experience declines, since the industry as a whole faces technical and economic challenges.

Irrigation Industry Challenges

If the irrigation industry is to thrive it must address several emerging challenges, including 1) minimization of irrigation's contribution to water pollution; 2) achievement of greater allocative efficiency, especially in cases where those who benefit are not the same as those who pay the cost; 3) integration of ecology and economics; 4) management of agricultural production risk in an uncertain water policy arena; and 5) reconciliation of water management and agricultural policy objectives.

Concerns about pollution from pesticides, nitrogen fertilizers and salinity are not new, and much progress has been made, especially during the last 30 years. It is widely recognized that one minimizes irrigation's contribution to pollution by reducing runoff into lakes and streams and by minimizing the application of irrigation water and pesticides. The continuing challenge is to find the best management practices for achieving these objectives and the most effective public policies for inducing their adoption.

Allocative efficiency concerns result primarily from growing competition among water users. Although competition from municipal and industrial water users has been present since the West was initially settled, it has become especially intense in the rapidly urbanizing areas of the region during the past two decades. Outdoor recreation demands became a major concern in the 1960s, but demands related to endangered species, ecology and water quality did not become major factors until the mid 1980s. Some of the more recent increases in competition are especially problematic for the irrigation industry, because they originate from uses where the beneficiaries bear only a small part, if any, of the costs. The beneficiaries of endangered species protection, for example, reside throughout the nation while the opportunity costs of protection are usually paid at a local or regional level. Although resource economists have extensively addressed most externality problems, we have done little to address the inefficiencies which often occur when water is politically reallocated to an alternative use at little if any cost to the beneficiaries. Although all sources of increased competition are problematic, it is the increased demands for water uses where there is a disassociation between those who benefit and those who pay that present the most daunting challenge to the irrigation industry.

Closely related to the issues of water quality and allocative efficiency is the need to integrate ecology and economics. In several regions the largest recent increases in competition for water have been environmental demands linked to ecological impacts. How water is used affects the ecological parameters that provide for wildlife habitat and other important environmental products. Ecologists have historically addressed ecological needs with little if any regard for economic considerations, while economists have focused on economic needs while paying only cursory attention to ecology. The future of irrigation in some areas may well depend on how ecological and economic objectives are balanced and on how successful we are in finding and implementing lower-cost ways of meeting ecological needs.

How irrigation production risk is managed is another important challenge that will continue to influence the irrigation industry. Historically irrigation in semi-arid areas has been regarded as an activity that reduces risk by compensating for variability in precipitation, but growing water policy uncertainty has led to increased risk for many irrigators. The most important sources of water policy uncertainty, at least in the western United States, have been evolving Indian water rights and endangered species requirements. Many irrigation rights that have been regarded as relatively secure for decades have been reallocated, sometimes unexpectedly. The most notable recent case was the within-season decision by the U.S. Bureau of Reclamation to cease all water deliveries to the 229,000 acre Klamath Oregon Irrigation District because of an endangered species lawsuit (*California Water Law and Policy Reporter,* 2001). This action seriously affected the Klamath District and led the Risk Management Agency of the USDA to take an intensive look at how agricultural risk could be affected by federal water use decisions (Gollehon, 2003). How this type of policy risk is managed in the future will significantly affect the economics of irrigation.

The risk management challenge is part of the broader issue of agricultural and trade policy. Agricultural and trade policy could evolve to discourage or limit irrigation because of environmental concerns or over-production. Although both the United States and Canada still subsidize water for irrigation in some cases despite chronic over-production and depressed agricultural prices, recent trends in the United States have discouraged future irrigation development, especially on fragile lands. Since the late 1980s producers who developed irrigation on lands that were unsuitable or who produced without an approved conservation plan have been ineligible for government payments. The Year

2002 Farm Bill retained most of the conservation programs that were in place in the 1990s and added incentive programs to encourage water conservation, especially where water was short or there was a water quality problem (NRCS Website). Policy pressures to discourage irrigation that adversely affects the environment result in part from domestic environmental concerns and in part from international pressures to encourage "green" agricultural trade policies.

Most of the historical challenges faced by the irrigation industry were due to rising irrigation costs, water scarcity and water quality concerns. These challenges were met primarily through research, education and resulting improvements in irrigation management. When rising energy prices threatened deep-well irrigation in the Southern Plains, research and development produced low-pressure sprinkler heads and improved irrigation scheduling practices that substantially reduced costs. The adverse economic implications of increased water scarcity in the southwestern United States were muted significantly by improved irrigation technologies such as subsurface and micro irrigation. Scheduling procedures and equipment for monitoring crop nutrient and crop water requirements are good examples of research-based technologies that have been helpful in meeting water quality as well as water quantity challenges.

The central question addressed by this paper is, What are the economic research needs for meeting the current, emerging and future challenges facing the industry, and how do these needs relate to current research programs?

Current Research Programs

The major source of funding for irrigation-related research in the United States is the Cooperative State Research, Education and Extension Service (CSREES), USDA. A summary of current CSREES programs in water resources was developed using a keyword search of the database of their current projects. This search found that there were 9,319 currently active projects on water, of which 1,988 addressed some element of irrigation (table 2). The irrigation program was heavily focused on water quality or some element of the environment, although there were nearly 200 projects addressing evapotranspiration and over 600 involving some element of efficiency (table 3). Of those involving efficiency, about 20 percent addressed one or more of the three leading water-saving technologies: sprinklers, and subsurface and micro irrigation. Only 10 percent of all water projects and 12 percent of all irrigation projects involved economics issues (table 2). Of the 900 projects that addressed the economics of water, over 40 percent involved water quality and nearly 25 percent had something to do with legal or institutional issues (table 4). Less than 2 percent involved endangered species, an issue which is of critical importance to the irrigation industry. Surprisingly, only 2 percent of the economics-of-irrigation projects focused on profitability or economic efficiency, suggesting that most involved public policy rather than firm-level economic concerns (table 5).

Table 2 Water and Irrigation Research in the United States and Canada

	United States		Canada	
	Water	Irrigation	Water	Irrigation
	Number of projects[b]			
Water quality	2,714	589	181	19
Water management	5,468	614	150	26
Economics/policy	1,604	373	23	2
Endangered species	179	37	1	0
Environment	5,584	1,220	29	3
Conservation	1,474	407	24	4
Blank[a]	9,319	1,988	220	43

Source: U.S. data compiled from CSREES Website, CRIS data base. Canadian data compiled from Canadian Agri-Food Research Website, ICAR data base.

[a] Numbers in the "blank" row represent the total number of projects that contain, in the project title, at least the one word listed above the corresponding column.

[b] Number of project titles that include the word listed above the column and the word or phrase listed to the left of the row.

The Canadian water resources research program was summarized from the Canadian Agri-Food Research (ICAR) database using the same keyword combinations. The Canadian research program was much smaller than the U.S. program, both as a whole and relative to the importance of irrigation. In total there were 220 water projects and 43 irrigation projects in Canada (table 2). The 43 irrigation projects represent 6.7 projects per 100,000 hectares of irrigation, compared to 11.4 projects per 100,000 hectares in the United States. More importantly, the Canadian research program reflects a very different set of water and irrigation problems (tables 3, 4 and 5). Over 80 percent of Canadian water research is related to water quality, compared to 29 percent in the United States. Only one of the water and none of the irrigation projects involved endangered species protection. The size of the Canadian program and the proportional emphasis on water quality probably reflect the fact that quantity issues are less of a factor in Canada than they are in the United States.

Research Needs: The Economic Science of Irrigation

The challenges facing the irrigation industry are in large measure economic challenges, or at least they can be cast as economic questions. We must address questions of agricultural production efficiency, allocative efficiency among water uses, and public policy (table 6). Improvement of agricultural production efficiency involves both technical and economic research to find and implement methods of producing at less cost and/or in more environmentally benign ways. Research on allocative efficiency must address conceptual

Table 3 Irrigation-related Research Projects in the United States and Canada

Irrigation type	Water qual.	Water mgt.	Effic'y	Econ.	ET	Waste water	Salin.	Precis. ag.	Policy	Blank[a]
	Number of U.S. projects[b]									
Irrigation	589	614	604	241	196	99	171	81	132	1,988
Sprinkler irrigation	56	63	57	19	26	7	10	13	8	125
Surface irrigation	61	61	48	12	19	9	18	7	12	97
Subsurf. irrigation	55	61	49	13	17	11	18	10	5	111
Micro irrigation	45	47	33	8	14	7	6	3	1	62
	Number of Canadian projects									
Irrigation	19	26	9	8	1	3	1	1	1	43
Sprinkler irrigation	2	2	1	0	0	0	0	0	0	3
Surface irrigation	5	4	1	0	0	0	0	0	1	6
Subsurf. irrigation	1	1	1	0	0	0	0	0	0	1
Micro irrigation	0	0	0	0	0	0	0	0	0	0

Source: U.S. data compiled from CSREES Website, CRIS database. Canadian data compiled from Canadian Agri-Food Research website, ICAR database.

[a] Numbers in the "blank" column represent the total number of projects that contain, in the project title, at least the one word listed to the left of the row.

[b] Number of project titles that include the word listed above the column and the word or phrase listed to the left of the row.

and empirical dimensions of efficiency and alternative institutional arrangements for achieving efficiency. Finally, public policy research is needed to address the public welfare implications of alternative agricultural, trade, environmental and water policy programs that affect irrigation. Specific research needs in each of these areas are discussed below.

Production Efficiency

Production efficiency is defined here to include both production costs and environmental emissions. The challenge is to produce at less cost and with less environmental harm. Costs can be reduced by developing new production technologies and/or by doing a better

Table 4 Economics of Water Research in the United States and Canada

	United States	Canada
	--------- Number of projects[b] ---------	
Irrigation	114	6
Recreation	27	0
Quality	385	26
Endangered species	16	1
Efficiency	80	8
Legal/institutional	223	0
Blank[a]	900	43

Source: U.S. data compiled from CSREES Website, CRIS database. Canadian data compiled from Canadian Agri-Food Research website, ICAR database.

[a] Numbers in the "blank" row represent the total number of projects in the U.S. and Canada, respectively, that contain the words "economics" and "water".

[b] Number of project titles that include the words "economics" and "water" plus the word or phrase listed to the left of the row.

Table 5 Economics of Irrigation Research in the United States and Canada

	United States	Canada
	--------- Number of projects[b] ---------	
Profitability	5	0
Economic feasibility	0	0
Management	83	8
Risk	2	3
Allocative efficiency	37	1
Blank[a]	241	8

Source: U.S. data compiled from CSREES website, CRIS database. Canadian data compiled from Canadian Agri-Food Research website, ICAR database.

[a] Numbers in the "blank" row represent the total number of projects in the U.S. and Canada, respectively, that contain the words "economics" and "irrigation".

[b] Number of project titles that include the words "economics" and "irrigation" plus the word or phrase listed to the left of the row.

job of managing available resources. Environmental harm can be reduced by producing alternative crops, by developing and adopting best management practices (BMPs) for reducing pollution from agriculture and by using water and chemical inputs more precisely. Continued research is needed in each of these areas.

Integrating on-farm production efficiency with the physical realities of hydrology presents an especially important research challenge for economists. Economists have historically conceptualized on-farm efficiency as crop output per unit of applied water. Only recently have they begun to recognize that reduced diversions by irrigator A may

Table 6 An Irrigation Management Research Agenda

Problem	Research need
I. Production efficiency	
A. Production costs	Develop cost-reducing technologies; find optimum management strategies; investigate risk management strategies.
B. Environmental costs	Develop and evaluate best management practices; estimate environmental costs.
C. Producer behaviour	Analyze producer utility functions; analyze technology adoption behaviour; investigate willingness to voluntarily internalize environmental externalities; develop an improved economic theory of the firm.
D. Integrating economics and hydrology	Develop comprehensive concept of irrigation efficiency.
II. Allocative efficiency	
A. Net benefits from irrigation	Producer benefits; social cost of pollution from irrigation.
B. Value of water in alternative uses	Technical linkages between stream flows, wildlife habitat, wildlife numbers and economic values.
C. Integration of ecology and economics	Develop an improved conceptual framework for integrating ecological risk and economics.
D. Institutions	Develop improved water markets, considering water right acquisition options, water banking and third party protection issues.
III. Public policy	
A. Agricultural policy impacts	Effect of crop subsidies on irrigation development incentives; effect of targeted conservation programs on irrigation activity; effect of trade liberalization on conservation requirements.
B. Endangered species policy	Estimate social costs and benefits of endangered species protection; develop endangered species policy that incorporates economic tradeoffs.
C. Water quality policy	Economic cost of uniform water quality standards; evaluation of coping options as an alternative to prevention and clean-up strategies.

result in less water available downstream for irrigator B, who previously used the return flow from Irrigator A at a later time in the season. Even less widely recognized is the fact that sometimes improved on-farm irrigation efficiency actually increases consumptive use, thus reducing the amount of water available for all downstream users (Huffaker and Whittlesey, 1995). Improved theoretical constructs that incorporate ground and surface water hydrology parameters are needed to evaluate when improvements in on-farm efficiency are consistent with improvements in social welfare.

An equally important research challenge for economists concerns two dimensions of the neoclassical theory of producer behaviour: that competitive firms maximize profits and that producers do not voluntarily internalize environmental costs. There is substantial evidence to suggest that agricultural producers do not always use least-cost or profit-maximizing methods of production (Supalla, Selley and Ahmad, 1995; Lin, Dean and Moore, 1974). Scientists investigating ways of reducing agricultural pollution have often found win-win opportunities where producers could both increase profits and improve environmental quality, contrary to the neoclassical axiom that if producers were not already maximizing profits they would go out of business (Supalla, Selley and Ahmad, 1995; Lee, 1998; Lin, Dean and Moore, 1974). Some of the explanations offered for this phenomenon are faulty economic analysis, imperfect producer information and the impact of inter-generational land transfers on the ability of producers to produce at below a profit-maximizing level over the long-term (Supalla, 2003). In any case, doing a better job of explaining producer behaviour is essential for formulating policy and for accurately predicting how producers will respond to the agricultural and environmental policies that affect the irrigation industry.

A closely related dimension of producer behaviour concerns environmental attitudes. Neoclassical economic theory holds that environmental costs will not be voluntarily internalized by business firms, i.e., they will not consider them unless required or induced to do so by incentives. There is increasing evidence, however, that some environmental costs are voluntarily considered by both individuals and firms. Much as many consumers voluntarily recycle or buy environmentally friendly products even if they cost more, many agricultural producers are also good stewards of the environment. A recent survey of irrigators in central Nebraska found that 85 percent believed that they should use environmentally friendly production practices even if to do so significantly reduced profits (Ahmad, Selley and Supalla, 1997). Failure to recognize environmental stewardship in behavioural models may lead to ineffective or unnecessarily costly policies for reducing agricultural pollution. The erroneous neoclassical model also contributes to a public image of uncaring, environmentally destructive agricultural producers, which leads to distrust and increases the likelihood that policies that unnecessarily limit irrigation will be implemented.

Allocative Efficiency

Whereas improved production efficiency would almost always have a positive impact on the irrigation industry, the implications of improved allocative efficiency are less apparent. Many observers believe that correcting for allocative efficiencies would mean less irrigation, because of the efficiency-distorting effects of federally subsidized irrigation water (Wahl, 1989). Others contend that environmental policies have sometimes resulted in reductions in irrigation activity that are economically inefficient (Souza, 2001). There is some truth to both arguments, but not much evidence on whether the net effect of correcting for allocative inefficiency would mean more or less irrigation.

Efficiently allocating water among uses is a problem that requires improved information on what is produced when water is used for different purposes, what that production is worth and what institutional arrangements are needed to induce efficiency. The quantity and value of agricultural products from irrigation are generally well understood and known. The greatest unknowns concern the opportunity costs of using water for irrigation. In some cases closing this information gap requires better knowledge of how irrigation affects water quality and other environmental parameters, while in other cases it requires better knowledge about what is produced when water is used in the service of public goods such as wildlife habitat or biological diversity. Consider, for example, the information needs for evaluating the effect of diverting water for irrigation from the Middle Platte River which provides habitat for sandhill cranes. Full knowledge of the opportunity cost of irrigation water in this case would require knowing how reduced stream flow would affect crane habitat, how changes in habitat would affect the population of cranes and how changes in the population of cranes would affect the economic value of cranes. This information is not available for the Central Platte, nor is this kind of information generally available for other cases involving irrigation and wildlife tradeoffs, such as those that involve the silver minnow in the Rio Grande in New Mexico or salmon in the Pacific Northwest. Without this information, it is conventional practice to err on the side of caution when making decisions about wildlife or other ecological needs, especially when threatened or endangered species are involved. Achieving allocative efficiency requires that these knowledge gaps be closed.

The allocative efficiency challenge in many cases can be characterized as the need to integrate ecology and economics. Ecologists as well as economists are aware of this challenge, especially those working on ecological risk, and some work is underway to address the problem (Bruins and Heberling, forthcoming). At this time, however, we lack a complete paradigm for integrating ecological risk and economic concerns in a way that is consistent with allocative efficiency.

An equally daunting challenge is the need for improved institutional arrangements for allocating water. Institutional arrangements that facilitate the movement of water to its highest-value uses while incorporating all costs and benefits are needed for allocative efficiency. Although water markets theoretically can provide this function and do exist in most of the western United States, none of them provide demand and supply forces for all water uses. Effective instream demands for environmental water usually exist entirely outside of markets, for example, and are subject to political rather than market pressures for reallocation. The difficulty of efficiently allocating water between irrigation and instream flow uses is further increased by a frequent disassociation between who benefits and who pays the opportunity costs.

Research is needed to improve existing water markets for those cases where all alternative uses are subject to market forces and to develop alternative institutional structures to reflect the demand for public goods, especially when there is a disassociation of benefits and costs. Research needs for improving markets include investigation of methods of reducing transaction costs, alternative acquisition methods such as auctions and the impact of different contract terms and conditions on water allocation. Research needs associated with institutional options for non-market allocation are less clear. Perhaps expanded work on integrating ecological risk and economics will be helpful. Additional evaluation of non-market values using improved contingent valuation, conjoint analyses or experimental economics may also be appropriate.

Public Policy Research

Many of the research needs previously identified involve public policy issues or at least areas where research results would serve as inputs to public policy analysis, but there are also more focused policy research needs that merit attention. These include investigating the impacts of current and alternative agricultural policies on irrigation activity, methods of targeting water conservation funds to those areas where water is especially scarce or there is a quality problem, and the social costs and benefits of endangered species protection. Improved knowledge in these areas should lead to more consistency in agricultural, water and environmental policy, greater allocative efficiency and a more stable irrigation industry.

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Endnote

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