Technical Memorandum 2.1

Irrigation and Montana's Economy: A Conceptual Framework

Revised August 2008

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I. INTRODUCTION AND BACKGROUND

This memorandum describes, in conceptual terms, how irrigation interacts with Montana's statewide and local economies and how investments in irrigation affect these economies. Based on our review of the relevant literature regarding the relationship between irrigation and the economy, we address three major measures of the irrigation-economy interaction: the net benefits to society as a whole; the net benefits to irrigators; and the net impacts on jobs and incomes in local and statewide economies. We also discuss how each of these measures might look different in the future than they have in the past. We conclude with a discussion of three cross-cutting issues: the distribution of positive and negative effects of irrigation among different groups; the consideration of past investments when evaluating the potential economic consequences of future investments in irrigation; and the significance of looking to the future when assessing the economic importance of investments in irrigation.

Decades ago, the relationship between irrigated agriculture and Montana's economy was straightforward. Agriculture dominated economic activities in most communities and, for much of the state, commercial agriculture would not have been feasible without farmers having a reliable supply of cheap water for irrigating crops. Communities' economic prosperity and growth depended largely on the ability of farmers to gain access to water suitable for increasing their production of crops and livestock. Accordingly, public policies that contributed and attracted funds for investments in irrigation infrastructure were seen as a straightforward way to promote economic development and improve the well-being of the state's families and communities.

Today, though, things are more complex. Irrigated agriculture, the economy, and the public policies affecting the relationship between them have all evolved in myriad ways. The agricultural sector has strengthened in some communities but weakened in others, as farmers use new technologies, produce new crops, and sell crops under market conditions that are sometimes dramatically different from those of the past. The economy has evolved so that industries other than irrigated agriculture now have a greater ability to attract investment and generate jobs and incomes. Moreover, the economic strength of many communities derives not from the strength of their industries, agricultural or otherwise, but from their ability to attract productive people. The ability to attract and retain productive people can be important both in urban communities experiencing robust economic growth and in rural communities struggling to arrest declines in population, economic diversity, and household earnings. Today, the relationship between irrigated agriculture and the overall economy is influenced by a wide range of public policies—farm subsidies, international trade, environmental protection, and much more—that can both encourage and discourage irrigation.

Within this setting, one cannot reasonably say that investments aimed at maintaining or increasing the supply of water available for irrigation would necessarily and automatically stimulate crop production, increase farmers'

incomes, and boost Montana's economy. To help develop a better understanding of the factors that would influence the economic consequences of future investments in irrigation, we recommend that Montanans view such investments from three perspectives:

- *The economic net benefit of irrigation to society as a whole*. When surface water is managed for irrigation, it increases the supply of crops and, perhaps, other goods and services, such as habitat for fish in reservoirs and canals, that have economic value to society as a whole. The value of the increases is called the gross economic benefit of irrigation. As water is used for irrigation, though, there may be decreases in the supply of other economically valuable goods and services, such as investment capital, hydropower, and fish habitat in free-flowing streams. The value of the decreases is called the gross economic cost of irrigation. The net economic benefit—the gross benefit minus the gross cost—represents the change in economic welfare for society as a whole that results from using water for irrigation.

- *The economic net benefit to irrigators*. Water for irrigation can increase the value of a farmer's crops, but it also can increase the costs associated with land, equipment, labor and other factors used to produce the crops. The difference between the two—the increase in the crop's value minus the increase in the costs of producing the crop—equals the economic net benefit to the irrigator. A positive (negative) net benefit may manifest itself as in increase (decrease) in the irrigator's net farm earnings, an increase in land value, or both.

- *The net economic-development impact to the local and statewide economies*. Irrigated agriculture in a particular location can interact with the nearby local economy and the overall statewide economy to impact jobs and incomes in multiple, dynamic ways. These impacts arise through the construction or installation of irrigation infrastructure; the management of the infrastructure; the diversion, use, and return flow of water, the consumption of goods and services other than water to produce irrigated crops, and the sale of the irrigated crops. In some circumstances, irrigated agriculture can stimulate both an increase in jobs and incomes for some and a decrease for others. The overall effect equals the net economic-development impact of irrigation.

It is important to note that the *economic value* of water used for irrigation is not the same as the *economic impact*. *Economic value* refers to the amount of other goods and services that someone (an irrigator or someone else) considers to be a fair equivalent for the water, so he or she would be indifferent between having the one or the other. Money is often used to facilitate the expression of value, but, as we explain below, value associated with many uses of water are difficult to measure in monetary terms. *Economic impact* refers changes in the structure of an economy stemming from irrigation or other use of water. The value of a water use need not correspond to its impact. A higher-value use, such a the production

of a high-value irrigated crop, may have higher or lower impacts on jobs and incomes than a lower-value use, for example.

In the following three sections of this memorandum, we describe the analytical framework for looking at the irrigation-economy relationship from each of these perspectives.

Before proceeding, however, we emphasize the importance of placing the analytical framework in its proper context. In particular, we encourage readers to bear in mind the following: (a) our task is to provide an unbiased description of all of the economic consequences of irrigated agriculture, and (b) we undertake this task fully cognizant of Montana's system of water rights and other aspects of the legal, institutional, and cultural structures within which these consequences materialize.

Unbiased description of economic consequences. The framework focuses on helping readers understand the full suite of economic contributions irrigated agriculture makes to Montana and its communities. Based on a solid conceptual foundation and extensive empirical evidence, it recognizes that:

- Irrigated agriculture can make both positive and negative to the economy.
- Although many contributions materialize only locally, others can reach across the state.
- Some of the contributions manifest themselves through long-standing markets and are highly visible and well understood, but others do not and are not. Neither category is necessarily more important than the other; their relative importance is an empirical issue.

The analytical framework takes a broad view of the relationship between irrigated agriculture and the economy. We adopt this view because it is the only one that can provide a full understanding of the potential economic consequences of future efforts to rehabilitate, sustain, or expand irrigation. We adopt this broad view recognizing that some might prefer a narrower perspective. Some advocates of irrigated agriculture might prefer that we describe only the industry's positive economic contribution for example, and some critics might prefer that we describe only its negatives. Neither of these narrower approaches would satisfy our objectives, however. Hence, we ask all readers to accept our assertion that we have no bias for or against irrigated agriculture. When we describe the positive economic consequences of irrigated agriculture, such as the production of valuable crops and job opportunities, nothing in our presentation is intended to diminish the potential adverse consequences, such as reductions in river-related recreational opportunities or habitat for native fish. Similarly, when we describe the negative economic consequences of irrigated agriculture, nothing in our presentation is intended to diminish the potential adverse consequences.

We fully understand that economic conditions vary across the state and irrigated agriculture plays a more intense role in the economies of rural communities than

in urban ones, and in eastern Montana than in western portions of the state. These differences do not dispel the powerful economic forces that we address with our focus that sees irrigated agriculture not in isolation but in the context of the broader economy. Our framework recognizes the importance of all these forces—some of which bolster the outlook for irrigated agriculture and others that present new challenges it must overcome—and sets the stage for describing, in subsequent technical memoranda, the overall role irrigated agriculture plays in Montana's economy.

Economics and water rights. Our framework for examining potential investments in irrigation focuses on how such investment might affect Montana's economy through its interactions with the competing demands for the state's water and water-related resources. Nothing resulting from the application of this framework should be construed as disregarding water rights and the system of laws that support them. The state's water rights exist essentially independent of economic factors, depending instead on the time at which the right was established and the ability of the water-right holder to comply with legal requirements for maintaining the right. Hence, if a water right currently prevents the use of a unit of water for irrigation but the economic analysis indicates that using the water for irrigation would yield net economic benefits, one should not construe this as a call for setting aside the non-irrigation water right. Similarly, if a water right currently allows the use of a unit of water for irrigation but the economic analysis indicates that using the water for something else would yield net economic benefits, one should not construe this as a call for setting aside the irrigation water right.

Our framework recognizes that the competing demands for Montana's water resources exist regardless of how the water-right system allocates the water to satisfy a particular demand. This approach is consistent with other segments of the economy. Our system of property rights allocates a parcel of land to the owner, for example, but people readily recognize that others have competing demands for the land. Under some circumstances, converting the land to a competing use might yield a net economic benefit and, hence, leaving the land in its current use constitutes a loss for the overall economy, but this economic fact is inconsequential until the owner decides to sell. The same reasoning applies to an economic assessment of water that is currently used or might be used for irrigation. The competing demands for water determine the extent to which future use of the water for irrigation would yield net economic benefits or net losses, but this economic reality would exist independent of the water-right system that governs the allocation of the water.

II. Net Benefit to Society

Water in a stream produces multiple goods and services, such as opportunities for fishing and energy for producing hydropower, that are valuable to society as

a whole and contribute to Montana's economy.[1] It produces another set of goods and services, however, when irrigators divert it, use it to irrigate crops, and return the surplus to the stream. Both elements of this change—the loss of the first set of goods and services and the creation of the second—can have important economic implications. One way to measure the economic importance of irrigation entails comparing the value of the goods and services derived from a body of water *with* irrigation versus the value of those that would be produced *without* it. The *with-vs.-without* difference equals the net economic benefits of using the water for irrigation. The net economic benefits can be positive or negative.

In this section we offer an analytical framework for identifying the goods and services that are lost or created when water is used for irrigation, estimating their societal value, and describing the net economic benefits of using water for irrigation.

A. Water is Valuable for the Goods and Services it Produces

From an economic perspective, water is important not in and of itself, but because it produces things that benefit people, imposes costs on them, or both.[2] Describing the economically important products derived from water is not a straightforward task, but one widely accepted approach combines economic with ecological concepts, as shown in Figure 1. Its central feature is the ecosystem's production of water-related *ecosystem goods and services*, which are important to people and, hence, have economic value. Their economic importance may arise when they are extracted, as when water is diverted from a stream to irrigate crops, or when they remain in place, as when boaters use a stream for recreation. The ecosystem produces these goods and services through processes, known as ecosystem functions, that derive from the ecosystem's structure. The left side of Figure 1 highlights the importance of human influences on the ecosystem. The arrow on the right side shows that sometimes humans place values on an ecosystem's structure, e.g., the diversity of species, rather than on the goods and services it produces. To simplify things, however, we use the term *goods and services* to represent all those water-related things with economic value.[3]

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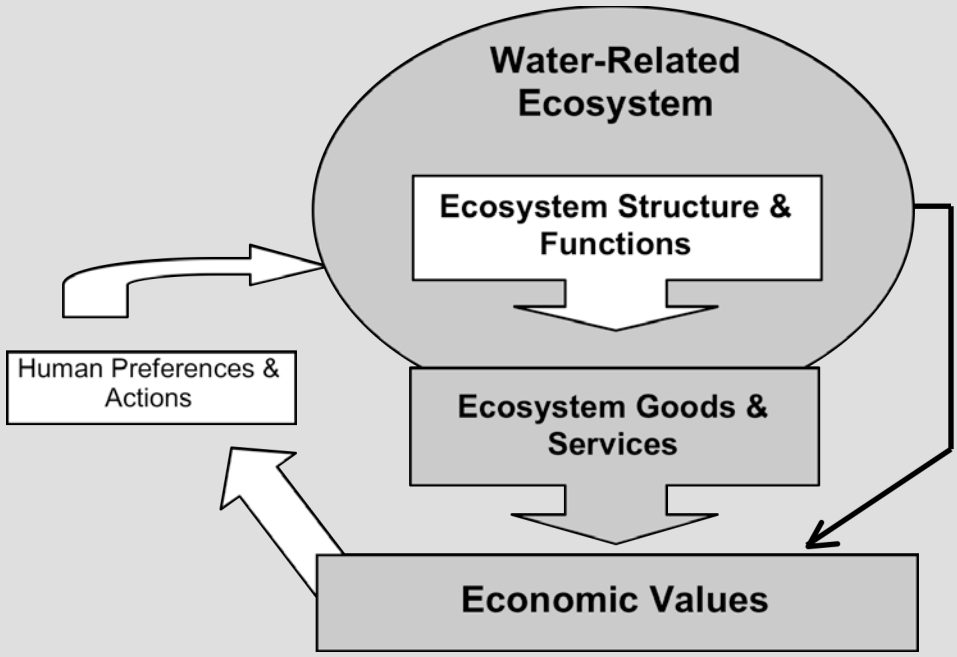
[1] Analogous statements apply to groundwater but, to expedite the exposition, we focus on the goods and services related to surface water.

[2] Some believe water is important not only for what it does for humans, but for its place in the environment, apart from people. They suggest economics should consider those values, and there are good arguments for doing so. Here, however, we focus on the connections between water and people. We do so not just to keep our task from becoming intractable but also because water's contributions to human quality of life underlie many, if not most, human actions affecting the water. We take a broad view, though, of the ways in which water affects human standards of living and quality of life.

[3] We also use "goods and services" to include things, such as damaging floods, that are economically important in a negative, rather than a positive sense.

Figure 1. Connections Between Ecosystems and Economic Values



Source: ECONorthwest, adapted from National Research Council, Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. National Academies Press.

The list of water-related goods and services is long and growing, as ecological scientists learn more about the inner workings of ecosystems and people find new ways to derive benefits from them. Table 1 illustrates the current list. Some of the goods and services in Table 1 will be unfamiliar to those who see water as having economic value only in terms of irrigation and other direct uses. Natural-resource and economic-development economists, however, now widely recognize the economic importance of the full slate of goods and services.[4]

The evolution in the understanding of goods and services derived from water-related ecosystems has important implications for our effort to describe the economic values of the state's water. Resource-management systems in Montana, including the water-appropriation system, were developed when the levels of understanding of ecosystems and the economy were much more limited than they are today. Consequently, these systems yield little, if any, local economic information regarding most of the goods and services shown in Table 1. As a result, one must look elsewhere for relevant studies and, where appropriate, extrapolate their findings to this setting. For many of the goods and services, however, there are no valuation studies, in Montana or elsewhere. One should not take the absence of a reliable estimate of the value of a good or service to

[4] *See*, for example, National Research Council, Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems. 2004. *Valuing Ecosystem Resources: Toward Better Environmental Decision-Making*. National Academies Press.

Table 1. Summary of All Functions, Goods, and Services of Montana's Water-Related Ecosystems

Functions		Examples of Goods and Services Produced
1	Production and regulation of water	Natural and human-built features of an ecosystem capture precipitation; filter, retain, and store water; regulate levels and timing of runoff and stream flows; and influence drainage.
2	Formation & retention of soil	Wetlands and biota accumulate organic matter, and prevent erosion to help maintain productivity of soils.
3	Regulation of atmosphere & climate	Biota produce oxygen, and help maintain good air quality and a favorable climate for human habitation, health, and cultivation.
4	Regulation of disturbances	Wetlands and reservoirs reduce economic flood damage by storing flood waters, reducing flood height, and slowing a flood's velocity.
5	Regulation of nutrients and pollution	Wetlands and riparian vegetation improve water quality by trapping pollutants before they reach streams and aquifers; natural processes improve water quality by removing pollutants from streams.
6	Provision of habitat	Wetlands, riparian vegetation, streams, and reservoirs provide habitat for economically important fish and wildlife.
7	Food production	Biota convert solar energy into plants and animals edible by humans.
8	Production of raw materials	Streams and biota generate materials for construction, fuel, and fodder; streams possess energy convertible to electricity.
9	Pollination	Insects facilitate pollination of economically important wild plants and agricultural crops.
10	Biological control	Water-related birds and microorganisms control pests and diseases.
11	Production of genetic & medicinal resources	Genetic material in wild plants and animals provide potential basis for drugs and pharmaceuticals.
12	Production of ornamental resources	Products from water-related plants and animals provide materials for handicraft, jewelry, worship, decoration, and souvenirs.
13	Production of aesthetic resources	Wetlands, riparian vegetation, streams, and reservoirs provide basis for enjoyment of scenery from roads, housing, parks, trails, etc.
14	Production of recreational resources	Streams, reservoirs, riparian vegetation, fish, waterfowl, and other wildlife provide basis for outdoor sports, eco-tourism, etc.
15	Production of spiritual, historic, cultural, and artistic resources	Wetlands, riparian vegetation, streams, and reservoirs serve as basis for spiritual renewal, focus of folklore, symbols of group identity, motif for advertising, etc.
16	Production of scientific and educational resources	Wetlands, riparian vegetation, streams, and reservoirs provide inputs for research and focus for on-site education.

Source: Adapted by ECONorthwest from De Groot, R., M. Wilson, and R. Boumans. 2002. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services." *Ecological Economics* 41: 393-408; Kusler, J. 2003. *Assessing Functions and Values.* Institute for Wetland Science and Public Policy and the Association of Wetland Managers, Inc.; and Postel, S. and S. Carpenter. 1997. "Freshwater Ecosystem Services." in *Nature's Services: Societal Dependence on Natural Ecosystems*. Edited by G.C. Daily. Washington, D.C.: Island Press, pgs. 195-214.

mean that the value is zero. Instead, the paucity of estimates means no more than that measuring water-related values can be devilishly difficult.

B. Several Approaches are Appropriate for Measuring the Value of Water-Related Goods and Services

Economists typically measure the economic value of a good or service in terms of what a person, group, or firm, which does not have it, is willing to give up to acquire it. It is not necessary to measure value in monetary terms, but doing so

generally simplifies the measurement. If money is used as the unit of measurement, then the value of a good or service is the amount the person, group, or firm is willing to pay for it. Sometimes, value is measured when a person, group, or firm already possesses a good or service. In this context, the value of the good or service equals the amount the person, group, or firm is willing to accept as compensation for relinquishing it.[5]

When an additional unit of a good or service is traded in a fully-functioning, competitive market, the price at which it is traded provides a good representation of both what the seller requires as compensation to relinquish it and what the buyer is willing to pay to acquire it. Thus, the market price a farmer receives for an incremental, or marginal increase in an irrigated crop traded in a competitive market probably provides a reasonable representation of the crop's value both to the farmer and to the overall economy.

A different picture materializes when one looks at the overall production of a crop. In general, a farmer's costs to produce an additional unit of a crop increase with quantity, and, conversely, the amount consumers are willing to pay for an additional unit decreases. When large quantities of a crop are produced and sold under competitive market conditions, producers increase production and consumers increase their purchases until the point where the amount consumers are willing to pay for an additional unit of the crop equals the producers' cost. This balance point determines the market price. When the market clears at this price, most units of the crop being sold cost farmers less than this amount to produce and they realize a net benefit, called a producer's surplus. At the same time, most consumers would have been willing to pay more than the market price for the units of the crop they purchased and, hence, they realize a net economic benefit, called a consumer's surplus.

Irrigation yields a net economic benefit when the value of the goods and services it produces exceeds the value of those that were used in the production process. When the converse is true, then it yields a net cost. A net benefit or cost can accrue to different parties. An irrigator realizes a net benefit—the producer's surplus—when she sells a unit of a crop for a price higher than the cost she incurred to produce it. A consumer can realize a net benefit—the consumer's surplus—when she buys a unit of a crop for less than she is willing to pay for it. A third party—an individual, household, business, or society as a whole—

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[5] In most settings, the two approaches for measuring value—the amount the buyer is *willing to pay to obtain* a good or service, and the amount the seller would *require as compensation to relinquish* it—yield equal, or closely similar, results. But, in some settings—when relinquishing control of a resource would lead to an outcome seen as morally repugnant, for example—the amount people require as compensation to relinquish a good or service can exceed, and perhaps far exceed, the willingness-to-pay measure of value. *See,* for example, the discussion in this important series of papers: Hanemann, M. 1991. "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review* 81 (3): 635-647; Amiran, E.Y. and D.A. Hagen. 2003. "Willingness to Pay and Willingness to Accept: How Much Can They Differ? Comment." *The American Economic Review* 93 (1): 458-463; and Hanemann, M. 2003. "Willingness to Pay and Willingness to Accept: How Much Can They Differ? Reply." *The American Economic Review* 93 (1): 464.

realizes a net cost or benefit, called a negative or positive externality, respectively, when the transaction between an irrigator and a consumer reduces or increases the value of goods and services available for the third party's use.

Most water-related goods and services are not traded in competitive markets and there are no prices one can use to measure their economic value. The absence of a market price does not mean these goods and services have no value, only that they are not traded. When goods and services are not traded in markets, economists must use non-market techniques for measuring their value.

Table 2 provides a classification of different ways in which society derives value from water-related goods and services, and provides a basis for understanding the different approaches economists use to measure the value of goods and services affected by irrigation. This classification system comes from a recent report prepared by the National Research Council, which has distilled several decades of research regarding the different ways in which society derives value from or assigns value to water–related goods and services and, hence, to water itself. (The National Research Council calls the classification system the *Total Economic Value* framework.) This classification system is useful for tracing the linkages between water uses and functions, and to identify the appropriate studies and data regarding economic values and impacts.

The National Research Council's classification system distinguishes between "Use Values" associated with activities involving human interaction with water and "Nonuse Values" that do not. Some of the "Use Values" involve direct interaction, even manipulation, as when water is diverted from a stream or aquifer and used for irrigation and industrial processing. With others, the involvement is indirect, as when people rely on an aquatic system to transport nutrients, mitigate flooding, or provide attractive aesthetics. Most, if not all, of the "Use Values" shown in Table 2 are associated with activities having a long tradition in Montana.

The "Nonuse Values" may be less recognizable to some, but not necessarily less important. In general, they refer to an important economic reality—most Americans and most Montanans place a value on knowing that some water resources exist in a more-or-less wild state and will be passed to future generations in this condition. Numerous studies have found citizens express this value even when they do not intend to use the water themselves. "Nonuse Values" are associated, for example, with Montana's strong tradition of conserving the state's agricultural lifestyle and landscapes. They also are associated with preferences of some Montanans for preventing the extinction of aquatic species.

Economists typically measure the "Use Values" associated with commercial activities by looking at how the use of a water-related good or service affects an enterprise's net earnings. One would measure the impact on net farm earnings, for example, to determine the value of water used by a given farmer, or set of farmers, to irrigate commercial crops. If the impact on net earnings is not directly and easily observable, an alternative approach entails looking at what buyers are

Table 2. Classification and Examples of Total Economic Values for Water-Related Goods and Services

Use Values		Nonuse Values
Direct	**Indirect**	**Existence and Bequest Values**
Irrigation	Nutrient retention, cycling	Cultural heritage
Potable water	Flood control	Resources for future generations
Industrial processing	Storm protection	Existence of species
Hydropower	Habitat function	Existence of wild places
Fishing	River bank stabilization	Other nonuse values
Transportation	Aesthetics	
Non-fishing recreation	Other indirect-use values	
Genetic material		
Scientific and educational opportunities		
Other direct-use values		

Source: ECONorthwest, adapted from National Research Council, Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems. 2004. *Valuing Ecosystem Services: Toward Better Environmental Decision-Making*. National Academies Press.

willing to pay for the opportunity to realize these net earnings in the future. Farmers typically pay more to purchase irrigable land, relative to comparable land that is not irrigable, with the buyer's willingness to pay the incremental amount representing the buyer's expectation that he or she will have higher future net earnings from the irrigable land in future years. The incremental willingness to pay more for irrigable land is, in economics terms, equivalent to the buyer's assessment of the expected stream of higher net earnings.

A different approach is required to measure "Use Values" associated with consumers' demand for goods and services, or with commercial demands that do not appear in a firm's financial reports. Here, the overall willingness to pay for a good or service (or for a set of goods and services) can have two components. One is the amount people actually pay for the good or service, i.e., their expenditures. The other exists if the amount they pay is less than what they would be willing to pay. In such an instance, the difference between the two is a net economic benefit consumers enjoy from acquiring the good or service. This net economic benefit is called consumer's surplus. The two components of value are often present when individuals, groups, and firms have access to water-related goods and services that are not traded in markets. For example, the total value anglers place on going fishing is often more than what they pay to do so. Their total willingness to pay, minus their actual expenditures (for travel,

equipment, and boat-launch fees, for example) equals the consumer's surplus they enjoy.

Consumer's surplus materializes for some of the "Use Values" and for all of the "Nonuse Values" shown in Table 2. Consumer's surplus is important because it represents an increase in well-being: a consumer is willing to pay *X* for a good or service, but pays a smaller amount and, in effect, gets something for nothing. Because consumers don't pay for it, the consumer's surplus cannot be directly observed through market transactions. Sometimes, economists can measure consumer's surplus in other ways, for example, by carefully asking consumers how much they would be willing to pay for something, and comparing consumers' responses with the amounts they actually pay. The methods economists use to measure consumer's surplus often are not familiar to many, perhaps most, members of the public.[6] They typically require data that are not routinely collected, and they can be cumbersome and expensive to employ.[7] These methods have been subjected to extensive scrutiny, however, and one extensive review by a noted authority in the economics of water has concluded that, when applied carefully to water-related goods and services, these methods are at least as accurate and reliable as the methods that measure values associated with market transactions.[8]

The preceding discussion supports the conclusion that describing the value of the goods and services that might be affected by irrigation requires a sophisticated approach that makes the best use of varied sources of information. Sometimes available valuation data or past studies may be sufficiently valid and accurate to measure the value of a specific good or service. When data and studies specific to a given good or service in Montana are not available (the more likely situation), it is necessary to look further afield for studies whose findings are applicable here. This process of utilizing the results of economic value studies performed elsewhere and applying them to new situations is called *benefit transfer*. Economists have developed guidelines for benefit transfer to ensure that it yields reasonable results, and we will follow these guidelines.[9] They require

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[6] Examples include the travel-cost method, which is used primarily to measure recreationists' willingness to incur travel costs to gain access to recreational opportunities; the contingent-valuation method, which involves asking consumers what they would be willing to pay for a specific good or service; and the conjoint valuation method, which isolates the value of a given good or service by asking consumers about differences in their willingness to pay for bundles that include it and other goods and services

[7] In some instances, there may be no conceptual basis for data and methods to measure the value of a good or service: the value associated with the religious and spiritual significance of some water resources, for example. We restate a point we made earlier: the inability to measure it does not mean that a value is zero.

[8] R.A. Young. 2005. *Determining the Economic Value of Water: Concepts and Methods*. Washington D.C.: Resources for the Future.

[9] U.S. Environmental Protection Agency. 2000. *Guidelines for Preparing Economic Analyses*. September.

clearly reporting the external study's data sources and key assumptions, and explicitly discussing the uncertainties inherent in the calculation.

Any description of the net economic benefits of irrigation will embody considerable uncertainty. For Montanans to have a full understanding of the net benefits of investments in irrigation, they must recognize both the results of relevant analyses and the uncertainty that surrounds them. In general, there is enough uncertainty that readers should use the results of any analysis regarding the economic importance of investments in irrigation with considerable caution. In most cases, analytical results represent not precise measurements, but general indicators of the value of the water-related goods and services that might be affected by irrigation in Montana. We already identified one source of ambiguity: many of the available numbers come from studies conducted outside the state or outside a specific region of interest within the state, and, as a general rule, the greater the ecological or economic distance between Montana and a study's focus, the more careful one must be when applying its results here. In addition, some of the relevant studies are several years old, and even those that are more recent may not fully reflect the current ecological or economic conditions, let alone the conditions likely to materialize in the future. Moreover, even the most attractive of studies—those conducted recently inside the state—generally do not tell the full story, insofar as they fail to account for factors, such as externalities, that can drive a wedge between the apparent and the true values of a particular good or service.

III. Net Benefit to Irrigators

The net economic benefit of irrigation that accrues to irrigators is a subset of the net benefit realized by Montanans as a whole. There are two general ways to measure it: by looking directly at the effects of irrigation on farmers' net earnings, and by looking at farmers' willingness to pay for irrigation water.

A. Farmers' Net Earnings

In concept, one could measure the increase in net earnings irrigators garner from irrigated land, relative to what they would earn if the land were not irrigated, by conducting experiments that randomly assign farmers to dry and irrigated lands, measure the differences in their net earnings, and use statistical techniques to isolate the effect of irrigation. In practice, such experiments are not possible, however. As a consequence, economists have used several alternative approaches that aim to approximate the results that would obtain if such experiments were conducted.

One approach compares the net earnings per acre some farmers derive from irrigated land with the net earnings per acre farmers—who may or may not be different—derive from nearby dry land. The difference in net earnings derived by this approach can represent the net benefit of irrigation only loosely, however, because the approach does not carefully control for the effects of factors other

than irrigation, such as differences in farmers' skills, soil type, and microclimate, that might contribute to the difference in net earnings.

A second approach uses models to describe how irrigation alters the behavior of crops and farmers. It uses biological models to describe, for a given plot of land, the potential increase in crop production, with-vs.-without irrigation, and multiplies this times the expected crop price to estimate the increase in gross earnings that farmers' theoretically could derive from the production of irrigated crops. To this amount are added any subsidies and other sources of income. This approach then uses economic models to describe the change in a farmer's costs associated with irrigated farming on the land versus dry-land farming, and subtracts the costs from the gross earnings to determine the net benefit.

A third approach looks in detail at data on the operations of irrigated farms and attributes to irrigation all the net earnings that cannot be attributed to other factors of production. Using data from actual farms, it first estimates the gross revenues that are representative of a given type of irrigated farming operation, and then subtracts all the farm's costs that are clearly attributable to seed, fertilizer, equipment, management, and other factors. The residual net earnings, if any, are assumed to be attributable to the land and the irrigation water. Repeating the exercise for comparable dry-land farming operations gives the residual attributable to the dry land. Comparing the two results indicates the incremental increase in net earnings derived from the irrigation water, alone.

B. Farmers' Willingness to Pay

If a farmer farming dry land expects that he or she would earn higher future net earnings from crop production by irrigating the land, then he or she should be willing to pay to obtain access to irrigation water. Under ideal conditions, the maximum amount he or she would be willing to pay would be only slightly less than the expected incremental increase in net earnings. Thus, if a farmer expects to earn $\$X$ more per year with irrigation, then he or she should be willing to pay slightly less than this amount for the water each year. Making such payments would leave him/her with net earnings from crop production higher than would obtain if the land were left dry.

Similarly, a farmer seeking to rent or buy land should be willing to pay more for a parcel of irrigated land than for a comparable parcel that lacks irrigation. The maximum increase in willingness to pay for irrigated land would represent the lower bound of the farmer's expected increase in annual net earnings from producing irrigated rather than dry-land crops.

Under ideal analytical conditions for measuring farmers' willingness to pay extra for irrigated land, there would be a fully functioning, competitive market for irrigation water or for irrigated-versus-dry land, with many farmers competing with one another for many units of water or for many parcels of land. These

conditions rarely, if ever materialize.[10] Consequently, economists have employed analytical methods that aim to approximate farmers' willingness to pay for irrigation water or to pay extra for irrigated land.

One of these examines situations where what farmers actually pay for water reveals what they are willing to pay for it. In some regions, for example, farmers irrigate their crops with groundwater and, in contrast with farmers that obtain water from large, multi-party irrigation projects, each farmer bears all the direct costs (exclusive of subsidies) of obtaining water for his or her fields. A farmer will opt to incur the cost only if he or she expects that the net earnings will cover the cost, but otherwise will prefer to farm dry land. In some places, pumping has lowered the water table and increased pumping costs enough that farmers have had to carefully weigh the costs against the potential net earnings from irrigating crops. In such settings there may be a discernible cost boundary at which farmers shift from incurring the costs to obtain water and prefer, instead, to farm dry land. This boundary identifies the maximum amount farmers are willing to pay to obtain water. Such a boundary is specific to the setting in which it occurs, but they may be sufficiently robust that it is reasonable to apply them elsewhere, for example, to other places with similar soil types, crop patterns, and market conditions.

A variation on this method estimates farmers' ability to pay for water. It involves gathering data regarding farming operations in an area. These are used to estimate the typical gross revenues from selling irrigated crops, and subtracting all the identifiable costs farmers typically would incur for seeds, fertilizer, equipment, farm-management, investment capital, and other factors of production. The residual, if any, is assumed the maximum amount the farmers' are able to pay for water without operating their farms in the red.

Another method focuses on the extra amount farmers are willing to pay for irrigated land. Some efforts have attempted to observe this amount directly, looking at what farmers have paid for parcels when there was no prospect of obtaining water and comparing this against what they have paid for the same parcels when water was available. Such circumstances can materialize, for example, when tenant farmers lease land without access to groundwater and later lease it after a well, pumps, and other infrastructure are in place. Ideally, the with-irrigation and without-irrigation events occur sufficiently close in time to one another that they are not distorted by significant changes in market conditions or other factors that influence willingness to pay for land.

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[10] The absence of a competitive market does not mean that competition does not exist. Instead, competition for water exists whenever society experiences tradeoffs in the goods and services that are available when water is used for irrigation. The competition may not manifest itself in any behavior; society may simply accept the tradeoffs without comment or action. Or, competitors may pursue their respective interests in venues other than markets, through legislative action, for example.

Other research has attempted to use statistical techniques to isolate the influence of irrigation from that of other factors that affect the price a which farmers rent or purchase land. This approach, called hedonic pricing analysis, looks at data for large numbers of land transactions and the many factors that might influence the price of the transaction. Under ideal conditions, the statistical techniques reveal, within the boundaries of the data, the average influence of each factor on the transaction price, with all other factors held constant.

C. Demand for, versus Value of Water

Each of these approaches and methods for measuring farmers' net benefits from irrigation is conceptually capable of producing reliable estimates of the net economic benefit of irrigation to farmers. The number of completed analyses is smaller than some might expect, however, as each approach and method is difficult to implement successfully. Reliable data are hard to obtain. Farm practices and markets are sufficiently complex that isolating the impact of irrigation on net earnings and the prices farmers pay for land, separate from other influences, can be challenging, if not insurmountable.

Smaller still are the numbers of analyses that show not just a point-estimate of farmers' net benefit from irrigation but the function that shows how this benefit varies as the cost of water, crop prices, climate, and other factors vary. The net benefit (marginal value) of an incremental increase in the supply of irrigation water is not constant. Ideally, to understand fully the economic importance of investments in irrigation, Montanans must understand how this importance shifts as relevant conditions change. This requirement is especially germane in situations where there exists a widespread perception that farmers "need" water. Such perception are at odds with economic reality: that water is an economically scarce resource for which there are competing demands, and each demand is sensitive to multiple factors, including the water's cost.

Some may perceive that farmers' demands are unlike those of others and not sensitive to price, and some studies have found that this perception may be correct in circumstances where farmers have access to large amounts of water at low prices.[11] In such settings, farmers tend to use more water than their crops require, but, where quantities are limited or prices high, farmers' demand for water is highly sensitive and they carefully ration their use of it.[12] As Montanans assess the economic importance of investments in irrigation they should take this relationship into account. All else equal, the economic net benefit to irrigators and, hence, to society as a whole, is different in situations where the supply of

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[11] *See,* for example, a discussion of the literature in Griffin, R. C. 2006. *Water Resource Economics: The Analysis of Scarcity, Policies, and Projects.* MIT Press. pp. 312-317.

[12] Griffin, R. C. 2006. *See* footnote 11.

water to farmers is plentiful and irrigation practices wasteful than in situations where the supply of water is tight and irrigation practices tight.[13]

IV. Net Impact to Local and Statewide Economies (Jobs and Incomes)

Using water to irrigate crops is important not just because it affects the overall value to society of the various goods and services derived from the state's water resources and influences irrigators' net earnings but also because it underlies jobs and incomes for many Montanans. In this section, we provide a conceptual framework for understanding and anticipating the local and statewide impacts of investments in irrigation on job and incomes. Economists often apply the term, *impact*, to describe a change in jobs, incomes, or related variables resulting from an investment, change in industrial activity, or other event. Such effects are distinct from, and not the same as, the change in the *value* of goods and services that might result from the event. Impacts and values are not necessarily related; it is possible, even common, for events with positive impacts to diminish the value of goods and services, and *vice versa*.

To construct our framework for analyzing economic impacts, we first describe the general process by which economies adjust to events, such as investments in irrigation, and observe that this process is highly dynamic, with extensive flexibility, diversity, and adjustment. We offer a framework for tracing the impacts of investments in irrigation in the context of a dynamic economy. This framework focuses on understanding the competing demands for water-related goods and services, and measuring how they respond to investments in irrigation. We finish with a discussion of the economic-base model, which is perhaps the most commonly used tool for measuring economic impacts. We conclude that this model should be rejected because it overlooks the economy's dynamic character and, hence, it almost certainly provides a misleading view of the economic impacts of investments in irrigated agriculture.

A. The Dynamic Economy

Investments in irrigation can effect strong responses in Montana's local, and statewide economies, in both the short and the long run. These changes will occur in four general stages, shown in Figure 2. In Stage 1, a decision to invest in irrigation is made and, in Stage 2, this action sends economic signals to the local and statewide economies (and also the larger regional, and national economies), indicating a change in the economic role of water resources. The signals have four major destinations, representing four components of the economy that may have strong economic interest in the water and competing demands for the water-related goods and services (we further discuss these competing demands,

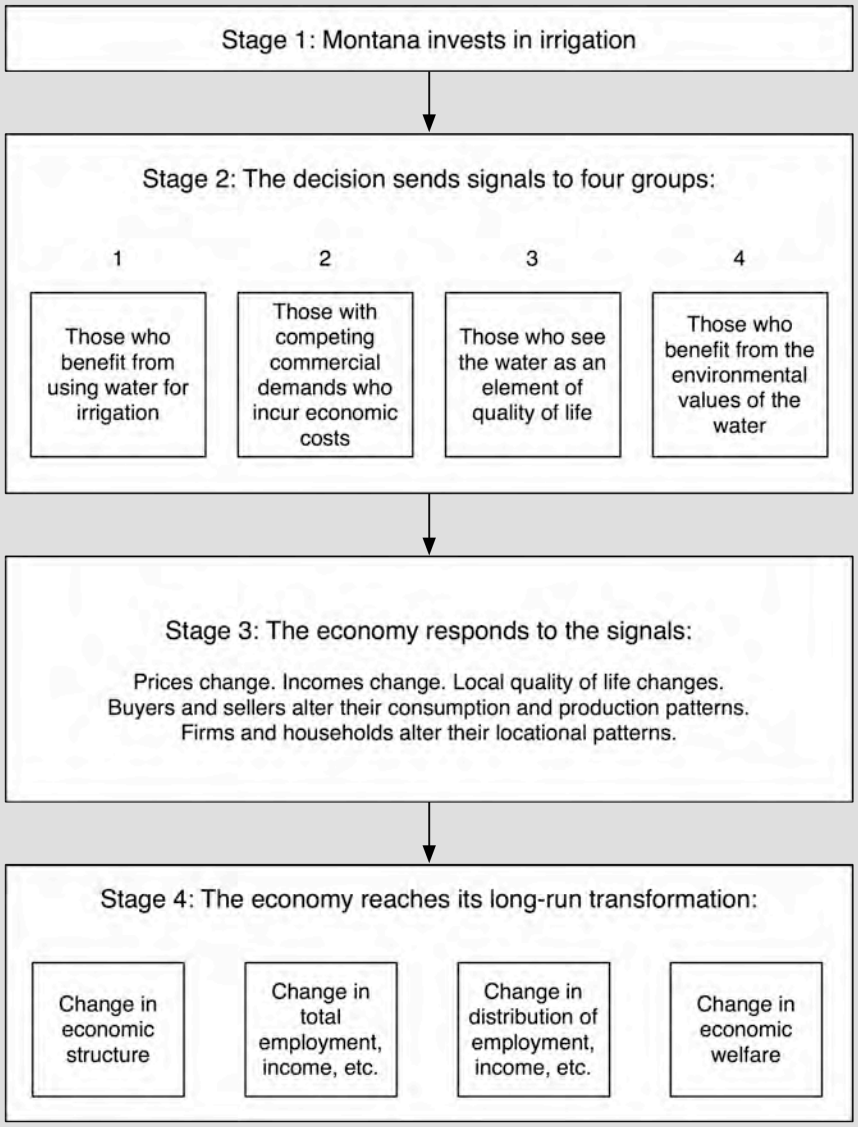
[13] An analogous observation applies to the impacts of investments in irrigation on jobs and incomes: the impacts depend not just on how the investment will affect the supply of irrigation water but also on the economic conditions in which the change in water supplies occurs.

below). Although Figure 2 shows Stages 1 and 2 occurring as a single, abrupt event, they generally transpire over a longer period.

Stages 3 and 4 of Figure 2 illustrate the dynamic character of the economy's response to the decision to invest in irrigation. In Stage 3, the economy responds to the economic signals sent in the second stage through changes in prices or incomes or both. If the prices of goods and services rise or fall to levels that otherwise would not occur, buyers and sellers adjust their behavior accordingly. A change in the output of a good or service, even in the absence of a price change, similarly causes a change in the level and distribution of incomes and a change in the behavior of buyers and sellers. The prices of some goods and services in some locations may rise in response to a reduction in supply or an increase in demand, and for the opposite reasons, the prices of some goods and services in some locations may decline. Separate price-effects and income-effects manifest themselves for the different, competing demands.

In Stage 4, prices and incomes reach their new levels, and the economy exhibits the long-run effects of the adoption of the irrigation-investment decision. (The long-run adjustment may entail feedback loops, through which changes in prices and incomes may influence future decisions affecting water management, irrigated agriculture, and other segments of the economy.) Alterations in the structure of the economy occur at the local and statewide levels (and the regional and national levels); that is, the distributions of water-related activity, quality of life, jobs, incomes, and wealth are different at each level than they would have been without it. The precise path through Stages 3 and 4—the transitional adjustment to the irrigation-investment decision—will depend, not just on the characteristics of the decision itself, but also on the multiple economic forces and trends that are continuously altering and shaping the economy at all levels. Individual concern often is raised about the impacts of the transition on capital, property, and labor markets. Most markets should adjust quickly to the investment decision, and they may even adjust in anticipation of the decision. The larger and more diverse the affected economy, the smoother the transition.

Figure 2. The General Process by Which Investment in Irrigation Leads to Changes in the Economy



Source: ECONorthwest

B. Impacts Materialize Via Competing Demands for Water-Related Goods and Services

In most times and places there is insufficient water to satisfy all the demands for all of the goods and services in Table 2. For example, water diversions for irrigation can limit the water available for instream uses, or *vice versa*. Hence, when water is used to produce one set of goods and services, the demands for others go unmet. In other words, there is competition for the water. Because this competition both reflects and shapes the economic values of the different goods and services, an understanding of the essential characteristics of this competition

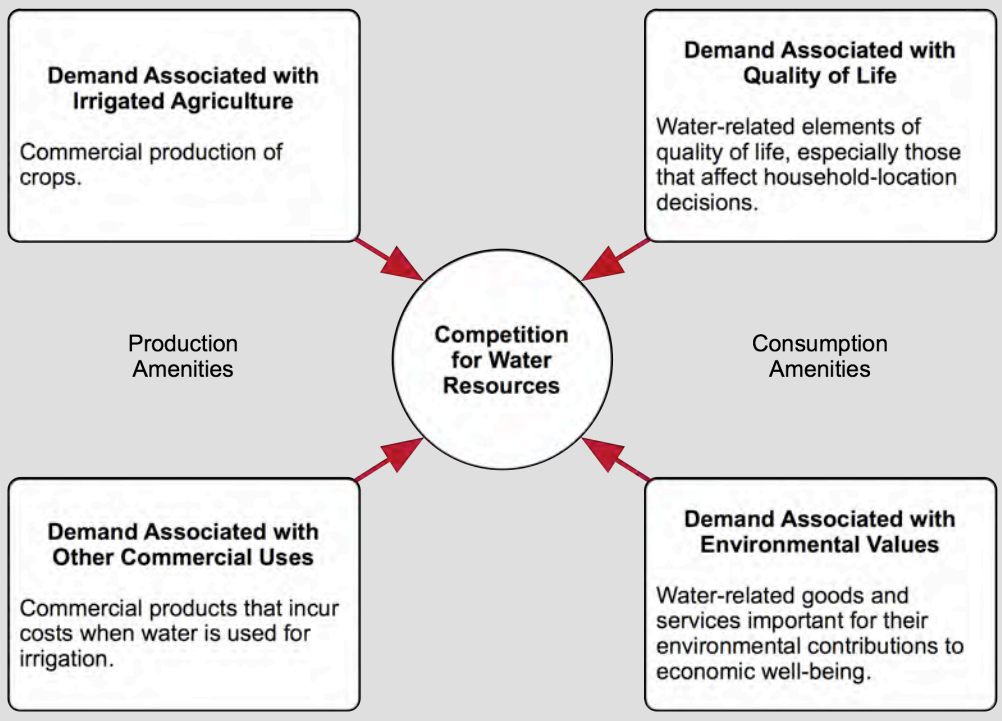
can provide useful insights into the values that exist today and how they change over time.

One could categorize the competition in any of a number of ways, but we employ a taxonomy that distinguishes among four types of demand, as illustrated in Figure 3.[14] Two of these, which we call demands for production amenities, include demands for those goods and services that are, or could be, inputs to processes that produce other goods and services. The other two, which we call demands for consumption amenities, include demands for those goods and services that directly enhance the well-being of consumers. To facilitate the discussion, we assume that one of them, which we call the dominant commercial demand, prevails and then look at the consequences for the others.

1. Competition for Production Amenities

On the left side of Figure 3 we place the competing demands for the production amenities of a water-related ecosystem. Irrigated agriculture, mining, and development are the most important of these demands. Demand for Montana's

Figure 3. The Competing Demands for Montana's Water Resources



Source: ECONorthwest

[14] For a broader discussion of the competition portrayed in Figure 3, *see* Courant, P.N., E. Niemi, and W.E. Whitelaw. 1997. *The Ecosystem-Economy Relationship: Insights from Six Forested LTER Sites*. ECONorthwest. Report to the National Science Foundation. Grant No. DEB-9416809. November.

water-related production amenities comes from private and public enterprises, which we define broadly to include private corporations, incorporated cities, and public agencies, as well as households that conduct ranching operations or other commercial activities.

Dominant Commercial Uses. We separate the demands for production amenities into two groups. One of these, shown in the upper left of Figure 3, dominates the use of water or a related resource at a particular place and time, typically using the resource directly and depleting the stock of the resource. This type of demand usually is associated with a familiar industry, such as ranching or mining, or with common development activities: urbanization, bridge construction, and the like. In general, only one product benefits from a particular use of water-related resources, but sometimes there may be more. A dam may benefit irrigators and consumers of hydroelectricity, for example.

Competing Commercial Uses. Sometimes, a dominant commercial use of water-related goods and services imposes costs on other commercial enterprises, which are represented in the bottom left of Figure 3. When an irrigator depletes stream flows and reduces fish habitat, for example, he or she may reduce the production of irrigators downstream who now have less water for their fields, or impose costs on fishing guides who now have fewer prime fishing spots for their customers.

We purposefully separate the demands on the left side of Figure 3 into two boxes to drive home the message that, at a given place and time, there may be competition within the state's commercial sectors for Montana's water and related resources. We do so because often people perceive that the competition for water occurs only between irrigation and environmental-protection interests. By highlighting the existence of competition within multiple commercial sectors, we emphasize the point that the positive consequences arising from irrigation can have offsetting negative effects on other commercial sectors.

2. Competition Directly from Consumers

On the left side of Figure 3, water-related goods and services are economically important because they are inputs in the production of other things—crops, hydroelectricity, etc.—that consumers want to have. On the right side, the connection to consumers is more direct. Here, consumers consider Montana's water resources economically important for how they directly contribute to their well-being. In economic parlance, these are known as consumption amenities.[15] There are two types of demand for water-related consumption amenities: one directly affects residential location decisions; the other does not.

Consumption Amenities and Residential Location. Some water-related goods and services, such as recreational opportunities and scenic vistas, contribute

[15] For the remainder of the memorandum we follow common practice and use "amenities" to refer to consumption amenities.

directly to the well-being of people who have access to them. Their contribution to consumers' well-being makes them economically important in their own right, but they have additional economic importance when they also influence the location decisions of households and firms. We show the demands for consumption amenities that influence location decisions in the upper right portion of Figure 3.

Economists' explanation of why some consumption amenities can influence location revolves around the concept of *consumer's surplus*, which we discuss in earlier sections. Whenever a consumer derives a benefit (increase in well-being) from a good or service that exceeds the cost he or she pays to obtain it, the net benefit represents an increase in well-being. This increment is called consumer's surplus.

In general, the nearer people live to amenities, the lower their cost of using them. Thus, consumers can increase their consumer's surplus, and, hence, their economic well-being, by living in a place that offers recreational opportunities, pleasant scenery, wildlife viewing, and other amenities they consider important. This consumer's surplus is, in effect, a *second paycheck* a resident receives from living in a place where she has easy access to these amenities, so that her total welfare is the sum of the second paycheck plus the purchasing power of her money income (her first paycheck). The size of the second paycheck, in effect, measures the quality of life residents enjoy by living in a given place.

Quality-of-life values can be powerful. Many Montanans say the primary reason they live here is to enjoy the quality of life. Some of them undoubtedly could enjoy higher earnings living elsewhere, but choose not to do so because their total welfare (the sum of the first and second paychecks) is higher here. Some aspects of this quality of life—the strength of communities, schools, and churches, for example—are not directly related to water, but others include open space, way of life, and opportunities for fishing and hunting, to mention a few. All else equal, if the state's water-related consumption amenities improve, some people already here will tend to stay and additional people will tend to move in. Degradation of the amenities will have the reverse impacts.

Environmental Values. The lower right portion of Figure 3 represents demands associated with economic values that do not necessarily entail a conscious, explicit use of water-related goods and services. We call these environmental values. There are two general categories: nonuse values and values of goods and services that generally go unrecognized.

Nonuse values arise whenever people place a value on maintaining some aspect of the environment, even though they do not use it and have no intention to do so. Research has documented nonuse values for maintaining the existence of species threatened with extinction, for example, and for special natural areas, such as national parks. They also can materialize when people want to maintain a particular cultural or ecological characteristic of a resource, as when people want to maintain the existence of landscapes associated with traditional ranching or native wilderness, for enjoyment by future generations.

Environmental values also can be important when a water-related ecosystem provides valuable services that people generally consume without being aware of them. Some of these are part of the so-called web of life: operating at local, regional, and global scales, they help sustain life. Others have a more direct link to the well-being of Montanans. On its own, for example, the natural resources found in a wetland may have no commercial value nor contribute in any visible way to the quality of life of nearby residents. Nonetheless, to the extent that the wetland helps support important functions and life of all types in the ecosystem, then it also helps support the people living nearby and contributes to their well-being. For example, wetlands help mitigate flooding, assimilate pollutants to clean the water, and help to purify the air. Even though those living nearby might not consciously consider the benefits of these services on a day-to-day basis, they probably would do so if they had a better understanding of them or if the services were to become threatened or noticeably diminished.[16] Many people today, for example, consciously consider the economic values associated with the services produced by the global climate, in ways that were unknown, even to scientists, just a few years ago. Some scientists and economists believe many more services have great economic value although this value and, hence, the demands for the services lie dormant.[17]

The demands stemming from environmental values are typically harder to measure, or even to observe, than the demands in the other three categories represented in Figure 3. People do not ordinarily link their behavior to the value they place on protecting an endangered species, a ranching landscape, or the natural resources of a wetland. Sometimes they do, however. Acting through political processes, people sometimes implement regulations to restrict activities potentially harmful to the continued existence of some species and landscapes, for example. Or, they may voluntarily alter their behavior, as when a rancher refuses to sell land to a developer, preferring instead to keep the land as ranchland for future generations.

Montanans are not the only ones who place a value on the resources inside the state. Residents of Miami, Seattle, Denver, and Minneapolis might want to protect a species or landscape in Montana for future generations. Though they live elsewhere, they represent values associated with water in Montana. Because they can originate from large populations, living near and far, environmental values can be huge in the aggregate, even if they are small on a per capita basis. Even though they originate outside the state, their economic power can materialize inside Montana if, for example, they alter federal legislation affecting

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[16] Researchers have found that environmental values typically increase as people learn more about the environment, the services it provides, and environmental degradation. *See,* for example, Blomquist, G.C. and J.C. Whitehead. 1998. "Resource Quality Information and Validity of Willingness to Pay in Contingent Valuation." *Resource and Energy Economics*, 20: 179-196.

[17] *See*, for example, Daily, G.C. 1997. *Nature's Services: Societal Dependence on Natural Ecosystem*. Washington, D.C.: Island Press.

the scope of federal programs or the behavior of federal agencies that influence the profitability of the state's irrigated farms.

3. Tracing Competition to Describe Impacts

Tracing the impacts of an investment in irrigation through the competing demands shown in Figure 3 requires a descriptive process similar to, but different in important ways, from the process that we outline above for describing the investment's net benefits. Both exercises require a straightforward description of the full, marginal consequences—positive and negative—of the investment. A description of net benefits should focus on the changes in the value of goods and services available to society resulting from the investment. A description of impacts, however, should focus on changes in jobs, incomes, or related variables.

For example, for a given investment, will it increase the amount of capital invested in Montana (or a local community) or will it displace investment that otherwise would occur in some other part of the statewide (or local) economy? To the extent that an investment in irrigated agriculture would displace investments that otherwise would occur, it is likely that the positive effects of the one will be offset, more or less, by the negative effects of the other, unless there is clear reason to believe that the effects would be markedly asymmetrical, in which case the net effects should be investigated. A similar approach is appropriate for the use of non-capital resources (labor, land, water, etc.) resulting from the investment that increased irrigation would consume: if the investment and subsequent irrigation activities would displace the resources from other uses that contribute to the statewide (or local) economy, it is reasonable to assume that the plusses and minuses would offset one another unless there is clear evidence indicating otherwise, in which case the net impact should be investigated. So-called "event studies" might augment the analysis if they can trace the effects of past investments similar to those that might occur in the future.

This analytical approach also applies for investments that would attract capital or other resources that otherwise would go elsewhere. In the extreme, a program or project that attracted investment with no offsetting costs would have no offsetting effects and constitute a pure benefit for the economy. Such outcomes are unlikely, however. Hence, here, as previously, the focus is on the net effects: even if the project or program were to attract new capital, it would divert labor, land, water, etc. from other uses.

Similar reasoning applies when looking at irrigation activities that follow an investment. The focus is on the full, marginal impacts as these activities affect the competing demands for water-related goods and services, as shown in Figure 3. In the general case, one irrigator, or group of irrigators, controls the water and uses it to irrigate a crop. The direct impacts on jobs and incomes are those closely associated with the activities of his individual or group. For the economy as a whole, however, the consequences for competing interests also must be taken into account.

Consider this hypothetical example: if a farmer diverts an acre-foot of water by adding it to already-irrigated ground, the net income derived from of the additional hay grown might be, say, $1. But, if the water had been left in the stream it might have provided habitat for fish and angler-related incomes of $2, and then, after being diverted by a downstream farmer to irrigate a dry ground, produced net income of $2. In this hypothetical example, augmenting irrigation on the already-irrigated ground would yield net income for the upstream farmer of $1, but an overall net income, for the economy as a whole, of negative $3.

Economists use the terms *spillover effects* or *externalities* to describe the economic consequences one resource-user's actions have on others. To discern the overall impacts of a particular irrigation investment, one must fully account for all the externalities. In the hypothetical example above, the externalities were negative. In general, whenever there is competition for water, any use of water—irrigation, municipal-industrial, recreational, etc.—will have negative externalities on competitors, and the overall impact of the use, seen from the perspective of the economy as a whole, will be less than the impact for the individual user. If, as in this hypothetical example, the negative externalities exceed the positive impact for the upstream irrigator, then the use diminishes the overall incomes of all Montanans.

4. Some Demands are Complementary

Irrigators don't just compete for water and impose negative externalities on others. Sometimes—many times—an irrigator's water use has positive impacts on the well-being of others. By flooding their fields in the spring and early summer, for example, an irrigator may increase the volume of water stored in shallow aquifers, which release some of the water to streams later in the year, sustaining fish habitat and fishing-related jobs and incomes.[18] By using land to produce irrigated crops rather than allowing it to be converted to a shopping center, a landowner may sustain the landscapes many Montanans cherish and attract to the community households that desire to live nearby.[19] By maintaining ecologically healthy wetlands capable of absorbing water during periods of high runoff, a farmer may decrease the likelihood of flood damage for downstream landowners. By maintaining healthy vegetation in riparian (streamside) areas, a farmer may reduce the likelihood that runoff from his or her land will enter the stream and degrade water quality enjoyed by boaters.

There are many more examples. In general, whenever there are complementary impacts, a given use of water will have positive externalities on others, and the

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[18] *See,* for example, Wetstein, J.H. 1989. *Return Flow Analysis of a Flood Irrigated Alluvial Aquifer*. University of Wyoming, Department of Civil Engineering. August.

[19] Loomis, J., V. Rameker, and A. Seidl. 2000. *Potential Non-Market Benefits of Colorado's Agricultural Lands: A Review of the Literature*. Colorado State University, Department of Agricultural and Resource Economics. Agricultural and Resource Policy Report. APR-00-02. February. Retrieved January 30, 2008, from http://dare.agsci.colostate.edu/csuagecon/extension/docs/landuse/agland.pdf.

overall jobs and incomes resulting from the use, seen from the perspective of the economy as a whole, will be greater than the those that accrue to the individual user. Some complementarities can be easily recognized, as when water flowing through an irrigation project provides habitat for fish and recreational opportunities for anglers. Other complementarities are more obscure, such as those associated with the complex, inner workings of the ecosystem, that have not been fully researched.

C. The Economic-Base Model

Measuring the impacts of an event, such as an irrigation investment, in the context of a dynamic economy presents a difficult analytical challenge. Consequently, many analytical tools for assessing economic impacts simplify things and assume the relationship between natural resources and the surrounding economies is static. This is especially true of the economic-base model. Because it is so frequently applied, and yields results so misleading, we single it out.

An economic-base model divides the economy of an area into two sectors: the export sector, which produces goods and services sold to buyers outside the area, and the local sector, which sells its products inside the area. Proponents of the economic-base model conclude that, because the export sector brings in money from the outside that is spent and re-spent on local goods, it is the "economic base" that "supports" the local sector. With such models, the fate of a region's economy is in the hands of outsiders: the only way the welfare of local residents improves is if outsiders buy more of the goods being exported from the area. Because industrial agriculture typically exports its products to other regions or countries, proponents of the economic-base approach often conclude that this industry plays a key, "basic" role in sustaining the economies of the community and state, and the welfare of all residents. Economic-base models also contain a simplifying assumption that arrests the economy in its current configuration. Operationally, application of the model often includes a snapshot of the economy, in the form of an input-output matrix based on data showing the pattern of transactions among different sectors of the economy at a given point in time.[20] The matrix is used to trace how an increase or decrease in the supply of a particular product would ripple through the economy if the pattern of these transactions remained unchanged.

These core characteristics of economic-base models are its fundamental weaknesses. Because of its distinction between "basic" and local industries, an economic-base model implicitly poorly recognizes the potential for local entrepreneurs and firms to develop new business activities that would generate growth. Instead, growth can occur only from outside sources. Because it focuses on industries, the model cannot see non-industrial, economic-growth

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[20] The input-output matrices often are derived from IMPLAN data sets compiled by Minnesota IMPLAN Working Group, Inc. (http://www.implan.com/).

mechanisms, such as those that occur when Montana's natural-resource amenities attract households and investment. Some evidence indicates this source of growth is as important as growth that originates with industrial investments.[21] Because of its simplifying assumption, the model rests on a conceptual inconsistency: it can describe change in an economy only by assuming the economy's structure remains frozen.

In general, the results from this approach would tend to overestimate the positive impacts and underestimate the negative impacts of an investment in irrigation. This bias can be called the dumb-person bias, because the technique explicitly assumes that farmers, investors, managers of firms, workers, and consumers would not adapt to the investment-related change in the production of irrigated agriculture but, instead, would continue to behave as if the change had not occurred.[22] In reality, farmers, investors, managers, workers, and consumers are neither static nor dumb. The regional and subregional economies of the U.S. are tremendously dynamic, and they adapt remarkably to changing conditions.[23] If the supply of a productive input, such as irrigation water, is increased (restricted), or if the demand for farmers' crops rises (falls), farmers and others will try to reduce their risks and to maximize their profits and earnings.[24]

Applying the economic-base model to investments in irrigation in Montana would entail constructing an input-output (probably IMPLAN) matrix showing the pattern of transactions among sectors of the economy at some point in the (preferably recent) past. The data embodied in the matrix, however, would reflect some questionable assumptions: that the national pattern of some transactions are representative of the pattern within Montana, for example, and that the data provide an accurate division of the irrigated-related goods and services, and any related economic activities into the so-called basic and non-basic categories. Moreover, the matrix would describe the average historical relationship between irrigated agriculture and other industrial sectors of the economy. It would not have the ability to anticipate how this relationship would change in response to investments in irrigation, and it would disregard the relationships between irrigated agriculture and those components of the economy competing for water and other scarce resources. Indeed, the economic-

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[21] Partridge, M. and D. Rickman. 2003. "The Waxing and Waning of Regional Economies: the Chicken-Egg Question of Jobs Versus People." *Journal of Urban Economics* 53: 76-97.

[22] Mendelsohn, R., W.D. Nordhaus, and D. Shaw. 1994. "The Impact of Global Warming on Agriculture: A Ricardian Analysis." *The American Economic Review* 84(4): 753-771.

[23] *See* Edmiston, K.D. 2004. "The Net Effects of Large Plant Locations and Expansions on County Employment." *Journal of Regional Science* 44(2): 289-319 for a description of a situation where the expansive effects of investments in one industry were more than offset by contractive effects elsewhere in the economy, an outcome that an economic-base model and IMPLAN matrix were unable to recognize.

[24] *See*, e.g., Robertson, G. 2003. *A Test of the Economic Base Hypothesis in the Small Forest Communities of Southeast Alaska*. Forest Service, Pacific Northwest Research Station. December.

base model and input-output matrix would assume no resources are scarce. Thus, the matrix could not show the tradeoffs that would occur as an investment in irrigation-diverted water to produce irrigated crops in one place and away from competing demands, including demands from other farmers. Equally significant, it could not describe how the interactions between irrigation and the rest of the economy respond to changes in the economy, such as changes in the price of crops, land, capital, or labor, or to changes in the ecosystem, such as drought conditions.

In sum, an economic-base model could be a reliable tool for describing the importance of investments in irrigated agriculture only within this limited scope: it could provide a static snapshot of some of this sector's positive impacts on the economy under the specific economic and ecological conditions at the point in time (currently 2006) represented by the data supplied by the federal government. We believe such snapshots would not prove useful in this project, insofar as the project has a *forward*-looking stance that seeks to describe the *overall* economic importance of irrigated agriculture, and the *marginal* impacts of potential investments in irrigation projects and programs. Using the economic-base model to describe the future economic importance of irrigation in Montana or the potential impacts of investments in irrigation would undermine the credibility of this entire project.

Rather than employ the economic-base model, we recommend that Montana use the straightforward, descriptive approach we explain above. This approach directly accounts not just for changes in agricultural and related commercial and industrial activity stemming from an investment in irrigation, but also for the consequences of drawing capital, workers, and other resources from alternative uses. Moreover, it accounts for non-market consequences of the investment, which are excluded from the economic-base approach.

V. Cross-Cutting Issues

Three issues cut across the preceding discussion. One is the distribution among different groups of the economic consequences of investments in irrigation. The second is the role of past investments in assessing the economic importance of future investments. The third is the difference in perspective that materializes when one looks to the future to discern the economic importance of investments in irrigation rather than looking to the past.

A. Distribution of Net Benefits and Impacts

A description of the net economic benefits and impacts of an investment in irrigation is not complete unless it addresses the distribution of effects among different groups. Any investment will produce winners and losers. Whether one is a winner or a loser will, of course, affect one's assessment of the immediate economic importance of a given investment. Sometimes, though, the distribution has broader consequences. Investments that impose costs on an already disadvantaged group, for example, might be widely seen in a negative light not

just by those in that group but by others as well. Past experience indicates that these concerns may be important:

- The gross and net benefits and impacts accruing to tribal members.
- Offsetting consequences among different groups of farmers, with an investment in irrigation benefiting one group at the expense of another.
- Benefits accruing primarily to households with high levels, and costs accruing to households with low levels of wealth and income.
- Differential consequences for rural and urban residents, with one group incurring costs to subsidize the other.

Benefits accruing primarily to non-Montanans, such as corporate stockholders, and costs accruing to Montanans.

B. The Role of Past Investments

Many Montanans advocate new investments in irrigation to reinforce past investments. Their argument goes something like this: "We've already invested a lot in this irrigation infrastructure and we necessarily should invest more now to keep that investment from going to waste. The greater the amount we've invested in individual projects, the greater the amount we should invest now to protect our past investment."

Economists see things differently. They see past investments and expenditures on irrigation infrastructure as sunk costs, i.e., costs that have already been incurred and cannot be recovered. Whether a new investment is made or not, the earlier costs will be unaffected. In such situations, the assessment of net benefits and net impacts of the new investment should look forward, not backward. The net benefits of the new investment will be the gross benefits that will accrue solely because of the investment minus the gross costs that will accrue solely because of the investment. Similar reasoning applies to the net impacts.

C. Looking to the Future

Montanans are likely to come to different conclusions regarding the economic importance of investments in irrigation if they look to the future rather than to the past. Looking to the past, they will assess investments in the context of technological, economic, political, social, and ecological conditions that are unlikely to be representative of the conditions that will determine the net benefits and impacts of investments in the future. Nobody can know the future, of course. Hence, it usually is reasonable to begin assessing the future consequences of investments by imagining that they would occur in the conditions that exist today. The necessary next step is to explicitly consider the potential effects of identifiable forces and trends that appear likely to alter these conditions significantly. Illustrative examples include, but are not limited to the trends and forces associated with climate change, globalization of markets, changes in the scarcity of and consumers' preferences for irrigated crops relative to other water-

related goods and services, growth in Montana's population and wealth, the costs of transporting Montana's crops to market, competing demands for investment funds, and advancements in irrigation-related technology.