THESIS

THE VALUE OF WATER IN AGRICULTURE: A TYPOLOGY OF WATER VALUATION METHODS AND ESTIMATE OF ECONOMIC ACTIVITY FROM WATER IN AGRICULTURE AND ASSOCIATED MUTUAL USES IN THE ARKANSAS RIVER BASIN, COLORADO

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ABSTRACT

THE VALUE OF WATER IN AGRICULTURE: A TYPOLOGY OF WATER VALUATION METHODS AND ESTIMATE OF ECONOMIC ACTIVITY FROM WATER IN AGRICULTURE AND ASSOCIATED MUTUAL USES IN THE ARKANSAS RIVER BASIN, COLORADO

The water-stressed Arkansas River Basin is experiencing a greater frequency of water transfers from agriculture to municipal and industrial uses. Removing water from agriculture may harm rural communities, impact ecosystems, and change recreation opportunities. In order to better understand the implications of transfers, the economic activity created by these water uses must be calculated. Previous water valuation efforts have neither included all stakeholder interests, nor quantified externalities of water allocation scenarios and thus do not accurately estimate the potential impact of transfers. This paper evaluates methods for calculating the value of water in agriculture, the value of water to recreational users, the economic spillovers from agriculture and recreation, and the value of environmental flows. Direct, indirect and induced economic activity from agriculture is estimated using IMPLAN; economic activity from recreation related to agricultural water is estimated using benefit transfer and IMPLAN. Implications to ecosystem benefits are described quantitatively. Impacts to economic activity in the region from potential reductions in irrigated acreage are considered, including hypothetical impacts from reduced water recreation. The results show that the vast majority of agriculture, and thus economic activity from agriculture, depends upon irrigation water. That said, irrigated crop farming makes up just 1% of employment and economic activity in the Arkansas Basin. However, the great quantities of water that are allocated to agriculture (almost 90% of all water withdrawn from basin water ways) offer recreation opportunities that generate employment and economic activity and support agro-ecosystems that have economic and consumer surplus benefits.

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Chapter 1: Introduction and Objectives

Colorado's Arkansas River flows from the high Rockies near Leadville, Colorado and continues southeast to Kansas, providing water to much of southeastern Colorado. Irrigation is the major water use in the Arkansas River Basin, with about 1.75 million acre-feet diverted for crop irrigation out of 2.05 million AF of total diversions (Ivahnenko and Flynn, 2010). Urban demand for water in the basin is steadily increasing with the growth of Pueblo and Colorado Springs. By 2050, municipal and industrial (M&I) demand for water in the Arkansas Basin is projected to increase between 141,000 and 195,000 acre-feet annually. Among the nine major water basins in Colorado, only the South Platte is projected to experience greater increase in municipal and industrial water demand (CWCB, 2012).

The Arkansas River Compact of 1948 apportions 40% of the river's flow to Kansas and 60% to Colorado. Like most Western states, water rights in Colorado follow the doctrine of prior appropriation, meaning that older claims to water rights have legal authority to withdraw their allotment before younger claims, regardless of the manner of use. The most senior, and thus most immutable, water rights tend to be held by agricultural producers, not cities or modern industries. Colorado continues to grow and urbanize faster than the national average, despite the fact that most waterways are fully allocated. During the past 25 years, withdrawals from Colorado waterways have increased in thermoelectric power, municipal and industrial sectors and decreased for livestock and mining (Ivahnenko & Flynn 2010). Water demand is expected to continue to shift towards urban uses. Further complicating matters is uncertainty about future precipitation patterns. As this report is being written, a second season of below average snowpack is portending that Colorado may suffer an unprecedented drought in 2013. **Without a doubt, the Arkansas River Basin suffers from significant and increasing water scarcity.**

Potential actions to manage water scarcity include limiting industrial growth and in-migration, increasing water storage capacity, mandating conservation, and re-allocation from agriculture to other uses. Because low-valued consumptive uses of water are common in agriculture, inter-sectoral tradeoff analyses often look to the agricultural sector to meet growing demand (Young, 2005). In response to the increased M&I demand and lack of water available for the purchase of new rights in the Arkansas Basin, water transfers, from agricultural to municipal and industrial uses, have increased (CWCB, 2012). On the surface, this may not seem cause for concern. Economics presumes that, if transactions are taking place willfully, both the buyer and seller are being made better off by the transaction. However, transactions can ignore potential third-party impacts. Irrigated agriculture is a vital base industry to many rural communities that spurs economic activity through purchases of input supplies and services. Agricultural water use and storage provide significant mutual-use benefits to ecosystems and outdoor recreation. Thus transferring water out of irrigated cropping may harm rural communities, impact ecosystems, and diminish recreation opportunities. At the same time, urban development and economic growth may benefit from transfers.

Re-allocation of water involves politically contentious tradeoffs. Re-allocation generally results in permanent fallowing of agricultural land and may induce a permanent change in water storage and in-stream flows. Stakeholders seek information about these tradeoffs in order to make better decisions. In 2008, the Arkansas Basin Roundtable Water

Transfer Guideline Committee developed a template for guiding ag-to-urban water transfers in the basin, but in order to evaluate the full implications of water transfers, the Roundtable needs empirical information about potential third-party impacts. **In order for water stakeholders and governments to make informed water allocation decisions, the full value of water in current uses and potential economic impacts of reductions to irrigated agriculture in this region must be determined.**

Purpose and Objectives

The purpose of this study is to provide information to stakeholders and governments about the value of water used in agriculture so they may make informed decisions about water policy and re-allocation. The United Nations stated in 1992 that *"Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource."* The 1992 "Dublin Statement" goes on to say that*, "Managing water as an economic good is an important way of achieving efficient and equitable use…"*. In order to treat water as an economic good and determine how it can be allocated to the most efficient and equitable uses, the value[1] of water in different uses must be determined and converted into easily comparable units – i.e. dollars. This study has four specific objectives:

a) Present a typology of economic methods for calculating the value of water,
b) Present estimates of the value of water from previous studies,
c) Provide an estimate of economic activity in the Arkansas Basin related to water allocated to agriculture, including mutual-use benefits and economic spillovers, and

[1] "Value" is a general term used to encompass economic activity, impact, contribution, or societal benefits. These terms will be defined in Chapter 2.

d) Suggest alternative processes and methods for calculating the value of water in agriculture in the Arkansas Basin.

First, four stakeholder groups or "sectors" are identified that have a stake in Arkansas River Basin agricultural water: agriculture, recreation, ecosystems, and supporting industries. Through a literature review, this study evaluates how different economic methods calculate the value of water and provides a range of estimates from different studies. Methods appropriate for measuring the value of water to each economic sector are selected, and values are calculated, where possible, to estimate economic activity related to irrigated agriculture, thereby quantifying potential impacts if Arkansas Basin water is transferred to other uses. Lastly, this study evaluates the shortcomings of these estimates and suggests more robust methods for calculating the value of water in agriculture given more time and resources.

Calculating the value of water is challenging because water is used and reused throughout its trip from the mountains to the sea. The full value of a unit of water depends upon the path it follows in the hydrological cycle and the values generated along that specific path (Seyam & Hoekstra, 2000). Like any industry, agriculture has many positive and negative externalities, and induces economic activity that spills over into other sectors of the economy. Water allocated to agricultural irrigation offers recreation opportunities and supports unique ecosystems up and downstream from where the water gets applied to crops. Agriculture can also harm water quality and use-up a significant portion of water via evaporation and evapotranspiration. In rural areas, agriculture is often a keystone base industry, inducing economic activity that is essential to the existence of rural communities. These externalities and spillovers influence the value of water allocated to agriculture.

An *externality*, in economics, is a cost or benefit that results from an activity that affects an uninvolved party. Externalities refer exclusively to costs and benefits that are not accounted for by the primary market transaction. In other words, for a cost or benefit to be considered an externality, the uninvolved party must not be compensated for the costs they incur or pay for the benefits they receive (Nicholson, 2005). For example, fisherman benefit from reservoirs that store water for agriculture, even though they do not pay for rights to the reservoir water. Fishing opportunities are therefore an externality of agricultural water storage. Fishing equipment retailers benefit as well, from the *economic spillovers* that occur as fishermen purchase gear and supplies. As opposed to competitive uses of water that alter up and downstream activities, *mutual-use benefits* do not impinge upon the use of water for irrigation downstream. Mutual-use benefits of agricultural water included rafting, fishing, and support of wetland ecosystems.

This multitude of costs and benefits, mutual and competitive uses make it challenging to estimate the full value of water that is allocated to agriculture. It has been widely documented that, if the positive externalities of mutual-use benefits are ignored, the per-unit value of water to farmers and ranchers is much less than the value to municipal and industrial users (Young, 1983; Vaux & Howitt, 1984; Howe & Goemans, 2003). However, the impacts from "drying up" agriculture extend beyond the agricultural producer. Agricultural producers are one stakeholder[2] group that has an interest in Arkansas River water, but many other stakeholders exist, including municipalities, property owners, outdoor recreation enthusiasts, and environmentalists. In order for water to be allocated in ways that provide for the greatest social benefits, all stakeholder

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[2] The term "stakeholders" is used instead of "users" because not all groups or individuals affected by water allocation decisions use the natural resource as a production input.

interests must receive consideration, despite the fact that many stakeholders do not own water rights. **Measurement of the water's value should take into account the impact of water allocation decisions upon all groups who may obtain utility from the resource, not just the water rights holders.** The full implications of water allocation decisions can be analyzed by evaluating the impact of the allocation on each stakeholder group. Although quantifying externalities to all stakeholders and measuring economic spillovers is an enormous task, calculating the full value of water facilitates analysis of the potential impact of water transfers. An estimate of the full value of water in agriculture will inform water allocation policy decisions to maximize the welfare of Colorado residents.

Figure 1 below illustrates the addition of mutual-use benefits and economic spillovers to the valuation of water allocated to agriculture. Agriculture, Recreation, and Ecosystem Services have direct value to stakeholders; economic activity from spillovers represents the indirect value of these water uses.

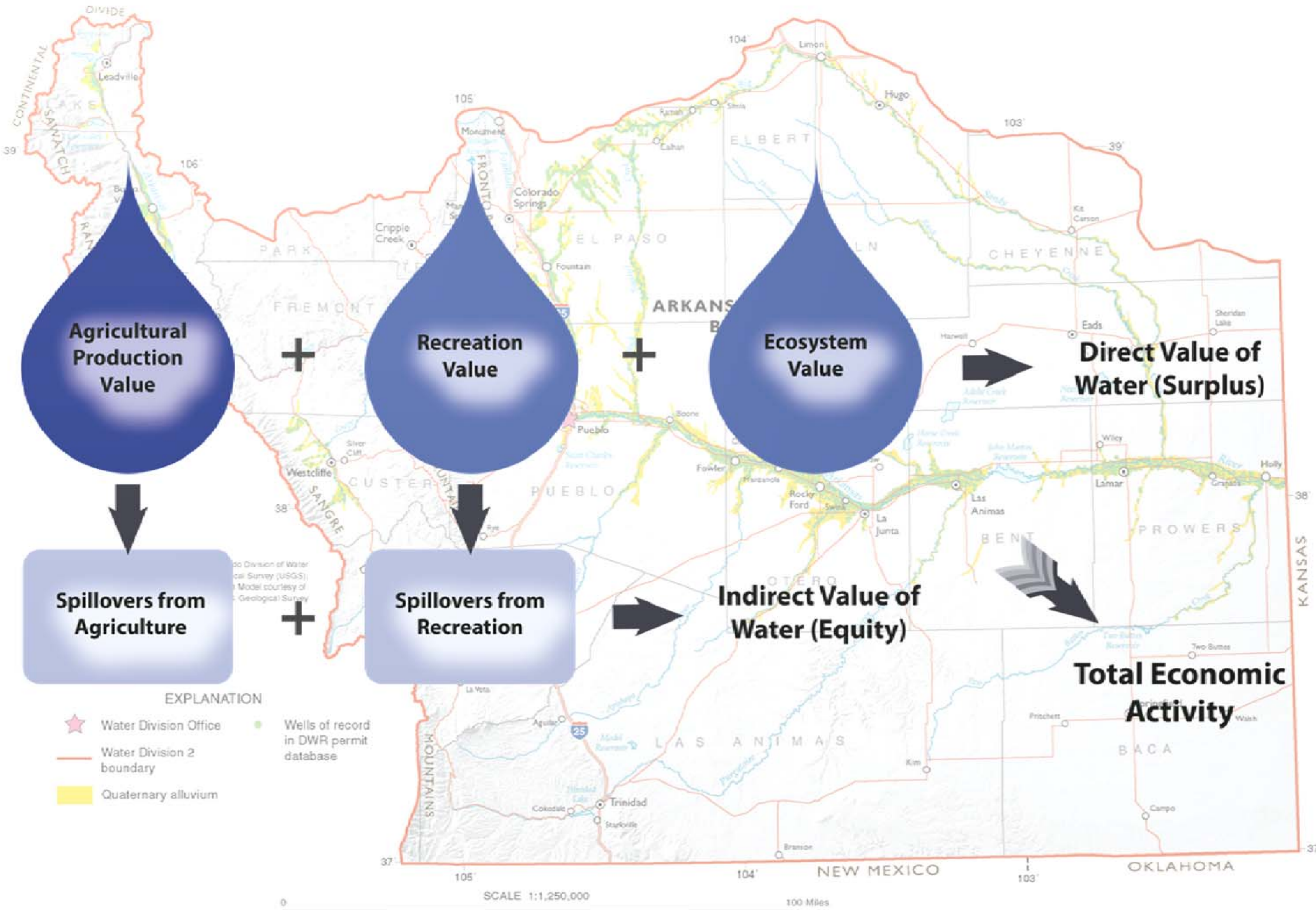

Figure 1: "Total Value Concept" of Water Used for Agricultural Water in the Arkansas River Basin

Figure 2 is an illustration of an economic model to estimate the value of water allocated to agriculture in the Arkansas Basin that includes mutual use benefits and economic spillovers. The boxes at left represent the economic sector; the center boxes show the valuation methodologies. This model calculates the value of water to agriculture and recreation, adds indirect and induced economic spillovers, and then evaluates ecosystem benefits.[3].

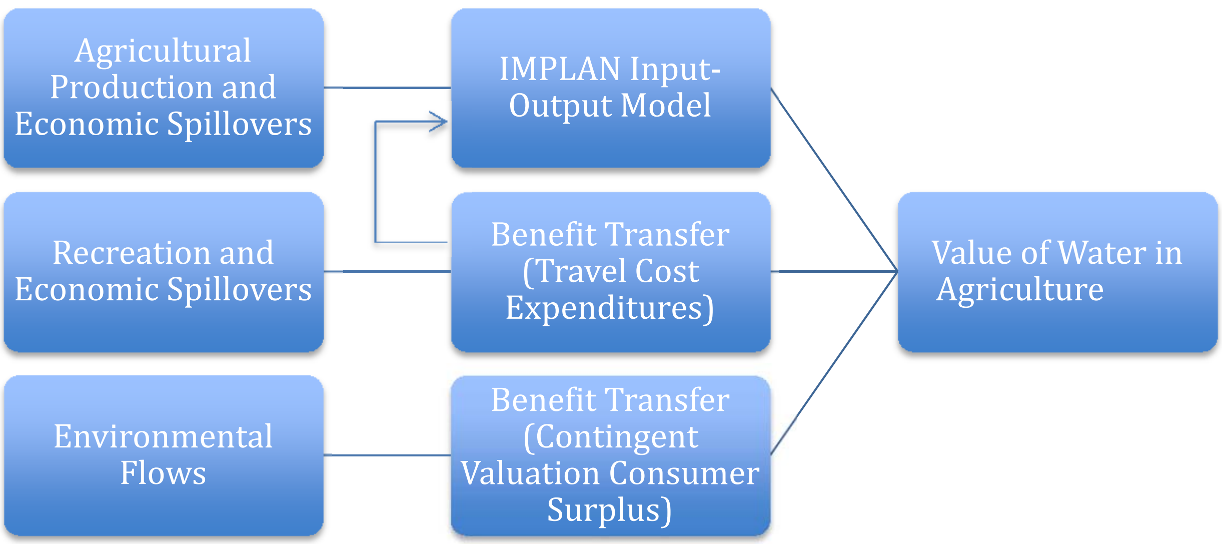

Figure 2: Diagram of model used to estimate the economic value of water used in agriculture

This model, explained in detail in chapter 4, is more comprehensive than current valuation methods because it includes mutual use benefits to recreation and ecosystems - positive externalities of water in agriculture. By combining recreation and ecosystem service values with an input-output model specified for agriculture in this region, this study calculates economic activity generated from water allocated to agriculture in the Arkansas Basin. The results (chapter 5) show that the vast majority of agriculture, and thus economic activity from agriculture, depends upon irrigation water. That said, irrigated

[3] The theoretical plausibility of indirect and induced economic activity from ecosystem services will be explored and discussed.

crop farming makes up just 1% of employment and economic activity in the Arkansas Basin. However, the great quantities of water that are allocated to agriculture (almost 90% of all water withdrawn from basin water ways) offer recreation opportunities that also generate employment and economic activity.

This research explains in detail the potential economic benefits of mutual-uses of agricultural water and explains a variety of methods that can be used to calculate the value of water. A model is developed that uses economic activity as a unit of measurement of the value of water. In chapter 5 the potential impacts from six different scenarios of reduced water availability are compared. The hope is that this model may help inform policy decisions and that this study may guide further, more rigorous research.

Many studies have evaluated the impact or potential impact of transfers from agriculture to M&I (Howe, Lazo, Weber 1990 ; Leones et al. 1997), but these efforts have focused on the impact to one sector, such as rafting, fishing, or agriculture. Howe & Goemans (2003) and Thorvaldson & Pritchett (2006) estimated losses to economic activity in the Lower Arkansas Basin related to water transfers from agriculture to M&I, but neither considered mutual use benefits. This study contributes to prior water valuation efforts by including mutual-use benefits enjoyed by stakeholders throughout the basin.

This study does not attempt to estimate the value of water to industrial and municipal uses because it is beyond the scope of our research. However, because many studies have shown that the marginal value of water to M&I is vastly greater than the marginal value to agricultural production (Young, 1983; Vaux & Howitt, 1984; Howe & Goemans, 2003), further research is strongly recommend to explore the potential benefits provided by a reallocation of water to municipal and industrial uses.

In chapter 2, I describe the geography of the Arkansas River Basin and the role water plays in the economy of the basin and the rest of Colorado. I also identify metrics for the value of water that are relevant to four perspectives: Arkansas Basin ag producers, the full Arkansas River Basin, the Front Range, and the State of Colorado. Through a review of literature in chapter 3, I describe and evaluate different methods for measuring the value of water to agriculture, recreation, and ecosystems and then compare and contrast current water valuation methods in a simple matrix. Chapter 4 describes in detail the model illustrated in diagram 2. Results from this model are presented in chapter 5, including six hypothetical scenarios of reduced irrigated acreage and recreation visitation. Lastly, I propose ways that the value of water estimates may be improved using more complex modeling techniques and original data collection. But first, this study needs framed in the context of a fundamental problem: water scarcity.

Chapter 2: Framing the Problem

This chapter explains the complexity of water valuation, describes the research location, the importance of hydrogreography and possible diversion scenarios, and gives an overview of the role of water in the economy of Colorado and the Arkansas Basin. The chapter sets the scene for the research problem introduced in chapter 1, that is, what is the value of water used in agriculture in the Arkansas Basin, including mutual-use benefits and economic spillovers, and how can those values be measured? The chapter concludes with a discussion of the different perspectives from which economic activity in the Arkansas River Basin can be evaluated and the units of measurement appropriate to each perspective.

The Complexity of Water Valuation

Here is what we know:

1) The earth has a limited amount of fresh water.
2) The global water cycle is an eternally sustainable process of water movement.
3) Humans use a lot of fresh water in industry, agriculture, home, and recreation.
4) Many ecosystems are dependent upon regular flows of fresh water.

We cannot live without water, but fortunately, most human uses of water do not permanently damage water quality or remove water from the water cycle[4]. Unlike non-renewable resources such as coal and oil, sustainable use of water resources is possible. Water is a scarce resource in the economic sense that if it were free and openly accessible to everyone, there would not be enough to go around. Herein lies our great obstacle: We want water to be abundantly available to everyone, but there is neither enough fresh water

[4] Some may argue that human-induced climate change may alter the water cycle to deleterious effects. Generally, floods and droughts are regional aberrations not variation in the overall supply of fresh water.

nor sufficient conveyance systems and allocation institutions in place to make that possible. Determining how to allocate scarce resources is a fundamental objective of economics. Although this thesis does not investigate allocation mechanisms specifically, **determining the value of different water uses is a first step towards efficient water allocation.**

Economists tend to advocate that markets, under the right conditions, allocate scarce resources efficiently. Markets are *efficient* if they provide goods and services to society using fewer resources than other institutions. In theory, markets connect sellers (supply) with buyers (demand) and market prices converge to represent value to producers and consumers. But, relative to markets for other important commodities such as oil and coffee, water markets are poorly developed. Many writers have suggested that water markets have been slow to develop because individuals resist commoditization of a basic human necessity[5]. Others contend that water markets work poorly because of water's unique physical properties (Young, 1983). Water is heavy and bulky, making it difficult to transport and store; the complex movement of water makes it difficult to track and measure, so property rights for water can be difficult to enforce.

Despite these unique properties, markets for water rights do exist, and the prices of these water rights transactions can represent the value of water. However, the vast and varied ways in which water is used and the public (non-excludable) nature of many water uses means that markets may not represent the value of water to all users. Concerns about

[5] While market-based allocation and distribution is widely accepted for gasoline and other basic goods, commoditization of water has met fierce resistance and, in some cases, even riots, such as the privatization of municipal water supply in Cochabamba, Bolivia in 2005.

increased water transfers in a market that does not include these third-party effects has motivated this research.

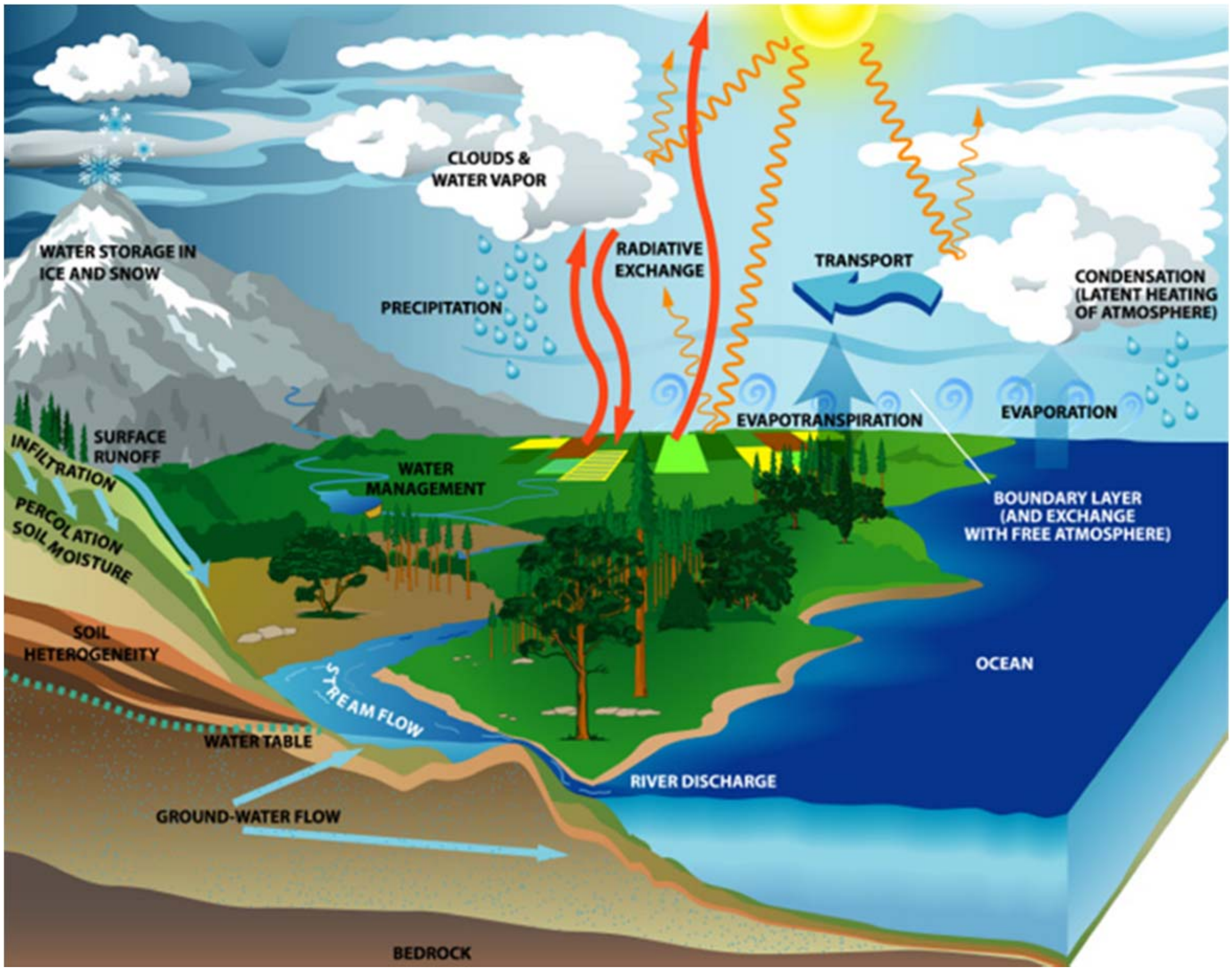

Figure 3: The Hydrological Cycle (Tutor Vista, 2010)

The hydrological cycle diagram above reminds us of water's many paths, properties, and services. Water's diverse uses and variable characteristics complicate valuation. Water is valuable to humans in obvious ways for drinking, bathing, and growing crops. It also benefits humans indirectly by supporting ecosystems upon which we depend, and by supporting a variety of recreation opportunities. These ecosystem and recreation benefits are often *public goods*; they are non-excludable and non-rivalrous in consumption (Young, 2005).

Some water uses may be complementary, while others may be competitive. For example, agricultural water conveyance and storage is often open-air and un-confined, supporting ecosystems that mimic natural lakes, streams, and wetlands. However, water consumed by growing crops (i.e. evaporated and evapotranspirated) is not available to downstream users. This study identifies water uses that are complementary to agriculture and attempts to measure these *mutual-use benefits*.

Capturing hydrogeography and competing or mutual uses is referred to as the *value-flow concept*. The value of water at a point along the river is a sum of its values at that location, plus the value of all subsequent uses downstream from return flows (Seyam & Hoekstra, 2000). How each use impacts the path that water takes, and thus opportunities for other uses, is fundamentally important to the value-flow concept. After water is withdrawn from its source, some of it will return to the watershed and some will be lost to evaporation and infiltration, thereby permanently decreasing stream flow. Water that does not return to the water system from which it was withdrawn is deemed *consumptive use* (Young, 2005). The ratio of water withdrawn to water consumed differs by use. According to a 2010 study by the U.S. Geological Survey, agriculture consumes about 55% of water withdrawn for irrigation; household water uses consume about 10% of water withdrawn (Ivanhenko & Flynn, 2010), the remaining 90% returns at some point to the watershed. The degree to which a water use returns water to the basin downstream and the timing of such returns are important factors in determining the system-wide effect of each user's diversion.

The value-flow concept suggests analyzing the path water takes from the point of origin, to the point of diversion, and then to the point of consumption or return flow from each user. Therefore, the location of water users relative to each other is critically important to valuation of water in any specific allocation scenario. Lastly, the location upstream or downstream of water uses is also important because the expense of moving water against gravity is high relative to its per-unit value. The geography of the Arkansas River Basin and the location of different types of water users relative to each other are described in the next section.

Water can also serve to dilute and transport pollutants. Agricultural runoff causes soil erosion and may pollute waterways with silt, chemicals and excessive nutrients. Water uses that negatively affect water quality may decrease its downstream value by decreasing crop productivity or increasing water treatments costs for other uses (Young, 2005). Consumptive use and degraded water quality are negative externalities of many water uses. Although this study does not attempt to measure negative externalities, consumptive use and water quality will be discussed throughout this analysis.

The Arkansas River Basin

The Arkansas River is part of the Mississippi River drainage that funnels all water east of the Great Continental Divide and west of the Eastern Continental Divide into the Gulf of Mexico. The headwaters of the “Ark” are near Leadville, Colorado at the Turquoise Reservoir. A 9-kilometer underground canal brings water to this reservoir through the Rocky Mountains from the Fryingpan River, part of the Colorado River Basin on the western side of the Great Continental Divide. An average 80,000 acre-feet of water is delivered to the Arkansas headwaters each year via the “Fry-Ark Project” in order to augment water available to the Front Range (Bureau of Reclamation, 2013). Snowpack in the Collegiate Peaks southwest of Leadville feeds the river before it passes through Salida and the Royal Gorge, the most popular whitewater rafting site in Colorado. The Arkansas River passes through Canon City just below the Royal Gorge, slowing and widening before filling the Pueblo Reservoir, six miles upstream from the growing city of Pueblo. The Southeast Colorado Water Conservancy District and the Bureau of Reclamation work together to manage flows out of the reservoir, into the plains of southeastern Colorado where most of the basin's agricultural production takes place.

The geography of the Arkansas River is very important to the political economy of water usage decisions. Although some ranching and small-acreage agriculture takes place up-river around Buena Vista and Salida, the vast majority of irrigated cropping in the Ark watershed is downstream of the Pueblo Reservoir in Crowley, Otero, Bent, and Prowers counties. The densest and most economically valuable recreation activities, rafting, kayaking, and fly-fishing, occur upstream from the Pueblo Reservoir between Buena Vista and Canon City, which is arguably also the most environmentally sensitive area. Lastly, large front-range municipalities like Aurora and Colorado Springs, the most likely recipients of future water rights transfers, may divert water upstream from the Pueblo Reservoir, possibly as far upstream as the river's headwaters at the Turquoise or Twin Lakes reservoirs. **To be clear, water diverted nearer to Leadville would never flow through the Arkansas Valley and the Royal Gorge as it currently must to supply downstream agricultural water rights holders.** However, if water were diverted from the Pueblo Reservoir or below, upstream fishing and rafting activities may not be affected. Still, the timing of water releases from the upper reservoirs is important to recreational users. Conflicts have transpired between rafting groups, who want higher flows (at least 700 cfs) to extend into August, and fisherman, who argue that higher flows and greater rafting traffic hurts fish growth and reproduction and makes fish more difficult to catch (Naeser & Smith, 1995).

Agriculture is the primary water use downstream (southeast) of the Pueblo Reservoir, although the meandering river and wetlands created by ag diversions offer habitat for birds and fish and therefore recreation opportunities for hunters and fisherman. In particular, the John Martin Reservoir near Hasty, Colorado offers recreation opportunities to thousands of boaters and fisherman. Reservoir levels and the timing of instream flows may be affected if water is diverted to uses other than agriculture. Wetlands created by agricultural diversions may be dried up completely. Conversely, other uses may consume less water. By slowing and spreading the river's water, ag diversions cause a greater amount of water to be lost to evaporation than if the water was left instream (Gates, conversation 3/13).

Although water rights can be sold and leased, Colorado water law dictates that water rights owners can only transfer their historic *consumptive* use, as determined through legal adjudication (CAWA, 2009). A water right holder may not transfer water rights or change water use practices in a way that alters historic return flows in volume, timing, or location and/or impacts senior water rights holders downstream. In effect, this means that only a small proportion of water withdrawn by current water rights owners can be transferred to other uses. The exception to this is water rights that are specific to Fry-Ark Project water. Water from this inter-basin transfer, deemed *imported* water, may be used to extinction; historic return flows are inconsequential to transfers of Fry-Ark water rights. Transfers of imported water or consumptive use water could, therefore, change the volume and timing of instream flows.

To summarize, the majority of Arkansas Basin water rights are held by downstream stakeholders (farmers), permitting a variety of non-consumptive uses upstream. This scenario makes for an appropriate application of the value-flow concept. Storage and transportation of agricultural water facilitates recreation and ecosystem uses; the value of water in the basin is a sum of the values of these mutual uses.

The Role of Water in the Arkansas Basin Economy

Water is indirectly involved in most any economic activity; it is a direct input to a few of Colorado's key industries, including farming, ranching, mining, manufacturing, and thermoelectricity. The table below gives an overview of the Colorado economy, by sector (in descending order of employment). This table presents the percent of employment, income, and GDP that each sector represents in the Colorado economy. This data, from the U.S. Department of Economic Analysis, is a snapshot of the Colorado economy in 2011. Jobs, income, and GDP that are tied to water recreation activities and ecosystem services are spread throughout the economy in a variety of sectors, including retail, accommodation, recreation, and government.

Table 1: Colorado Employment, Income, and GDP by Industry

	Sector	Percent of Colorado State Total Employment	Income	GDP
1	Government and government enterprises	14.21%	17.66%	12.85%
	Federal, civilian	1.72%	3.49%	N/A
	Military	1.75%	3.08%	N/A
	State and local	10.74%	11.09%	N/A
2	Retail trade	9.48%	5.55%	5.73%
3	Health care and social assistance	9.03%	8.84%	6.30%
4	Professional, scientific, and technical services	8.79%	11.89%	9.71%
5	Accommodation and food services	7.57%	3.39%	3.32%
6	Finance and insurance	6.22%	6.94%	6.62%
7	Administrative and waste management services	6.03%	4.00%	3.14%
8	Real estate and rental and leasing	5.71%	2.81%	11.76%
9	Construction	5.69%	5.70%	3.58%
10	Other services, except public administration	4.92%	3.63%	2.50%
11	Manufacturing	4.46%	6.23%	7.79%
12	Wholesale trade	3.23%	5.02%	5.20%
13	Arts, entertainment, and recreation	2.76%	1.29%	1.19%
14	Information	2.63%	6.01%	8.57%
15	Transportation and warehousing	2.51%	2.71%	2.48%
16	Educational services	1.94%	1.09%	0.75%
17	Mining	1.75%	3.04%	4.14%
18	Farm	1.39%	0.73%	0.97%
19	Management of companies and enterprises	1.04%	2.60%	2.17%
20	Utilities	0.27%	0.71%	1.23%

(U.S. Bureau of Economic Analysis, 2011)

These statistics are heavily skewed by the Denver Metro area, which contains half of the entire population of the state. This study evaluates 17 Colorado counties, listed in table 2 below. Counties in yellow are considered Upper Arkansas River Basin and counties in green are considered Lower Arkansas River Basin. The growing cities of Pueblo and Colorado Springs house many government jobs; the military is the single largest employer in the area. Farming and ranching make up a slightly larger proportion of employment in the Arkansas Basin than the state of Colorado overall (1.89% versus 1.39%).

Table 2: Counties in the Arkansas River Basin, Colorado

Arkansas Basin Counties				
Upper Basin	Chaffee Custer Fremont Lake Teller El Paso	Lower Basin	Baca Bent Cheyenne Crowley Huerfano Kiowa	Las Animas Lincoln Otero Prowers Pueblo

Table 3 provides an overview of employment and output in the Arkansas Basin. If all agricultural sectors are aggregated, agriculture and animal husbandry is the ninth largest economic sector (by employment) in the Arkansas Basin, accounting for 1.89% of employment within the Arkansas Basin (MIG Inc., 2011).

Table 3: Arkansas Basin's Top Ten Industries, by Employment

Sector #	Description	Employment	Output
440	Federal Government* (military)	44,059	$8,057,465,000
413	Food services and drinking places	34,288	$1,859,604,000
438	State & local govt*, Education	32,804	$1,741,668,000
437	State & local govt*, Non-education	28,395	$1,734,837,000
360	Real estate establishments	20,968	$2,948,849,000
394	Offices of physicians, dentists, and other health pract.	16,485	$1,752,376,000
329	Retail Stores - General merchandise	10,873	$635,245,800
331	Retail Nonstores - Direct and electronic sales	10,151	$615,881,300
1-14	All agriculture and animal husbandry	10,036	$1,514,920,221
36	Construction, other new nonresidential structures	9,640	$955,054,800
	Total of Top Ten	**217,699**	**21,815,901,121**

(*Employment and payroll only; MIG Inc. 2011)

On the following page, table 4 shows the amount of water withdrawn for different uses in Colorado in 2005. According to this U.S. Geological Survey data, 90% of all water withdrawals in Colorado are diverted for farming and ranching (Ivahnenko and Flynn, 2010) although those sectors represent only 1.39% of state employment. Municipal and industrial use accounts for another 7.5% of ground and surface water withdrawals, with the remainder withdrawn for use in mining and thermoelectric power generation. Between 1985 and 2005, water withdrawals increased in thermoelectric power and industrial industries, 12.2% and 18.4%, respectively, and decreased 45.6% for livestock and 76.5% for mining (Ivahnenko & Flynn, 2010). Although irrigated acres decreased about 10% during the twenty years, irrigation withdrawals decreased less than 1%, indicating that the least intensively farmed acres have been abandoned or that irrigation on remaining acreage has intensified. Surfacewater withdrawals account for 81.3% of all water withdrawals.

Table 4: Annual Water Withdrawals in Colorado in 2005 by Use

Sector	Surfacewater withdrawals (Mil gal/day)	Percent of Surfacewater Withdrawals	Total Withdrawals (Mil gal/day)	Percent of Total
Aquaculture	71.16	0.64%	87.99	0.65%
Public Supply total	762.31	6.86%	864.17	6.34%
Domestic self-supply & public supply		0.00%	563.94	4.14%
Domestic from public supply		0.00%	529.51	3.89%
Domestic total self-supplied	0	0.00%	34.43	0.25%
Industrial	138.83	1.25%	142.44	1.05%
Irrigation, Crop	9,970.68	89.69%	12,280.35	90.11%
Irrigation, Golf Courses	32.89	0.30%	40.64	0.30%
Livestock	22.11	0.20%	33.06	0.24%
Mining	1.63	0.01%	21.42	0.16%
Mining, fresh	1.24	0.01%	6.44	0.05%
Mining, saline	0.39	0.00%	14.98	0.11%
Thermoelectric (38,174.4 gigawatt hrs)	116.71	1.05%	123.21	0.90%
TOTALS	11,116.32	100.00%	13,627.71	100.00%

(U.S. Geological Survey, Ivanhenko and Flynn, 2010)

Water withdrawals in the Arkansas River Basin (1,827.58 Mgd) account for 13.5% of all withdrawals in Colorado (13,581.22 Mgd). Within the Arkansas Basin, crop irrigation accounts for 87.01% of all withdrawals.

Table 5: Water Withdraws by Economic Sector

	Units	Percent of Ark Basin	Percent of Colorado
Population	874,260		18.74%
Crop Irrigation	1,590.25	87.01%	12.91%
Livestock	5.93	0.32%	17.94%
Public Supply	106.73	5.84%	12.35%
Domestic (self supply)	7.01	0.38%	20.36%
Industrial	73.79	4.04%	51.80%
Mining	2.79	0.15%	13.03%
Thermoelectric	36.90	2.02%	29.95%
Total Withdrawals	1,827.58	99.77%	13.46%

(U.S. Geological Survey, Ivahnenko & Flynn, 2010)

Water withdrawals do not represent the total water imbedded in a final product. For example, livestock require feed in the form of hay or grain; the water used directly in the production of feed grain is used indirectly in the production of livestock. Similarly, it should be noted that water withdraws do not represent water consumption because, as mentioned above, much water withdrawn from lakes, rivers, and aquifers returns to the same or nearby ground or surface water sources. Consumptive use is estimated to be 55.1% of irrigation withdrawals, 100% for livestock, 84% for thermoelectric cooling and 10% for domestic water (Ivahnenko & Flynn, 2010).

Recreation and tourism, industries vital to the Arkansas Basin economy, are dependent upon water resources. Many "non-consumptive" activities, such as boating and fishing, depend to various degrees upon reliable water availability despite the fact that they do not withdraw water from lakes, rivers, and man-made reservoirs. Although they do not appear in tables 4 and 5 above, the economic contribution from these activities should not be overlooked when evaluating the value of water and efficiency of water allocation.

This section illustrates that the vast majority of water withdrawn from lakes, rivers and reservoirs in Colorado is used for agriculture. In the Arkansas River Basin a greater proportion of water withdrawn is put to industrial and thermoelectric uses than in the rest of the state, but agriculture remains the largest user of water in the region by a wide margin. Because the majority of Colorado water use rights are possessed by farmers and ranchers, other users turn to agriculture to meet growing demands. This phenomenon has motivated this research. The next section will evaluate how the value of water can be defined and measured differently by different users.

Value and Standing

"Value" is a broad term that can encompass economic activity, economic impacts, and social benefits. In order to provide meaningful comparison of the value of water to different users, it is important to define more specifically what is meant by the term "value" and explain more clearly what is being measured in this study. Watson et al. (2007) provide an explanation of commonly misused economic terms, including benefit, impact, and economic activity. Their case is normative, not etymological, but offers a clear set of working definitions, listed in table 6 below.

Table 6: Definitions of common economic terms that can represent "value"

Term	Definition
Economic Activity	Dollars spent within region that are attributable to a given industry, event, or policy.
Economic Activity Analysis	An analysis that tracks the flow of dollars spent within a region (market values). Both economic impact and economic contribution analysis are types of economic activity analysis.
Economic Contribution	The gross change in economic activity associated with an industry, event, or policy in an existing regional economy.
Economic Impact	The net changes in new economic activity associated with an industry, event, or policy in an existing regional economy.
Economic Benefit	A net increase in total social welfare. Economic benefits include both market and nonmarket values.
Cost-Benefit Analysis	An economic efficiency analysis that measures net changes or levels in social welfare associated with an industry, event, or policy. This type of analysis includes both market and non-market values and accounts for opportunity costs.
Input-Output Model	A specific methodological framework that characterizes the financial linkages in a regional economy between industries, households, and institutions. Input-Output only measures economic activity and does not include any non-market values.

(Watson et al. 2007)

The terms *economic activity, economic contributions, economic impact,* and *economic benefit* each refer to a type of economic value. Different valuation methods measure different types of value. A distinction should be made between economic activity (dollars actually spent), and surplus, a true metric of social welfare. In order to measure total social benefit (utility or surplus), researchers must reveal a complete willingness-to-pay schedule (demand curve) for each stakeholder group and water use. To be clear, this study is not a cost-benefit analysis or a welfare analysis; it does not provide sufficient information to determine whether or not water transfers from agriculture offer a net benefit to Colorado.

The model presented in chapter 4 represents value as a snapshot of economic activity that occurs because of water allocated to agriculture, it does not estimate consumer or producer surplus. However, calculating value from a snapshot of how water is being used in the basin today will yield a baseline against which other allocation scenarios can be measured.

Different measurements of economic activity are important to different people. Here is an example of four different perspectives or "standings" that may be relevant to the Arkansas Basin: the perspective of the agricultural producer, the counties included in the Arkansas River Basin watershed, the Front Range[6] of Colorado, and a state-wide perspective. The metrics of value relevant to each sector as seen from those four perspectives are described in table 7, below. Value to agricultural producers would be considered private value; value to the Arkansas River Basin, Front Range, and Colorado includes private and public values. Chapter 3 will describe different methods for measuring the metrics of value listed in this table.

[6] Counties along the eastern slope of the Rocky Mountains where most of Colorado's population is concentrated are considered the Front Range.

Table 7: Metrics of Economic Value to Different Sectors in the Arkansas River Basin

Metrics of Economic Value in the Arkansas Basin		Stakeholder			
		Agricultural Producers	**Arkansas Basin**	**Front Range**	**Colorado**
Sector	**Agricultural Production**	Net farm income; Property values	Economic activity from agriculture; Employment	Ag sector output (GDP), Productivity, Regional integration (Multiplier)	Ag sector output (GDP), Productivity, Regional integration (Multiplier)
	Recreation	Property values	Economic activity from recreation; Employment	Recreation industry output; Consumer surplus (WTP)	Recreation expenditures from visitors; Consumer surplus (WTP)
	Environment	Existence and bequest value; Ecosystem services	Ecosystem services; Economic activity; Existence and bequest value	Ecosystem services; Consumer surplus; Ecology/Biodiversity	Ecosystem services; Consumer surplus; Ecology/Biodiversity
	Spillover Effects from Ag and Rec	Multiplier effect of ag and rec on local community	Multiplier effects of ag and rec industries; Leakages	Regional economic integration and multiplier effects	State economic integration and multiplier effects

Chapter 3: Theory and Literature

An Introduction to Determining the Value of Water

The United Nations stated in 1992 that *"Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource."* The 1992 "Dublin Statement" goes on to say that*, "Managing water as an economic good is an important way of achieving efficient and equitable use…"*. In order to treat a resource as an economic good the value[7] of the resource must be determined and converted into easily comparable units – i.e. dollars. A price is a monetization of value. Simply put, water can have a high economic value because it is scarce and can be put to many uses that satisfy people's needs. Because an individual's willingness to pay for water rarely approaches or exceeds the utility they obtain from it, the economic benefits (value) of water typically exceed the price (Ward & Michelesen, 2002). Therefore prices do not always communicate the full value of a good.

This chapter contains an extensive review of different water valuation methods. This review is the initial step towards developing a comprehensive empirical model to estimate the value of water in agriculture, including mutual use benefits to recreation and ecosystems. A variety of terms are used to distinguish between types of water value monetization: market priced versus non-market values, inductive versus deductive methods, and revealed versus stated preferences. Market priced sectors include anywhere water or access to water is paid for explicitly or where water is an input to a priced output. Non-market sectors refer to areas or activities where a direct fee is not charged for water

[7] As described in chapter 2, "value" is a general term used to encompass economic activity, impact, contribution, or societal benefits.

even though a service or benefit is provided. The total value of water in agriculture in the Arkansas River Basin includes both market and non-market sectors. This may require deductive and inductive methods to measure stated or revealed preferences. Deductive methods derive value via a hypothetical mathematical representation of economic activities. For example, production functions that include water as a production input permit deduction of the marginal value of a unit of water. Inductive methods evaluate actual transaction records (sale and lease) to determine individuals' willingness to pay for a resource or input in a given sector and/or region. Inductive methods also include "hedonic pricing" that determines the value of water by comparing rent or sale prices for land with and without water. Both of these examples reveal preferences that represent, at least theoretically, the value of water to the purchaser.

One complication to analyzing water value is the fact that theoretical valuation methodologies (deductive) often produce vastly different estimates than actual values revealed through real-world decisions and transactions (inductive) (Young, 2005). Generally, the value of water observed in water rights and land value markets is considerably lower than the value estimated by traditional water-crop production functions. Applied economists tend to believe that generalizations based on observations of actual behavior – inductive methods – are more feasible and reliable than the results of deductive methods (Young, 2005). Lastly, where there are no markets or financial transactions of any sort, analysts can simple ask individuals what a resource is worth. Stated preference valuation methodologies suffer fierce criticism from some economists and technocrats, but in many instances they offer the only viable way to estimate the value or benefit of a resource. Market priced goods are often easier for economists to value empirically. Also, shadow priced and un-priced sectors are less tangible and more esoteric to policy makers and the general public. Thus, "value of water" estimates in economics literature tend to focus on market price valuation methods. Non-market goods and services, however, can offer significant social benefits that must be quantified in order to determine most appropriate and efficient policies. The inclusion of shadow price sectors is a key feature of this research.

In this chapter, valuation methods for a variety of water uses are explained, compared and contrasted. A matrix is provided at the end of the chapter that describes water value estimates from different regions using different methodologies. In some instances, values for different activities may be simply added together, but where units of measurement are not equivalent or where there is risk of double-counting values, additive methods may be inaccurate. All dollar amounts have been converted to 2012 dollar equivalents unless otherwise noted.

Market-Based Values versus Non-Market Water Values

This section explains the differences between market-based and non-market values, both of which must be included in order to estimate the full value of a resource. Water is a scarce resource for which, at least theoretically, a competitive market can be developed. Where a market has been developed, a variety of methods have been used to estimate a monetary value for water (Young, 2005). When a market functions efficiently, water prices can represent valid and accurate measures of water's economic value (Ward & Michelsen, 2002). Griffin & Perry (1985) used regression analysis to evaluate water transactions along irrigation canals in Texas. They found that volumetric rates exert a strong negative influence on water consumption, but did not estimate the per-unit value of water.

Econometric analyses of water prices are rare mostly because truly functional water markets are rare (Griffin & Perry, 1985). This type of market-based valuation presumes the market has achieved equilibrium, meaning that sufficient information has been available and sufficient transactions have taken place for buyers and sellers to reveal a continuous demand curve for water rights (Easter et al., 1998). Lastly, the validity of market-based values depends upon how well the market is representing all stakeholders' interests – their willingness-to-pay. Some stakeholders, such as recreationists and ecosystems, depend upon existing water storage and river flows but generally do not own water rights. It is unlikely that water rights transactions could represent their interests.

In contrast to market-based valuation, non-market valuation attempts to estimate the economic value, in dollar terms, that members of society receive from uses of water resources which are not allocated via a competitive market (Loomis, 1997). Non-market valuation methodologies, such as travel cost analysis, can be used to measure the value of in-stream flows to society at large (Ward, 1986). "*Nonmarket economic valuation can be defined as the analysis of actual and hypothetical human behavior to derive estimates of the economic value (called accounting or shadow prices) of goods and services in situations where market prices are absent or distorted* (Young, 2005)." Whereas market-based deductive and inductive valuation methods measure the potential revenue generated from the resource, non-market valuation methods measure a willingness-to-pay in order to use the resource or a change in welfare from exclusion from the resource (willingness-to-accept). The absence of markets for many water-related goods and services requires that economists use these alternative methods to account for the value of public water allocation and other policy choices. Non-market valuation methods such at travel cost analysis and contingent valuation are useful tools for determining the economic value of water to ecosystems and recreation activities. These methods are discussed in the recreation and ecosystem value sections below.

One simple and compelling way to measure the value of a resource is by calculating its net factor income (NFI). The net factor income estimates the relationship between the size of the natural resource and all economic activity related to it (Woodward & Wui, 2000). In its simplest form, this method would divide the gross economic output of the region (GDP) by the total units of water (i.e. acre feet) withdrawn or consumed. The benefits of this method, aside from being exceedingly simply, is that it captures all economic activity associated with all industries, recreation, and ecosystem services. The major drawback is that there is no way of telling how much of that economic activity is directly or even indirectly related to water. Also, this method only measures economic activity that has already occurred, it does not measure willingness-to-pay and cannot estimate consumer surplus.

The net factor income method is used by Summit Economics in their 2009 report to the Front Range Water Council (Summit, 2009). They estimated that sales of all goods and services totaled $145,964 per acre-foot of water withdrawn in the Front Range, $3,688/AF in Eastern Colorado, and $13,602/AF in Central Colorado. Since most of this economic activity has very little to do with water, sales of agricultural good and services per acre-foot is much more interesting ($1,130 per acre-foot of water withdrawn in the Front Range, $1,014/AF in Eastern Colorado, and $333/AF in Central Colorado). The group did not estimate sales per acre-foot of water used in recreation or ecosystems. They note that a survey would be required to isolate recreation expenses related to water (Summit, 2009).

The rest of this chapter will discuss more robust and specific methods for calculating the value of water.

Value of Irrigation to Agriculture

The simplest way to calculate the direct value of water to agriculture is to evaluate the prices agricultural producers pay for water. But, since market prices are rarely available for irrigation water, indirect approaches must be used to estimate value (Ward & Michelsen, 2002). Where water is used as an input in a production process, such as in agriculture, an analyst can compute the value of water as the contribution water makes to output from that industry. For irrigated agriculture, subtracting all non-water production costs from gross crop output yields a residual value (net revenue) that can be attributed to water (Colby, 1989). This residual method indicates the maximum a farmer would pay for water (the break-even cost of water). By dividing the net revenue by the quantity of water used, the average value product of water can be derived (Colby, 1989). Residual value models can be built upon production output data from the region of study, or from scientific field trials that can be scaled up to the study area. With either method, values are usually imputed from annual or average-annual crop output and therefore represent the value of water in agriculture for one year.

Although mathematically simple, a few shortcomings arise with this method. In order for the residual method to prove accurate, all non-water production inputs must be competitively priced so that their marginal contribution to output value is equal to their price (Young & Gray, 1985). If there are other inputs that are not competitively priced, one cannot assume that the residual profit is attributable entirely to water. Owned inputs (non-priced capital endowments) are particularly troubling for residual imputation

(Young, 2005). Examples of owned inputs that contribute to output include land quality, location, and management. Assigning prices to owned inputs and subtracting these costs[8] from net revenue can improve the accuracy of residual imputation, particularly when making long-term value estimates.

The residual method finds a point estimate value of water, it does not evaluate changes in production methods or technology. Residual imputation can be made more sophisticated to represent variability in ag production using Positive Mathematical Programing (PMP). Positive Mathematical Programing is a non-linear, self-calibrating method to model agricultural production and resource use (Howitt, 1995). PMP assumes farmers experienced a profit-maximizing equilibrium in some baseline year. Coefficients to a non-linear production function are estimated from actual (positive) production activities in that year. Modern algorithms and microcomputers have facilitated solving the complex quadratic production problems that arise in PMP (Howitt, 1995). These models have been used in agricultural economics because their structure can easily suit economic production theory: they represent (variable) agricultural production conditions and allow for analysis of the adjustments due to technical, economic and institutional changes (Fragoso et al., 2008). While linear programming assumes constant returns to scale and thus no profit-maximizing level of production, PMP can account for farmers' responses to heterogeneous land quality and crop prices. Because of their non-linear representation of resource inputs, Positive Mathematical Programing approaches have been used in economic analysis investigating farmers' responses to water policies (Cortignani & Severini, 2008).

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[8] Owned inputs, while not priced, can be considered opportunity costs because they could be employed in other means of economic productivity not associated with ag production or water. See Young, 2005.

Therefore, because PMP methods represent dynamic agricultural production behavior, they can be used to estimate a realistic demand curve for water.

PMP models maximize an objective (profit, usually) subject to certain constraints, such as the availability of water. A residual value can be computed from a PMP production function much the same as it can be computed from basic production function. A PMP production function, however, may represent many different activities or production technologies and calculates a theoretical optimal allocation of the constrained resource to these different activities. Calculating a residual value of water from a PMP model is ostensibly more accurate than basic residual methods and is advantageous if the goal is to evaluate a variety of alternative water-using production activities. It is, however, much more complicated to calibrate and requires detailed data about a multitude of possible water uses.

Data from an input/output model can also be used to calculate the residual value of water. Using input/output data has the same risks of unpriced and owned inputs, but offers the advantage of capturing economic activity that spills over into supporting industries. This and other methods to measure the spillover values of water are discussed in detail later.

Regardless of the method used to derive a residual value of water, local data should be used. Conradie and Hoag (2004) review models that have been used to estimate the value of irrigation water and conclude that regional and temporal variation in cropping methods and productivity means that models must be built uniquely to each region and time period. Specifically, they contend that accurate estimates require use of a comprehensive set of enterprise budgets.

Hedonic Property Value Method

Another way to evaluate the value of water to agriculture is by looking at how the availability of irrigation affects property values. This is known as the hedonic valuation method. Modern hedonic valuation methods are often attributed to Rosen (1974), but the method was perfected for valuing agricultural production attributes in the late 1980's by Raymond Palmquist. Rather than treating land as a homogeneous factor of production, Palmquist derived a bid function for agricultural land that includes differential characteristics that affect the productivity potential of a given parcel (Palmquist, 1989). The bid function predicts how much a farmer would be willing to pay to use a specific parcel of land, given its unique characteristics. The amount of irrigation available to that parcel is one such characteristic.

In a hedonic bid function, the dependent variable is rent or sale prices for property – data that is readily available. Identifying the independent variables, including irrigation availability, and locating or collecting data for all relevant characteristics is the difficult part of hedonic valuation. Ready and Abdalla (2005) estimate the amenity and disamenitity impacts of proximity to agriculture using a hedonic property value model, but the authors do not attempt to draw conclusions about amenities and disamenities of irrigated versus non-irrigated agriculture. In order for the hedonic method to estimate the value of water accurately, irrigation must be a fixed characteristic of the land. If water rights can be easily traded and irrigation systems easily shifted to bring water to different locations, that is, if the water market is separate from the land market, hedonic valuation may fall apart (Crouter, 1987). Jan Crouter's 1987 results for Weld County suggested that land and water markets are not distinctly separate.

Hedonic valuation methods may offer significant advantages over agricultural production methods described above; the value estimates are much less sensitive to the vagaries of a specific year and can represent the value of a full gamut of amenities provided by irrigated agriculture, including tourist, ecosystem, and existence values. Furthermore, hedonic estimates represent the expected value of water for the foreseeable future – the capitalized value of water. However, the hedonic property method requires a lot of time and effort (Young, 2005). Detailed data for every property in the study area, or a representative sample may be difficult, expensive, and time consuming to collect. Specification and estimation of the model requires considerable econometric skills. Also, since property prices may represent aesthetic, recreation, bequest, and production attributes associated with water, it is impossible to separate out what types of water value are represented by variance in property prices. Lastly, these values will only represent private value to the seller and buyer, not public value to the region.

The valuation methods described above are intended to measure the value of water in agricultural production. To achieve a more accurate estimate of the total economic value of water in agriculture, the valuation effort must measure the economic activity that occurs as water travels to and from the agricultural user. The next two sections discuss methods to calculate the value of water to ecosystems and recreation, mutual use benefits of water in agriculture.

Value of Water to Outdoor Recreation

Popular water recreation activities, including kayaking, rafting, and fishing, are enjoyed along the rivers and streams of Colorado. Likewise, reservoir storage of agricultural water often creates recreational activities, as well as hunting and fishing habitat. These activities can represent non-consumptive uses of water allocated to agriculture that may be lost with water transfers that divert stream flow from historical patterns. Even though water used for recreation is not traded in water rights markets, it nonetheless has value to visitors, represented by recreationists' willingness to pay (Colby, 1990). Federal benefit-cost procedures used by the U.S. Army Corps of Engineers (U.S. Water Resources Council, 1983) recognize these values. Legislation adopted in the 1980s gave the Colorado Division of Water Resources the authority to appropriate water for in-stream flows and lake level maintenance (Colby, 1990). In fact, private individuals can dedicate their water rights to in-stream flow maintenance and the CWRB has responsibility for filing objections to water transfers that may impair in-stream flow rights.

If users must pay for access to water based recreation, a minimum value for the resource can be equated to that price (Gibbons, 1986). But direct markets for recreational activities, such as user fees or guided fishing or rafting trips, typically represent a small proportion of recreational uses of in-stream or in-reservoir water. The benefits of water to stakeholders who do not pay user fees, or buy water rights, or use water in economic production can be measured by non-market valuation methods. The value of in-stream flows for recreation are most frequently determined by travel cost or contingent valuation methods. These methods often require original data collection via surveys, but can be used to measure the value of in-stream flows to society at large (Ward, 1986).

Although users often do not pay explicitly for access to a water resource, they may still incur indirect costs in order to use the resource. The amount a user is willing to pay in order to enjoy a water recreation activity may be calculated by adding together market transactions related to the recreation activity such as fishing gear, boat fuel, and lodging expenses. Summing these expenditures is the first step of the travel costs method for determining the value of an outdoor recreation activity. If visitation rates and/or indirect water recreation expenditures decrease with lower in-stream flows or reservoir levels, the travel cost method can be used to deduce the value of water to recreators and estimate a demand curve for recreation water. Some of the general assumptions of this method include the fact that higher aggregate travel costs represent greater value and, for the case of water recreation, greater quantity or quality of water induces greater willingness to pay to travel to a water recreation site.

The *individual* travel cost method estimates demand for the recreation site based on the number of visits made to the site per person, per year. The *zonal* method estimates demand based on the number to trips made per year, per capita, from a specific zone (Young, 2005). In both cases, if travel costs are higher as distance from the site increases and if fewer trips are made from greater distances, an appropriate downward slopping demand curve can be revealed from visitor behavior. The individual method requires collecting travel cost data from each individual visitor. The zonal method assumes all trips from a given zone have the same cost, therefore analysts only need to collect the number of visitors and number of trips made from each zone to create a data set that can be used to estimate demand. This data may be collected by parks or recreation sites, or may be deduced from parks and recreation permit sales.

The travel cost method (TCM) has been used to estimate demand for water-based recreation activities such as rafting, kayaking, and fishing (Johnson et al., 1990; Hynes & Hanley, 2006). The Colorado Department of Wildlife (CDOW) has contracted BBC Research

& Consulting to estimate economic activity[9] from hunting, fishing, and wildlife every few years since 1988 using a simplified travel cost model (BBC, 2008). The group takes average in-state and out-of-state trip, equipment, and access fee expenditures as estimated from 2002 and 2006 U.S. Fish and Wildlife surveys and multiplies those average expenditures by user days estimated from CDOW surveys and license sales. This is a relatively crude method (one expenditure estimate is used for all Colorado visitors, to any Colorado recreation site), but it can be helpful to get an overview of how economic activity may have changed since the study was first commissioned in 1988. McKean & Taylor (2000) used the individual travel cost method to estimate willingness-to-pay and consumer surplus of fishing on Lower Snake River reservoirs. They calculated from survey data of sport fishermen that the average consumer surplus per individual for a day of fishing was about $38. The McKean & Taylor study is good example of a rigorous and contemporary travel cost study; their estimate of consumer surplus per fisherman per day is on par with other estimates of the consumer surplus value of reservoir fishing (Rosenberger, 2010).

Leones et al. (1997) show through regression analysis that visitation rates of rafters are correlated with flow levels, and the degree of correlation varies by location. Because demand for these activities varies with flow levels, the travel cost method could be used to calculate the value of greater flows or potential impact of reduced flows, although few TCM studies have done this. Estimating the relationship between flow levels and user days or correlation between flow levels and value of a user-day involves a bit of guesswork and is a challenge for the model used in this paper.

[9] BBC uses the term economic impact, but I believe they are simply estimating dollars spent on those activities, not calculating a net change in new activity. See Value and Standing in Chapter 2 for definitions of economic activity, impact, and contribution.

Another way to measure the value of a resource is to simply ask individuals what they would be willing to pay to recreate in a given location. This stated preference, as opposed to revealed preference, method is called contingent valuation. Using survey responses, contingent valuation yields individual willingness-to-pay functions (bid functions) in the absence of market data (Daubert & Young, 1981). Contingent valuation (CV) has become more and more popular over the years. It is the only valuation method that can measure the "existence" or "bequest" value of a resource, since market data is not generally available to reveal those values. CV suffers criticism mostly because it elicits hypothetical preferences to hypothetical situations, making it difficult to defend the validity of estimates. Some studies that have shown that human subjects report higher willingness-to-pay values in response to hypothetical questions than those individuals would actually pay in real life (Hausman, 2012). However, convergence across thousands of studies and comparison to revealed preferences from TCM and hedonic studies have greatly improved confidence in this method.

Daubert and Young (1981) used CV to estimate the value of in-stream flows in the Poudre River. The bid function created from survey responses measures the marginal rate of substitution between income and in-stream flow levels; an indifference curve. The aggregated maximum bids map out the total in-stream flow benefits; the first derivative is the marginal benefit function or the "Hicksian compensated demand" function. The willingness –to-pay is the Hicksian compensated surplus because the recreationists cannot adjust the in-stream flow. Daubert and Young showed that the rate of stream flow in cubic feet per second was highly significant in explaining individuals' willingness-to-pay for recreation access to the Poudre River. (The variable for "flow" in their WTP function explained 20% of fishing bid variations and 38% of white-water bid variation.) WTP for fishing access peaked at about $75/day under optimal flow conditions for fish habitat. WTP for rafting access continually increased with increased flow, albeit at a decreasing rate. Their study showed that marginal recreational values ($18-$25/AF) exceeded some marginal irrigation values in August in September, indicating that diversion to upstream agricultural reservoirs should be increased in the spring when flows were high and decreased in the fall when recreationists want more water. The authors make the point that water managers should look at balancing marginal values between irrigators and recreationists to produce the most efficient allocations.

In 1980, Walsh et al. calculated that the marginal benefit of an acre-foot of water was highest ($52/AF) on western Colorado rivers in August and September when rivers were flowing at about 35% of maximum. This was a sum of benefits to fishing, kayaking, and rafting. Walsh et al showed that including the effects of congestion at a recreation site improves contingent valuation estimates. The total benefit is reached where the cost of incremental congestion equals the benefit of incremental use, and includes the management costs of additional users. Congestion effects were not considered in the Daubert and Young study. Hanson, Hatch, and Clouts (2002) used a CV survey to determine the potential impacts of reduced reservoir levels on recreation, property, and non-use values. They found there would be "immense economic impacts" from reducing reservoir levels because of reduced visitation rates, property values, and non-user willingness-to-pay. Gibbons (1986) notes, however, that he recreational value is not just the value of the water level, but the "total site value". Gibbons points out that values tend to be higher at unique and unusual sites and near metropolitan areas. Recreation value also depends upon water quality, particularly for swimming and fishing. The value of these attributes is reflected in travel cost, contingent valuation, and hedonic property valuation methods, therefore care must be taken to control for variation in attributes when comparing different recreation sites.

Gibbons (1986) argues that the travel cost method is better than a contingent valuation because it uses actual market data, but contingent surveys are better for determining resource value in a wider range of situations. Cameron (1992) points out that TCM studies reflect preferences of current consumer behavior, but may not forecast hypothetical scenarios they way CVM studies can. She argues that the two methods can be combined to produce a "more comprehensive picture of preferences" and tie the revealed preferences of current users to the stated preferences of potential users (Cameron, 1992). Eiswerth et al. (2000) supplemented travel cost data with CV responses to determine how much water levels affect demand for trips to a lake recreation site. Using the methods together, authors estimated that visitors to Walker Lake in Nevada are willing to pay between $16 and $24 per year for each additional foot of lake water (Eiswerth et al., 2000).

Both methods estimate how much a user is willing to pay to spend a day recreating at a water site. If the methods are robust, analysts can reveal a valid demand curve and estimate the total benefit or surplus provided by the resource. This is different from the economic contribution of a water recreation site as would be determined by actual expenditures. These expenditures offer spillover or "multiplier" benefits to rural communities (Colby, 1990). Quantifying the impacts of these expenditures is difficult because they are so widely spread across economic sectors. This is discussed in more detail in "Spillover Effects". Although there has been some efforts to evaluate recreation expenditures in the Arkansas River Basin (Corona Research, 2009; Greiner & Werner, 2011), it does not appear that a true travel cost analysis or contingent valuation survey has been conducted, and therefore the literature does not offer specific estimates of the value of water recreation in the Arkansas River Basin.

Ecosystem Service Value of Water

Water allocated to agriculture is stored and transported in rivers, reservoirs, and canals, which support ecosystems that mimic natural lakes, streams, and wetlands. These ecosystems, whether natural or human induced, have value to society at large. In fact, water everywhere is an ecosystem service, as humans did not carve the river valley nor bring about the rain that did. Ecosystem services methodologies measure, broadly, "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment, 2005). These benefits include food, water, timber, leisure, spiritual benefits, etc. (Wallace, 2007) and can come in the form of direct production inputs (such as fertile soil), as indirect value from habitat for plants and animals, or as existence or option values (Goulder & Kennedy, 1997).

Ecosystem services are often un-priced inputs to economic activities, such as the contribution of natural snow to the economic activity of a ski resort. The contribution ecosystems offer to production activities may be teased out using a residual method, or in the case of habitat that draws visitors, using the travel cost method. Where ecosystem services offer direct value to economic activities, such as the provision of water, care must be taken not to double count the ecosystem's value. For example, the ecosystem service value of water to agriculture and the residual imputation value of water to agriculture are one in the same. However, water ecosystems may offer benefits external to the production activity. For example, an irrigation canal may support trees and shrubs that are habitat for bats and birds that help manage agricultural pests. In this case, the ecosystem service of the irrigation canal is the avoided cost of other forms of pest management. This avoided cost is external to the primary purpose of providing water to crops. Another example is the cost savings provided by a water intensive technology as opposed to the next cheapest alternative, such as diluting pollutants rather than using chemical or mechanical treatment. Higher stream flows dilute wastes and pollution, which decreases costs of water treatment to meet water quality standards for withdrawal and discharge water (Colby, 1990). This avoided cost method is one way to use market-based data to measure the value of an ecosystem.

Similar to avoided costs, the replacement cost method attributes a value to the natural resource by determining the cheapest alternative method of providing services equivalent to those provided by the ecosystem. For example, the value of a wetland in the treatment of wastewater might be estimated using the cost of chemical or mechanical alternatives (Woodward & Wui, 2000). The replacement cost method is generally an upper bound on the true value since the producer may choose not to actually use the alternative considered (Anderson & Rockel, 1991).

The hedonic property method described for valuing irrigation water can also be used to measure the value of water to recreation and ecosystems. Lansford and Jones (1995) estimated the recreational and aesthetic value of lake water in central Texas by comparing property values at different distances from the lake and at different water levels. Controlling for a wide variety of housing characteristics that influence property value, the authors estimated the marginal value of an acre-foot of water to lie between

$164 and $202 per acre-foot (Lansford & Jones, 1995). Again, the hedonic property value method is an inductive valuation method that calculates value to private users (homeowners); it does not calculate the use and non-use value of water to visitors or non-visitors who do not participate in the housing market.

Individuals' appreciation of water goes beyond its contribution to production activities, property values, or avoided costs. Furthermore, water bodies are often public goods: once provided, these goods can be enjoyed by many participants in a watershed. The cost of providing reservoirs or in-stream flows is the same whether they are provided to one or many participants, and it is often infeasible to exclude use. As a result, a market price reflected through private transactions will not reflect the full value of environmental flows. In response to this concern, economists use shadow-price or non-market methods of calculating the environmental or "ecosystem service" value of natural resources. Shadow-price methods (travel cost or hedonic prices) can be used to value water in some instances, but are not sufficient to value a large stretch of river with many different ecosystem services (Loomis et al., 2000). Individual willingness-to-pay for the existence of stream and lake wildlife habitat (existence value), the option to use the resource in the future (option value), and guaranteeing availability for future generations (bequest value) are considered non-user values and may contribute significantly to the total value of a lake or stream (Colby, 1990). Some economists argue that the best, albeit only, method to quantify these values is contingent valuation (Loomis, 1997). Contingent valuation survey responses indicated that households near the South Platte River would be willing to pay $28 per month to maintain a water level that provides a collection of ecosystem services (Loomis et al., 2000). Many other CV studies have estimated the value of water's ecosystem services; a variety of value estimates appear in a matrix at the end of this chapter.

The important upshot of this section is that in-stream values can be estimated and compared to the value of water in off-stream uses. An individual's willingness-to-pay for in-stream water may be small, but over a large number of users the aggregate benefit could be large enough to warrant reallocation (Daubert & Young, 1981). Colby and Daubert & Young argue that the economic value of water in-stream for ecosystems and recreation can often exceed the benefits of off-stream uses, and therefore economic development and efficiency could benefit from increased attention to in-stream flow protection. For each ecosystem and recreation activity there is an optimal amount of water (really, an optimal range of CFS) that offers the greatest benefit. Optimal flow ranges have been estimated for many different activities and ecosystems (Leone, 1997; Young, 1981; Walsh et al., 1980). In order to produce more efficient water distribution outcomes, water allocation decision makers should evaluate where and to which activities the value of additional water is highest and where it is lowest, and tailor allocation decisions accordingly.

Regional Economic Impacts – Spillover Effects from Agriculture and Recreation

The direct value of water can be estimated using the methods described above, but economic impacts spread beyond the direct value of a given activity. Every dollar spent, or not spent, towards some good or service, creates a ripple effect through the economy. Ripples include economic activity in the form of dollars spent when purchasing inputs and induced effects from the income redistribution that occurs as things are bought and sold. This is best illustrated with an example. Suppose that a grad student develops a habituation to double-shot soy cappuccinos. Every day this student travels to his favorite cafe and spends $3.25 for the coffee beverage. Clearly, the café gains $3.25, and the grad student trades $3.25 of his research assistanceship stipend for his daily jolt of joy. This is the direct effect of the purchase. In order to receive the student's business, the café must purchase coffee beans from Honduras, soy milk from a grocery distributor, and pay the wages of an exceptionally talented barista (coincidentally, also a grad student). The café's expenses, inputs and labor, are indirect effects of the $3.25 purchase. Occasionally, at the end of her shift, the talented barista walks down the street and spends some of her wages on a couple of pints of her favorite ale. This economic activity is called an induced effect, since it is induced by the wages the barista receives because of the young man's cappuccino addiction. Every economic "shock", be it an input supply constraint, price change, or bump in final demand, has direct, indirect, and induced effects.

Irrigated crop sales, broadly defined, are one component of the value of water in agriculture, but water also have value in how irrigated agriculture effects supporting industries. Agriculture, like most industries, requires inputs and creates outputs that may become inputs in other industries. These are called backward and forward linkages, respectively. Goods sold at the farm gate are intermediate goods in other industries, including the meatpacking and dairy sectors. Agriculture, by supporting input suppliers and transportation systems, is the economic base for many rural communities across the West. The Colorado Department of Agriculture estimates that Colorado's agriculture and food industry generates an estimated $20 billion of direct and indirect economic activity annually; $6.5 billion in farm receipts, $4.5 billion in farm inputs, and $9 billion added through processing. This does not include the economic activity induced by farmers' incomes, such as meals at restaurants and clothes for their kids. These components of economic activity may be of particular importance to regional policy makers. As illustrated in table 6, chapter 2, different measurements of "value" are important to different stakeholders. Regional and state policy makers who wish to maximize economic activity within their constituency may seek information about the relative size of indirect and induced effects between industries.

The degree to which the direct economic effects of an industry spillover into indirect effects is the "multiplier" of that industry. Multiplier effects represent how economic activity spreads through the economy. To capture the long-term effect of a permanent change to a local economy, we want to evaluate the direct, indirect *and* induced effects (income effects). Including households as a processing sector in the model adds induced effects and yields a "type II" multiplier (Loomis, 2002). This multiplier is defined as:

$$(\text{Direct} + \text{Indirect} + \text{Induced})/\text{Direct} \qquad (1)$$

Analysts employ a variety of regional economic impact models to calculate multiplier effects. These models fall into four basic categories 1) economic base models, 2) input/output models, 3) social accounting matrices, and 4) integrated econometric and input/output models (Loveridge, 2004). These models disaggregate, to various degrees, industries in the region and then calculate the varying impacts of some "exogenous shock". The "shocks" in our case would be varying availabilities of irrigation water.

Economic base analysis provides limited detail and is very susceptible to modeler manipulation since they require the analyst to define the economic base rather than drawing upon observed data (Loveridge, 2004). These back-of-the-envelope models are rarely used now that computer programs can easily run more sophisticated models. Economic base modeling can be made more descriptive by calculating a net factor income, that is, measuring the value of the economic base in terms of an input factor such as water or land. Still, this method is not very descriptive and is only satisfactory for high-level analysis. I/O models offer much greater industry detail. Sales and purchases data is organized into spreadsheets that can be manipulated and interacted with matrix algebra. I/O models are typically off-the-shelf programs that use existing data sets, such as the popular IMPLAN model. This makes them relatively cheap and easy to use. Social accounting matrices require a bit more data but allow attention to the distributional (i.e. welfare) effects of a shock. A SAM expands on a standard I/O model by including interinstitutional transfers, investment income from outside the region, and wages earned outside the region by residents within the region. IMPLAN proprietary data and software incorporates social accounting matrices. The greatest weakness of economic base and input/output models lies in the assumption of fixed-prices. These models assume supply of labor and other non-tradeable inputs as well as demand for output are infinite (perfectly elastic). This causes fixed-price models to over-estimate multiplier effects for large changes in output.

Equilibrium Displacement Modeling represents an industry or market with a system of supply and demand relationships and analyzes the comparative statics of these relationships when one or more of them suffers a shock to supply or demand (Piggott, 1992). The shock could be a new technology, marketing campaign, or natural event, such as a drought. The new competitive equilibrium that arises (via the equi-marginal principle) represents a maximization of producer and consumer surplus (Harrington & Dubman, 2008). Equilibrium displacement modeling (EDM) has been applied to Colorado agriculture and might be used to gain insights into the contribution of irrigated cropping to the Colorado economy. EDM can overcome limitations found in traditional impact analysis and better depict the economic web that ties together water, crop inputs, crop sales and value-added endeavors, particularly if they include positive mathematical programming (PMP) to represent non-linear supply and demand relationships[10]. An EDM model may also be used to characterize the "option value" of maintaining irrigated cropping. In this case, an option value is expressed as the opportunities that exist for value-added enterprises, given the presence of irrigated cropping. As an example, a cheese processing facility is likely to be located in a region that has enough dairy cattle, and by extension, sufficient irrigated forage production for dairy feed. Current and potential forward linkages may be eliminated with transfers of agricultural water. These options, called forward-linkages, cannot be modeled with a standard input-output model.

[10] Using PMP methods in an ED model is called Equilibrium Displacement Mathematical Programming (EDMP); this method been adopted and promoted by the USDA (ERS, 2008).

While EDM models can estimate the effect of a change of one variable upon all other variables in the system, acquiring data on all the variables can be a major challenge. Prices and input and output costs need to be included. Elasticities of supply and demand need to be acquired or endogenously estimated. Computable General Equilibrium (CGE) refers to a class of integrated models that use regression analysis to endogenize variable factors that are assumed fixed in simpler models. Among regional economic impact tools, integrated econometric and I/O models require the greatest amount of detailed data because they are simultaneously solving for many of the model's input coefficients, such as wages or water prices. Though complex and time consuming to build, CGE models are a standard tool of empirical analysis, and are widely used to analyze the aggregate welfare and distributional impacts of policies whose effects may be transmitted through multiple markets (Wing, 2004).

The considerable time and effort required to acquire and compile data makes ED models, and particularly CGE models, time consuming and costly to produce. A CGE model can hypothetically model dynamic responses to every economic transaction, but the complexity often influences analysts to reduce the number of sectors in the model. Therefore a CGE may offer greater depth and accuracy of prediction, at the cost of breadth. Also, the causal path of CGE estimates may be difficult to follow and the results difficult to interpret. However, given sufficient time and resources, a CGE may be the most desirable way to estimate the value of water because it most closely represents economic theory.

Each model type has a tendency to estimate a larger or smaller multiplier value. Economic base models tend to predict larger multipliers than I/O models, which estimate larger values than integrated models (Loveridge, 2004). EB models often include government and capital, which are generally excluded in I/O models. I/O models more carefully identify backward linkages than EB models. SAM multipliers tend to be larger than standard I/O estimates because they incorporate induced changes from outside income. Adding supply and demand constraints in integrated econometric + I/O modeling dampens the estimated impacts of exogenous shocks. It is important, however, that the model be selected to match the region, scope, or policy under analysis rather than the desired outcome. Loveridge cautions practically that "*the magnitude of error in estimating the direct effects may be far greater than errors introduced by choice of modeling technique*." As they say, junk in, junk out.

The seminal use of an input/output model to estimate the value of water in Colorado was conducted by Gray and McKean in 1975. This research effort was a precursor to the development of IMPLAN, which involved the U.S. Forest Service's Land Management Planning Unit in Fort Collins, and Dr. Wilbur Maki at the University of Minnesota (MIG Inc.). Gray and McKean extended a basic I/O model to an analysis of sector-by-sector water use by adding data about consumptive use of water per dollar of output in each sector. This allowed the authors to look at the effect that a shock in final demand would have on water consumed. They note that some industries, such as food processing, use little water directly, but can have large impacts on water use due to their connections to agriculture. Their input/output model estimated that a $1 increase in final demand for food processing required an additional 590 gallons of water ($1 in 1975 translates to $4.21 in 2012 dollars). Since Gray and McKean's study in 1975, I/O models have been used many times over to estimate impact of drought and water transfers.

Despite their predictive weaknesses, I/O models continue to be used because they are quick and simple, and reflect impacts on hundreds of economic sectors.

Howe and Goemans (2003) used IMPLAN to analyze the impact of past water transfers in Colorado's lower South Platte and Arkansas River basins. They estimated the value lost in the lower Arkansas Basin from reduced exports equated to about $51 per acre-foot, or $232 over ten years. The authors presume that, because the lower Ark Basin has few base industries, it would take about ten years for the rural counties to recover from reduced irrigation. Thorvaldson and Pritchett (2006) estimated future economic impacts in the Lower South Platte River Basin from reduced irrigated acreage due to transfers as predicted by the Colorado Statewide Water Supply Initiative (SWSI, 2010). They estimated direct, indirect and induced effects per acre of land removed from agriculture, not reduced acre-feet of water. This may be more representative of what would occur if water rights are sold, rather than leased. The impacts ranged from $418 to $1,096 per acre, depending on how crop choices change. Note that this reflects changes in economic activity, not net benefit. They estimated the multiplier for irrigated agriculture to range from 1.19 to 1.23, meaning that a dollar change in ag output caused a $.19 - $.23 change in economic activity in other sectors within the region. The model estimated in this paper builds upon the methods used by Thorvaldson and Pritchett.

IMPLAN has also been used to model impacts from changes in whitewater recreation due to reduced in-stream flows. Leones et. al used a survey to collect information on recreation expenditures, and a regression analysis to estimate the correlation between flow levels and visitation rates (Leones et al., 1997). The authors used these calculations to shock the amusement and recreation sector of IMPLAN to estimate the region-wide impact to economic activity. Although they did not calculate the impact per acre-foot, Leones et al. point out that the impact depends upon the timing of flow-level changes; the greatest impacts would occur with augmentation of flow levels in mid to late summer.

This section illustrates that there are a handful of methods to quantify economic spillovers and multiplier effects of economic activity that lie along a spectrum from simplistic to complex. The most complex methods (CGE and EDM) require the greatest amount of data and mathematical rigor but are arguably more accurate than base analysis and input/output models. However, input/output models, and particularly those with ready-made data sets like IMPLAN, are cost effective and produce an accurate snap-shot of economic spillovers. Estimates of impacts from shocks to one or more industries would benefit from EDM or CGE methods that respond dynamically to changes, representing real world economic phenomena such as input substitution, economies of scale, and diminishing returns.

Water Transfers

This research has been motivated by the prospect of water transfers occurring despite a dearth of knowledge about their potential impacts. Water transfers occur when it becomes costly or ecologically prohibitive to acquire new water rights. The Arkansas River is "fully appropriated," meaning that no new water rights are available. Every divertable drop has been allocated, and in dry years we see that Ark River water has actually been *over*-allocated. This scarcity puts pressure on uses with the lowest marginal benefit of water to sell or lease their water rights to uses with higher value.

In 1984, Bob Young estimated that the average marginal value for irrigation water in Colorado was near or below $70[11] per acre-foot for 90 percent of irrigation demand, with only specialty crops yielding higher values for the remaining 10 percent (Young, 1984). The net direct foregone value from reduced irrigation in Colorado mostly falls in the range of $12-$82 per acre-foot; industrial and household willingness to pay is five to ten times higher. Given the relatively low value of water in agriculture, and the low percentage of Colorado workers who are employed in ag and related industries, Young argued that from a statewide perspective the direct and indirect economic impact of water transfers is minimal. Although agriculture has a high economic multiplier due to many forward and backward production and processing linkages[12], the income and employment effects of transfers are small relative to total income and employment in the state. In 1986, Young attempted to explain why there had been relatively few transfers among water users despite this discrepancy in marginal willingness-to-pay, citing large transaction costs relative to the per-unit value of water, an agency preference for infrastructure projects over market solutions, and the difficulty identifying and compensating those who would be impacted by indirect effects. In addition to the above structural conditions, he explains that non-efficiency goals enter into the equation, such as a cultural preference for open access to water, the "greenbelt effect" of irrigated agriculture, and a belief that control over water access gives community cohesion to agrarian and indigenous communities (Young, 1986). He argues that, in order to prescribe a transfer, the benefits would have to exceed the foregone benefits plus the transaction costs, but does not devise an estimable model to

[11] All values in this paper are converted to 2012 dollars. For example, Young's estimate of $30/acre-foot in 1982 would be equivalent to $70 in 2012.
[12] The multiplier ratio of agriculture seems to vary by study. 2.7 according to Gray & McKean in 1975; about 1.2 according to Thorvaldson & Pritchett in 2006.

determine potential or foregone benefits. Colby (1990) concurs that benefits can be maximized using the equi-marginal principal, adding that transfers are limited by the fact that in-stream flows are not generally considered ‘beneficial use’.

In response to these arguments for and against transfers, many researchers have decided to cut to the chase and measure the impacts of changes to water allocations rather than calculate the potential value of water to each stakeholder. This is a natural application for regional economic impact models. Howe, Lazo, and Weber (1990) recognized the dilemma of indeterminate foregone benefits and created a model to estimate the full impact of transfers. The authors used an input-output (IMPLAN) model for historical analysis, and the Colorado Forecasting and Simulation Model (COFS), a combination econometric and input-output model, for future analysis. Their model showed that if baseline irrigation levels remain unchanged (i.e. no transfers) there would be no notable changes to employment and economic value in the region. However, in the most severe case where enough transfers occur to completely stop irrigated agriculture by 2020, the Arkansas River Valley would suffer a 21% reduction in farm employment and value. This would cause a significant uncompensated cost to local economies, but would be insignificant at the state level because the income losses to agriculture would be more than offset by the savings to cities. The marginal values in ag and urban were estimated to be $92 and $3,460 per acre-foot, respectively. The authors conclude that states should not fear water transfers, but note that the areas of origin will warrant transitional assistance.

Equilibrium displacement models have become more commonly used to estimate the effects of transfers because they represent how a change in one industry alters the equilibrium between supply and demand in other industries. Goodman (2000) uses a

Computable General Equilibrium (CGE) model to compare the effects of temporary water transfers to increases in reservoir storage. He concludes that, although both transfers and increased storage offer potential welfare gains, economies would adapt to temporary transfers, making it unreasonable to support the high capital costs of developing increased storage (~$263 million). Goodman contends that his CGE model provides a more realistic and accurate analysis of impacts from water transfers than input-output analyses because it "*allows for behavioral changes in response to changing conditions*" (Goodman, 2000).

Seung et al. (2000) used a CGE model to evaluate the impact of reallocating water from agriculture to wetlands in Nevada, considering the potential reduction in ag production vis-à-vis the increase in recreation related expenditures. They found that, over a six-year period, the augmentation of recreation related expenditures was not great enough to compensate the reductions in agricultural output (Seung et. al, 2000). The researchers admit that they measure changes in output (economic impact), not consumer or producer welfare. Both of these studies measure trade-offs between water users. This research is interested in mutual-use benefits. It does not appear that researchers have used regional economic modeling to estimate mutual-use value of water allocated to agriculture.

Alternatives to Economic Valuation of Water

Chapter 3 has discussed a variety of market and non-market methodologies that can be used to measure the value of water to agriculture, recreation and ecosystems. Using these methods, researchers have estimated the value of water in lakes, reservoirs, and river basins around the world. Although it is important to tailor any valuation effort to the particulars of the region under analysis, water value estimates from one region may be quite similar to other comparable regions. Applying methods and/or results from a well-studied region to a less studied region is called *benefit transfer*. When budget or time constraints prohibit primary research, or when the potential resource impacts are expected to be low, benefit transfer is a second-best alternative to primary research (Rosenberger & Loomis, 2001). This technique can save tremendous time and money, and if the studied region is quite similar to the un-studied region, provide accurate estimates of water value.

Benefit transfer methods range from simple, for example using per square mile, per capita, or per acre-foot estimates from one region as proxy values in another region, to complex, such as using regression analysis across many studies to determine the relevance of particular variables or site characteristics (Young, 2005). There are two types of benefit transfer approaches: transfer of values and transfer of functions (Rosenberger & Loomis, 2001). Colorado State University and Oregon State University hold databases of environmental valuation studies that facilitate benefit transfer.

Lastly, it should be noted that economic valuation is not the only way to determine value and "optimal" allocation of a resource. Optimal allocation of a natural resource should be based upon a thorough analysis of the complete social impact (deLange, 2006). Some argue that the "true" social impact of water allocation decisions may be incompletely measured in a normal cost-benefit analysis; that is to say, market-based valuation methodologies cannot account for the total cost of different resource allocations. Non-economic forms of resource valuation may be helpful in understanding the impact of water allocation decisions. Stakeholder analysis is a method of assessing the respective interests of multiple stakeholders in a system. Stakeholder analysis, when used in complement with conventional economic approaches, may serve to overcome the deficiencies of those approaches (Grimble and Chan, 1995). A process in which all stakeholders can learn about the biophysical interdependencies of their management, use, consumption, or enjoyment of a resource can help to fairly and equitably solve natural resource management problems (Ravnborg and Westermann, 2002). Ag producers, recreationists, residential users and industries are all stakeholders in the Arkansas River Basin.

Measuring Water Value - Summary

Below, two tables provide a summary of water valuation efforts that have used some of methods described in this chapter. The first table describes different valuation methods and lists the common pros and cons of each method. The second table gives examples of water value estimates from a variety of studies. All values have been converted to 2012 dollars.

Value of Water: Model Characteristics

Value Type	Typical Magnitude	Study Type	Description	Pros	Cons
Agricultural Production	Low	Water Sale and Lease Transactions	Simple accounting method. A lower bound on value of water to ag.	Quick and simple to calculate, represents real-world behavior.	Does not measure full value, just a slice of economic activity related to water. Data is often limited.
	High	Linear Production Functions (Residual Method)	Estimate a linear production function (constant prices) from enterprise budgets, solve for un-priced input (water).	Common and simple; models production accurately for snapshots or small changes.	Cannot calibrate production functions to real world by adding constraints or risk. In reality, ag does not have constant input and output prices. Hard to isolate water value from other un-priced inputs.
	High	Input-Output Model (Residual Method)	Subtract the output (value added) of non-irrigated ag sector from irrigated ag sector.	Comprehensive data; Can estimate spillover effects to other industries.	Over-estimates because output includes all value-added activity (i.e. taxes). Hard to isolate value of water from other un-priced inputs.
	Mid	Positive Mathematical Programming (Residual Method)	Estimates coefficients to a non-linear production function from a baseline year; self-calibrating to base year data.	More closely represents real farm production behavior and heterogeneous land quality, with relatively low data requirements; allows for changes in input and crop prices.	Economically rigorous to develop, risk of specification error; used to be limited by computers and software.
	Low	Equilibrium Displacement Models (EDM, EDMP, CGE)	Compares competitive supply/demand equilibrium across many industries.	More closely represents dynamic economy-wide responses to output and input shocks. Can be used to model optimal resource allocation that maximizes consumer and producer surplus.	Depending on type, can require lots of data and be time consuming to develop.

	Low	Hedonic Property Value	Compare land values with and without irrigation	Represents capitalized value; values more constant than production output. Includes (private) non-production benefits like recreation or habitat.	Heavy data requirements; time consuming. Can't separate use from non-use value. Changes with zoning and development.
Recreation	Low	User fees, licenses, guiding services	Sum of taxes, fees, and paid services.	Clear; data defensible and easily acquired.	A lower-bound value; does not capture full willingness-to-pay
	Mid	Travel Cost Method	Shadow prices of recreation from secondary expenditures	May use real expenditure data, represents revealed (not stated) preferences.	Comprehensive data collection can be difficult.
	High	Contingent Valuation Method	Survey method, asks willingness-to-pay of recreationists	Data specific to use and area. Can represent public benefits and passive-use values.	Data is stated (hypothetical), not revealed willingness-to-pay. Requires sophisticated survey.
Environment	Low	Conservation Payments	Resources spent on conservation: state and non-profit	Easy to obtain; clear dollar amounts.	A very lower bound value
	Mid	Contingent Valuation Method	Survey method, asks willingness-to-pay for ecosystem	Can represent non-use values (i.e. existence or bequest value). Data specific to region.	Data is stated (hypothetical), not revealed willingness-to-pay. Requires sophisticated survey.
	High	Ecosystem Services (Avoided Cost or Net Factor Income)	Economic activity related to presence of resource (not ag or recreation), or costs avoided by services provided by ecosystem, i.e. flood control, water treatment	Can represent real economic activity from ecosystems, costs and benefits.	Not all ecosystems have a second-best service alternative. Hard to determine what is real data. Can produce outlandishly high values.
	Varies	Benefit Transfer	Using results or techniques from a representative region	Cheap, saves time, and can yield accurate results. Can be used for rec, environment, or ag values.	Hard to validate accuracy of results.
Spillover Effects from Ag and Rec	High	Input/Output Models (IMPLAN)	Inputs and outputs assumed to exhibit constant elasticity	Ready-made models available, with data for purchase; lots of industry detail.	Do not capture forward linkages; assume fixed prices for labor and other inputs.

	Med	Equilibrium Displacement Models (EDM)	Compares competitive supply/demand equilibrium across many industries.	More closely represents dynamic responses to output and input shocks, but with less data econometrics than CGE. Can be used to model optimal allocation that maximizes consumer and producer surplus.	May trade depth for breadth.
	Med	Computable General Equilibrium (CGE)	Uses econometrics to reflect dynamic industry responses to changes; prices and resources are endogenous.	Dynamic. Can respond to input substitution, constraints and price changes. Can model forward linkages.	Heavy data reqs; takes lots of time to build. Hard to interpret results and show causal path.

Figure 4: Water Valuation Model Characteristics

Value of Water by Sector - Baseline Values				
Value Type	**Study Type**	**Location**	**Baseline Value**	**Units/Sensitivity**
Agricultural Production Value	Farm budget residual (Bush & Martin 1986)	Central Arizona	Alfalfa: $73/AF; Cotton $254/AF	Residual Income from irrigation
	Linear Production Functions; USDA studies 1982-83 (Colby, 1988)	Arizona, California, Idaho, New Mexico, Texas, Washington	$40/AF for Sorghum in Arizona; $1,024/AF for Tomatoes in California	Range of crops and locations
	Discrete Stochastic Sequential Programming; (Taylor & Young 1995)	Colorado Canal, Crowley County, CO	$56/AF	Average foregone benefits of transferring irrigation water
	CGE; Transfer of 1/3 of region's ag water to wetlands (Seung et al. 2000)	Stillwater National Wildlife Refuge, Nevada	$280/AF	Loss to ag: $35.9 mil over 6 years
Spillover Effects from Ag	Input/Output model (IMPLAN); Historic Transfers (Howe & Goemans, 2003)	Lower Arkansas Basin, CO	$51/AF	Measured reduced exports with transfers (lost surplus value)
	Input/Output model (IMPLAN); Potential Transfers (Thorvaldson & Pritchett, 2006)	South Platte and Arkansas River Basins, CO	$20.3 Million; $486/acre	Losses to total econ. activity from 14% reduction in irrigated crop sales
	IMPLAN vs. Equilibrium Displacement Mathematical Programming (EDMP)	Arkansas and Rio Grande River Basins, CO	IMPLAN: $100 Million; IMPLAN w/ EDMP: $83 Million	Total Impact of Drought; Compares I/O to EDMP
Recreation Value	Parks and Rec Costs related to water	Arkansas Headwaters Recreation Area	$1.41 per visitor activity	Park revenue divided by visitors; Activity-days may double count visitors

Recreation Value	All travel cost studies for water recreation in Western States; OSU Database	Western States (excluding AK, HI)	River Fishing: $56-$68 Reservoir Fishing: $34/$45 River Boating: $29/$56 Reservoir Boating: $7/$13 Waterfowl Hunting: $48/$61 Other Water Rec: $23/$31	Represents median/average consumer surplus per day, per individual
	National Survey of Fishing Expenditures; U.S. Fish and Wildlife	All U.S.	$57/day	Expenditures per day, trout fishing
	Commercial Rafting Expenditures; Johnson & Moore (1993)	Arkansas River, CO	$121/day	Expenditures per day, commercial river rafting
	Contingent Valuation Survey; instream flows for fishing (Daubert & Young, 1981)	Cache la Poudre River, CO	$75/day; $18 - $25/AF	Willingness-to-pay: per day for best fishing flow levels; per AF for augmenting flows
	Travel Costs paired with Contingent Valuation survey; lake recreation (Eiswerth, 2000)	Walter Lake, Nevada	$16 - $24 per individual for an additional foot of lake level	Annual
Recreation and Environment	CGE; Transfer of 1/3 of region's ag water to wetlands (Seung et al. 2000)	Stillwater National Wildlife Refuge, Nevada	$11.86/AF	Gain to rec: $1.526 mil over 6 years
	CSU Benefit Transfer Toolkit (Medians and averages from many recreation and ecosystem studies) (Loomis & Richardson 2007)	Intermountain West	Fishing: $37/$88 Hunting: $40/$81 Wildlife viewing: $45/$54 Wetland: $19/$91 per acre	Represents median/average consumer surplus per day, per individual (except wetland)
Environmental Value	Ecosystem Services, Contingent Valuation (Loomis et al. 2000)	South Platte River, Colorado	$332/household/year; $25 - $92 million total	Willingness-to-pay for ecosystem services from improved water quality; total depends on number of participating households

Figure 5: Baseline Values

Chapter 4: Measuring Economic Activity Attributable to Water Allocated to Agriculture in the Arkansas Basin

The previous chapter explained methods that can be used to measure the value of irrigation water to agriculture, recreation, and ecosystems, and the spillover effects that accrue to supporting industries and households as a result of irrigated cropping. This chapter synthesizes an analytical model from selected methods to estimate economic activity that can be attributed to irrigated agriculture, including mutual-use benefits and economic spillovers. Economic activity from agriculture and agricultural spillovers is modeled with an input-output model modified to represent the specifics of the Arkansas Basin. Economic activity from water-related recreation is calculated by multiplying historical user numbers by estimates of user-day expenditures taken from existing literature. Ecosystem service values are evaluated qualitatively.

This research proposes that economic activity attributable to water in agriculture is a sum of direct value to farmers, mutual use benefits to ecosystems and recreation upstream and downstream, and economic spillovers to supporting industries. This framework is illustrated below in equation 1.

$$\begin{array}{ll} & \textit{Irrigated Crop Sales} \\ + & \textit{Recreation Expenditures}_{AW} \\ + & \textit{Ecosystem Services}_{AW} \\ + & \textit{Economic Spillovers} \\ \hline = & \textit{Total Economic Activity}_{AW} \end{array} \tag{1}$$

Where:

- Irrigated Crop Sales represents direct farmer revenue from irrigated crops,
- Recreational Expenditures $_{AW}$ represents dollars spent directly on recreation activities involving water allocated to agriculture,
- Ecosystem Services $_{AW}$ represents the ecosystem benefits of water allocated to agriculture, and
- Economic Spillovers represent indirect and induced economic activity from irrigated ag sales and recreation direct expenditures.

First, it should be noted that, with the exception of ecosystem service benefits, which are described qualitatively, this model quantifies economic activity, not net social benefit (*surplus*). The model estimates dollars flowing throughout the regional economy, not willingness-to-pay, the common metric of consumer and producer surplus. Second, the total economic activity in equation 1 represents *complementary* uses and consequentially, complementary economic activity. This model only measures *positive* economic activity*;* negative externalities and opportunity costs associated with water in agriculture and potential competing uses are not quantified and subtracted from the total economic activity calculation described above. As described in chapter 2, negative externalities may include deterioration of water quality from pollution and salinization effects of agriculture and recreation, and the opportunity costs of lesser return flows from evaporation or evapotranspiration (*consumptive use*). Calculating the magnitude of negative externalities is beyond the scope of this research effort. Lastly, this model does not quantify potential value-added opportunities (*forward linkages)* related to irrigated ag, or measure impacts of changes to agriculture or recreation to forward-linked industries.

Above disclaimers aside, measuring economic activity is useful because it serves as a baseline quantification of the value of water under the status quo. The value of Arkansas River water under alternative allocation scenarios could be compared to this baseline. Methods for measuring social benefit, forward linkages, and the potential implications of consumptive use and pollution by ag and recreation will be reviewed in chapter 6.

This valuation approach expands upon earlier efforts to estimate the value of water in agriculture by adding mutual-use benefits. Howe & Goemans (2003) and Thorvaldson & Pritchett (2006) estimate the impact of water transfers on economic activity related to irrigated ag sales and supporting industries in the Lower Arkansas Basin, but neither study adds mutual-use benefits to recreation and ecosystem services. This study adds economic activity related to recreation activities in order to more comprehensively calculate the value of water used in agriculture. Ecosystem service benefits from water allocated to agriculture and estimates of their economic value are evaluated in this study as well. The four components of economic activity listed in equation 4.1 are calculated in three distinct steps:

Step 1: Calculate the direct, indirect, and induced economic activity from irrigated agriculture in the Arkansas River Basin,

Step 2: Calculate the direct and indirect economic activity from recreation where agricultural water rights provide recreational opportunities, and

Step 3: Calculate the value of water to ecosystems where water allocated to agriculture supports ecosystem services.

The natural next step, which is not tackled in this research, would be quantifying lost value from consumptive use and water quality degradation, and subtracting those negative externalities from the agricultural, recreation and ecosystem values.

Step 1: Economic Activity from Water Used in Agriculture

This research provides insights into the economic value of water in agriculture. At a basic level, value comes from the use of irrigation water as a factor of production in producing irrigated crops that are sold in markets. In this section, the means for measuring the production value via production functions, enterprise budgets, and an input/output model is explained.

Water is an input in the agricultural production process, and production theory provides a conceptual framework to represent the value of water in that process. Agricultural production requires land, human labor, and a collection of inputs including materials, technology, energy, and water. Agricultural output, in this context, is the gross revenue from crop sales, and therefore also depends upon crop prices. The following general equation represents agricultural output as a function of these inputs. This is an example of a *production function.*

$$\textit{Ag Output} = f(\textit{Land, Labor, Materials, Technology, Energy, Water}) \qquad (2)$$

A *production function* can be estimated empirically from agricultural yield data by statistically quantifying the relationships between inputs and output. These relationships are represented by technical coefficients that describe the production process for a given crop. A production function measures physical output, such as bushels of corn for a given acreage, but it does not necessarily describe economic activity. A *cost function* transforms the production relationships into economic (monetary) relationships by considering the cost minimizing or profit maximizing behavior of farmers. A cost function is a specific type of production function that describes the economic activity related to a given level of output. Equation 3 is an example of a cost function.

$$Total\ Costs = \beta_1 Land + \beta_2 Labor + \beta_3 Machinery + \beta_4\ Materials + \beta_5\ Energy \qquad (3)$$

The β 's are coefficients representing the price or cost of each input. Using these coefficients, agricultural economists have developed *enterprise budgets* for different regions and different crops. An *enterprise budget* displays the representative quantities of inputs (and their costs) used to produce a unit of output, such as a bushel of corn. Profits are calculated on a per input unit basis (e.g. per acre) for input, overhead, and total costs. The Colorado State University Extension Service publishes enterprise budgets for major crops for each agricultural region in Colorado. Enterprise budgets for major crops in southeast Colorado, including irrigated corn, wheat, alfalfa, melons, and dryland wheat, are used in this study to specify cost functions that model economic activity in agricultural production in the Arkansas River Basin (Appendix 1, CSU Extension, 2012).

Cost functions for each agricultural sector, and every other industry in a given region, can be represented in an input/output model. As explained in chapter 3, an input/output model can be used to evaluate gross economic output (direct effects), inter-industry linkages (indirect effects) and household expenditures (induced effects) related to any given industry (Loomis, 2002). An input/output model accounts for all purchases and sales made by every industry in a region. Each sale and purchase is an interaction between different industries and/or different regions. These interactions, sales and purchases, are the factors of production in equations 2 and 3. Sales and purchases of inputs between industries make up the *economic spillovers* component of equation 1. Quantifying these interactions allows analysis of how an expansion or contraction in one area of an economy impacts other areas of the economy. Evaluating the economy-wide effects of a change in demand or output of an industry is referred to as *impact analysis*.

The input/output (I/O) method of impact analysis, which earned Wassily Leontief the 1973 Nobel Prize, is derived from a series of linear production (cost) functions[13], each representing a different industry. The final product of an industry, that which is purchased by consumers or other industries, is referred to as the industry's *final demand*, denoted as $Y_{i.}$ Final demand can be split into domestic demand, which is distributed within the region of analysis, and exports, which leave the region. An industry's total economic contribution, denoted as X_i, is the sum of final demand and all production inputs. Production inputs or *intermediate demand* are outputs from other industries, and are denoted as Z_j. This yields a simple equation for total output[14]. *Total Output = Intermediate Demand + Final Demand*

$$X_i = Z_j + Y_i \tag{4}$$

The subscript i indicates that this equation represents a series of linear production functions for industries X_1 through X_i. Intermediate demand, the production inputs represented by Z_j, are actually a sum of different inputs $(Z_1, Z_2, \ldots Z_j)$ *or* $\sum_{j=1}^{j=n} Z_j$. Dividing the equation above by the total output for each industry simplifies the production functions to represent the production of one unit of output from each industry.

$$\frac{X_i}{X_i} = \frac{Z_i}{X_i} + \frac{Y_i}{X_i} \quad \Rightarrow \quad x_i = \sum_{j=1}^{j=n} a_{ij} x_j + y_i \tag{5}$$

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[13] From here forward, the term *production function* refers to a measurement of economic output rather than physical output.

[14] In order to illustrate the input/output derivation more simply, we assume a closed economy, meaning that all inputs come from within the region and all output remains in the industry. Variables can be expanded to represent leakages in and out of the region under analysis.

Where x_i represents one unit of output from industry *i.* Intermediate demands are denoted as $a_{ij}x_{i,}$ where a_{ij} is a coefficient that explains how much of x_j is purchased by industry *i* from industry *j* to produce one unit. (This coefficient is similar to the input quantities in an enterprise budget.) In order to solve this series of equations using matrix algebra, the number of columns must equal the number of rows, *i=j*. Note that many of the *a* coefficients will be zero since not all industries buy or sell inputs from or to each other. The series of equations for all industries can be represented in matrix notation as:

$$X = AX + Y \qquad (6)$$

X is an i x 1 vector of gross output, *A* is an i x j vector of input coefficients, and *Y* is an i x 1 vector of final demand. Solving for final demand yields:

$$X - AX = Y \qquad (7)$$

By using the identity matrix, equation 4.5 can be simplified to:

$$(I - A)X = Y \qquad (8)$$

By multiplying both sides by the inverse of *(I – A),* we arrive at an equation for gross output.

$$X = (I - A)^{-1}\ Y \qquad (9)$$

The matrix $(I - A)^{-1}$ is a matrix of multipliers know as the Leontief Inverse, or multiplier matrix. Gross output can be calculated simply by multiplying final demand by the multiplier matrix. Similarly, final demand and gross output can be traced back to input expenditures. This derivation is provided to show how input-output models can simultaneously calculate the direct, indirect, and induced economic activity attributable to a given industry or industries. (Direct, indirect and induced economic activity related to irrigated agriculture in the Arkansas Basin are displayed in chapter 5.)

Water is generally an un-priced input and is not represented as an industry or "sector" in an I/O model. However, an I/O model can demonstrate economic activity that occurs *because* water is being used in agricultural production. Agricultural production that does not use irrigation is referred to as *dryland agriculture*. In order to calculate economic activity related to water, irrigated agricultural output needs separated from dryland ag output. In order to calculate the economic activity that occurs because of water allocated to agriculture, dryland ag output is simply subtracted from total ag output.

$$Irrigated\ Ag\ Output = Total\ Ag\ Output - Dryland\ Ag\ Output \qquad (10)$$

If modeling a change or "shock" to irrigated agriculture, an estimate or assumption must be made regarding alternative uses for the fallowed land. Two alternatives are considered: dryland cropping or a return to native vegetation/rangeland. This model evaluates three possible counter-factual scenarios for the geographic area of this study: 1) dryland acreage remains unchanged so that all land that is "dried-up" is returned to native vegetation, 2) all irrigated agricultural acreage is replaced with dryland farming, and 3) 1/3rd of irrigated acreage is converted to dryland farming, which appears to be consistent with the ratio of native rangeland to dryland acres in the region. These three counter-factual scenarios provide a wide sensitivity analysis of potential impacts.

In spring 2013, Dr. James Pritchett and the CSU Department of Ag and Resource Economics purchased IMPLAN (Version 3.0) to facilitate evaluation of economic activity in Colorado. IMPLAN expands on a standard I/O model by including a social accounting matrix to account for inter-institutional transfers, investment income from outside the region, and wages earned outside the region by residents within the region. Using data from nation-wide averages, IMPLAN has developed production functions for each industry and estimated regional purchasing coefficients (RPCs), that is, the amount of inputs coming from within the same region as the industry (MIG Inc., 2012). Lazarus, Platas, and Morse (2002) found that, while these national averages provide a good approximation of local conditions, estimates can be improved by creating production functions specific to the region of analysis. Their study found that tweaking RPCs had less of an effect.

Ratios of non-water inputs appear in IMPLAN in the production functions for each sector; these *production coefficients* make up the *A* matrix described in the input/output derivation above. Those coefficients can be vetted against the input expenses that appear in southeastern Colorado enterprise budgets[15]. As explained above, crop enterprise budgets provide an estimate of the costs a farmer incurs in order to produce one unit (acre, bushel, or farm) of a particular crop. The data from enterprise budgets is used to adjust the production functions for each cropping sector in IMPLAN so that the model more accurately represents agriculture in the Arkansas River Basin. Enterprise budgets are also used to create a unique sector that represents dryland agriculture. This process is described in more detail below.

IMPLAN data is organized into 440 sectors. Production agriculture is represented in15 IMPLAN sectors; 12 of these sectors exist in the Arkansas River basin, including a unique *dryland wheat* sector created for this analysis. Employment, output, and labor income for these 12 sectors are listed in the table below. This data represents the 17 Arkansas Basin counties listed in table 3, chapter 2.

[15] Enterprise budget are provided as appendices X – XX.

Table 8: Arkansas Basin Agricultural Output by Sector

Arkansas Basin Agricultural Output by Sector			
Industry Description	**Employment**	**Output**	**Labor Income**
Grain farming	3,399	$276,128,296	$27,486,749
Cattle ranching and farming	3,356	$657,900,513	$30,796,621
Animal production, except cattle	1,214	$70,190,941	$9,046,186
All other crop farming	696	$319,562,683	$86,529,659
Dryland wheat	474	$38,500,038	$2,700,660
Dairy cattle and milk production	304	$31,971,066	$858,552
Greenhouse, nursery, and floriculture	239	$35,247,486	$15,452,736
Vegetable and melon farming	204	$42,253,365	$13,141,543
Oilseed farming	113	$19,547,691	$2,664,418
Poultry and egg production	24	$20,655,645	$1,881,074
Fruit farming	11	$2,455,281	$839,385
Tree nut farming	2	$446,497	$123,725
Total Agricultural	10,036	$1,514,859,502	$191,521,309
Ag (Direct) as percent of total Arkansas River Basin	1.89%	2.09%	0.70%

(MIG inc., 2011)

Animal production activities use relatively little water directly and are therefore removed from the analysis of direct value of water to agriculture. It should be noted, however, that animal production uses a lot of water indirectly, through the irrigation of feed and forage for animals. This is an example of a forward linkage of irrigated agriculture. Oilseed farming represents sunflower production in the Arkansas Basin. Since sunflowers are rarely irrigated, this sector is removed from this analysis. Tree nut farming is also removed because it is a miniscule component of Arkansas Basin agriculture. This leaves five agricultural sectors, listed below in table 9. IMPLAN sectors do not correspond directly to the North American Industry Classification System (NAICS). To aid in comparing IMPLAN sectors to NAICS and other industry nomenclature, the five irrigated agriculture sectors evaluated in this analysis are described in table 9.

Table 9: Description of IMPLAN agricultural sectors relevant to water use in the Arkansas Basin[16]

IMPLAN Sector Title	Description
Grain farming	Dry peas and beans, wheat, corn, rice, barley, rye, sorghum, and oats
All other crop farming	Hay, hay seed, peanuts, hops, mint, and spices
Greenhouse, nursery, and floriculture production	Crops grown under any kind of cover, flowers, other nursery plants, shrubs, and trees
Vegetable and melon farming	Edible plant, root, and tuber crops for food or seed, except sugar beets and peanuts
Fruit farming	Apples and pears, grapes, stone fruits and berries

(MIG Inc. 2012, and NAICS 2007)

IMPLAN has developed production functions for each sector based on averages of nation-wide data. In order to improve accuracy, IMPLAN production functions for Grain Farming, Other Crops (hay), and Vegetables and Melon Farming, are compared to CSU enterprise budgets for the Arkansas River Basin, and altered where appropriate[17]. Table 10 below is an example of a comparison between an enterprise budget and IMPLAN productions function. Enterprise budget costs and returns are converted to units (cents) per dollar of total output, the same units used in IMPLAN production function coefficients (called *absorption* coefficients in IMPLAN). Table 10 compares a 2009 enterprise budget for irrigated wheat farming in Southeast Colorado to IMPLAN's Grain Farming sector. Although IMPLAN lists 106 industries that contribute to grain production, more than 65% of grain farming production costs come from just five sectors: Real Estate, Fuel & Oil, Fertilizer, Ag. Support Services, and Monetary Authorities and Credit (banking).

[16] Not all of the crops listed for each sector in table 9 are grown in the Arkansas Basin.
[17] IMPLAN's national average production functions are used for greenhouses and fruit farming; CSU does not publish budgets for nurseries and greenhouses, and fruit farming is a very minor component of irrigated agriculture in the Ark Basin.

Table 10: Irrigated Wheat enterprise budget compared to IMPLAN's Grain Sector

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERTILIZER (N)	$0.71	$0.11	Fertilizer (3130)	$0.09	-$0.02	-24%
HERBICIDE	$0.19	$0.03	Pesticides (3131)	$0.06	$0.03	88%
SEED	$0.29	$0.05	Grains (3002)	$0.05	$0.00	3%
IRRIGATION ENERGY	$0.46	$0.07	.8 Electricity (3031)	$0.01	-$0.07	-1057%
IRRIGATION REPAIR	$0.14	$0.02	Agriculture…support services (3019)			
CUSTOM HARVEST	$0.43	$0.07	Agriculture…support services (3019)	$0.09	-$0.14	-160%
SPRINKLER LEASE	$0.86	$0.14	Agriculture…support services (3019)			
FUEL	$0.17	$0.03	Refined Petrol. Products (3115)	$0.10	$0.08	281%
REPAIR & MAINTENANCE	$0.09	$0.01	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.00	2%
CROP INSURANCE	$0.33	$0.05	NONE	$0.00	-$0.05	N/A
INTEREST	$0.28	$0.04	.75 Monetary authorities and credit (3354)	$0.05	$0.00	4%
GENERAL FARM OVERHEAD	$0.29	$0.05	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.03	-$0.01	-48%
OWNERSHIP COSTS (Mach)	$0.23	$0.04	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	-$0.01	-48%
FACTOR PAYMENTS	$0.71	$0.11	Real estate…and related services (3360)	$0.12	$0.01	5%
TOTAL COSTS	**$5.18**	**$0.82**	**RELATED IMPLAN SECTOR**	**$0.62**	-$0.19	-31%
Value Added Sector						
LABOR	$0.03	$0.00	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$0.09	$0.01	*Value Added* (Indirect Business Tax)			
RECIEPTS BEFORE FACTOR PAYMENTS	$1.05	$0.17	*Value Added* (Proprietor Income)			
VALUE ADDED	**$1.17**	**$0.18**				

(Colorado State University Extension; MIG Inc. 2012)

Budgets for irrigated corn and irrigated silage corn were compared to IMPLAN's Grain Farming sector in the same manner as irrigated wheat (table 10). Although IMPLAN's costs are similar to the enterprise budgets for corn, wheat, and silage corn, there are some notable differences. Relative to the enterprise budgets for Southeast Colorado, IMPLAN's national averages tend to overestimate fuel costs and underestimate electricity and machinery ownership costs. Also, IMPLAN does not include crop insurance – a significant cost for grain farmers. Some of these incongruences can be explained by unique characteristics of Colorado agriculture. For example, irrigated agriculture in Colorado often requires significant pumping, which uses a lot of electricity. Owners of large Colorado farms may choose to own rather than rent large farm equipment, which would explain why rental costs are greater and ownership costs lesser in IMPLAN's production functions. The high national averages for fuel costs and lack of crop insurance do not have a clear explanation. Perhaps IMPLAN simply lacked sufficient data or level of detail to estimate these costs accurately.

In the same manner as above, CSU enterprise budgets for alfalfa, cantaloupe and chili peppers were compared to IMPLAN's Other Crops and Vegetable and Melon Farming sectors, respectively. IMPLAN production functions for Grains, Other Crops, and Vegetable and Melon Farming were altered to more closely represent cost estimates in CSU enterprise budgets. IMPLAN's national average production functions are used un-altered for Greenhouses and Fruit Farming. Crop production in each of these five sectors depends heavily upon irrigation. Wheat is the only significant crop that is sometimes grown without irrigation in the Arkansas Basin. A unique sector (Dryland Ag) was created to model economic activity related to dryland wheat production. The production function for

Dryland Ag was modeled after the Grain Farming sector and modified to more closely represent CSU's enterprise budget costs and returns estimates.

Another major difference between IMPLAN and enterprise budgets is the fact that accounting costs such as taxes and labor are part of what IMPLAN calls *value added* economic activity. Total output is a sum of input costs and value added. IMPLAN defines the percent of total output that is spent on input costs the *total absorption coefficient* (MIG Inc. 2012). The ratio of value added to input costs varies by crop and region. This was taken into account, and the ratio of input costs (*intermediate expenditures* or *absorption*) to value added was compared between IMPLAN and CSU enterprise budgets. The IMPLAN production function for grains estimates that input costs, on average, account for about 68% of total output; enterprise budgets for wheat, corn, and silage corn estimate average costs to be about 74% of total output. IMPLAN was altered so that intermediate expenditures (costs) equal 71% of total output, which is half way between the IMPLAN and enterprise budget estimates. Returns from alfalfa in Colorado seem to be much higher than IMPLAN's average estimates for Other Crop Farming (64% versus 32%). The total absorption coefficient and value added categories in IMPLAN were altered to reflect the higher returns of Colorado alfalfa. Similarly, the returns to labor, taxes, and farmer income were higher for cantaloupe and chili pepper farming in Colorado than estimated in the vegetable and melon sector. Lastly, from CSU enterprise budgets and expertise of CSU agricultural economist James Pritchett, the absorption coefficient for dryland wheat was estimated to be .80, meaning about 80% of dryland wheat output goes towards input costs, and 20% is returned to labor, taxes, and proprietor income.

Average dryland wheat harvested in the Arkansas Basin is 250,820 acres resulting in production of 6.5 million bushels (NASS 2005- 2011), which equates to an average yield of 26 bushels/acre. Average wheat prices between 2007 and 2011 were $5.89/bushel (NASS 2007-2011); gross output from dryland wheat production is therefore estimated to be $38.5 million. This amount is subtracted from the *Grain Farming* sector, and added to the new *Dryland Wheat* sector. IMPLAN estimates that the ratio of output to employment for the modified grain sector is $81,251 per employee. Keeping this same ratio, dryland wheat would employ 473.8 individuals. IMPLAN matrices are re-built with these modifications, providing a descriptive snapshot of economic activity related to dryland and irrigated agriculture in the Arkansas Basin.

The Colorado Division of Water Resources (CDWR) has estimated the number of acre-feet that may be transferred from ag to other uses in the Arkansas Basin, and the number of acres of irrigated farmland these transfers would dry up. They estimate that between 35,000 and 73,000 acres (8% to 17% of ag land) may be dried up by water transfers by 2050 to meet non-ag demands (SWSI, 2010). Shocks are made to the six sectors above to reflect reductions in acreage due to expected water transfers; augmentation to dryland wheat production is modeled simultaneously. Two shocks are modeled: an 8% reduction and a 17% reduction in acreage. These reductions correspond to the SWSI's low and high estimates of transfers that will occur by 2050 to meet growing M&I demands. Modeling these shocks estimates how economic activity from irrigated agriculture and recreation may change if farmers transfer water to other uses.

In order to shock the six agricultural sectors in IMPLAN (five irrigated crop sectors plus the dryland ag sector), changes in acreage must be converted to reductions to gross output, the *X* vector in IMPLAN. This model assumes a percent reduction in acreage causes an equivalent percent reduction in gross output for all sectors. This assumption may slightly overestimate the impact of acreage reductions since less productive lands would presumably be dried up before more productive parcels. The results of these two shocks are presented in chapter 5; the three hypothetical dryland scenarios (no change, 1/3rd irrigated converted to dryland, all irrigated converted to dryland) are estimated under both shocks.

For the IMPLAN analysis of Arkansas Basin agriculture, changes in acreage are converted to changes in gross output (dollars). Gross output represents the backward linkages (input costs) and value added (profit, taxes and labor) that are affected by changes in production. Because gross output already reflects economic activity to supporting industries, it should not be used to shock IMPLAN's multiplier matrix. If expected reductions to gross output are used to shock ag sectors in IMPLAN these input expenditures would be double counted. To prevent this, the $(I-A)^{-1}$ matrix of technical coefficients (multiplier matrix) is exported from IMPLAN to a spreadsheet and the transactions from the six agriculture sectors to all other sectors are replaced by zeros. This prevents double counting economic activity related to input purchases that are already accounted for in gross output. The results from this model, the amount of direct, indirect, and induced economic activity from irrigated agriculture in the Arkansas Basin, are presented in Chapter 5.

Step 2: Economic Activity from Water Used in Recreation

The goal of this step is to estimate the economic activity that results from recreation activities that can occur because water is allocated to agriculture. Step two estimates economic activity from recreation that occurs under two scenarios: 1) as water is currently allocated, and 2) if water is removed from downstream agriculture, per the estimates of the Statewide Water Supply Initiative (SWSI), resulting in a 5% and 10% decrease in water recreation visitation. Unfortunately, IMPLAN cannot be used to estimate recreation expenditures because of two complicating issues. First, it is impossible to isolate water recreation expenditures from other activities in the "Other Recreation and Amusement" sector in IMPLAN (Sector 409). Second, even if water recreation activities could be isolated in sector 409, this economic activity would only represent direct expenditures, such as for guiding services and water use fees and licenses. Fuel, food, lodging, and sporting goods expenditures make up the vast majority of money spent on private water recreation activities. These expenditures appear in retail, hospitality, and service sectors accounts, not in "Other Recreation and Amusement". Therefore, this study calculates economic activity related to water recreation activities independent from IMPLAN.

In order to determine the economic activity that occurs because of recreation associated with agricultural water, two variables need defined: 1) the number of recreational user-days (per year) provided by ag water, and 2) the expenditures that occur per user-day. Multiplying these two variables yields an estimate of the (annual) economic activity from water recreation. This process is illustrated in equation 11.

Economic Activity from Recreation = (User-Days) x *(Expenditures Per User-Day)* (11)

Multiplying these two variables produces an estimate of economic activity that is similar to the direct plus indirect output in IMPLAN. Recall from the valuation of irrigated agriculture that *total economic activity* is defined as the direct economic activity (farm-gate sales), plus economic spillovers from that direct activity, and recall that economic spillovers include indirect activity (input expenditures) and induced activity (income effects). Recreation expenditures, that is, dollars spent on travel costs and equipment, represent direct economic activity. Average multipliers from IMPLAN can be used to estimate the indirect and induced economic activity that results from these recreation expenditures. Adding this approximation of economic spillovers from recreation expenditures yields an estimate of the total economic activity coming from water recreation. These numbers can be compared to the estimates of activity from irrigated agriculture revealed from IMPLAN.

The Arkansas Headwaters Recreation Area estimates the number of river recreation user-days each year for recreation activities upstream from the Pueblo Reservoir. Most recreation activities in the lower basin occur at the Pueblo and John Martin Reservoirs. Annual user-day estimates for activities at these reservoirs were obtained from the state park managers at each reservoir (Colorado Department of Parks and Wildlife). The average annual number of user-days from 2007 – 2011 is used as an estimate of expected user-days.

Next, typical daily expenditures for visitors to each of the three recreation areas needs determined. Due to time and funding constraints, this study does not collect primary data on recreation expenditures along the Arkansas River, which would require an extensive survey of Arkansas Basin visitors. Instead, this study uses value estimates from previous studies. Corona Research conducted a survey of Colorado state parks visitors in 2008/2009. The group asked questions about visitors' expenditures, per vehicle, per day at each major Colorado state park. Average daily expenditures for each park are multiplied by average 2007-2011 visitor numbers to estimate the average direct and indirect economic activity that occurs because of Arkansas River recreation activities.

The crux of recreation valuation in this study is determining how many recreation user-days exist *because* water is allocated to agriculture. Researchers have determined that water levels affect visitation rates more at some sites than others (Leones et. al., 1997, Hanson, Hatch, and Clouts, 2002), and that the effect of water levels varies by type of activity (Walsh et al., 1978; Daubert & Young, 1981). It seems safe to assume that water levels affect recreation user-days and/or expenditures per user-day, but it is difficult to determine this relationship accurately without collecting primary data over many years and performing rigorous statistical analysis. In order to overcome this obstacle, this research assumes that expenditures per user-day remain the same regardless of the level of water. This assumption isolates one variable, the number of user-days at different water levels. Correlation between user-days and water levels is discussed in chapter 5.

The last significant obstacle to step 2 is determining the relationship between *agriculture* and in-stream flow or reservoir levels. The worst-case scenario, for recreation, would be if water transferred from agriculture to M&I is diverted far upstream, near the Twin Lakes Reservoirs. If diversions occur far upstream, an 8% - 17% decrease in irrigated acreage could would mean a significant reduction in annual flows through the most frequently fished and rafted stretches of the river, and significant reductions to reservoir levels. The impact on flow levels could be significantly less, however, if water is diverted from the Pueblo Reservoir. The impact of transfers also depends upon whether or not return flows occur within the Arkansas Basin. An upstream diversion may not have much of an impact if a significant portion of the flow is returned to the river, albeit with some disturbance in timing. The variety of possible diversion scenarios makes it difficult to predict the impact that transfers would have on economic activity related to water recreation activities. This study calculates three hypothetical scenarios: No decrease in water recreation visitation, a 5% decrease in visitation, and a 10% decrease in visitation. The 5% and 10% decreases in visitation are considered in concert with 8% and 17% reductions in irrigated crop acreage. Estimates of economic activity under these three scenarios is reported in chapter 5.

Step 3: Value of Agricultural Water to Ecosystems

As explained in chapter 3, ecosystems can have value directly in many economic activities and indirectly by supporting habitat for species that have direct value, such as ducks for hunting or natural forage areas for livestock. Ecosystems can also have non-use value to individuals who simply enjoy knowing the ecosystem exists or wish to conserve the ecosystem for future generations. The direct value of ecosystems can often be determined by market or shadow priced methods, such as the residual method, hedonic property value method or travel cost method discussed previously. The primary direct values of ecosystems in the Arkansas Basin are agriculture and recreation, which are measured in steps 1 and 2. Other direct values, such as pollution dilution or fire and flood protection, may be calculated by avoided or replacement cost methods. However, avoided and replacement costs generally represent cost *savings*, which implies *reduced* economic activity.

Agricultural water creates agro-ecosystems that many individuals find pleasing. The Arkansas Valley is a more lush and verdant place because of agricultural water diversions. This phenomenon has an effect on the value of residential property in the basin. Although a hedonic property study is beyond the scope of this research project, it should be noted that agro-ecosystems that depend upon irrigation water marginally influence economic activity related to residential real estate.

Aside from aesthetic value and value to property, agro-ecosystems may also have value to individuals who simply like knowing the ecosystems exist or like knowing that they will remain unchanged for future generations to appreciate. The existence value and bequest value of irrigated agriculture can only be revealed by asking individuals what they would be willing to pay in order to keep agriculture unchanged. A contingent valuation survey is a rigorous and time consuming endeavor that is beyond the scope of this project; however, some general estimates of non-use value of irrigated agriculture can be pulled from previous studies. Benefit transfer can be used to get an estimate of the magnitude of economic value related to ecosystem services. Estimates of CV values that may be relevant to irrigated agriculture in the Arkansas basin are provided in chapter 5.

Chapter 5 presents estimates of the direct economic activity and economic spillovers from agriculture and recreation as water is currently allocated and potential impacts from an 8% and 17% reduction to irrigated acres, representing potential transfers of agricultural water rights. The impacts of an 8% and 17% reduction to irrigated agriculture will be analyzed alongside potential increases in dryland wheat farming. Chapter 5 also shows total economic activity induced from water-based recreation activities and the impact from five and ten percent reductions to water recreation visitor numbers, in case ag-to-urban water transfers impact water recreation. The economic activity from both agriculture and recreation will be summarized according to the six scenarios described in table 11 below. Lastly, chapter five discusses potential measurements of economic activity from environmental flows and suggests other methods for quantifying the value of water to ecosystems.

Table 11: Description of Potential Water Allocation Scenarios and Value Measurement

SCENARIO	DESCRIPTION OF SCENARIO
Status Quo	Total Value of Irrigated Agriculture, Including Mutual-Use Benefits to Water Recreation
Scenario 1	Impact of 8% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation
Scenario 2	Impact of 8% Reduction in irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation
Scenario 3	Impact of 8% Reduction in Irrigated Acreage; 1/3rd Converted to Dryland; 5% Reduction to Recreation Visitation
Scenario 4	Impact of 17% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation
Scenario 5	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation
Scenario 6	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; 10% Reduction to Recreation Visitation

Chapter 5: Results

Chapter four proposed that economic activity attributable to water in agriculture can be calculated as a sum of direct value to farmers, mutual use benefits to ecosystems and recreation upstream and downstream, and economic spillovers to supporting industries (equation 1). This chapter calculates the sum of economic activity from agriculture and recreation related to water and estimates potential impacts to those sectors if irrigated acreage is reduced to meet growing municipal and industrial demand. The first section contains the results of the IMPLAN analysis of economic activity related to irrigated agriculture and economic spillovers (indirect and induced activity) from irrigated agriculture. The next section provides estimates of economic activity from recreation expenditures based on values culled from previous surveys and studies and adds calculation of economic spillovers from those activities using multipliers from IMPLAN. The results also include a survey of potential economic values of environmental flows in the Arkansas Basin. Aggregate impacts corresponding to the scenarios presented in table 11 above are given at the end of the chapter; impacts are given in terms of total dollars, dollars per irrigated acre, dollars per acre foot, and full-time equivalent jobs.

Agriculture

The modified IMPLAN model explained in chapter 4 produced the following results. Irrigated agriculture in the Arkansas Basin provides 4,661 agricultural jobs (full-time equivalents) and almost $700 million in direct economic activity. About 40% of the $700 million is labor and proprietor income; the other 60% of economic activity goes towards input and operation costs. Dryland wheat farming provides 474 jobs and about $38.5

million in economic output. For comparison, this is about 10% of the employment provided by irrigated crop farming and about 5% of total irrigated output. Table 12 below shows economic output and employment for the main cropping sectors in the Arkansas River Basin.

Table 12: Irrigated and Dryland Agriculture, Direct Employment and Output

Direct Output Arkansas Basin Crop Farming				
Industry Description	**Employ-ment**	**Value Added***	**Intermediate Expenditures****	**Total Output**
Grain farming	3,399	$78,548,607	$197,579,689	$276,128,296
All other crop farming	696	$142,559,627	$177,003,057	$319,562,683
Greenhouse, nursery, & floriculture	239	$23,198,823	$12,048,663	$35,247,486
Vegetable and melon farming	204	$28,325,301	$13,928,060	$42,253,365
Oilseed farming	113	$8,688,674	$10,859,017	$19,547,691
Fruit farming	11	$1,324,782	$1,130,498	$2,455,281
Total Irrigated Crops	**4,661**	**$282,645,814**	**$412,548,984**	**$695,194,802**
Dryland Wheat	474	$7,792,115	$30,707,923	$38,500,038

*Labor and property income, minus subsidies **Input costs

Indirect and induced multipliers for each ag sector are shown in table 13 below. The indirect multiplier reflects economic spillovers to supporting industries; the induced multiplier reflects household expenditures from labor and proprietor income.

Table 13: Economic Multipliers of Irrigated and Dryland Agriculture

Economic Multipliers Arkansas Basin Crop Farming				
Industry Description	**Direct Effects**	**Indirect Effects**	**Induced Effects**	**Total Multiplier**
Oilseed farming	1.0000	0.2434	0.1269	1.3703
Grain farming	1.0000	0.4142	0.1200	1.5342
Vegetable and melon farming	1.0000	0.1619	0.2936	1.4555
Fruit farming	1.0000	0.2099	0.2714	1.4813
Greenhouse, nursery, and floriculture	1.0000	0.0979	0.3101	1.4080
All other crop farming	1.0000	0.2718	0.2216	1.4934
Average Irrigated Farming	**1.0000**	**0.2332**	**0.2239**	**1.4571**
Dryland wheat	1.0000	0.4367	0.1083	1.5450

Each agricultural sector has a very different indirect and induced multiplier. Dryland wheat has a very high indirect multiplier (.44) and a low induced multiplier (.11). This is because dryland wheat farming has a low ratio of income to expenses. Said another way, input and operations costs make up most of the economic activity from dryland farming. Conversely, vegetable and melon farming has a high induced multiplier but a low indirect multiplier because returns are high relative to input costs. For comparison, table 14 shows the multipliers of the largest industries in the Arkansas Basin (by employment). The average multiplier of irrigated agriculture sectors (1.46) is just slightly smaller than the average of all economic sectors in the region (1.49). The multiplier for Dryland Wheat (1.55) is slightly larger than the average for all industries in the region. Note, however, that multipliers DO NOT reflect output per acre. Dryland wheat creates significantly less economic activity per acre, which will be illustrated in table 17.

Table 14: Economic Multipliers of Largest Industries in Arkansas Basin by Employment

Economic Multipliers of Largest Employers			
Industry	**Indirect Multiplier**	**Induced Multiplier**	**Total Multiplier**
Federal government* (military)	0.0000	0.4696	1.4696
Food services and drinking places	0.2442	0.2580	1.5023
State & local govt*, Education	0.0000	0.5361	1.5361
State & local govt*, Non-education	0.0000	0.5353	1.5353
Real estate establishments	0.2388	0.0824	1.3211
Offices of physicians, dentists, and other health pract.	0.2414	0.4255	1.6669
Retail stores - General merchandise	0.1790	0.3090	1.4879
Retail non-stores - Direct and electronic sales	0.2283	0.1304	1.3586
Construction, other new nonresidential structures	0.2662	0.3370	1.6031
Average of All Industries in Region	**0.2725**	**0.2284**	**1.4939**

The agricultural sector multipliers from table 13 above are used to calculate the economic spillovers from Arkansas Basin agriculture, shown in table 15 below. Again, economic spillovers are the sum of indirect economic activity from supporting industries, and induced economic activity from labor and proprietor earnings.

Table 15: Economic Spillovers from Irrigated and Dryland Agriculture

Economic Spillovers from Arkansas Basin Crop Farming			
Industry Description	**Indirect Activity**	**Induced Activity**	**Total Economic Spillovers**
Grain farming	$67,208,705	$35,041,670	$102,250,375
All other crop farming	$132,358,778	$38,354,192	$170,712,970
Greenhouse, nursery, and floriculture	$5,704,912	$10,349,719	$16,054,631
Vegetable and melon farming	$8,870,419	$11,466,712	$20,337,131
Oilseed farming	$1,913,886	$6,062,153	$7,976,039
Fruit farming	$667,351	$544,057	$1,211,408
Total Irrigated Crops	**$216,724,051**	**$101,818,504**	**$318,542,555**
Dryland Wheat	$16,812,098	$4,171,059	$20,983,157

The total economic activity generated by an industry is a sum of direct activity and economic spillovers. Table 16 shows the total economic activity from each crop sector. The total activity attributable to irrigated agriculture is over $1 billion; total activity from dryland wheat is about $60 million. The lion's share of total economic activity from agriculture in the Arkansas Basin (over 80%) comes from irrigated farming of grains and hay (mostly corn, wheat, and alfalfa).

Table 16: Total Economic Activity from Irrigated and Dryland Agriculture

Total Economic Activity	
Industry Description	
Grain farming	$378,378,671
All other crop farming	$490,275,653
Greenhouse, nursery, and floriculture	$51,302,117
Vegetable and melon farming	$62,590,496
Oilseed farming	$27,523,730
Fruit farming	$3,666,689
Total Irrigated Crops	**$1,012,982,693**
Dryland Wheat	$59,483,195

Table 17 shows economic activity from irrigated agriculture in aggregate dollars, dollars per irrigated acre, dollars per acre-foot of water withdrawn for crop irrigation, and dollars per full-time equivalent job. To determine the average economic activity per acre of irrigated land, total economic activity is divided by the total number of irrigated acres in the region, according to the 2007 USDA Census of Agriculture. On average, an acre of irrigated agriculture supports $2,206 annually in total economic activity, $1,514 from direct activity and $692 from economic spillovers. An acre of dryland wheat supports about $237 annually in total economic activity. On an acre-by-acre basis, irrigated agriculture supports almost ten times as much economic activity as dryland wheat farming.

Dividing total economic activity by the number of acre-feet of water withdrawn for crop irrigation in the region (from USGS, Ivahnenko & Flynn, 2010) estimates the dollars of economic activity generated per acre-foot of irrigation water. On average, an acre-foot of water withdrawn for crop irrigation generates $637 in economic activity related to agriculture, $437 from direct activity and $200 from economic spillovers.

The last measurement in table 17 is dollars of economic activity per full-time equivalent employee (FTE). The total economic activity from irrigated agriculture equates to an average of $131,516 per FTE. Dryland wheat induces $89,461 per FTE. Dryland farming requires more labor per dollar of farm gate sales, so although the employment multiplier for dryland farming is high, the output per employee is much lower than for irrigated cropping.

Table 17: Measurements of Economic Activity from Agriculture – Irrigated and Dryland

Value of Arkansas Basin Agriculture			
Measurement	**Direct Impact**	**Spillovers**	**Total Impact**
Total Value of Irrigated Acres	$695,194,802	$317,787,891	$1,012,982,693
Per Irrigated Acre	$1,514	$692	$2,206
Per Acre Foot	$437	$200	$637
Per Employee (Full-Time Equivalent)	$149,166	$104,473	$131,516
Total Value of Dryland Wheat Acres	$38,500,038	$20,983,157	$59,483,195
Per Dryland Wheat Acre	$153	$84	$237
Per Employee (Full-Time Equivalent)	$81,258	$109,797	$89,461

In the table above, activity per acre, per acre-foot, and per FTE represent *average* value*s*. This does not mean that losing an acre-foot of water would mean losing $637 in economic activity nor that an additional acre of irrigated agriculture would generate $2,206. The impact of a one unit gain or loss at a given point in time is the *marginal* impact. This study did not estimate the *marginal* value of additional water or acres of farmland, which would be subject to a myriad of factors at a particular moment in time, such as crop prices and drought conditions.

The two tables on page 90 show the economic impact of potential reductions to irrigated agriculture. Reductions of 8% and 17% were made to the direct output of the five irrigated agriculture sectors. Note that because IMPLAN multipliers reflect the multiplying effects of final demand rather than output, they slightly overestimate the impact of a shock to output of one or more industries. (The over-estimate comes from IMPLAN multipliers double-counting sales from the shocked industry(s) to other industries.) To correctly estimate the multiplier effects of reduced output, direct purchase coefficients were exported from IMPLAN and input/output calculations were performed manually to avoid double counting sales from the six agricultural sectors.

The first table below shows the impact from reduced crop acreage; the second table shows the potential mitigating effects of increased dryland wheat farming. These tables, used together, provide a range of forecasts of economic impacts from reduced acres of irrigated agriculture. For example, if a 17% reduction to irrigated acreage could cause a $174 million loss in total economic activity, but if 1/3rd of the lost acreage is replaced by dryland wheat that brings $6 million in economic activity, the net loss would be $168 million. These estimates may overestimate impacts somewhat because they assume that acreage reductions occur to all crops equally. Realistically, lower valued crops and less productive lands would be fallowed before higher value crops and more productive lands. Note that loss of economic activity from the least productive acres (lowest economic output) would be significantly less than the impacts estimated below.

Economic impact can also be measured in units of jobs lost or created by contractions or expansions to one or more economic sectors. IMPLAN calculates employment multipliers for each sector based on national averages of output per worker. Multipliers are reported in number of full-time equivalent jobs per million dollars of output. Table 20 below shows the predicted job impacts from potential reductions to irrigated agriculture output. The potential mitigating effects of increased dryland agriculture are presented in table 21.

Table 18: Potential Economic Impacts from Reductions to Irrigated Agriculture

Impact of Reductions to Irrigated Agriculture		8% Reduction			17% Reduction		
Industry Description	**Current Output**	**Direct Impact**	**Spillovers**	**Total Impact**	**Direct Impact**	**Spillovers**	**Total Impact**
Grain farming	$276,128,296	-$22,090,264	-$11,195,533	-$33,285,797	-$46,941,810	-$23,790,508	-$70,732,318
All other crop farming	$319,562,683	-$25,565,015	-$11,934,593	-$37,499,608	-$54,325,656	-$25,361,011	-$79,686,667
Greenhouse, nursery, and floriculture	$35,247,486	-$2,819,799	-$1,105,783	-$3,925,582	-$5,992,073	-$2,349,789	-$8,341,861
Vegetable and melon farming	$42,253,365	-$3,380,269	-$1,475,048	-$4,855,317	-$7,183,072	-$3,134,476	-$10,317,548
Oilseed farming	$19,547,691	-$1,563,815	-$558,501	-$2,122,316	-$3,323,107	-$1,186,815	-$4,509,923
Fruit farming	$2,455,281	-$196,422	-$90,675	-$287,098	-$417,398	-$192,685	-$610,083
Total Irrigated Crops	**$695,194,802**	**-$55,615,584**	**-$26,360,134**	**-$81,975,718**	**-$118,183,116**	**-$56,015,284**	**-$174,198,400**

Table 19: Potential Economic Activity from Increased Dryland Wheat Production

Potential Mitigating Effects of Increased Dryland Wheat Production				
Dryland Wheat Augmentation	**Additional Acres (Dryland Wheat)**	**Direct Output**	**Spillovers**	**Total Economic Activity**
8% Reduction to Irrigated				
1/3rd Acreage Converted to Dryland Wheat	12,244	$1,880,803	$977,570	$2,858,373
All Acreage Converted to Dryland Wheat	36,732	$5,642,410	$2,932,709	$8,575,118
17% Reduction to Irrigated				
1/3rd Acreage Converted to Dryland Wheat	26,019	$3,996,707	$2,077,335	$6,074,042
All Acreage Converted to Dryland Wheat	78,056	$11,990,120	$6,232,006	$18,222,127

Table 20: Potential Employment Impacts from Reductions to Irrigated Agriculture

Employment Impacts	Direct Output	Direct Employment	Percent of Ag Employment	Total Employment	Percent of Regional Employment
Irrigated Ag Status Quo	$695,194,802	4,660.5	90.77%	7,702.3	1.45%
8% Shock to Irrigated	-$55,615,584	-604.0	-11.76%	-949.9	-0.18%
17% Shock to Irrigated	-$118,183,116	-1,283.4	-25.00%	-2,018.5	-0.38%

Table 21: Potential Employment Growth from Increased Dryland Wheat Production

Potential Mitigating Effects of Increased Dryland Wheat Production			
Dryland Wheat Augmentation	**Direct Output**	**Change in Direct Employment**	**Change in Total Employment**
8% Shock to Irrigated			
1/3rd Acreage Converted to Dryland Wheat	$40,409,060	23.5	33.0
All Acreage Converted to Dryland Wheat	$44,170,667	69.8	97.9
17% Shock to Irrigated			
1/3rd Acreage Converted to Dryland Wheat	$42,524,964	49.5	69.5
All Acreage Converted to Dryland Wheat	$50,518,377	147.9	207.6

It is interesting to evaluate which supporting industries would suffer the greatest impact from reduced irrigated cropping. The following table shows the ten IMPLAN sectors that would suffer the greatest losses in dollars of output. Some of these sectors are exactly what one would expect, such as loss of electrical utility income from reduced irrigation pumping and loss of income to agricultural support services. Others, however, seem unusual, such as loss to "imputed rental activity from owner-occupied dwellings". These peculiarities represent the nature of IMPLAN, which uses national averages and generalizations of economic activity by sector.

Table 22: Sectors suffering greatest losses with reduced irrigated agriculture

Sectors with Greatest Losses		
IMPLAN Sector	**8% Reduction**	**17% Reduction**
Real estate establishments	-$5,270,087	-$11,198,934
Monetary authorities and depository credit intermediation activities	-$2,894,799	-$6,151,448
Imputed rental activity for owner-occupied dwellings	-$1,632,350	-$3,468,743
Electric power generation, transmission, and distribution	-$1,150,391	-$2,444,581
Support activities for agriculture and forestry	-$920,268	-$1,955,569
Wholesale trade businesses	-$808,810	-$1,718,722
Food services and drinking places	-$705,587	-$1,499,372
Other state and local government enterprises	-$647,186	-$1,375,271
Offices of physicians, dentists, and other health practitioners	-$609,304	-$1,294,771
Fertilizer manufacturing	-$604,905	-$1,285,423

In summary, irrigated agriculture creates $695 million in direct economic activity and $318 million in economic spillovers. This translates to 4,660 full-time jobs from direct activity and another 3,042 jobs indirectly. Dryland wheat farming generates $38.5 million in direct economic activity and another $21 million in economic spillovers. This translates to 474 and 190 full-time equivalent jobs, respectively. Irrigated agriculture provides ten times as many jobs as dryland agriculture, although dryland ag provides more jobs per dollar of output. Dryland wheat farming has high economic and employment multipliers, meaning that a large proportion of dollars spent and earned on dryland wheat farming gets re-spent within the Arkansas River Basin. The total economic activity from dryland wheat farming, however, is quite small. The mitigating effects of replacing irrigated acreage lost with dryland acreage, therefore, would be economically negligible. However, it should be noted the mitigating effects are being compared to the *average* value of irrigated agriculture. Reductions to irrigated acreage at the margin would most likely occur to the least productive lands and lowest value crops. The mitigating effects of dryland wheat would be more significant compared to marginally unproductive agriculture than when compared to average values.

This section has discussed in detail the value of irrigated agriculture versus dryland agriculture. A main contribution of this study is the addition of mutual-use benefits from water used in irrigated agriculture. The next section will quantify the mutual-use benefits to water recreation.

Recreation

This section describes the economic activity generated by water recreation activities in the Arkansas River Basin. Multiplying the average number of user-days in the Arkansas Headwaters Recreation Area, Pueblo Reservoir, and John Martin Reservoir by daily visitor expenditure estimates from the 2009 Corona Research survey yields an estimate of average annual expenditures made by water recreation enthusiasts. Average annual water recreation expenditures in these three areas total about $223 million. This is an estimate of direct economic activity, comparable in units to the agriculture estimates made above. Note that these expenditures represent daily costs or *variable* costs, not capital purchases such as boats, kayaks, or fly-rods. Visitor numbers, expenditures per visitor, and total recreation expenditures are shown in table 23 below for average visitation rates 2007 – 2011, and given 5% and 10% reductions in visitation that could hypothetically occur if water is transferred from agriculture to other uses.

Table 23: Recreation Expenditures by Site

Scenario	Site	Visitors* (Average 2007 - 2011)	Expenditures per Visitor per Day**	Total expenditures
No Change	Arkansas Headwaters Recreation Area	751,967	$81.36	$61,180,051
	Pueblo Reservoir	1,753,748	$86.54	$151,769,352
	John Martin Reservoir	121,468	$78.82	$9,574,108
	Totals	**2,627,183**		**$222,523,511**
5% Reduction to Visitation	Arkansas Headwaters Recreation Area	714,369	$81.36	$58,121,049
	Pueblo Reservoir	1,666,061	$86.54	$144,180,884
	John Martin Reservoir	115,395	$78.82	$9,095,402
	Totals	**2,495,824**		**$211,397,336**
10% Reduction to Visitation	Arkansas Headwaters Recreation Area	676,770	$81.36	$55,062,046
	Pueblo Reservoir	1,578,373	$86.54	$136,592,417
	John Martin Reservoir	109,321	$78.82	$8,616,697
	Totals	**2,364,465**		**$200,271,160**

*From Colorado Department of Parks and Wildlife **From Corona Research, 2009

Economic multipliers were taken from IMPLAN to estimate the indirect and induced economic activity from the $223 million in recreation expenditures. The average economic multipliers from sectors related to recreation (sporting goods, food, accommodations, fuel) appear in table 24 below, along with indirect, induced, and total economic activity representative of these multipliers. Economic spillovers total $127 million, bringing total economic activity from water recreation to $349 million. If water transfers decreased reservoir levels and instream flows, and those decreases led to a 10% reduction in recreation visitors, total economic activity from water recreation would fall to about $314 million per year.

Table 24: Multipliers and Economic Spillovers from Recreation Expenditures

Economic Activity from Water Recreation Expenditures				
Measure	**Direct**	**Indirect**	**Induced**	**Total**
Multiplier	1.00	0.2714	0.2974	1.5688
Economic Activity	$222,523,511	$60,390,365	$66,182,568	$349,096,445
5% Reduced Visitation	$211,397,336	$57,370,847	$62,873,440	$331,641,623
10% Reduced Visitation	$200,271,160	$54,351,329	$59,564,312	$314,186,800

Table 25 includes the job impacts based on the average employment multipliers of outdoor recreation retail, service, and hospitality sectors. A 10% reduction in recreation visitation could cost 450 full-time equivalent jobs.

Table 25: Employment from Direct and Total Recreation Expenditures

Employment from Water Recreation Expenditures				
Measure	**Direct Employment**	**Direct Activity per FTE**	**Total Employment**	**Total Activity per FTE**
Multiplier	15.5277		20.3161	
Status Quo	3,455.3	$64,401	4,520.8	$49,222
5% Reduced Visitation	3,282.5	$64,401	4,294.8	$49,222
10% Reduced Visitation	3,109.8	$64,401	4,068.7	$49,222

Presumably, expenditures vary more by type of recreation activity than by site of recreation. To test this hypothesis, an effort was made to compare recreation expenditures by site to expenditures by type of recreation activity. Recreation activities related to Arkansas River water are split into five categories: River Boating, River Fishing, Reservoir Boating, Reservoir Fishing, and other General Water Recreation. Again, due to time and funding constraints, it was not possible to conduct an original survey to capture visitation and expenditures data, so data was drawn from previous research. As explained in chapter 3, the practice of extrapolating valuation results from one region or resource and projecting those numbers on another region or resource is referred to as *benefit transfer* (Young, 2005; Rosenberger & Loomis, 2001). For example, the value of a river fishing user-day in the upper Arkansas basin may be estimated by applying the value (or an average of values) estimated from another similar river (or rivers).

Chapter 3 discussed a variety of market and non-market methodologies that can be used to measure the value of water to agriculture, recreation and ecosystems. Using these methods, researchers have estimated the value of water in lakes, reservoirs, and river basins around the world. Oregon State University (Rosenberger) and Colorado State University (Loomis & Richardson) house databases of recreation studies that have estimated consumer surplus per user, per day, for a variety of outdoor recreation activities. Consumer surplus measures the amount individuals are willing to pay, beyond what they are required to pay in order to participate. It can be described as the area under the demand curve. Consumer surplus is a useful metric for comparing the relative value or benefit of different policy scenarios, but consumer surplus is not synonymous to economic activity, the metric used to measure the value of water in agriculture in step 1.

In order to measure economic activity, this study attempts to estimate actual recreation expenditures, not willingness-to-pay. Recreation expenditure data is surprisingly sparse in economics literature. Considerable sleuthing was required to locate the estimates of daily expenditures provided in table 26 below. With the exception of expenditure estimates from the world-class Glen Canyon fishery and rafting and kayaking on the Klamath River, the expenditures by activity listed below are not drastically different than the state park visitation expenditures used in economic activity calculations above.

Table 26: Estimates of Expenditures per User-Day for Five Recreation Categories

Recreation Activity	Typical Daily Expenditures	Author,Year, and Location
River Boating	$57; $121; $218	Stratus Consulting (2000), (Kayaking) Golden Whitewater Park, CO; Greiner & Werner (2012), (Commercial Rafting) Arkansas River, CO; Johnson & Moore (1993), (Rafting and Kayaking) Klamath River, OR/CA
River Fishing (Cold Water)	$57; $393	U.S. Fish & Wildlife (2006), Trout, Nationwide; Douglas & Harpman (1994), Lee's Ferry AZ, Colorado River
Reservoir Fishing (Warm Water)	$75	Loomis & Ng (2009), Pueblo State Park
Reservoir Boating	$107	Hushak (2000), Ohio Lakes & Reservoirs
Other River/Lake Recreation	$82	Corona Research (2009); Average Expenditures ARHA, Pueblo Reservoir, and John Martin Reservoir

"River Boating" includes private kayaking, private rafting, and commercial rafting. Daily expenditures are significantly different for each of these activities, so a range of values are provided. Although these expenditure estimates may be more valid that the averages revealed by the 2009 Corona Research survey, determining the number of user-days for each activity proved more difficult. Managers of the Arkansas Headwater Recreation Area estimate the number of annual user-days for a variety of activities, including fishing, boating, camping, and picnicking, using ratios from a 2001 survey of visitors. Unfortunately, more precise data on the number of activity-days per year is not currently available. Collecting this data would likely require a robust survey of recreation enthusiasts throughout the Arkansas Basin, but would improve the validity of estimates of recreation expenditures.

Recreation and Water Levels

Sale or lease of agricultural water rights could impact river and reservoir water levels, which could impact economic activity from water recreation activities. In order to evaluate how visitation rates may be correlated with water levels, visitation numbers in low-flow years were compared to the number of visitors that would be expected if water levels were typical. To estimate expected visitation numbers, user-days were normalized to average visitation growth rates from 1991-2011, using a normal (near median) flow year (1991) as the base year. For example, average annual growth in river boating user days from 1991 – 2011 was 2.63%. In 1991, a normal flow year, ARHA estimated 208,657 boater-days on the Upper Arkansas River. Given 2.63% annual growth, we would expect about 278,000 boater days in 2002, if flows were near median. In 2002, a drought year where average summer flows were only about 32% of normal summer flows, there were 194,076 boater-days; about 70% of the 278,000 boater-days that would have been expected in 2002 if it were a normal flow year. The table below compares actual boater-days to expected boater days in drought years 1992, 2002, 2004, 2005, and 2010.

Table 27: Drought year user-days compared to expected and average user-days for normal flow levels

Drought Year	Boater-Days			Summer flow level as % of median
	Average	Expected**	Actual*	
1992	283,252	214,151	236,292	83%
2002	283,252	277,706	194,076	32%
2004	283,252	292,521	272,553	69%
2005	283,252	300,223	301,307	83%
2010	283,252	341,883	286,284	77%

(*Arkansas Headwater Recreation Area visitor data; Average summer flow (May-Sept) data from USGS. **Expected user-days are based on average annual growth rates

In the lowest flow years, 2002, 2004, and 2010, boater-days were significantly less than would have been expected for normal flows in those years. During lesser droughts, such as 1992 and 2005, actual boater-days were still very close to expected boater days. This is a very rudimentary analysis (statistical significance cannot be accurately calculated from this small sample of data), however, it appears that small changes to flow levels (say, less than 15%), have a negligible influence upon user-days. An in-depth statistical analysis of the correlation between flow levels and user-days and/or expenditures should be performed to account for the myriad of factors that may affect river recreation. User-day growth rates were much higher from 1991-2000 than they have been since, indicating that the state of the economy may be a significant factor in river recreation. This and other endogenous factors make it difficult to estimate expected user-days or compare low-flow years over time without performing a comprehensive regression analysis of river recreation user-days. This type of analysis is possible, however, and suggested for future research efforts on this topic.

Just a few estimates of the correlation between water levels and recreation can be found in academic literature. Via survey, Hanson et al. (2002) found that a 1-foot lowering of reservoir levels in Alabama could decrease user expenditures 4% to 30%, depending on the reservoir. In 1980, Walsh et al. calculated that the marginal benefit of an acre-foot of water was highest ($52/AF) on western Colorado rivers in August and September when rivers were flowing at about 35% of maximum. This was a sum of benefits to fishing, kayaking, and rafting. Leones et al. (1997) found through a regression analysis of rafter behavior on the Rio Grande River in New Mexico that the influence of water levels on visitor numbers depends upon the particular river stretch. Their results confer with the assumption made in this study that, while visitor days may depend upon flow levels, expenditures per day do not vary much with flows (Leones et al. 1997). Brown et al. (1991) suggest that a more efficient approach to determining how flow-levels affect visitation may be to simply request an expert's judgment. Since many fishing, rafting and kayaking experts exist in the Arkansas Basin, this may be the easiest, cheapest, and perhaps most accurate way to determine how river flows influence visitation and expenditures. The takeaway here is that, given the sparse literature, this study cannot draw definitive conclusions about the relationship between water levels and recreation visitors. 5% and 10% reductions to visitation are modeled above. In the table of aggregate impacts provided at the end of this chapter the 5% and 10% reductions in visitation are assumed to coincide with 8% and 17% reductions in irrigated agricultural acreage.

Potential direct economic impacts from 5% and 10% reductions to recreation visitors are $11 million and $22 million, respectively. Total impact to economic activity from those reductions could be $17.5 million and $35 million, respectively. The reductions could cost 225 and 450 full-time equivalent jobs. These impacts would be additional to the agricultural impacts. Total impacts are summarized at the end of this chapter.

Ecosystem Services and Irrigated Agriculture

As explained in chapter 4, it is difficult to put the value of ecosystem services related to irrigated agriculture into units of economic activity like the agriculture and recreation values shown above. However, the replacement cost method and the hedonic valuation method could be used to estimate economic activity from agro-ecosystems that is not directly related to agricultural production or recreation. Replacement cost or avoided cost methods could be used to estimate costs averted in the Arkansas Basin because of the presence environmental flows, for example from pollution dilution or fire and flood protection. Note that these values would likely reflect *decreased* economic activity, since natural disasters and pollution mitigation efforts generate economic activity.

Avoided and replacement cost methods measure a direct use value of an ecosystem. Ecosystems also offer *passive use* benefits. Economist Alan Randall has been evaluating what he calls non-commodity outputs of agriculture (Randall, 2002, 2007). He argues that the value of agriculture includes passive use value to individuals who may see no production value benefits from agriculture, and that passive use values must be included in measurement of the total economic value of agricultural land (Randall, 2007). Indeed, inhabitants may simply enjoy the sights and sounds of irrigated agriculture and may be willing to pay more to live in areas where agriculture is present. A study of property values (hedonic valuation method) could determine the economic activity related to passive use of agro-ecosystems, specifically the influence of proximity to farmland on real estate prices. In their study of Pennsylvania property values Ready and Abdalla (2005) found that proximity to open space and pasture land was positively correlated with property values, but proximity to animal production facilities was negatively correlated. A similar analysis of the Arkansas Basin could provide an estimate of economic activity from the passive use value of irrigated agriculture. This would represent value capitalized over many years of home ownership, but could be converted into an annual value and added to the agricultural production and recreation values presented above.

Although a hedonic property value study could provide an estimate of economic activity from non-commodity benefits of agricultural production in the Arkansas Valley, these benefits are not explicitly ecosystem service benefits. Ecosystem service valuation more commonly determines consumer surplus or willingness-to-pay, not economic activity. The contingent valuation method has been used to estimate willingness-to-pay for environmental flows. For example, Loomis et al. (2000) calculated that households in the South Platte River Basin would be willing to pay $332 per year in order to ensure ecosystem services related to river flow levels. There are 390,772 households in the Arkansas Basin. If just 10% of households in the Arkansas Basin were willing to pay $332/year for environmental flows, e-flows would represent a value of $13 million; if 90% of Arkansas Basin households were willing to pay $332 annually, that number would leap to $117 million. To be clear, these numbers, $13 million - $117 million, represent a range of potential consumer surplus from environmental flows, not economic activity.

Summary Scenarios

The scenarios presented in table 27 below provide a range of estimates of the value of water in agriculture and impacts of reductions to irrigated acreage. If water is sold or leased from agricultural users to municipal or industrial uses, some of the formerly irrigated lands will likely be used to farm dryland wheat. Dryland farming is considerably less productive than irrigated farming, so the mitigating effects of replacing irrigated acres with dryland wheat are marginal. If water transfers decrease instream flows and lower reservoir levels, fewer people may participate in water recreation activities. The table includes the impacts of hypothetical reductions in the number of water recreation visitors (5% and 10%) that may be correlated with 8% and 17% reductions in irrigated acreage. The aggregate value and impacts are also converted to dollars per irrigated acre, dollar per acre-foot, and full-time equivalent jobs. This assumes that recreation values and impacts are directly related to agricultural acres.

Total economic attributable to irrigated agriculture and water recreation in the basin is $1.36 billion. This number represents economic activity from agriculture, mutual-use benefits to recreation, and the economic spillovers from both industries. Scenario 1 represents the direct and indirect impacts of an 8 percent reduction in irrigated acreage of all crop sectors. Impacts of reduced irrigated acreage would be lessened if 1/3rd of lost acreage were converted to dryland wheat, which is modeled in scenario 2. Scenario 3 adds impacts from a 5% reduction in water recreation visitation, modeling potential impacts if water removed from agriculture decreases demand for water recreation. Scenarios 4, 5, and 6 represent impacts from a 17 percent reduction in irrigated acreage, potential mitigating effects of dryland wheat, and a 10% reduction in recreation visitation, respectively.

Impacts would be least if dyland farming replaces some of the lost economic activity and if water levels for recreation are maintained. Impacts would be greatest if lost irrigated acreage was entirely fallowed and if transfers impacted water levels and decreased recreation visitation.

Table 27: Total Economic and Employment Impacts from Six Scenarios

SCENARIO	DESCRIPTION OF SCENARIO	AGRICULTURE	RECREATION	TOTAL	TOTAL EMPLOYMENT
Scenario 1	Impact of 8% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation	-$81,975,718	No Loss to Rec	-$81,975,718	-949.9
Scenario 2	Impact of 8% Reduction in irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation	-$79,117,345	No Loss to Rec	-$79,117,345	-916.9
Scenario 3	Impact of 8% Reduction in Irrigated Acreage; 1/3rd Converted to Dryland; 5% Reduction to Recreation Visitation	-$79,117,345	-$17,454,822	-$96,572,167	-1143.0
Scenario 4	Impact of 17% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation	-$174,198,400	No Loss to Rec	-$174,198,400	-2018.5
Scenario 5	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation	-$168,124,358	No Loss to Rec	-$168,124,358	-1949.0
Scenario 6	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; 10% Reduction to Recreation Visitation	-$168,124,358	-$34,909,644	-$203,034,003	-2401.1

Table 28: Total Economic and Employment Impacts from Six Scenarios per Irrigated Acre and Acre Foot

SCENARIO	DESCRIPTION OF SCENARIO	PER IRRIGATED ACRE	PER ACRE FOOT*	EMPLOYMENT PER THOUSAND IRRIGATED ACRES	EMPLOYMENT PER THOUSAND ACRE FOOT*
Scenario 1	Impact of 8% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation	-$2,232	-$644	-25.9	-7.5
Scenario 2	Impact of 8% Reduction in irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation	-$2,154	-$622	-25.0	-7.2
Scenario 3	Impact of 8% Reduction in Irrigated Acreage; 1/3rd Converted to Dryland; 5% Reduction to Recreation Visitation	-$2,629	-$759	-31.1	-9.0
Scenario 4	Impact of 17% Reduction in Irrigated Acreage; None Converted to Dryland Wheat; No Loss to Recreation	-$2,232	-$644	-25.9	-7.5
Scenario 5	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; No Loss to Recreation	-$2,154	-$622	-25.0	-7.2
Scenario 6	Impact of 17% Reduction in Irrigated Acreage; 1/3rd Acres Converted to Dryland Wheat; 10% Reduction to Recreation Visitation	-$2,601	-$751	-30.8	-8.9

(*Includes economic activity from water recreation)

How is Ag Water Related to Mutual Uses

The value of water in agriculture in the Arkansas Basin is a sum the value of irrigated agriculture and other economic activities that use agricultural water. If these other activities do not negatively impact the amount of water or quality of water available to crop irrigation, they may be considered mutual-use benefits of irrigated agriculture. The value of water at a point along the river is a sum of its values at that location, plus the value of prior or subsequent uses. It has been shown above that recreation and ecosystem services can be mutual uses that contribute significantly to the value of water allocated to agriculture. The question that remains is: Would these mutual-use benefits exist if water were allocated to other uses?

Water that is sold or leased by farmers has clear impacts to agriculture and supporting industries the Arkansas Basin, as shown in the results from the two shocks modeled above. The impacts to recreation and ecosystems depend upon where and when water is diverted, and how much is returned to the river basin. As explained in chapter 2, municipal and industrial uses return a large proportion of the water they withdraw. According to the 2010 USGS study by Ivanhenko and Flynn, 90% of water withdrawn for M&I is eventually returned to a river system. If these return flows occur within the Arkansas Basin, total flows downstream could theoretically increase with transfers from agriculture to municipal and industrial uses, maintaining or even augmenting mutual-use benefits to recreation and ecosystems. If water is transferred out of the basin, both agriculture and mutual-use benefits will be harmed.

Chapter 6: Summary and Conclusions

Summary

Water in the Arkansas River basin is scarce. Water rights holders will continue to lease and sell their rights to willing buyers. Re-allocations of water often are primarily motivated by differences in price elasticities of demand among users (deLange, 2006), but the Arkansas River watershed has many stakeholders who are not party to these transfers and are not included in traditional use-value estimates. This process can neglect the socio-economic and environmental impacts of allocation decisions. This research effort compares water valuation methodologies and estimates the total economic activity from agriculture and mutual-use sectors. Adding mutual-use values brings us closer to a comprehensive "value of water" estimate, a step closer to determining the full costs of transferring water from agriculture to other uses.

Many economic valuation methods exist which can measure the value of water to different stakeholders. An in-depth review of these methods is provided in chapter 3. "Value" may be represented as economic activity, economic benefit, jobs, or consumer and producer surplus, depending on the valuation method, and care must be taken to not compare apples and oranges. This study measures the value of water to agriculture and recreation primarily in units of economic activity, dollars spent because of the presence of water. Direct economic activity and economic spillovers from agriculture are estimated by modifying a generalized input-output model (IMPLAN) to more closely represent farming in the Arkansas River Basin. Expenditures estimates from a previously conducted travel-costs survey (Corona Research, 2009) are used to estimate dollars spent by water recreation visitors. Multipliers from the IMPLAN model enable estimation of economic spillovers from these expenditures. Methods for calculating the value of ecosystem services in terms of economic activity and consumer surplus are discussed. This study uses the valuation strategies above to estimate the value of water in agriculture in the Arkansas River basin and suggests ways in which these estimates could be improved.

The total annual economic activity from irrigated agriculture in the Arkansas Basin is $1,013 million. If all irrigated acreage were converted to dryland wheat (a hypothetical exercise, not a real possibility), the dryland wheat farming would create $108 million in activity. Therefore, the surplus economic activity of irrigation is $905 million. These dollars, which includes agricultural output and economic spillovers from agriculture, support farmers, farming supply industries, and rural communities. The transportation and storage of irrigation water in the Arkansas River Basin supports another $349 million in annual economic activity related to recreation expenditures. This does NOT include capital expenditures on boats, kayaks, fly-rods, etc. and therefore should be considered a low estimate of economic activity from recreation. Together, irrigated agriculture and recreation generate $1.36 billion in economic activity, which converts to $2,889 per irrigated acre or $857 per acre-foot of water withdrawn for agriculture.

Table 29: Total Economic Activity and Employment from Irrigated Agriculture and Recreation

STATUS QUO	AGRICULTURE	RECREATION	TOTAL	TOTAL EMPLOYMENT
Total Value of Irrigated Agriculture, Including Mutual-Use Benefits to Water Recreation	$1,013,737,357	$349,096,445	$1,362,833,802	12,223.2

Water used in agriculture may offer additional environmental benefits. The bucolic landscape provided by irrigated agriculture has existence and bequest value to residents and visitors, and area homeowners may benefit from increased property value. The diversion of agricultural water creates verdant oases in an otherwise arid region, providing habitat for birds, bugs, and other aquatic life. A study of the South Platte Basin revealed that households were willing to pay about $332 annual to preserve these ecosystem services (Loomis et al., 2003). If roughly half of Arkansas Basin households have a similar willingness to pay, the consumer surplus from ecosystem services would be around $65 million.

The 2010 Statewide Water Supply Initiative (SWSI), which received considerable input from the Colorado Water Conservation Board, has predicted that the Arkansas Basin would need to fallow 8% - 17% of irrigated acres by 2050 to meet municipal and industrial water demand in the area. Agriculture and supporting industries would clearly be impacted by ag-to-urban transfers. An 8% reduction to irrigated acreage could reduce economic activity related to agriculture in the region by $82 million and cost 950 jobs. Converting 1/3rd of the lost acres to dryland wheat could reduce the impact by only about $3 million and save about 33 full-time job equivalents. Further impacts could occur to recreation industries that benefit from water currently allocated to agriculture downstream. Although recreation expenditures and water levels are certainly correlated, a robust econometric study of the relationship between instream flow levels and recreation expenditures would need to be performed in order to estimate the expected impact of reduced flows. Ecosystems and ecosystem services could also be impacted by reduced agriculture. The benefits of ecosystems are most commonly measured in terms of consumer surplus, a measure of social benefit which is based on individuals' willingness-to-pay, but ecosystems can contribute to economic activity as well through their influence on property values. The dollar values, annualized, from a hedonic property valuation should be added to the economic activity from agriculture and recreation.

The results of this study conclude with a significant caveat: It is impossible to estimate the impact of water transfers without knowing the exact nature of the impending transfer. In order to accurately estimate the value of water in a river basin, the valuation methods must account for the river basin's unique hydrogeography. This study has discussed the importance of the location of water diversions relative to one another, and the importance of return flows. Municipal and industrial water diversions that occur downstream from the Pueblo Reservoir and that return significant flows within the basin would have a much lesser economic and environmental impact than diversions that take place upstream and divert water out of the basin permanently.

Limitations

The limitations of this study can be split into two main categories: Limitations of data, and limitations of design. Collecting comprehensive recreation visitor numbers could improve the validity of estimates of economic activity from recreation. If this data were available over many years (time series data), visitation rates could be regressed on flow levels (and other control variables) to determine the impact of flow levels on recreation. Data is presumably available to conduct a hedonic property value study, but that exercise was simply beyond the time and resource limitations of this effort.

The design of this study could benefit from expanding the scope of stakeholders and impacts and by incorporating dynamic economic interactions. Many alternative water uses and externalities exist that are not considered in the value estimates above. An exhaustive valuation of water would include all third-party benefits and positive and negative externalities from a nearly infinite array of allocation possibilities. For example, although agricultural uses return a large portion of water withdrawn, ag uses can increase the salinity and temperature of the water rendering it less valuable in production, consumption, and ecological purposes downstream. This research does not estimate empirically the negative externalities of irrigated agriculture and its mutual uses. Also, water allocation decision makers should compare the benefits and costs of water in agriculture to the potential benefits and costs of alternative uses. In other words, this study measures the economic impact of reduced irrigated acreage, but does not estimate the economic impact of increased municipal and industrial water use. Lastly, this compound model needs a counterfactual analysis. The model must estimate the economic value of agriculture and associated uses given varying quantities of water transfers from ag to municipal and industrial uses. Measuring the value of water in agriculture and impacts to agricultural uses alone does not allow us to analyze total social welfare. As Ward and Michelsen state in their review of the value of water in agriculture, *"…an important objective of water allocation policy…is to allocate the water resource to those agricultural, residential, industrial, recreational, endangered species, and other uses that will make the most productive use of the water available for these purposes* (Ward and Michelsen, 2002)." Municipal and industrial water demand represents a large and growing share of interests. In order to understand the value of water to ag producers, future research should aim to compare the ag value to the value of water to other entities.

It should also be noted that government intervention (subsidies) or market weaknesses (i.e. incomplete information) may mean water values are different than they would be under competitive equilibrium. If markets are distorted, value of water estimates may not reflect society's interests, regardless of the method of imputation (Young, 2005). Market distortions are not considered in this study.

The second shortcoming has to do with the inability of this model to track dynamic changes to the Arkansas River Basin economy over time. An input/output model uses fixed coefficients, meaning the model cannot represent changes to economies of scale or input substitution. An ideal model could respond dynamically to represent general equilibrium outcomes. Furthermore, the impacts are presented as homogeneous throughout the basin, while in reality impacts would be localized to the areas where transfers take place. Although the basin-wide impacts could be negligible, impacts to particular rural communities in the eastern plains with few economic alternatives could be devastating. Agriculturally dependent communities may see this research as an opportunity to share the potential plight of water transfers with upper basin recreational interests, thereby bringing greater concern to the issue.

These limitations aside, this research brings us much closer to understanding the value of water allocated to agriculture. Although this study does not represent the value of Arkansas Basin water to all stakeholders, it represents more interests than many previous studies.

Conclusions

Water scarcity is a hot topic in Colorado these days. This study arose from the need to provide more information to decision makers about the value of water to agricultural producers in the Arkansas River Basin. Another motive for this study was the fact that natural resource allocation decisions often underestimate or overlook the value of the resource to some stakeholders. The overall impact of natural resource allocation decisions can be analyzed by evaluating the impact of the allocation on each stakeholder group. Consideration of all stakeholder values could result in more equitable and efficient allocation of resources in general.

It has been shown that the Arkansas River Watershed has numerous stakeholders, many of whom are impacted by transfers of water from Ag to M&I. Multiple valuation strategies need to be employed in order to compare the value of water between different stakeholders. Different valuation methods are required for measuring the value of water to agricultural, industrial and municipal, and recreational users, as well as the value of in-stream flows. Different valuation methods use different units to measure value, and care needs to be taken not to compare apples and orange.

The geography of the Arkansas Basin has created a unique interplay between farmers and recreationists. The fact that most Arkansas Basin water rights are held by downstream farmers means that transportation and storage of ag water offers mutual-use benefits upstream. Almost all agricultural impacts from transfers will occur in the Lower Basin, and almost all recreation impacts will occur in the Upper Basin. Paddlers and fishermen should take an interest in where and when farmers sell or lease their water rights.

On one hand, the results of this study may overestimate the value of water to agriculture because the model assumes that acreage is reduced to all crops equally, when in reality the lowest value crops and/or least productive lands would be the first victims of water transfers. On the other hand, these results may underestimate the value of water to agriculture because the input/output model does not include forward linkages to industries that use agricultural crops, such as cattle production or food processing. Recreation expenditure estimates surely underestimate economic activity from water recreation because a) many private recreationists may not appear in the numbers from the three state parks evaluated in this study, and b) some proportion of high-ticket gear expenditures can be attributed to recreational opportunities in the Arkansas Basin.

Evaluating the economic activity created by ecosystems is tricky. Ecosystem service valuation is a young discipline, and although methods for calculating economic activity from ecosystems is improving, measuring consumer surplus is perhaps more appropriate. The environmental value of water allocated to agriculture in the Arkansas Basin is ambiguous because, although agriculture may keep more water in basin waterways than other uses, ag may have a harmful effect on water quality. The more appropriate question may be: Do people prefer agro-ecosystems to other environments? And what would they be willing to pay to protect agro-ecosystems?

While some stakeholders worry that emphasis on monetary valuation of water will lead to unsustainable resource use decisions (deLange, 2006), the fact remains that people respond to prices. Bahtia et al. (2002) have shown that if water resources are managed in an integrated fashion where the economics, legal and environmental aspects complement each other, increased prices do improve equity, efficiency and sustainability of the resource. Relative to markets for other goods, markets for water and particularly water ecosystems are very poorly developed. This means there is an opportunity to nurture a market that is more holistic, i.e. one that includes all stakeholders and internalizes spatial and temporal externalities. It is difficult for any market to integrate information about long-run impacts. In order to ensure sustainability, resource allocation decisions should not discount future stakeholder values and prioritize present interests. The goal, rather, should be to maximize net welfare over many generations. While this approach may seem radical and politically untenable, I believe a strong argument can be made that it will appropriately address the goals of "optimal" allocation and sustainability.

Like all resource decisions, water allocation decisions will involve trade offs. Relative to the total economy of the Arkansas Basin, agriculture is a minor component, but potential equity issues are significant. Waterways may redistribute money from affluent urban areas to poor rural areas via irrigation, recreation, tourism, and supporting business. The compound model recommended in this paper does not offer a comprehensive valuation of water, but it does bring us significantly closer than current methods. I am curious if the results from this model will support water allocation decisions that differ from status quo.

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Appendix 1: Enterprise Budgets

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Southeastern Colorado - Irrigated Alfalfa

Estimated Production Costs & Returns — **NUMBER OF ACRES** **100**

GROSS RECIPTS FROM PRODUCTION							
GROSS RECIPTS	**Unit**	**Price**	**Yield**	**Per Acre**	**Per Ton**	**Estimated Value to Farm**	**YOUR FARM**
ALFALFA	BU	$130.00	6	$780	$130.00	$78,000	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$780**	**$130.00**	**$78,000**	**$0**

DIRECT COSTS							
	Unit	**Cost/ Unit**	**Quantity**	**Cost Per Acre**	**Cost Per Bu**	**Estimated Value to Farm**	**YOUR FARM**
OPERATING PREHARVEST							
ESTABLISHMENT ALLOC	ACRE	$31.00	1.00	$31	$5.17	$3,100	
FERT. (P)	ACRE	$45.00	1.00	$45	$7.50	$4,500	
HERBICIDE	ACRE	$25.00	1.00	$25	$4.17	$2,500	
INSECTICIDE	ACRE	$20.00	1.00	$20	$3.33	$2,000	
CUSTOM AERIAL SPRAY	ACRE	$6.00	1.00	$6	$1.00	$600	
IRRIGATION LABOR	ACRE	$25.00	1.00	$25	$4.17	$2,500	
INTEREST	ACRE	$12.92	1.00	$13	$2.15	$1,292	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$165**	**$27.49**	**$16,492**	**$0**
HARVEST COSTS							
REPAIR & MAINTENANCE	ACRE	7.00	1.00	7	1.17	$700	
LABOR	ACRE	5.00	1.00	5	0.83	$500	
CUSTOM SWATH	ACRE	17.00	1.00	17	2.83	$1,700	
CUSTOM BALING	ACRE	17.00	1.00	17	2.83	$1,700	
CUSTOM HAUL/STACK	ACRE	16.00	1.00	16	2.67	$1,600	
Total Harvest Costs				62	$10.33	6,200.00	
Total Operating Costs				**$227**	**$37.82**	**$22,692**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	3.33	$2,000	
OWNERSHIP COSTS	ACRE	16.00	1.00	16	2.67	$1,600	
REAL ESTATE TAXES	ACRE	12.00	1.00	12	2.00	$1,200	
DEPRECIATON	ACRE	73.00	1.00	73	12.17	$7,300	
	ACRE	0.00	1.00	0	0.00	$0	
Total Property & Ownership Costs				121	$20.17	12,100.00	$0
Total Direct Costs				**$348**	**$57.99**	**$34,792**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**$432**	**$72.01**	**$43,208**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50	$8.33	$5,000	
RETURN TO MANAGEMENT & RISK				**$382**	**$63.68**	**$38,208**	**$0**

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Southern Colorado - Cantaloupe

Estimated Production Costs & Returns — **NUMBER OF ACRES** **20**

GROSS RECIPTS FROM PRODUCTION

GROSS RECIPTS	Unit	Price	Yield	Per Acre	Per Bu	Estimated Value to Farm	YOUR FARM
CANTALOUPE	BOX	$10.40	700	$7,280	$10.40	$145,600	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$7,280**	**$10.40**	**$145,600**	**$0**

DIRECT COSTS

	Unit	Cost/ Unit	Quantity	Cost Per Acre	Cost Per Bu	Estimated Value to Farm	YOUR FARM
OPERATING PREHARVEST							
FERTILIZER	ACRE	$77.42	1.00	$77	$0.11	$1,548	
SEED	ACRE	$125.00	1.00	$125	$0.18	$2,500	
TRANSPLANTS	ACRE	$250.00	1.00	$250	$0.36	$5,000	
INSECTICIDE	ACRE	$60.00	1.00	$60	$0.09	$1,200	
HERBICIDE	ACRE	$125.00	1.00	$125	$0.18	$2,500	
FUNGICIDE	ACRE	$40.00	1.00	$40	$0.06	$800	
CUSTOM FERTILIZER APP.	ACRE	$6.00	1.00	$6	$0.01	$120	
BLACK PLASTIC INSTALLED	ACRE	$225.00	1.00	$225	$0.32	$4,500	
IRRIGATION ENERGY	ACRE	$15.00	1.00	$15	$0.02	$300	
IRRIGATION REPAIR	ACRE	$10.00	1.00	$10	$0.01	$200	
WATER SHARES	ACRE	$25.00	1.00	$25	$0.04	$500	
FUEL & OIL	ACRE	$34.32	1.00	$34	$0.05	$686	
LABOR	ACRE	$60.00	1.00	$60	$0.09	$1,200	
INTEREST	ACRE	$89.48	1.00	$89	$0.13	$1,790	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$1,142**	**$1.63**	**$22,844**	**$0**
HARVEST COSTS							
CUSTOM HARVEST w/ LABOR	ACRE	550.00	1.00	550	0.79	$11,000	
REPAIR & MAINTENANCE	ACRE	15.00	1.00	15	0.02	$300	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
Total Harvest Costs				565	$0.81	11,300.00	
Total Operating Costs				**$1,707**	**$2.44**	**$34,144**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	0.03	$400	
OWNERSHIP COSTS (Mach)	ACRE	35.00	1.00	35	0.05	$700	
MISC OR OTHER	ACRE	0.00	1.00	0	0.00	$0	
REAL ESTATE TAXES	ACRE	8.00	1.00	8	0.01	$160	
DEPRECIATON	ACRE	210.00	1.00	210	0.30	$4,200	
Total Property & Ownership Costs				273	$0.39	1,260.00	$0
Total Direct Costs				**$1,980**	**$2.83**	**$35,404**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**$5,300**	**$7.57**	**$110,196**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50			
RETURN TO MANAGEMENT & RISK				**$5,250**	**$7.57**	**$110,196**	**$0**

2007 Estimated Production Costs and Returns - Chili Peppers in Southern Colorado

	Unit	Price or Cost/Unit	Quantity	Value or Cost Per Acre	Value or Cost/Unit Production	Your Farm
GROSS RECEIPTS FROM PRODUCTION:						
CHILI PEPPERS	BU	10.00	600	6,000.00		
TOTAL RECEIPTS				**6,000.00**	**10.00**	
DIRECT COSTS						
Operating Preharvest						
CUSTOM FERTILIZER APPLICATION	ACRE	4.50	2	9.00	0.02	
FERTILIZER (11-25-0)	LB	0.30	250	75.00	0.13	
FERTILIZER (32-0-0)	LB	0.07	300	21.00	0.04	
INSECTICIDE (Asana)	ACRE	18.00	1.00	18.00	0.03	
BLACK PLASTIC w/INSTALLATION	ACRE	225.00	1.00	225.00	0.38	
FUNGICIDE (2 lbs of Bravo + 1 pt Cocide)	ACRE	14.00	1.00	14.00	0.02	
CUSTOM FUNGICIDE APPLICATION	ACRE	6.00	1.00	6.00	0.01	
HAND LABOR (Planting)	HR	10.00	6.00	60.00	0.10	
SEED	LB	40.00	2	80.00	0.13	
HAND LABOR (Weeding)	ACRE	40.00	4	160.00	0.27	
OPERATOR LABOR	ACRE			14.04	0.02	
IRRIGATION ENERGY	ACRE			12.00	0.02	
WATER SHARES	ACRE			24.00	0.04	
FUEL	ACRE			30.37	0.05	
REPAIR & MAINTENANCE	ACRE			13.30	0.02	
INTEREST EXPENSE	DOLS			34.88	0.06	
Total Preharvest	DOLS			**796.59**	**1.33**	
Operating Harvest						
HAND PICKING	ACRE			500.00	1.00	
Total Harvest				**500.00**	**0.83**	
Total Operating Costs				**1,296.59**	**2.16**	
Property and Ownership Costs						
MACHINERY OWNERSHIP COSTS	DOLS			71.38	0.12	
Total Property and Ownership Costs	DOLS			**71.38**	**0.12**	
TOTAL DIRECT COSTS				**1,367.97**	**2.28**	
NET RECEIPTS BEFORE FACTOR PAYMENTS				**4,632.03**	**7.72**	
FACTOR PAYMENTS						
LAND @ 4.00%	DOLS			0.00	0.00	
RETURN TO MANAGEMENT AND RISK	DOLS			**4,632.03**	**7.72**	

BREAKEVEN ANALYSIS - PER ACRE RETURNS OVER TOTAL DIRECT COSTS ($/ACRE)

			ALTERNATIVE PRICES $/TON				
			-25%	-10%		+10%	+25%
			$ 7.50	$ 9.00	$ 10.00	$ 11.00	$ 12.50
ALTERNATIVE YIELDS	-25%	450	$2,007.03	$2,682.03	$ 3,132.03	$ 3,582.03	$ 4,257.03
	-10%	540	$2,682.03	$3,492.03	$ 4,032.03	$ 4,572.03	$ 5,382.03
TONS		600	$3,132.03	$4,032.03	$ 4,632.03	$ 5,232.03	$ 6,132.03
	+10%	660	$3,582.03	$4,572.03	$ 5,232.03	$ 5,892.03	$ 6,882.03
	+25%	750	$4,257.03	$5,382.03	$ 6,132.03	$ 6,882.03	$ 8,007.03

Ag Management Guide 2009

Southern Colorado - Irrigated Corn

Estimated Production Costs & Returns — **NUMBER OF ACRES** 200

GROSS RECIPTS FROM PRODUCTION

GROSS RECIPTS	Unit	Price	Yield	Per Acre	Per Bu	Estimated Value to Farm	YOUR FARM
CORN	BU	$3.96	200	$792	$3.96	$158,400	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$792**	**$3.96**	**$158,400**	**$0**

DIRECT COSTS

	Unit	Cost/ Unit	Quantity	Cost Per Acre	Cost Per Bu	Estimated Value to Farm	YOUR FARM
OPERATING PREHARVEST							
FERTILIZER N	ACRE	$77.42	1.00	$77	$0.39	$15,484	
SEED	ACRE	$56.00	1.00	$56	$0.28	$11,200	
HERBICIDE	ACRE	$23.00	1.00	$23	$0.12	$4,600	
INSECTICIDE	ACRE	$15.00	1.00	$15	$0.08	$3,000	
CUSTOM AERIAL SPRAY	ACRE	$8.00	1.00	$8	$0.04	$1,600	
SPRAY (OTHER)	ACRE	$0.00	1.00	$0	$0.00	$0	
IRRIGATION ENERGY	ACRE	$52.00	1.00	$52	$0.26	$10,400	
IRRIGATION REPAIR	ACRE	$10.00	1.00	$10	$0.05	$2,000	
SPRINKER LEASE	ACRE	$60.00	1.00	$60	$0.30	$12,000	
CROP CONSULTANT	ACRE	$8.00	1.00	$8	$0.04	$1,600	
CROP INSURANCE	ACRE	$23.00	1.00	$23	$0.12	$4,600	
REPAIR & MAINTENANCE	ACRE	$10.00	1.00	$10	$0.05	$2,000	
FUEL & OIL	ACRE	$14.30	1.00	$14	$0.07	$2,860	
LABOR	ACRE	$6.00	1.00	$6	$0.03	$1,200	
INTEREST	ACRE	$30.83	1.00	$31	$0.15	$6,166	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$394**	**$1.97**	**$78,710**	**$0**
HARVEST COSTS							
CUSTOM HARVESTING	ACRE	30.00	1.00	30	0.15	$6,000	
HAULING	ACRE	25.00	1.00	25	0.13	$5,000	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
Total Harvest Costs				55	$0.28	11,000.00	
Total Operating Costs				**$449**	**$2.24**	**$89,710**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	0.10	$4,000	
OWNERSHIP COSTS (Mach)	ACRE	35.00	1.00	35	0.18	$7,000	
MISC OR OTHER	ACRE	0.00	1.00	0	0.00	$0	
REAL ESTATE TAXES	ACRE	8.00	1.00	8	0.04	$1,600	
DEPRECIATON	ACRE	51.50	1.00	52	0.26	$10,300	
Total Property & Ownership Costs				115	$0.57	12,600.00	$0
Total Direct Costs				**$563**	**$2.82**	**$102,310**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**$229**	**$1.14**	**$56,090**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50			
RETURN TO MANAGEMENT & RISK				**$179**	**$1.14**	**$56,090**	**$0**

Colorado State University — Department of Agricultural and Resource Economics

Ag Management Guide 2009

Southern Colorado - Irrigated Corn (Silage)

Estimated Production Costs & Returns — NUMBER OF ACRES **200**

GROSS RECIPTS FROM PRODUCTION							
GROSS RECIPTS	**Unit**	**Price**	**Yield**	**Per Acre**	**Per Ton**	**Estimated Value to Farm**	**YOUR FARM**
CORN - SILAGE	BU	$32.00	25	$800	$32.00	$160,000	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$800**	**$32.00**	**$160,000**	**$0**

DIRECT COSTS	**Unit**	**Cost/ Unit**	**Quantity**	**Cost Per Acre**	**Cost Per Bu**	**Estimated Value to Farm**	**YOUR FARM**
OPERATING PREHARVEST							
FERTILIZER N	ACRE	$60.00	1.00	$60	$2.40	$12,000	
SEED	ACRE	$60.00	1.00	$60	$2.40	$12,000	
HERBICIDE	ACRE	$35.00	1.00	$35	$1.40	$7,000	
INSECTICIDE	ACRE	$16.00	1.00	$16	$0.64	$3,200	
CUSTOM AERIAL SPRAY	ACRE	$8.00	1.00	$8	$0.32	$1,600	
SPRAY (OTHER)	ACRE	$0.00	1.00	$0	$0.00	$0	
IRRIGATION ENERGY	ACRE	$52.00	1.00	$52	$2.08	$10,400	
IRRIGATION REPAIR	ACRE	$10.00	1.00	$10	$0.40	$2,000	
SPRINKLER LEASE	ACRE	$60.00	1.00	$60	$2.40	$12,000	
CROP CONSULTANT	ACRE	$8.00	1.00	$8	$0.32	$1,600	
CROP INSURANCE	ACRE	$25.00	1.00	$25	$1.00	$5,000	
REPAIR & MAINTENANCE	ACRE	$10.00	1.00	$10	$0.40	$2,000	
FUEL & OIL	ACRE	$20.02	1.00	$20	$0.80	$4,004	
LABOR	ACRE	$6.00	1.00	$6	$0.24	$1,200	
INTEREST	ACRE	$31.45	1.00	$31	$1.26	$6,290	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$401**	**$16.06**	**$80,294**	**$0**
HARVEST COSTS							
CUSTOM CUT/HAUL	ACRE	35.00	1.00	35	1.40	$7,000	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
Total Harvest Costs				35	$1.40	7,000.00	
Total Operating Costs				**$436**	**$17.46**	**$87,294**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	0.80	$4,000	
OWNERSHIP COSTS (Mach)	ACRE	60.00	1.00	60	2.40	$12,000	
REAL ESTATE TAXES	ACRE	0.00	1.00	0	0.00	$0	
DEPRECIATON	ACRE	52.50	1.00	53	2.10	$10,500	
	ACRE	0.00	1.00	0	0.00	$0	
Total Property & Ownership Costs				133	$5.30	26,500.00	$0
Total Direct Costs				**$569**	**$22.76**	**$113,794**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**$231**	**$9.24**	**$46,206**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50			
RETURN TO MANAGEMENT & RISK				**$181**	**$9.24**	**$46,206**	**$0**

Ag Management Guide 2009

Southeastern Colorado - Irrigated Wheat

Estimated Production Costs & Returns — **NUMBER OF ACRES** **200**

GROSS RECIPTS FROM PRODUCTION

GROSS RECIPTS	Unit	Price	Yield	Per Acre	Per Ton	Estimated Value to Farm	YOUR FARM
WHEAT	BU	$6.35	70	$445	$6.35	$88,900	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$445**	**$6.35**	**$88,900**	**$0**

DIRECT COSTS

	Unit	Cost/ Unit	Quantity	Cost Per Acre	Cost Per Bu	Estimated Value to Farm	YOUR FARM
OPERATING PREHARVEST							
FERT. (N)	ACRE	$50.00	1.00	$50	$0.71	$10,000	
HERBICIDE	ACRE	$13.00	1.00	$13	$0.19	$2,600	
SEED	ACRE	$20.00	1.00	$20	$0.29	$4,000	
IRRIGATION ENERGY	ACRE	$32.00	1.00	$32	$0.46	$6,400	
IRRIGATION REPAIR	ACRE	$10.00	1.00	$10	$0.14	$2,000	
SPRINKLER LEASE	ACRE	$60.00	1.00	$60	$0.86	$12,000	
FUEL	ACRE	$12.00	1.00	$12	$0.17	$2,400	
REPAIR & MAINTENANCE	ACRE	$6.00	1.00	$6	$0.09	$1,200	
CROP INSURANCE	ACRE	$23.00	1.00	$23	$0.33	$4,600	
LABOR	ACRE	$2.00	1.00	$2	$0.03	$400	
INTEREST	ACRE	$19.38	1.00	$19	$0.28	$3,876	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$247**	**$3.53**	**$49,476**	**$0**
HARVEST COSTS							
CUSTOM HARVEST	ACRE	30.00	1.00	30	0.43	$6,000	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
Total Harvest Costs				30	$0.43	6,000.00	
Total Operating Costs				**$277**	**$3.96**	**$55,476**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	0.29	$4,000	
OWNERSHIP COSTS	ACRE	16.00	1.00	16	0.23	$3,200	
REAL ESTATE TAXES	ACRE	6.00	1.00	6	0.09	$1,200	
DEPRECIATON	ACRE	85.50	1.00	86	1.22	$17,100	
	ACRE	0.00	1.00	0	0.00	$0	
Total Property & Ownership Costs				128	$1.82	25,500.00	$0
Total Direct Costs				**$405**	**$5.78**	**$80,976**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**$40**	**$0.57**	**$7,924**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50	$0.71	$10,000	
RETURN TO MANAGEMENT & RISK				**-$10**	**-$0.15**	**-$2,076**	**$0**

Colorado State University — Department of Agricultural and Resource Economics

Ag Management Guide 2009

Southeastern Colorado - Dryland Wheat

Estimated Production Costs & Returns — **NUMBER OF ACRES** **1200**

GROSS RECIPTS FROM PRODUCTION							
GROSS RECIPTS	**Unit**	**Price**	**Yield**	**Per Acre**	**Per Ton**	**Estimated Value to Farm**	**YOUR FARM**
WHEAT	BU	$6.35	15	$95	$6.35	$114,300	
NET GOV'T PAYMENTS	ACRE			$0	$0.00	$0	
Total Receipts				**$95**	**$6.35**	**$114,300**	**$0**

DIRECT COSTS	**Unit**	**Cost/ Unit**	**Quantity**	**Cost Per Acre**	**Cost Per Bu**	**Estimated Value to Farm**	**YOUR FARM**
OPERATING PREHARVEST							
FERT. (N)	ACRE	$23.00	1.00	$23	$1.53	$27,600	
FERT. (P)	ACRE	$5.00	1.00	$5	$0.33	$6,000	
HERBICIDE (Banvel)	ACRE	$12.00	1.00	$12	$0.80	$14,400	
HERBICIDE (Roundup)	ACRE	$13.00	1.00	$13	$0.87	$15,600	
SEED	ACRE	$10.00	1.00	$10	$0.67	$12,000	
FUEL	ACRE	$13.00	1.00	$13	$0.87	$15,600	
REPAIR & MAINTENANCE	ACRE	$6.00	1.00	$6	$0.40	$7,200	
CROP INSURANCE	ACRE	$20.00	1.00	$20	$1.33	$24,000	
LABOR	ACRE	$2.00	1.00	$2	$0.13	$2,400	
INTEREST	ACRE	$8.84	1.00	$9	$0.59	$10,608	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
	ACRE	$0.00	1.00	$0	$0.00	$0	
Total Pre-Harvest Expenses				**$113**	**$7.52**	**$135,408**	**$0**
HARVEST COSTS							
CUSTOM CUTTING	ACRE	18.00	1.00	18	1.20	$21,600	
CUSTOM CUTTING OVER 20 BU	ACRE	2.70	1.00	3	0.18	$3,240	
CUSTOM HAUL	ACRE	2.70	1.00	3	0.18	$3,240	
	ACRE	0.00	1.00	0	0.00	$0	
	ACRE	0.00	1.00	0	0.00	$0	
Total Harvest Costs				23	$1.56	28,080.00	
Total Operating Costs				**$136**	**$9.08**	**$163,488**	**$0**
PROPERTY & OWNERSHIP COSTS							
GENERAL FARM OVERHEAD	ACRE	20.00	1.00	20	1.33	$24,000	
OWNERSHIP COSTS	ACRE	16.00	1.00	16	1.07	$19,200	
REAL ESTATE TAXES	ACRE	2.00	1.00	2	0.13	$2,400	
DEPRECIATON	ACRE	39.33	1.00	39	2.62	$47,200	
	ACRE	0.00	1.00	0	0.00	$0	
Total Property & Ownership Costs				77	$5.16	92,800.00	$0
Total Direct Costs				**$214**	**$14.24**	**$256,288**	**$0**
NET RECEIPTS BEFORE FACTOR PAYMENTS				**-$118**	**-$7.89**	**-$141,988**	**$0**
FACTOR PAYMENTS							
Land @ 4%				$50	$3.33	$60,000	
RETURN TO MANAGEMENT & RISK				**-$168**	**-$11.22**	**-$201,988**	**$0**

Appendix 2: Comparing Enterprise Budgets to IMPLAN Production Functions

Irrigated Wheat

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERTILIZER (N)	$0.71	$0.11	Fertilizer (3130)	$0.09	-$0.02	-24%
HERBICIDE	$0.19	$0.03	Pesticides (3131)	$0.06	$0.03	88%
SEED	$0.29	$0.05	Grains (3002)	$0.05	$0.00	3%
IRRIGATION ENERGY	$0.46	$0.07	.8 Electricity (3031)	$0.01	-$0.07	-1057%
IRRIGATION REPAIR	$0.14	$0.02	Agriculture…support services (3019)			
CUSTOM HARVEST	$0.43	$0.07	Agriculture…support services (3019)	$0.09	-$0.14	-160%
SPRINKLER LEASE	$0.86	$0.14	Agriculture…support services (3019)			
FUEL	$0.17	$0.03	Refined Petrol. Products (3115)	$0.10	$0.08	281%
REPAIR & MAINTENANCE	$0.09	$0.01	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.00	2%
CROP INSURANCE	$0.33	$0.05	NONE	$0.00	-$0.05	N/A
INTEREST	$0.28	$0.04	.75 Monetary authorities and credit (3354)	$0.05	$0.00	4%
GENERAL FARM OVERHEAD	$0.29	$0.05	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.03	-$0.01	-48%
OWNERSHIP COSTS (Mach)	$0.23	$0.04	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	-$0.01	-48%
FACTOR PAYMENTS	$0.71	$0.11	Real estate…and related services (3360)	$0.12	$0.01	5%
TOTAL COSTS	**$5.18**	**$0.82**	**RELATED IMPLAN SECTOR**	**$0.62**	-$0.19	-31%
Value Added Sector						
LABOR	$0.03	$0.00	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$0.09	$0.01	*Value Added* (Indirect Business Tax)			
RECIEPTS BEFORE FACTOR PAYMENTS	$1.05	$0.17	*Value Added* (Proprietor Income)			
VALUE ADDED	**$1.17**	**$0.18**				

Irrigated Corn						
COST	COST/BU	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDG.	Percent +/-
FERTILIZER (N)	$0.39	$0.10	Fertilizer (3130)	$0.09	-$0.01	-9%
SEED	$0.28	$0.07	Grains (3002)	$0.05	-$0.02	-51%
HERBICIDE	$0.12	$0.03	Pesticide (3131)	$0.06	$0.01	11%
INSECTICIDE	$0.08	$0.02	Pesticide (3131)			
CUSTOM AERIAL SPRAY	$0.04	$0.01	Agriculture…support services (3019)	$0.09	-$0.05	-58%
IRRIGATION REPAIR	$0.05	$0.01	Agriculture…support services (3019)			
CUSTOM HARVEST	$0.15	$0.04	Agriculture…support services (3019)			
SPRINKLER LEASE	$0.30	$0.08	Agriculture…support services (3019)			
IRRIGATION ENERGY	$0.26	$0.07	.8 Electricity (3031)	$0.01	-$0.06	-949%
CROP CONSULTANT	$0.04	$0.01	Misc tech services (3380)	$0.00	-$0.01	-466%
CROP INSURANCE	$0.12	$0.03	NONE	$0.00	-$0.03	N/A
REPAIR & MAINTENANCE	$0.05	$0.01	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.00	14%
FUEL & OIL	$0.07	$0.02	Refined Petrol. Products (3115)	$0.10	$0.08	477%
INTEREST	$0.15	$0.04	.75 Monetary authorities and credit (3354)	$0.05	$0.01	21%
HAULING	$0.13	$0.03	Truck Transport (3335)/Rail Transport (3333)	$0.02	-$0.02	-90%
GENERAL FARM OVERHEAD	$0.10	$0.03	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.03	$0.01	22%
OWNERSHIP COSTS (Mach)	$0.18	$0.05	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	-$0.02	-86%
FACTOR PAYMENTS	$0.25	$0.06	Real estate…and related services (3360)	$0.12	$0.05	87%
TOTAL COSTS	**$2.76**	**$0.70**	**RELATED IMPLAN COSTS**	**$0.64**	-$0.06	-9%
LABOR	$0.03	$0.01	*Value Added* (Employee Compensation)	$0.01		
REAL ESTATE TAXES	$0.04	$0.01	*Value Added* (Business Tax)	$0.01		
RECIEPTS BEFORE FACTOR P	$1.13	$0.29	*Value Added* (Proprietor Income)	$0.29		
VALUE ADDED	**$1.20**	**$0.30**		$0.30		

Irrigated Corn Silage

COST	COST/BU	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDG.	Percent +/-
FERTILIZER (N)	$2.40	$0.08	Fertilizer (3130)	$0.09	$0.02	20%
SEED	$2.40	$0.08	Grains (3002)	$0.05	-$0.03	-60%
HERBICIDE	$1.40	$0.04	Pesticide (3131)	$0.06	-$0.01	-14%
INSECTICIDE	$0.64	$0.02	Pesticide (3131)			
CUSTOM AERIAL SPRAY	$0.32	$0.01	Agriculture…support services (3019)	$0.06	-$0.03	-50%
IRRIGATION REPAIR	$0.40	$0.01	Agriculture…support services (3019)			
SPRINKLER LEASE	$2.40	$0.08	Agriculture…support services (3019)			
CUSTOM CUT/HAUL	$1.40	$0.04	.25 Agriculture…support services (3019); Truck Transport Services (3335)	$0.03	-$0.01	-31%
IRRIGATION ENERGY	$2.08	$0.07	.8 Electricity (3031)	$0.01	-$0.06	-939%
CROP CONSULTANT	$0.32	$0.01	Misc tech services (3380)	$0.00	-$0.01	-461%
CROP INSURANCE	$1.00	$0.03	NONE	$0.00	-$0.03	N/A
REPAIR & MAINTENANCE	$0.40	$0.01	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.00	15%
FUEL & OIL	$0.80	$0.03	Refined Petrol. Products (3115)	$0.10	$0.08	308%
INTEREST	$1.26	$0.04	Monetary authorities and crediit (3354)	$0.06	$0.02	55%
GENERAL FARM OVERHEAD	$0.80	$0.03	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.03	$0.01	23%
OWNERSHIP COSTS (Mach)	$2.40	$0.08	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	-$0.05	-207%
FACTOR PAYMENTS	$2.00	$0.06	Real estate…and related services (3360)	$0.12	$0.06	89%
TOTAL COSTS	**$22.42**	**$0.70**	**RELATED IMPLAN COSTS**	**$0.65**	-$0.05	-8%
LABOR	$0.24	$0.01	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$0.00	$0.00	*Value Added* (Business Tax)			
RECIEPTS BEFORE FACTOR P	$9.34	$0.29	*Value Added (Proprietor Income)*			
TOTAL VALUE ADDED	**$9.58**	**$0.30**				

Irrigated Alfalfa

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERTILIZER (P)	$7.50	$0.06	Fertilizer (3130)	$0.05	-$0.01	-15%
HERBICIDE	$4.17	$0.03	Pesticides (3131)	$0.05	$0.00	-8%
INSECTICIDE	$3.33	$0.03				
CUSTOM AERIAL SPRAY	$1.00	$0.01	Agriculture…support services (3019);	$0.09	$0.03	68%
CUSTOM SWATH	$2.83	$0.02				
CUSTOM BALING	$2.83	$0.02				
CUSTOM HAUL/STACK	$2.67	$0.02	.25 Agriculture…support services (3019); Truck Transport (3335); Rail Transport (3333)	$0.05	$0.03	149%
ESTABLISHMENT ALLOCATION	$5.17	$0.04	Grains (3002); All other crop farming (3010)	$0.05	$0.01	13%
FUEL	$0.00	$0.00	Refined Petrol. Products (3115)	$0.16	$0.16	#DIV/0!
INTEREST	$2.15	$0.02	.75 Monetary authorities and credit (3354)	$0.05	$0.03	207%
REPAIR & MAINTENANCE	$1.17	$0.01	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.00	-1%
GENERAL FARM OVERHEAD	$3.33	$0.03	Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.06	$0.04	150%
OWNERSHIP COSTS	$2.67	$0.02	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.03	$0.01	34%
FACTOR PAYMENTS	$8.33	$0.06	Real estate…and related services (3360)	$0.08	$0.01	20%
TOTAL COSTS	**$47.15**	**$0.36**		**$0.68**	$0.31	86%
LABOR	$0.83	$0.01	*Value Added* (Employee Compensation)			
IRRIGATION LABOR	$4.17	$0.03	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$2.00	$0.02	*Value Added* (Indirect Business Tax)			
RECIEPTS BEFORE FACTOR PAYMENTS	$75.85	$0.58	*Value Added* (Proprietor Income)			
VALUE ADDED	**$82.85**	**$0.64**				

Cantaloupe

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERTILIZER (P)	$0.11	$0.01	Fertilizer (3130)	$0.03	$0.02	177%
HERBICIDE	$0.18	$0.02	Pesticides (3131)	$0.05	$0.02	66%
INSECTICIDE	$0.09	$0.01				
FUNGICIDE	$0.06	$0.01				
SEED	$0.18	$0.02	.75 Vegetables and Melons (3003)	$0.01	-$0.01	-60%
TRANSPLANTS	$0.36	$0.04	.15 Agriculture…support services (3019); .25 Vegeatables and Melons (3003)	$0.02	-$0.02	-78%
IRRIGATION ENERGY	$0.02	$0.00	.8 Electricity (3031)	$0.02	$0.01	706%
IRRIGATION REPAIR	$0.01	$0.00	.85 Agriculture…support services (3019)	$0.09	$0.00	-4%
WATER SHARES	$0.04	$0.00				
CUSTOM FERTILIZER APPLICATION	$0.01	$0.00				
.75 CUSTOM HARVEST (Harvest)	$0.59	$0.06				
BLACK PLASTIC INSTALL	$0.32	$0.03				
FUEL	$0.05	$0.00	Refined Petrol. Products (3115)	$0.06	$0.06	1148%
REPAIR & MAINTENANCE	$0.02	$0.00	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.01	463%
.25 CUSTOM HARVEST (Haul)	$0.20	$0.02	Truck Transport (3335); Rail Transport (3333)	$0.01	-$0.01	-99%
INTEREST	$0.13	$0.01	.75 Monetary authorities and credit (3354)	$0.02	$0.01	59%
GENERAL FARM OVERHEAD	$0.03	$0.00	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.02	$0.02	682%
OWNERSHIP COSTS	$0.05	$0.00	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	$0.01	226%
FACTOR PAYMENTS	$0.07	$0.01	Real estate…and related services (3360)	$0.05	$0.05	653%
TOTAL COSTS	**$2.52**	**$0.25**		**$0.42**	**$0.17**	**68%**
LABOR	$0.09	$0.01	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$0.01	$0.00	*Value Added* (Indirect Business Tax)			
RECIEPTS BEFORE FACTOR PAYMENTS	$7.57	$0.74	*Value Added* (Proprietor Income)			
VALUE ADDED	**$7.67**	**$0.75**				

Chili Peppers

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERTILIZERS	$0.17	$0.02	Fertilizer (3130)	$0.03	$0.01	81%
INSECTICIDE	$0.03	$0.00	Pesticide (3131)	$0.05	$0.05	1007%
FUNGICIDE	$0.02	$0.00				
SEED	$0.13	$0.01	Vegetables and Melons (3003)	$0.01	$0.00	16%
IRRIGATION ENERGY	$0.02	$0.00	.8 Electricity (3031)	$0.02	$0.01	715%
WATER SHARES	$0.04	$0.00	.75 Agriculture…support services (3019)	$0.08	$0.04	90%
CUSTOM FERTILIZER APPLICATION	$0.01	$0.00				
CUSTOM FUNGICIDE APPLICATION	$0.01	$0.00				
BLACK PLASTIC INSTALL	$0.38	$0.04				
FUEL	$0.05	$0.00	Refined Petrol. Products (3115)	$0.06	$0.06	1160%
REPAIR & MAINTENANCE	$0.02	$0.00	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	$0.01	468%
CUSTOM HARVEST	$1.00	$0.10	.25 Agriculture…support serv. (3019); Truck Transport (3335); Rail Transport (3333)	$0.03	-$0.07	-210%
INTEREST	$0.06	$0.01	.75 Monetary authorities and credit (3354)	$0.02	$0.01	248%
GENERAL FARM OVERHEAD	$0.03	$0.00	.2 Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.02	$0.02	690%
OWNERSHIP COSTS	$0.12	$0.01	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	$0.00	37%
FACTOR PAYMENTS	$0.08	$0.01	Real estate…and related services (3360)	$0.05	$0.04	551%
TOTAL COSTS	**$2.17**	**$0.21**		**$0.41**	**$0.20**	95%
LABOR	$0.39	$0.04	*Value Added* (Employee Compensation)			
REAL ESTATE TAXES	$0.01	$0.00	*Value Added* (Indirect Business Tax)			
RECIEPTS BEFORE FACTOR PAYMENTS	$7.72	$0.75	*Value Added* (Proprietor Income)			
VALUE ADDED	**$8.12**	**$0.79**				

Dryland Wheat

ENTERPRISE BUDGET COST	COST/ BUSHEL	COST/ DOLLAR	MAPS TO IMPLAN SECTOR(S):	COST/ DOLLAR	DIFFERENCE: IMPLAN - ENT. BUDGET	PERCENT DIFFERENCE
FERT. (N)	$1.53	$0.10	Fertilizer (3130)	$0.09	-$0.03	-38%
FERT. (P)	$0.33	$0.02				
HERBICIDE (Banvel)	$0.80	$0.05	Pesticides (3131)	$0.06	-$0.06	-99%
HERBICIDE (Roundup)	$0.87	$0.06				
SEED	$0.67	$0.04	Grains (3002)	$0.05	$0.00	5%
CUSTOM CUTTING	$1.20	$0.08	Agriculture…support services (3019)	$0.09	-$0.01	-7%
CUSTOM CUTTING OVER 20 BU	$0.18	$0.01				
CUSTOM HAUL	$0.18	$0.01	Truck Transport (3335)/Rail Transport (3333)	$0.02	$0.01	44%
FUEL	$0.87	$0.06	Refined Petrol. Products (3115)	$0.09	$0.03	55%
REPAIR & MAINTENANCE	$0.40	$0.03	.25 Farm machinery and equip. (3203); Maintain/repair nonres. structures (3039); .25 Wholesale trade and dist. (3319)	$0.01	-$0.01	-85%
CROP INSURANCE	$1.33	$0.09	NONE	$0.00	-$0.09	N/A
INTEREST	$0.59	$0.04	.75 Monetary authorities and credit (3354)	$0.05	$0.01	16%
GENERAL FARM OVERHEAD	$1.33	$0.09	Electricity (3031); Natural Gas (3032);Water and Sewer (3033);Accounting (3368);Legal (3367); .25 Monetary authorities… (3354)	$0.04	-$0.05	-140%
OWNERSHIP COSTS (Mach)	$1.07	$0.07	.75 Wholesale trade (3319); .75 Farm Machinery and equip. (3203); Tires (3150); Vehicle Parts (3283)	$0.02	-$0.05	-193%
FACTOR PAYMENTS	$3.33	$0.22	Real estate…and related services (3360)	$0.12	-$0.11	-89%
TOTAL COSTS	**$14.68**	**$0.98**	**RELATED IMPLAN COSTS**	**$0.63**	-$0.36	-57%
LABOR	$0.13	$0.01	*Value Added* (Employee Compensation)	0.87%		
REAL ESTATE TAXES	$0.13	$0.01	*Value Added* (Indirect Business Tax)	0.87%		
RECIEPTS BEFORE FACTOR PAYMENTS	$0.00	$0.00	*Value Added* (Proprietor Income)	0.00%		
VALUE ADDED	**$0.26**	**$0.02**				