Identifying Cost-Effective Sources for Water Transfers from Agriculture to Endangered Species Preservation in the Platte River Basin

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Introduction

The Platte River Basin has four species listed as threatened or endangered under the federal Endangered Species Act (ESA), with a 56-mile long section of the Central Platte River designated as critical habitat. To comply with the ESA mandate for species recovery, it is estimated that 373,000 acre-feet of additional water must be made available annually to augment the current flows through the critical habitat (Frasier et al., 1999). In 1997 Nebraska, Wyoming, and Colorado entered into a cooperative agreement with the United States Secretary of the Interior to develop and implement a program that would increase stream flows to aid species recovery.

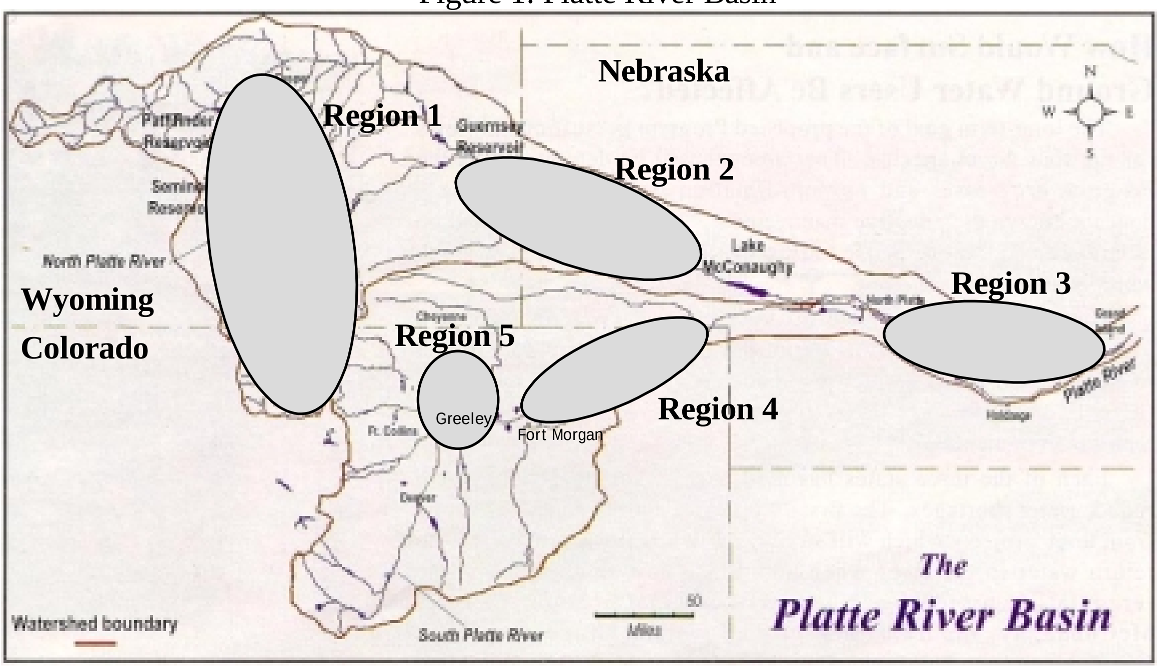
Construction of new water storage and conveyance facilities to meet these demands appears to be no longer feasible. The most cost effective sites have already been developed (Turner and Perry, 1997) and recent environmental concerns effectively prohibit new construction. Reallocation of water from current low-valued uses appears to be the lowest cost alternative to meet the emerging higher valued water demands. Irrigated agriculture being the largest water user and relatively low-valued at the margin is likely to be targeted to fulfill these endangered species habitat requirements. The question of identifying target sources within agriculture and the associated impacts still remains.

The economic model developed in this paper estimates the forgone agricultural value that is lost when transferring water from each of five agriculturally distinct regions across the Platte River Basin. The model is based on a Discrete Sequential Stochastic Programming (DSSP) approach, which is a technique that allows for decisions to be optimized through multiple stages of expected occurrences. The economic model is parameterized with output from a hydrologic model that accounts for the basin wide effects (return flow effects, transfer losses, changes in reliability, etc.) associated with transfers from the agricultural sector in each of the regions.

Modeling Framework

Based upon producer and irrigation district employee interviews conducted in June 1999, the basin was segmented into five regions with similar agricultural practices, water deliveries, water institutions, and weather (Figure 1). For each of these distinct regions a 1,000 acre representative farm was constructed from survey and census farm data.

Figure 1: Platte River Basin



The representative farm framework in each region varies in crops produced, crop yields, crop prices, cropping budgets, crop rotations, types of irrigation used, amount of irrigation water available, probability of water supplies, precipitation and the evapotranspiration (ET) requirements for each crop. Consequently, the value of water in agriculture varies across these regions due to the productivity of the lands and these other farm parameters.

Agricultural production is sequential in nature, where many farm decisions are influenced by earlier decisions and information that becomes available only after earlier choices have been made (Anderson, Dillon and Hardaker, 1977). To account for the sequential nature of agricultural production, the model incorporates the uncertainty of crop production into the objective function and allows for sequential decisions to be made. DSSP was developed by Cocks in 1968 to solve sequential decision problems under uncertainty.

DSSP is characterized by using a sequence of decision making time periods, a set of decision variables for each stage, discrete probabilities for each state of nature and stage, and a structure that logically represents the flow of information through the stages of the decision process (Kaiser and Apland 1989). The structure of the model can be viewed as a decision tree, where the decisions are linked in time sequence with their associated probabilities of outcomes. As we move along the decision tree we are faced with forks representing possible outcomes or decisions. If these event forks (state of natures) are not limited, the problem can quickly become too large to manage. The model in this study simplifies the farm decision process into two sequential time periods in which irrigation water can become available to the farm.

Due to the natural variability of stream flows and the stochastic variable is identified as the quantity of irrigation water available at these two time periods. Anderson, Dillon, and Hardaker (1977) recommend limiting states of nature that are essentially continuous by approximating discrete distributions into two or three categories. Irrigation water available in the first and second time periods is limited to three states of nature, either: wet, average, or dry water conditions. The first time period takes place from April 1st to June 30th. The decisions to be made at this time period determine the amount of the farm's land that will be used to grow each of the crops and how to efficiently irrigate them up to June 30th. The second time period begins July 1st and continues through the end of October. Irrigation water available in this period is allocated to grow all previously planted crops for the remainder of the growing season. The decisions made at this point will be the irrigation strategy that maximizes profits based on the water supply available, and the harvesting activities.

As formulated, the model has the ability to deficit irrigate in either one or both of the time periods subject to the supply of water available. The model identifies the optimal crop mix and optimal irrigation schedule based on the state of nature and time period by maximizing the total expected profit of the representative farm. The DSSP objective function maximizes total expected profit resulting from two sequential stages, subject to acreage, agronomic, and irrigation water constraints. Mathematically, the model is represented as follows:

$$\text{Max} \quad \sum_{k=1}^{5}\sum_{i=1}^{49}\sum_{s1=1}^{3}\sum_{s2=1}^{3}\Big[ACRE_{k,i,s1,s2}\big(Y_{ki} * (P_k - HC_k) - NC_{ki}\big) - \big(I_{k,i,s1,s2} * Ic \big)\Big] * P1_{s1} * P2_{s1,s2}$$

$$\begin{aligned}
\text{s.t.}: \quad & ACRE_{k,i,s1} + I_{k,i,s1} \leq Land \quad Available \\
& ACRE_{k} \leq B_k \\
& ACRE_{k,i,s1} * (Wreq\ 1_{k,i,s1} - R_1) \leq W1 \\
& ACRE_{k,i,s1,s2} * (Wreq\ 2_{k,i,s1,s2} - R_2) \leq W2 \\
& ACRE_{k,i,s1,s2} \leq ACRE_{k,i,s1}
\end{aligned}$$

where $ACRE_{k,i,s1,s2}$ is the quantity of acres planted for each crop k ($k = 1,\ldots,5$) across all irrigation strategies i (i = 1,…,49), for both of the time periods and all possible states of nature $s1,s2$ ($s1$ = 1,2,3 ; $s2$ = 1,2,3). The quantity of acres is multiplied by the crop yield and the difference between crop price, P_k, and the per unit cost of harvesting HC_k to get a per acre value of production that then has the per acre non-harvest costs subtracted NC_{ki}, the value of non-harvest costs is dependent upon crop (*k*) and irrigation strategy (*i*). The cost of maintaining idle land is then subtracted from the total value of all crop production. The quantity of idle land ($I_{k,i,s1,s2}$) is a function of all crops produced, irrigation strategies used, and all time periods and is multiplied by the cost of idle land (*Ic*). Finally, the expected returns, under each state of nature are weighted by the joint probability of its outcome ($P1_{s1,} * P2_{s1,s2}$).

The objective is subject to several constraints. The first constraint forces total acreage used by crops and idle land equal to the total land available. In the second constraint the B_k parameter represents the minimum rotational requirements for each of the crops. The third constraint limits the quantity of water used by the crops in the first time period ($Wreq_1$) minus the effective precipitation in the first time period (R_1) to be less than the amount of water available (*W1*). The fourth constraint requires that the total water required for each crop in the second time period ($Wreq_2$) less the areas effective precipitation (R_2) to be less than the total quantity of water available in the second time period (W*2*). The last constraint links the acreage planted of each crop in the first period ($ACRE_{k,i,s1}$) to the second time period ($ACRE_{k,i,s1,s2}$).

Due to the two sequential stages in the model and the variability of how crops respond to water stress we will see crop yields be affected differently depending upon the crop, magnitude of water stress, and timing of when water is taken away from the farm. The long run expected profitability will be determined for each representative region under the current baseline conditions and then compared to the estimated conditions after a specified policy scenario. Thus, allowing us to estimate the loss of economic activity associated with each of the policies for each of the five regions.

Data

The results of mathematical programming models are dependent upon the data that is used as input. Most of the data used in this economic model was derived from secondary data sources, and validated through producer interviews conducted throughout the basin. Along with regional farm parameters it was also necessary to identify the responsiveness of each crop to water stress so that different levels of irrigation could be evaluated based upon water availability.

Regional Cropping Data

The counties located in each of the five regions were identified and county-based farm census figures were used to estimate the average farm size and major irrigated crops produced. Once the major irrigated crops in each of the regions were identified cropping budgets were used to find the area-specific costs of production for each of the crops.

When seeking to value water, a consistent form, place, and time of water must be chosen as a reference point. Past valuation studies have valued water “at-the-point-of-diversion”, “at-the-plant”, or “at-the-headgate”. Valuation of water at the various reference places entails inclusion or exclusion of different costs in crop budgets. This study will measure the value of water at-the-headgate, thus cost to deliver to the headgate are excluded and costs after headgate (e.g. irrigation labor and equipment) are included.

Crop budgets from the repective state Cooperative Extension Services were used to estimate area-specific costs of production. The accounting stance of the budgets in the two states were not directly comparable and the costs had to be adjusted to create a comparable base.

Specifically, land costs, unpaid labor, management labor, and other fixed costs were adjusted to a comparable basis. For the regions located within Wyoming, cropping budgets were used based upon areas with similar characteristics in Colorado or Nebraska**.**

The value of crop sales reflect the state specific five-year average crop price. The crops considered in these regions are alfalfa, sugarbeets, drybeans, soybeans, corn, and meadow hay with no one area growing more than five of these crops. Common rotational practices for each area were determined by interviews with producers in each region and were reconfirmed with the county census irrigated harvest estimates.

Irrigation and Water Use Data

Water constraints were constructed using average evapotranspiration (ET) requirements for each crop in each region (USGS Platte River database). In addition to irrigation water fulfilling these ET requirements, the average effective precipitation during the growing season for each region was included. Historical average rainfalls for each region were adjusted using effective precipitation equations to identify the percentage of rainfall available for crop use.

The variability of water conditions were developed based upon historic agricultural diversions for each of the regions. Due to the lack of metered agricultural diversions in Region 1 the variability in water conditions was based upon historic river flows. This region is characterized by lack of storage, therefore, variability of flows in the river were used to estimate the variability of agricultural diversions for the region.

Diversions and stream flows were estimated for a baseline condition and each of the alternative policies considered using a hydrolgic model developed using MODSIM. MODSIM is a generalized river basin network model that uses advanced network optimization algorithms for simultaneously assuring that water is allocated according to physical, hydrological, and institutional aspects of river basin management, including interstate compact agreements. This hydrologic model estimates the timing and magnitude of impacts on flows, diversions and reservoir levels associated with water transfers from each region. (For a complete description of MODSIM see Labadie, 1994). The estimated diversions from MODSIM are used to develop the probabilities of the states of nature and the expected magnitudes of diversions to be incorporated into the economic model.

Crop-Water Production Functions and Crop Yields

Understanding the relationship between applied water and crop yield production is critical to determining the value of irrigation water. The relationship between relative yield and relative evapotranspiration (ET) was modeled to be segmented linear by growth stage as shown in previous studies (Doorenbos and Kassam, 1979; Vaux and Pruitt, 1983). Using the generalized production functions developed by Doorenbos and Kassam forty-nine possible irrigation strategies were developed for each crop. Each of the individual irrigation schedules has different associated yields, costs, and water requirements.

Following Doorenbos and Kassam, values of the yield response factor were specified for each growth stage for each of the crops. From the growth stage yield responses average yield responses for the first and second time periods were calculated. The model may deficit irrigate crops using seven different levels in each of the two time periods: 0% (no deficit), 10%, 20%, 30%, 40%, 50%, and 100% (total deficit). This resulted in 49 (7^2=49) possible irrigation strategies for each crop in each region. The quantity of water applied for crop production was adjusted to represent the quantity of water available for evapotranspiration through the use of area specific irrigation efficiencies that accounted for on-farm application and delivery losses.

Methodology of Hydrologic and Economic Models Used Together

The output from the hydrologic model was compiled into total monthly agriculture diversions over a twenty-four year time period for each of the five regions. This estimated data set was then used to create the specific water level conditions for each region under the specific policies to be examined.

The MODSIM output was to aggregate the monthly diversions into an early and late time period so that it could conform to the two time period economic model. Once the total early and total late diversion quantities were estimated for all twenty-four years the data set was used to estimate the variability and magnitude of each regions water supply. The early time period was broken up into three equally likely states of nature, identified as either WET, AVERAGE, or DRY. The eight observations within each of the categories were then averaged to find an area specific quantity of water that was associated with each of the conditions. The same procedure was used for late time period diversions. Once these thresholds were developed we were able to estimate the joint probabilities of all the possible outcomes (for example, what is the probability of a year that is wet early and then dry late in Region 4?).

The estimated total water diversions were then scaled to represent a diversion for a representative 1,000 acres of farmland within each of the regions. To do this it was necessary to approximate under what specific conditions a representative farm would receive enough water to irrigate their crops without agronomic constraint. It was estimated that a representative farm would be expected to receive this quantity of water (full water) when the year was wet both early and late in the season. The proportion of total available water compared to the representative farms's unconstrained demand was calculated under baseline conditions and held constant for all policy alternatives. After the wet water quantities were identified the other states of nature were estimated in a similar fashion based upon the percentage of total water that was diverted under each condition for the region.

Once these steps were done to develop the baseline conditions for each region the process was repeated using the forecasted diversions corresponding with each of the policy alternatives. Using the altered water diversion levels associated with each policy, the economic model estimated the producer's responses and the ultimate impact on expected profits. The individual farm impacts were then scaled up to represent the total impact on the region by calculating how many 1,000 acre representative farms could be serviced by the total agricultural diversions in each of the regions under baseline conditions.

Baseline Model Solutions

Based upon historical water diversion along with flow records (1975-1998) and the use of MODSIM, a baseline predicted water diversion estimate for each region was produced for a 24-year period. These values were used to develop an expected economic condition for each of the 1,000 acre representative farms. In each region the expected profit, crop acreages, and water availability was estimated. The value of the objective functions (expected returns above operating costs) were as follows (Table 1):

Table 1: Regional baseline profitability per 1,000 acres of representative land

	Baseline Profitability
Region 1	$25,314
Region 2	$169,022
Region 3	$166,159
Region 4	$142,219
Region 5	$176,894

The values above are given per 1,000 acres of "typical" farmland in each of the five regions. Region 1 has the lowest expected profit value, this region begins in northern Colorado and extends down river to south central Wyoming near Casper. The area is characterized by high elevation and short growing season, agricultural activity is limited to low yielding flood irrigated alfalfa, mountain hays, and pasture, thus it was expected to have relatively low returns.

It was expected that the marginal impacts from a water transfer would be lowest within Region 1. However, it is necessary to estimate the ability of water acquired upstream to make its way downstream and be of use in offsetting shortages at the critical habitat. These issues were addressed with the use of MODSIM, which estimated the effects of different policies on all regions simultaneously, therefore accounting for the percentage of water transferred from agriculture to the amount actually received in the critical habitat to offset shortages.

Representative Alternatives for Quantitative Analysis

A set of water transfer alternatives were selected to illustrate the range of institutional characteristics and locations of potential water transfer alternatives. By examining quantitative impacts of this range of alternatives, the significance of location, alternative flow protection policies, the use of environmental storage accounts, and changes in consumptive use and diversion patterns can be explored.

While a range of alternatives for increasing instream target flows are examined, no attempt is made to identify the optimal alternative for meeting specific flow, or target flow shortage reduction levels. Here the focus is on hydrologic and economic impacts of a discrete set of specified alternatives. In particular, water transfers are uniformly defined in terms of water right changes totaling 10,000 acre-feet per year. To provide for appropriate comparison between alternatives, impacts at the critical habitat are used directly. Alternatives are evaluated in terms of costs per unit reduction in target flow shortage at the critical habitat.

Overview of Alternatives

A total of 22 water transfer alternatives are considered, covering transfers from each of five representative regions in the basin. For each region, a water rights transfer of 10,000 acre-feet annually is considered. A set of the most senior flow rights in each region is typically chosen because in virtually all conditions these water rights will be in priority. Transfers of up to 20% of these flow rights from any given ditch is allowed, and transfers are distributed as needed amongst several ditches to achieve the total annual reduction of 10,000 acre-feet. The timing of the use reduction is made proportionally to the historical pattern of diversions from each irrigation diversion. For example, if May through September diversions have typically been in the ratio of 1:2:4:2:1, respectively, then the actual transfer of water rights ranges from 4,000 acre-feet in July, for example, to only 1,000 acre-feet in each of May and September.[1]

[1] Irrigated agriculture in Region 1 is geographically distinct from the other regions. For this reason we represent a water transfer from Region 1 as an increased inflow. The distribution of increased inflow is based on the distribution of average monthly consumptive use for Yampa River basin irrigators, as reported by Smith et al., 1998.

The reduction in flow rights reduces diversions by a full 10,000 acre-feet in the target region, but results in a much smaller reduction in consumptive use. The typical ratio of the consumptive use reduction to the change in diversion is about 50%, resulting in an annual increase in available instream flow (some of which is diverted and used by junior appropriators) of about 5,000 acre-feet. The timing and availability of these flows at the critical habitat is not only a function of use by junior appropriators, but also of river losses, and the timing of return flows at both the original senior, and new junior uses. The MODSIM model takes all of these effects into account.

In the representative alternatives considered for this study, water rights from existing consumptive uses may be transferred to an instream flow right at the downstream state line, to storage in an environmental account at Lake McCaunghy, to both (in the case of Colorado and Wyoming transfers), or may be left entirely unprotected. In each case the impact of the alternative on reducing target flow shortages at the critical reach is quantified. The foregone economic benefits resulting from reductions in consumptive water use are quantified only for the most favorable institutional conditions.

Specific Economic Impacts of Selected Policies

The hydrologic impacts of 22 different policies were quantified through the use of the hydrologic model. The most promising alternatives were identified by analyzing the ability of each to reduce instream flow shortages at the critical region (Grand Island). For each policy the resulting instream flows at Grand Island were compared to the baseline flow levels. In each case however, we are not only concerned with increased instream flows, but also with the timing of those flows, and their availability to decrease critical habitat shortages under "average", "dry", and "wet" conditions (U.S. Fish and Wildlife Service, 1996). The "yield" of water in terms of the proportion of water transferred that is available to reduce shortages in the flow levels is thus an intrinsic component of our analysis. The yield per unit of water not diverted upstream was calculated by comparing the identified shortage with and without each alternative. This process was repeated for all 24 years and averaged for each of the 25 alternatives (Table 2).

Table 2: Representative Alternatives for Quantitative Analysis

Alternative Type	Region	State	State instream flow?	Environmental account?	Yield at Grand Island	Alternative Name
Transfer	1 - North Platte	WY	n	n	0.0611	Region 1 WY Transfer A
			n	y	0.2898	Region 1 WY Transfer B
			y	n	0.0610	Region 1 WY Transfer C
			y	y	0.2898	Region 1 WY Transfer D
	2 - North Platte	WY	n	n	0.0506	Region 2 WY Transfer A
			n	y	0.4782	Region 2 WY Transfer B
			y	n	0.0492	Region 2 WY Transfer C
			y	y	0.4788	Region 2 WY Transfer D
	2 - North Platte	NE	n	n	0.0739	Region 2 NE Transfer A
			n	y	0.4146	Region 2 NE Transfer B
			y	n	0.0698	Region 2 NE Transfer C
	3 - Central Platte	NE	n	n	0.0500	Region 3 NE Transfer A
			n	y	0.4929	Region 3 NE Transfer B
			y	n	-0.0094	Region 3 NE Transfer C
	4 - South Platte	CO	n	n	-0.0364	Region 4 CO Transfer A
			n	y	0.4286	Region 4 CO Transfer B
			y	n	-0.0153	Region 4 CO Transfer C
			y	y	0.4293	Region 4 CO Transfer D
	5 - South Platte	CO	n	n	-0.0217	Region 5 CO Transfer A
			n	y	0.4083	Region 5 CO Transfer B
			y	n	-0.0029	Region 5 CO Transfer C
			y	y	0.4088	Region 5 CO Transfer D

Notes:

1. State instream flow is based on the priority, consumptive use reduction, and timing, of the transferred rights. At state line for CO and WY; at Grand Island for NE.
2. Environmental account establishes instream priority at Grand Island; volume is the amount of transferred consumptive use.
4. Yield at Grand Island is in terms of reductions to target flow shortages per unit of water diverted.

Table 2 describes the characteristics of each alternative examined and the yield that resulted, the alternative within each region that resulted in the largest yield per unit of water was selected for continued economic analysis. The importance of establishing an "environmental account" in storage facilities becomes apparent when evaluating the potential yields, without the use of an environmental account it is estimated that less than 10% of each acre-foot transferred would be available for offsetting shortages, regardless of the transfer location. This significance relates directly to the timing needs identified for habitat restoration. For transfers originating in WY and CO an instream flow right protecting the water to the Nebraska state line increased the yield of water transfers and was also included for these regions.

<u>Economic Impact Results</u>

The basin wide agricultural impacts associated with six water transfer policies were estimated. The economic impacts reflect the basin wide changes in diversions that were estimated to occur as a result of each policy. Each water transfer policy originating from Wyoming and Colorado include the use of an environmental account and instream flow protection to the Nebraska state line. Water transfers originating within Nebraska do not have state line protection since the environmental account already protects the water to the critical habitat. Total agricultural losses for each of the water transfer policies are as follows: (Table 3):

Table 3: Total Agricultural Impacts Associated with Water Transfers from each Region. (Per 10,000 af transfer)

	Region					
Policy	1	2	3	4	5	Total
Region 1 WY Transfer D	$ (60,053)	$ 0	$ (37,080)	$ 0	$ 0	$ (97,133)
Region 2 WY Transfer D	$ 0	$ (161,635)	$ (99,333)	$ 0	$ 0	$ (260,968)
Region 2 NE Transfer B	$ 0	$ (168,042)	$ (40,005)	$ 0	$ 0	$ (208,047)
Region 3 NE Transfer B	$ 0	$ 0	$ (872,591)	$ 0	$ 0	$ (872,591)
Region 4 CO Transfer D	$ 0	$ 0	$ (152,603)	$ (427,934)	$ 15,122	$ (565,414)
Region 5 CO Transfer D	$ 0	$ 0	$ (146,232)	$ 57,373	$ (267,229)	$ (356,087)

We can see that each water transfer policy can result in negative or positive effects in other regions. Since all of the water transfer policies use an environmental account at Lake McConaughy to establish a Nebraska water right and control the timing of flows, all of the alternatives have impacts in Region 3. This results from the inability of users within Nebraska to divert water that is now protected in an environmental account in Lake McConaughy Transfers from Region 1 had the lowest total impacts at approximately $97,000. Therefore, withholding 10,000 af from senior diverters in Region 1, establishing an instream right to protect this water to the state line, and then retiming and protecting the flows with an environmental account in Region 3 resulted in approx. $60,000 of agricultural losses within region 1 and approximately $37,000 within region 3. The downstream impacts were due to the inability of region 3 users to divert water that is now sitting in Lake McConaughy for environmental purposes. The direct losses in region 1 are comparably smaller than those for all other regions. This is due to the fact that agriculture in this region is limited to low yielding flood irrigated alfalfa, mountain hays, and pasture. Due to the crops in this region being relatively tolerant to water stress and having low yields the area does not lose much hay production in order to reduce annual diversions by 10,000 af. The largest impacts were seen within region 3 and were estimated at approximately $870,000. These impacts were relatively high due to the fact that the region primarily produces high yielding corn and soybeans and does not produce significant amounts water stress tolerant crops like alfalfa. Thus, the area is unable to water stress hay sacrificing only marginal amounts of low valued crops and is faced with large losses of corn and soybean.

It is the impact in terms of water yielded at the critical region that is of most concern. Using the average percentage yielded annually in the critical area the costs that are imposed on each region for given an additional acre-foot to offset target flows in the critical reach can be computed (Table 4):

Table 4: Regional cost imposed on Ag. for each acre-foot available critical reach shortages

Policy	Average % Yield in Critical Area	Region 1	2	3	4	5	Total
Region 1 WY Transfer D	0.2898	-20.72	0.00	-12.80	0.00	0.00	-$33.52
Region 2 WY Transfer D	0.4788	0.00	-33.76	-20.75	0.00	0.00	-$54.50
Region 2 NE Transfer B	0.4146	0.00	-40.53	-9.65	0.00	0.00	-$50.18
Region 3 NE Transfer B	0.4929	0.00	0.00	-177.03	0.00	0.00	-$177.03
Region 4 CO Transfer D	0.4293	0.00	0.00	-35.55	-99.68	3.52	-$131.71
Region 5 CO Transfer D	0.4088	0.00	0.00	-35.77	14.03	-65.37	-$87.11

We can see that it would impose an estimated $20.72 of lost agricultural activity to Region 1 to obtain 1 acre-foot of water for offsetting critical habitat shortages. This value reflects the idea that you would need to reduce diversions in Region 1 by approximately 3 af to accomplish 1 af of reduced shortages. The total agricultural losses associated with a transfer from Region 1 must also account for the impacts that this policy has within Region 3. Region 3 will lose an estimated $12.80 of foregone benefits due to the Region 1 transfer for a total loss of $33.52 per unit of water available to offset critical habitat shortages. The estimated total losses range from a low of $33.52 to a high of $177.03 from a transfer originating within Region 3.

Conclusions

Water transfers from current agricultural users have the ability to increase instream flows for habitat restoration. Such water transfers are most beneficial when they are accompanied by a water rights transfer to an instream flow right, and managed through the use of an environmental account in a basin storage facility. Without the use of an environmental account it is estimated that less than 10% of each acre-foot transferred would be available for offsetting shortages, regardless of the transfer location. The result of using an environmental account within the state of Nebraska is that all of the policies examined result in negative impacts within Region 3 (Central Nebraska).

When evaluating the cost effectiveness of water transfers it is necessary to examine both the basin-wide hydrologic relationships and the regional economic analysis together. Although water transfers that originate closer to the critical region have a larger percentage of the water available for decreasing habitat shortages, these options do not appear to have the lowest costs. A transfer from Region 3 has the highest yield per unit of water, however the increased yield is unable to offset the high cost impacts on agriculture in this region. Even though a larger quantity of water would need to be transferred from upstream in Region 1 to accomplish the same reduction in shortages, this study shows that it is likely to have much lower costs.

If a compensated water transfer originating from Region1 that included the use of both an instream flow right and environmental account was to be used it would be necessary to compensate both producers from Region 1 and Region 3. Although compensation would be required for losses in both regions, targeting Region 1 appears to represent the most cost effective location for transfers for endangered species preservation.

Findings of this study indicate that the location of water sources and the resulting hydrology is essential for evaluating the economic impacts of water transfers. Sensitivity of the results to the presence or absence of an environmental account indicate that further research is warranted to evaluate alternative institutional arrangements to assure conveyance of transferred water.

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