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Final Report
An Economic Analysis of Water Balance

Prepared for Dawson Public Power District

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Executive Summary

The water balance approach examines all sources of water inflow and outflow from a geographic region, From this broad perspective, water consumption outcomes within a region are not the responsibility of any particular type of land use, whether that is forestry, housing, or agriculture, but of all uses. This implication from water balance points to an economic interpretation of the water balance approach. That interpretation is that economic analysis of water policy must also take this broad perspective, by examining both financial gains and amenity values associated with each of the multiple types of land uses and land management practices within a region.

Three primary recommendations follow from this economic interpretation of the water balance approach. The first is that water policy should not be seen as a punitive action against a particular "responsible" land use, but rather a search for the most efficient course of action among a variety of options. Efforts to improve water outcomes should consider a broad range of actions to change behavior, including incentives to encourage land use that promotes desired outcomes. Water policy in Nebraska should function to 1) increase water consumption that yields high marginal increases in combined financial and amenity benefits per unit of water, and reduce water consumption that yields low marginal gains (or even losses) in combined financial and environmental benefits per unit of water; and 2) encourage technologies and management practices that increase the combined financial and environmental gain per unit of water.

Second, the Nebraska Department of Natural Resources and other interested parties in the state should seek to estimate and value the environmental amenity benefits of a full range of potential water policies including land management, efforts to utilize water resources more efficiently, intentional groundwater recharge projects, vegetation management programs, and improved reservoir management. This information can then be utilized to design even more efficient water policies for the state of Nebraska, and regions within the state.

Third, it is critical to find ways to bank and transfer water between "wet" years and "dry" years. Such approaches, if technically feasible in terms of providing environmental benefits and financial gain, could be among the most beneficial water policies to pursue, since water in "dry" years is both more environmentally valuable and more financially valuable as an input into agriculture.

Table of Contents

List of Tables and Figures

I. Introduction

Water management is a subject of substantial interest in the state of Nebraska. In the Platte River system in Nebraska, water management strategies have been implemented to ensure the survival of endangered species in that ecosystem and to protect stream flow appropriations. In other areas of the state, water management strategies have been implemented to ensure adequate stream flow for the purpose of satisfying interstate compacts between Nebraska other states.

The water balance approach provides an important lens to examine these water management strategies. Water balance examines all sources of water entering and exiting a region. It further recognizes that water balance is a function of each of these sources. An important implication of the water balance approach, therefore, is that outcomes of water consumption within the region are not the sole responsibility of any particular source of water entering or exiting a region, but of all sources. Or, in terms of land use, all sources of land use are responsible for water consumption within a region. A solution for an undesirable outcome in the water system, therefore, is not properly seen as a punitive action against a particular "responsible" party, but rather a search for the most efficient course of action among a variety of options.

This implication from water balance also points to an economic interpretation of the water balance approach. In particular, economic analysis of water policy must examine both financial gains and amenity values associated with all types of water consumption.

Given this background, the Dawson Public Power District contracted with the UNL Bureau of Business Research to examine the water balance approach from an economic perspective. We do so in the current report. In the next section, we briefly describe the water balance approach, at least as it is interpreted by economists. We then propose an economic interpretation of the water balance approach. In particular, we propose an approach for considering the economic consequences of changes to the entry and exit of water from a particular geographic region. This economic approach to examining such changes jointly considers both the financial and environmental benefits (whether positive or negative) of changes in water consumption. All potential changes in water consumption can then be searched to identify policies that will yield the highest net benefit. This should produce a balanced menu of water policies.

In the third section, we consider the economic impact of current water policy using a prominent example of water policy in Nebraska. In particular, we consider the implications of water policy to the topic of irrigation and stream flow along a section of the Platte River region. We begin with a brief discussion of the issue. We then consider the economic impact of current approaches to this water policy, using the example of improving stream flow through purchasing water rights to take acres out of irrigated production, under both a low and medium impact scenario. Economic impact estimates are provided in terms of the total economic impact both on-farm and off-farm at key supplier businesses as well as other businesses that rely on a local supply of agricultural production.

In the fourth section, we provide a set of recommendations for water policy in Nebraska reflecting both water balance and economics concepts.

II. The Water Balance Approach in Economics

This section considers the economics of water balance. We begin by considering the basics of the water balance approach. Water balance has been defined as follows: "A water balance is an accounting of all water volumes that enter and leave a three-dimensional space over a specific period of time as well as any changes in storage."[1] In this case, a system is any spatial area which contains water over a period of time.

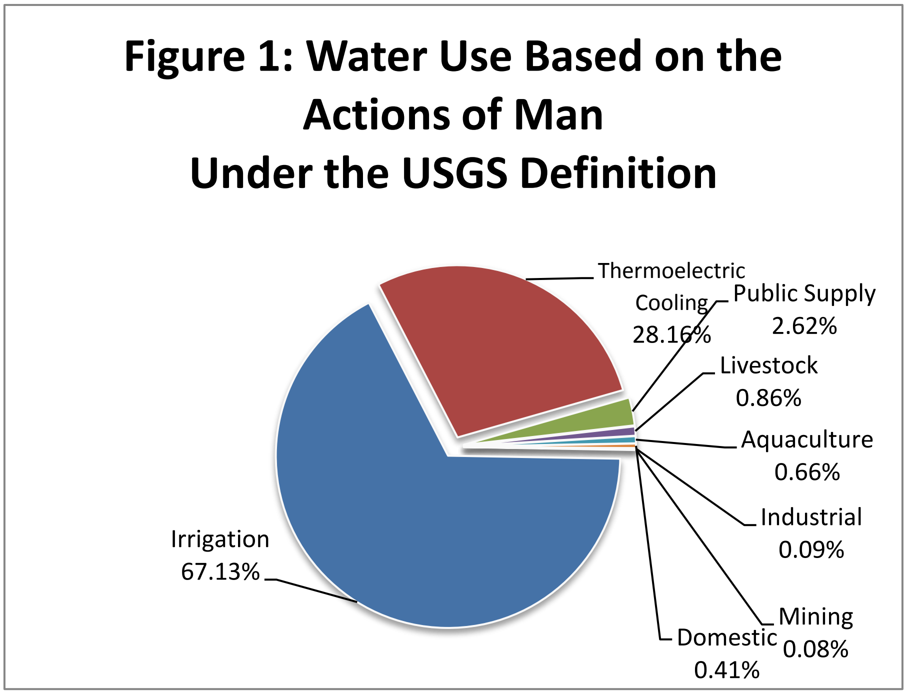
Because a component of the water balance conversation pertains to amounts of water used, delineations are made between water use and water consumption. Water use is the amount of water over a given period of time that is subject to use in agriculture, industry, energy production, and domestic and residential purposes, including in-stream uses such as fishing, recreation, transportation and waste disposal.[2] Water consumption, on the other hand, is an action that takes water out of a specific area, such as a stream or a basin, so that it can no longer be used in other ways.[3]Water use falls into different subsets based upon the nature of its use.

[1] Burt, C.M. PhD., P.E., D. WRE. (1999). Irrigation Water Balance Fundamentals. USCID Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balance. San Luis Obispo, California.

[2] Water Use. November 19, 2011. In *OECD Glossary of Statistical Terms*. Retrieved from stats.oecd.org/glossary/detail.asp?ID=2915.

[3] Consumption. 2011. In *Nebraska Water Balance Alliance Glossary*. Retrieved from www.nebraskawaterbalance.com/glossary.html.

Featured below is Figure 1, a pie chart illustrating the different areas of water use due to the actions of man.[4]

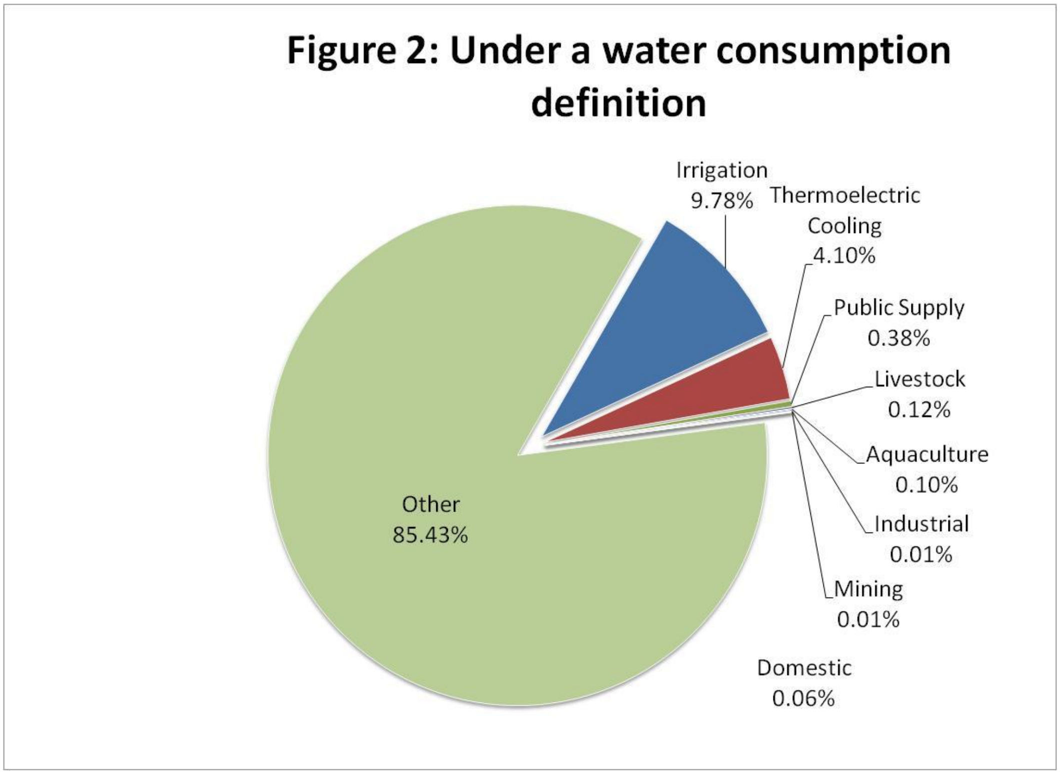


Source: Kwapnioski (see footnote 4)

It is important to note that this pie chart does not reflect all accounts of water in a system. That is to say, while the above chart demonstrates where water has been used and in what proportion to other uses of water, this chart does not reflect how much water is used in proportion to all available water in a system.

Figure 2 is a pie chart that illustrates water consumption from a perspective of all water in a system.[5] This pie chart illustrates the difference between water use and water consumption. Under these definitions, for example, Thermo-electric cooling represents two distinct values. Under a water use definition, Thermo-electric cooling represents twenty-eight percent of all water used *from* a system, whereas under a water consumption definition, Thermo-electric cooling represents only two percent of all water used *in proportion* to the total amount of water that is available.

[4] Kwapnioski, F., P.E. *Our Economy, Our Water, Our Future* [PowerPoint Slides]. Date Unknown.
[5] Kwapnioski, F., P.E. *Our Economy, Our Water, Our Future* [PowerPoint Slides]. Date Unknown.



Source: Kwapnioski (see footnote 4)

Herein lays the utilization of a water balance (also known as a water budget) model. In a water balance model, water consumption is not measured against the other uses of water, but rather measured as a decrease from the amount of water available for use in a system. In other words, all sources by which water exits the system (as well as enters the system) are of interest in terms of understanding the water system and in considering water policy.

Thus, an essential element of the water balance approach is to consider all of the ways in which water enters and exits a particular water shed or geography. This is primarily a scientific phenomenon but does also relate to the social science of economics, in particular through land use. That is because land use is one factor which influences both the entry and exit of water from a hydrological system. Most, if not all, land use also represents a human choice, and economics is a social science that examines human decision-making.

An economics approach to water balance, with its focus on all sources by which water enters or exits a region, would naturally focus on the incentives for water consumption on all types of land. Stated another way, a water balance approach to the economics of water consumption would focus on environmental and financial issues related to land management practices for all types of land use, including dry-land agriculture, grasslands and rangelands, forestlands, or unmanaged lands.

How would this be done? In theory, an economic approach to the balanced use of water would seek to equilibrate the marginal benefits of water consumption over all land uses and land management practices. A unit of water consumed in every setting would achieve the same marginal benefit, which is the sum of the financial benefit from the water, but also the amenity benefit (including negative amenities – i.e., amenity costs). Potential positive amenity benefits of water in alternative land uses would include an improvement to the scenic value of the land. An example of an amenity cost (i.e., negative benefit) of water use could include reduction in stream flow that impacts species habitat.

In this setting, marginal land management practices on alternative land uses would produce the same combination of financial and amenity benefits. Subject to meeting minimum requirements for stream flow, the decision-rule could be to: 1) increase water consumption that yields high marginal increases in combined financial and amenity benefits per unit of water, and reduce water consumption that yields low marginal gains (or even losses) in combined financial and environmental benefits per unit of water; and 2) encourage the adoption of technologies and management practices that increase the combined financial and environmental benefit per unit of water.

This approach of considering both the environmental benefits (either positive or negative) and the financial benefits of various changes to water consumption has several important implications. First, while the method heavily weighs the environmental benefits from changes in water consumption, financial considerations are given equal weight. Thus, it is possible that changes in water consumption with substantial environmental benefits may also carry large financial costs, and as a result, receive a poor ranking. This implies that some changes in water consumption with substantial environmental benefits may not be recommended by the combined financial and environmental approach. At the same time, changes in water consumption with more modest environmental benefits, but small financial costs, may be selected as strong candidates for expansion.

This magnitude of environmental benefits is also influenced by intervening factors such as plant physiology, soil science, or hydrology. Further, amenities values also will depend on human valuations of various changes in the environment. Such human valuations may vary from situation to situation (i.e., limited value transfer) and in general be difficult to calculate.

As the model identifies potentially beneficial changes in water consumption, the next question is how to incentivize this change. Such beneficial changes may not occur on their own in a market economy because markets often do not exist for environmental benefits such as improved stream flow, wetlands protection, or other potential benefits from changing land use practices. Land owners or renters would not have an incentive to incorporate these non-market environmental benefits into their decisions about land use. Incentive systems to change behavior include regulatory action, or efforts to work through market forces such as price. Regulatory actions could limit certain land uses or agricultural practices. Alternatively, taxes or subsidies could encourage agricultural managers or other land managers to incorporate the environmental costs or benefits into their decisions. Taxes could be applied to land uses that provide negative environmental benefits. Those taxes would be set, to the degree practical, to the level of the negative benefit. Alternatively, subsidies could be provided to alternative agricultural or land use practices. Land use or agricultural practices would change as a result.

Finally, the economic approach to water balance has important implications for water policy during so called “dry” years. In particular, in such years, both the financial gains and the environmental costs of water use rise substantially. For example, in the case of irrigation, gains from marginal irrigation rise substantially in years when rainfall is limited. At the same time, environmental benefits from using less water in irrigation also can rise substantially. In terms of the economics of water use, these tendencies indicate that the combined financial and environmental benefit of water consumption may either rise or fall in dry years. The outcome would depend on whether financial gains or environmental costs from additional water consumption rise most quickly. The other implication is that there is high economic return to practices that could transfer water use from “wet” years to “dry” years.

III. The Example of Irrigation and Stream Flow in Nebraska

A. Background

Restrictive irrigation practices have been put into place in Nebraska for two historical reasons. The first is that an agreement was made between the Federal Government (DOI), Nebraska, Colorado and Wyoming in 1997 in order to maintain water levels in the Platte River system at specific times in order to create the most protective habitat for endangered species in that ecosystem. When water levels were found to be below those dictated by the agreement, known as the Platte River Recovery Implementation Program, water diversion was halted on certain irrigated farming acres.[6]

The second occurrence is in the Republican River system and centers on the contested issue of the state of Kansas receiving enough stream flow from the Republican River. "Under the terms of the Compact, Colorado receives 54,100 acre-feet of water, Nebraska receives 234,500 acre-feet of water, and Kansas is allocated 190,300 acre-feet of water."[7] In addition, Kansas is granted use of the entire water supply downstream from the southernmost river that crosses the Nebraska-Kansas state line. In order to satisfy the Compact conditions, water diversion has been halted on certain irrigated farming acres or restricted on irrigated farming acres in certain Natural Resources Districts.

In the former case, irrigation was halted and a payment was made to the farmers whose land was taken out of irrigated production. This was done as a measure of remuneration for the amount they could have financially made should the land have been in irrigated production. In the latter case, allocations were reduced for irrigators within selected regions of Natural Resources Districts. Of course, at the same time, an active private market has continued to function for the sale and purchase of water.

This being the case, it is clear that multiple assumptions have been made about water use in the Platte and Republican River systems. The assumption has been made that stream flow can be accurately measured with internal validity and statistical significance, enough validity and significance to declare as satisfied the stipulations of a multi-million dollar interstate compact.

[6] Final Platte River Recovery Implementation Program (2009). Retrieved from http://www.platteriverprogram.org/PubsAndData/ProgramLibrary/Platte%20River%20Recovery%20Implementation%20Program%20Document.pdf.

[7] Kansas Interstate River Compacts (2009). Retrieved from http://skyways.lib.ks.us/ksleg/KLRD/Publications/Water_Resources/InterstateRiver Compacts.pdf.

The assumption has also been made in both the Platte and the Republican River systems that diverted water use by irrigating farmers is the most culpable user of water in either systems.

The Nebraska Water Balance Alliance hopes to use a water balance approach to improve water management in Nebraska.[8] The group also considers several implications of the water balance approach. One implication is that water diversion for supplemental irrigation by agricultural producers is not the primary source of consumptive water use in Nebraska river basins. They also aim to examine alternative methods to reduce consumptive water use by utilizing producer driven outcomes, such as monitoring and reducing low or no benefit evapotranspiration.

B. The Economic Impact of the Current Approach

This section considers the economic impact of the current approach utilized in Nebraska to improve stream flow. A common approach is to attempt to improve stream flow by purchasing water rights and taking acres out of irrigated production. While this approach may be workable, there may be advantages to adopting a water balance approach to the issue, where feasible. In particular, an approach that considers multiple ways to improve stream flow, on multiple types of land uses, may yield the same improvement in stream flow but at a lower economic impact.

One way to consider this issue is to examine the economic impact[9] of water rights purchases that take land out of irrigated production. Studies of this kind typically model the reduction in agricultural activity resulting from reduced irrigation and then estimate the broader impact on the wider regional economy. The wider impact occurs because reduced agricultural production leads to less demand for agricultural suppliers and processors and less property taxes to support public sector activity.

We conduct such an analysis for the case of the three-county region of Buffalo, Dawson, and Lincoln counties, which are core counties for the Dawson County Public Power District. Specifically, we estimate the regional economic impact of current efforts to return water to the Platte River from "overappropriated" regions. We consider two scenarios. The first is roughly

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[8] Water Balance Alliance. 2011. In *Nebraska Water Balance Alliance Mission*. Retrieved from www.nebraskawaterbalance.com/glossary.html.

[9] Economic impact studies are not the same as benefit cost analyses. Benefit cost analyses would look at the benefits from improved streamflow and compare those benefits with the economic costs of reduced agricultural activity. Such economic costs would include the reduction in land values and the reduced value or idling of infrastructure investments that are very costly or even prohibitively expensive to move to other areas.

similar to efforts called for in the Integrated Management Plan of the Central Platte Natural Resources District (NRD). We also consider another scenario of a larger reduction in irrigation called for in the Integrated Management Plan and Districtwide Ground Water Management Rules and Regulations of the South Platte NRD, which is located in the panhandle region of Nebraska. That Plan and Rules and Regulations, which were adopted and are being implemented in another region of the state, called for the purchase by the South Platte NRD of acreage equivalent to 2.7% of all irrigated acres within district boundaries. We explore the economic consequences of a similar target in the combined Buffalo, Dawson, and Lincoln counties region. Both of these examples simply assess the first increment costs of returning depletions to 1997 levels, not the goal of returning to Fully Appropriated, which is the ultimate expectation for both of these areas. Also, in order to keep our examples modest, we refrain from presenting the more severe reductions that have been required for some areas within Nebraska. For example, the Nebraska Platte – Republican Resources Area CREP program (September 2011) goal is to reduce the application of water for cropland irrigation in the priority area by 125,000 acre-feet annually.

Table 1 shows the irrigated and non-irrigated acres for 5 major crops in Buffalo, Dawson, and Lincoln County Nebraska. Our analysis of these counties is simply an example for consideration. In particular, this section should not be seen as an assessment of the economic impact of the Integrated Management Plan of any particular Natural Resources District. Our analysis and Table 1 focuses on data from the year 2010 from the United States Department of Agriculture's National Agricultural Statistics Service (NASS).

Table 1
Irrigated and Non-Irrigated Acres in 2010 in the Buffalo, Dawson and Lincoln Counties

Crop	Irrigated Acres	Non-irrigated Acres
Corn	524,000	76,000
Wheat	2,500	27,200
Soybean	163,200	27,200
Alfalfa	37,300[1]	48,200[1]
Hay	40,000[1]	51,600[1]

Source: USDA National Agricultural Statistical Service
[1] Data was not broken down into irrigated and non-irrigated acres. Data on irrigated and non-irrigated acres was available for Alfalfa in 2008 and 2009. The average ratio from those years was used to allocate 2010 Alfalfa and Hay acres into irrigated and non-irrigated acres.

Note that there are many more irrigated acres in production, in this example, than non-irrigated acres. The largest number of irrigated acres is in corn production. These are the principal types of crop production reported in the NASS data for the 3 counties.

Our economic impact estimates will reflect the reduction of acres of irrigated production, primarily to non-irrigated production, but also in some cases out of agriculture. We consider two scenarios. One is a 3,500 acre reduction in irrigated production. This is roughly similar to the 3,400 acres of irrigated production taken out of production in the Integrated Management Plan of the Central Platte NRD. This figure represents the loss to irrigation of approximately 0.51% of the irrigated production listed in Table 1. The second scenario considers the reduction in the percentage of irrigated acres in the Integrated Management Plan of South Platte NRD, which required an approximately 2.7% reduction in irrigated acres. This would be an equivalent of a reduction in 18,600 irrigated acres in the Buffalo, Dawson, and Lincoln county region. We assume that irrigated production is taken out of corn, soybeans, wheat, alfalfa and hay proportionate to the current irrigated acres, as seen in Table 1. It is further assumed that all of the new acres of non-irrigated production would produce corn, soybeans, wheat, alfalfa, and hay according to their share of dry-land acres listed in Table 1. We utilized the average yield for each crop in 2010 (either irrigated or non-irrigated yield, as appropriate) to estimate the resulting change in crop production.

Table 2 shows the resulting change in production for all 5 crops impacted in our simulation. Results are shown for both scenarios; the 3,500 acre and the 18,600 acre scenario.

Table 2
Annual Change in Crop Production and Sales

	Annual Change under 3,500 Acre		Annual Change under 18,600 Acre	
Crop	Crop Production	Crop Sales	Crop Production	Crop Sales
Corn	-323,000 bu	-$1,260,000	-1,714,000 bu	-$6,696,000
Wheat	14,000 bu	$76,000	73,000 bu	$403,000
Soybeans	-26,000 bu	-$247,000	-137,000 bu	-$1,315,000
Alfalfa	1,600 tons	$125,000	8,600 tons	$665,000
Hay	700 tons	$53,000	3,800 tons	$283,000
Total		-$1,253,000		-$6,660,000

Source: BBR calculations

The changes in crop production for each crop in each scenario are shown in Table 2. The resulting change in sales can be determined by multiplying the change in crop yields by the expected price. Our crop price assumptions were based on then current prices and forecasts for the next few years published in *2009 Agricultural Outlook* of the Food and Agricultural Policy Research Institute (FAPRI) of the University of Missouri and Iowa State University. [10] As seen in Table 3, we estimate a decrease of $1,253,000 in annual crop sales under the 3,500 acre scenario. The estimated decrease in sales is $6,660,000 under the 18,600 acre scenario.

[10] Corn ($3.92/bu), Wheat ($5.52/bu) were based on the average outlook price from FAPRI for the 2010 to 2015 period. Alfalfa and hay prices vary significantly by geography so we utilized a price of $77.50 per ton of Alfalfa, $75.00 per ton of hay and $9.60 per bushel of soybeans reported in the University of Nebraska-Lincoln publication *Cornhusker Economics*.

Changes in production and sales of corn and other crops are what drive the estimate of the change in local economic activity. The relationship between the change in crop sales and employment, income, and output (business receipts) throughout the community is captured through "economic multipliers." Economic multipliers show the change in total economic activity in the District for each $1 of sales in the crops that we study such as corn or wheat.

The IMPLAN software developed by the Minnesota Implan Group, Inc. was used to estimate relevant economic multipliers for corn, wheat, soybeans, alfalfa, and hay in the Buffalo, Dawson, and Lincoln county region. This was possible because the IMPLAN model can be used to examine the economic impact of a change in activity in over 500 industry sectors in every county, or combination of counties, in the United States. Economic multipliers from IMPLAN are applied to estimates of the change in future crop sales to estimate the total change in economic activity throughout the economy.

The total change in crop sales from Table 2 is presented again in Table 3, which also shows the resulting economic impact. The total estimated annual loss in economic activity (business receipts) in the Buffalo, Dawson, and Lincoln county region both on and off of the farm is $1,771,000 per year under the 3,500 acre scenario. The total estimated annual loss is $9,411,000 per year under the 18,600 acre scenario.[11][12]

This reduction in business receipts implies that business will change the number of workers and labor income (wages and benefits). Economic multipliers also capture these impacts on the labor market. Table 3 also shows these labor market impacts. The expected income loss is $549,000 per year under the 3,500 acre scenario. Note that this labor income is a component of business receipts. It would not be appropriate to add the reduction in annual labor income to the reduction in annual business receipts. The expected income loss is $2,917,000 under the 18,600 acre scenario.

[11]Our calculations of economic impact utilize the same economic multiplier for a dollar of revenue from producing irrigated corn or dry land corn, irrigated soybeans or dryland soybeans, and irrigated or dryland production for other crops. Estimates of economic impact would likely vary modestly if separate economic multipliers had been calculated for irrigated and dryland crop production. For example, using a survey of agricultural producers, Lamphear (2005), calculated that in a year with typical rainfall irrigated agriculture would have an economic multiplier 2.46 while dryland agriculture would have a multiplier of 2.15 (assuming no change in cropping patterns in the absence of irrigation). This result suggests that the estimated economic impact in this study would have been modestly larger if we had calculated separate economic multipliers for irrigated and non-irrigated agriculture. Such an effort is left for future research.

[12] Lamphear, Charles, 2005. *Economic Importance of Irrigated Agriulture 2003.* Lincoln, Nebraska: Nebraska Policy Institute (October).

Table 3
Annual Change in Crop Sales and the Resulting Economic Impact

Economic Measure	Annual Change in Amount ($) 3,500 Acres	18,600 Acres
Crop Sales	-$1,253,000	-$6,660,000
Economic Impact (Business Receipts)	-$1,771,000	-$9,411,000
Labor Income	-$549,000	-$2,917,000
Employment	-19	-101

Source: BBR calculations

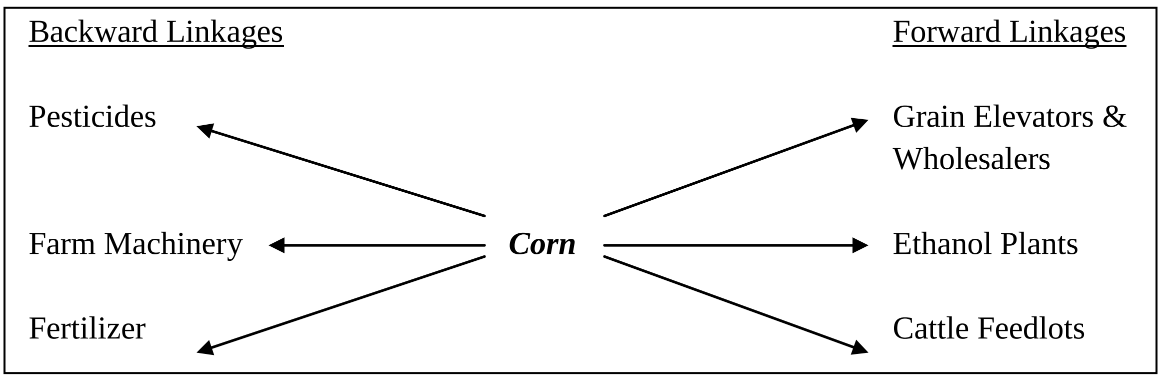
Table 3 also shows the loss of employment. There would be a loss of 19 jobs associated with the $549,000 decline in income under the 3,500 acre scenario and a loss of 101 jobs under the 18,600 acre scenario.

Forward Linkages

Economic impact analysis of the kind reported in Table 3 reflects the change in economic activity in the directly affected industry (agriculture, in this case), and in supplier industries, due to the multiplier effect. Business receipts change in the supplier industries due to a change in purchases of supplies by agricultural producers. These purchases of supplies reflect "backward" linkages in the economy. Backward linked industries are the suppliers. As seen in the example in Figure 3, some of the backward linked industries for corn production would be pesticides, fertilizer, and farm machinery. The multiplier effect in an economic impact analysis captures how activity in these backward linked industries change in response to a change in a directly affected industry.

There are, however, also “forward” linkages in the economy. “Forward” linked industries are the customers of the directly affected industry (agriculture, in this case). Figure 1 shows some forward linked industries for the example of corn production. These industries also may change their activity if corn production changes. In particular, the large supply of grain produced each year by agricultural producers is the basis for a number of grain processing businesses in the Buffalo, Dawson, and Lincoln county region. Grain elevators and wholesalers are key examples of such “forward” linked industries.

Figure 3
Backward and Forward Linked Industries for Corn Production



Businesses in these forward linked industries would decline if corn production declines but lost activity in such forward linked industries were not captured in Table 3.As a result, we consider the economic impact on these forward linked industries, where possible, through a separate analysis. For example, we do estimate the potential change in employment among grain elevators and wholesalers due to a lower local supply of corn. The estimated loss of agricultural production under the 3,500 acre scenario would reduce corn production by 0.4% in the Buffalo, Dawson, and Lincoln county region. An estimated 2.0% loss of corn production in the 3-county region would occur under the 18,600 acre scenario. We assume a proportional change in employment in the corn wholesaling and elevator business. This would mean a loss of 1 job in this forward linked industry under the 3,500 acre scenario and 4 jobs under the 18,600 acre scenario. These corn industry impacts are included in the impact estimates in Table 5.

Change in Property Value

Property values also will decline due to the shift of irrigated acres to non-irrigated acres. The University of Nebraska-Lincoln through its publication *Cornhusker Economics* (Johnson, Wilson and Van Newkirk, 2011)[13] produces an annual report on farmland values in regions of Nebraska. That report suggests that there is a $2,200/acre difference in the value of irrigated farmland versus non-irrigated farmland in the Central and Southwest Agricultural Districts, where Buffalo, Dawson, and Lincoln County are located. To estimate the change in property value, 90% of the change in farmland value was multiplied by the $2,200/acre difference and the number of acres in the 3,500 or 18,600 acre scenario. As seen in Table 4, there is an estimated $6.80 million decline in property values in the Buffalo, Dawson, and Lincoln county region under the 3,500 acre scenario. The loss in property value of $6.80 million leads to annual decline in property taxes of $100,000, given the assessment rate for agriculture property and a property tax rate that averages 1.97% across the three-county region. Under the 18,600 acre scenario, there would be a loss of $36.2 million in property value and a $533,000 decline in annual property tax revenue.

Table 4
Change in Property Value and Annual Tax Revenue

	Change in Amount ($)	
Economic Measure	3,500 Acres	18,600 Acres
Property Values	-$6,803,000	-$36,155,000
Annual Property Taxes	-$100,000	-$533,000

Source: BBR calculations

This loss in agricultural property values has important implications for local economies. One implication is on tax revenue for local governments and school districts. This loss in revenue is not available for funding government jobs and government services. A loss in government employment and activity results, and there is also a multiplier effect from the change

[13] Johnson, Bruce, Roger Wilson, and Sara Van Newkirk, 2011. "Nebraska Agricultural Landmarkets Showing Strong Gains," *Cornhusker Economics*. University of Nebraska-Lincoln Extension, March 16, 2011

in local government activity. The IMPLAN model, despite all of its advantages, does not directly estimate tax revenue impacts. As a result, economic impacts due to a change in property values are not represented in Table 3, and must be estimated separately.

In Table 5 we estimate the economic impact of the change in property values in the three-county region. We focus on the total change in local property tax revenue, including both education, municipal and county taxes, and miscellaneous taxes. This change in revenue leads to a change in government activity. Estimates in Table 5 include an estimate of the economic impact of that change in government activity as well as the change in employment for grain wholesalers and elevators due to forward linkages. The total annual economic impact from the resulting loss in government expenditures (and reduced activity in forward linked industries) is an annual loss of $259,000 in business receipts under the 3,500 acre scenario. The labor market impact is a loss of $121,000 in income spread over 5 jobs. Under the 18,600 acre scenario, the annual economic impact would be a loss of $1,374,000 in business receipts, including $644,000 in labor earnings spread over 25 jobs.

Table 5
Annual Economic Impact from Change in Property Tax Revenue and Forward Linked Industries

	Annual Change in Amount ($)	
Economic Measure	3,500 Acres	18,600 Acres
Economic Impact (Business Receipts)	-$259,000	-$1,374,000
Labor Income	-$121,000	-$644,000
Employment	-5	-25

Source: BBR calculations

Overall Economic Impact and Discussion

The total change in economic impact from crop sales, forward linkages, and property taxes is the sum of the economic impact estimates reported in Tables 3 and 5. These overall economic impacts are reported in Table 6 below. Under the 3,500 acre scenario, the total annual impact is a loss of $2,029,000 in business receipts, $670,000 in labor income, and 24 jobs. Under the 18,600 acre scenario, the total annual economic impact is a loss of $10,785,000 in business receipts, $3,561,000 in labor income spread over 126 jobs.

On a per acre basis, these results suggest an annual loss of $580 in economic output and $191 of labor income in the three-county region for each acre taken out of irrigated product. There would be 1 job lost for each 147 acres taken out of irrigated production.

Finally, note that this report did not consider any positive economic impact due to spending by agricultural producers whose irrigation rights were purchased. It was appropriate to exclude such impacts. In particular, such spending is not expected to represent a net gain for the regional economy. A portion of the spending may be funded by increased taxes on agricultural producers within the region. The other portion of the spending would be funded by external sources. However, it is reasonable to assume that these external sources may have sponsored other environmentally beneficial projects in a region if not contributing to the purchase of water rights, implying that payments for water rights would not represent a net positive impact on the regional economy.

These figures further indicate that current policies to reduce irrigation and improve stream flow through purchasing water rights; while manageable, also generate a significant economic impact, in the range of millions of dollars to tens of millions of dollars per year. And, while there is a need for Nebraska to maintain adequate stream flow, and to meet its obligations under interstate treaties or Federal regulations, these results raise the question of whether there is a way to meet these obligations at a lower impact on the economy. In other words, could policies be designed to meet these obligations by alternative methods (besides taking acres out of irrigated production) that would yield the same gains in terms of meeting the state's obligations for stream flow, but have a smaller economic impact than pictured in Table 6?

Table 6
Overall Annual Economic Impact

	Annual Change in Amount ($)	
Economic Measure	3,500 Acres	18,600 Acres
Economic Impact (Business Receipts)	-$2,029,000	-$10,785,000
Labor Income	-$670,000	-$3,561,000
Employment	-24	-126

Source: BBR calculations

C. Literature Review

On an annual basis, Nebraska receives an average of 598 millimeters of water. Of that amount, 575 millimeters is derived from precipitation and 23 millimeters comes from river inflow. Of the 598 millimeters that Nebraska receives, approximately 505 millimeters a year is consumed by evapotranspiration, 33 millimeters by other consumptive uses within the state (such as industrial and municipal uses of water) and 58 millimeters leave the state in surface water flow.[14][2] As you can see by this example, from an outside perspective, Nebraska would appear to be a net water generator but only by a relatively small amount, a sum derived from the rounding up of millimeters. Any net gain in water is from the rounding of such a sum. Of the 505 millimeters per year of water consumed by evapotranspiration within the state, only 8% is derived from supplemental irrigation.

Groups interested in utilizing this type of water balance approach, including the Nebraska Water Balance Alliance, wish to consider water in a comprehensive and sustainable fashion that employs the water budget model from a perspective of total water availability and consumption in a system.[15]

Production agriculture provides a useful setting in which to consider the value of the water balance approach. In production agriculture, both precipitation and supplemental irrigation are inputs into crop production. Absent a water balance perspective, irrigated agriculture might be viewed as a major consumer of water in Nebraska. As a result, irrigated agriculture has come under restrictions in the past when water use has been deemed to exceed Nebraska's water availability.[16]

But, given that dry land agricultural, native species, forests, and invasive species also contribute to water consumption, the question arises: can a reduction in water use from these sources also help Nebraska meet its water policy goals. Some research is considering these possibilities. For example, different methods of managing water in an on-farm capacity are currently being employed in Nebraska.[17] On Paulman Farms in Sutherland, Nebraska, methods

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[14]Martin, Derrel, 2011. "Advances in Irrigation Technology," PowerPoint presentation at the 2011 UNL Water For Food Conference. University of Nebraska-Lincoln, Lincoln, Nebraska. May 4th, research.unl.edu/events/wff2011/video.php?id=15_maximizingwaterusepanel

[15] F. Kwapnioski, personal communications, December 14, 2001.

[16] Author Unknown. (2009). Final Platte River Recovery Implementation Program. Retrieved from http://www.platteriverprogram.org/PubsAndData/ProgramLibrary/Platte%20River%20Recovery%20Implementation%20Program%20Document.pdf.

[17] R. Paulman, personal communications, May 25, 2011.

are being employed to decrease evapotranspiration, consume less water and to measure all water consumption more accurately so as to know how to accomplish and measure possible credits to the previous objectives.[18] Such measurement methods include employing evapotranspiration gauges, measuring water delivered out of pivot irrigation devices, measuring groundwater saturation levels and measuring the water consumption of various crops and land uses.[19]

In any event, reduction in on-farm water consumption is just one aspect of a water balance approach to water management. Further, water management experts inside and outside of NEWBA note that there is not a one-to-one correlation between reduced on-farm water consumption and reduced basin-wide water consumption. As noted in discussions with personnel at the Nebraska Department of Natural Resources, the relationship between such types of water savings at a particular location (on-farm or at another location) and basin-wide savings is not "additive. [20]" In other words, one cannot simply add up the water savings at individual locations to calculate the total basinwide savings. Researchers in California have made this point regarding production agriculture in California's Central Valley. [21] However, while on-farm water savings may not be strictly additive, these savings may have systemwide benefits. The difficulty is in measuring the magnitude of these benefits, particular since the relationship between on-farm water savings and basinwide water savings varies substantially by place and by annual climate conditions. On-farm measurements of water savings are an important first step in quantifying these gains but analysis of multiple sites over a larger geography and alternative climate conditions would be needed to develop estimates of basin-wide implications, including implications for aquifer recharge and stream flow. Finally, any estimates that were developed would be measured with significant uncertainty. However, such research would need to be conducted in order to develop a system to credit the basin-wide benefits from on-farm water savings, or other efforts to save water in other types of land uses. While these would be significant efforts, we note that the basin-wide benefits of current policies such as irrigation reduction and limitation face similar uncertainties, and methods have been identified and agreed to credit these reductions.

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[18] R. Paulman, personal communications, May 25, 2011.
[19] R. Paulman, personal communications, May 25, 2011.
[20] S. Gaul, J. Schneider, personal communications, May 6, 2011.
[21] Burt, C.M. PhD., P.E., D.WRE. *Where is all the water going?* [PowerPoint Slides]. February 1, 2010. Burt, C.M., 2009. *Water Conservation's Role in California Water Transfers.* Presented at the Annual Technical Conference of the Irrigation Association, San Antonio, Texas (September 2nd).

Another issue is the timing and location of water savings. Again, water management experts inside and outside of NEWBA note that water savings need to be delivered to the time and place of greatest need. For example, use of a water balance concept promotes that when water consumption is reduced, this water either directly mitigates shortage or is otherwise generally storable and available to the system as needed., provided that infrastructure is utilized and developed to provide this water only when, where and to the extent the shortage is actually occurring. This is sometimes referred to as "Integrated or Conjunctive" water management. For example, "the Nebraska Department of Natural Resources and Platte Basin NRDs, among other efforts, contracted with irrigation canals in the Platte Basin in 2011 to divert water when stream flows were in excess of required amounts. These efforts will enhance recharge to the aquifer, providing water in the river at a later time to reduce or eliminate shortages in river flows that might otherwise occur."[22]

In summary, a water-balance management approach would identify the relative value of multiple ways to consider water consumption such as: 1) reducing irrigation (and eventual evapotranspiration) through high-efficiency agriculture, and 2) quantifying the consumption in dry-land and native rangeland agriculture, reduction in riparian zone vegetation, or reducing evaporation from reservoirs or non-agricultural land uses. Efforts also can be made to transport water across time and space through storing and transporting water. Further, a water-balance management approach would, where feasible, seek to measure basin-wide water savings resulting from such efforts to reduce consumptive use on farms or other land parcels. When quantification is feasible, a water management approach would develop standards to provide appropriate credit for each of these activities.

IV. Recommendations

Three primary recommendations follow from the economics issues surrounding the water balance approach. The first is that many land uses influence water consumption in Nebraska geographic regions, whether that land use is irrigation, forestry, rain-fed agriculture, or unmanaged land. From this perspective, no particular land use is on its own totally responsible

[22] Email correspondence from Jim Schneider, October 11, 2011, refining the authors' interpretation of the presentation "Integrated Water Management: New Data and Information Studies," Platte River Basin-Wide Plan Meeting. Grand Island, Nebraska (July 21)., Jim Schneider, 2011

for trends in water consumption within the geographies of Nebraska. Further, efforts to improve water outcomes should consider a broad range of actions to change behavior, including incentives to encourage land use that promotes desired outcomes. The goal in making policy is to search for and implement the most efficient courses of action, meaning those actions that grow a combination of financial gain and environmental benefit. Financial gain refers to the proprietor income and resource income of Nebraskan's and environmental benefits include the value created by environmental outcomes such as improved stream flow, maintenance of wetlands, or other habitat restoration, among others. These goals could be achieved by 1) increasing water consumption that yields high marginal increases in combined financial and amenity benefits per unit of water, and reducing water consumption that yield low marginal gains (or even losses) in combined financial and environmental benefits per unit of water; and 2) encouraging technologies and management practices that increase the combined financial and environmental gain per unit of water.

Searching for and implementing these policies would naturally require a great deal of information about the environmental benefits (and the value of those benefits) and financial gains associated with various types of technologies and land management practices. State agencies and others interested in water policy in Nebraska should endeavor to gather this information. We therefore recommend that the Nebraska Department of Natural Resources and other interested parties make additional efforts to estimate and value the environmental benefits of a full range of practices including land management efforts to utilize water resources more efficiently, intentional groundwater recharge projects, vegetation management programs, and improved reservoir management. This information can then be utilized to design even more efficient water policies for the state of Nebraska, and regions of the state.

A final policy issue relates to water policy during "dry" years. Water policy in these years requires still more information about combined financial and environmental benefits in a dry-year setting. This is because both the financial gains and environmental costs of increases in water consumption can rise substantially during such "dry" years. Such increases have an uncertain impact on the combined financial and environmental gains from marginal water consumption. It may vary from case to case whether financial or environmental consequences rise more during "dry" years. This result suggests that it is critical to identify additional ways to bank and transfer water between "dry" years and "wet" years. Such approaches, if technically feasible, in terms of providing environmental benefits and financial gain in dry years, could be among the most beneficial water policies to pursue.

Appendix A: Interviews

In order to learn about the scientific and technical aspects of water policies, the research team conducted several interviews. Some individuals were interviewed because of their activities of the Nebraska Water Balance Alliance. Other individuals were interviewed because of their relation to the issue of water management as a whole. Some of these individuals are employees of the state, either directly, or by virtue of having received financial remuneration from a state-to-private-party contract.

The first interview conducted was with Frank Kwapnioski, P.E. Kwapnioski is a paid consultant with the Nebraska Water Balance Alliance and has spent the majority of his prior professional career as an engineer working in water resources and water operations with the Nebraska Public Power District. Most recently, he has worked with people within and without the NEWBA on the aspects and tenets of water balance. Kwapnioski also serves as the coordinator for the group.

The second interview conducted was with Jay Holmquist, Executive Director of the Nebraska Rural Electric Association, an organization that acts as an association of the generators and transmitters of electricity in rural areas. Holmquist acts as the Treasurer of the Nebraska Water Balance Alliance

Also interviewed was Bob Heinz, General Manager of Dawson Public Power District. Power districts have an interest in water management as a significant portion of their revenue is generated by agricultural producers using electrical power to pump water for irrigation purposes. Inasmuch, the Nebraska Water Balance Alliance proposes a solution to water management that would decrease variance in the pumping demands for water. This decreased variance, according to Heinz, would allow for greater predictability of the Dawson Public Power District's profit margin.

Also interviewed were Jim Schneider, Ph.D. and Steven Gaul of the Nebraska Department of Natural Resources. Schneider, the Deputy Director of the DNR, and Gaul, the Comprehensive Planning Coordinator of the DNR, were interviewed as to how monetary value could be assessed for water rights and also as to how the water balance approach and a decrease in consumptive use could be integrated into the water management of the state of Nebraska. Furthermore, Schneider was again interviewed regarding current projects underway at the DNR that incorporate modes of irrigation and reductions in consumptive use that are also promoted by the Nebraska Water Balance Alliance.

Also interviewed was Roric Paulman. Paulman is the owner of Paulman Farms in Sutherland, Nebraska. On his farmland, Paulman is implementing techniques during the 2011 growing season to measure consumption of water by agricultural producers.

Also interviewed was Dr. Charles Burt, of the Irrigation Training and Research Center in San Luis Obispo, California. Dr. Burt provided information pertinent to water balance issues as a function of academic research pertaining to agriculture in general, outside the parameters of either profitability or direct engagement in the crafting of state policy as it relates to irrigation or the subsequent purchasing of the right to irrigate.

Also interviewed was Dr. Derrel Martin. Martin, a Professor of Biological Systems Engineering at the University of Nebraska – Lincoln, provided expertise and information regarding the amounts of water that accrue in Nebraska on an annualized basis. Martin also provided information as to how that water is environmentally distributed upon its arrival, that is to say, what amounts arrive via stream flow and what amounts via precipitation and also how that water leaves the state in the same regard but also with the addition of consumptive human use.

Another individual consulted was Michael Jess, former Director of the Nebraska Department of Natural Resources. Jess provided information regarding the transactions between those selling water rights and those buying water rights and the process of understanding the nature of such transactions.

Appendix B: Water Balance Definitions

The Nebraska Water Balance Alliance, on its website, www.nebraskawaterbalancealliance.com, provides the following definition for water balance, and the related concept of water budget.

Water Balance: Is a process to allocate water consumption. Optimal allocation requires an understanding of the value of the various consumptions and a negotiation of the opportunities and tradeoffs associated with sustainability. By using a comprehensive budget/balance approach to quantify the supply and demands, there may be more water to allocate than was previously believed.

Water Budget: An inventory and understanding of total water supply and needs. Much of the required data for the development of a water budget is available and just needs to be appropriately compiled and assessed to be useful.