ECONOMICS OF GROUNDWATER MANAGEMENT ALTERNATIVES IN THE REPUBLICAN BASIN

Raymond J. Supalla[1]
Christopher L. Thompson[1]

ABSTRACT

In 2005 the State of Nebraska, in cooperation with local Natural Resources Districts (NRD's), implemented policies to reduce irrigation in the Republican Basin to comply with the Republican Interstate Compact. These policies limit the amount of water which irrigators can apply over a five year period. In this paper an optimization program called Water Optimizer was used to analyze the optimal irrigation management responses to these limitations and to estimate the cost to irrigators and the Basin economy. The optimal strategy was found to be deficit irrigation in most cases, with no reductions in irrigated acres until allocations were reduced to less than about 70 percent of unrestrained requirements. If optimal strategies were followed and average weather occurred, it was estimated that under current polices annual costs would be $27 per affected acre, or $278 per acre foot change in applied water to reduce irrigation. When expressed in terms of the primary policy objective, which is to reduce consumptive use, costs were found to average $344 per acre foot of decrease in evapotranspiration (ET) from irrigation. The aggregate economic effects since the control policies were implemented, however, were found to be small relative to the total regional economy. Favorable weather, high crop prices and improved agricultural technologies have mitigated much of the expected adverse impact of irrigation reductions on the regional economy.

INTRODUCTION AND BACKGROUND

In 1998 Kansas sued Nebraska and Colorado alleging that they had violated the Republican River Compact by allowing the proliferation and use of thousands of wells hydraulically connected to the Republican River and its tributaries, thus adversely affecting the amount of stream flow reaching Kansas. The states of Colorado, Kansas and Nebraska settled this lawsuit in December 2002. The Settlement Agreement required Nebraska and Colorado to significantly reduce their consumptive use from irrigation to levels that met Compact entitlements. Nebraska's entitlement is 49 percent and Colorado's 11 percent of total Republican Basin consumptive use. Compliance is defined as a five year moving average, except in dry years when compliance is measured on a two or three year moving average basis. This paper addresses the economics of policy options used by Nebraska to comply with this Agreement.

Under Nebraska law, surface water is administered by the Nebraska Department of Natural Resources (NDNR) following the Appropriation Doctrine of first in time, first in right, and groundwater is administered by Natural Resources Districts (NRD's) using a correlative rights approach. The Republican Basin encompasses three NRD's, called the

[1] Raymond J. Supalla and Christopher L. Thompson are Professor and Research Associate, respectively, Department of Agricultural Economics, University of Nebraska – Lincoln.

Lower Republican NRD (LRNRD), the Middle Republican NRD (MRNRD) and the Upper Republican NRD (URNRD) (Figure 1)[2]. Each of these NRD's has worked with the NDNR to develop management plans that reduce irrigation to meet Compact requirements. This paper presents estimates of the on-farm cost of limiting irrigation using these management plans, assuming that irrigators optimally respond to the associated regulations. It also addresses the regional economic consequences of the reductions in agricultural production which have resulted from reduced irrigation.

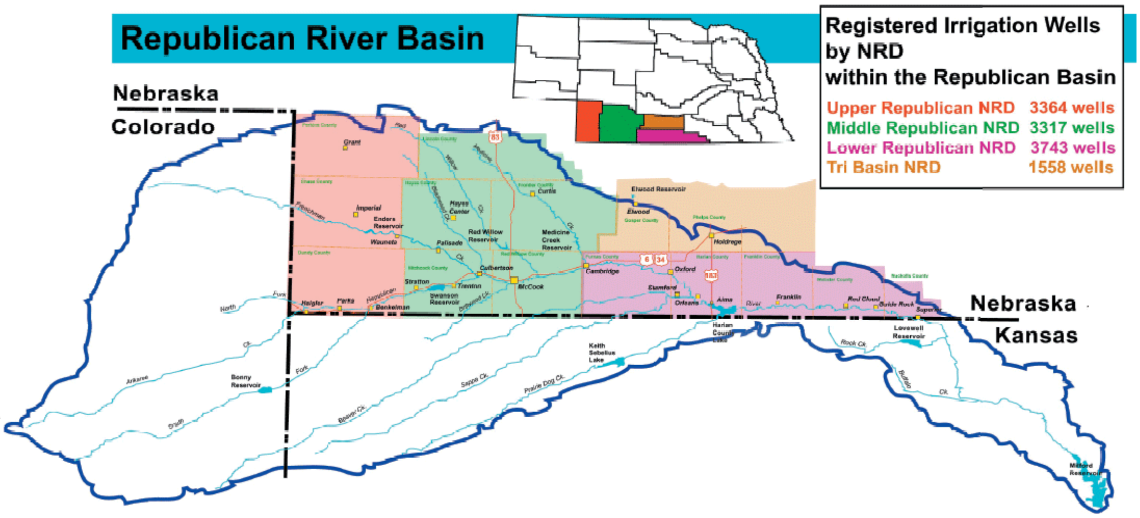

Figure 1. Map of the Republican River Basin.

DESCRIPTION OF THE REPUBLICAN BASIN

The Republican Basin begins with the North Fork and South Fork Republican rivers in the high plains of northeastern Colorado. These rivers meet to form the major trunk of the Republican immediately southeast of Benkelman, Nebraska. The Republican River then flows generally eastward along the southern border of Nebraska, passing through the Swanson and Harlan County reservoirs before curving southward into Kansas. Growing season rainfall varies from 16 inches at the western edge of Nebraska to 28 inches at the east end of the Basin. Elevation ranges between 3,284 feet and 1,598 feet above mean sea level.

Agriculture in the Basin is a mix of irrigated crops, dryland crops and rangeland. There are about one million certified irrigated acres in the Basin, distributed across the URNRD (435,337), the MRNRD (310,168) and the LRNRD (325,876)[3]. The major irrigated crops are corn (60%), Soybeans (17%), wheat (5%) and other (18%). There is about 1,450,000 acres of dryland crop production in the Basin, consisting primarily of wheat in the west and a corn-soybean rotation in the east. Historically there has also been a significant amount of dryland grain sorghum produced throughout the Basin, but grain sorghum acreage has decreased substantially in recent years. Dryland wheat is usually produced in

---

[2] The Tri-Basin NRD is also partially located within the Republican Basin, but the Settlement Agreement did not require it to reduce consumptive use from irrigation.

[3] Producer reported irrigated acres are certified as accurate estimates of historical irrigation by NRD staff.

a two year summer fallow–wheat rotation or in a three year eco-fallow rotation of corn-fallow-wheat.

About 65 percent of the irrigated land is irrigated with sprinkler systems, primarily center pivots, and 35 percent with gravity systems, primarily gated pipe (Table 1). About 10 percent of all irrigated land receives some surface water, although most surface watered acreage also receives supplemental groundwater. Over 95 percent of the total water applied comes from groundwater. Total irrigation water applied in the Basin averaged 1.1 million acre-feet per year during the five years prior the Settlement Agreement, with average per acre applications of 14.7, 12.0 and 8.9 inches in LRNRD, MRNRD and URNRD, respectively.

Table 1. Irrigated Acres, Irrigation System Type and Water Pumped, Pre-Settlement Baseline

	Irrigated Acres	**% Distribution by System**	**Water Pumped (Acre-feet)**	**Average Application In./Acre**
Upper Republican NRD				
Sprinkler	407,778	93.7	498,044	
Gravity	27,559	6.3	33,709	
Total	435,337		531,753	14.7
Middle Republican NRD				
Sprinkler	134,375	43.3	134,317	
Gravity	175,793	56.7	175,162	
Total	310,168		309,479	12.0
Lower Republican NRD				
Sprinkler	130,533	40.1	97,051	
Gravity	195,343	59.9	145,238	
Total	325,876		242,289	8.9
Total Republican Basin				
Sprinkler	672,686	62.8	729,412	
Gravity	398,695	37.2	354,109	
Total	1,071,381		1,083,521	12.1

METHODS AND PROCEDURES FOR ESTIMATING ON-FARM COST OF IRRIGATION REDUCTIONS

The on-farm cost of reducing irrigation was estimated using Water Optimizer, which is a non-linear optimization model developed at the University of Nebraska (http://wateroptimizer.unl.edu). This model computes the profit maximizing irrigation management strategies when both water and land are constrained. It determines the optimum crops to produce, the optimum amount of water to apply to each crop and the optimum number of acres to irrigate. The on-farm cost of irrigation reductions was defined as the difference in net economic returns for two different water supply levels, assuming that irrigators maximize profits as determined with the Water Optimizer model. The major inputs that determine the profit maximizing strategies include crop water requirements, comparative crop yields, crop prices, production costs and irrigation costs.

Crop Water Requirements

The estimated production functions which define the relationship between water applied and grain yields are probably the most important inputs to this analysis. Most of the economic effects stem directly from how crop yields change as the amount of water applied is reduced. Production functions were estimated separately for central locations within each NRD, for four irrigated crops (corn, soybeans, wheat and grain sorghum), assuming the most typical irrigation system (center pivot sprinklers at a water use efficiency of 0.75), and a medium soil having a water holding capacity of 1.5 inches per foot of rooting depth.

Estimating the water applied versus crop yield production functions required four critical inputs for each case: non-irrigated yield, maximum irrigated yield, maximum irrigation requirement, and water use efficiency. The parameter values used in this analysis were the same as those developed for general use in Water Optimizer (See http://wateroptimizer.unl.edu for data sources and procedures) and are shown here in Table 2.

Each of the production functions used in Water Optimizer and in this analysis were defined as

$$Y = Y_d + \left(Y_m - Y_d\right)\left(1 - \left(1 - \left[\frac{I_a}{I_m}\right]\right)^{1/\beta}\right) \tag{1}$$

Where: Y = grain yield in bushels per acre
Y_d = non-irrigated yield
Y_m = maximum yield from a fully watered crop
I_a = irrigation water applied, inches
I_m = irrigation water applied for maximum yield, inches
β = water use efficiency, assumed to be 0.75

Source: Martin (1989).

Production functions describing how crop yields respond to water applied are graphically depicted in Figure 2, for the four major crops at a representative location within the MRNRD, using input data from Table 2. Note that crop yield response to water diminishes as more and more irrigation water is applied. Recognizing the presence of diminishing returns to water is of crucial importance for understanding the economic effects from reduced irrigation. The profit maximizing irrigator logically continues to apply successive amounts of water to a crop as long as the additional water will produce a net economic gain. The first inch of water applied to a crop produces a large economic gain, whereas the last inch applied may cost as much as the value of what it produces.

Table 2. Crop Water Requirements[a]

	LRNRD	MRNRD	URNRD
Corn			
Non-Irrigated Yield	**83.7**	**62.8**	**50.2**
Max Irrigated Yield	**213.4**	**209.4**	**201.3**
Irrigation Needed for Max Yield	**12.7**	**15.2**	**16.7**
Wheat			
Non-Irrigated Yield	**55.6**	**52.9**	**49.1**
Max-Irrigated Yield	**73.5**	**78.9**	**83.2**
Irrigation Needed for Max Yield	**5.0**	**7.5**	**10.0**
Grain Sorghum			
Non-Irrigated Yield	**72.9**	**58.9**	**50.7**
Max-Irrigated Yield	**139.5**	**139.5**	**139.5**
Irrigation Needed for Max Yield	**10.0**	**12.7**	**14.2**
Soybeans			
Non-Irrigated Yield	**37.3**	**29.1**	**21.0**
Max-Irrigated Yield	**66.6**	**64.5**	**57.6**
Irrigation Needed for Max Yield	**10.8**	**13.0**	**14.2**

[a]All estimates assume a center pivot system and a water use efficiency of 0.75. The representative values for each NRD were based on available estimates for centrally located counties, Franklin for the LRNRD, Red Willow for the MRNRD and Chase for the URNRD.

Crop Prices, Production and Irrigation Costs

The crop prices used for corn, wheat, grain sorghum and soybeans were based on futures market prices for December 2010, with basis adjustments to reflect average Nebraska prices (Table 3). These prices also closely correspond to the price forecasts available from the Food and Agricultural Policy Research Institute (FAPRI, http://www.fapri.iastate.edu/) and from the Economic Research Service, USDA (http://ers.usda.gov/).

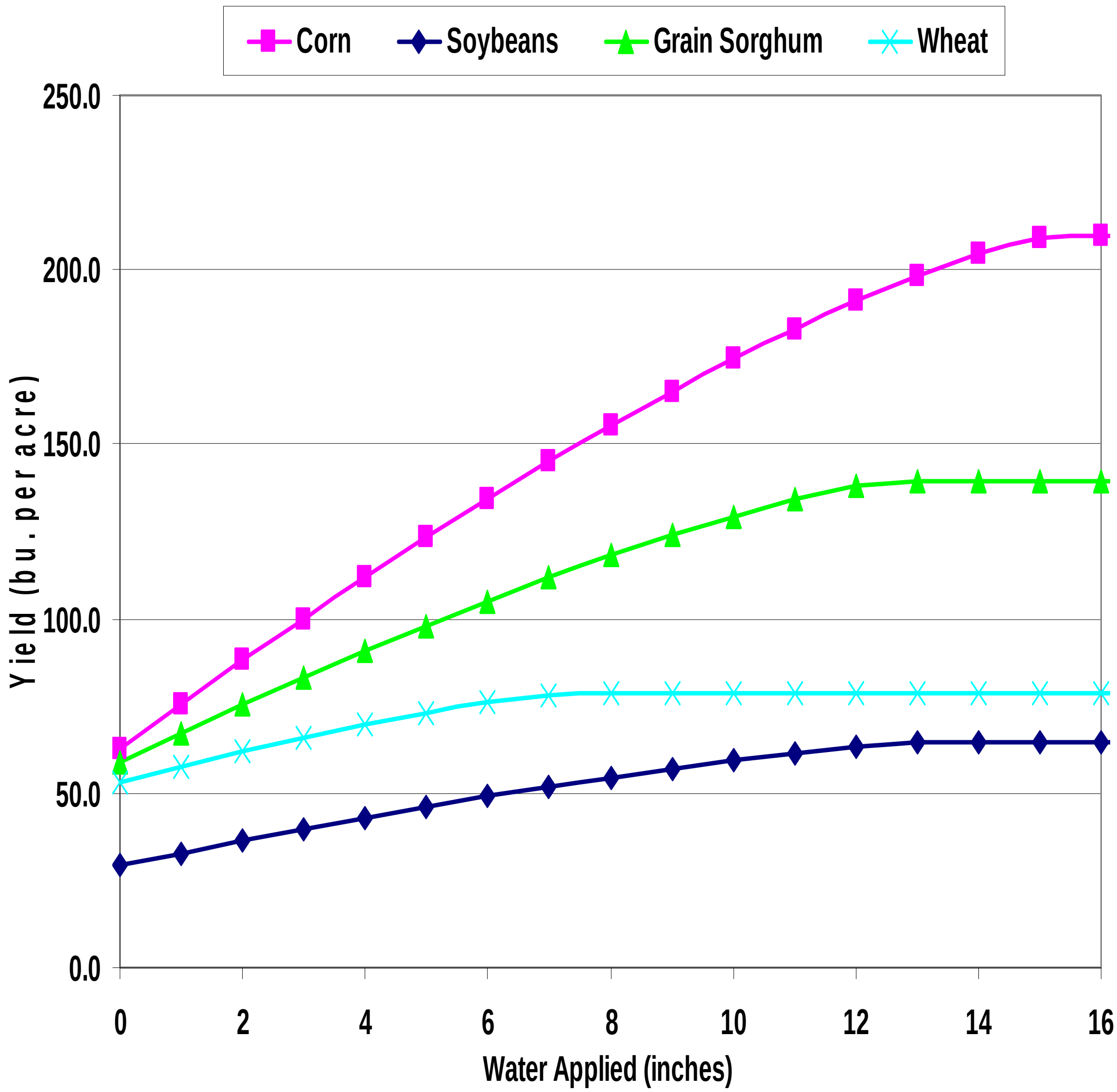

Figure 2. Production Functions for Corn, Soybeans, Grain Sorghum, and Wheat, in the Middle Republican NRD

The crop production costs used in this analysis were estimated for the Water Optimizer model based on 2010 Nebraska crop budgets data produced by the Department of Agricultural Economics, UNL (Wilson, 2010). The costs for each crop include yield dependent costs and other variable production costs (Table 3). Yield dependent costs include all costs that vary with crop yield. Grain handling, drying grain and nitrogen fertilizer were the main yield dependent costs. Other production costs included those costs associated with producing a crop which were variable in the sense that they could be avoided if the crop was not produced, such as seed, chemicals, fertilizer and field operations. Costs which are unaffected by how the land is managed, such as overhead and management charges, insurance, taxes and some depreciation costs were not considered. Irrigation costs were addressed as a separate category.

Table 3. Crop Prices and Production Costs

	Crop Prices	Yield Dependent Costs[a] ($/bushel)	Other Variable Costs Except Irrigation[b] ($/acre)
Corn	**3.76**	**.37**	**271.77**
Wheat	**4.99**	**.33**	**196.12**
Grain Sorghum	**3.20**	**.61**	**182.36**
Soybeans	**9.08**	**.08**	**164.16**

[a] Includes all costs that vary with yield such as grain handling, grain drying and nitrogen.
[b] Includes costs for seed, chemicals, fertilizer, labor, field operations and use related depreciation. Costs which are not affected by what crop is produced, such as overhead and management charges, insurance or taxes are excluded.

Irrigation costs depend on irrigation system type, feet of lift, pressure required and energy cost. Within the Republican Basin irrigation costs range from about $2.00 per inch for a gravity system, a shallow well and an electric pump, to about $8.00 per inch for a center pivot requiring moderately high pressure, pumping from a deep well and using a diesel pump. This analysis used a mid range cost of $5.50 per inch.

OPTIMUM MANAGEMENT STRATEGIES WHEN WATER IS LIMITING

When water becomes the limiting input, producers have three basic management options, deficit irrigate, plant crops that use less water and/or irrigate fewer acres. The profit maximizing practices at different levels of available water were analyzed in detail for Red Willow County, which is in the MRNRD and centrally located within the Republican Basin. We found that if water was unrestricted and rainfall was normal, producers would grow 80 percent corn and 20 percent soybeans, applying 15.2 inches to corn and 12.9 inches to soybeans, resulting in average water use of 14.8 inches per irrigated acre.[4] The optimal strategy, if the available supply of applied water was reduced by less than 30 percent of the combined requirement for both crops, was to deficit irrigate. It was not optimal to begin reducing irrigated acres until the amount of water available for corn was less than 13 inches, which is 85 percent of the full corn requirement, and the amount available for soybeans was less than 8.5 inches, which is 65 percent of the full soybean requirement. It was never profitable to produce lower water using crops such as grain sorghum or wheat at any water supply allocation (Table 4).

Deficit irrigation is clearly a preferred management strategy when one expects average weather, or has a sufficiently large multi-year allocation to compensate for less than expected rainfall during the season. A 20 percent reduction in applied water, for example, would cost irrigators $36 per acre if they followed deficit irrigation practices and $50 per

[4] Irrigated soybean acreage was limited to a maximum of 20 percent to more realistically represent current practices.

Table 4. Optimal Management Strategies when Applied Water is Controlled, Red Willow County

Optimal Crop Choices[a]							
Allocation Level (% of Demand)	Allocated Amount (In./Acre)	Corn Acres (% of all)	Water Applied to Corn (In/Acre)	Soybean Acres (% of all)	Water Applied to Beans (In./Acre)	Dryland Acres[b] (% of all)	Total Net Return ($/Acre)
100	14.8	80	15.2	20	12.9	0.0	$352
90	13.3	80	14.0	20	10.5	0.0	$339
80	11.8	78	13.0	20	8.5	2.4	$316
70	10.3	67	13.0	20	8.5	13.5	$290
60	8.9	55	13.0	20	8.5	24.8	$264
50	7.4	44	13.0	20	8.5	36.2	$238
40	5.9	32	13.0	20	8.5	47.5	$212
30	4.4	21	13.0	20	8.5	58.9	$186
20	3.0	10	13.0	20	8.5	70.3	$160
10	1.5	0	0.0	20	7.4	80.0	$134
0	0.0	0	0.0	0	0.0	100.0	$100

[a]The cropping pattern was restricted to a maximum of 20% soybeans to reflect current production practices.

[b] Optimal dryland crop was eco-fallow, a corn-fallow-wheat rotation.

acre if they fully irrigated both crops by reducing irrigated acres. However, if the irrigator does not have a remaining allocation that is large enough to compensate for rainfall risk, then the optimal strategy may be different. Rainfall risk is not a factor as long as the irrigator has enough water remaining in his multi-year allocation to compensate by applying more irrigation water than planned when rainfall is less than average. Similarly, if rainfall is more than average the produce can meet the optimal outcome by applying less irrigation water than planned and carrying the surplus forward to a future year, or by irrigating as planned resulting in higher than expected yields. Rainfall risk becomes a factor only if the producer is approaching the end of a multi-year allocation period and does not have enough water available to compensate for below average rainfall.

The effects of rainfall risk were evaluated for an optimal management strategy which incorporated deficit irrigation, and for a full irrigation strategy. For this analysis it was assumed that in higher than average rainfall years the irrigator would not decrease his planned irrigation level unless total available water exceeded crop requirements. The findings indicate that deficit irrigation is substantially better at capturing the upside of rainfall variability, with no significant differences on the downside, when compared to a full irrigation strategy. If you plan to deficit irrigate, rather than choosing to fully irrigate by putting your limited water on fewer acres, then when rainfall is above average the net returns from the deficit strategy are much higher than those from a fully watered strategy (Figure 3). Downside rainfall risk is very similar for both the deficit irrigation and fully watered strategies. Hence, deficit irrigation appears to be an even more strongly preferred strategy when rainfall risk is considered.

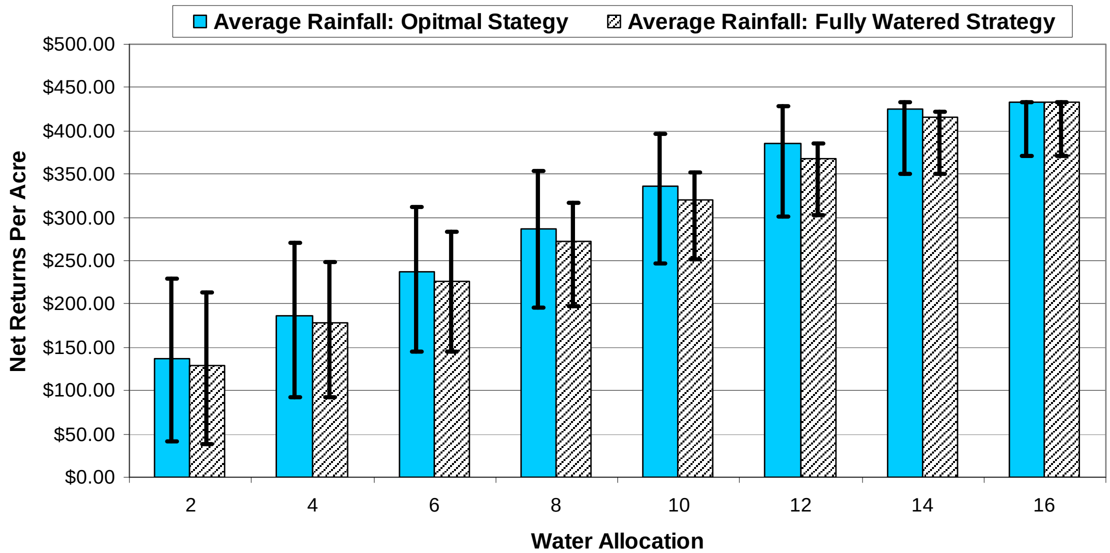

Figure 3. Distribution of Net Returns Depending on Management Strategy and Rainfall Amounts in Red Willow County Nebraska

Assuming profit maximizing behavior and no adjustments for risk, net returns over variable costs were estimated to range from $160 per acre with a three inch water supply, to $352 per acre at a full water supply of 14.8 inches, given the conditions described for Red Willow County (Table 4). This means that a reduction from 14.8 to 3.0 inches would cost irrigators $192 per acre (352-160 = 192), or an average of $16.27 for each one inch reduction in applied water. Cost per inch of reduction increases substantially as the reduction in available water gets larger, with the first 10 percent reduction in applied water costing $9.00 per inch, and the final 10 percent costing $17 per inch (Table 5).

What is most important from a producer perspective is the cost of reducing the amount of water that can be applied, because that is how the regulations are currently administered. The appropriate policy variable, however, is cost per unit change in evapotranspiration (ET) from irrigation, because the policy objective is to reduce the effect of irrigation on consumptive use in the Basin. When optimal management practices are followed and regulations are administered based on applied water, the cost of reducing ET from irrigation was estimated to range from $26 per inch at a 20 percent reduction in applied water to $22 per inch for large reductions (Table 5).

Table 5. On-farm Cost of Reducing Applied Water and ET, by Allocation Level

Allocation (% of Demand)	Allocation Amount (In./Acre)	Change in Applied Water (In./Acre)	Change in ET from Irrigation (Ac./Inches)	Change in Net Returns ($/Acre)	Cost of Reducing Applied Water ($/Inch)	Cost of Reducing ET ($/Inch)
100	14.8					
90	13.3	1.4	0.5	$13	$8.90	$24.27
80	11.8	2.9	1.4	$36	$12.46	$25.89
70	10.3	4.4	2.6	$62	$14.16	$23.99
60	8.9	5.9	3.8	$88	$15.00	$23.23
50	7.4	7.4	5.0	$114	$15.50	$22.84
40	5.9	8.8	6.2	$140	$15.84	$22.60
30	4.4	10.3	7.4	$166	$16.08	$22.43
20	3.0	11.8	8.6	$192	$16.26	$22.32
10	1.5	13.3	9.8	$218	$16.41	$22.29
0	0.0	14.7	11.1	$252	$17.11	$22.76

CURRENT AGGREGATE ON-FARM COSTS FROM REDUCING IRRIGATION

The management plans currently in place in the Republican Basin specifically restrict the amount of water that can be pumped per certified irrigated acre and acknowledges the need to reduce irrigated acres, especially in dry years. The Lower Republican NRD (LRNRD), Middle Republican NRD (MRNRD) and Upper Republican NRD (URNRD) restrict irrigation withdrawals over the next five years to 45, 60 and 67.5 inches, respectively. Irrigators may manage their allocations however they want over a five year period. There are no restrictions on what crops can be produced, how they are irrigated, or on how much water can be pumped in a single year. A limited amount of water not used during the five year allocation period can be carried forward to subsequent periods, but exceeding the five year allocation by essentially borrowing from subsequent periods in not allowed. Since 2005 there have been temporary retirements of irrigated acres under the federal CREP and EQIP programs and through the occasional purchasing of annual irrigation rights by the NDNR, but no well defined long-term land retirement program is in place.[5]

[5] CREP is the acronym for the federal Conservation Retirement Enhancement Program, which has been used in the Basin to pay farmers for converting irrigated land to conservation uses that do not involve any dryland or irrigated crop production for a contract period of 10 to 15 years. EQIP is the acronym for Environmental Quality Improvement Program, which has been used for paying farmers to convert land from irrigated to dryland crop production for a period of three years.

Cost of Reduced Pumping Allocations

The aggregate costs from the current allocation program depend on the economic factors discussed above, on how many acres have been affected by pumping limits, and by how much water was being applied before the limits were imposed. The first step in the analysis consisted of estimating how much water was being applied before the current regulations were imposed. This was done using historical well pumping distributions which depict the percentage of the wells which pumped more or less than particular amounts, expressed in inches per acre. A log normal distribution was assumed based on work by Martin (Martin,2004). Log normal distributions were estimated for each NRD by inputting the mean historical pumping level and then varying the standard deviation until the total area under the distribution curve matched NRD estimate of historical average annual volume pumped by all wells. These pumping distributions were used to determine how many acres historically received more water than the current allocation (Table 6).

The second step consisted of using Water Optimizer to compute optimal net returns for regulated and non-regulated water levels, for typical conditions in each NRD. Typical conditions were defined based on centrally located counties within each NRD. Franklin, Red Willow and Chase counties were used to represent the LRNRD, MRNRD and URNRD, respectively. County level data defined the irrigation requirements for each crop, as described in Table 2. Typical irrigation system characteristics and economic variables were assumed to be the same in each location and the same as those used above for evaluating alternative management practices.

On-farm costs resulting from the current allocation levels in each NRD were estimated at $20.7 million per year for the entire Republican Basin, which is an average of $27.43 per affected acre.

Table 6. On-farm Cost of Current Allocation Programs

	Net Returns at Current Allocation ($/Acre)	Prior Net Returns ($/Acre)[1]	Acres Affected by Regulations	Cost of Regulations ($/Acre)	Cost of Regulations Total
Lower Republican NRD	$341.24				
Historical Use					
9.0 to 10.5 Inches		$354.41	48,881	$13.17	$ 643,763
10.5 to 12.0 Inches		$374.85	39,105	$33.61	$1,314,319
12.0 Inches or More		$379.14	74,951	$37.90	$2,840,643
Totals			162,937	$29.45	$4,798,725
Middle Republican NRD	$318.74				
Historical Use					
12.0 to 13.5 Inches		$331.24	31,107	$12.50	$ 388,838
13.5 to 15.2 Inches		$350.34	27,915	$31.60	$ 882,114
> 15.2 Inches		$352.06	96,152	$33.32	$3,203,785
Totals			155,174	$28.84	$4,474,736
Upper Republican NRD	$270.53				
Historical Use					
Regulated @ 14.5 Inches		$296.70	435,337	$26.17	$11,392,769
Republican Basin Total			753,448	$27.43	$20,666,230

[1]For the Lower and Middle Republican NRD's, acres receiving less than the unrestricted requirement were evaluated at the midpoint of the indicated range in water applied, and acre receiving the average irrigation requirement or more were evaluated at the required amount.

For the Upper Republican NRD, all irrigators were assumed to be using their previous allocation of 14.5 inches before the current regulations were implemented.

Per acre costs were very similar for each NRD, which is perhaps a reflection of a general desire to implement policies which distribute the economic burden of meeting Compact requirements fairly evenly across NRD's. However, it important to note that the Compact costs estimated for the URNRD reflect the fact that they had an allocation program in place before obligations to meet Compact in-stream flow requirements became an issue. If costs for the URNRD were estimated relative to an unregulated state, as they were for the LRNRD and MRNRD, they would have been much higher.

In addition to thinking in terms of costs per acre, it is useful from a policy perspective to consider on-farm costs in terms of dollars per unit reduction in water applied or consumed. Estimated on-farm costs for current allocation policies average $278 per acre foot change in applied water ($20,700,000/74,293 =$278) and $344 per acre foot change in ET from irrigation ($20,700,000/60,006 = $344). The costs per acre foot change in ET from irrigation are higher than the costs per acre foot change in applied water, because the reduction in ET averages about 80 percent of the reduction in applied water for the current allocation programs in the Basin.

Farm Level Cost of Reducing Irrigated Acres

Irrigated land retirement is an alternative method of reducing irrigation. This could be accomplished by leasing or purchasing irrigation rights and the cost is theoretically equal to the difference in net returns with and without irrigation water, expressed in annual terms or as a capitalized value. Land retirement costs are very difficult to estimate, however, because whereas allocation rules apply to all acreage, retirement costs depend on what land is retired. If the land retired is in the eastern part of the Basin where rainfall is higher, the difference in annual net returns between irrigated and dryland is about $150 per acre at current crop prices, but this difference increases to over $250 per acre at the western end of the Basin. These values are for lands having typical productivity and irrigation costs. If one was able to retire irrigated land beginning with the least productive land in the highest rainfall areas, the farm level costs would be well below the estimate of $150 per acre, per year. These costs would be incurred by irrigators if acres were reduced using regulations without compensation, or by general taxpayers if compensation were paid.

Retiring irrigated land by leasing or purchasing irrigation rights is the most cost effective way of reducing ET from irrigation, assuming that no excess compensation is paid[6]. If acreage controls were used to reduce ET from irrigation in the central part of the Basin, the change in ET would be about 11.1 inches per acre and the cost would depend on the productivity of the land involved. If producers were forced to retire some part of their irrigated acres, the cost to them for typical pivot irrigated land in Red Willow County would be about $200 per acre for a one year shift to dryland, assuming current crop prices and a reduction in land taxes of about $50 per acre. This translates to a cost of $18.00 per inch, or $216 per acre foot of reduction in ET, compared to a cost of over $325 per acre foot to achieve the same result with allocation in the same location.

OBSERVED IMPACTS FROM ALLOCATION POLICIES: 2005-2009

The above discussion addresses expected farm level effects of reduced irrigation in a weather normal year. How does this compare with what the Basin has actually experienced since post Settlement Agreement regulation began in 2005? In particular, have we seen the expected reductions in agricultural production and regional economic activity?

The estimated effect of allocation on net farm income of $20.7 M., expressed as net returns over variable costs, represents a change in agricultural production of about $14 M., with the difference accounted for by reduced farm input costs. Although this total is not insignificant in absolute terms, it amounts to less than five percent of the total value of irrigated crop production in the Basin, which makes the aggregate impacts difficult to

[6] Voluntary willing buyer and willing seller land retirement plans often result in payments well in excess of what is required to make the producer equally well off.

detect. A review of Basin wide trends in the value of agricultural production shows that agricultural values increased substantially after 2005, due primarily to crop price increases (Figure 4). When crop prices were held constant at their 10 year averages, Basin production was found to be nearly constant across most of the past decade. The inability to observe an impact in Figure 4 from regulations adopted in 2005, may be due to the fact that in the five years before 2005 growing season rainfall averaged 3.3 inches less than what has been experienced since 2005, at three representative weather stations. If adjustments were made for rainfall, the data would suggest some decline in production due to reducing irrigation, but still a very small change compared to the total.

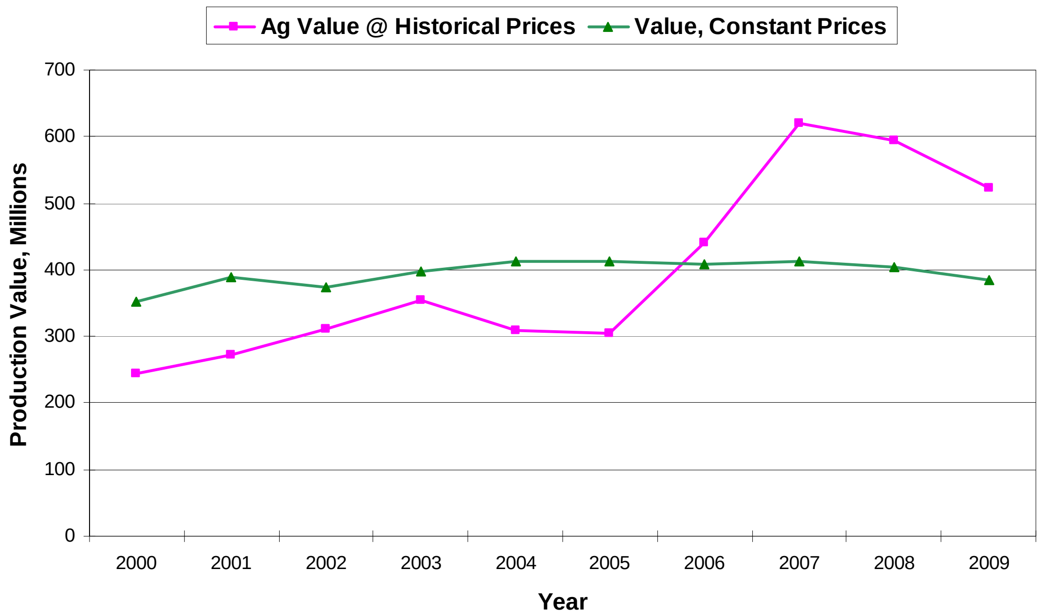

Figure 4. Republican Basin Agriculture Production Trends

One rather good measure of the effect of changes in irrigated agriculture on total regional economic activity is sales tax revenue. Sales taxes are levied on most consumer products, except services and some agricultural inputs. Sales tax trends in the Republican Basin show slower growth rates compared to what occurred in other rural areas or at the state level in recent years, but the Republican Basin economy has not experienced an absolute decline since the post Compact Settlement regulations were imposed in 2005 (Figure 5). This is due in part to the fortune of reasonably good weather and to the technologies that have led to increased grain yields and improved production efficiencies over time.

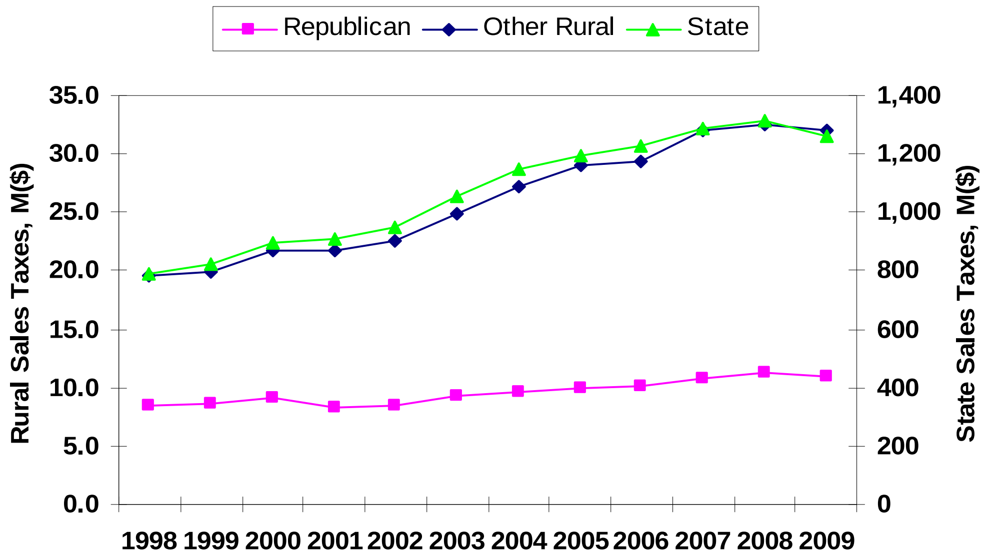

Figure 5. Nebraska Sales Tax Revenue, by Region

SUMMARY AND STUDY LIMITATIONS

This study addressed the economic consequences from policies designed to reduce irrigation in the Nebraska Republican Basin. It was found that the optimal strategy was to deficit irrigate, if the available supply of applied water was reduced by less than 30 percent of the combined requirement for both crops. It was not optimal to begin reducing irrigated acres until the amount of water available for corn was less than 85 percent of the full corn requirement, and the amount available for soybeans was less than 65 percent of the full soybean requirement. It was never profitable to produce lower water using crops such as grain sorghum or wheat at any water supply allocation. If optimal strategies were followed and average weather occurred, the cost of reducing irrigation by limiting applied water was estimated at $27 per affected acre, $278 per acre foot change in applied water, and $344 per acre foot of decrease in ET from irrigation, under current polices and economic conditions. It was also found that ET from irrigation, which is the major policy objective, could be achieved much cheaper if an acreage retirement policy was used, especially if the policy procedures led to retirement of the least productive land. The observed effects on the total Basin economy of the regulations adopted in 2005 were found to be surprisingly small. This is due in part to favorable weather, high crop prices and improved agricultural technologies.

It is important to note that the results from this analysis reflect current crop prices, a very simplified approach to representing the diversity of irrigation operations in the Basin, and assumed optimal irrigator responses to water limiting regulations. Estimated costs would be quite different if alternative assumptions were made, although the estimates are believed to represent midrange outcomes for current economic conditions.

REFERENCES

Economic Research Service, USDA (http://ers.usda.gov/)

Food and Agricultural Policy Institute. (http://www.fapri.iastate.edu/)

Martin, Derrel L. 2004. Personal Communication.

Martin, Derrel L., J. R. Gilley and R. J. Supalla. 1989. "Evaluation of Irrigation Planning Decisions." *Journal of Irrigation and Drainage Engineering*, Vol. 15, No. 1.

Nebraska Department of Natural Resources. 2010. Integrated Water Management Plans. http://www.dnr.state.ne.us/IWM/docs/IMP_approvedplans.html

Water Optimizer Model and Descriptive Documents. (http://wateroptimizer.unl.edu)

Wilson, Roger. 2010. Nebraska Crop Budgets. http://cropwatch.unl.edu/web/economics/budgets