Non-Binding Arbitration Initiated 10/21/08
Pursuant to
Decree of May 19, 2003, 538 U.S. 720
Kansas v. Nebraska & Colorado
No. 126, Orig., U.S. Supreme Court

Economic Impacts on Kansas of Diminished Surface Water Supplies to the Lower Republican River Basin Caused by Nebraska in 2005 and 2006

by

Dr. Bill Golden

Dr. Terry Kastens

Dr. Kevin Dhuyvetter

Dr. John Leatherman

Dr. Allen Featherstone

Dr. Tom Johnson

January 20, 2009

Table of Contents

Cover Page i

Table of Contents ii

Executive Summary iii

I. Economic Impacts Associated with Reduced Water Supplies 1

II. Estimating the Reduction in Agricultural Output 1
- A. Water Response Functions 2
- B. Water Shortage 2
- C. Acres 3
- D. Irrigation Efficiency 3
- E. Irrigation Technology Mix 4
- F. Precipitation 4
- G. Crop Prices 5
- H. Irrigated Crop Mix 5
- I. Non-Irrigated Crop Mix 5
- J. Irrigated Crop Yield 6
- K. Non-Irrigated Crop Yield 8
- L. Other Relevant Costs 8
- M. Deriving the Value of Undelivered Water to KBID 8

III. Indirect and Total Economic Impacts of Reduced Water Supplies 9
- A. Introduction 9
- B. Analysis Method 9
- C. Geographic Scope of the Analysis 10
- D. Timeframe of the Analysis 10
- E. The Kansas IMPLAN Model 10
- F. Analysis of the Direct Effects 10
- G. Modeling Household Spending Changes 11
- H. Indirect Impacts 11
- I. Adjusting Losses to Present Value 12

IV. Summary 12

V. Tables 14

VI. References 22

Economic Impacts on Kansas of Diminished Surface Water Supplies to the Lower Republican River Basin Caused by Nebraska in 2005 and 2006

Executive Summary

This report provides methods, assumptions, and estimates related to the economic losses to Kansas resulting from the state of Nebraska's being out of compliance with the terms of the Final Settlement Stipulation approved by the May 19, 2003 Supreme Court Decree in *Kansas v Nebraska & Colorado*, No. 126, Orig. (the Decree). Irrigated crop producers with classified irrigated acreage within the Kansas Bostwick Irrigation District (KBID) incurred losses in crop revenues and profits. The analysis considered losses that irrigated crop producers incurred in 2005 and 2006 due to violations of the Decree by Nebraska. The analysis took into account location (above and below Lovewell Reservoir), irrigation technology (flood and center pivot), as well as the impact of expected crop mix changes in the face of expectations of reduced water availability.

Although a smaller number than those within KBID, irrigators outside of KBID also suffered economic damages by reduced flows in the Republican River. To derive an estimate of these damages this analysis assumed non-KBID irrigators had irrigation cost structures similar to the KBID irrigators. Finally, in addition to the direct economic impacts to producers of irrigated crops, this report also estimated the indirect economic impacts to the Kansas economy.

This report used water quantity shortages experienced by Kansas irrigators due to Nebraska being out of compliance with the Decree. The estimated water shortage quantities were based on Book (2009) and were evaluated at the farm headgate. The shortages to KBID irrigators were 22,384 acre feet in 2005 and 18,988 in 2006. For non-KBID Kansas irrigators the quantities were 4,432 acre feet in 2005 and 4,693 in 2006.

This analysis relied heavily upon information provided by KBID in its annual reports. Where such data were not available to develop the required estimates we used data from the USDA's National Agricultural Statistics Service (NASS) for either the north-central crop reporting district of Kansas or for the three counties most directly associated with KBID: Cloud, Jewell, and Republic. We analyzed all major crops considered for irrigation in KBID: wheat, corn, milo (grain sorghum), soybeans, sunflowers, ensilage, and alfalfa.

This analysis answers the question, How would crop yields, revenues, costs, water use, etc. have differed had water been available to KBID and other Kansas water users in 2005 and 2006 as required by the Decree? As such, our study relied on models of crop yield response to irrigation water. Our models were based on Kansas State University (KSU) research and developed using expected yield response to water data reported in Stone et al., 2006.

This study estimated not only the value of irrigation water where it was not available but also the value of additional quantities of irrigation water where only limited amounts might otherwise be available. Therefore, an expected crop yield at differing quantities of irrigation water was estimated. The estimated yields were then used to develop an estimate of what irrigated yields would have been had water been available as per the Decree.

Differences in actual and/or expected crop yields were multiplied by crop price to obtain the additional revenue that would have been obtained had water been available as per the Decree. For establishing expected crop production costs associated with different water availability scenarios, Kansas State University (KSU) crop- and region-specific crop budgets were used. Most fixed costs for non-irrigated production were estimated to be the same as for irrigated production – since producers are severely limited in the short run from making changes to these inputs across different amounts of irrigation water availability.

To make clear our analytical procedures, we first estimated the value of Kansas' water shortage by assuming irrigators could get all the irrigation water they economically desired. This analysis was one that compared KBID producers having optimal (profit-maximizing) irrigation water in 2005 and 2006 to the amounts they actually received from KBID in those years. But, since expectations of all desired water is probably optimistic, we next considered the case where the optimal water quantity desired by KBID irrigators exactly matched what would have been available to them under the Decree, i.e., what they actually received plus the estimated shortage as reported by Book (2009), for each of 2005 and 2006. In this latter analysis, the lost profit for the KBID producers is $85.27 per acre-foot in 2005 and $121.35 in 2006. The water shortages caused by Nebraska resulted in a direct loss to Kansas irrigators of $2,286,708 in 2005 and $2,873,784 in 2006.

Economic impacts emanate beyond the direct economic impacts to producers of irrigated crops (Supalla et al., 2006). This is due to the interconnected nature of the economy. Businesses buy from and sell to other businesses. Labor earns wages and salaries that are used to purchase household goods and services. Thus, when an economic impact occurs on the farm, it sets in motion a "ripple" effect that impacts interlinked economic sectors elsewhere in the economy. The Kansas state economy was modeled in a detailed accounting system called a Social Accounting Matrix (SAM), which estimates the indirect economic effects that are known to accompany the observable direct economic changes.

It was estimated that the initial impact of the total gross income losses reduced Kansas household disposable income by $1,727,587 in 2005 and $2,171,117 in 2006. These values, when applied to the Kansas SAM, resulted in an indirect economic impact of $1,019,625 in 2005 and $1,276,281 in 2006. Evaluated at the vantage point of December 31, 2008, the total impact to the state of Kansas sums the total gross income loss (i.e., the direct loss to irrigators) with the indirect economic impacts and appropriate interest charges to yield the total economic damages to the state of Kansas. These were estimated to be $4,221,672 for 2005 and $4,858,780 for 2006, which sums to a total of $9,080,452 in 2008 dollars.

The estimation of the direct profit loss to producers was based on assumptions relative to the producers' response to diminished water supplies, the response of crop yield to applied irrigation water, crop revenues, and measures of variable and fixed expenses. The estimation of indirect impacts was based on assumptions pertaining to the income distribution of impacted producers and their purchasing patterns.

Economic Impacts on Kansas of Diminished Surface Water Supplies to the Lower Republican River Basin Caused by Nebraska in 2005 and 2006

I. Economic Impacts Associated with Reduced Water Supplies

When agricultural water use is restricted, crop production, in all likelihood, will be reduced and producers and local communities will incur negative economic impacts. These direct economic impacts ripple through the economy, creating additional indirect impacts. The short term magnitude of these impacts depends upon the magnitude of the water use reductions and the relative economic importance of agriculture to the affected communities.

II. Estimating the Reduction in Agricultural Output

A reduction in agricultural output results in a direct negative economic impact to the regional economy. The magnitude of the reduction in agricultural profits defines the farm level economic impact (EI), which is simply the difference between the estimated profits that were actually observed (P_A) and the expected profits (P_E) had water been available as required by the Final Settlement Stipulation approved by the May 19, 2003 Supreme Court Decree in *Kansas v Nebraska & Colorado*, No. 126, Orig. (the Decree). The direct economic impact (EI) can be defined as

$$EI = P_E - P_A,$$

where P_A designates actual observed profit when water is restricted and P_E designates the profit when water is available under the Decree. The magnitude of the economic impact depends on several factors: 1) the magnitude of the water use reduction, 2) the current level of water use efficiency in the production process, 3) the number of acres involved, 4) the precipitation that occurred during the period, 5) the crop mix for the area, 6) crop yields that depend on crop-specific production functions, and 7) prices and costs. The data and assumptions associated with these factors, as well as their impact on the final economic estimate, are documented in the following sections.

What previously was called actual observed profit (P_A) consists of two components, the profit derived from limited irrigation crop production on the classified (as irrigable) acres that received water ($P_{A,I}$), and the profit derived from non-irrigated production on the classified (as irrigable) acres that did not receive water ($P_{A,N}$), but which would be irrigated if water were available. The profit when water is available (P_E) also has two components, the profit derived from fully irrigated production using center pivot technology ($P_{E,CP}$) and the profit derived from fully irrigated production using flood technology ($P_{E,F}$). The economic impact (EI) then can be redefined as

$$EI = (P_{E,CP} + P_{E,F}) - (P_{A,I} + P_{A,N}).$$

To a large extent, the economic impact will be determined by the crop choices made by producers, which are determined by their expectations of irrigation water availability. Since these expectations may vary within KBID, for the area above Lovewell Reservoir and the area below Lovewell Reservoir, the economic impacts (EI) were calculated separately for each area.

Profit (*P*) for a crop can be defined as

$$P = PR * Y - VC - FC,$$

where *PR* is the crop price, *Y* is the crop yield, *VC* are variable costs (fertilizer, fuel, etc.) associated with the crop's production, and *FC* are the fixed costs (land, equipment, etc.).

Losses associated with reduced irrigation water are greater in short-run economic settings (e.g., consider a farmer planning for an expected full-irrigation corn crop and finding that he has no water) than in long run economic settings (e.g., the farmer plans around an expectation of reduced water for the year, adjusting crop mixes and crop inputs accordingly).

A. Water Response Functions

This analysis answers the question, How would crop yields, revenues, costs, water use, etc. have differed had water been available to KBID and other Kansas water users in 2005 and 2006 as required by the Decree? As such, our study fundamentally depended upon models of crop yield response to irrigation water. But, since our analysis was specific to 2005 and 2006, the water response functions must also incorporate actual precipitation (we use the words precipitation and rainfall interchangeably in this report). Otherwise, we would not have been able to account for whether 2005 or 2006 were years that required more or less irrigation water than normal. Also, and this is especially true in years like 2005 and 2006 when fertilizer prices were historically high, care should be taken to account for meaningful economic interactions between the price of nitrogen fertilizer and irrigation water, at least for crops that depend heavily upon nitrogen, such as corn. In particular, the economic optimal input levels for nitrogen fertilizer and irrigation water are lower than for either input when it is considered by itself. Put another way, in areas where natural precipitation sufficiently substitutes for irrigation water, producers optimally apply higher rates of nitrogen fertilizer (and achieve higher crop yields) than in areas dependent upon irrigation to meet part of crops' water needs.

In 2005, Kansas State University (KSU) developed a water response function that incorporates each of the requirements noted above. We refer to this model as IPYsim (for irrigation and precipitation yield simulation). IPYsim was developed using expected yield response to water data reported in Stone et al., 2006, which were the same data underlying KSU's Crop Water Allocator (KSU-CWA). But, unlike KSU-CWA, IPYsim brought in the needed nitrogen information to better depict the economic optimal producer irrigation decision.[1]

B. Water Shortage

The purpose of this analysis was to place a value on water that was not delivered as required by the Decree. The quantities of water valued were taken from Book (2009) and were the result of estimations from a hydrological model as described in that report. These data are summarized in Table 1. This analysis valued only 50,497 acre feet of the total two-year state-line shortage of 78,960 acre feet. The difference between these

[1] Although it is not labeled as such, the IPYsim model is what underlies the Excel spreadsheet referred to as KSU-NPI_CropBudgets.xls, which can be found at http://www.agmanager.info/crops/budgets/proj_budget/decisions/, along with a paper that documents the associated techniques.

two numbers was not valued because a) it would be Kansas' part of the additional evaporation from Harlan County Reservoir and transportation losses that would have occurred had there been adequate water, or b) additional evaporative losses in Kansas, or c) return flows that would end up downstream in Kansas, for example, in Milford Reservoir. A water shortage of 41,372 acre feet to farms in KBID was valued, along with a shortage of 9,125 acre feet to non-KBID farms in the area, which used less irrigation water than they would have had it been available.

C. Acres

Irrigated acreage in KBID has varied over the years. The estimation of damages for KBID requires an estimation of the expected number of acres that would have been irrigated had water been available as per the Decree. This report estimated that 13,006 and 12,991 acres would have been irrigated in the KBID area above Lovewell Reservoir in 2005 and 2006, respectively. Likewise, it estimated that 25,429 (2005) and 25,398 (2006) acres would have been irrigated in the KBID area below Lovewell Reservoir. These estimates were based on the seven-year average proportion of the classified acres irrigated in the 1994 to 2000 crop years (Table 2). The KBID annual reports suggest that at the start of the crop season for these years there were no expected water use restrictions and, as such, these years represent the expected percent of classified acres (89.2%) that would have been irrigated had water use not been restricted. So, as an example, we estimated that 38,436 acres would have been irrigated in KBID in 2005 had water been fully available (i.e., 89.2% of the 2005 43,100 classified acres). Then, Table 2 shows that the estimate for the area below Lovewell would comprise 66.2% of these irrigated acres, and hence the 25,429 acres noted as an expectation of 2005 irrigated acres below Lovewell.

D. Irrigation Efficiency

Rogers et al. (1997) defines irrigation efficiency (E_I) as the percent of water that reaches the farm headgate *and* is used beneficially in crop production. Irrigation efficiency (E_I) can be defined as

$$E_I = 100(W_B / W_F),$$

where W_F is the water delivered to farm headgate, and W_B is the amount of water that is beneficially used in crop production. Season-long irrigation efficiency depends upon the coefficient of water application uniformity, water application rate, water delivery system capacity and length, sprinkler package if a sprinkler, soil type, field slope, irrigation timing, and individual management practices. Due to the variability in observed irrigation efficiencies, ranges of efficiencies are often reported (Table 3).

The estimation of expected water use requires a point estimate of irrigation efficiency for the different irrigation technologies. The irrigation technology survey, reported in KBID's annual report, indicates that there were 45.8 acres irrigated with subsurface drip technology (SDI) in 2006. Since the acreage irrigated with SDI is small and since reported efficiencies for SDI are comparable to those reported for center pivots, the SDI acres were considered center pivot acres in our analysis. For this report it was assumed that flood irrigation technology has a season-long irrigation efficiency of 65%.[2] It was assumed that center pivot technology has a season-long irrigation efficiency of 90%.[3]

E. Irrigation Technology Mix

Center pivot technology has higher irrigation efficiency than flood technology. As such, an acre-inch of water used in the production of an irrigated crop would have a higher value when it is applied with center pivot technology than when applied with flood technology. KBID conducts a survey of irrigation technology every four years. At the present time, the KBID data are not available separately by location (above or below Lovewell Reservoir). This report assumed that the technology mix was the same for the area above Lovewell Reservoir as the area below Lovewell Reservoir. Additionally, it assumed that the percent of land irrigated with center pivot technology grew in a linear fashion between the 2002 and 2006 irrigation technology surveys (Table 4).

The irrigation technology survey included all classified acres in KBID. Based on previous assumptions, all classified acres would not have been irrigated had irrigation water been available as per the Decree (Table 2 shows irrigated percent of classified acres to be 89.2% during the 1994-2000 period). Additionally, we know that all classified acres were not irrigated in 2005 and 2006. This raises the question, What percent of the observed and expected irrigated acres was irrigated with center pivots? The assumption we used was that, because center pivot irrigation is associated with greater fixed costs than is flood irrigation, when producers decide to leave some land un-irrigated, they abandon flood acres before pivot acres. Thus, we estimated that any irrigated acreage is irrigated with center pivot technology up to the maximum available. As an example, Table 2 shows there to be 43,048 classified acres in KBID in 2006 (actual computations consider location-specific potential pivot acres). Table 4 shows that 42.0% of these acres could be pivot irrigated (i.e., 18,080 acres). We would expect a total of 38,389 irrigated acres in 2006 if water were available as per the Decree (i.e., 43,048 x 89.2%). So, in the irrigation cost and water efficiency calculations we use in our analysis, we assumed 47.1% center pivot and 52.9% flood in 2006. Comparable values for 2005 were 42.9% pivot and 57.1% flood. Finally, to ensure equal treatment of the fixed costs of ownership for irrigation equipment whether it was used or not, we used these pivot percentage breakouts against actual reported irrigated acres as well as the acreage presumed to be irrigated if water were available as per the Decree.

F. Precipitation

The amount of precipitation varies from year to year and has an impact on crop production and profitability. As growing season precipitation increases, non-irrigated crop yields are expected to increase and the variable cost of irrigated production should decrease because less irrigation water is required to get optimal yields. Both factors influence the economic impacts that occurred in 2005 and 2006. Growing season precipitation for 2005 and 2006 was used in models of crop yield.

---

[2] The point estimate for flood technology is the approximate midpoint of the ranges referenced in Table 3.
[3] The point estimate for center pivot technology is set above the midpoint of the ranges referenced in Table 3. The irrigation technology survey, reported in KBID's annual report, suggests that the population of center pivots in KBID is relatively new, which would suggest a higher efficiency than average.

Growing season precipitation can be defined as the precipitation that occurs prior to and during the growing season that can possibly be of beneficial use to crop production.[4] Table 5 reports the time frames used to calculate growing season precipitation by crop.

Monthly precipitation was obtained from the KBID annual reports. Based on these data, Table 6 reports the annual and calculated crop-specific growing season precipitation used in this report.

G. Crop Prices

Table 7 depicts crop price information used in this analysis. The loan-adjusted 2005 and 2006 crop prices were used in computing expected crop revenue in those years. The 1994-2000 averages only were used in model calibration, as described later.

H. Irrigated Crop Mix

This analysis depends on estimates of irrigated and non-irrigated crop mix, both above and below Lovewell, for each of the two study years 2005 and 2006, as well as for a scenario that likely would have played out had water been available as per the Decree in those years. KBID annually collects and reports information on irrigated crop mix across years, both above and below Lovewell, but it does not collect non-irrigated crop mix information. For that we used National Agricultural Statistics Service (NASS) data for the three counties most directly associated with KBID: Cloud, Jewell, and Republic. For the "Decree water available" scenario we assumed that KBID producers in 2005 and 2006 would have selected crops similar to the way they did in years 1994-2000.

Table 8 depicts the irrigated crop mix information used in this analysis. The zeroes in the above-Lovewell 2005 row indicate that the observed irrigated crop mix in 2005-2006 would have been different had adequate water been available as per the Decree. Thus, we used the 1994-2000 average for that scenario.

I. Non-Irrigated Crop Mix

During the 2005 and 2006 crop years, had water been available as per the Decree there would have been 13,006 (2005) and 12,991 (2006) acres irrigated in the KBID area above Lovewell Reservoir. Likewise, there would have been 25,429 (2005) and 25,398 (2006) acres irrigated in the KBID area below Lovewell Reservoir. But, a portion of these acres was irrigated and a portion was not irrigated in 2005 and 2006 (the portion above Lovewell in 2005 was 0). In order to calculate lost profits, it was necessary to develop estimates of the non-irrigated crop mix that was actually planted in 2005 and 2006. For that, we used NASS data for 2005 and 2006 associated with Cloud, Jewell, and Republic counties. To segregate irrigated from non-irrigated data when NASS reported only "total," Table 9 shows the non-irrigated crop mix information for this analysis. The 94-00 row in Table 9 is included only for comparison purposes.

---

[4] While the National Engineering Handbook applies the concept of growing season precipitation, it does not provide a formal definition. The National Engineering Handbook is published by the USDA Soil Conservation Service and is available at: http://www.info.usda.gov/CED/ftp/CED/neh15-02.pdf

J. Irrigated Crop Yield

Importantly, our analysis depended upon determining irrigated and non-irrigated crop yields in 2005 and 2006. Besides knowing what irrigated yields were in KBID during 2005 and 2006, we determined what irrigated yields would have been had water been available as per the Decree (referred to as fully irrigated). We started by establishing expected yields in 2006 given a simple linear time trend of yields observed in KBID during the period 1962-2006. Because some of the years had missing yields, especially for crops such as alfalfa and sunflowers, we computed the trend two ways. First, we used all observed data for a crop. Secondly, we used all observed data for a crop but dropped out observations associated with water-short years (i.e., 1991-1993, 2001-2006). Then, by crop, we used the maximum yield from the two methods as our expected fully-irrigated yield for 2006. We call these trend yields and use the same trend yield for 2005 as that determined for 2006. These trend yields are reported in Table 10.

Like many water response models, IPYsim depends on establishing a yield goal. As defined here, the yield goal is the expected crop yield given that neither nitrogen fertilizer nor water is limiting. Yield goals were calibrated so that, given long run nitrogen fertilizer and crop prices, and long run annual precipitation, IPYsim will simulate economically optimal yields equal to the trend yields already discussed. We used the 1962-2006 average annual precipitation of 28.22 inches (Table 6) as the expected annual precipitation. We used the average nitrogen fertilizer to crop price ratio (by crop) observed over the 1994-2000 time period for calibration, as well as a water cost also associated with that same time period. We used a nitrogen fertilizer price of $0.2162 per pound and the 1994-2000 crop prices reported in Table 7.[5] Water cost (a composite of center pivot and flood technology) for the 1994-2000 time period was estimated to be $0.3166 per net acre-inch applied (net is defined as after delivery efficiency is accounted for – see Table 3).[6] The calibrated yield goals are reported along with the targeted trend yields in Table 10.

Once IPYsim is calibrated for yield goals, the relevant annual precipitation (IPYsim depends upon annual, not growing season precipitation), crop prices, and nitrogen fertilizer prices can be applied, for each of 2005 and 2006, to derive model-expected crop yields given different water availability scenarios. Relevant annual precipitation was determined by adding to the 1962-2006 measure of 28.22 inches the difference between the year- and crop-specific growing season precipitation shown in Table 6. For example, the relevant 2005 annual precipitation for corn is 28.22 + (20.25 – 16.73), or 31.74 inches. Using the procedures already noted for price establishment, nitrogen fertilizer price was estimated to be $0.3267/lb in 2005 and $0.3740/lb in 2006. Similarly, water cost was estimated to be $0.9020 per net applied acre-inch in 2005 and $1.0236 in 2006.

---

[5] NASS, in its Agricultural Prices Summary, reports spring-time annual prices for the nitrogen sources of anhydrous ammonia (82% N), urea (45% N), urea ammonium nitrate or UAN (28% nitrogen) and UAN (32% nitrogen). In our calculations we estimated the nitrogen fertilizer product mix to be 40% anhydrous ammonia, 35% urea, 12.5% UAN-28% and 12.5% UAN-32%.

[6] For estimating irrigation water costs we assume total head feet to be 79.3 for pivots (i.e., 10 feet of lift and 30 psi (pounds per square inch) at the sprinkler-pressurizing pump) and 23.1 head feet for flood (i.e., 0 feet of lift and 10 psi to pressurize the delivery lines). We compute an average cost across natural gas, diesel, and electricity fuel sources. We assume 0.885 water horsepower-hours (whph) per kilowatt-hours of electricity, 61.7 whph per 1000 cu feet (mcf) of natural gas, and 12.5 whph per gal of diesel. We assume 90% efficiency in conversion of engine hp to whph. Finally, for computing our water costs we use energy prices from the Energy Information Administration (http://tonto.eia.doe.gov/).

It is important to note that yield goals are not the maximum possible yields that can occur in any given year. Rather, they are merely expected yields given non-limiting irrigation water and nitrogen fertilizer (i.e., yields expected if irrigation water and nitrogen fertilizer were free). Also, model-expected yields from particular levels of crop inputs should be used as relative measures rather than as direct yield estimates. An especially good or bad year weather-wise likely would lead to higher or lower yields, respectively, regardless of crop input quantities. Accordingly, to derive the fully irrigated crop yield we expect in some year, say 2005, we multiplied the actual observed yield in that year times the ratio of the model-predicted yield when all desired irrigation water is available to the model-predicted yield when less than the desired amount of irrigation water is available (i.e., when the actual amount of water applied in 2005 is used).

The base yield modeling framework just described is most appropriate for corn since it is the crop where yield-response-to-irrigation data are most prevalent and the crop most frequently managed in an irrigation setting. Although agronomically and economically defensible, it is possible that this framework may not adequately capture certain aspects of producer behavior given unaccounted-for farm level decisions, especially for crops other than corn, and thus might predict desired crop-specific irrigation quantities that are not consistant relative to corn. In particular, 1994-2000 data from the Water Right Information System (WRIS) of the Division of Water Resources of Kansas suggest the following percentages of irrigation water for north-central Kansas, by crop relative to corn: milo 69.5%, soybeans 90.1%, alfalfa 75.1%, sunflowers 53.4%, and wheat 57.5%.[7]

Despite the historical values noted above for irrigation water use relative to corn, our models estimated slightly higher desired irrigation water quantities for soybeans than for corn and considerably higher desired irrigation water quantities for alfalfa than for corn. These differences could be due to various factors that are not accounted for in our profit-maximizing framework. For example, producers may not fully account for differences in optimal irrigation water associated with nitrogen fertilizer costs (soybeans and alfalfa generally require no nitrogen fertilizer). Or, producers may see higher costs (than we have estimated) associated with irrigating alfalfa relative to corn, especially with flood irrigation since alfalfa does not lend itself very well to furrow irrigation. Regardless of the reasons for the differences between our base models' expectations and historical other-crop-to-corn water use information, we estimated that our corn model was appropriate. Then, we adjusted water use for the other crops according to the percentages reported above. These amounts of irrigation water were then applied to the associated crop models to derive fully-irrigated yields. Finally, as described earlier, observed irrigated yields were multiplied by the ratio of model-expected yields under full irrigation to model-expected yields under partial irrigation to arrive at the crop yields we would expect to observe in 2005 and 2006 given that water were available as per the Decree (reported in Table 10 as expected yields, fully-irrigated). The various estimates of irrigation water amounts actually applied or desired to be applied, and consistent with the estimated crop yields shown in Table 10, are reported in Table 11.

---

[7] WRIS data are annual water use at the individual producer water right scale. To derive these suggested values, WRIS data were first cleaned by discarding observations reporting less than 0.1 acre feet of usage and above 5 acre feet of usage. An acres-weighted average (i.e., across water right owners) was developed for each county, followed by an acres-weighted average (across counties) to the north central crop reporting district, followed by an acres-weighted average (across year) to the 1994-2000 time period.

K. Non-Irrigated Crop Yield

Non-irrigated crop yields are reported in Table 12. They were taken from NASS-reported yields for Cloud, Jewell, and Republic counties. For a given year, the non-irrigated yields were assumed to be the same for below and above Lovewell.

L. Other Relevant Costs

We have already discussed fertilizer and irrigation water costs. Other relevant costs were taken from KSU-reported crop budgets, with some adjustments. For example, we estimated one hour of labor per acre of flood irrigated land, which compares to 0.5 hours for center-pivot-irrigated land. Annual depreciation and interest were computed separately for pivot and flood irrigation delivery systems.

In our analysis, some costs for non-irrigated crops were adjusted upwards from their typical non-irrigated crop budgets to reflect the fact that water shortages induced some acres to be non-irrigated when they otherwise would be irrigated. For example, we assigned the same land charge to non-irrigated crops as we did to irrigated crops, which is consistent with the fact that cash rents do not immediately adjust downwards to reflect anticipated water shortages. Moreover, the water tax was paid either way. Similarly, we assigned the same per-acre irrigation equipment charge, farm machinery depreciation, and interest charge to non-irrigated crops as we did to irrigated crops. Also, we assumed labor costs for non-irrigated production were the same as for irrigated production, which is consistent with the fact that farmers in this region of Kansas do not have outlets for their excess labor in the short run. We added 25% of the difference between irrigated and non-irrigated fertilizer charges to the non-irrigated crops to reflect the likelihood that extra fertilizer was applied in anticipation of additional water receipts. We added 33% of the irrigation fuel charges to non-irrigated crops to reflect the fact that irrigators are required to pay a demand charge. Finally, we added 50% of the expected irrigation equipment repairs to non-irrigated crops to reflect the fact that weather can cause unused irrigation equipment to deteriorate and be in need of repairs due to non-use.

M. Deriving the Value of Undelivered Water to KBID

The first valuation considered all desired water, valuing that total additional water on a "per-acre-foot at the farm headgate" basis. Then, we multiplied that per-acre-foot value by the 22,384 acre-feet in 2005 and the 18,988 acre-feet in 2006, which were the shortages at the farm headgates according to Table 1. This valuation is reported in Table 13.

Table 13 suggests that more than the Table-1 acre-feet shortages were desired at the farm headgates each year in order for KBID to receive its desired irrigation amounts. So, the per-acre foot lost profit value is merely multiplied by the Table-1 shortage to derive a value for the water shortage as per the Decree.

Our analysis depends upon estimating an average *per-unit* value of irrigation water. But, with diminishing returns to irrigation water, the first inch of water is worth more than the next, and so on. So, an average per-unit value of water depends critically upon the range of water quantities considered. As a top end to that range, Table 13 assumed all water economically desired by KBID irrigators. But, this is probably optimistic given the water shortage quantities reported in Table 1. In particular, even if Nebraska were in compliance with the Decree, KBID irrigators would not expect to get all the water they desired. Rather, their water quantity expectation would be what they received plus what Table 1 says they were short. So, the appropriate top end of the water quantity range to use for computing an average per-unit value of water was less than that implied by Table 13, causing the appropriate average value per acre-foot to be higher than that reported in Table 13.

To appropriately estimate the average value per acre-foot of water we adjusted downwards the desired net irrigation amount and made corresponding reductions to nitrogen fertilizer (i.e., if less water were applied, nitrogen requirements also would decrease), until the adjusted *desired* additional (beyond what was received) irrigation water was exactly the amount that equates to the Table-1-reported shortage each year across KBID. Note that we performed this analysis at the aggregated above- and below-Lovewell scale since KBID could have re-allocated this additional water as desired. Table 14 reports the results of this analysis. This table shows that, for all Kansas irrigators impacted, the 2005 cost was **$2,286,708**, the 2006 cost was **$2,873,784**. We used these values as our measures of the direct economic impacts to Kansas irrigators.

III. Indirect and Total Economic Impacts of Reduced Water Supplies

A. Introduction

It is generally understood that economic impacts occur beyond those that can be observed directly. This is due to the interconnected nature of the economy. Businesses buy from and sell to other businesses. Labor earns wages and salaries that are used to purchase household goods and services. Thus, when an economic loss occurs, it sets in motion a “ripple” effect that impacts interlinked economic sectors elsewhere in the economy. The overall effect is typically greater than the direct effect by some increment of value. In this section, we estimated the value of the Kansas statewide indirect effects associated with diminished water supplies to the Lower Republican River Basin. Additionally, we combined the direct and indirect impacts and made adjustments for the time value of money.

To estimate the economic impacts, the Kansas state economy was modeled in a detailed accounting system called a Social Accounting Matrix (SAM). The SAM uses published government economic data to comprehensively account for all financial transactions occurring in the region at a point in time. The accounts show how all industry sectors, households, and other institutions are financially linked one to another. The accounting system provides a rich and detailed description of the economy. Economic changes can be tracked throughout the economy as the impact “ripples” through the various interconnected economic sectors, households, etc. This is more commonly known as the multiplier effect. By estimating the size of the multiplier effect, it becomes possible to determine the size and direction of the indirect economic effects that are known to accompany the observable direct economic changes.

B. Analysis Method

Social Accounting Matrix analysis is a system of accounting for the economic transactions occurring in a national, state, or regional economy over a period of one year. SAM analysis is an extension of input-output (I-O) analysis in that it accounts for a wider variety of financial flows in the economy. A SAM model creates a computerized spreadsheet, charting the flow of dollars between local business sectors, households, government, and other non-local consumers of locally-produced goods and services. SAM analysis enables estimates of how spending in one area of the economy “ripples” through the economy to other sectors.

Consistent with the methods approved in the *Kansas vs. Colorado* case concerning the Arkansas River Compact (Whittlesey et. al., 1998), the SAM modeling system used for this analysis is the Micro-IMPLAN (IMpact analysis for PLANing) system developed by the U.S. Forest Service (Minnesota IMPLAN Group, Inc.). The IMPLAN system consists of the software necessary to construct economic accounts, an impact analysis routine, and national, state, and county-level data files containing information related to economic activity.

C. Geographic Scope of the Analysis

The geographic scope of the analysis was the state of Kansas. While the scope of the direct impacts analysis was confined to the area comprising and surrounding KBID, the indirect economic impacts are not limited thereto. This is because all of the indirect impact is associated with changes in household income levels. Household spending is most certainly not confined to a narrow geographic area as households travel significant distances to purchase needed household goods and services. Subsequent rounds of spending and re-spending spreads the impacts even more broadly. Thus, the indirect economic impacts were most appropriately modeled at the broadest geographic scale. Given that our interest was estimating damages to Kansas, the appropriate scale was the state of Kansas.

D. Timeframe of the Analysis

Our impact analysis was confined to 2005 and 2006. Specification of the timeframe is important insofar as it influences the nature of the direct and indirect economic impacts, explained further below. Data for the year 2004 were chosen to build the model used in this analysis. This year was chosen because of our extensive use of and confidence in these data. Absent any major structural change in the economy, the differences observed from year to year are generally small. Thus, a 2004 model was constructed and used to determine economic impacts for 2005 and 2006.

E. The Kansas IMPLAN Model

The Kansas IMPLAN model was constructed using standard procedures and solving for Type SAM multipliers. The multipliers constructed to measure the impacts associated with household spending were of primary interest (Type SAM). The Type SAM multiplier uses all of the information in the social accounting matrix to capture the effects of inter-institutional transfers. For households, the Type SAM multipliers use information about inter-institutional transfers to account for commuting, Social Security tax payments, as well as household income taxes and savings.

F. Analysis of the Direct Effects

To assess the indirect effects for 2005 and 2006, we assume an uncertainty in farmers' minds around the availability of water across years (long run) and for the season (short run). As described earlier, this uncertainty would lead to some adjustments in farmers' production processes being made to mitigate the expected loss in profit associated with diminished water availability. But, in the face of such uncertainty, many such profit-protecting adjustments cannot be made, leaving the farmers with what effectively can be referred to as sunk costs that cannot be recouped. The value of water shortage numbers reported in Table 14 incorporate our estimates of such sunk costs and thus these were the direct impacts used to estimate the indirect effects.

Production expenses that are sunk cannot be reversed. Thus, there is little change in regional input purchases. There only is one place to absorb the losses in the near-term, which is through a reduction in farm profitability. The only economic sector available to adjust to this shock in the short term is household consumption. In the short term, there is nothing to offset this effect. Thus, 100 percent of the shock accrues to net household income change. In Table 14, it was estimated that net farm profits (farmers' household income) declined by $2,286,708 in 2005 and $2,873,784 in 2006 due to water shortages. This is the value of the direct economic impact to farm profitability and, thus, farm household income.

This scenario related to the direct effects is offered with one important caveat. The assumption is that there were no short term local market effects (local commodity price changes) associated with lower levels of commodity production. We do not believe any such market effects occurred.

G. Modeling Household Spending Changes

To model household spending changes, assumptions were made about which households were changing their spending behavior. IMPLAN has the capacity to model nine separate household income classes. No data are available showing household income distribution of Bostwick irrigators. It was assumed that one-third of the total income loss accrued to each of three income classes bracketed by $50,000 and $150,000 as shown in Table 15.

The first step required estimating disposable income for each household income class. We did this using information available in the SAM. Agricultural producers' profits are considered proprietary income. We took the proportion of proprietary income going to households to total proprietary income. This nets out employee contributions to social insurance as a leakage of household income. Then, for each household income class, we sum total commodity purchases. Dividing total commodity purchases by household proprietary income (net of social insurance contributions) yields the disposable income to proprietary income ratio. This process removed the proportion of household income used to pay taxes and savings. This ratio is shown for the three income classes in Table 15 together with the resulting values representing the decline of household disposable income spending. As a result, household disposable income spending declined by an estimated $1,727,587 in 2005 and $2,171,117 in 2006.

H. Indirect Impacts

Given the assumptions of the direct economic impacts, analysis of total impacts was straightforward. In the IMPLAN impact analysis, each of the three household income classes was shocked by its respective reduction in disposable income. IMPLAN uses a national expenditure profile for each of the income classes and permits the value of imported commodity purchases to leak from the region (Kansas).

Shown in Table 16 are total indirect impacts to the state, as measured by value added. Value added is essentially equivalent to Gross Domestic Product which is the standard measure of economic performance at the national level. It consists of four components: employee compensation (wage and salary payments together with certain fringe benefits), proprietary income (payments received by self-employed individuals), other property type income (interest, rents, royalties, dividends and corporate profits), and indirect business taxes (primarily excise and sales taxes). This is a very broad measure of income and the best indicator of the change in the economic welfare of both the Kansas private and public sectors. In Table 16, the impacts distributed to Kansas industries are shown using a standard two digit North American Industry Classification System (NAICS) aggregation. The indirect impacts to Kansas were $1,019,625 in 2005 and $1,276,281 in 2006.

I. Adjusting Losses to Present Value

This report first estimates economic impacts for the years 2005 and 2006 without accounting for the time lag between when the economic impacts occurred and the present. For this computation we use the interest rate series reported by the Federal Reserve Bank of Kansas City for agricultural operating loans in the Tenth District, which encompasses both Kansas and Nebraska. The average quarterly-reported annual rates for 2006, 2007, and 2008 (only first three quarters) are 9.06%, 8.98%, and 7.43%, respectively. Table 17 summarizes the economic impacts in 2005 and 2006 and adds the interest necessary to bring them to present value as of December 31, 2008. At the time of ultimate settlement, appropriate interest charges would need to be added to the bottom line in Table 17 to account for interest due from December 31, 2008 to the date of payment.

IV. Summary

We estimated the direct loss suffered by Kansas farmers due to Nebraska's overuse of irrigation water to be $2,286,708 in 2005 and $2,873,784 in 2006. To estimate the indirect impacts associated with the direct losses to Kansas farmers in the area of the Kansas Bostwick Irrigation District in 2005 and 2006, we assumed, in the short term, that 100 percent of the direct impact accrued to household income. This direct loss to household income affected a wide variety of household goods and service purchases, requiring a state-wide perspective in assessing the indirect effects.

An IMPLAN state-scale model was used to assess the impact of changes associated with reduced household spending. After calculating the proportion of disposable income for three household income classes, we estimated that in-state household spending declined by $1,727,587 in 2005 and $2,171,117 in 2006. We estimated the indirect loss to the Kansas economy to be $1,019,625 in 2005 and $1,276,281 in 2006.

To account for the fact that economic losses to Kansas accrued before they will be compensated, an interest charge was added to the economic losses to bring them up to present value as of December 31, 2008. Total indirect impacts, together with the direct impacts and interest, account for all of the impacts to Kansas's private and public sectors. The loss to the Kansas economy was estimated to be $4,221,672 for 2005, and $4,858,780 for 2006, which sum to a total of $9,080,452 as of December 31, 2008.

V. Tables

Table 1. Water Shortage Information (acre-feet).[a]

	2005	2006	Total
A. Water shortage at state line	42,860	36,100	78,960
B. Evaporation from Harlan County Reservoir[b]	1,341	2,717	4,058
C. Transportation loss in Nebraska	968	778	1,746
D. Adjusted water shortage at state line (A-B-C)	40,551	32,605	73,156
E. Water shortage at above-Lovewell farm headgates	10,947	8,801	19,748
F. Water shortage at below-Lovewell farm headgates	11,437	10,187	21,624
G. Total water shortage to KBID farms (E+F)	22,384	18,988	41,372
H. Evaporation and return flow part of shortage (D-G)	18,167	13,617	31,784
I. Return flows used outside of KBID	4,432	4,693	9,125
J. Total water shortage valued in this report (G+I)	26,816	23,681	50,497

[a] Table information was obtained or computed from Book (2009)
[b] Only Kansas' portion of evaporation

Table 2. Irrigated Acres in Kansas Bostwick Irrigation District.

Year	KBID Classified	KBID Irrigated	Above Lovewell	Below Lovewell	Irrigated, % of Classified	KBID Irrigated Acres,% Above	Below
1991[a]	42,488	30,881	7,680	23,201	72.7%	24.9%	75.1%
1992[a]	42,458	23,589	9,880	13,709	55.6%	41.9%	58.1%
1993[a]	42,537	33,858	11,153	22,705	79.6%	32.9%	67.1%
1994	42,523	34,933	10,792	24,141	82.2%	30.9%	69.1%
1995	42,523	38,485	12,357	26,128	90.5%	32.1%	67.9%
1996	42,574	35,431	15,188	20,243	83.2%	42.9%	57.1%
1997	42,574	38,985	13,282	25,703	91.6%	34.1%	65.9%
1998	42,574	38,486	12,702	25,784	90.4%	33.0%	67.0%
1999	42,650	38,788	12,708	26,080	90.9%	32.8%	67.2%
2000	42,650	40,711	12,691	28,020	95.5%	31.2%	68.8%
2001[a]	42,805	39,186	12,261	26,925	91.5%	31.3%	68.7%
2002[a]	42,922	39,442	12,451	26,991	91.9%	31.6%	68.4%
2003[a]	43,021	36,460	13,433	23,027	84.7%	36.8%	63.2%
2004[a]	43,114	23,035	0	23,035	53.4%	0.0%	100.0%
2005[a]	43,100	23,439	0	23,439	54.4%	0.0%	100.0%
2006[a]	43,048	28,579	5,925	22,654	66.4%	20.7%	79.3%
Average[b]	42,581	37,974	12,817	25,157	89.2%	33.8%	66.2%

[a] Years of short supply; start season with restrictions.
[b] Average is based on the years when water was not in short supply. Data are based on KBID annual reports. Minor modifications have been made to ensure total irrigated acres balances with the acreage above and below Lovewell.

Table 3. Ranges of Irrigation Efficiency for Center Pivot and Flood Technology.

Source	Flood	Center Pivot	Subsurface Drip
Rogers et al. (1997)	50% - 90%	70% - 95%	70% - 95%
KSU-CWA[a]	50% - 80%	85% - 90%	95%
UNL-WO[b]	50% - 75%	70% - 80%	NR[c]

[a] KSU-CWA: Kansas State University's Crop Water Allocator
[b] UNL-WO: University of Nebraska at Lincoln's Water Optimizer
[c] NR: not reported

Table 4. Historical Irrigation Technology Mix in KBID.

Year	Center Pivot	Flood[a]
1994[b]	4.0%	96.0%
1995	6.0%	94.0%
1996	8.0%	92.0%
1997	10.0%	90.0%
1998[b]	12.0%	88.0%
1999	15.8%	84.3%
2000	19.5%	80.5%
2001	23.3%	76.8%
2002[b]	27.0%	73.0%
2003	30.8%	69.3%
2004	34.5%	65.5%
2005	38.3%	61.8%
2006[b]	42.0%	58.0%

[a] Ditch and Pipe reported together as Flood
[b] Surveyed years; other years have been interpolated

Table 5. Periods Used in Growing Season Precipitation Calculations.[a]

Crop	Beginning Date	Ending date
Alfalfa	Apr 1	Sep 30
Corn	Apr 15	Aug 31
Ensilage	Apr 15	Aug 31
Milo	May 1	Sep 15
Soybeans	May 1	Sep 15
Sunflower	Jun 1	Sep 15
Wheat	Sep 15	May 15

[a] Kansas Crop Planting Guides (http://www.oznet.ksu.edu/library/crpsl2/l818.pdf) were used as guide for the starting dates and expert opinions were used as ending date.

Table 6. KBID Annual and Growing Season (by Crop) Precipitation in Inches.

	Annual	Growing Season Precipitation						
Time Period	Precipitation	Corn	Milo	Soybean	Alfalfa	Sunflower	Ensilage	Wheat
Normal[a]	28.22	16.73	16.73	17.03	12.82	13.37	16.73	13.37
2005	31.97	20.25	19.27	19.27	22.69	17.53	20.25	12.14
2006	26.18	15.34	15.84	15.84	19.56	12.42	15.34	10.37

[a] Normal is considered to be the 1962–2006 average.

Table 7. Crop Prices Used in Analysis.

Source	Year	Corn	Milo	Soybean	Alfalfa	Sunflower	Ensilage	Wheat
NASS District Level[a]	94-00	$2.18	$1.91	$5.40	$74.57	$0.0908	$17.12	$3.30
KBID Values for Crop Census[b]	2005	$1.50	$1.40	$5.00	$70.00	$0.1000	$20.00	$3.12
NASS District Level[a]	2005	$1.94	$1.55	$5.36	$74.00	$0.0865	$15.21	$3.12
FSA Loan Rates for KBID**	2005	$1.97	$1.81	$4.86	NA	$0.0911	NA	$2.77
KBID Values for Crop Census[b]	2006	$3.00	$3.00	$5.70	$100.00	$0.1000	$25.00	$4.19
NASS District Level[a]	2006	$2.62	$2.95	$5.20	$104.00	$0.1000	$20.54	$4.19
FSA Loan Rates for KBID[c]	2006	$1.95	$1.81	$4.85	NA	$0.0912	NA	$2.79
Price used in calibration[d]	94-00	$2.29	$2.06	$5.54	$74.57	$0.1004	$17.12	$3.41
Price used in analysis[e]	2005	$1.97	$1.81	$5.00	$70.00	$0.1000	$20.00	$3.12
Price used in analysis[e]	2006	$3.00	$3.00	$5.70	$100.00	$0.1000	$25.00	$4.19

Prices for alfalfa and ensilage, $/T; sunflowers, $/lb; others, $/bu
NASS ensilage prices based on 0.90*(8.0*corn price) +0.10*(8.0*corn price *0.8)
[a] Monthly average -- Oct price for corn, milo, soybeans; Jun price for wheat; Jul price for alfalfa; market year average for sunflowers (statewide price substituted for district prices for alfalfa and sunflowers)
[b] KBID did not report a wheat price; the NASS District price was substituted.
[c] FSA loan prices were the average for Cloud, Jewell, and Republic County, Kansas, for the stated year.
[d] Price used was the average of the greater of the NASS District prices and the average 2005-2006 loan prices.
[e] Price used was the greater of the KBID and associated loan prices.

Table 8. Irrigated Crop Mix.

Source	Year	Corn	Milo	Soybean	Alfalfa	Sunflower	Ensilage	Wheat
KBID above Lovewell	2005	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
KBID above Lovewell	2006	51.1%	8.0%	28.8%	11.9%	0.0%	0.2%	0.0%
KBID above Lovewell	94-00[a]	75.1%	0.3%	22.3%	2.2%	0.0%	0.1%	0.0%
KBID below Lovewell	2005	53.6%	5.1%	32.8%	7.2%	1.0%	0.2%	0.0%
KBID below Lovewell	2006	46.1%	1.4%	43.3%	9.2%	0.0%	0.1%	0.0%
KBID below Lovewell	94-00[a]	71.7%	0.5%	26.4%	1.3%	0.2%	0.0%	0.0%

[a] 94-00 is used to represent crop mix if water were available as per the Decree.

Table 9. Non-Irrigated Crop Mix.

Source	Year	Corn	Milo	Soybean	Alfalfa[a]	Sunflower[a]	Ensilage[b]	Wheat
KBID Counties (NASS)	2005	7.3%	20.7%	13.3%	3.9%	2.6%	0.4%	51.6%
KBID Counties (NASS)	2006	6.7%	17.9%	18.2%	4.0%	1.3%	0.5%	51.5%
KBID Counties (NASS)	94-00[c]	6.2%	26.6%	8.6%	4.3%	1.4%	0.4%	52.5%

[a] NASS-reported "all alfalfa" assumed to be 75% non-irrigated; "all sunflowers" assumed to be 100% non-irrigated

[b] Ensilage comprised of corn silage (assumed 33% non-irrigated) plus sorghum silage (assumed 90% non-irrigated)

[c] 94-00 is used to represent crop mix if water were available as per the Decree.

Table 10. Irrigated Yield Information.

	Year	Corn	Milo	Soybean	Alfalfa	Sunflower	Ensilage	Wheat
		bu/ac	bu/ac	bu/ac	T/ac	lb/ac	T/ac	bu/ac
Trend Yield[a]	for 2005-2006	169.7	110.1	61.1	6.2	2626.9		69.3
Yield Goal[b]	for 2005-2006	171.1	111.4	61.2	6.2	2654.9		70.0
Model Yield (fully irr.)[c]	2005	165.9	106.5	58.1	5.1	2458.8		65.0
Model Yield (fully irr.)[c]	2006	168.3	108.8	59.6	5.2	2406.3		66.4
Model Yield (actual irr.)[c]								
Below Lovewell	2005	150.5	105.1	53.6	4.9	2458.8		64.5
Above Lovewell	2005	120.3	90.3	43.1	4.2	2121.2		54.0
Below Lovewell	2006	142.6	103.7	52.5	4.7	2373.3		64.8
Above Lovewell	2006	133.9	99.9	49.7	4.5	2275.1		62.4
Actual Reported Yield								
Below Lovewell	2005	187.0	119.7	58.0	7.6	1330.2	14.3	62.1
Above Lovewell	2005	187.0	119.7	58.0	7.6	1330.2	14.3	62.1
Below Lovewell	2006	167.1	93.0	55.6	6.4	2205.9	23.9	60.9
Above Lovewell	2006	146.9	122.0	51.0	5.9	2107.2	19.9	58.1
Expected Yield (fully irr.)[d]								
Below Lovewell	2005	206.1	121.3	63.0	8.0	1330.2	29.6	65.0
Above Lovewell	2005	206.1	121.3	63.0	8.0	1330.2	29.6	65.0
Below Lovewell	2006	197.2	97.6	63.1	7.0	2406.3	28.4	66.4
Above Lovewell	2006	184.7	132.9	61.2	6.8	2406.3	26.6	66.4

[a] Trend yield is the expected yield in 2005-2006 given water is not limiting; wheat is based on a pre-determined yield goal of 70.

[b] Yield goal is selected in IPYsim to generate economically optimal yields equal to trend yields at long-run (1994-2000) fertilizer N and crop prices; wheat is arbitrarily set at 70.

[c] These model-expected yields are directly from IPYsim and take no account of actual yields observed in these years.

[d] Expected yields are derived by multiplying observed yield times the ratio of fully-irrigated to actual irrigated model yields.

General notes: Above Lovewell yields in 2005 assumed to be same as below Lovewell. Ensilage yields are assumed to be corn yields/6.9527.

Table 11. Inches of Water Applied Information.

	Year	Corn	Milo	Soybean	Alfalfa	Sunflower	Ensilage	Wheat
Water Delivered to Farm Gate[a]								
Below Lovewell	2005	5.78	5.78	5.78	5.78	5.78	5.78	5.78
Above Lovewell	2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Water to Crop[b]								
Below Lovewell	2005	4.38	4.38	4.38	4.38	4.38	4.38	4.38
Above Lovewell	2005	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Delivered to Farm Gate[a]								
Below Lovewell	2006	7.79	7.79	7.79	7.79	7.79	7.79	7.79
Above Lovewell	2006	6.12	6.12	6.12	6.12	6.12	6.12	6.12
Net Water to Crop[b]								
Below Lovewell	2006	5.98	5.98	5.98	5.98	5.98	5.98	5.98
Above Lovewell	2006	4.70	4.70	4.70	4.70	4.70	4.70	4.70
Desired Irrigation Water Delivered to Farm Gate								
Below Lovewell pivot	2005	9.11	6.33	8.21	6.84	4.87	9.11	5.24
Below Lovewell flood	2005	12.62	8.76	11.37	9.47	6.74	12.62	7.26
Above Lovewell pivot	2005	9.11	6.33	8.21	6.84	4.87	9.11	5.24
Above Lovewell flood	2005	12.62	8.76	11.37	9.47	6.74	12.62	7.26
Desired Net Irrigation Water to Crop[b]								
Below Lovewell	2005	8.20	5.70	7.39	6.16	4.38	8.20	4.72
Above Lovewell	2005	8.20	5.70	7.39	6.16	4.38	8.20	4.72
Desired Irrigation Water Delivered to Farm Gate								
Below Lovewell pivot	2006	13.44	9.34	12.12	10.09	7.18	13.44	7.73
Below Lovewell flood	2006	18.62	12.93	16.78	13.97	9.94	18.62	10.71
Above Lovewell pivot	2006	13.44	9.34	12.12	10.09	7.18	13.44	7.73
Above Lovewell flood	2006	18.62	12.93	16.78	13.97	9.94	18.62	10.71
Desired Net Irrigation Water to Crop[b]								
Below Lovewell	2006	12.10	8.40	10.91	9.08	6.46	12.10	6.96
Above Lovewell	2006	12.10	8.40	10.91	9.08	6.46	12.10	6.96

[a] Prorates KBID-reported water use over KBID-reported irrigated acres using same amount for each crop
[b] Assumes irrigation-technology-specific water delivery efficiencies and a blend of pivot and flood
Note that wheat is not particularly relevant because KBID reports no irrigated wheat.

Table 12. Non-Irrigated Crop Yield Information.

	Year	Corn bu/ac	Milo bu/ac	Soybean bu/ac	Alfalfa T/ac	Sunflower lb/ac	Ensilage T/ac	Wheat bu/ac
KBID Counties (NASS)	2005	94.6	86.1	38.8	3.1	1490.0	10.1	40.3
KBID Counties (NASS)	2006	67.3	73.8	29.9	2.7	1252.2	9.7	46.5

NASS-reported yields for Cloud, Jewell, and Republic counties helped derive these estimates.
Crop-mix estimates reported in Table 9 were used to fill in unreported-by-NASS information, along with an estimate that irrigated alfalfa, silage, and sunflower yields are double those of their non-irrigated counterparts.

Table 13. Value Based on All Desired Water.

	Below Lovewell	Above Lovewell	Total
2005			
In Kansas Bostwick Irrigation District (KBID):			
A. Total water desired at farm gate, ac-ft (C+D)	22,689	11,821	34,510
B. Desired inches per acre classified	9.20	10.51	9.61
C. Water delivered to farm gate, ac-ft	11,299	0	11,299
D. Additional water desired at farm gate, ac-ft	11,390	11,821	23,211
E. Lost profit from this water shortage	$465,152	$1,471,146	$1,936,298
F. Lost profit per acre-foot at farm gate (E/D)	$40.84	$124.45	$83.42
G. Water shortage at farm gate, ac-ft (Table 1)			22,384
H. Water quantity valued (min{D,G})			22,384
I. Value of water shortage at farm gate (FxH)			$1,867,345
Outside of KBID:			
J. Water shortage at farm gate, ac-ft (Table 1)			4,432
K. Value of water shortage at farm gate (FxJ)			$369,732
Value of water shortage, KBID + non-KBID (I+K)			**$2,237,077**
2006			
In Kansas Bostwick Irrigation District (KBID):			
A. Total water desired at farm gate, ac-ft (C+D)	32,955	17,232	50,187
B. Desired inches per acre classified	13.32	15.48	13.99
C. Water delivered to farm gate, ac-ft	14,711	3,023	17,734
D. Additional water desired at farm gate, ac-ft	18,244	14,209	32,453
E. Lost profit from this water shortage	$1,576,283	$1,546,160	$3,122,444
F. Lost profit per acre-foot at farm gate (E/D)	$86.40	$108.82	$96.21
G. Water shortage at farm gate, ac-ft (Table 1)			18,988
H. Water quantity valued (min{D,G})			18,988
I. Value of water shortage at farm gate (FxH)			$1,826,930
Outside of KBID:			
J. Water shortage at farm gate, ac-ft (Table 1)			4,693
K. Value of water shortage at farm gate (FxJ)			$451,537
Value of water shortage, KBID + non-KBID (I+K)			**$2,278,467**

Table 14. Value Based on Only Water Due.

	Below Lovewell	Above Lovewell	Total
2005			
In Kansas Bostwick Irrigation District (KBID):			
A. Total water desired at farm gate, ac-ft (C+D)	22,145	11,538	33,683
B. Desired inches per acre classified	8.98	10.26	9.38
C. Water delivered to farm gate, ac-ft	11,299	0	11,299
D. Additional water desired at farm gate, ac-ft	10,846	11,538	22,384
E. Lost profit from this water shortage	$445,564	$1,463,209	$1,908,773
F. Lost profit per acre-foot at farm gate (E/D)	$41.08	$126.82	$85.27
G. Water shortage at farm gate, ac-ft (Table 1)			22,384
H. Water quantity valued (min{D,G})			22,384
I. Value of water shortage at farm gate (FxH)			$1,908,773
Outside of KBID:			
J. Water shortage at farm gate, ac-ft (Table 1)			4,432
K. Value of water shortage at farm gate (FxJ)			$377,934
Value of water shortage, KBID + non-KBID (I+K)			**$2,286,708**
2006			
In Kansas Bostwick Irrigation District (KBID):			
A. Total water desired at farm gate, ac-ft (C+D)	24,113	12,609	36,722
B. Desired inches per acre classified	9.75	11.32	10.24
C. Water delivered to farm gate, ac-ft	14,711	3,023	17,734
D. Additional water desired at farm gate, ac-ft	9,402	9,586	18,988
E. Lost profit from this water shortage	$1,019,366	$1,284,904	$2,304,270
F. Lost profit per acre-foot at farm gate (E/D)	$108.42	$134.04	$121.35
G. Water shortage at farm gate, ac-ft (Table 1)			18,988
H. Water quantity valued (min{D,G})			18,988
I. Value of water shortage at farm gate (FxH)			$2,304,270
Outside of KBID:			
J. Water shortage at farm gate, ac-ft (Table 1)			4,693
K. Value of water shortage at farm gate (FxJ)			$569,514
Value of water shortage, KBID + non-KBID (I+K)			**$2,873,784**

Table 15. Annual Household Spending Changes.

Household Income Group	2005 Gross Income Loss	Disposable Income Factor	2005 Commodity Purchase Decline	2006 Gross Income Loss	Disposable Income Factor	2006 Commodity Purchase Decline
$50,000-$75,000	-$762,236	76.40%	-$582,357	-$957,928	76.40%	-$731,867
$75,000-$100,000	-$762,236	77.51%	-$590,784	-$957,928	77.51%	-$742,458
$100,000-$150,000	-$762,236	72.74%	-$554,446	-$957,928	72.74%	-$696,792
Total	-$2,286,708		-$1,727,587	-$2,873,784		-$2,171,117

Table 16. Kansas Value Added Impact Associated with Reduced Household Spending.

Industry	2005	2006
Ag, Forestry, Fish & Hunting	-$4,494	-$5,604
Mining	-$10,553	-$13,554
Utilities	-$24,165	-$30,434
Construction	-$5,294	-$6,616
Manufacturing	-$37,907	-$47,650
Wholesale Trade	-$64,310	-$80,946
Transportation & Warehousing	-$24,701	-$31,017
Retail Trade	-$127,242	-$161,080
Information	-$21,510	-$26,978
Finance & Insurance	-$80,241	-$101,114
Real Estate & Rental	-$51,082	-$64,310
Professional- Scientific & Technical Services	-$29,620	-$37,378
Management of Companies	-$7,230	-$9,260
Administrative & Waste Services	-$19,179	-$24,115
Educational Services	-$12,542	-$15,813
Health & Social Services	-$164,170	-$209,021
Arts- Entertainment & Recreation	-$13,665	-$17,072
Accommodation & Food Services	-$49,385	-$62,165
Other Services	-$52,180	-$65,581
Government & Non-NAICs	-$220,155	-$266,573
Indirect Value Added Impact Subtotal	-$1,019,625	-$1,276,281

Table 17. Summary of Economic Impacts.[a]

	2005	2006	Combined
Direct Gross Income Loss (Table 14)	$2,286,708	$2,873,784	N/A
Indirect Value Added Loss (Table 16)	$1,019,625	$1,276,281	N/A
Total Impact Before Interest	$3,306,333	$4,150,065	N/A
Interest	$915,339	$708,715	$1,624,054
Total Impact Evaluated at 12/31/2008	**$4,221,672**	**$4,858,780**	**$9,080,452**

[a] Interest compounded annually from end of years designated; interest rates are average quarterly rates for farm operating loans as reported by the Kansas City Federal Reserve Bank for the 10th District (only first three quarters in 2008). Rates used are 9.06% (2006), 8.98% (2007), and 7.43% (2008).

VI. References

Book, D.E., "Engineering Analysis of Losses to Kansas Water Users Resulting from Overuse of Republican River Supply in Nebraska." Report prepared by Spronk Water Engineers, Inc. January 20, 2009.

KSU – CWA. Kansas State University's Crop Water Allocator available at http://www.oznet.ksu.edu/mil/cwa/

Minnesota IMPLAN Group, Inc. *IMPLAN Professional Version 2.0: User's Guide, Analysis Guide, Data Guide*. Stillwater, MN: Minnesota IMPLAN Group, Inc. 1999.

Rogers, D. H., F.R. Lamm, M. Alam, T.P. Trooien, G.A. Clark, P.L. Barnes and K. Mankin, "Efficiencies and Water Losses of Irrigation Systems." Irrigation Management Series, Kansas State University Research and Extension Service, Publication MF-2243, Manhattan, Kansas, 1997.

Stone, L.R., A.J. Schlegel, A.H. Khan, N.L. Klocke, and R.M. Aiken. "Water Supply: Yield Relationships Developed for Study of Water Management." Journal of Natural Resources & Life Sciences Education. 2006. 35:161-173.

Supalla, Raymond, T. Buell and B. McMullen. 2006. "Economic and State Budget Cost of Reducing the Consumptive Use of Irrigation Water in the Platte and Republican Basins", Department of Agricultural Economics, UNL. August 21, 2006. http://watercenter.unl.edu/WRRI/Downloads/Supalla-CostToReduce-10-2006.pdf (last accessed April 21, 2008).

Whittlesey, N.K., J.R. Hamilton, M.H. Robison, and D.B. Willis. "Evaluation of Kansas' Claim for Money Damages for Its Losses from Colorado's Violations of the Arkansas River Compact 1950-94." Kansas V. Colorado, No. 105 Original, U.S. Supreme Court, 1998.