Task 5 Project Memorandum
Texas A&M University
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Impacts of Selected Water Management Strategies on Key Parameters of Water Quality and Impacts of Moving Water from Rural and Agricultural Areas

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Executive Summary

The northern Texas Panhandle Region contains large quantities of ground water reserves. The withdrawal and transfer of this ground water from rural agricultural areas can have a negative impact on future producer income. In addition, the reduction in gross sales from the abandonment of irrigated agriculture can have a far-reaching affect on the regional economy. The specific objectives of this study include: Assist in identifying the construction and operational costs of moving water from rural to other agricultural and urban areas; Identify the marginal value of water to the primary agricultural production users in Region A; Identify areas that may be impacted by the transfer of water and assess the potential economic impacts of exporting water from these areas.

The total project cost to establish a well production field and to transport water was estimated at $460 million (50 miles) to $1.65 billion (550 miles), depending on the distance transported. The annualized cost to move water 50 miles was $322.13 an acre-foot with $223.27 of the total being fixed cost to recoup the investment and the remaining $98.87 representing the variable cost (out-of-pocket) expenditures to pump/transport the water. The cost per acre-foot of water escalated as the distance transported increased. Total, fixed, and variable costs for the 550 mile distance were $936.45, $730.20 and $206.25 per ac-ft, respectively, assuming a project life of 40 years.

The gross receipts generated per unit of water pumped provide an indication of how valuable various enterprises are in using a scarce resource (water) to the local and/or regional economy. These estimates represent only the marginal value of a unit of water (acre-inches or acre-feet) and do not reflect the profitability to the individual producer that would be considerably less. The analysis revealed crops produce $115 to $305 per acre-foot; whereas, livestock operations generate $23,385 to $45,980 per acre-foot of water utilized. These estimates may seem extreme but appear appropriate. For example, a 25,000 capacity feedlot will use about the same amount of water as is used in producing a section (500 irrigated acres) of corn. The feedlot typically employs approximately 25 employees, while it takes two to three sections to fully employ a grain producer.

Three areas in Region A where water rights have already been purchased for the purpose of exportation were identified to analyze the impact on those areas via the change in gross crop receipts. These areas are: Roberts County; Carson and Hutchinson Counties; and Dallam and Hartley Counties. In the Roberts County scenario, the

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feasibility of exporting the water to nearby counties capable of irrigated production was analyzed because of the relatively rough terrain in the county being incapable of irrigation. None of the irrigated crops grown came close to generating the gross receipts ($117.43/ac-ft - $304.20/ac-ft) to cover the total cost of the pipeline ($322.13/ac-ft). The use of excess pipeline capacity by irrigated production could be justified as long as the variable cost of transporting the water ($98.87/ac-ft) is covered. However, this analysis suggests it is economically infeasible to irrigate low value crops (sorghum, wheat and soybeans) with transported water and is highly questionable whether it would be economically beneficial to irrigate high value crops (corn, cotton and peanuts) in normal years with respect to commodity price and the variable cost of irrigation.

The difference in relative impact on the local/regional economy of exporting water from Carson/Hutchinson versus Dallam/Hartley counties is significant. Exporting the same amount of water from Dallam/Hartley will result in a 50+ percent ($228.24 versus $149.76 per ac-ft) greater loss in gross receipts compared to exporting it from the Carson/Hutchinson county area. Several factors contribute to this disparity. First, the crop composition of Dallam/Hartley area favors a high value crop (corn). Second, the Dallam/Hartley compared to the Carson/Hutchinson area appears to have a relative advantage in producing both corn and wheat as indicated by both the gross receipts and the marginal value per unit of water pumped. Finally, Carson/Hutchinson appears to have a relative advantage in producing dryland crops compared to Dallam/Hartley because of the level of rainfall and soil types. Therefore, if water is to be exported, it should come from Roberts County, then Carson/Hutchinson Counties and finally from Dallam/Hartley Counties to minimize the adverse impacts from a regional economy standpoint.

Introduction

The transfer of ground water from rural agricultural areas can have a negative impact on future producer income in Region A of the Texas Panhandle. In addition, the reduction in gross sales from the abandonment of irrigated agriculture can have a far-reaching affect on the regional economy. Texas A&M University's role in Task 5 is to assist in evaluating the *Impacts of Moving Water from Rural and Agricultural Areas.* The specific objectives of Task 5 addressed by the Texas A&M Amarillo team includes the following:

- Assist in identifying the construction and operational costs of moving ground water from rural to other agricultural and urban areas.

- Identify the marginal value of water to the primary agricultural production users in the Panhandle Region. Assess the potential economic impacts to agricultural and rural areas.

- Assist in identifying agricultural areas that may be impacted by the transfer of the water.

- Prepare a memorandum on the findings to be used to develop Chapter 5 of the Senate Bill 2 plan that describes the impact of selected management strategies on water quality and impacts of transferring water from rural to urban areas.

The format of this memorandum will follow closely to the objectives as outlined above. In the first section, the construction and operational costs associated with a pipeline to move water are estimated for various distances. The second section includes the relative marginal value of water estimates for each of the primary agricultural water user groups in the region. These users are defined as: the predominant irrigated crops and the livestock operations existing in the region. In the third section, three possible areas of water exportation are identified and the potential economic impacts on producer income and area economies are estimated.

Construction and Operational Costs of Moving Water

Results of the Senate Bill 1 regional planning process indicate that currently developed water supplies are insufficient in some areas (counties) of Texas to support future generations. Water management strategies, such as, water conservation, wastewater reclamation, and weather modification, among others can play a role in closing the growing gap between available water supplies and municipal demand. However, water transfers and accessing water through water right transactions from areas with excess water supplies are considered one of the most viable solutions to the problem. Water transfers often result in the movement of water from one region to the other or even to a destination far away from the source of water. Water transfers and water marketing have the potential to affect regional irrigation supplies and agriculture as many realize that much of the exported water will detract from agricultural groundwater resources.

Water marketing not only requires a thorough knowledge of the actual market opportunities and trends, but also knowledge of the rules, laws, regulations, and water rights. There exists procedural protocols that must be followed for the transfer of water rights, and the associated costs of transferring water vary considerably depending on the region of Texas (Griffin and Characklis, 2002). However, water marketing has proven to be beneficial in most cases in spite of its high costs of transfer (Chang and Griffen, 1992). Due to seasonality of agricultural production, water transferred from one area to another solely for irrigation purposes may require either a larger pipeline or a terminal storage facility. The addition of a water storage facility to meet the seasonal irrigation requirement will definitely add fixed cost to the project. On the other hand, annual capacity utilization of a pipeline project meant exclusively for irrigation purposes without a terminal storage facility would have to be very low (maybe 50 percent to 60 percent) due to the seasonal water use resulting in a relatively much higher cost ($/ac-ft transported). Due to the seasonality of crop water use in the region, the cost associated with the transfer of water for solely agricultural purposes was not assembled.

This analysis identifies the estimated cost of moving water 50 to 550 miles regardless of its use, i.e. agricultural, municipal, or industrial. In the following sections of this report, the fixed costs as well as operational expenses to move water from the Texas Panhandle Planning Region (Region A) to other areas of the of the state has been estimated.

Results and Discussion

The costs of transferring water may be grouped into three main categories; construction cost or capital (structural) expenditures, other project (non-structural) costs, and operational expenses. The construction costs include materials, labor charges and equipment costs during the construction phase. The non-structural costs of the project include costs incurred for engineering, legal counsel, land acquisition, contingencies, land and easement costs, environmental studies, mitigation, and interest during construction. The operational or annual costs include maintenance, operation and energy costs, debt service, and expenses incurred for repairs (Parnell, 2004).

Capital/Structural Costs

The capital costs of moving water from one area to another through a pipeline include both construction as well as non-structural costs. The construction expenditures include the costs associated with the groundwater rights, the development of a well field (87 wells in this particular scenario) and transmission/pipeline costs. The costs for the well field include costs incurred on test holes, groundwater wells, power supply to the wells, and transmission to the well field storage tank, storage tank, pump station and unpaved access roads to the wells. The well cost includes drilling, stainless steel well screen with packing, stainless steel liner, turbine pump, wellhead, control valves, electrical service entry, controls and enclosure, and emergency generator. Electrical power distribution to well cost also needs to be estimated.

The capital costs have been calculated using the *Engineering News Record Construction Cost Index* (*ENR CCI*) values. The values from the *ENR CCI* table include the building, pumps, control equipment and all other materials, labor, and installation costs averaged over 20 major cities in the country. This index value measures how much it would cost to purchase a hypothetical package of goods and services compared to what expenses are in the base year (1997). The index values are reported monthly from 1997 to present. The capital costs have been estimated for the year 2004 based on the *ENR CCI* values of the respective Second Quarter values (7017, 7064, and 7109) for the year 2004. The average of the monthly index values for the Second Quarter 2004 is 7030. The construction costs of different pipelines have been verified from pipeline contractors of the Dallas/Fort Worth area. Those contractors are listed in the *Blue Book Directory* of construction and building estimates of *ENR*. Several drilling companies were contacted concerning the costs of drilling test holes that were estimated to be $7/foot of depth.

Groundwater Rights

Currently, water permits have been issued on approximately 268,000 acres in Roberts County. The cost of these groundwater rights according to last year's data ranged from $345 to $373 per acre of land. These types of permits are predominately rendered in Roberts and Gray Counties. Based on the use of the water, different water rates are observed. Irrigated land sells for more than dryland, so the difference in the cost of the land is the value of water (Crowell, 2004). The groundwater rights for 300,000 acres at the rate of $500 per acre have been assumed and included in the cost estimates of the water transfer project with an annual capacity of 150,000 acre-feet of water proposed to be transferred from Region A.

Well fields

The costs for well fields include expenditures incurred on test holes, groundwater wells, power supply to the well, transmission to the well field storage tank, storage tank, pump station and unpaved access roads to wells. The construction costs for drilling test holes were estimated by drilling companies in the area at $7/foot of depth. Total number of test holes at the rate of 8 test holes per square mile and 0.7 square miles per well is 488. The cost of one test hole at a nominal depth of 600 feet is $4,200, and the total cost of 488 test holes would be $2,049,600.

The total number of groundwater wells is assumed to be 87 out of which 58 wells have a capacity of 1,500 gallons per minute (GPM) each with the remaining 29 wells each having a capacity of 1,000 GPM. The well cost includes drilling, stainless steel screen with packing, stainless steel liner, turbine pump, wellhead, valves, electrical service entry, controls and enclosure, and emergency generator. The estimated cost of each well is $300,000. Power expenses to the well (1 mile/well) include three electrical conductors, pole mounted with insulators, protection devices, jumpers, sectionalizing switches and cutouts. The estimated cost of power is $68,000 per well, resulting in a total cost of $5,916,000 for 87 wells. The pipeline transmission to the well field storage tank is constructed from ductile iron or lined steel pipe with a diameter of 18 inches. The total length of this pipe has been estimated at 375,000 feet and the estimated expenditures for the total cost on the pipe for transmission to the well field storage tank is $25,875,000. Three storage tanks are assumed to be included within the well fields. The capacity of each well field storage tank is 9 million gallons. The cost of this type of storage tank, ground and mounted fixed roof with foundations is $3,872,092 per tank. However, as per observations made by the Keith Kothmann Company based in Dallas, Texas, the need for remote storage tanks is not clear and for surge tanks the use of HDPE fabric pillow tank could significantly reduce the cost to be incurred. According to the Keith Kothmann Company, the estimated cost of this type of tank is $1,250,000 and is 32 percent of the tank cost based on the *ENR CCI*. Storage tank pump station cost includes the pump with emergency generator, pump house, maintenance facility, infrastructure at the site, manifold piping and valves. It has also been observed that two instead of three storage tank pump stations would be sufficient and pumps can be rotated for maintenance purposes.

It should be mentioned that pump station costs are different for various pumping head requirements, discharge rates, and structural requirements. The values from the cost tables of the *ENR CCI* for the pump station construction costs are mainly based on the station size or the horsepower. These costs are calculated based on the costs needed to construct a pump station of a particular horsepower or size. These include costs incurred for buying pumps, housing, motors, electric control, site work, and all the materials. When the water is to be pumped from another source, such as a river or reservoir, an intake structure is also required for drawing the water from the source. The cost of constructing an intake structure is typically about 45 percent of the pump station expense. The costs of the pump stations of different sizes are estimated based on the actual construction costs. The costs of the pump stations of different sizes were estimated based on the average horsepower for different years (Texas Water Development Board, 1999). The groundwater well field also includes the cost of unpaved access roads to wells at

3,000 feet per well at an estimated total cost of $3,523,500. The cost includes six inch imported gravel, with drainage swale, and allowance for low water crossings, gates, etc.

Transmission/Pipeline

The costs for constructing a pipeline include factors such as: pipe materials, bedding requirements, geological conditions, urbanization, terrain, and special crossings. The unit costs of different pipelines are based on the pipe diameters that range from 12 to 120 inches, soil type, and level of urban development. Based on the level of urban development, pipelines are categorized as either pipeline-rural (soil) when the pipeline is constructed in soil in a rural area, pipeline-rural (rock) when the pipeline is constructed in rock in a rural area, pipeline-urban (soil) when the pipeline is constructed in soil in an urban area, pipeline-urban (rock), pipeline-rural (combination rock and soil), pipeline–urban (combination rock and soil). The pipeline costs were verified and estimated to range from $300 to $350 depending on rural soil types of pipeline with a pipe size of 90 inch diameter, and from $250 to $300 with a rural soil type of pipeline with a pipe size of 78 inch diameter, and range from $350 to $400 for constructing a pipeline with a pipe size of 78 inch diameter in a rock rural area (Driver Pipeline Company, 2004). The unit cost listed in the cost tables (Appendix A, Tables A-1 to A-10) represents the installed cost of the pipeline and appurtenances, such as markers, valves, thrust restraint systems, corrosion monitoring and control equipment, air and vacuum valves, blow-off valves, erosion control, revegetation of right-of-way, fencing, and gates (Texas Water Development Board, 1999).

Pipeline easements are of two types (i.e., temporary and permanent easements). A permanent easement is constructed to support the pipeline for permanent operation and maintenance, and for protection from other construction activities. Temporary easements are considered a good way to provide more workspace during construction, facilitate equipment movement and material storage especially during construction and other construction related activities without interfering or trespassing. The estimated construction costs were based on easement structures of 40 inches for permanent and 40 inches for temporary easements (Kothmann, 2004).

Other Project/Non-Structural Costs

Other project/non-structural costs include: expenditures for engineering, legal counsel, financing, contingencies, land, easements, surveying and legal fees for land acquisition, environmental and archeology studies, permitting, mitigation, and interest during construction. These costs are added to the capital costs to estimate the total project cost.

Engineering, Legal, Financing, and Contingencies

These costs include expenses incurred for engineering, legal, financing and contingencies. According to the Texas Water Development Board, it is approximately 30 percent of the total construction costs for pipelines and 35 percent for all other construction purposes. However, according to industry estimates, 30 percent contingencies seem too high and the suggested amount of contingencies is only 7 percent (Keith Kothmann Company, 2004) and that appears too low. It is very difficult to get an accurate estimate of contingencies as it varies from project to project. It is assumed that engineering, legal and financing fees including contingencies at the rate of 15 percent of well field and transmission/pipeline cost would be reasonable and are included in the project cost. Another 15 percent for development fees has also been added to the project cost to cover of any unexpected cost increase. It is added that a provision of some preliminary expenses has also been made in the project costs in addition to development fees.

Interest during Construction

Interest costs during construction is another expense that also needs to be included in the project costs. In accordance with the Texas Water Development Board guidelines, interest during construction is calculated as the total of interest accrued at the end of the construction period using a 6 percent annual interest rate on total borrowed funds, less a 4 percent rate of return on investment of unspent funds.

Total Project Costs

Total project costs for various distances have been estimated by adding both structural as well as non-structural costs. The details of the project costs for distances ranging from 50 to 550 miles are in the Appendix A, Tables A-1 to A-10. A summary of project costs, assumed project life, and annualized fixed costs of moving water from Region A through a pipeline project is in Table 1.

Table 1. Estimated project cost and annualized fixed cost of moving water 50 to 550 miles.

Distance	Project Cost	Useful Life, 30 Years	Useful Life, 40 Years	Annualized Fixed Cost, 30 Years	Annualized Fixed Cost, 40 Years
Miles	Million $	Annualized Cost, Million $		$/ac-ft	
50	$460.96	$33.49	$30.64	$223.27	$204.27
100	$586.84	$42.63	$39.00	$284.20	$260.00
150	$724.30	$52.62	$48.14	$350.80	$320.93
200	$783.99	$56.96	$52.10	$379.73	$347.33
277*	$994.08	$72.22	$66.07	$481.47	$440.47
350	$1,152.08	$83.70	$76.57	$558.00	$510.47
400	$1,283.18	$93.22	$85.28	$621.47	$568.53
450	$1,403.39	$101.96	$93.27	$679.73	$621.80
500	$1,517.88	$110.27	$100.88	$735.13	$672.53
550	$1,648.06	$119.73	$109.53	$798.20	$730.20

* Baseline cost estimate obtained from a MESA Water Inc. pipeline project for Roberts County to Lake Bridgeport.

Operational/Annual Costs

The annual costs include all the expenses incurred after the construction of the project. These include operation and maintenance, pumping power costs, water costs, repayment of loans, debts, interest, and all other miscellaneous costs required for the maintenance of the project.

Debt Service

As specified in Texas Water Development Board guidelines, debt service for all construction projects is calculated using an annual interest rate of 6 percent with a repayment period of 40 years for reservoir projects and 30 years for all other construction projects. Annualized gross investment corresponding to total estimated project costs for different pipeline length scenarios has been calculated using the debt service factor of 0.06646 or 0.07265 for 40 years or 30 years of useful life of the project, respectively.

Operation and Maintenance

Operation and maintenance expenditures include operation and maintenance of the pipeline, pump stations, well field storage tanks, labor costs, material costs, and repair costs, etc. In accordance with the Texas Water Development Board (TWDB) guidelines, the operation and maintenance costs are approximately one percent of the total estimated construction costs for pipelines, distribution facilities, tanks and wells. However, operation and maintenance costs have been assumed at the rate of 2.5 percent of the estimated total expenses for intake and pump stations. Well repair and maintenance at the rate of one-half percent of the estimated total cost of the well fields has also been included in the variable cost.

Pumping Energy Costs

In accordance with the TWDB guidelines, the energy costs are calculated based on the pumping capacity of the pumping stations in terms of horsepower and a power rate of $0.05 per kWh. Energy requirements have been estimated using the guidelines provided by Texas Cooperative Extension Engineer, Leon New (New, 2005). Details of energy requirements and costs of energy for moving water are given in the Appendix A, Table A-11. The energy cost is a major component of the variable cost for moving water. A power rate of $0.06 kWh will increase the annual energy cost ranging from $2.5 million to $4.0 million depending on the distance water to be moved, Appendix A, Table A-12. Based on the data currently available, the annual variable cost of moving water is summarized and in Table 2. The marginal cost of moving water in terms of $/acre-foot has been calculated by dividing the total variable cost by quantity of water (i.e. 150,000 acre-feet, the annual capacity of the proposed project). The cost estimates indicate that variable cost is $98.87 to move one acre-foot of water 50 miles, and it is $206.25 for one acre-foot of water to be transported a distance of 550 miles.

Table 2. Annual variable costs and marginal cost of water transferred 50 to 550 miles.

Distance	Operation & Maintenance	Energy	Well Replacement	Total Variable Costs	Marginal Cost
Miles	Million $				$/ac-ft
50	$1.80	$12.61	$0.43	$14.83	$98.87
100	$2.74	$14.70	$0.43	$17.86	$119.08
150	$3.51	$14.70	$0.43	$18.63	$124.22
200	$4.47	$16.33	$0.43	$21.22	$141.49
277*	$5.67	$16.33	$0.43	$22.42	$149.48
350	$6.90	$16.33	$0.43	$23.66	$157.70
400	$7.90	$17.96	$0.43	$26.28	$175.23
450	$8.71	$17.96	$0.43	$27.09	$180.63
500	$9.48	$17.96	$0.43	$27.87	$185.78
550	$10.46	$20.05	$0.43	$30.94	$206.25

* Baseline cost estimate obtained from a MESA Water Inc. pipeline project for Roberts County to Lake Bridgeport.

The estimated annual fixed costs, as well as variable costs, have been added to determine the total costs associated with moving water from one area to another. Total costs in terms of $/ac-ft for two scenarios of differing project life, i.e. 30 and 40 years, are estimated and in Table 3. The total costs range from $322.13 to $1,004.45 in the case of a project life of 30 years for distances ranging from 50 miles to 550 miles. Similarly, the total costs of moving water range from $303.13 to $936.45 assuming 40 years of project life. The change in project life assumptions only affects fixed cost without any influence on variable cost. The distance affects both fixed and variable cost; hence, total costs increase as the number of miles the water is transported increases.

Table 3. Annual fixed and variable costs of moving water for various distances for two scenarios of project life.

	Project Life, 30 Years			Project Life, 40 Years		
Distance	Fixed Cost	Variable Cost	Total Cost	Fixed Cost	Variable Cost	Total Cost
Miles	$/ac-ft			$/ac-ft		
50	$223.27	$98.87	$322.13	$204.27	$98.87	$303.13
100	$284.20	$119.08	$403.28	$260.00	$119.08	$379.08
150	$350.80	$124.22	$475.02	$320.93	$124.22	$445.16
200	$379.73	$141.49	$521.22	$347.33	$141.49	$488.82
277*	$481.47	$149.48	$630.95	$440.47	$149.48	$589.95
350	$558.00	$157.70	$715.70	$510.47	$157.70	$668.17
400	$621.47	$175.23	$796.69	$568.53	$175.23	$743.76
450	$679.73	$180.63	$860.37	$621.80	$180.63	$802.43
500	$735.13	$185.78	$920.91	$672.53	$185.78	$858.31
550	$798.20	$206.25	$1,004.45	$730.20	$206.25	$936.45

* Baseline cost estimate obtained from a MESA Water Inc. pipeline project for Roberts County to Lake Bridgeport.

Marginal Value of Water to the Primary Agricultural Production User Groups

Approximately 92 percent of the available groundwater in Region A is used for agriculture. This water is principally utilized for growing grain crops (89 percent) and raising livestock (3 percent). The change in gross receipts per acre-foot of water for irrigated versus dryland cropping alternatives was calculated for the primary irrigated crops; corn, cotton, peanuts, sorghum, soybeans and wheat to estimate the relative economic value of water used for farming. The value added in dollars per acre-foot per year for five livestock operations; fed cattle, dairy, stocker cattle, cow-calf and swine was also estimated. This allows direct comparison between crop and livestock enterprises with respect to their economic importance in the use of underground water supplies to the regional economy.

It should be noted that results of this study have ***nothing*** *to do with the relative profitability of these enterprises or their ability to pay for water. The analysis simply indicates the value to the regional economy of underground water utilized in these enterprises. However, comparing the cost of irrigation to the marginal value of water to a specific irrigated crop can provide insight on relative profitability of crops grown in the region and indicate which crops may face reduced water applied or increased abandonment in instances of rising irrigation costs or falling commodity prices. .*

Gross receipts for irrigated cotton, peanuts, sorghum and wheat were compared to growing these crops dryland to estimate the marginal value of applying water to these crops. Alternative dryland crops were utilized to calculate gross receipts for those crops where limited or no dryland crop acreage data was available. In these cases, dryland sorghum was assumed to be the substitute for irrigated corn and soybeans, since dryland versions of these two crops were considered unfeasible for the area. The value of irrigation water applied was calculated by subtracting the dryland alternative gross receipts from the gross receipts of the irrigated crop and then dividing by the acre-foot per acre of water applied to that crop.

Five-year weighted averages of acreage and yield by crop were utilized for this analysis. Acreage and yield data were obtained from the Texas Agricultural Statistics Service (TASS, 2000 - 2004). Average crop prices were derived from a combination of the Texas Cooperative Extension (http://agecoext.tamu.edu/resources/basis/online/) and TASS data. Water use by crop was estimated by using the long-term average water use numbers generated by the Texas A&M Amarillo (TAMA) model used to estimate irrigation demand for the region.

Livestock enterprises were evaluated in a similar manner using five-year averages of relevant data. Gross sales or the value added were calculated for all major livestock enterprises in the region and divided by the enterprise's water use expressed in acre-foot during the production period. The average livestock price data utilized in the analysis originated from the Livestock Market Information Center and TASS. The daily water requirements utilized for individual livestock categories were identified in "Task 2: Estimated Livestock Water Requirements for Region A - Panhandle" (Marek et al., 2004).

Results and Discussion

The gross receipts generated per unit of water pumped provide a relative indication of how valuable various enterprises are in using a scarce resource (water) to the local and/or regional economy. These estimates represent only the marginal value of a unit of water (acre-inches or acre-feet) and do not reflect the profitability to the individual producer that would be considerably less. The change in gross receipts per acre-foot of water for irrigated versus dryland cropping alternatives was calculated for the primary irrigated crops; corn, cotton, peanuts, sorghum, soybeans and wheat to estimate the relative economic value of water used for farming, Table 4.

The estimated gross receipts for the major irrigated crops ranged from $164.22 per acre for sorghum to $520.88 per acre for peanuts, Table 4. Subtracting the dryland alternative yielded an estimated change in gross receipts due to water applied by crop that ranged from $94.45 for sorghum to $399.76 for corn production. The amount of water applied varied considerably by crop. Corn (18.55 inches per acre) and peanuts (17.04 inches per acre) used substantially more than the other crops.

Dividing the change in gross receipts by the water use by crop provides a standardized estimate of the value of water applied allowing a comparison among crops. A distinct pattern developed between the crops. The marginal value per acre-foot applied for cotton, peanuts and corn was $304.20, $264.63 and $258.64, respectively. These values were approximately double that of the other three irrigated crops grown in the region, wheat, sorghum and soybeans which had marginal values per acre-foot of water applied of $147.22, $117.43 and $117.43, respectively. These results suggest a strong relative benefit to the regional economy from use of scarce water resources in cotton, peanuts and corn production rather than in wheat, sorghum and soybeans production.

No conclusions can be drawn about the overall profitability of these crops for producers from the marginal value per acre-foot applied. However, it does provide an indication of the marginal profitability of applying water since a majority of the irrigation costs between crops are similar such as pumping costs, costs associated with the distribution systems, etc. The relative accuracy of this analysis seems to be validated by another recently completed study on the impact of rising natural gas prices (Guerrero et al., 2005). In that study, producers facing higher natural gas prices were found to decrease irrigation 5 percent to 8 percent on peanuts, cotton and corn, whereas, irrigation was reduced 18 percent to 22 percent on wheat, soybeans and sorghum. Therefore, the observed reduced water use pattern in high natural gas years is rational behavior given the marginal value per acre-foot applied values calculated in this analysis. Producers reduced water applied more on the lower marginal value crops relative to the higher marginal value crops when faced with rising natural gas prices.

Table 4. Irrigated versus dryland gross receipts, change in marginal value per acre, long-term water use in inches per acre, and marginal value in dollars per acre-inch and acre-foot.

Crop	Gross Receipts, Irrigated ($/acre)	Dryland Alternative Crop	Gross Receipts, Dryland ($/acre)	Change in Marginal Value ($/acre)	LTA Water Used (in/ac)	Marginal Value ($/ac-in)	Marginal Value ($/ac-ft)
Corn	$469.53	Sorghum	$69.77	$399.76	18.55	$21.55	$258.64
Cotton	$432.87	Cotton	$159.89	$272.98	10.77	$25.35	$304.20
Peanuts	$520.88	Peanuts	$145.07	$375.81	17.04	$22.05	$264.63
Sorghum	$164.22	Sorghum	$69.77	$94.45	9.65	$9.79	$117.43
Wheat	$209.44	Wheat	$83.67	$125.77	10.25	$12.27	$147.22
Soybeans	$167.71	Sorghum	$69.77	$97.94	10.01	$9.79	$117.43

The estimated values of water for the six major alternative livestock operations in the region are listed in Table 5. Beef and dairy operations were assumed to be complete businesses where receipts from all products (milk, calves and cull cows) were counted in the calculation of gross receipts. Fed beef and stocker enterprises were considered value added operations; therefore, the sales value minus the purchase value was utilized in the analysis. Hog operations were considered a hybrid of the two containing both farrow-to-finish and finishing operations.

Daily water use by species included only what the animal consumed and additional water usage for cleaning, etc. The water utilized indirectly through the production of grain and/or forage was not included in this estimate, only the water directly pumped for use in the livestock operations was included. The marginal value generated by the six livestock operations ranged considerably with hogs generating the most impact with $45,979.66 of net receipts per acre-foot pumped. Hog enterprises were followed by dairy, fed beef, winter stockers, summer stockers and beef cow operations which accounted for $36,210.89, $35,736.18, $33,839.91, $26,082.69, and $23,385.07 per acre-foot, respectively.

Table 5. Livestock operations, gallons of water consumed by livestock group, dollars per head, head per acre-inch, and dollars per acre-inch and acre-foot, Region A.

Livestock	Gal/Hd	$/Hd	Hd/ac-in	$/ac-in	$/ac-ft
Beef Cows	20	$524.00	3.72	$1,948.76	$23,385.07
Fed Beef	15	$246.79	12.07	$2,978.01	$35,736.18
Summer Stockers	12	$172.93	12.57	$2,173.56	$26,082.69
Winter Stockers	12	$149.57	18.85	$2,819.99	$33,839.91
Dairy Cows	65	$2,637.74	1.44	$3,017.57	$36,210.89
Hog Operations	5	$92.44	41.45	$3,831.64	$45,979.66

The large disparity between crop and livestock enterprises in the marginal value generated per acre-foot of water utilized has significant implications with respect to the regional economy. Crops produce $115 to $305 per acre-foot; whereas, livestock operations basically generate $23,385 to $45,980 per acre-foot of water utilized. These estimates may seem extreme but appear appropriate. For example, a 25,000 capacity feedlot will use about the same amount of water as is used in producing a section (500 irrigated acres) of corn. The feedlot typically employs approximately 25 employees, while it takes two to three sections to fully employ a grain producer. Again, this analysis addresses the impact on the regional economy of the various agricultural enterprises using water. It does not address the profitability or desirability of individual enterprises.

Economic Impact of Water Exportation on the Regional Economy

The potential exportation of water from rural areas is a growing concern to the residents of Region A. While compensation received by the individual holders of water rights are expected to leave them financially neutral or better off, the long-term impacts to the local economy are unknown. Short run impacts are expected to be positive due to increased income of water right holders assuming these individuals are local residents, and the economic activity generated from pipeline construction. The degree of positive influence on the local economy from the pipeline construction will be dependent on the amount of purchased materials and labor used from the area. The more inputs used from the local region, the larger the impact. However, the long run impacts are expected to be negative if irrigated farming activities are decreased due to the lack of water. The reduced activity will adversely affect output handlers such as elevators as well as input providers like fertilizer and seed dealers, equipment dealers, repair services, etc.

This analysis looks at the potential impact to a local economy from a reduction in irrigated agriculture. The impact is evaluated in terms of a loss in gross receipts. This loss estimate provides a helpful indication, but is an underestimate of the total impact that may be two to three times greater. A more sophisticated analysis that can be conducted utilizing models such as IMPLAN that also evaluate the secondary effects on input suppliers, employment, etc. is necessary to estimate the total impact on the local/regional economy.

Three areas in Region A where water rights have already been purchased for the purpose of exportation were identified to analyze the impact on those areas via the change in gross receipts. These areas are: Roberts County; Carson and Hutchinson Counties; and Dallam and Hartley Counties. In the former two areas, water is already being exported from those counties, while in the latter area no movement of water has presently occurred.

Results and Discussion

The three areas identified have distinctly different alternative agricultural uses. Roberts County has very little irrigated cropland. Most of the underground water is located in relatively rough terrain incapable of being irrigated. Intensive animal operations were not considered an option because of the relatively low water use and the ability to locate elsewhere in the region closer to grain supplies. Therefore, it was assumed there was no viable local agricultural uses for this water. In this scenario, the feasibility of exporting the water to nearby counties capable of irrigation is analyzed.

The remaining areas, Carson/Hutchinson and Dallam/Hartley counties, do have significant acreages of irrigated crops. However, the crop composition and associated yields of crops in these two areas vary considerably. In these two areas, it is assumed that the export of water will lead to a loss in irrigated crop production in the same proportion as the existing crop composition within the respective area. The impact is estimated by the change in gross receipts from the irrigated crop composition to an alternative dryland crop composition and is presented on an acre-inch and acre-foot basis. Dryland sorghum was considered the alternative for irrigated corn and soybeans in both areas.

Roberts County Scenario

The feasibility of moving underground water from Roberts County to other Panhandle counties for use in irrigated crop production involves analyzing several pieces of information. First is the identification of the variable and total costs of pumping and moving the water, which was laid out, in a previous section. Second is the marginal value of applying that water to irrigated crops. The marginal value is determined by adjusting the increase in gross receipts by the additional costs incurred from irrigating.

The estimated cost of transporting water and the anticipated increase in gross receipts from the primary irrigated crops grown in the region are presented in Table 6. While the marginal value of the gross receipts is not adjusted for the additional cost of irrigation, one fact is already apparent. A pipeline project as outlined cannot be economically justified for irrigated crop production given the returns of the crops currently grown in the region. None of the irrigated crops grown came close to even generating the gross receipts ($117.43 - $304.20/ac-ft) let alone the net value of irrigation costs to cover the total cost of pipeline costs regardless of the assumption of a 30-year project life ($322.13/ac-ft) or barely the more optimistic assumption of a 40-year life ($303.13/ac-ft).

The investment in a pipeline project to move water to irrigated cropland areas appears economically infeasible. However, the use of an existing pipeline that was developed for higher value end users warrants additional analysis. The use of excess pipeline capacity by irrigated production could be justified as long as the variable cost of transporting the water ($98.87/ac-ft) is covered. The gross receipts generated by the irrigated crops in the region are sufficient to cover the estimated variable cost of water transportation. However, the gross receipts needs to be adjusted for the “additional” variable costs associated with irrigation in determining producer profitability. These costs include; additional seed, fertilizer field operations and harvest costs along with the labor, irrigation delivery equipment lube and maintenance.

An examination of the Extension Crop budgets (Amosson et al., 2000-2004) for the region indicate that these additional variable costs for irrigation range from $95.40/ac-ft to $191.52/ac-ft depending on the crop which typically accounts for two-thirds to three-quarters of the gross receipt increase depending on the crop. This suggests it is economically infeasible to irrigate the low value crops (sorghum, wheat and soybeans) and highly questionable whether it would be beneficial to irrigate high value crops (corn, cotton and peanuts) with transported water in normal years with respect to price.

Table 6. Transportation costs of water and the marginal value of gross receipts generated by crop, Region A.

Cost of Transported Water - 50 Miles	$/ac-in	$/ac-ft
Variable Cost	$8.24	$98.87
Total Cost - 30 Year Life	$26.84	$322.13
Total Cost - 40 Year Life	$25.26	$303.13
Marginal Value in Gross Receipts		
Corn	$21.55	$258.64
Cotton	$25.35	$304.20
Peanuts	$22.05	$264.63
Sorghum	$9.79	$117.43
Wheat	$12.27	$147.22
Soybeans	$9.79	$117.43

Carson/Hutchinson and Dallam/Hartley Scenarios

Wheat and corn production occur on 66 percent of the irrigated acreage in the Carson and Hutchinson Counties, Table 7. The remaining irrigated acreage is split between sorghum, soybeans and cotton production. Dryland cotton yielded gross receipts of $165.06 per acre, whereas, wheat and sorghum generated $84.65 and $71.16, respectively, per acre. The long-term average water use ranged from 18.96 inches per acre for corn to 9.60 inches per acre for sorghum. The marginal value per unit of water pumped was consistent with what was found for the region. Cotton and corn production generated the highest return with $305.88 and $242.16, respectively, per acre-foot pumped. The remaining crops generated between $101.52 and $112.80 per acre-foot pumped. The marginal value given the area's crop composition was $12.48 per acre-inch or $149.76 per acre-foot.

Table 7. Irrigated versus dryland gross receipts, percent of irrigated acres, change in marginal value per acre, long-term average water use in inches per acre, and marginal value in dollars per acre-inch and acre-foot, Carson and Hutchinson counties.

Crop	Gross Receipts, Irrigated ($/acre)	% of Irrigated Acreage	Gross Receipts, Dryland ($/acre)	Change in Marginal Value ($/acre)	LTA Water Used (in/ac)	Marginal Value ($/ac-in)	Marginal Value ($/ac-ft)
Corn	$454.28	23%	$71.16	$382.72	18.96	$20.18	$242.16
Cotton	$473.76	7%	$165.06	$308.70	12.11	$25.49	$305.88
Sorghum	$161.36	15%	$71.16	$90.20	9.60	$9.40	$112.80
Wheat	$168.39	43%	$84.65	$83.74	9.86	$8.49	$101.88
Soybeans	$153.85	13%	$71.16	$82.69	9.77	$8.46	$101.52
Marginal value weighted by crop acreage distribution.						$12.48	$149.76

[1]Sorghum was considered the dryland alternative to corn and soybeans.

Corn and wheat plantings accounted for 94 percent of the irrigated acreage in Dallam and Hartley Counties, Table 8. Sorghum was the only other irrigated crop with any significant acreage (4 percent). Corn production generated by far the largest amount of gross receipts per acre ($474.23) and the highest marginal value of $23.10 per acre-inch or $277.20 per acre-foot applied. While wheat did not generate the second largest amount of gross receipts, it did have the second highest marginal value of $12.60 per acre-inch or $151.23 per acre-foot applied. The estimated net gross receipts generated for the area given its crop composition was $19.02 per acre-inch or $228.24 per acre-foot.

Table 8. Irrigated versus dryland gross receipts, percent of irrigated acres, change in marginal value per acre, long-term average water use in inches per acre, and marginal value in dollars per acre-inch and acre-foot, Dallam and Hartley counties.

Crop	Gross Receipts, Irrigated ($/acre)	Percent of Irrigated Acreage	Gross Receipts, Dryland ($/acre)	Change in Marginal Value ($/acre)	Long-Term Average Water Used (in/ac)	Marginal Value ($/ac-in)	Marginal Value ($/ac-ft)
Corn	$474.23	63%	$59.55	$44.65	17.95	$23.10	$277.20
Cotton	$247.73	1%	$165.06	$82.67	11.57	$7.15	$85.74
Sorghum	$151.30	4%	$59.58	$91.72	9.32	$9.84	$118.09
Wheat	$211.54	31%	$78.58	$132.96	10.55	$12.60	$151.23
Soybeans	$167.20	1%	$59.88	$107.62	9.40	$11.44	$137.39
Marginal value weighted by crop acreage distribution.						$19.02	$228.24

[1]Sorghum was considered the dryland alternative to corn and soybeans.

The difference in relative impact on the local/regional economy of exporting water from Carson/Hutchinson versus Dallam/Hartley is significant. Exporting the same amount of water from Dallam/Hartley will result in a 50+ percent ($228.24 versus $149.76 per ac-ft) greater loss in gross receipts compared to exporting it from the Carson/Hutchinson county area. Several factors contribute to this disparity. First, the crop composition of Dallam/Hartley area favors a high value crop (corn). Second, the Dallam/Hartley compared to the Carson/Hutchinson area appears to have a relative advantage in producing both corn and wheat as indicated by both the gross receipts and the marginal value per unit of water pumped. Finally, Carson/Hutchinson appears to have a relative advantage in producing dryland crops compared to Dallam/Hartley because of rainfall and soil types.

The exportation of water from the agricultural areas of the region can have a dramatically different impact on the local economy. In areas such as Roberts County, the exportation of water can actually have a positive impact on the local economy since there are few or no agricultural uses for the water. Producers receive payments for water rights, which a portion maybe spent in the local community helping the economy. In areas where the exportation of water will cause a loss of irrigated crop production, the impacts on the local community can be highly variable. The magnitude of the impact will depend on the relative value of the irrigated crop versus its dryland alternative. Across the region, with the variable rainfall and soil types, the differences in economic impact to the local community can be significant.

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Appendix A

Construction Costs at Varying Distances

Table A-1. Construction and operational cost of moving water (150,000 acre-feet, 50 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to well field storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	11510.4	FT	$316.88	$3,647,462
	Pipeline-Rural, Soil	78	inch	242985.6	FT	$280.50	$68,157,461
	Pipeline-Rural, Rock	78	inch	9372	FT	$420.16	$3,937,740
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		50	MI	$29,341.14	$1,467,057
	Environmental studies and Permitting			792000	FT	$0.80	$632,016
	Subtotal						$86,814,496
	Sum (2+3)					$172,147,249	
4	Engineering and Contingencies(15% of 2 and 3)						$51,644,175
	Total Capital Cost (2-4)						$223,791,424
5	Interest During Construction						$25,694,433
	Total Construction Cost (2+3+4+5)						$249,485,858
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$400,835,858	
7	Development Fee (15% of 1-6)			1	LS		$60,125,379
							$61,475,379
	TOTAL PROJECT COST (1-7)						$460,961,236
	Annual Costs					30 Years	40 Years
	Debt Service					$33,488,834	$30,635,484
	Operation and maintenance					$1,798,219	$1,798,219
	Energy Costs					$12,605,947	$12,605,947
	Replacement Wells(0.5% of initial well field Cost)					$426,664	$426,664
	Total Annual Cost					$48,319,663	$45,466,313
	Annual cost of water ($ per ac-ft/yr)					$322.13	$303.11

Table A-2. Construction and operational cost of moving water (150,000 acre-feet, 100 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to well field storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
							$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	23020.8	FT	$316.88	$7,294,923
	Pipeline-Rural, Soil	78	inch	485971.2	FT	$280.50	$136,314,922
	Pipeline-Rural, Rock	78	inch	18744	FT	$420.16	$7,875,479
	Storage tank	9	MG	1	EA	$3,872,091.99	$3,872,092
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Pressure Reducing station			1	EA	$250,000.00	$250,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		100	MI	$29,341.14	$2,934,114
	Environmental studies and Permitting			792000	FT	$0.80	$632,016
	Subtotal						$174,906,506
	Sum (2+3)					$260,239,260	
4	Engineering and Contingencies(15% of 2 and 3)						$78,071,778
	Total Capital Cost (2-4)						$338,311,038
5	Interest During Construction						$38,842,911
	Total Construction Cost (2+3+4+5)						$377,153,949
	Development Costs						
6	Preliminary expenses			1	LS	$2,707,500	$2,707,500
	Sum					$379,861,449	
7	Development Fee (15% of 1-6)			1	LS		$56,979,217
							$59,686,717
	TOTAL PROJECT COST (1-7)						$586,840,666
	Annual Costs					30 Years	40 Years
	Debt Service					$42,633,974	$39,001,431
	Operation and maintenance					$2,739,331	$2,739,331
	Energy Costs					$14,696,293	$14,696,293
	Replacement Wells(0.5% of initial well field Cost)					$426,664	$426,664
	Total Annual Cost					$60,496,263	$56,863,719
	Annual cost of water ($ per ac-ft/yr)					$403.31	$379.09

Table A-3. Construction and operational cost of moving water (150,000 acre-feet, 150 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261,000	FT	$20.00	$5,220,000
							$85,332,753
3	Transmission to lake Bridge port						
	Pipeline-Rural, Soil	90	inch	34,531	FT	$316.88	$10,942,385
	Pipeline-Rural, Soil	78	inch	728,957	FT	$280.50	$204,472,382
	Pipeline-Rural, Rock	78	inch	28,116	FT	$420.16	$11,813,219
	Storage tank	9	MG	2	EA	$3,872,091.99	$7,744,184
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Pressure Reducing station			2	EA	$250,000.00	$500,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		150	MI	$29,341.14	$4,401,171
	Environmental studies and Permitting			1,056,000	FT	$0.80	$842,688
	Subtotal						$256,448,989
	Sum (2+3)					$341,781,743	
4	Engineering and Contingencies(15% of 2 and 3)						$102,534,523
	Total Capital Cost (2-4)						$444,316,265
5	Interest During Construction						$51,013,817
	Total Construction Cost (2+3+4+5)						$495,330,082
	Development Costs						
6	Preliminary expenses			1	LS	$4,061,372	$4,061,372
	Sum					$499,391,454	
7	Development Fee (15% of 1-6)			1	LS		$74,908,718
							$78,970,090
	TOTAL PROJECT COST (1-7)						$724,300,172
	Annual Costs					30 Years	40 Years
	Debt Service					$52,620,407	$48,136,989
	Operation and maintenance					$3,511,418	$3,511,418
	Energy Costs					$14,696,293	$14,696,293
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$71,254,782	$66,771,364
	Annual cost of water ($ per ac-ft/yr)					$475.03	$445.14

Table A-4. Construction and operational cost of moving water (150,000 acre-feet, 200 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
							$85,332,753
3	Transmission to lake Bridge port						
	Pipeline-Rural, Soil	90	inch	46042	FT	$316.88	$14,589,973
	Pipeline-Rural, Soil	78	inch	971942.4	FT	$280.50	$272,629,843
	Pipeline-Rural, Rock	78	inch	37488	FT	$420.16	$15,750,958
	Storage tank	9	MG	2	EA	$3,872,091.99	$7,744,184
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	1	EA	$7,393,968.09	$7,393,968
	Pressure Reducing station			3	EA	$250,000.00	$750,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		200	MI	$29,341.14	$5,868,228
	Environmental studies and Permitting			1320000	FT	$0.80	$1,053,360
	Subtotal						$341,513,475
	Sum (2+3)					$426,846,228	
4	Engineering and Contingencies(15% of 2 and 3)						$64,026,934
	Total Capital Cost (2-4)						$490,873,163
5	Interest During Construction						$56,359,209
	Total Construction Cost (2+3+4+5)						$547,232,372
	Development Costs						
6	Preliminary expenses			1	LS	$4,061,372	$4,061,372
	Sum					$551,293,744	
7	Development Fee (15% of 1-6)			1	LS		$82,694,062
							$86,755,433
	TOTAL PROJECT COST (1-7)						$783,987,806
	Annual Costs					30 Years	40 Years
	Debt Service					$56,956,714	$52,103,830
	Operation and maintenance					$4,595,833	$4,545,808
	Energy Costs					$16,329,376	$16,329,376
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$78,308,586	$73,405,677
	Annual cost of water ($ per ac-ft/yr)					$522.06	$489.37

Table A-5. Construction and operational cost of moving water (150,000 acre-feet, 277 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	64000	FT	$316.88	$20,280,576
	Pipeline-Rural, Soil	78	inch	1349000	FT	$280.50	$378,394,500
	Pipeline-Rural, Rock	78	inch	52000	FT	$420.16	$21,848,320
	Storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	1	EA	$7,393,968.09	$7,393,968
	Pressure Reducing station			4	EA	$250,000.00	$1,000,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		277	MI	$29,341.14	$8,127,496
	Environmental studies and Permitting			2101000	FT	$0.80	$1,676,598
	Subtotal						$466,070,694
	Sum (2+3)					$551,403,447.74	
4	Engineering and Contingencies(15% of 2 and 3)						$82,710,517
	Total Capital Cost (2-4)						$634,113,965
5	Interest During Construction						$72,805,288
	Total Construction Cost (2+3+4+5)						$706,919,252
	Development Costs						
6	Preliminary expenses			1	LS	$7,500,000.00	$7,500,000
	Sum					$864,419,252.49	
7	Development Fee (15% of 1-6)			1	LS		$129,662,888
							$137,162,888
	TOTAL PROJECT COST (1-7)						$994,082,140
	Annual Costs					30 Years	40 Years
	Debt Service					$72,220,067	$66,066,699
	Operation and maintenance					$5,832,672	$5,782,647
	Energy Costs					$16,329,376	$16,329,376
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$94,808,779	$88,605,386
	Annual cost of water ($ per ac-ft/yr)					$632.06	$590.70

Table A-6. Construction and operational cost of moving water (150,000 acre-feet, 350 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	80572.8	FT	$316.88	$25,532,231
	Pipeline-Rural, Soil	78	inch	1700899.2	FT	$280.50	$477,102,226
	Pipeline-Rural, Rock	78	inch	65419.2	FT	$420.16	$27,486,531
	Storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	1	EA	$7,393,968.09	$7,393,968
	Pressure Reducing station			4	EA	$250,000.00	$1,000,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		350	MI	$29,341.14	$10,269,399
	Environmental studies and Permitting			2376000	FT	$0.80	$1,896,048
	Subtotal						$578,029,639
	Sum (2+3)					$663,362,393	
4	Engineering and Contingencies(15% of 2 and 3)						$99,504,359
	Total Capital Cost (2-4)						$762,866,752
5	Interest During Construction						$87,587,936
	Total Construction Cost (2+3+4+5)						$850,454,688
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$1,001,804,688	
7	Development Fee (15% of 1-6)			1	LS		$150,270,703
							$151,620,703
	TOTAL PROJECT COST (1-7)						$1,152,075,391
	Annual Costs					30 Years	40 Years
	Debt Service					$83,698,277	$76,566,930
	Operation and maintenance					$6,900,042	$6,900,042
	Energy Costs					$16,329,376	$16,329,376
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$107,354,359	$100,223,012
	Annual cost of water ($ per ac-ft/yr)					$715.70	$668.15

Table A-7. Construction and operational cost of moving water (150,000 acre-feet, 400 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261,000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	92083.20	FT	$316.88	$29,179,693
	Pipeline-Rural, Soil	78	inch	1943884.80	FT	$280.50	$545,259,686
	Pipeline-Rural, Rock	78	inch	74764.80	FT	$420.16	$31,413,178
	Storage tank	9	MG	4	EA	$3,872,091.99	$15,488,368
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	2	EA	$7,393,968.09	$14,787,936
	Pressure Reducing station			5	EA	$250,000.00	$1,250,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		400	MI	$29,341.14	$11,736,456
	Environmental studies and Permitting			2640000	FT	$0.80	$2,106,720
	Subtotal						$666,954,998
	Sum (2+3)					$752,287,752	
4	Engineering and Contingencies(15% of 2 and 3)						$112,843,163
	Total Capital Cost (2-4)						$865,130,914
5	Interest During Construction						$99,329,314
	Total Construction Cost (2+3+4+5)						$964,460,228
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$1,115,810,228	
7	Development Fee (15% of 1-6)			1	LS		$167,371,534
							$168,721,534
	TOTAL PROJECT COST (1-7)						$1,283,181,762
	Annual Costs					30 Years	40 Years
	Debt Service					$93,223,155	$85,280,260
	Operation and maintenance					$7,895,599	$7,895,599
	Energy Costs					$17,962,459	$17,962,459
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$119,507,876	$111,564,981
	Annual cost of water ($ per ac-ft/yr)					$796.72	$743.77

Table A-8. Construction and operational cost of moving water (150,000 acre-feet, 450 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300 HP	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18 inch	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9 MG	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100 HP	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15 Feet	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90 inch	inch	103593.60	FT	$316.88	$32,827,154
	Pipeline-Rural, Soil	78 inch	inch	2186870.40	FT	$280.50	$613,417,147
	Pipeline-Rural, Rock	78 inch	inch	84110.40	FT	$420.16	$35,339,826
	Storage tank	9 MG	MG	5	EA	$3,872,091.99	$19,360,460
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	2	EA	$7,393,968.09	$14,787,936
	Pressure Reducing station			6	EA	$250,000.00	$1,500,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		450	MI	$29,341.14	$13,203,513
	Environmental studies and Permitting			2904000	FT	$0.80	$2,317,392
	Subtotal						$748,486,389
	Sum (2+3)					$833,819,142	
4	Engineering and Contingencies(15% of 2 and 3)						$125,072,871
	Total Capital Cost (2-4)						$958,892,014
5	Interest During Construction						$110,094,419
	Total Construction Cost (2+3+4+5)						$1,068,986,433
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$1,220,336,433	
7	Development Fee (15% of 1-6)			1	LS		$183,050,465
							$184,400,465
	TOTAL PROJECT COST (1-7)						$1,403,386,898
	Annual Costs					30 Years	40 Years
	Debt Service					$101,956,058	$93,269,093
	Operation and maintenance					$8,706,306	$8,706,306
	Energy Costs					$17,962,459	$17,962,459
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$129,051,486	$120,364,522
	Annual cost of water ($ per ac-ft/yr)					$860.34	$802.43

Table A-9. Construction and operational cost of moving water (150,000 acre-feet, 500 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	115,104	FT	$316.88	$36,474,616
	Pipeline-Rural, Soil	78	inch	2,429,856	FT	$280.50	$681,574,608
	Pipeline-Rural, Rock	78	inch	93,456	FT	$420.16	$39,266,473
	Storage tank	9	MG	5	EA	$3,872,091.99	$19,360,460
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	1	EA	$6,760,199.40	$6,760,199
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	2	EA	$7,393,968.09	$14,787,936
	Pressure Reducing station			7	EA	$250,000.00	$1,750,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		500	MI	$29,341.14	$14,670,570
	Environmental studies and Permitting			3,168,000	FT	$0.80	$2,528,064
	Subtotal						$826,145,688
	Sum (2+3)					$911,478,441	
4	Engineering and Contingencies(15% of 2 and 3)						$136,721,766
	Total Capital Cost (2-4)						$1,048,200,207
5	Interest During Construction						$120,348,268
	Total Construction Cost (2+3+4+5)						$1,168,548,475
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$1,319,898,475	
7	Development Fee (15% of 1-6)			1	LS		$197,984,771
							$199,334,771
	TOTAL PROJECT COST (1-7)						$1,517,883,247
	Annual Costs					30 Years	40 Years
	Debt Service					$110,274,218	$100,878,521
	Operation and maintenance					$9,478,292	$9,478,292
	Energy Costs					$17,962,459	$17,962,459
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$141,734,124	$128,745,936
	Annual cost of water ($ per ac-ft/yr)					$944.89	$858.31

Table A-10. Construction and operational cost of moving water (150,000 acre-feet, 550 miles).

	Item	Size		Quantity	Unit	Unit Price	Cost
1	Groundwater Cost						
	Groundwater Rights			300,000	Acre	$500.00	$150,000,000
	Subtotal						$150,000,000
2	Wellfields						
	Test Holes			488	EA	$4,200.00	$2,049,600
	Groundwater wells	300	HP	87	EA	$300,000.00	$26,100,000
	Power to wells(1mile/well)			87	Mile	$68,000.00	$5,916,000
	Transmission to wellfield storage tank	18	inch	375,000	FT	$69.00	$25,875,000
	Wellfields storage tank	9	MG	3	EA	$3,872,091.99	$11,616,276
	Storage tank pump station(1800 HP peak capacity)	1100	HP	3	EA	$2,851,959.12	$8,555,877
	Unpaved Access roads to wells(3000 ft/well)	15	feet	261000	FT	$20.00	$5,220,000
	Subtotal						$85,332,753
3	Transmission/Pipeline						
	Pipeline-Rural, Soil	90	inch	126614.40	FT	$316.88	$40,122,078
	Pipeline-Rural, Soil	78	inch	2672841.60	FT	$280.50	$749,732,069
	Pipeline-Rural, Rock	78	inch	102801.60	FT	$420.16	$43,193,120
	Storage tank	9	MG	6	EA	$3,872,091.99	$23,232,552
	Initial Pump station(12000 HP peak capacity)	9600	HP(Avg)	1	EA	$8,872,761.17	$8,872,761
	Booster Pump station(8000 HP peak capacity)	6400	HP(Avg)	2	EA	$6,760,199.40	$13,520,399
	Booster Pump station(10000 HP peak capacity)	5000	HP(Avg)	2	EA	$7,393,968.09	$14,787,936
	Pressure Reducing station			8	EA	$250,000.00	$2,000,000
	Discharge Structure			1	LS	$100,000.00	$100,000
	Easement Rural	80'/40'		550	MI	$29,341.14	$16,137,627
	Environmental studies and Permitting			3432000	FT	$0.80	$2,738,736
	Subtotal						$914,437,278
	Sum (2+3)					$999,770,031	
4	Engineering and Contingencies(15% of 2 and 3)						$149,965,505
	Total Capital Cost (2-4)						$1,149,735,536
5	Interest During Construction						$132,005,966
	Total Construction Cost (2+3+4+5)						$1,281,741,501
	Development Costs						
6	Preliminary expenses			1	LS	$1,350,000	$1,350,000
	Sum					$1,433,091,501	
7	Development Fee (15% of 1-6)			1	LS		$214,963,725
							$216,313,725
	TOTAL PROJECT COST (1-7)						$1,648,055,227
	Annual Costs					30 Years	40 Years
	Debt Service					$119,731,212	$109,529,750
	Operation and maintenance					$10,458,004	$10,458,004
	Energy Costs					$20,052,805	$20,052,805
	Replacement Wells(0.5% of initial wellfield Cost)					$426,664	$426,664
	Total Annual Cost					$150,668,685	$140,467,223
	Annual cost of water ($ per ac-ft/yr)					$1,004.46	$936.45

Table A-11. Details of energy costs for the 50-mile scenario at $0.05 kWh.

Pumping Costs	Well Capacities 58 Wells at 1500 gpm 29 Wells at 1000 gpm
Horse Power Requirement	1500 * 525 ft total head / (3960 * 0.63 Pump Efficiency * 0.95 Gear Head Efficiency) = 332.27 HP 1000 * 525 ft total head / (3960 * 0.63 Pump Efficiency * 0.95 Gear Head Efficiency) = 221.51 HP
Energy Cost Calculation	HP Reg * Fuel Factor (0.7456999) * Energy price $0.05/KwH * Number of Wells * 24 hours * 365 days = 332.27 * 0.7456999 * 0.05 * 58 *24 *365 = $6,249,445 221.51 * 0.7456999 * 0.05 * 29 *24 *365 = $2,098,148
Energy Costs for Storage Tank and Booster Stations	12,900 HP * 0.7456999 * 0.05 *24 * 365 = $4,213,354
Total Energy Cost = $12,605,947	

Table A-12. Details of energy costs for the 50-mile scenario at $0.06 kWh.

Pumping Costs	Well Capacities 58 Wells at 1500 gpm 29 Wells at 1000 gpm
Horse Power Requirement	1500 * 525 ft total head / (3960 * 0.63 Pump Efficiency * 0.95 Gear Head Efficiency) = 332.27 HP 1000 * 525 ft total head / (3960 * 0.63 Pump Efficiency * 0.95 Gear Head Efficiency) = 221.51 HP
Energy Cost Calculation	HP Reg * Fuel Factor (0.7456999) * Energy price $0.06/KwH * Number of Wells * 24 hours * 365 days = 332.27 * 0.7456999 * 0.06 * 58 *24 *365 = $7,553,334 221.51 * 0.7456999 * 0.06 * 29 *24 *365 = $2,517,778
Energy Costs for Storage Tank and Booster Stations	12,900 HP * 0.7456999 * 0.06 *24 * 365 = $5,056,024
Total Energy Cost = $15,127,136 **Difference from $0.05 kWh = $2,521,189**	