Appendix D

2016 Panhandle Regional Water Plan Task 5 Report: Agricultural Water Management Strategies

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Agricultural Water Management Strategies

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Agriculture is the primary user of water in the Panhandle Water Planning Area (PWPA). Agriculture is projected to account for 92% of the total water use in the PWPA in 2020. Counties with irrigation shortages in the region are projected to reach 156,704 acre-feet per year in 2020 and be 148,520 acre-feet per year deficit by 2070. Given the limited renewability of aquifers in the area, there is no readily available water supply in or near the high demand irrigation counties that could be developed to fully meet these shortages. Therefore, water management strategies for reducing irrigation demands in the Ogallala Aquifer for all 21 counties in the PWPA were examined. These strategies focus on Dallam, Hartley, and Moore Counties, which are the only counties in the region showing water demands that cannot be met with existing supplies, along with Sherman County, which is another major irrigation demand county that was projected to have a minimal surplus, Table 1. Hopefully, the use of irrigation management strategies and local groundwater rules will prolong the life of irrigated agriculture within these counties.

Table1: Irrigation Shortages by County Identified in the PWPA, 2020-2070.

County	Projected Need (acre-feet per year)					
	2020	2030	2040	2050	2060	2070
Dallam	79,399	91,675	94,226	87,452	77,836	68,218
Hartley	77,305	93,368	98,650	92,699	83,415	74,130
Moore	0	0	0	0	3,882	6,171
Sherman*	0	0	0	0	0	0

*Sherman has a small surplus of 32 acre-feet in each decade.

Methodology

Water savings, implementation cost, savings from reduced pumping and the impact in gross crop receipts were estimated for each proposed water management strategy evaluated in the planning effort and described in the forthcoming sections. The year 2013 was selected as the baseline for evaluating strategies. Baseline adoption rates for strategies were estimated using secondary data sources and future adoption rates (2020 – 2070) were identified under the guidance of the Panhandle Water Planning Group (PWPG) Agriculture committee, Table 2. Since final implementation rates of conservation strategies do not occur until 2070, the water savings, direct cost and net cost of all strategies were evaluated over a 60-year planning horizon (2020 – 2079). A five-year average (2006 – 2010) of Farm Service Agency (FSA) irrigated acreage for the region was used to establish a baseline from which effectiveness of alternative conservation strategies were measured. FSA irrigated acreage estimates were increased in some counties based on local knowledge to account for farms known not to be registered with FSA. The five-

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year average of irrigated acreage was used to dampen distortions resulting from acreage shifts between crops caused by volatile crop prices. Water availability was assumed to remain constant in measuring the impacts of the various water conservation strategies.

In addition, the Agricultural subcommittee of the PWPG identified three combinations of the previously mentioned strategies that may likely be employed in irrigation deficit counties. The combinations of strategies were: 1) change in crop type, irrigation scheduling, and changes in irrigation equipment; 2) changes in crop variety, irrigation scheduling, and changes in irrigation equipment; and 3) change in crop type, advances in plant breeding, irrigation scheduling, and changes in irrigation equipment. When implementing multiple strategies the impact on potential water savings are not additive in most instances. The cumulative water savings from use of multiple strategies was estimated using a stepwise procedure; first revising water use after implementing one strategy and then using the revised water use as the base before introducing the second strategy and repeating the process for the third and fourth strategy. For example, the impact of changing crop type on water use was estimated, then based on the revised water use, the impact of scheduling was identified and water use revised again, and based on this estimate, the effectiveness of changes in irrigation equipment was made. The water savings of the three combinations of strategies considered was done for the four identified counties and the region as a whole. In examining the cost effectiveness of the strategy combinations (done on a regional basis), it was assumed the cost was additive.

Implementation costs were defined as the costs that could be borne by producers and/or the government associated with implementing a strategy. The savings in pumping cost takes into the account the variable cost savings from the reduced irrigation. The variable cost of irrigation is assumed be $9.10 per acre-inch (Texas A&M AgriLife Crop and Livestock Budgets, 2014). All costs were evaluated in 2014 dollars. The loss in gross receipts was estimated by strategy, where warranted. The impact on the regional economy resulting from a change in gross receipts was not estimated but is discussed.

Table 2: Estimated Potential Water Savings and Future Adoption Percentage of Water Conservation Strategies, 2013-2070

Water Management Strategy	Annual Regional Water Savings (% of irrigation or ac-inch/ac/yr.)	Assumed Baseline Use 2013	Goal for Adoption 2020	Goal for Adoption 2030	Goal for Adoption 2040	Goal for Adoption 2050	Goal for Adoption 2060	Goal for Adoption 2070
Irrigation Scheduling	10%	20%	35%	50%	75%	85%	90%	95%
Irrigation Equipment Changes	Furrow to MESA or LESA 3.5	87%	90%	91.5%	93%	94.5%	96%	98%
	MESA or LESA to LEPA or SDI 1.3	75%	80%	85%	90%	95%	100%	100%
Change in crop type	7.8-8.6	10%	15%	20%	25%	30%	35%	40%
Change in crop variety	4.10 (corn) 3.0 (sorghum)	40%	50%	60%	70%	70%	70%	70%
Conversion to Dryland	13.9	0%	2.5%	5%	5%	5%	5%	5%
Soil Management	1.75	70%	75%	80%	85%	90%	95%	95%
Advances in Plant Breeding	Corn, cotton, and soybean 15% (2020-2030) 30% starting in 2040	0%	50%	75%	85%	95%	95%	95%
	Wheat and sorghum 12% starting in 2030	0%	0%	50%	75%	85%	95%	95%
Precipitation Enhancement	1.0	38%	38%	38%	38%	38%	38%	38%

Description of Agricultural Conservation Strategies

In this plan, the Agriculture subcommittee of the PWPG identified eight potential agricultural water conservation strategies to be evaluated. These strategies include: irrigation scheduling; irrigation equipment changes; change in crop type; change in crop variety; conversion to dryland; soil management; advances in plant breeding for drought tolerance; and precipitation enhancement. Precipitation enhancement is considered a limited use strategy since it cannot be implemented by an individual producer and little interest has been shown in implementing this strategy by ground water districts in the region with the exception of the Panhandle Groundwater Conservation District. A description of each of these strategies is presented in the following sections.

Irrigation Scheduling

Irrigation scheduling refers to the process of allocating irrigation water according to crop requirements based on meteorological demands and field conditions with the intent to manage and conserve water, control disease infestations, and maximize farm profit. In a region like the Panhandle, where irrigation water availability is increasingly becoming limited, proper and accurate irrigation scheduling is critical to ensure profitable agricultural production and conservation of the existing water resources. Soil water measurement-based methods, plant stress sensing-based methods, and weather-based methods are the common irrigation scheduling tools. The prevalent soil-based irrigation scheduling method utilized in the region today employs soil moisture probes that estimate soil moisture at different depths to schedule irrigation. Irrigation scheduling based on crop evapotranspiration reported by ET networks in the region is also an important weather-based irrigation scheduling method since this data references the climatic demand, which varies annually and can vary substantially within the season. Plant stress-based irrigation scheduling techniques using thermal sensors are also a developing irrigation scheduling strategy but are not yet widespread in use. The soil moisture probe and thermal sensor methods can allow for automation of irrigation scheduling by wireless connection of the sensors to respective irrigation systems. Proper and accurate irrigation scheduling can save up to 2 to 3 acre-inches of irrigation per year for corn. In this analysis, the water savings from this strategy is assumed to be 10% of the water applied for each crop.

The cost of irrigation scheduling can vary significantly depending on several factors including the level of service, equipment costs, and area served. More money tends to be invested in irrigation scheduling of higher value crops. A range of $3.00 to $12.00 per acre for irrigation scheduling was identified based on discussions with industry representatives, depending on the level of service. In this analysis, a $5.00 per acre annual cost was assumed for irrigation scheduling. Irrigation scheduling costs can be reduced if the producer choses to buy the soil moisture probe. Typically, the cost of a soil moisture probe ranges from $1,300 to $2,650, depending on the company and level of sophistication of the probe.

Irrigation Equipment Changes

Current irrigation methods practiced in the Texas Panhandle include conventional furrow irrigation (CF), center pivot irrigation (MESA: Mid Elevation Spray Application, LESA: Low Elevation Spray Application, and LEPA: Low Elevation Precision Application) and subsurface drip irrigation (SDI).The average application efficiency of CF, MESA, LESA, LEPA, and SDI is 60, 78, 88, 95, and 97%, respectively (Amosson et al., 2011). These application efficiencies are the percentage of irrigation water applied that is used by the crop with the remainder being lost to runoff, evaporation or deep percolation. Switching from low efficiency irrigation systems such as CF and MESA to more efficient irrigation systems such as LEPA and SDI improves the efficiency of irrigation system water use and can help conserve groundwater resources. Switching irrigation systems can be a costly strategy to conserve irrigation water, but that cost can be partially offset by the decrease in pumping cost. The water conservation strategy of changing irrigation equipment includes establishing new MESA and LESA systems in CF irrigated fields and converting MESA and LESA to LEPA to improve its application efficiency. Establishing MESA, LESA, LEPA, or SDI systems requires a major investment, while converting MESA and LESA to LEPA using conversion kits are comparatively less expensive.

The regional water savings estimate in 2020 from this strategy is 3.5 and 1.3 acre-inches per acre for conversion of furrow to MESA/LESA and MESA/LESA to LEPA, respectively. It should be noted that water savings from this strategy vary by county and over time as the amount of water pumped changes.

Initial investment in irrigation equipment varies depending on the dealer and spacing between sprinkler drops or tape in the case of SDI. In consultation with industry representatives and other secondary sources, the cost of adding a quarter-mile (125 acres) sprinkler system was estimated to be $75,000-$80,000. The estimates to convert a MESA or LESA quarter-mile sprinkler system to LEPA ranged from $7,000-$10,000, depending on the spacing of the drops. The estimates for installing a SDI system ranged from $1,200-$1,500 per acre, depending primarily on whether drip tapes were spaced 80 inches or 40 inches apart.

The implementation cost of this strategy is estimated using the costs associated with the irrigation equipment required for each of the systems and their respective adoption rate. The total cost (fixed cost + variable cost) of applying one acre-inch of water per acre for intermediate water use for furrow, MESA, LESA, LEPA, and SDI are $12.26, $13.98, $13.60, $13.76, and $17.04, respectively (Amosson et al., 2011). These values were inflated to 2014 values using price index for farm machinery (USDA, 2014). The assumed adoption percentage of the irrigation systems during each decade was used along with the acreage and average water use to estimate the amount of irrigation applied using these systems during the baseline period and future periods. These irrigation amounts were multiplied with the cost per acre-inch to get the total cost of irrigation during the baseline and future time periods. The difference in cost between successive time periods is the cost of implementation for this strategy.

Change in crop type

There are considerable differences in water requirements among different crops. Selection of crops with lower water requirements can be an effective water conservation strategy. Corn, cotton, wheat, and grain sorghum are the four major crops in the Panhandle region accounting for about 90% of the irrigated acreage. Corn has one of the highest water requirements of any irrigated crop grown in the Texas High Plains because of a longer growing season than most other spring crops, which can adversely affect yield in limited moisture situations (Howell et al., 1996). The seasonal evaporative demand for corn is 28 to 32 inches, for wheat is 26 to 28 inches, for cotton is 13 to 27 inches, and for grain sorghum is 13 to 24 inches. To date, the majority of water used for irrigation has been applied to high water use crops such as corn. On the other hand, cotton, wheat, and grain sorghum can tolerate lower moisture availability and are more suited to deficit irrigation practices. Considerable amounts of irrigation water can be saved by shifting from high water use crops like corn to lower water use crops like cotton, wheat or grain sorghum. In this analysis, it is assumed that shifting from corn to low water use crops can save 7.8-8.6 acre-inches per acre depending on the crop choice.

The cost of implementing this water conservation strategy is evaluated in terms of an "opportunity cost" expressed by the reduced land values which reflect the water availability required to produce crops. Land that has "good" water availability to support corn production is worth more compared to the land with "fair" availability of water that can support cotton, wheat, or grain sorghum. Hence the cost of adoption of this strategy for one acre of land is estimated as the difference between the average land value in the region for irrigated cropland with good water availability and that of irrigated cropland with fair water availability. This per acre cost of adoption is then multiplied by the assumed acreage of adoption to get the total cost. The total cost is divided by the estimated water savings to get the cost incurred by producers to generate an acre-foot of water savings. The land values reported by the Texas chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA, 2013) provided the average land value for these two classes of irrigated cropland in the region. ASFMRA (2013) reported that the value of irrigated cropland with good water availability in the region ranges from $2,800 to $4,000 per acre. The average of these two values ($3,400) was used as the average land value for irrigated cropland with good water availability in the region. The value of irrigated cropland with fair water availability in the region ranges from $1,800 to $2,500 per acre. The average of these two prices ($2,150) was used as the average land value for irrigated cropland with fair water availability in the region.

Change in crop variety

The evaporative demand for short season varieties can be significantly lower than that for long season varieties. Short season varieties of corn and grain sorghum use less water than the conventional longer season varieties. Thus, converting from long season varieties to short season varieties of corn and grain sorghum can be a useful water conservation strategy. In addition, short season hybrids may be seeded earlier to possible avoid insect threat, and have the potential of planting a third crop in two years either by planting a short season variety prior to or following a wheat crop (Howell et al., 1996). Early planting of the short season hybrids can also help avoid high evaporative demand periods and save water. The seasonal evapotranspiration for short season corn hybrids was found to be generally 5 inches less than that of long season hybrids (Howell et al., 1998). The water use of short season grain sorghum is about 0.6 inches less than that of long season varieties. Therefore, considerable water savings can be realized by substituting long season varieties of corn and grain sorghum with the short season varieties. In this analysis, the water savings from adopting short season corn and short season grain sorghum are assumed to be 4.1 and 3.0 acre-inches per acre, respectively.

The implementation cost of this water conservation strategy was assumed to be the compensation needed to account for the loss in yield and profitability of employing the strategy. Howell et al. (1998) reported that the yield from short season hybrids was about 15% less than that from the full season hybrids. A partial budget analysis considering the loss in revenue versus the reduction in pumping cost, fertilizer, and harvest expense indicates that approximately half of the revenue reduction is profit loss (Texas A&M AgriLife Crop and Livestock Budgets, 2014). In this analysis, the loss of revenue from short season corn and grain sorghum is estimated as 15% of the average revenue for the last 5 years and the implementation cost is assumed to be half of that amount. The average revenue was calculated using the average corn and grain sorghum yield and the average price received in Northern High Plains for last 5 years (USDA, 2014). It should be noted that the reduction in gross receipts and associated expenditures is expected to have a negative impact on the regional economy.

Conversion to Dryland

The strategy of converting from irrigated crop production to dryland crop production would save all of the irrigation water normally used on irrigated acreage. Converting from an irrigated to dryland cropping system may be a viable economic alternative for some producers in the Panhandle on marginally irrigated lands or as a regional strategy to conserve water reserves. The primary dryland crops grown in the area are winter wheat, grain sorghum, and cotton. Conversion programs that provide incentives to conversion to dryland, identifying and adopting crops that perform well in the region under rainfed conditions, and developing higher yielding heat and drought-tolerant varieties will be critical in implementing this strategy. Other highly drought tolerant crops like canola, safflower, mustard, camelina, jatropha, castor, guar, and rapeseed are currently being evaluated for suitability and profitability, but sustained markets and returns on investments are still valid concerns. This analysis assumes 13.9 acre-inches per acre water savings by the adoption of this strategy over the entire region; however, the amount varies by county depending on crop composition.

The cost of implementing this water conservation strategy is evaluated in terms of reduced land values. Land that has sufficient water available for irrigation is worth much more compared to dry cropland. Therefore, the cost of adoption of this strategy for one acre of land is estimated as the difference between the average land value in the region for irrigated cropland and that of dryland. This per acre cost of adoption is then multiplied by the assumed acreage of adoption to get the total cost. The land values reported by the Texas chapter of the American Society of Farm Managers and Rural Appraisers (ASFMRA, 2013) provided the average land value for irrigated and dry cropland in the region. The value of irrigated cropland with fair water availability in the region ranges from $1,800 to $4,000 per acre. The average of these two values ($2,900) was used as the average land value for irrigated cropland availability in the region. The average land value of dry cropland ranged from $500 to $700 per acre in the western parts of the region and from $700 to $1,100 in the Eastern parts of the region resulting in an overall average of $750 per acre. Therefore, the cost assumed in the analysis to retire an acre of irrigated land was $2,150 ($2,900 - $750). In addition to the implementation cost, the loss in gross receipts from the conversion of irrigated to dryland crop production was estimated.

Soil Management

Effective soil management practices can increase the efficiency of both irrigation and rainfall events, increase soil infiltration, reduce runoff, reduce evaporative loss, and conserve moisture available within the soil profile. Thus, these practices promote efficient use of the available water and enhance crop production and sustainability of the region’s natural resources. Conservation tillage practices, furrow diking, and introduction of fallow and low water use crops in the crop rotation are the most important land management practices that can lead to water conservation within the region.

Conservation tillage is defined as tillage practices that minimize soil and water loss by maintaining a surface residue cover of more than 30% on the soil surface (CTIC, 2014). Conservation tillage can reduce evaporation, increase rainfall infiltration, water storage, soil moisture conservation, and water use efficiency. Conservation tillage systems are also reported to have economic advantages as it reduces machinery, fuel, and labor costs. Conservation tillage is a term covering a wide range of tillage practices with the common characteristic of reduced soil and water loss. Different tillage practices such as minimum tillage, reduced tillage, no-till;

ridge tillage, vertical tillage, and strip tillage are often interchangeably used with the term conservation tillage. In this analysis, the water savings from adopting effective soil management strategy is assumed to be 1.75 acre-inches per acre.

The initial capital investment in equipment may impede the adoption of soil management practices. The purchase price of conservation tillage equipment capable of doing strip till or vertical tillage varies considerably depending on the size and company that made it. For example, a six-row strip till implement costs approximately $32,000, whereas a 24-row prices out at $116,500 (Texas A&M AgriLife Crop and Livestock Budgets, 2014). A 14-foot vertical tillage implement costs $39,000, where a 40-foot version priced out at $116,500. The appropriate size of conservation implements depends upon the equipment compliment of the producer.

The implementation cost of soil management strategy is estimated as the difference between the cost of conventional tillage and conservation tillage. It is assumed that the average conventionally tilled field will be disked once, chiseled once, and cultivated three times during the year. This will be followed by two herbicide applications; one pre-plant and one post-plant. In the case of conservation tillage (strip tillage is assumed as it is most common in the region), it is assumed that the field is chiseled once and cultivated two times. There are three herbicide applications in conservation tillage; one burn down, one pre-plant, and one post-plant application. The cost of disc ploughing, chiseling, and cultivation are $12.09, $12.61, and $10 per acre, respectively (Texas Agricultural Custom Rates, 2013). The cost of burn down, pre-plant, and post plant herbicide application are assumed to be $19.50, $17.36, and $15.69 per acre, respectively (Texas A&M AgriLife Crop and Livestock Budgets, 2014). The cost of conventional and conservation tillage are calculated using this data as $87.75 and $85.16 per acre, respectively.

Advances in Plant Breeding

Plant breeding has played a major role in increasing crop productivity and enhancing the efficiency of inputs such as irrigation. Previously, plant breeding efforts were mainly concentrated on hybridization and selection to produce improved planting materials like composite seeds and F1 hybrid seeds. The success stories in this era were hybrid corn and semi dwarf varieties of wheat and rice that triggered the green revolution. The advances made in genetic engineering led to the plant biotechnology era, which began in the 1980s when transgenic plants were produced. Transgenic planting materials for several crops are commercially available now. The commercial varieties for several crops with genetically modified organisms (GMOs) are also widely in use. From a water conservation standpoint, varieties with higher water use efficiency and enhanced drought tolerance can lead to substantial water savings. The adoption of drought resistant varieties with high water use efficiency can be a potential water conservation strategy. The first wave of drought resistant varieties for corn, cotton, and soybeans are expected to be released by 2020 followed by a second wave in 2040 that will improve drought and heat tolerance even more. This analysis assumes that the first round of drought resistant varieties will reduce water use by 15% and the second round of varieties will reduce the water use an additional 15% compared to current varieties. It is also assumed that drought tolerant varieties of wheat and grain sorghum will be available by 2030 and will reduce the water use by 12%.

The implementation cost of this strategy assumed an additional cost of drought resistant seed estimated at a dollar for every one percent reduction in water use. Therefore it was assumed a 15 percent reduction in water use is will cost $15 per acre and a 30 percent reduction will cost $30 per acre. Cost estimates were made after consultation with industry personnel and researchers working in the area. These costs were then multiplied with the annual total acreage for corn, cotton and soybeans, affected by incorporation of this strategy. It is also assumed that drought tolerant varieties of wheat and grain sorghum will cost $12/acre for a 12 percent reduction in water use.

Precipitation Enhancement

Precipitation enhancement, commonly known as cloud seeding or weather modification, is a process in which clouds are inoculated with condensation agents (such as silver iodide) to enhance rainfall formation. Cloud seeding is also used as a technique for hail suppression or reducing hailstone size (Encyclopedia Britannica, 2014). Currently, cloud seeding is conducted in almost one-fifth of the land area of Texas, covering about 31 million acres. In 2012, the weather modification programs in Texas conducted 162 missions, treating 353 thunderstorms. Analysis showed that the treated storms lived 40% longer, covered 47% more area, and produced 124% more rain than the untreated storms. The estimated increase in water availability was 1,517,266 acre-feet at a cost of $11/acre-foot (TDLR, 2014). Precipitation enhancement can help conserve groundwater by reducing the irrigation requirement. It can also increase reservoir levels and could have positive impact on dryland farms and ranches. This analysis assumes a water savings of one acre-inch per acre for all irrigated acreage in the region by precipitation enhancement.

The strategy of precipitation enhancement is adopted only by the counties in the Panhandle Groundwater Conservation District (PGCD). In consultation with PGCD personnel, the cost of adoption of this strategy per acre feet of water saved is estimated as $6.28 in the 2006 plan. Since this was a local estimate of the cost it was determined to be more accurate than the TDRL cost for the area. This 2006 PGCD value was adjusted to 2014 dollars (USDA, 2014). The cost of adoption of this strategy per acre-foot of water saved is estimated to be $8.11

Results

Cumulative water savings, implementation cost, reduced cost and the change in gross receipts for each of the water conservation strategies and combinations of strategies are presented in Table 3. An excess of 61 million acre feet of water is projected to be utilized for irrigation within the region over the 50-year planning horizon (2020 – 2070) without adoption of any new conservation strategies or increases in the implementation level of current strategies. Since final implementation rates of conservation strategies do not occur until 2070, the water savings, direct cost and net cost of all strategies were evaluated over a 60-year planning horizon (2020 – 2079). Each of the conservation strategies is discussed in order of projected magnitude of water savings followed by the combinations of strategies that were considered.

Anticipated advances in plant breeding (drought resistant varieties) in corn, cotton, sorghum, soybeans and wheat were estimated to generate by far the largest amount of water savings, 13.8 million ac-ft., which was 22.6 percent of the total irrigation water pumped over the 60-year planning horizon. Implementing this strategy was expected to cost $113.3 million resulting in an average cost of $8.20 per ac-ft. of water saved. The reduction in pumping cost ($1.5 billion) is expected to more than offset the implementation cost.

The change in crop type was estimated to generate 6.4 million ac-ft. of water savings, which was 10.5 percent of the total irrigation water pumped over the 60-year planning horizon. Implementing this strategy was expected to cost $199.9 million resulting in an average cost of $31.27 per ac-ft. of water saved. The difference in land values used to estimate implementation costs inherently takes into account reduced pumping costs, therefore, no additional benefit with respect to cost savings was identified. However, achieving these water savings came at an additional cost. The move to lower productive crops resulted in a loss in gross crop receipts of $3.0 billion, resulting in a negative impact on the regional economy.

Proper and accurate irrigation scheduling can save up to 2 to 3 acre-inches of irrigation per year for corn. In this analysis, the water savings from this strategy is assumed to be 10% of the water applied for each crop. Increased use of irrigation scheduling to improve the water use efficiency was estimated to save 4.7 million ac-ft. or approximately 7.7 percent of total water pumped. Implementation costs were estimated at $209.4 million resulting in a cost per ac-ft. of water saved of $44.69. The resultant reduction in pumping cost was estimated at $511.6 million, which is more than double the implementation cost.

Table 3: Estimated Water Savings and Costs Associated with Proposed Water Conservation Strategies in Region A

Water Management Strategy	Cumulative Water Savings (WS)	Implementation Cost (IC)	IC/WS	Cost Savings	Net Cost/WS	Loss in Gross Receipts
	ac-ft.	$1,000	$/ac-ft.	$1,000	$/ac-ft.	$1,000
Irrigation Scheduling	4,685,325	209,396	$44.69	511,637	($64.51)	-
Change in Crop Variety	3,064,326	602,294	$196.55	-	$196.55	1,204,587
Irrigation Equipment Changes	3,643,928	55,638	$15.27	397,917	($93.93)	-
Change in Crop Type	6,394,663	199,934	$31.27	-	$31.27	3,006,360
Soil Management	1,970,123	(34,989)	($17.76)	215,137	($126.99)	-
Precipitation Enhancement	813,923	6,601	$8.11	88,880	($101.09)	-
Irrigated to Dryland Farming	4,156,337	145,226	$34.94	-	$34.94	2,805,477

Advances in Plant Breeding	13,821,966	113,322	$8.20	1,509,359	($102.63)	-
Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	13,602,712	265,034	$19.48	1,485,416	($89.72)	3,006,360
Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	10,325,042	867,328	$84.00	1,127,495	($25.20)	1,204,587
Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	22,928,545	378,356	$16.50	2,503,797	($92.70)	3,006,360

Converting irrigated land to dryland production yielded water savings of 4.2 million ac-ft. or 6.9 percent of the total pumped. The estimated change in land values resulted in an implementation cost of $145.2 million and a resultant cost of $34.94 per ac-ft. of water saved. Since the implementation cost was evaluated as a change in land values it can be deduced that any value attributed to reduced pumping is captured in the change in land prices, therefore, no additional savings for reduced pumping cost was calculated. The change in land use from irrigated to dryland resulted in a considerable loss in gross receipts that was estimated at $2.8 billion dollars over the planning horizon which would be a significant negative impact on the regional economy.

Additional conversion of non-efficient irrigation delivery systems in the region, such as furrow to MESA and MESA to more efficient systems (LESA, LEPA, or subsurface drip irrigation) resulted in a savings of 3.6 million ac-ft. (7.7 percent of total irrigation water pumped). Investment in these more efficient systems results in an implementation cost of $55.6 million which translates into a cost of $15.27 per ac-ft. of water saved. The savings producers may capture from reduced pumping cost was estimated at $ 397.9 million resulting in a net cost savings of $342.3 million. This strategy was not expected to have any adverse effects on gross receipts while increasing investment and reducing pumping cost, thus, having a slightly positive impact on the regional economy.

The change to shorter season corn and sorghum varieties yielded the sixth largest water savings of 3.1 million ac-ft. or 5.1 percent of the total pumped. The implementation cost for this strategy which was assumed to be the loss in producer profitability was estimated at $602.3 million. Change in producer returns was used in calculating the implementation cost which included the benefits of reduced pumping costs; therefore, no additional savings were credited to this strategy. In addition, changing crop variety leads to lower yields that reduce gross cash receipts ($1.2

billion) which has a negative impact on the regional economy. The results of this strategy are very dependent on the yield reductions of short season varieties and crop prices. Lower prices and yield reductions increase the feasibility of this strategy.

The soil management conservation strategy encompasses a number of activities from including fallow in a rotation to the adoption of conservation tillage. Increasing the level of soil management yielded water savings of 2.0 million ac-ft. or 3.3 percent of total irrigation water pumped. The implementation cost of increased soil management was assessed by evaluating the cost differential between conventional and reduced till. The change in relative cost of fuel and chemicals and conservation tillage methods has made conservation tillage more cost effective than conventional tillage while achieving water savings. The implementation of increased conservation tillage was estimated to reduce costs $35.0 million over the planning horizon, resulting in a negative cost per acre-foot of water saved (-$17.76). The savings in pumping costs ($215.1 million) added to the viability of this strategy reducing the cost per acre-foot of water saved (-$126.99).

The precipitation enhancement strategy was projected to save 813,923 ac-ft. under the assumption that increased rainfall would result in a one acre-inch reduction in pumping. The estimated implementation cost associated with this strategy was $6.6 million resulting in a cost of $8.11 per ac-ft. of water saved. It should be noted that the total cost of this strategy is more than stated since it is used to benefit all land including dryland crops and pasture and only the proportional cost was attributed to the irrigated land. The savings in pumping cost was estimated at $88.9 million. This strategy should yield a positive impact to gross receipts in the region, since additional rainfall will occur not only on irrigated land but on dryland and pasture operations increasing their productivity. It should be noted, that unlike the other strategies considered, this is not a strategy a producer can individually adopt. Currently, only the Panhandle Groundwater Conservation District practices precipitation enhancement in Region A, and there are no indications that other districts of the region plan to incorporate this strategy.

The Ag subcommittee of PWPG identified three combinations of strategies that may likely be used in deficit irrigated counties. These strategies were also evaluated for the region as a whole. The combination of change in crop type, irrigation scheduling, and irrigation equipment resulted in an estimated water savings of 13.6 million ac-ft. or 22.6 percent of the total pumped; the strategy of implementing changes in crop variety, irrigation scheduling, and irrigation equipment was projected to save 10.3 million ac-ft. or 16.9 percent of the total pumped; and the combination of change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment had estimated water savings of 22.9 million ac-ft. or 37.5 percent of the total pumped. The interaction between some strategies results in lower water savings from implementing multiple strategies. It was estimated that the water savings from the combinations of strategies versus the additive water savings was reduced 7.5 percent, 10.4 percent and 19.5 percent, respectively, while the pumping cost savings ranged from 1.1 to 2.5 billion over the planning horizon for these combinations. It should be noted that all three combinations involved either change in crop type or a change in crop variety which results in a decrease in gross receipts having a negative impact on the regional economy.

Dallam County: Irrigation Shortages and Water Savings from Conservation Strategies

It is projected that Dallam County will have an irrigation shortage of 78,969 ac-ft. in 2020 (Table 4). This annual shortfall will increase to 93,817 ac-ft. in 2040 before falling to 67,839 ac-ft. by 2070. Advances in plant breeding was the most effective water saving strategy evaluated when fully implemented in Dallam County reducing annual use by 82,123 ac-ft. It was projected this strategy would meet the projected shortage by 2060. The effectiveness of the remaining strategies once fully implemented ranked as follows: change in crop type (50,048 ac-ft.), irrigation scheduling (27,734 ac-ft.), irrigation equipment (23,484 ac-ft.), conversion to dryland (18,489 ac-ft.), change in crop variety (16,142 ac-ft.) and soil management (10,737 ac-ft.). Precipitation enhancement was not considered a viable option for the county.

Three combinations of strategies identified by the Ag subcommittee of PWPG were evaluated. However, it is important to understand that implementation of certain strategies can diminish the effectiveness of others if they are also implemented. The combination of change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment was estimated to be the most effective meeting the projected shortage by 2040 and generating a surplus of 72,773 ac-ft. (140,612 - 67,839) in 2070. While less effective, the combination of change in crop type, irrigation scheduling, and irrigation equipment was able to cover the projected shortage by 2060, however, the strategy of implementing changes in crop variety, irrigation scheduling, and irrigation equipment was unable to generate sufficient water savings to offset shortages in the time periods.

Table 4: Dallam County Projected Annual Irrigation Shortage and Water Savings by Strategy (acre-ft./year), 2020-2070.

		2020	2030	2040	2050	2060	2070
Projected Irrigation Demand		290,465	255,849	224,569	195,921	170,116	144,312
Projected Shortage		-79,399	-91,675	-94,226	-87,452	-77,836	-68,218
Projected Water Savings							
Water Saving Strategies	Change in Crop Type	8,341	16,683	25,024	33,365	41,707	50,048
	Change in Crop Variety	5,381	10,761	16,142	16,142	16,142	16,142
	Soil Management	2,147	4,295	6,442	8,590	10,737	10,737
	Conversion to Dryland	9,245	18,489	18,489	18,489	18,489	18,489
	Irrigation Equipment	5,947	9,635	13,579	15,566	20,841	23,484
	Irrigation Scheduling	5,547	11,094	20,338	24,036	25,885	27,734
	Precipitation Enhancement	0	0	0	0	0	0
	Advances in Plant Breeding	19,445	33,500	72,708	81,256	82,123	82,123
	Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	18,554	34,891	54,501	67,115	81,034	92,438
	Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	15,371	28,653	45,278	50,309	56,603	60,638
	Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	34,218	61,174	106,343	121,011	132,167	140,612

Hartley County: Irrigation Shortages and Water Savings from Conservation Strategies

It is projected that Hartley County will have an irrigation shortage of 77,305 ac-ft. in 2020 (Table 5). This annual shortfall will increase to 98,650 ac-ft. in 2040 before falling to 74,130 ac-ft. by 2070. Advances in plant breeding was the most effective water saving strategy evaluated when fully implemented in Hartley County reducing annual use by 66,615 ac-ft. It was projected that this strategy by itself would not meet the projected shortage during the modeling time horizon thus, implementing a combination of strategies will be required to meet irrigation needs. The effectiveness of the remaining strategies once fully implemented ranked as follows: change in crop type (41,054 ac-ft.), irrigation scheduling (25,895 ac-ft.), irrigation equipment (21,928 ac-ft.), conversion to dryland (17,263 ac-ft.), change in crop variety (13,218 ac-ft.) and soil management (9,320 ac-ft.). Precipitation enhancement was not considered a viable option for the county.

Three combinations of strategies identified by the Ag subcommittee of PWPG were evaluated. However, it is important to understand that implementation of certain strategies can diminish the effectiveness of others if they are also implemented. The combination of change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment was estimated to be the most effective meeting the projected shortage by 2050 and generating a surplus of 46,379 ac-ft. in 2070. While less effective, the combination of change in crop type, irrigation scheduling, and irrigation equipment was able to cover the projected shortage only in the last year modeled (2070), however, the strategy of implementing change in crop variety, irrigation scheduling, and irrigation equipment was unable to generate enough water savings to offset shortages in the time periods.

Table 5: Hartley County Projected Annual Irrigation Shortage and Water Savings by Strategy (acre-ft./year), 2020-2070.

		2020	**2030**	**2040**	**2050**	**2060**	**2070**
	Projected Irrigation Demand	268,060	232,514	201,640	174,225	150,144	126,063
	Projected Shortage	-77,305	-93,368	-98,650	-92,699	-83,415	-74,130
	Projected Water Savings						
Water Saving Strategies	Change in Crop Type	6,842	13,685	20,527	27,369	34,211	41,054
	Change in Crop Variety	4,406	8,812	13,218	13,218	13,218	13,218
	Soil Management	1,864	3,728	5,592	7,456	9,320	9,320
	Conversion to Dryland	8,632	17,263	17,263	17,263	17,263	17,263
	Irrigation Equipment	5,553	8,996	12,679	14,535	19,460	21,928
	Irrigation Scheduling	5,179	10,358	18,990	22,442	24,169	25,895
	Precipitation Enhancement	0	0	0	0	0	0
	Advances in Plant Breeding	15,812	27,154	59,014	65,927	66,615	66,615
	Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	16,448	30,857	48,401	59,374	71,566	81,413
	Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	13,837	25,741	40,843	45,606	51,565	55,385
	Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	29,197	52,161	90,476	103,095	113,047	120,509

Moore County: Irrigation Shortages and Water Savings from Conservation Strategies

It is projected that Moore County will have adequate water available for irrigation until 2040 when a deficit of 4,960 ac-ft. will occur (Table 6). This annual shortfall will increase to 12,764 ac-ft. in 2070. As standalone strategies, implementing advances in plant breeding or change in crop type were sufficient to meet projected deficits in all time periods considered with estimated annual savings 32,271 ac-ft. and 19,951 ac-ft., respectively, by 2070. The effectiveness of the remaining strategies once fully implemented ranked as follows: irrigation scheduling (10,716 ac-ft.), irrigation equipment (9,081 ac-ft.), change in crop variety (7,685 ac-ft.), conversion to dryland (7,144 ac-ft.) and soil management (5,194 ac-ft.). Precipitation enhancement was not considered a viable option for the county.

Three combinations of strategies identified by the Ag subcommittee of PWPG were evaluated. However, it is important to understand that implementation of certain strategies can diminish the effectiveness of others if they are also used. Implementing any of the three combinations of strategies was sufficient to meet projected shortages. The combination of change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment was estimated to be the most effective generating a surplus of 42,642 ac-ft. in 2070. While less effective, the combination of change in crop type, irrigation scheduling, and irrigation equipment and the strategy of implementing changes in crop variety, irrigation scheduling, and irrigation equipment also were sufficient generating annual surpluses of 23,606 ac-ft. and 11,629 ac-ft., respectively, by 2070.

Table 6: Moore County Projected Annual Irrigation Shortage and Water Savings by Strategy (acre-ft./year), 2020-2070.

		2020	**2030**	**2040**	**2050**	**2060**	**2070**
	Projected Irrigation Demand	143,035	134,402	123,297	109,598	92,010	76,022
	Projected Shortage	7	7	7	7	-3,882	-6,171
	Projected Water Savings						
Water Saving Strategies	Change in Crop Type	3,325	6,650	9,976	13,301	16,626	19,951
	Change in Crop Variety	2,562	5,124	7,685	7,685	7,685	7,685
	Soil Management	1,039	2,078	3,117	4,155	5,194	5,194
	Conversion to Dryland	3,572	7,144	7,144	7,144	7,144	7,144
	Irrigation Equipment	2,300	3,726	5,251	6,020	8,059	9,081
	Irrigation Scheduling	2,143	4,286	7,858	9,287	10,001	10,716
	Precipitation Enhancement	0	0	0	0	0	0
	Advances in Plant Breeding	7,446	13,321	28,560	31,763	32,271	32,271
	Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	7,276	13,693	21,372	26,349	31,849	36,370
	Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	6,341	11,862	18,614	20,507	22,875	24,393
	Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	13,308	24,120	41,895	47,571	52,037	55,406

Sherman County: Irrigation Shortages and Water Savings from Conservation Strategies

It is projected that Sherman County will have adequate but marginal surplus of water available for irrigation throughout the planning horizon (Table 7). Therefore, implementing any of the conservation strategies will only add to the surplus. The effectiveness of the individual strategies once fully implemented ranked as follows: advances in plant breeding (49,844 ac-ft.), change in crop type (28,639 ac-ft.), irrigation scheduling (16,450 ac-ft.), irrigation equipment (14,030 ac-ft.), conversion to dryland (10,967 ac-ft.), change in crop variety (9,325 ac-ft.) and soil management (6,739 ac-ft.). Precipitation enhancement was not considered a viable option for the county.

Three combinations of strategies identified by the Ag subcommittee of PWPG were evaluated. However, it is important to understand that implementation of certain strategies can diminish the effectiveness of others if they are also used. The combination of change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment was estimated to be the most effective, generating an estimated annual water savings relative to the baseline of 83,721 ac-ft. in 2070. While less effective, the combination of change in crop type, irrigation scheduling, and irrigation equipment and the strategy of implementing changes in crop variety, irrigation scheduling, and irrigation equipment also generated substantial annual savings of 54,121 ac-ft. and 35,802 ac-ft., respectively, by 2070.

Table 7: Sherman County Projected Annual Irrigation Shortage and Water Savings by Strategy (acre-ft./year), 2020-2070.

		2020	**2030**	**2040**	**2050**	**2060**	**2070**
	Projected Irrigation Demand	220,998	207,789	190,719	169,531	148,344	127,157
	Projected Shortage	32	32	32	32	32	32
	Projected Water Savings						
Water Saving Strategies	Change in Crop Type	4,773	9,546	14,320	19,093	23,866	28,639
	Change in Crop Variety	3,108	6,217	9,325	9,325	9,325	9,325
	Soil Management	1,348	2,696	4,043	5,391	6,739	6,739
	Conversion to Dryland	5,484	10,967	10,967	10,967	10,967	10,967
	Irrigation Equipment	3,553	5,756	8,112	9,300	12,451	14,030
	Irrigation Scheduling	3,290	6,580	12,064	14,257	15,354	16,450
	Precipitation Enhancement	0	0	0	0	0	0
	Advances in Plant Breeding	11,572	20,447	44,121	49,226	49,844	49,844
	Change in Crop Type, Irrigation Scheduling & Irrigation Equipment	10,876	20,435	31,957	39,312	47,470	54,121
	Change in Crop Variety, Irrigation Scheduling & Irrigation Equipment	9,048	16,859	26,664	29,657	33,401	35,802
	Change in Crop Type, Advances in Plant Breeding, Irrigation Scheduling & Irrigation Equipment	20,156	36,498	63,651	72,285	78,846	83,721

Additional Irrigation Supply from Groundwater Wells

While the PWPG does not recommend new groundwater wells as a strategy to meet future irrigation needs during the planning period, drilling of new wells is an option for irrigation water users who require additional supplies. Approximate cost estimates were developed to determine the expense associated with installing irrigation wells. Calculations assumed a well with a depth of 375 feet, pumping at less than 700 gpm costs $95 per foot; and pumping equipment is estimated at $75 per foot. At the 500 foot well depth level, drilling cost was estimated at $110 per foot and pumping equipment cost estimates varied as to whether a submersible or electric turbine was employed (personal communication with Curry Drilling). Table 8 summarizes two scenarios: a pumping rate of less than and greater than 700 gallons per minute.

Table 8: Estimated Costs of Irrigation Wells in Region A

Pumping Rate (gpm)	Approximate Well Depth (ft.)	Approximate Well Casing Diameter (in.)	Approximate Pumping Unit Diameter (in.)	Well Cost	Pumping Equipment Cost	Total Cost
Less than 700	375	12¾	4 - 6	$33,750	$25,500	$59,250
Greater than 700	500	16	8	$55,000 $55,000	$54,500[1] $61,000[2]	$109,500 $116,000

[1] Assumes submersible pump and associated equipment
[2] Assumes electric turbine and associated equipment

Summary of Irrigation Conservation Strategies

Prioritizing and implementing the eight irrigation conservation strategies will depend on the individual irrigator and regional support for the strategy. The one strategy that yields the largest water savings is the adoption of drought resistant varieties of corn, cotton, sorghum, soybeans and wheat which are being developed with the aid of advances in plant breeding. It is estimated to have the potential to save 13.8 million ac-ft. (cumulative savings), which was 22.6 percent of the total irrigation water pumped over the 60-year planning horizon and is significantly more than the other strategies evaluated. The cumulative effectiveness of the remaining strategies in millions of ac-ft. ranked as follows: change in crop type (6.4), irrigation scheduling (4.7), conversion to dryland (4.2), irrigation equipment (3.6), change in crop variety (3.1), soil management (2.0) and precipitation enhancement (0.8).

Implementation cost can be a critical barrier to the adoption or rate of adoption of water conservation strategies. The estimated cost of implementing the various strategies expressed in $/ac-ft. of water savings varied considerably. The cost of implementing soil management actually was negative suggesting producers would save money by utilizing soil conservation techniques (-$17.76 per ac-ft.). Precipitation enhancement, advances in plant breeding, and irrigation equipment were the next three most cost effective strategies at $8.11, $8.20 and $15.27 per ac-ft., respectively. The remaining strategies where implementation cost where identified included change in crop type, conversion to dryland and irrigation scheduling had implementation costs estimated at $31.27, $34.94 and $44.69 per ac-ft., respectively.

Water savings generated by conservation strategies not only help meet regional goals for water conservation but have a direct benefit to producers through reduced pumping costs. Savings in pumping cost exceeded the estimated cost of implementation for five of the strategies leading to a negative net cost per acre foot of water saved. These strategies were; soil management (-$126.99), advances in plant breeding (-$102.63), precipitation enhancement (-$101.09), irrigation equipment (-$93.93) and irrigation scheduling (-$64.51). This suggests these strategies may be readily adopted if the implementation cost can be overcome. The remaining three strategies, change in crop variety, conversion to dryland and change in crop type had a positive net cost to implementation indicating more significant monetary enticements will be necessary to encourage adoption of these strategies.

Water conservation strategies can have significantly different impacts on the regional economy which is often measured by the change in gross receipts or costs. The impact on the regional economy should be a major consideration in prioritizing strategies to be implemented. In this planning effort, no attempt was made to quantify the impacts of individual strategies on the regional economy; however, the anticipated direction of effect(s) was included. Change in crop type, change in crop variety and conversion to dryland are all anticipated to have a negative impact due to the reduction in production. The remaining five conservation strategies are all expected to have a positive impact due to a reduction in costs without reducing yields leading to a “freeing up” of income to be spent in the economy.

The counties of Dallam, Hartley and Moore are projected to have irrigation shortfalls while Sherman is expected to have a marginal surplus. None of the individual or combinations of strategies evaluated was able to generate sufficient water savings to cover projected deficits in the near term (prior to 2050) in Dallam and Hartley Counties. Once fully in place, two of the combinations of strategies yielded sufficient water savings to overcome the projected deficits in later years. The two combinations were; change in crop type, advances in plant breeding, irrigation scheduling, and irrigation equipment and change in crop type, irrigation scheduling and irrigation equipment. In Moore County, implementing advances in plant breeding or change in crop type or any of the three combinations of strategies were sufficient to meet projected deficits in all time periods while employing one or any combination of identified water conservation strategies will add to the projected surplus in Sherman County.

Several caveats to this analysis need to be mentioned. First, the associated water savings with these strategies are “potential” water savings. In the absence of water use constraints, most of the strategies considered will simply increase gross receipts. In fact, the improved water use efficiencies generated from some of these strategies may actually increase the depletion rate of the Ogallala Aquifer. Second, potential water savings may be overestimated when combinations of strategies are implemented. For example, the savings associated with the implementation of irrigation equipment efficiency improvements cannot be applied to irrigated land that is converted to dryland farming. In this analysis, the decrease in water savings from using multiple conservation strategies is estimated for three combinations. Finally, precipitation enhancement is not a strategy that a producer can implement. It has to be funded and implemented by a group such as a water district. Currently, only the Panhandle Groundwater Conservation District practices precipitation enhancement. At this time, none of the other water districts have any plans to adopt precipitation enhancement; therefore, estimated water savings may be overestimated depending on location.

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