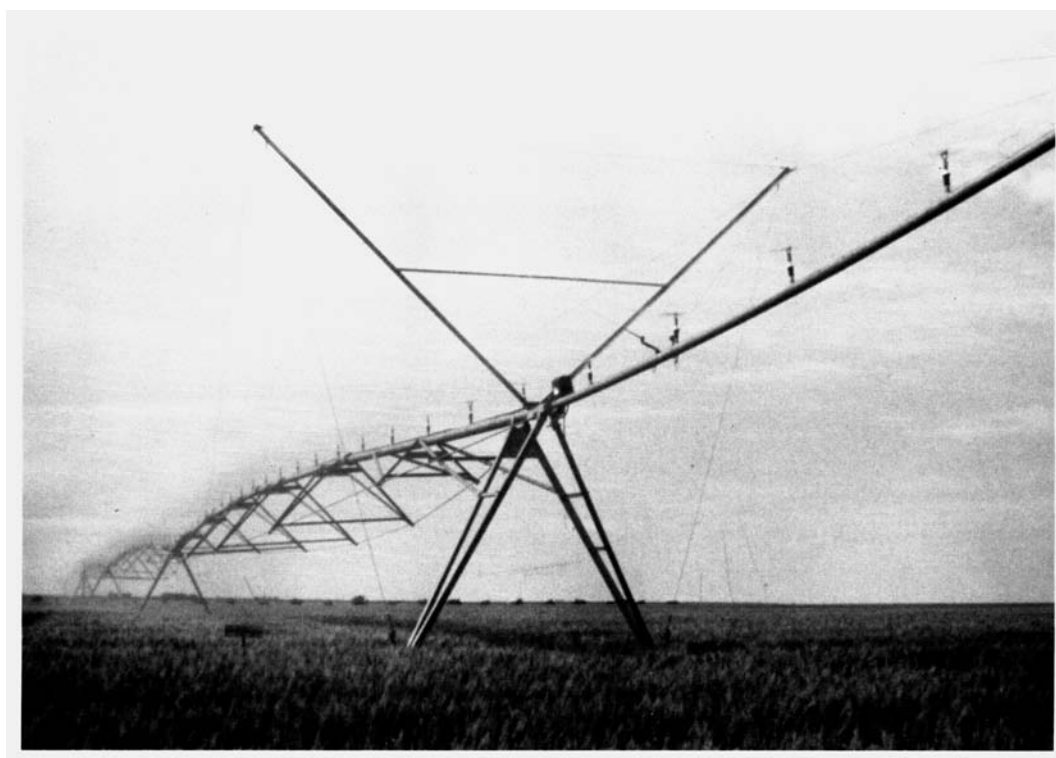


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# SELECTING IRRIGATED CROPS FOR NET INCOME AND WATER CONSERVATION IN WESTERN KANSAS

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Report of  
Progress  
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Agricultural  
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Station

Kansas  
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Walter R.  
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Director

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SELECTING IRRIGATED CROPS FOR NET INCOME AND WATER

CONSERVATION IN WESTERN KANSAS<sup>1</sup>

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ABSTRACT

A linear programming model was developed to estimate use of land and water by western Kansas irrigators for highest net income or water conservation. The model included the effect of availability of water on the best crop mix for flood and center pivot irrigation systems. The amount of water available was based on well yield, which was specified at levels of 1500, 1300, 1100, 900, 700, 500, or 300 gallons per minute (GPM). The authorized amount of water was 2 acre feet per acre. In general, at GPM above 500 for both the flood and center pivot systems, the combination of fully irrigated corn and limited irrigated wheat provided the highest net income. For the center pivot system, the land use was 82 percent to corn and 18 percent to wheat; water pumped was 95 percent to corn and 5 percent to wheat. For the flood system, the land use was 44 percent to corn and 56 percent to wheat; water pumped was 71 percent to corn and 29 percent to wheat. Below 500 GPM, land use shifted from fully irrigated corn to limited irrigated wheat for both systems. At 300 GPM, the result for center pivot was one circle of limited irrigated wheat; for the flood system, 32 percent of the land and 60 percent of the water were used for corn, and 68 percent of the land and 40 percent of the water for wheat. The highest annual net income occurred with the greatest amount of water pumped. However, results also showed that a relatively large reduction in water use could be made with a relatively small annual loss in net income. Selecting a crop mix that conserves water may prolong the life of the Ogallala aquifer, thereby increasing the total net returns over the long term. Worksheets, based on the results of this study, are included to help irrigators in western Kansas plan their crop mix.

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## INTRODUCTION

Planning a mix of irrigated crops affects an irrigator's net income and the efficiency of water use. Irrigators who want the highest net income or more efficient use of water must decide which crops to grow, how many acres for each crop, and how much water to apply to each crop. These decisions are based on the different responses of crops to water and the costs and returns of each crop.

Irrigators are interested in the net income from irrigation because of the time and investment involved. They also are interested in an efficient use of water that avoids any waste. Water use and efficiency affect net returns. However, having the highest water use efficiency (bushels per unit of water) does not mean that net returns will be highest. Neither do high water use and maximum production mean maximum net returns. As more water is applied per acre, crop yields generally increase, but each increase in yield is less than for the previous unit of water applied. Thus, the water use efficiency generally decreases as water use increases. The most profitable use of water is somewhere between the amount that provides highest water use efficiency and the amount that provides for maximum yield. If the cost of putting on the additional unit of water is less than the increase in the value of the crop produced by it, an irrigator will increase net returns by using the additional water. Maximum net return occurs when the cost of the added unit of water is equal to the increase in the value of the crop produced by it.

Efficient use of water is particularly important in western Kansas, where the water supply is diminishing. So long as the use of water for irrigation from the Ogallala Aquifer exceeds the recharge, the water table will continue to decline.

A declining water table affects irrigators because it lowers the well yield measured in gallons per minute (GPM), thereby, increasing the time needed to pump an equivalent amount of water. This further increases pumping costs because the water lift is higher. Also, well yield determines the amount of water that can be supplied during critical crop stages. Thus, selecting the acreage of crops and scheduling of irrigation are affected by well yield. Irrigators in some parts of western Kansas have experienced large decreases in well yield as the water table has declined.

Also, there are major differences in well yield from farm to farm. These differences are caused by hydrologic factors, such as the saturated thickness and soil porosity, storage, and transmissibility. In most counties of western Kansas, the GPM of wells ranges from that adequate for domestic use only to over 2000. Because of these well yield differences, the acreage and crops that fit a specific farm may not be best for a neighboring farm.

The research underlying this report shows that goals relating to net income and water conservation are not necessarily in conflict. Irrigators need a method to help in evaluating this complex situation. This report

provides worksheets and instructions to help irrigators in western Kansas estimate the best use of land and water for flood and center pivot systems.

#### METHODS

Analyzing crop selection requires knowing the GPM level, the cost of irrigation, yield response to water for different crops irrigated, labor requirements, and much more. No single source of data, such as farm records or experimental plot data, is available that contains all the necessary information. Therefore, a linear programming model was developed that integrates the information from many research projects into a decision-making and income-maximizing framework.

This report is the result and working document of economic modeling research supported by the Kansas Water Resources Research Institute (KWRRI) and Kansas Agricultural Experiment Station<sup>3</sup>. Some important assumptions of the model are:

1. Soil is a silt loam that stores about 4.17 inches of water per foot of soil, of which 2.22 inches is available to plants.
2. The authorized amount of water for irrigation is 2 acre feet per acre.
3. The application efficiency for a center pivot system is 85 percent.
4. The irrigation efficiency for a flood system is 60 percent.
5. For center pivot systems, the field size is 160 acres, of which 130 acres are irrigated with a maximum authorization for 260 acre feet of irrigation water.
6. For flood systems, all 160 acres of the field are irrigated with a maximum authorization for 320 acre feet of irrigation water.
7. Rainfall is average for the year.
8. Natural gas is the power source.

This model is used to estimate the most profitable crop mix for different GPM's (1500, 1300, 1100, 900, 700, 500, and 300) and the associated water use. The model considers three irrigated crops: corn, grain sorghum, and wheat. Several irrigation regimes for each crop are included: preseason irrigation only, limited irrigation, and full irrigation. Water requirements during prevegetative, vegetative, flowering, yield formation, ripening, and postripening stages are considered for each

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<sup>3</sup>More details of the economic model may be found in KWRRI Completion Report 258, Kansas Water Resources Research Institute, Kansas State University, Manhattan, KS 66506.

crop. The well yield and field size determine how much water will be available during the critical flowering and yield formation stages. If moisture deficit occurs during these critical stages, then crop yield per acre may be reduced.

The adverse effect of low well yield can be reduced by storing some water in the soil from preseason rainfall or irrigation. The soil texture and depth of soil determine how much water can be stored. In a 5 foot profile of silt loam soil, 0.9 acre foot of water is the maximum that can be stored. This is approximately equivalent to two, 6-inch irrigations. However, water does drain from the soil, and the longer the storage time, the more water will be lost to depths below the root zone. Also, evaporation of water will take place at the soil surface. Therefore, the 0.9 acre foot maximum for the silt loam soil will likely not be accomplished with the preseason irrigation practice because of evaporation and drainage.

Kansas water law can influence crop selection. This law provides for permits that authorize 2 acre feet per acre per designated field. So, if an irrigation system has an efficiency of 85 percent, then 1.7 acre feet will be available to the crop ( $.85 \times 2 \text{ ft} = 1.7 \text{ ft}$ ). The 1.7 acre feet of irrigation water plus the normal amount of rainfall during the growing season is less than the 24-26 inches of water required by corn plants. For a flood system, which may have a lower irrigation efficiency, the amount available is even less. Therefore, full crop water-needs cannot be met within the authorized limit in most years, so that farmers must either store water in the soil from preseason rainfall or irrigation, accept lower yields, or change the crop mix and redistribute water so that more is applied per acre to more water-responsive crops.



## RESULTS

### Overview

The model was used to test the effect of different amounts of GPM on crops selected for the flood and center pivot systems. A worksheet for each system is included at the end of this report to help plan for an irrigated crop mix that provides a higher net return or more efficient use of water. While doing the crop planning, the irrigator will likely use several copies of a worksheet to test several different situations. A suggestion for finding the best crop mix is to first work through a situation using your current crop acreage and water pumped. The estimated total net returns will likely be different from your actual farm returns, but they should be close. Call this first worksheet your "base" plan. Then test another situation (plan 1), which for example, changes the acreage but keeps water pumped per crop acre the same. Then compare plan 1 with the base plan for the change in net return. With a few plans, you will see the pattern in results that occurs by substituting one crop for another. Also, test the effect of changing the amount of water pumped per acre and keeping acreage unchanged. This test will show the effect of redistributing water among crops.

Comparing results between the "base" plan (which is the current crop mix) and other plans will provide a reasonable estimate of the changes to be expected. Factors that affect the net returns from irrigation are quite different from farm to farm. But the percent change in net income among plans for a specific field may be very similar, in which case the worksheet approach may be useful.

The net return is the amount remaining after paying operating cash expenses. The fixed costs, such as depreciation and taxes on well and equipment, and land taxes have not been subtracted out. Therefore, this is the net return to the operator for labor, management, and investment.

Net returns are based on current prices and costs of production. Commodity prices used are current government loan rates. The model selects the most profitable amount of water pumped based on the yield that is expected for each different irrigation regime. Information about crop yield responses to water was based on irrigation experiments conducted at the Southwest Kansas (Garden City and Tribune) and Colby branch experiment stations. Weather data were collected at Dodge City and Garden City. Fertilizer costs were estimated based on the cost of replacing nutrients taken from the soil by the crop. Other operating costs were estimated using 1985 Farm Management Guides published by the Cooperative Extension Service.

The model considers the amount of labor required for the different crops and the amount available for the irrigated field. If additional labor is needed, the assumption is that it can be hired.

Results for center pivot and flood systems are discussed separately. Unless an irrigator has both systems, only one section and the corresponding worksheet need to be studied.

## Center Pivot Irrigation System

The model was used to study the effect of 1500, 1300, 1100, 900, 700, 500, and 300 GPM on crop mixes. Several combinations of crops were studied for each GPM level; the combination providing highest net income with no restrictions on acreage, acreage equally divided among two crops, and only one crop. The summary of results (Table 1) may be helpful in selecting the combination that best fits your situation. The first row of each GPM group shows the results when the model was allowed to select the most profitable combination of crops, the acreage of each crop, and the amount of water pumped. The next six rows in each group are combinations of specified acreage equally divided among two crops and only one crop.

The crop mix that maximizes net income is 108 acres of fully irrigated corn (82 percent of the land) and 22 acres of wheat (18 percent) for well yields of 500 GPM or higher (Table 1). Water pumped is 95 percent to corn and 5 percent to wheat. Because the center pivot system is assumed to have a higher irrigation efficiency than the flood system, a higher percent of the land and water is used to fully irrigate corn with the pivot system than with the flood system.

Below 500 GPM, the land use shifts away from fully irrigated corn to limited irrigation of wheat. At 300 GPM, the most profitable use of water and land is 130 acres of wheat (Table 1). The shift away from fully irrigated corn allows use of less water, therefore, the authorized water limit does not influence the results. With 130 acres of wheat and one irrigation, the amount of water pumped is much below the authorized limit.

Unequal field sizes, as shown in Table 1, may not be desirable or practical. A field equally divided in two may be desired. Under this situation, the 130 acres equally divided with 65 acres each of corn and wheat gives highest net income among crop combinations for GPM above 500 (water pumped is 80 percent to corn and 20 percent to wheat). Below 500 GPM, the crop combination shifts to equal acres of grain sorghum and wheat, with 68 percent of the water pumped to grain sorghum and 32 percent to wheat.

Another possibility is to have one crop per circle. One circle of corn provides higher net income than either wheat or grain sorghum for GPM levels above 700. Below 700 GPM, the advantage shifts to wheat.

Under center pivot irrigation, corn loses some of the advantage it has with flood irrigation. This loss is primarily due to higher pumping costs for center pivot systems. Corn's highest profitability occurs with full irrigation. However, under these conditions, pumping costs are much higher for corn than for grain sorghum.

**Planning Net Income with Worksheet.** Table 1 reports model results for specific combinations of crops and amounts of water pumped. Irrigators have a variety of situations and many may have crop combinations that do not fit those included in the table. Therefore, model results were put into a



Table 1. Acres Irrigated, Water Pumped, and Net Income for Center Pivot System Irrigating 130 Acres.

GPM	Net Income, \$	Acres Irrigated			Water Pumped			
		Corn	Wheat	Gr.So.	Corn	Wheat	Gr.So.	Total
1500	7305	108	22	-	248	13	0	260
	6786	65	-	65	149	0	77	226
	6833	65	65	-	149	37	0	186
	6066	-	65	65	0	37	77	114
	6113	-	130	-	0	74	0	74
	6019	-	-	130	0	0	154	154
	6789	130	-	-	260	0	0	260
	1300	7214	108	22	-	248	13	0
6706		65	-	65	149	0	77	226
6767		65	65	-	149	37	0	186
6026		-	65	65	0	27	77	114
6087		-	130	-	0	74	0	74
5964		-	-	130	0	0	154	154
6698		130	-	-	260	0	0	260
1100		7089	108	22	-	248	13	-
	6597	65	-	65	149	0	77	226
	6668	65	65	-	149	37	0	186
	5971	-	65	65	0	37	77	114
	6051	-	130	-	0	74	0	74
	5890	-	-	130	0	0	154	154
	6574	130	-	-	260	0	0	260
	900	6923	108	22	-	248	13	0
6453		65	-	65	149	0	77	226
6559		65	65	-	149	37	0	186
5898		-	65	65	0	37	77	114
6004		-	130	-	0	74	0	74
5792		-	-	130	0	0	154	154
6408		130	-	-	260	0	0	260
700		6642	108	22	-	248	13	0
	6209	65	-	65	149	0	77	226
	6358	65	65	-	149	37	0	186
	5776	-	65	65	0	37	77	114
	5925	-	130	-	0	74	-	74
	5627	-	-	130	0	0	154	154
	6126	130	-	-	260	0	0	260
	500	6085	106	24	-	243	14	0
5751		65	-	65	149	0	77	226
5957		65	65	-	149	37	0	186
5555		-	65	65	0	37	77	114
5781		-	130	-	0	74	0	74
5327		-	-	130	0	0	154	154
5521		130	-	-	257	0	0	257
300		5446	-	130	-	0	74	0
	4430	65	-	65	135	0	77	212
	5104	65	65	-	149	37	0	186
	5039	-	65	65	0	37	77	114
	4580	-	-	130	0	0	154	154
	3716	130	-	-	205	0	0	205

worksheet format that allows an irrigator to specify conditions different from those reported. The procedure used summarizes and generalizes model results<sup>4</sup>. Thus, worksheet results may not exactly duplicate results shown in Table 1.

An example will illustrate the use of the worksheet (Table 2). Let's assume a farmer has 130 acres irrigated with one well, delivering 900 GPM. This farmer is interested in irrigating equal acres of corn and wheat. He applies 6 inches per irrigation four times during the season to corn and one, 6-inch irrigation to wheat.

To use the worksheet, you must know the acreage irrigated by each well, the GPM of each well, the amount of water applied per acre to each crop, and the acreage of each crop per field irrigated. This information is reported on lines 1 through 4 on the worksheet. Next, you are ready to make the net return calculation. Line 5 in the calculations is a negative number, which is a constant and remains the same for all situations. Line 6 is the value of well yield: net income increases \$120 for every increase of 100 in GPM. With higher GPM, fewer hours are needed for pumping water so the cost of equipment maintenance and labor is lower, and consequently, net income is higher. The energy cost of pumping is constant for the same volume of water.<sup>5</sup> Lines 7, 8, and 9 calculate the water pumped and net returns to corn, wheat, and grain sorghum, respectively. Water pumped is acres times amount pumped per acre. Net income is water pumped per crop times the value of 1 acre foot of water per crop. Total net return, shown on line 10, is the sum of the values for each crop plus the value for GPM less the constant. The calculations on line 11 show total acreage irrigated and total water pumped. The calculation on line 12 determines water pumped per acre for the irrigated field to be sure it is within the specified limit.

The water pumped is called the gross irrigation requirement. It is the amount pumped, not the amount used by the crop. To estimate the amount available to the crop, multiply the water pumped by .85. This result is based on an irrigation efficiency of 85 percent.

The actual worksheet at the end of the report includes limits on water pumped per crop and per field. Values used in the worksheet should fall within the specified limits.

The worksheet example (Table 2) shows a GPM of 900 (6.9 per GPM irrigated acre and 13.85 GPM per acre of corn, which are well above the specified limits on the actual worksheet). The water applied to corn and wheat per acre are within limits specified. The 1.25 acre feet per acre for the irrigated field is below the upper limit specified for water pumped.

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<sup>4</sup>Results from the linear programming solutions were summarized using multiple regression. The net return variable was regressed on crop acreage and water use.

<sup>5</sup>For more information regarding estimation of irrigation pumping costs, see Kansas Water Resources Research Institute Completion Rep. 247.

Table 2: EXAMPLE, CENTER PIVOT SYSTEM WORKSHEET

- 
- (1) Well GPM 900 Acres per field 130 GPM Per Acre 6.92  
(2) Acres corn 65 Water pumped per acre of corn 2 Ac ft  
(3) Acres wheat 65 Water pumped per acre of wheat .5 Ac ft  
(4) Acres gr. sorgh. 0 Water pumped per acre of gr. sorgh. 0 Ac ft

Net Return Calculations

- (5) Constant \$-1095.80  
(6) 900 GPM x 1.2 = \$ 1080.00  
(7) 65 acres corn x 2 Ac. ft. per acre = 130 x \$23.05 = \$ 2996.50  
(8) 65 acres wheat x .5 Ac. ft. per acre = 32.5 x \$79.96 = \$ 2598.70  
(9) 0 acres grain sorghum x 0 Ac. ft. per acre = 0 x \$35.86 = \$ 0  
(10) TOTAL NET RETURN = \$ 5579.40  
(11) 130 TOTAL ACRES 162.50 Total Ac. ft pumped  
(12) TOTAL WATER PUMPED / TOTAL ACRES = 1.25 Ac. ft per acre
- 

The \$5579 is the expected return from 65 acres each of corn and wheat, after paying cash operating expenses. This is the return earned by the operator for his labor and investment in land and irrigation equipment.

Now let's suppose the irrigator is interested in knowing the effect of shifting more land away from wheat to corn; for example, 80 acres of corn and 50 acres of wheat. This is plan 1. These changes appear on lines 2, 3, 7, and 8 of the worksheet. On lines 7 and 8, new calculations are made for the income derived from these crops. For corn, the calculation is 80 x 2 x \$23.05, giving an income of \$3688. For wheat, the calculation is 50 x .5 x \$79.96, giving an income of \$1999. Total income is now \$5671. Income increased \$92 (\$5671 - \$5579 = \$92) or 1.6 percent over the base plan. Water pumped is still within specified limits.

Plan 2 might consider increasing water pumped to corn from 2 acre feet to 2.5 acre feet, while wheat acreage and water applied remain as in the base plan. This change is entered on lines 2 and 7. The calculation for income from corn on line 7 is 65 x 2.5 x \$23.05, giving an income of \$3746. Total net income increases to \$6329. The increase is \$750 or 13 percent over the base plan.

The appropriate use of the worksheet is for comparing the results of new plans with those of the existing base plan. The results are most accurate when estimating the percent changes in income of a new plan compared to the base plan.

**Planning Water Use with Worksheet.** Changes in crop mix influence net income and water pumped, so both may be considered when planning a crop mix. The previous section focused on changes in annual net income resulting from changes in the crop mix or the amount of water pumped. This is a relatively short-term focus. Long-term plans should consider the possibility of conserving water and, thereby, extending the life of the aquifer. Table 1 shows that fairly large reductions in water pumped can be made with relatively small losses in annual net returns. It is possible that in the long term, selecting a crop mix requiring less water pumped annually than the amount that provides the highest annual net income will extend the number of years for irrigation. Therefore, more total net income will be obtained over the life of the aquifer. In the economic model, the only cost associated with water was the cost of pumping. If the irrigator puts a value on water in addition to pumping costs, than the economic optimum is to pump less water.

The following illustration shows the use of the worksheet to plan a crop mix that considers a change in water pumped. The base plan, discussed in the previous section, estimated net income from 65 acres of corn with 2 acre feet pumped per acre and 65 acres of wheat with .5 acre feet pumped per acre. The result was \$5579 net income and 163 acre feet of water pumped. This is \$34.23 net income per acre foot pumped.

Now consider the effect of substituting 65 acres of grain sorghum with 1.25 acre feet per acre for the 65 acres of corn. Line 2 on the worksheet is changed to zero acres of corn, line 3 remains unchanged, and line 4 changes to 65 acres grain sorghum and 1.25 acre feet pumped per acre. Lines 5 and 6 are unchanged; income on line 7 changes to zero; line 8 remains unchanged; and line 9 changes to show 65 acres grain sorghum, 1.25 acre feet pumped per acre, and \$2913.62 net income from grain sorghum ( $65 \times 1.25 \times \$35.86 = \$2913.62$ ). Total income is \$5497, and water pumped is 114 acre feet. Compared with the original base plan, income decreases from \$5579 to \$5497, or \$82 less. Water pumped decreases from 163 acre feet to 114, or 49 acre feet less. Net income decreases 2 percent, and water pumped decreases 30 percent. However, net income per acre foot pumped increases from \$34.23 to \$48.22. By selecting a crop mix that provides less annual net income but requires less water pumped, the irrigator may be able to obtain more net income in the long term.

### **Flood Irrigation System**

The model was used to analyze the effect of 1500, 1300, 1100, 900, 700, 500, and 300 GPM on the crop mix on 160 acres of gated pipe, flood irrigated land. Several combinations of crops were studied for each GPM level: the combination providing highest net income with no restrictions on acreages, two crops of equal acreage, and only one crop. The summary of results (Table 3) may help you select the crop mix appropriate for your farm. The

first row of each GPM group shows results when the model was allowed to select the most profitable combination of crops, the acreage of each crop, and the amount of water pumped. The next six rows in each group are combinations of specified acreage equally divided among two crops and only one crop.

The model was allowed to have fewer than 160 acres or fewer than 320 acre feet of water. For each GPM group of 500 or higher, the combinations total 160 acres with 320 acre feet pumped or less except the last row in each group. The last row shows 147 acres of corn irrigated with 320 acre feet pumped. The remaining 13 acres are idle. The model chooses to use all available water on fewer than the allowed 160 acres.

In the model, the alternative irrigation regimes from which the most profitable one was selected included one, two, three, or four irrigations. For corn, the model selects four irrigations, but in doing so, the limit on water available allows only 147 acres to be irrigated. To irrigate 160 acres would require a regime of two or three irrigations on some of the acreage. The loss in revenue from pumping 320 acre feet on 160 acres utilizing three irrigations on some acreage is greater than the loss from having 13 acres idle but allowing 147 acres to be fully irrigated.

At 300 GPM, pumping time available becomes more important than the amount of water pumped in determining corn acreage. Below 500 GPM, fully irrigated corn begins to lose its comparative advantage over use of water and land for wheat or grain sorghum.

The crop mix that maximizes net income remains essentially the same for 500 GPM and higher (Table 3). This mix is 71 acres of fully irrigated corn (44 percent of the acres) and 89 acres of wheat irrigated preseason or in early fall (56 percent of the land). Above 500 GPM, the authorization of 2 acre feet per acre determines and limits the acreage for fully irrigated corn. Fully irrigated corn is the preferred crop, but it requires more than 24 inches of irrigation per acre in most years to meet the plants' requirements. With an irrigation efficiency of 60 percent, only 14.4 inches of the authorized 24 are available to the crop. Thus, the most profitable mix is 71 percent of the authorized water on 44 percent of the irrigated land to fully irrigated corn and 29 percent of the water on 56 percent of the land to partially irrigated wheat.

Below 500 GPM, well yield, the crop mix shifts away from corn to wheat. At 300 GPM, 51 acres (32 percent) and 60 percent of the authorized water are used for fully irrigated corn, whereas 109 acres (68 percent) and 40 percent of the authorized water (as preplant or in early fall irrigation) are used for wheat.

Suppose you want to have the 160 acres equally divided into two fields. The model selects the most profitable choice of crops as 80 acres each of corn and wheat for wells with GPM of 500 or higher. The model allocates 75 percent of the water to corn and 25 percent to wheat. Below 500 GPM, the mix shifts away from corn to grain sorghum. At 300 GPM, the most profitable

Table 3. Acres Irrigated, Water Pumped, and Net Income for Flood System Irrigated 160 acres.

GPM	Net Income, \$	Acres Irrigated			Water Pumped			Total
		Corn	Wheat	Gr.So.	Corn	Wheat	Gr.So.	
1500	8332	71	89	-	211	83	0	294
	7893	80	-	80	187	0	133	320
	8200	80	80	-	222	74	0	296
	7507	-	80	80	0	127	133	260
	7376	-	160	0	0	254	0	254
	7639	147	-	160	0	0	267	267
	7017	147	-	-	320	0	0	320
1300	8243	71	89	-	211	83	0	294
	7803	80	-	80	186	0	133	320
	8110	80	80	-	222	74	0	296
	7428	-	80	80	0	127	133	260
	7290	-	160	-	0	254	0	254
	7565	-	-	160	0	0	267	267
	6926	147	-	-	320	0	0	320
1100	8073	71	89	-	211	83	0	294
	7634	80	-	80	187	0	133	320
	7940	80	80	-	222	74	0	296
	7276	-	80	80	0	127	133	260
	7127	-	160	-	0	254	0	254
	7423	-	-	160	0	0	267	267
	6757	147	-	-	320	0	0	320
900	7848	71	89	-	211	83	0	294
	7408	80	-	80	187	0	133	320
	7715	80	80	-	222	74	0	296
	7075	-	80	80	0	127	133	260
	6907	-	160	-	0	254	0	254
	7233	-	-	160	0	0	267	267
	6526	147	-	-	320	0	0	320
700	7519	71	89	-	211	83	0	294
	7021	80	-	80	187	0	133	320
	7382	80	80	-	222	74	0	296
	6779	-	80	80	0	127	133	260
	6582	-	160	-	0	254	-	254
	6940	-	-	160	0	0	267	267
	6148	147	-	-	320	0	0	320
500	6851	70	90	-	208	84	0	292
	6212	80	-	80	180	0	133	313
	6685	80	80	-	219	74	0	293
	6210	-	80	80	0	127	133	260
	5967	-	160	-	0	254	0	254
	6362	-	-	160	0	0	267	267
	5354	144	-	-	314	0	0	314
300	5240	51	109	-	152	101	0	253
	3567	29	-	80	87	0	133	220
	4574	58	80	-	173	74	0	247
	5067	-	80	80	0	75	133	208
	5013	-	160	-	0	148	0	148
	4358	-	-	160	0	0	206	206
	2714	77	-	-	229	0	0	229

mix is 80 acres of wheat using 36 percent of the water pumped and 80 acres of grain sorghum using 64 percent.

Suppose you want to have only one crop and not mix the acreage. Under this condition, the model selects grain sorghum twice irrigated, which is more profitable than having either 160 acres of wheat or 160 acres of corn for GPM of 500 or higher. In this case, the authorization of 2 acre ft per acre does not limit the acreage or the amount applied per acre. Net income is higher for twice irrigated grain sorghum than for using the authorized amount of water on 160 acres of wheat or 160 acres corn. Below 500 GPM, the most profitable situation shifts to wheat. At 300 GPM, 160 acres of wheat is more profitable than 160 acres of either corn or grain sorghum.

Fully irrigated corn is not feasible on 160 acres with an authorization of 2 acre feet, a 300 GPM well, and a 60 percent efficient irrigation system. Therefore, a limit on water or on pumping time will eliminate fully irrigated corn for this size of field.

**Planning Net Income with Worksheet.** Table 3 reports model results for specific combinations of crops and amounts of water pumped. Irrigators have a variety of situations, many of which may not fit those included in the table. Therefore, model results were put into a worksheet format that allows an irrigator to specify conditions different from those reported. The procedure used summarized and generalized model results. Thus, worksheet results may not exactly duplicate results shown in Table 3.

An example will illustrate the use of the worksheet (Table 4). Let's assume an irrigator has 160 acres irrigated with one well, delivering 900 GPM. This irrigator is applying 2.5 feet per acre on 80 acres of corn and 80 acres of wheat irrigated at .75 foot per acre. This situation will be referred to as the base plan.

To use the worksheet, you must know the acreage irrigated by each well, the GPM of each well, the amount of water applied per acre to each crop, and the acreage of each crop per field irrigated. This information is reported on lines 1 through 4 of the worksheet. Next, you are ready to make the net return calculation. Line 5 in the calculations is a number that is a constant and remains the same for all situations. Line 6 is the value of well yield; net income increases \$168 for every increase of 100 in GPM. With higher GPM, fewer hours are needed for pumping water so the cost of equipment maintenance and labor is lower, and consequently, net income is higher. The energy cost of pumping is constant for the same volume of water over all GPM levels<sup>6</sup>. Lines 7, 8, and 9 calculate the water pumped and net returns to corn, wheat, and grain sorghum, respectively. Water pumped is acres times amount pumped per acre. Net income is water pumped per crop times the value of 1 acre foot of water per crop. Total net return on line 10 is the sum of the values for each crop plus the value for GPM plus the constant. The calculations for lines 11 and 12 show total acreage irrigated

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<sup>6</sup>For more information regarding estimation of irrigation pumping costs, see Kansas Water Resource Research Institute Completion Rep. 247.

and total water pumped. The last calculation determines water pumped per acre for the irrigated field to be sure it is within the specified limit (see actual worksheet at the end of this report for limits.)

The water pumped is called the gross irrigation requirement. It is the amount pumped, not the amount used by the crop. To estimate the amount available to the crop, multiply the water pumped by .60. This result is based on an irrigation efficiency of 60 percent.

Table 4: EXAMPLE, FLOOD SYSTEM WORKSHEET

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(1) Well GPM	<u>900</u>	Acres per field	<u>160</u>	GPM Per Acre	<u>5.6</u>
(2) Acres corn	<u>80</u>	Water pumped per acre of corn	<u>2.5</u>	Ac ft	
(3) Acres wheat	<u>80</u>	Water pumped per acre of wheat	<u>1</u>	Ac ft	
(4) Acres gr. sorgh.	<u>0</u>	Water pumped per acre of gr. sorgh.	<u>0</u>	Ac ft	
<u>Net Return Calculations</u>					
(5)				Constant	\$ <u>6.93</u>
(6)			<u>900</u>	GPM * 1.680 =	\$ <u>1512.00</u>
(7)	<u>80</u>	acres corn x <u>2.5</u> Ac. ft. per acre =	<u>200</u>	x \$16.24 =	\$ <u>3248.00</u>
(8)	<u>80</u>	acres wheat x <u>1.0</u> Ac. ft. per acre =	<u>80</u>	x \$21.69 =	\$ <u>1735.20</u>
(9)	<u>0</u>	acres grain sorghum x <u>0</u> Ac. ft. per acre =	<u>0</u>	x \$20.15 =	\$ <u>0</u>
(10)				TOTAL =	\$ <u>6502.13</u>
(11)	<u>160</u>	TOTAL ACRES	<u>280</u>	Total Ac. ft pumped	
(12)	TOTAL WATER PUMPED / TOTAL ACRES =		<u>1.75</u>	Ac. ft per acre	

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The worksheet example (Table 4) shows a GPM of 900 (5.6 per irrigated acre and 11.3 GPM per acre of corn, which are well above the specified limits on the actual worksheet). The water pumped to corn and wheat per acre are within the limits specified. The 1.75 acre feet per acre for the field is below the limit specified for water pumped.

The \$6502 is the expected return of the base plan from 80 acres each of corn and wheat, after paying cash operating expenses. This is the return earned by the operator for his labor and investment in land and irrigation equipment.

Now let's suppose the irrigator is interested in knowing the effect on income of shifting 20 acres from wheat to corn. Plan 1 includes 100 acres of corn and 60 acres wheat, keeping water pumped as in the base situation. These changes are reported on lines 2, 3, 7, and 8. On lines 7 and 8, new calculations are made for the income derived from each crop, thereby changing the total income. The calculation for corn is  $100 \times 2.5 \times \$16.24$ , giving an income of \$4060. The calculation for wheat is  $60 \times 1 \times \$21.69$ , giving an income of \$1301. The total income for plan 1 is \$6880. This is



an increase of \$378 or 5.8 percent over the base situation ( $\$6880 - \$6502 = \$378$ ).

Plan 2 might be to increase water pumped to corn from 2.5 to 3 feet per acre, with corn acreage, wheat acreage, and water pumped to wheat the same as in the base plan. The changes are made in lines 2 and 7. The new calculations for income from corn are  $80 \times 2 \times \$16.24$ , giving an income of \$3898. The other values remain unchanged except total income, which increases to \$7152. Total income for plan 2 increases \$650 or 10 percent over the base plan income ( $\$7152 - \$6502 = \$650$ ). Water pumped in plan 2 is 320 acre feet, or 2 acre feet per acre, which is the authorized water limit.

The appropriate use of the worksheet is for comparing the results of new plans with the existing base plan. The results are most accurate when estimating the percent changes in income of a new plan compared to the base plan.

**Planning Water Use with Worksheet.** Changes in crop mix influence net income and water pumped, so both may be considered when planning a crop mix. The previous section illustrated the use of the worksheet to estimate changes in annual net income resulting from changes in the crop mix or the amount of water pumped. This is a relatively short-term focus. Long-term plans should consider the possibility of conserving water and, thereby, extending the life of the aquifer. Table 3 shows that fairly large reductions in water pumped can be made with relatively small losses in annual net returns. It is possible that in the long term, selecting a crop mix requiring less water pumped annually than the amount that provides the highest annual net income will extend the number of years for irrigation. Therefore, more total net income will be obtained over the life of the aquifer. In the economic model, the only cost associated with water was the cost of pumping. If the irrigator puts a value on water in addition to pumping costs, then the economic optimum is to pump less water.

The following illustration shows the use of the worksheet to plan a crop mix that considers a change in water pumped. The base plan discussed for flood irrigation estimated net income from 80 acres of corn with 2.5 acre feet per acre and 80 acres of wheat with 1 acre foot per acre. The result was \$6502 net income and 280 acre feet of water pumped. This is \$23.22 net income per acre foot pumped.

Consider the effect of substituting 80 acres of grain sorghum with 1.75 acre feet pumped per acre for the 80 acres corn. Line 2 of the worksheet is changed to zero acres of corn, line 3 remains unchanged, and line 4 is changed to show 80 acres of grain sorghum and 1.75 acre feet pumped per acre. Line 5 remains unchanged; line 6 remains unchanged since we assume the same well yield; line 7 is changed to zero net income from corn; line 8 remains unchanged; line 9 changes to 80 acres grain sorghum with 1.75 acre feet giving \$2821 net income ( $80 \times 1.75 \times \$20.15 = \$2821$ ). Total net income for this plan is \$6075 compared to \$6502 for the base plan. Water pumped is 220 acre feet compared to 280 for the original example. Total net income decreases \$427, or 7 percent, and water pumped decreases 60 acre feet or 21 percent. However, net income per acre foot pumped increases to \$27.61 from

\$23.22 for the base situation. By selecting a crop mix that provides less annual net income but requires less water pumped, the irrigator may be able to obtain more net income in the long term.

#### SUMMARY

Planning an irrigated crop mix that considers net income and efficient water use is a problem facing many irrigators in western Kansas. This report provides two worksheets, one for center pivot and one for flood systems, and examples of how to use each to plan for net income or for water use.

An economic model was developed to study the relationship between crop mix and net income for different well yields. Several combinations of crops were studied for each GPM level for flood and center pivot irrigation systems; that combination providing highest net income with no restrictions on acreage, acreage equally divided among two crops, and only one crop.

In general for GPM above 500 with both flood and center pivot systems, the combination of irrigated corn and wheat provides the highest net income. Results are based on an authorization of 2 acre feet per acre. For center pivot systems, the land use was 82 percent to corn and 18 percent to wheat; water pumped was 95 percent to corn and 5 percent to wheat. For flood systems, the land use was 44 percent to corn and 56 percent to wheat; water pumped was 71 percent to corn and 29 percent to wheat.

Below 500 GPM, land use shifts from fully irrigated corn to limited irrigations of wheat for both the center pivot and the flood irrigation systems. For 300 GPM, the result for center pivot is one circle of limited irrigated wheat; for flood irrigation, 32 percent of the land and 60 percent of the water are used for corn, and 68 percent of the land and 40 percent of the water for wheat.

Because the center pivot system is assumed to have a higher irrigation efficiency than the flood system, a higher percent of the land and water is used to fully irrigate corn with the center pivot system. Under center pivot irrigation, corn loses some of the advantage it has with flood irrigation. The loss is primarily due to higher pumping costs for the center pivot systems. Corn's highest profitability occurs with full irrigation. However, under these conditions, pumping costs are much higher for corn than for grain sorghum.

Price changes for the produce sold and inputs purchased will change the net returns of the irrigated crops. If the pattern in price changes continues much the same as in the recent past, than the percent changes among different plans may be affected little. So long as the price relationship among commodities remains fairly stable, the comparative advantage among crops will also remain stable.

Sound water management does not conflict with net income, especially in the long term. The highest annual net income does occur with the highest amount of water pumped for the levels of GPM studied. However, the results also show that a relatively large reduction in water pumped can be made with a relatively small loss in net income.

CENTER PIVOT SYSTEM WORKSHEET

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- (1) Well GPM \_\_\_\_\_ Acres per field \_\_\_\_\_ GPM Per Acre \_\_\_\_\_
- (2) Acres corn \_\_\_\_\_ Water pumped per acre of corn \_\_\_\_\_ Ac. ft.
- (3) Acres wheat \_\_\_\_\_ Water pumped per acre of wheat \_\_\_\_\_ Ac. ft.
- (4) Acres gr. sorgh. \_\_\_\_\_ Water pumped per acre of gr. sorgh. \_\_\_\_\_ Ac. ft.

Net Return Calculations

- (5) \_\_\_\_\_ Constant \$ 1095.80
- (6) \_\_\_\_\_ GPM x \$1.20 = \$ \_\_\_\_\_
- (7) \_\_\_\_\_ acres corn x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$23.05 = \$ \_\_\_\_\_
- (8) \_\_\_\_\_ acres wheat x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$79.96 = \$ \_\_\_\_\_
- (9) \_\_\_\_\_ acres gr. sorgh. x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$35.86 = \$ \_\_\_\_\_
- (10) TOTAL NET RETURNS = \$ \_\_\_\_\_
- (11) \_\_\_\_\_ TOTAL ACRES \_\_\_\_\_ Total Ac. ft pumped
- (12) TOTAL WATER PUMPED / TOTAL ACRES = \_\_\_\_\_ Ac. ft per acre
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Limits and restrictions on use of worksheet:

1. For wells with GPM per acre of 3.1 or higher, do not exceed 2 acre feet per acre of water pumped.
2. For wells below 3.1 GPM per acre, do not exceed 1.5 acre feet per acre of water pumped.
3. Range in water pumped to corn: 1.5-2.5 acre ft. per acre.
4. Range in water pumped to wheat: .3-.75 acre ft. per acre.
5. Range in water pumped to grain sorghum: .75-1.25 acre ft. per acre.
6. Range in GPM: 300 to 1500.
7. 5 GPM per acre of corn or greater.



FLOOD SYSTEM WORKSHEET

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(1) Well GPM \_\_\_\_\_ Acres per field \_\_\_\_\_ GPM Per Acre \_\_\_\_\_

(2) Acres corn \_\_\_\_\_ Water pumped per acre of corn \_\_\_\_\_ Ac.ft.

(3) Acres wheat \_\_\_\_\_ Water pumped per acre of wheat \_\_\_\_\_ Ac.ft.

(4) Acres gr. sorgh. \_\_\_\_\_ Water pumped per acre of gr. sorgh. \_\_\_\_\_ Ac. ft.

Net Return Calculations

(5) \_\_\_\_\_ Constant \$ 6.93

(6) \_\_\_\_\_ GPM \* 1.680 = \$ \_\_\_\_\_

(7) \_\_\_\_\_ acres corn x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$16.24 = \$ \_\_\_\_\_

(8) \_\_\_\_\_ acres wheat x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$21.69 = \$ \_\_\_\_\_

(9) \_\_\_\_\_ acres gr. sorgh. x \_\_\_\_\_ Ac. ft. per acre = \_\_\_\_\_ x \$20.15 = \$ \_\_\_\_\_

(10) \_\_\_\_\_ TOTAL = \$ \_\_\_\_\_

(11) \_\_\_\_\_ TOTAL ACRES \_\_\_\_\_ Total Ac. ft pumped

(12) TOTAL WATER PUMPED / TOTAL ACRES = \_\_\_\_\_ Ac. ft per acre

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Limits and restrictions on use of worksheet:

1. For wells with GPM per acre of 3.1 or higher, do not exceed 2 acre feet per acre of water pumped.
2. For wells below 3.1 GPM per acre, do not exceed 1.5 acre feet per acre of water pumped.
3. Range in water pumped to corn: 1.7-3.0 acre ft. per acre.
4. Range in water pumped to wheat: .5-1.6 acre ft. per acre.
5. Range in water pumped to grain sorghum: .75-1.75 acre ft. per acre.
6. Range in GPM: 300 to 1500.
7. 6 GPM per acre of corn or greater.



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