ANALYSIS OF THE ECONOMIC LIFE OF THE IRRIGATION WATER SUPPLY IN THE OKLAHOMA PANHANDLE

By

DAVID DUNN HENDERSON

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Thesis Approved:

Harry P. Mapp Jr.
Thesis Adviser

Alan Baquet

Luther G. Tweeten

Norman N. Durham
Dean of the Graduate College

PREFACE

This study is concerned with the estimated growth and decline of irrigated agriculture in the Oklahoma panhandle during the period 1980 to 2029. A recursive linear programming (RLP) model is specified to accomplish the objective. The model is capable of projecting future crop production for the region and determining the growth of irrigated and dryland production under two scenarios. A comparison between alternative irrigation systems as pumping costs increase over time was an important part of this study.

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CHAPTER I

THE RESEARCH PROBLEM

Introduction

Irrigated agriculture has been responsible for increased economic activity in the Oklahoma panhandle. Irrigated production has enabled producers to both increase and stabilize income and yield per acre. Primary and secondary multiplier effects generate additional economic activity. The 11,500 acres irrigated in 1950 have increased steadily to 386,000 acres irrigated with a sharp increase in 1964 (Table I). From 1966-72, water level declines of more than 40 feet have occurred in some areas of concentrated well development (Hart, Hoffman, and Goemaat). At some point in time, the water table will decline sufficiently to result in reduced irrigated production, resulting in a decline in the economic activity of the region.

Description of the Study Area

Location and Size

The Oklahoma panhandle, consisting of Cimarron, Texas, and Beaver Counties, is 5680 square miles in area. The rectangular panhandle is an eastward sloping plateau with its highest point in extreme northwest Cimarron County at an altitude of 4,978 feet and its lowest point at the Cimarron River on the eastern edge of Beaver County at an alti-

TABLE I

IRRIGATION STATISTICS--OKLAHOMA PANHANDLE

Year	No. Farms	Total Acres	No. Farms Gravity System	Acres Gravity System	No. Farms Sprinkler System	Acres Sprinkler System	Number Irrigation Wells	Total Acres Irrigated (Groundwater)
1977	1,155	385,900	896	301,650	259	85,700	2,172	384,000
1975	1,094	404,610	901	329,460	193	75,150	2,112	402,550
1973	1,530	427,000	1,360	324,500	175	102,500	2,207	422,680
1971	1,375	356,360	1,165	302,938	255	54,422	1,846	344,040
1969	960	315,518	835	282,618	141	32,900	1,634	312,518
1967	1,150	263,000	1,010	224,850	145	38,150	1,358	261,000
1965	745	138,000	586	122,000	104	16,000	972	135,500
1963	304	84,500	241	72,560	75	11,940	409	83,020
1959	275	71,500		65,820	46	5,680	365	69,520
1958	279	69,575		62,623	53	6,960		67,375
1957	267	76,500		68,360	49	8,140	359	75,225
1956	266	71,200		64,700	41	6,500	336	70,100
1955	212	34,247		32,030		2,317		32,797
1954		24,680		23,758		922		23,580
1952		13,000						
1950	53	11,500						

Source: Schwab, Delbert. Irrigation Survey Oklahoma. Department of Agricultural Economics, Oklahoma State University, Various Issues.

tude of 1990 feet. The average slope of the area is 14 feet per mile. The area consists of upland plains with some stream flood plains and intermediate slopes. Most of the surface has very broad gentle swells or hills, shallow depressions, and some dune covered areas. Depressions, which dot much of the plains in Cimarron and Texas Counties, and parts of Beaver County, range from a few feet to about 40 feet in depth (Hart, Hoffman, and Goemaat).

The Ogallala Formation, which consists of semiconsolidated clay, sand, and gravel is the princpal source of ground water in the Oklahoma panhandle. The sediments that compose the formation are believed to have been eroded from the Rocky Mountains and carried by streams to be deposited in the eroded and dissected surfaces of the pre-Ogalalla rocks ranging back to prehistoric times. The formation runs through parts of eastern Colorado, Nebraska, western Kansas, eastern New Mexico, the Oklahoma panhandle, and the high plains of Texas. Unconnected distinct subdivisions can be identified in the formation. This is the case in the Oklahoma panhandle. The supply of water is distinct and independent of aquifers underlying Kansas and Texas. The surface area overlying the Ogallala aquifer in the panhandle is 5325 square miles. Only the Black Mesa area in northwestern Cimarron County does not overlie the aquifer. Figure 1 outlines the study area.

Climate

The panhandle has a semiarid climate with an annual rainfall of about 20 inches. Normally, 75 percent of the rainfall occurs during the warm season, from April to September. A steady and frequently

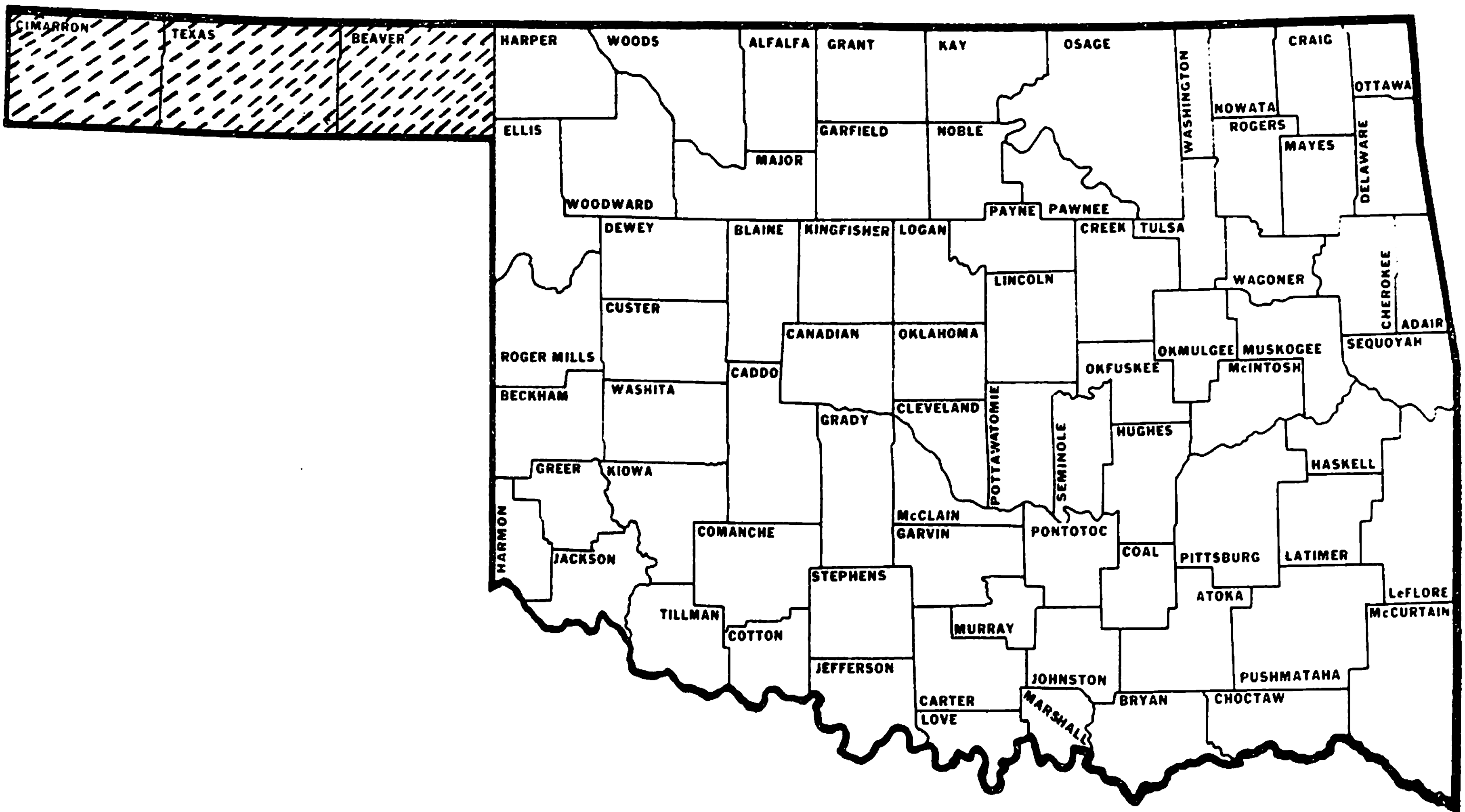

Figure 1. Map of Oklahoma Showing the Area of Study

strong wind is an important climatic characteristic. Because of the wind, much of the rainfall evaporates before it can be absorbed. Wide fluctuations in rainfall occur from year to year, and apparently, a favorable or unfavorable pattern of precipitation can persist for several years. Table 20, Appendix B, shows the distribution of mean monthly rainfall for the last 12 years. The length of the growing season averages 185 days per year with the first frost in mid to late October, and the last frost in mid April. The temperature is highly variable reaching above 100° in summer and below 0° in the winter.

Soil and Water Resources

The major soil type in the study area is a clay loam soil interspersed with either silty loam or silty clay laom soils. These clay soils are deep, level, and well drained. They comprise 65 percent of the total irrigable land base. Sandy soils comprise 35 percent of the total irrigation land base, have steeper slopes, and are relatively porous. Thirty-two percent of the land overlying the aquifer is not suitable for irrigation, soils with slopes too steep for irrigation, and roughs and breaks along the stream beds. A detailed description of the soil classifications is in Table II.

Under natural conditions the water table underlying the Oklahoma panhandle is near equilibrium with natural recharge equal to natural discharge. There are slight variations in the water level in response to changes in annual precipitation, streamflow, and evapotranspiration. Based on an estimated average coefficient of storage[1] of 0.1, the

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[1]This implies that the volume of water the aquifer releases by gravity is only 10 percent of the volume of the saturated material.

TABLE II

SOIL CLASSIFICATIONS--OKLAHOMA PANHANDLE

		Panhandle Acreage	Acreage Over- lying the Aquifer	Irrigable Acreage Overlying the Aquifer	Totals
Not Suitable for Irrigation	Acres	1,247,688	1,080,412		
	%	34.52	31.71		
Clay Soils Irrigable by Surface Systems	Acres	1,171,396	1,159,766	1,159,766	
	%	32.41	34.03	49.84	Clay Totals
Clay Soils Irrigable by Surface and Center Pivot Systems	Acres	367,780	357,820	357,820	1,517,596
	%	10.50	10.50	15.38	65.21
Sandy Soils Irrigable by Surface and Center Pivot Systems	Acres	400,876	390,159	390,159	
	%	11.09	11.45	16.76	Sandy Soils
					809,591
					34.79
Sandy Soils Irrigable by Center Pivot Systems	Acres	426,614	419,432	419,432	
	%	11.80	12.31	18.02	
Totals	Acres	3,614,350	3,407,609	2,327,197	2,327,197
	%	100	100	100	100

Source: Thompson, Mark. Soils and Groundwater Resource Situations in the Oklahoma Panhandle. Unpublished paper, Department of Agricultural Economics, Oklahoma State University, Stillwater, 1978.

quantity of water stored in the Ogallala aquifer underlying the Oklahoma panhandle in 1976 was computed to be 50 million acre feet (Hart, Hoffman, and Goemaat).

Two major variables used to classify the water resources are depth to water and the thckness of the saturated material. There is 23 percent of the irrigable land with a depth to water less than 100 feet, 58 percent with a depth to water greater than 100 feet but less than 200 feet, and 19 percent with a depth to water greater than 200 feet. There is 33 percent of the irrigable land with a saturated thickness greater than 400 feet, and 37 percent with a saturated thickness less than 200 feet. Tables III and IV summarize these data.

Type of Agricultural Production

Production of feedgrains, hay, and silage characterize the agriculture of the panhandle. Concentrated cattle feeding operations have recently become important. The area has large acreages of extensive low input, low yield dryland crop production. Wheat and grain sorghum are the major crops and account for more than 90 percent of dryland production. More than 25 percent of the wheat produced is irrigated and more than 50 percent of the grain sorghum produced is irrigated. Virtually all of the corn grain produced is irrigated, and most of the alfalfa hay is irrigated. Table V presents a review of past production of these crops for selected years.

Development of Irrigation

Hart, et al. reported that irrigation began in the 1930's and by the end of the decade there were less than 30 wells. The drilling

TABLE III

SOIL AND WATER RESOURCE SITUATION ACREAGES

Depth to Water (ft)	Soil Type	Saturated Thickness (ft)					
		50	150	250	350	450	550
	All	172381	202447	113302	52545	-	-
75	Clay	74579	111120	31790	19670	-	-
	Sandy	97802	91327	81512	32768	-	-
	All	-	413816	148898	204677	137965	445831
150	Clay	-	273768	104070	162672	120935	218783
	Sandy	-	139048	44828	42005	17030	227048
	All	-	73451	40763	146556	174565	-
225	Clay	-	70701	38955	127216	172247	-
	Sandy	-	2750	14558	21658	2318	-

[1]Blank areas constituted such a small part of the study area that they were combined with adjacent categories.

TABLE IV

SOIL AND WATER RESOURCE SITUATION PERCENTAGES

Depth to Water (ft)	Soil Type	Saturated Thickness (ft) 50	150	250	350	450	550
	All	07.4	08.6	04.8	02.2		
75	Clay	03.2	04.7	01.3	00.8		
	Sandy	04.2	03.9	03.5	01.4		
	All		17.7	06.3	08.7	05.9	19.
150	Clay		11.8	04.4	05.9	05.1	09.
	Sandy		05.9	01.9	01.8	00.7	09.
	All		03.1	01.7	06.2	07.5	
225	Clay		03.0	01.2	05.4	07.4	
	Sandy		00.1	00.5	00.8	00.0	

TABLE V

CROP STATISTICS FOR THE OKLAHOMA PANHANDLE

Crop	Year	Acres Planted	Acres Harvested	Production (bu)	Yield/Acre (bu)
Wheat	1978	862,000	630,000	10,800,000	17.2
	1978 (irr)	137,200	110,800	3,910,000	35.3
	1977	1,125,000	741,000	17,537,000	23.7
	1977 (irr)	161,700	141,100	5,870,000	41.6
	1976	977,000	475,000	10,202,000	21.48
	1976 (irr)	144,000	129,500	4,918,500	37.95
	1975	1,013,000	815,000	12,885,000	15.81
	1975 (irr)	127,000	120,500	4,170,000	34.61
	1974	994,000	861,000	8,815,000	10.24
	1974 (irr)	105,900	100,100	2,258,000	22.56
	1969	742,500	511,800	11,460,400	22.39
	1964	772,500	432,500	5,291,000	12.23
	1959	830,000	814,500	12,487,000	15.33
Grain Sorghum	1978	338,400	296,500	11,012,000	37.1
	1978 (irr)	108,800	101,600	6,625,000	65.2
	1977	374,400	322,000	11,556,000	35.9
	1977 (irr)	107,300	89,600	5,921,000	66.1
	1976	507,000	395,000	9,930,000	25.14
	1976 (irr)	94,750	89,350	5,387,000	60.29
	1975	361,800	294,900	9,850,000	33.4
	1975 (irr)	97,400	86,310	6,116,000	70.86
	1974	350,700	295,700	12,180,000	41.19
	1974 (irr)				
	1969	392,000	267,900	14,521,200	54.37
	1964	286,500	175,300	4,856,300	27.70
	1959	285,000	175,000	4,710,000	26.91
Corn (all irr)	1978	62,600	44,100	3,457,000	78.4
	1977	85,800	61,600	6,302,000	102.3
	1976	85,100	70,600	7,739,000	109.62
	1975	86,600	67,880	6,118,000	90.13
	1974	86,030	70,310	7,146,900	101.65
	1969	56,500	28,850	2,814,700	97.56
	1964	5,400	1,300	5,000	3.85
	1959	3,300		75,000	

TABLE V (Continued)

Crop	Year	Acres Planted	Acres Harvested	Production (ton)	Yield/Acre (ton)
Alfalfa[1] Hay	1978		32,200	414,000	4.34
	1977		17,300	63,700	3.68
	1976		17,000	78,800	4.64
	1975		14,000	48,000	3.43
	1974		14,020	49,420	3.52
	1969		14,320	63,120	4.41
	1964		12,100	52,100	4.31

[1]There are no figures available on irrigated production.

Source: Oklahoma Crop and Livestock Reporting Service. Oklahoma Agricultural Statistics, Various issues, 1959-78.

of irrigation wells continued at a slow but steady pace until 1964 when the rate increased rapidly in Cimarron and Texas counties. Drought conditions and advances in technology are reasons for the increase. In 1960, about 400 wells were used to irrigate 80,000 acres; in 1965, 972 wells irrigated 135,500 acres. In 1973, 2,207 wells irrigated 422,000 acres; in 1977, 2,172 wells irrigated 384,000 acres, indicating a reduction of irrigation. Reasons for the decline were 1) low crop prices, 2) increase in the price of natural gas, and 3) a more even distribution of rainfall (Schwabb).

Because wells are generally in a group the effect of heavy pumpage is readily apparent by the lowering of water levels. During the period 1966-71, water levels declined at the rate of 1 to 5 feet per year in the Boise City area, and 1 to 7 feet per year in the Guymon area. Beaver county, with fewer wells, showed less decline.

During this same period, estimates of pumpage were calculated from crop acreages and the amount of water applied annually to the various crops. Hart, et al., determined that in the 7 year period, Beaver county pumpage was estimated to be 310,000 acre feet; Cimarron county pumpage estimated to be 1,100,000 acre feet; and Texas county estimated to be 2,800,000 acre feet. During this period (1966-71), the amount of groundwater in storage was reduced by 2 percent. Complete dewatering of the aquifer is not a realistic possibility, but it is estimated that if groundwater pumpage remains constant, 50 percent of the aquifer would be dewatered in 42 to 55 years. If the usage of groundwater continues to increase as it has during the past decade, the rate of depletion will accelerate. Dewatering of the aquifer will not be uniform. Areas where the aquifer is heavily developed for irrigation would be depleted by more than 50 percent in less time, whereas areas remote from concentrated centers may show little or no depletion (Hart, et al.).

The Problem and Objectives of the Study

The Ogallala aquifer underlying the Oklahoma panhandle has both an economic life and a physical life. The aquifer is physically exhausted when all of the water has been pumped. The aquifer is economically exhausted when *ceteris paribus*, the total cost of pumping and distributing the water is so high that the net return per unit of irrigated crop produced is less than the net return per unit of crop produced under dryland production.

With high levels of irrigated production continuing into the future, declines in the water level are inevitable. As the water level declines, saturated thickness is decreased which reduces the efficiency of the well. The water has to travel a greater vertical distance and the pump must work more hours to deliver the same amount of water. *Ceteris paribus*, net returns will progressively decline per unit of irrigated crop produced as the water level declines. Assuming a continued decline in the static water level based on the amount of water pumped, some crops will become uneconomical to irrigate in certain water resource situations. Another factor that will influence the economic life of the aquifer is the expected increase in the price of natural gas. About 92 percent of the pumps in operation are powered by natural gas (Schwab). Again, ceteris paribus, net returns will progressively decrease per unit of irrigated crop produced as the price of energy increases.

The adjustment from irrigated to dryland production could result in serious primary and secondary economic effects. Reduced farm income and land values, investment losses, a decline in the rate of growth, etc., coupled with the multiplier effect could create serious economic and social problems for the region. The severity of the problems depend on the economic life of the aquifer as well as the adjustments in production practices that can mitigate the effects of the depletion of a scarce resource.

The objectives of this study are to analyze the impact of the declining water supply on irrigated production of the key crops in the panhandle over time, and to analyze the impact of an increasing price of natural gas on the eocnomic life of the aquifer. Specifically, a recursive linear programming (RLP) model is developed that depicts the panhandle's expected crop production to the year 2029 in order to 1) project changes in total irrigated and dryland acreage and the rate of decline of the water table in the soil and water resource situations, 2) estimate the acreages of irrigated and dryland production of the various crops, 3) project changes in production patterns among soil and water resource situations, and 4) estimate net returns to the region.

The normative output from the model yields what should happen to maximize net returns over time subject to a series of restrictions. With an appropriate perspective, researchers and policy makers will be able to judge the extent and magnitude of resource requirement and flexibility.

The rest of the thesis is organized as follows. Chapter II present the analytical model used in this analsis. It discusses the recursive linear programming (RLP) model used to determine production patterns, groundwater depletion, and changes in net returns, all over time.

Chapter III describes the methodology and assumptions used in establishing the benchmark conditions of soil and water resources of the panhandle in 1980, and specifies the input data of the recursive linear programming (RLP) model.

Chapter IV presents the empirical results and Chapter V contains the summary and conclusions of the study. Limitations of the study and recommendations for future research are given.

CHAPTER II

THE ANALYTICAL MODEL

Methodology

Literature Review

A recursive linear programming (RLP) model is used to analyze the impact of the declining water supply and an increasing price of natural gas on irrigated and dryland crop production. The RLP model is an adaptation of a static linear programming (LP) model. Changing conditions of time necessitate revision of the LP model for time period t + 1, based upon the solution for period t and conditions that exist in period t + 1. The revision may involve the objective function, the input-output coefficients, the right hand side restrictions, or any combination thereof.

Bekure, using an RLP model, conducted an aggregate economic analysis to determine the economic life of the central basin of the Ogallala Formation. The entire region overlying the aquifer was treated as one producing unit stratified by different soil and water resource situations, each associated with different costs and returns. This macro approach focused on alternative scenarios regarding the rate of development of irrigated acreage.

Mapp and Dobbins used a micro approach to focus on the potential effects of increasing energy costs on irrigated agriculture in the

Oklahoma panhandle. Patterns of crop production, agricultural output, net returns, and water use were analyzed on representative farm firms with different soil and water resource situations.

Bekure's macro study was completed before recent shifts in the prices of energy inputs, and Mapp and Dobbins used a micro approach to study farm firm reactions to increasing natural gas prices. Both micro and macro approaches were considered for this study. In the micro approach representative farm firms typical of the area are defined, optimal solutions for each representative firm are obtained and the results are aggregated for the region. "Aggregation bias" is likely because it is very difficult to specify a sufficient number of representative farms to insure that their aggregation will present a realistic picture of production, water use and income for the entire region. The macro approach ignores asset indivisibilities, labor availability problems, individual firm investment decisions, equity positions and other factors of importance at the firm level. It has the advantage of simplicity in terms of data requirements and is perhaps less expensive to solve. Sharples provides a good discussion of the pros and cons of the micro versus macro methodology.

This study uses a macro approach that focus on the potential effects of the declining water supply and increasing energy costs of the economic life of the water supply in the Oklahoma panhandle. Individual farm operators irrigating from specific water resource situations would likely find the economic life of the irrigation water supply reasonably close to the results obtained in the macro model for those water resource situations.

The Analytical Model

The three county Oklahoma panhandle overlying the Ogallala aquifer is treated as a single producing unit, stratified by different soil and water resource situations which are associated with different costs and returns. The RLP production model shown in the flow diagram of Figure 3 has two computational aspects. The first part is a linear programming model that maximizes net returns above total costs subject to a set of restrictions specified for period t. The second part is an updating process where changes related to the first part are computed and employed in revising certain parameters of the LP model for the subsequent t + 1 period.

At any production period t, the inputs to the model are 1) the soil and water resource base and the appropriate set of production restrictions represented by vector B_t, 2) the various crop enterprises, selling and buying activities represented by matrix P_t, 3) the associated input-output coefficients of the activities in P_t represented by matrix A, and 4) the net returns accruing from the activities in P_t represented by vector C_t as shown in Figure 2.

The outputs of the model are 1) the number of dryland acres and the acres irrigated for the various crops grown on each soil and water resource situation under different levels of water application, 2) the volume of water pumped from each soil and water resource situation, 3) the level of other inputs used, specifically capital and labor, and 4) the total net returns from all enterprises.

In the second part of the model, several calculations are made to update and specify the parameters of the LP model for period t + 1.

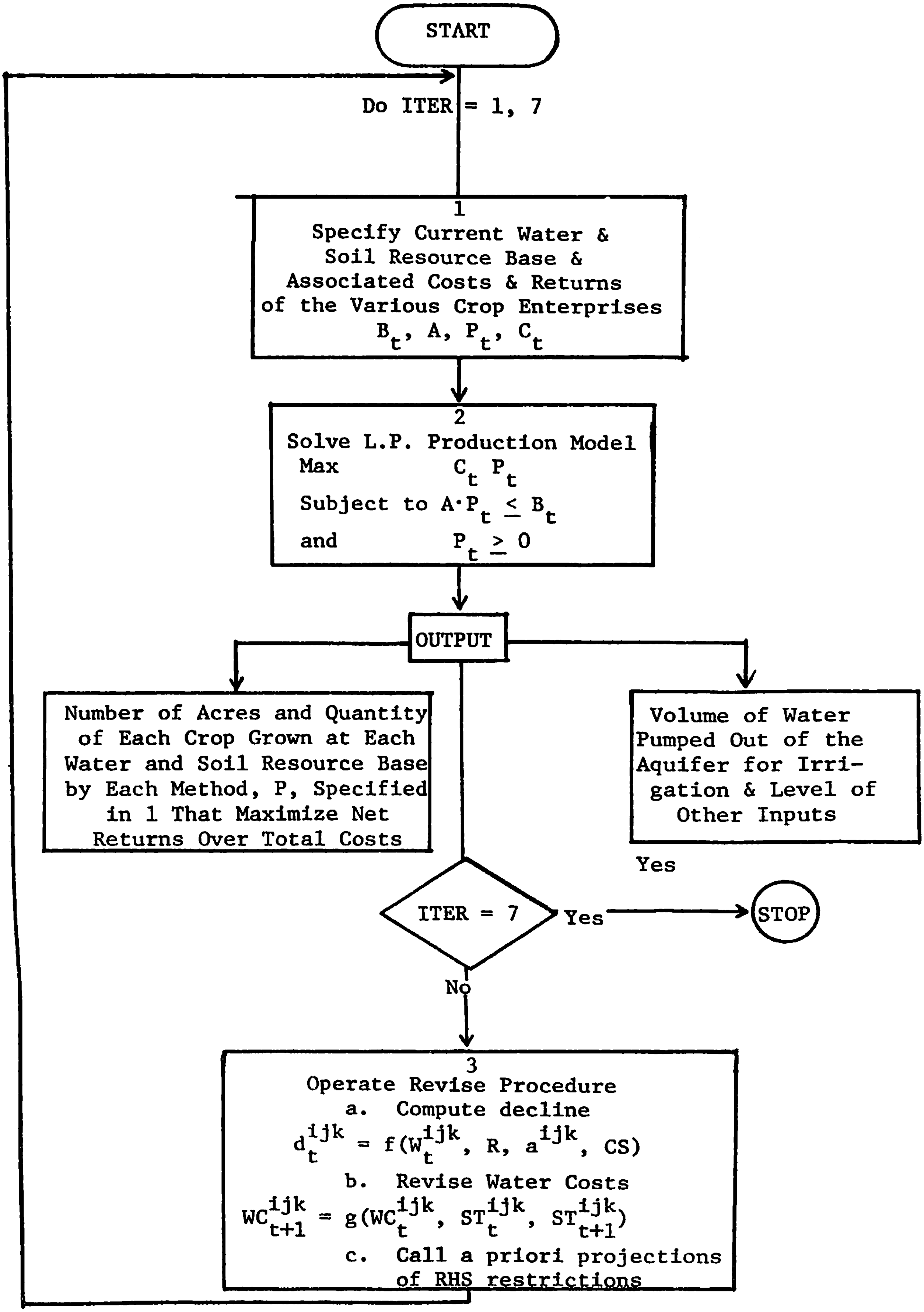

Figure 2. The Recursive Linear Programming Model

First, the volume of water pumped from a soil and water resource situation is denoted as W_t^{ijk}, (where i = 75, 150, 225, represents the three depths to water; j = 50, 150, . . ., 550, represents the six saturated thicknesses and k = c, s, represents either clay or sandy soil). The decline of a static water level d_t^{ijk}, at the end of production period t is calculated as a function of the volume of water pumped W_t^{ijk}, the recirculation coefficient[1], R = 0.2, the appropriate surface (land) area a^{ijk}, and the coefficient of storage[2], CS = 0.1. Implicity, we have:

$$d_t^{ijk} = f(W_t^{ijk}, R, a^{ijk}, CS). \tag{1}$$

It should be noted that in this study industrial and municipal pumpage is assumed to be offset by recharge from precipitation.

Based on the decline in the static water level, a new saturated thickness ST_{t+1}^{ijk} is computed. Using equation derived from repeated irrigation costs runs based on relationship (7) of Chapter III, new water costs WC_{t+1}^{ijk} are derived from the previous water cost WC_t^{ijk}, the new saturated thickness ST_t^{ijk}. Implicity we have:

$$WC_{t+1}^{ijk} = g(WC_t^{ijk}, ST_t^{ijk}, ST_{t+1}^{ijk}) \tag{2}$$

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[1]The recirculation coefficient is defined as the percentage of water applied that percolates back through to the water table. (Hart, et al.)

[2]This implies that the volume of water the aquifer releases by gravity is only 10 percent of the volume of the saturated material. (Hart, et al.)

These water costs are used to update the cost of the water buying activities in P_t by revising the appropriate elements of vector C_t. Most of the right hand side restrictions in vector B_t are upper limits to crop production in the soil and water resource situations. A priori projections are used to revise the production restrictions in vector B_t in each new production period. Detailed explanations concerning the a priori projections and water cost revisions are given in Chapter III.

When this process is completed, the inputs of the production model are updated and the model is ready to generate the production pattern for period t + 1. The complete process is iterated for t = 7 periods, the first four periods representing a span of five years each, and the last three periods representing a span of ten years each. The model is run once for 1977 benchmark conditions by whose results the initial conditions for 1980 are specified. Then t is made to represent the five year period 1980-84. When t + 7, the calendar year period is 2020-29 and the production has been depicted for a period of one-half century.

Two Scenarios

Projecting long term rates of water withdrawal entails a complex interaction of physical, economic, political, and social factors that are impossible to predict with accuracy.

Physical factors include the possibilities that exist to increase the marginal productivity per acre inch of water if breakthroughs occur in plant breeding, fertilizer application, and pumping and distribution efficiencies. Progress in these areas, as well as techniques to influence the weather, all serve to slow down the rate of water withdrawal. The transfer of water from surplus areas, if politically and economically feasible, may entirely alter the importance of groundwater in the study area.

Many economic factors play a role in determining rates of water withdrawal. Input and output prices and availability of inputs will influence the producers decision to irrigate or produce dryland. Internationally, world supply and demand situations will influence the rate of water withdrawal. The spread of the green revolution to less developed countries is important in that it could increase world food supplies which would relieve pressure on irrigated agriculture in the study region to produce more exports. This would slow down the rate of water withdrawal. On the other hand, it is expected that as income rises in the less developed countries, demand for food in general, and meat in particular, will increase. This would have an effect on the concentrated livestock operations in the study area and increase the rate of water withdrawal.

Political factors include commodity price supports and export programs. The reduction of international trade barriers to allow production to migrate to areas of economic opportunity and comparative advantage will have an effect on the demand for water from the aquifer. For instance, the tarrifs the Common Market imposes on American agricultural products reduces exports of grains from the U.S. and reduces slightly the pressure on water withdrawal. Socially, population growth must be mentioned; if it increases rapidly, there will be an increased demand for the water.

It is obvious that with so many possibilities in the future, any prediction is subject to error. What can be done is to devise two scenarios representing different time frames of the aquifer life so that the actual events may occur somewhere between the two scenarios. The first scenario was designed to trace the impact of the decline in the water table through time if current input and output prices maintain current levels and the water table declines gradually. Essentially, rising pumping costs are hypothesized to lead to a shift from high to lower intensity irrigation levels and eventually to dryland production. The second scenario is designed to evalute the potential effect on profitability and irrigated production patterns of a gradual increase in the price of natural gas, all other prices remaining constant. It is hypothesized that the economic life will be shortened somewhat by the rise in the price of natural gas.

The RLP production model was run under each scenario, with Scenario I representing a gradual decline in the water table and Scenario II representing a continuous increase in the price of natural gas. The price of natural gas is allowed to rise by 2 percent per year relative to all other input and output prices. Although an increase of 2 percent per year does not seem large, it is not expected that the price of natural gas will increase by itself without any price change in the other inputs or outputs. In scenario II, natural gas cost \$1.40/MCF in 1980-84, \$1.54/MCF in 1985-89, \$1.69/MCF in 1990-94, \$1.86/MCF in 1995-99, \$2.25/MCF in 2000-09, \$2.73/MCF in 2010-19, and \$3.30/MCF in 2020-29. These prices are quite similar to predictions made by Holloway. These figures are used to update the cost of the water buying activities in P_t by revising the appropriate elements of vector C_t in Scenario II.

This chapter describes the analytical model used in this study. The next chapter describes how the inputs used in the model were derived.

CHAPTER III

THE INPUT DATA FOR THE RECURSIVE LINEAR PROGRAMMING MODEL

The input data used to specify the RLP production model and the assumptions used in developing the data are presented in this chapter. The first step in depicting the irrigated crop production pattern is to inventory the soil and water resources in the study area and stratify them according to their common characteristics.

The Soil Classification Scheme

The Soil Conservation Service (SCS) county soil surveys provide the basic data. The soils of each county were divided into irrigable and non-irrigable groups using the irrigated capability units as the criterion of classification. Non-irrigable soils account for 34 percent of the total land base. Irrigable soils were subdivided into clay and sandy soils and further subdivided according to suitability for irrigation by alternative irrigation systems. Clay soils that are deep, well drained, and nearly level (0 to 3 percent slope) are best suited for surface irrigation systems. Sandy soils are characterized by poor drainage and moderate to steep slope and are best suited for center pivot systems. Clay soils irrigable by surface systems comprise 50 percent of the land overlying the aquifer; clay soils irrigable by surface and center pivot systems comprise 15 percent; sandy soils only irrigable by center pivot comprise 18 percent; and sandy soils irrigable by both methods comprise 17 percent of the acreage overlying the aquifer. These soil groups were identified and color coded on a map of each county. To simplify, clay soils were combined, assumed to be irrigated by surface systems, and account for 65 percent of the irrigable acreage. Sandy soils were combined, assumed to be irrigated by center pivot systems, and account for 35 percent of the total irrigable acreage. Table II in Chapter I summarizes the distribution.

The Soil and Water Resource Situation Strata

Hydrologic maps of each county were used to inventory the water resources (Hart, Hoffman, Goemaat). Two maps for each county were utilized. The saturated thickness maps indicated the number of feet of water saturated material in the aquifer. The depth to water maps indicated the distance from the ground to the static water level. By superimposing the depth to water maps over the saturated thickness maps, the land overlying the aquifer was divided into 35 distinct water resource situations. The water resource maps were underlaid below the soil maps and the areas were planimetered to determine the complete soil and water resource situation (Thompson). These 70 soil and water resource situations were reduced to 26 situations by disregarding categories representing very small portions of the study area and by combining the original hydrologic data into fewer water resource stata. Tables III and IV (Chapter I) present the acreages and percentages of the total irrigable land base.

When soil type, depth to water, and saturated thickness are considered, there are 26 categories which serve as upper limit land restrictions in the model. The number of acres in each of the 26 soil and water resource situations constitute the land base on which the total crop production activities take place. They are entered in the B_t vector as right hand side restrictions.

The A Priori Production Goals

The Quantity of Crops Produced

The Water Resources Council has developed projections of agricultural production from 1980-2020. The projections, referred to as OBERS projections, are based on domestic supply-demand relationships and foreign export conditions that existed in the 1950-72 period. The projections represent an attempt, imperfect though it may be, to forecast the economic future with the specification of assumptions and methodology introducing considerable objectivity into the process.[1]

The broadest assumptions underlying the methodology of the OBERS E' projections are: 1) a replacement fertility level, 2) an increase of private output per manhour of 2.9 percent annually, 3) reasonably full employment (4 percent unemployment), 4) no foreign

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[1]The Water Resources Council has a number of OBERS projections on hand as a result of different assumptions of fertility levels, export trends, and updated informations. OBERS C, developed in 1967 assumed a high fertility rate and low export level. OBERS E in 1972 assumed a low fertility rate and a low export level. OBERS E', 1975, assumed a low fertility rate but a high export level and has the highest production projections of all three. It is these high projections of OBERS E' used in this study.

conflicts, and 5) production will migrate to areas of economic opportunities and away from slow growth or declining areas.

Domestic consumption is based on a functional relationship between per capita demand and real income levels for each commodity. Total real disposable income, expressed in constant dollars, is projected to increase at 4.1 percent annually in 1980, and 3.8 percent annually from 1981 to 2020. As real income increases, income elasticity for food decreases; i.e., consumption increasing at a decreasing rate.

Export projections are based on estimated world consumption requirements and the corresponding portion the U.S. is estimated to contribute. World population growth is expected to be 2 percent per year, and export projections are based on the assumption of continued growth in demand and a return to trends established prior to 1972.

Expected crop yield changes involve complex biological relationships, production inputs, and managerial factors. OBERS adjustment factors are based on recent yield trends and give consideration to possible trends in technology, resource availability, and input-product price relationships. The general technique used in estimating future yields is a curvilinear Spillman regression model that projects yields to increase at a decreasing rate over time. A linear extrapolation of the base period, 1950-1974, to the year 2020, serves as a maximum constraint.

OBERS Projections tend to show exports, yields, and domestic consumption increasing at a decreasing rate over time. Long term projections are less reliable than short run. National production projections are more reliable than individual state projections. The broader the economic activity, and the shorter the time horizon, the more reliable the projections.

State Production Projections

The underlying assumption for state estimations is that agricultural production has historically and increasingly moved to areas of comparative economic advantage. Factors such as precipitation, growing season, and soil and water resources are considered in state estimates. The projection techniques provide an extension of historical trends from 1950-1975, but at a decreasing rate of change.

Regional Production Projections

Reduction of the State of Oklahoma projections to the panhandle's projections involves a simple average of the percentage of state crop production that took place in the panhandle for agricultural census years 1954, '59, '64, '69, '74. These average percentages were held constant in determining the panhandle's share of projected state production (Table VI).

One problem encountered in using OBERS projections is their scope or broadness. They require state production of a crop to be greater than one percent of national output if projections are to be made on a state level. This includes wheat, grain sorghum, barley, and hay. For these crops a simple average (5 census years) was taken of the pandhandle's percentage of state production. OBERS did not project state production of alfalfa hay, corn, or soybeans. For these crops, simple methods were developed to project panhandle production.

OBERS provide hay projections for the state, and a five census year average of panhandle hay as a percent (1.58%) of state hay is multiplied by a five census year average of panhandle alfalfa hay as a percent (59.5%) of panhandle hay. The product (.94%) is used to derive panhandle alfalfa hay as a percentage of projected Oklahoma hay.

There is a simple average of Oklahoma's percentage of national production of corn. This average is held constant and used to estimate Oklahoma's future production of corn as a function of national projections. It is assumed that the panhandle will produce 90 percent of state projections.

A simple two year average of the panhandle's percentage of national soybean output was used to estimate future regional production of soybeans as a function of national projections. These average percentage distributions of crop production are presented in Table VI, and country, state, and panhandle crop projections are presented in Table VII.

The Distribution of Production

Unless the model is controlled in some way, all production would take place on the most profitable soil and water resource situations, on clay soils with the lowest depth to water. Therefore, it is assumed that irrigated crop production is distributed among the 26 soils and water resource situations according to the weight each one carries with respect to the total number of irrigable acres (Table IV, Chapter I). These weights were calculated in the following manner:

$$g^{ijk} = \frac{a^{ijk}}{A} \tag{3}$$

TABLE VI

AVERAGE PERCENTAGE DISTRIBUTIONS USED TO DERIVE PANHANDLE PRODUCTION GOALS FROM OBERS E' STATE AND NATIONAL PROJECTIONS

Crop	Method	5 Census Year Average
Wheat	Panhandle wheat production as a percentage of Oklahoma wheat production	.0949
Grain Sorghum	Panhandle grain sorghum production as a percentage of Oklahoma grain sorghum production	.4421
Barley	Panhandle barley production as a percentage of Oklahoma barley production	.0243
Hay	Panhandle hay production as a percentage of Oklahoma hay production	.0158
Alfalfa Hay	Panhandle alfalfa hay production as a percentage of panhandle hay production	.5951
	Panhandle alfalfa hay production as a percengate of Oklahoma hay production	.0094
Corn	Oklahoma corn production as a percentage of U.S. corn production	.0013
	Panhandle corn production as a percentage of Oklahoma corn production	.9
	Panhandle corn production as a percentage of U.S. corn production	.0011

Crop	Method	2 Census Year Average
Soybeans	Panhandle soybean production as a percentage of U.S. soybean production	.0000033532

TABLE VII

PROJECTED QUANTITY OF CROPS PRODUCED FOR THE COUNTRY, STATE, AND PANHANDLE (1980-2020)

	Production Period						
Crop	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Wheat (1,000 bu.)							
US	1,701,665	1,763,986	1,844,662	1,925,338	2,006,014	2,108,817	2,211,620
OK	140,236	148,655	159,142	169,629	180,116	197,819	215,522
Pan	13,310	14,109	15,104	16,099	17,095	18,775	20,455
Grain Sorghum (1,000 Cwt.)							
US	572,332	633,639	714,176	794,713	875,250	932,094	988,938
OK	13,788	14,897	16,904	18,911	20,918	22,277	23,635
Pan	6,096	6,586	7,473	8,361	9,248	9,849	10,449
Barley (1,000 bu.)							
US	509,014	549,684	284,494	619,304	654,113	698,877	743,641
OK	21,261	24,136	27,046	29,954	32,863	37,424	41,986
Pan	517	586	658	730	801	911	1,021
Hay (1,000 bu.)							
US	131,986	139,617	147,065	154,513	161,961	172,790	183,618
OK	3,157	3,426	3,990	3,990	4,272	4,980	5,688
Pan	49	54	63	63	67	78	90

TABLE VII (Continued)

Crop	Production Period						
	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Alfalfa (1,000 bu.)							
US	63,748	67,434	71,320	74,629	78,226	83,456	88,686
OK	1,524	1,654	1,791	1,927	2,063	2,405	2,747
Pan	29	32	34	37	40	46	53
Corn (1,000 bu.)							
US	6,078,769	6,610,181	7,317,351	8,024,521	8,731,691	9,270,959	9,810,226
OK	7,709	8,383	9,280	10,177	11,074	11,758	12,422
Pan	6,938	7,545	8,352	9,159	9,966	10,582	11,197
Soybeans (1,000 bu.)							
US	1,738,010	2,061,304	2,344,010	2,626,717	2,909,423	3,071,054	3,232,684
OK	4,733	5,614	6,384	7,154	7,924	8,364	8,805
Pan	5	6	7	8	9	10	10

where:

i = 75, 150, 225, represents the three depths to water

j = 50, 100, ..., 550, represents the k^{th} saturated thickness class

k = c, s, represents either clay or sandy soils

g^{ijk} = the weight for soil and water resource situation (i, j, k)

a^{ijk} = the number of irrigable acres in soil and water resource situation (i, j, k), and

A = 2,317,187 (the total number of irrigable acres).

Since the number of irrigable acres in the 26 soil and water resource situations sum to A, the weights sum to 1.0. Hence we have:

$$g^{ijk} = 1.0 \quad \sum_{i=1}^{3} \sum_{j=1}^{6} \sum_{k=1}^{2} \qquad (4)$$

The production of any one crop is distributed among the 26 soil and water resource situations by multiplying these weights by the appropriate <u>a priori</u> projected production for the specified period given in Table VII. For any period t, let p_t^x, X = 1, 2, . . ., 6, represent the <u>a priori</u> projection of total production for the six irrigated crops in model. The distribution of production among each soil and water resource situation is given by:

$$p_t^{xijk} = g^{ijk} \cdot p_t^x \qquad (5)$$

where p_t^{xijk} is the upper limit for production of the X^{th} crop in soil and water resource situation (i, j, k), in period t. These 26 upper limites for each crop are entered in the B_t vector as right hand side restrictions.

Capital and Labor

There are no restrictions to limit the use of capital and labor. It is assumed that all capital necessary can be borrowed at a 10 percent simple interest rate and the labor necessary for all operations can be hired at a wage rate of $3.50 per hour. There are accounting restrictions to sum the total amount of capital and labor required for all production activities in the 26 soil and water resource situations.

Crop Enterprise Activities

Only the crops currently being irrigated in significant quantity are considered for enterprise activities. This includes wheat, grain sorghum, barley, alfalfa, corn grain, and soybeans. Wheat activities are dryland production, eight, twelve, and eighteen acre inches of water application. Grain sorghum activities include dryland production, six, eighteen, and twenty-four acre inches of irrigation water. There is no six inch activity for grain sorghum on sandy soils because more water is necessary to sustain a crop on that soil. Barley is produced either dryland and under eighteen inches of irrigation water; corn and soybeans are produced only with twenty-four acre inches of water and alfalfa is produced only with thirty-three inches of water. The irrigated wheat activities are only charged the variable cost of an acre inch of water because it is a spring crop. Irrigation systems are invested in only if they are profitable for the summer crops when the systems must cover the total cost of an acre inch of water.

The input levels, costs, yields, and net returns for the 25 enterprise activities are shown in Appendix A. Farm management specialists were consulted in order to develop current budget data.

Prices

Relative prices are of more concern than absolute prices. Included in the OBERS projections are historical deflated prices for the various crops as well as projections of deflated prices. The deflated price is assumed constant throughout time. For instance, the deflated price of wheat was $1.39 in 1954, and is expected to be $1.39 in 2020. A conversion factor was derived by dividing the deflated price of any other crop by the deflated price of wheat. Wheat was then adjusted up to $3.00 to represent current input output price relationships. The other crop prices were adjusted by multiplying their conversion factor by $3.00, the adjusted price of wheat. The historical deflated prices, conversion factors, and adjusted prices are presented in Table VIII.

Per Acer Inch Water Costs

Per acre inch water costs vary among water resource situations, between irrigation systems, and over time. Presented here are the assumptions used to specify variables of the Irrigation Costs Program used to determine pumping costs.

In studying the geohydrology of the Oklahoma panhandle with 10 aquifer tests and 35 specific capacity tests, the researchers, (Hart, et al.) found a large variance in key parameters; transmissivity[1]

[1]A unit of measurement dealing with the vertical flow of water in the aquifer; (Hart, Hoffman, Geomaat) 1976.

TABLE VIII

CROP PRICES

Crop	Units	Deflated Price	Conversion Factor	Adjusted Price
Wheat	bu.	1.39	1.00	3.00
Grain Sorghum	cwt.	1.77	1.27	3.82
Barley	bu.	1.00	.72	2.16
Alfalfa Hay	ton	-	18.00	54.00
Corn	bu.	1.06	.76	2.29
Soybeans	bu.	2.50	1.80	5.40

ranged from 500 to 11,800 feet squared per day, the storage coefficinet ranged form 0.002 to 0.11, and hydraulic conductivity[2] ranged from 2.1 to 55 feet per day. With this amount of variation, it is hard to specify cost estimations without some basic assumptions.

One basic assumption is that well yield is dependent on saturated thickness; the deeper the saturated thickness, the greater the potential well yield. According to the Hart, et al., geohydrological study, the water aquifer may yield up to 2300 GPM. Associated with each saturated thickness interval is the assumption of a potential maximum yield of about 4 GPM per foot of saturated thickness and an actual yield of about 3 GPM per foot of saturated thickness. These somewhat arbitrary yields simplify the model, allow uniform intervals, and seem realistic based on empirical evidence. It should be mentioned that well development is only 425 feet in the 450 foot saturated thickness interval and only 500 feet in the 550 feet saturated thickness interval.

According to a relationship between percent of maximum drawdown and percent of maximum yield for a water table well in a homogeneous water table aquifer, the most economical situation is 90 percent of maximum yield with 67 percent maximum drawdown (Universal Oil Products Company). It is assumed that shallow water resource situations are yielding near maximum capacities with a high percentage drawdown, and in deep water situations, there is a lower percentage of maximum yield with a lower percentage of drawdown. These relationships are

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[2]A unit of measurement dealing with the horizontal flow of water in the aquifer, synonymous with "field coefficient of permeability"; see Hart, Hoffman, Geomaat, 1976.

presented in Table IX and the initial water resource situations are presented in Table X.

Irrigation Systems

Center pivot systems cover about 130 acres and operate within an initial range of 500 and 1000 GPM. Saturated thicknesses of 350 feet, 450 feet, and 550 feet are assumed to yield 1000 GPM. With equal yield, the drawdown is less in the deeper saturated thicknesses as indicated the Drawdown (6) column in Table X.

Surface irrigation system costs were estimated under the assumption that irrigated acres vary according to discharge capacity. Assuming that an irrigator requires 6 GPM per acre per day to adequately irrigate a water intensive crop like corn, the GPM capacity is apportioned to the proper number of acres. This is presented in Table X.

Irrigation cost runs were made in order to determine initial engine and pump requirements, initial fixed, variable, and total costs per acre inch for each water resource situation under both irrigation systems. The results are presented in Table XI and additional details are provided in Appendix C.

These acre inch costs are multiplied by the number of acre inches a crop enterprise uses and entered in the vector C_t. If a crop enterprise enters the solution, water costs are taken into account in net returns.

The Relationship Between Declining Water Table, Well Yield, and Pumping Costs

The decline in the static water level is directly proportional

TABLE IX

RELATIONSHIP OF IRRIGATION COST PARAMETERS

Saturated Thickness (ft.)	Maximum Yield (GPM)	Percentage Maximum Yield	Actual Yield (GPM)	Percentage Maximum Drawdown	Drawdown (ft.)
50	250	.90	225	.67	35
150	600	.85	500	.60	90
250	950	.80	750	.55	140
350	1350	.75	1000	.50	175
450	1800	.70	1250	.45	200
550	2300	.65	1500	.40	220
450	1800	.55	1000	.35	155
550	2300	.45	1000	.25	135

Source: Ground Water and Wells. St. Paul: Johnson Division, Universal Oil Products Co. 1972.

The table is interpreted: with a saturated thickness of 250 feet, the maximum yield is assumed to be 950 GPM. Eighty percent of the maximum yield is 750 GPM, which corresponds to a 55 percent drawdown, 140 feet.

TABLE X

INITIAL WATER RESOURCE SITUATIONS AND IRRIGATION PARAMETERS

Soil and Water Resource Situation	Depth to Water (ft.)	Saturated Thickness (ft.)	Well Depth (ft.)	GPM	Drawdown (ft.)	Acres Irrigated
Surface System						
75-50-C	75	50	125	350	35	60
75-150-C	75	150	225	500	90	80
75-250-C	75	250	325	750	140	125
75-350-C	75	350	425	1000	175	165
150-150-C	150	150	300	500	90	80
150-250-C	150	250	400	750	140	125
150-350-C	150	350	500	1000	175	165
150-450-C	150	450	575	1250	200	210
150-550-C	150	550	650	1500	220	250
225-150-C	225	150	375	500	90	80
225-250-C	225	250	475	750	140	125
225-350-C	225	350	550	1000	175	165
225-450-C	225	450	625	1250	200	210
Center Pivot						
75-150-S	75	150	225	500	90	130
75-250-S	75	250	325	750	140	130
75-350-S	75	350	425	1000	175	130
150-150-S	150	150	300	500	90	130
150-250-S	150	250	400	750	140	130

TABLE X (Continued)

Soil and Water Resource Situation	Depth to Water (ft.)	Saturated Thickness (ft.)	Well Depth (ft.)	GPM	Drawdown (ft.)	Acres Irrigated
150-350-S	150	350	500	1000	175	130
150-450-S	150	450	575	1000	155	130
150-550-S	150	550	650	1000	135	130
225-150-S	225	150	375	500	90	130
225-250-S	225	250	475	750	140	130
225-350-S	225	350	550	1000	175	130
225-450-S	225	450	625	1000	155	130

TABLE XI

INITIAL ENGINE SIZES AND ACRE INCH COSTS

Soil and Water Resource Situation	Depth to Water (ft)	Saturated Thickness (ft)	Engine Size (HP)	Fixed Cost per Acre Inch ($)	Variable Cost per Acre Inch ($)	Total Cost per Acre Inch ($)
Surface Systems - Clay Soils						
75-50-C	75	50	50	1.20	1.48	2.68
75-150-C	75	150	50	1.19	1.51	2.70
75-250-C	75	250	110	1.04	1.62	2.66
75-350-C	75	350	150	.98	1.71	2.69
150-150-C	150	150	70	1.47	1.79	3.26
150-250-C	150	250	130	1.20	1.87	3.07
150-350-C	150	350	190	1.14	1.98	3.12
150-450-C	150	450	280	1.06	2.11	3.18
150-550-C	150	550	370	1.09	2.24	3.33
225-150-C	225	150	90	1.72	2.06	3.78
225-250-C	225	250	170	1.43	2.16	3.59
225-350-C	225	350	250	1.29	2.25	3.54
225-450-C	225	450	330	1.23	2.38	3.61
Center Pivot Systems						
75-150-S	75	150	90	1.92	1.91	3.83
75-250-S	75	250	150	2.15	2.01	4.16
75-350-S	75	350	220	2.41	2.11	4.52
150-150-S	150	150	110	2.11	2.19	4.29
150-250-S	150	250	190	2.36	2.29	4.64

TABLE XI (Continued)

Soil and Water Resource Situation	Depth to Water (ft)	Saturated Thickness (ft)	Engine Size (HP)	Fixed Cost per Acre Inch ($)	Variable Cost per Acre Inch ($)	Total Cost per Acre Inch ($)
150-350-S	150	350	270	2.62	2.39	5.01
150-450-S	150	450	270	2.73	2.34	5.07
150-550-S	150	550	250	2.83	2.28	5.10
225-150-S	225	150	130	2.27	2.46	4.73
225-250-S	225	250	220	2.65	2.56	5.10
225-350-S	225	350	300	2.75	2.61	5.35
225-450-S	225	450	300	2.87	2.59	5.46

to the net volume of water removed from the aquifer. It can be computed with the following equation:

$$d_t^{ijk} = \frac{W_t^{ijk} \cdot (1-R)}{CS \cdot a^{ijk}} \qquad (6)$$

where:

d_t^{ijk} = the decline in the static water level in feet in soil and water resource situation (i, j, k)

CS = coefficient of storage, 0.1

a^{ijk} = the appropriate surface (land) area

Such an approach does not yield an average decline in the water table throughout the study area. It is assumed that water will not move from areas of high pressure to areas of low pressure in sufficient velocity to insure a uniform decline.

The effects of a declining water table are two-fold. First, it increases the pump lift (total dynamic head) by the amount it has declined. Secondly, a decline in the water table results in a decrease in the saturated thickness which affects well capacity. As the saturated thickness decreases the new well capacity is computed from relation (7):

$$GPM_{t+1} = \left[\frac{ST_{t+1}}{ST_t}\right]^2 \cdot GPM_t \qquad (7)$$

where:

GPM_t = the original well capacity in period t

GPM_{t+1} = the new well capacity in period t+1

ST_t = the original saturated thickness in period t

ST_{t+1} = the remaining saturated thickness in period t+1

Curvilinear relationships were developed to determine the change in water costs as the water levels, saturated thicknesses, and well capacities decrease over time.

Using equations (6) and (7), a number of cost runs were made to determine the change in water costs as the water levels, saturated thicknesses, and well capacities decrease over time. A number of irrigation cost runs were made simulating these changes. Engines and pumps were respecified each time well yield decreased by 250 GPM. Curvilinear relationships appear to capture the cost changes. For surface irrigation systems, the equation developed was:

$$WC_{t+1} = \sqrt{\frac{\sqrt[2]{ST_t}}{\sqrt{ST_{t+1}}}} \cdot WC_t \qquad (8)$$

For center pivot systems, the equation developed was:

$$WC_{t+1} = \sqrt{\frac{\sqrt[3]{ST_t}}{\sqrt{ST_{t+1}}}} \cdot WC_t \qquad (9)$$

where:

ST_t = the saturated thickness in period t

ST_{t+1} = the saturated thickness period t+1

WC_t = the water cost in period t

WC_{t+1} = the water cost in period t+1

Equations (8) and (9) are used to revise the water buying activities in vector C_t for period t+1 based on the amount of water pumped and the decline in saturated thickness resulting in the solution of period t.

This chapter presented the input data and how it was revised over time. The next chapter presents the results of the analyses.

CHAPTER IV

RESULTS OF THE RECURSIVE LINEAR PROGRAMMING PRODUCTION MODEL

The changes projected for the study area under Scenarios I and II are presented in this chapter. Scenario I traces the impact of the decline in the water table through time if current input and output prices maintain current levels and the water table declines gradually. Scenario II evaluates the effect on profitability and irrigated production patterns of a gradual increase in the price of natural gas. Presented and analyzed here are the mode's estimates of the number of acres irrigated, the depletion of the aquifer, the quantity of crops produced under irrigations, the pattern of irrigated crop production among the 26 soil and water resource situations, and the aggregate annual income for the region.

Benchmark Conditions

Elements of the input-output matrix and the right hand side restrictions were described in the previous chapters. The solution for 1980 was obtained by using the Mathematical Programming System - Extended (MPSX) simple algorithm on the IBM-370 computer. The key solution variables were compared with the reported values of those variables for the year 1977 to establish benchmark conditions and test the validity of the model. Criterion variables of the test include irrigated acreage under surface and center pivot systems, the acreages of the various irrigated crops, and the relative spread of dryland production to irrigated production for the different systems.

In 1977, 85,000 acres of center pivot irrigation and 300,000 acres of surface irrigation were reported (Table 1, Chapter I). The model solution contained 68,000 acres under center pivot irrigation and 193,000 acres under surface irrigation. The model further depicts dryland production of 255,000 acres on sandy soils, 3.6 times the acreage irrigated, and 373,000 acres of dryland production on clay soils, almost twice the acreage irrigated on clay soils (193,000). The model's irrigated acreage of individual crops appeared very similar to those reported in 1976; irrigated wheat is reported to be 129,000 acres and irrigated grain sorghum is 89,000 acres whereas the model depicts 130,000 acres of irrigated wheat and 80,000 acres of irrigated grain sorghum.

Exact reproduction of the actual events of 1977 is not the goal in verifying benchmark conditions. There are a number of items that deserve a closer look and some practical observations suggest that the model's initial solution may be quite reasonable. First, the budgets used in fulfilling production requirements represent good management techniques with yields considerably above county or study area averages. It is doubtful all producers in the study area could obtain these yields if their equipment and management practices are at all outmoded, or if they use any marginal lands. With the higher yields, it takes less irrigated and dryland production, hence lower acreages to fulfill the production requirements. Second, all irrigators may not apply as much water as suggested by the budgets. Some may irrigate alternate rows, others may irrigate before planting only and some others may irrigate once or twice after planting. Whether three, eight or eighteen acre inches are applied, the producer reports the acreage as irrigated. To the extent that this situation occurs in actual practice, farmers will have to irrigate more acres than the model indicates to meet the same production goal because yields per acre are smaller at lower rates of water application than at higher rates. Third, an irrigator using a center pivot system may report a whole quarter section (160 acres) being irrigated when only 130 acres are actually irrigated. Also, farmers may intentionally overreport the number of acres irrigated because of suspicion of future governmental control and allocation of water within the aquifer. Finally, a linear programming (LP) model is a normative tool describing what should be rather than what is. When these factors are taken into account, the model is judged to perform satisfactorily in the initial period.

Results of Scenario I: Projected Changes in Irrigated and Dryland Acreage and the Rate of Decline in the Water Table

Clay Soils

The empirical results of Scenario I (Table XII) project that as the study area produces its regional share of the six irrigated crops over time, the number of acres surface irrigated stays fairly constant from the initial 1980-84 period until the 1995-99 period. There are 193,000 acres irrigated in the initial period and 200,000 acres irrigated in 1995-99, followed by a decline to 161,000 acres in the 2000-09 period. There are 75,000 acres surface irrigated in the period

TABLE XII

SCENARIO I - ESTIMATES OF TOTAL IRRIGATED AND DRYLAND ACREAGES (1980-2029)

Crop	Period 1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
<u>Clay Soils</u> (Acres)							
Wheat Dryland	212,294	225,038	240,914	312,626	369,487	625,408	694,472
Wheat Irrigated	94,657	100,342	111,032	106,292	93,081	9,041	5,574
Grain Sorghum Dryland	147,137	229,667	282,389	349,910	485,964	564,056	611,425
Grain Sorghum Irrigated	61,053	36,810	36,562	43,970	14,172	6,992	3,412
Total Dryland*	372,918	470,016	540,480	681,580	876,342	1,213,236	1,332,532
Total Irrigated**	193,604	178,368	193,132	200,141	161,433	74,697	67,646
<u>Sandy Soils</u> (Acres)							
Wheat Dryland	147,728	156,596	217,778	232,129	275,333	379,863	429,876
Wheat Irrigated	36,505	42,244	24,715	26,343	30,495	7,148	-
Grain Sorghum Dryland	100,737	108,086	135,737	162,562	230,049	311,489	330,485
Grain Sorghum Irrigated	18,429	19,912	20,682	20,829	13,468	-	-

TABLE XII (Continued)

Crop	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
				Period			
Total Dryland*	255,660	272,812	362,581	404,752	516,438	703,908	774,272
Total Irrigated**	67,763	75,365	59,983	62,600	60,751	23,587	14,044

*Includes barley.

**Includes alfalfa, corn, and soybeans.

2010-19, and 68,000 acres surface irrigated at the conclusion of the study. Increases in irrigated acreage are due to the greater production goals of each successive period and the shift to less intensive levels of water application as the cost of pumping water increases. Producers have an economic incentive to cut back on water application as water costs rise, but decreased yields due to decreased water application result in more irrigated acreage to fulfill production goals. Dryland production increases steadily on clay soils starting with 373,000 acres and concluding with 1,300,000 acres. The largest increase occurs after the 2000-09 period which corresponds to the largest decrease in irrigated production. The rising water costs in some of the water resource situations tend to divert production from high intensity levels of water application to less intensive levels and finally to dryland for those crops that have dryland alternatives. For those crops produced only on irrigated land, rising water costs results in production being terminated when net returns per acre fall to zero.

Declines in the static water level by soil and water resource situation are presented in Table XIII. Water resources with small depths to water and deep saturated thicknesses (75-250-C, 75-350-C) experience increased declines in their water levels over time as a result of increased pumping to irrigate increased production. In these situations the water table declines 12 feet (2.4 feet per year) in the initial period, 33.5 feet (3.3 fpy) in the period 2000-09, and then 26 feet (2.5 fpy) during the final period. Other water resource situations with larger depths to water (150-150-C) and smaller saturated thicknesses (75-50-C) show reductions in the decline in the water

TABLE XIII

SCENARIO I - ESTIMATED DECLINES IN THE STATIC WATER LEVEL
BY SOIL AND WATER RESOURCE SITUATIONS (1980-2029)

Soil and Water Resource Situation (WRS)	Static Water Level Decline (ft.)						
	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
75-50-C	12.11	12.54	6.91	2.70	5.88	6.30	.02
75-150-C	12.11	12.97	14.22	14.94	21.90	6.30	6.72
75-150-S	11.86	12.70	13.91	15.12	28.79	6.50	.78
75-250-C	12.10	12.97	14.22	15.48	33.46	28.84	6.72
75-250-S	11.86	12.70	13.55	14.71	31.76	6.52	6.96
75-350-C	12.10	12.97	14.22	15.48	33.46	31.37	26.13
75-350-S	11.57	12.39	13.55	10.49	22.42	18.14	6.96
150-150-C	10.31	8.85	9.55	8.72	15.92	6.62	6.72
150-150-S	11.57	11.16	6.34	7.03	6.08	6.52	6.94
150-250-C	11.71	12.55	13.73	8.72	14.87	6.30	6.72
150-250-S	5.21	5.65	2.56	2.80	6.08	6.52	6.94
150-350-C	10.45	11.20	12.30	10.20	5.87	6.30	6.72
150-350-S	2.12	2.31	2.55	2.79	6.07	.68	.78
150-450-C	5.47	5.93	6.70	7.39	16.24	6.53	6.96
150-450-S	2.12	.24	.25	.27	.58	.68	.78
150-550-C	2.06	2.24	2.47	2.70	5.87	6.30	6.72
150-550-S	.22	.23	.25	.27	.58	.68	.78
225-150-C	5.97	6.38	6.91	2.70	5.87	6.30	5.94
225-150-S	2.13	2.31	2.56	2.80	6.08	6.50	6.93
225-250-C	2.06	2.24	2.47	2.70	5.87	6.30	6.72

TABLE XIII (Continued)

Soil and Water Resource Situation (WRS)	Static Water Level Decline (ft.)						
	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
225-250-S	.17	.18	.20	.22	.47	.55	.63
225-350-C	2.06	2.24	2.47	2.70	5.87	6.30	6.72
225-450-C	2.06	2.24	2.47	2.70	5.84	6.30	6.72

level as production is switched to less intensive water applications and as irrigated production is replaced by dryland production.

Sandy Soils

The number of acres irrigated by center pivot system follows a pattern similar to the surface irrigated acres. Irrigated acreage is faily constant from the initial period with 68,000 acres, to the 2000-09 period with 61,000 acres. A large decline in acreage irrigated occurs in the 2010-19 period with only 23,500 acres being irrigated. Dryland production increases steadily from 256,000 acres in the initial period to 774,000 acres in the terminal period, with the biggest increase occurring after the 2000-09 period.

Declines in the static water level follow a pattern similar to the clay soils beginning with declines of 11.86 feet (2.4 feet per year) in WRS 75-250-S, increasing to 31.8 feet (3.2 fpy) in the 2000-09 period, before decreasing substantially at the conclusion of the study. The total acreages of dryland and irrigated production for both soils are given in Table XII. The declines in the static water level by soil and water resource situation are given in Table XIII.

Projected Acreages in Irrigated and Dryland Crop Production

Clay Soils

As the static water level declines and the cost per acre inch of water increases, producers are provided an economic incentive to reduce water applications. For those crops with reduced levels of water application irrigators will switch to the less intense levels and then to dryland production. This applies to wheat, grain sorghum, and barley. Corn, alfalfa, and soybeans are only produced at one irrigation level without a dryland alternative. As water costs increase, these activities will drop out of the solution when their net returns become negative and the land will be available for dryland production of the other crops. The net return of wheat is the most sensitive to water cost changes followed by grain sorghum, soybeans, corn, and alfalfa respectively. Wheat is the first crop to shift to less intense application levels and finally to dryland production. There are 95,000 acres of irrigated wheat in the initial period, 110,000 acres in the 1990-94 period, and only 5,000 acres of irrigated wheat at the conclusion. There are 61,000 acres of irrigated grain sorghum in the initial period, 41,000 acres irrigated in the 1995-99 period and only 3,000 acres of irrigated production occurring in the terminal period. There is no irrigated barley. Alfalfa and soybeans show progressive increases in irrigated acreage from the beginning to the end. Irrigated corn acreage increases from an initial 35,000 acres to 54,000 acres in the terminal period. Dryland wheat increases steadily from 212,000 acres in the initial period up to 700,000 acres in the terminal period. The largest increase comes after the period 2000-09 when dryland wheat acreage increases from 370,000 acres to 625,000 acres. Dryland grain sorghum increases from 147,000 acres up to 611,000 acres with the largest increase occurring after the 1995-99 period. These changes are presented in Table XIV.

TABLE XIV

SCENARIO I - CLAY SOILS - ESTIMATES OF ANNUAL IRRIGATED AND DRYLAND ACREAGES OF THE VARIOUS CROPS (1980-2029)

Crop		Period						
		1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Wheat	Dry (Acres)	212,294	225,038	240,914	312,626	369,487	625,408	694,472
"	8"	10,368	10,990	24,178	28,856	71,355	-	5,574
"	12"	20,226	21,440	22,952	56,975	-	9,041	-
"	18"	64,066	67,912	63,902	20,461	21,726	-	-
Grain Sorghum	Dry (Acres)	147,137	229,667	282,389	349,910	485,864	564,056	611,425
"	6"	27,681	-	-	22,479	-	5,174	3,412
"	18"	22,075	28,440	27,065	18,124	10,448	1,818	-
"	24"	11,297	8,370	9,497	3,367	3,724	-	-
Barley	Dry (Acres)	13,487	15,311	17,177	19,044	20,891	23,772	26,635
"	18"	-	-	-	-	-	-	-
Alfalfa	33" (Acres)	2,981	3,236	3,495	3,769	4,003	4,831	5,648
Corn	24" (Acres)	34,805	37,848	41,897	45,947	49,996	53,642	53,411
Soybeans	24" (Acres)	108	132	146	163	181	191	201

Sandy Soils

Wheat irrigated on sandy soils began with 37,000 acres in the initial period and increased to 42,000 in the subsequent, 1985-89 period. There were 30,000 acres irrigated in the 2000-09 period, 7,000 acres irrigated in the 2010-19 period, and no irrigated wheat at the conclusion of the study. Irrigated grain sorghum acreage increased steadily from 18,000 acres in the initial period up to 21,000 acres in the 1995-99 period. There were only 13,000 acres irrigated from 2000-09, and no irrigated grain sorghum after that. All barley was produced dryland, alfalfa showed steady increases from the beginning to the end, and corn and soybeans peaked in the period 2000-09. Dryland acreage for wheat showed a large increase after 1985-89, and another large increase after 2000-09. Dryland grain sorghum showed a large increase after 1995-99, and a larger increase after 2000-09. In summary, the most dramatic shifts from irrigated to dryland production occurred after the period 2000-09. These shifts are presented in Table XV.

Changes in Production Patterns Among Water Resource Situations

Clay Soils

For the first two time periods there was a little movement in production patterns except for water resource situations with shallow saturated thicknesses. Equation 8 of Chapter III is used to revise water costs, and the equation is set up so that shallow saturated thicknesses experience rapid price increases. There was a major shift

TABLE XV

SCENARIO I - SANDY SOILS - ESTIMATES OF ANNUAL IRRIGATED AND DRYLAND ACREAGE OF THE VARIOUS CROPS (1980-2029)

Crop		Period						
		1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Wheat	Dry (Acres)	147,728	156,596	217,778	232,124	275,333	379,863	429,867
"	8"	-	-	-	-	-	7,148	-
"	12"	-	19,158	-	-	15,247	-	-
"	18"	36,505	23,068	24,715	26,343	15,548	-	-
Grain Sorghum	Dry (Acres)	100,037	108,086	135,737	162,562	230,049	311,489	330,485
"	18"	11,127	12,022	15,952	15,537	13,468	-	-
"	24"	7,302	7,890	4,730	5,292	-	-	-
Barley	Dry (Acres)	7,195	8,130	9,066	10,061	11,056	12,556	13,911
"	18"	-	-	-	-	-	-	-
Alfalfa	33" (Acres)	1,355	1,471	1,592	1,713	1,834	2,138	2,442
Corn	24" (Acres)	10,763	11,705	12,957	13,673	14,878	14,268	11,583
Soybeans	24" (Acres)	28	33	37	42	46	33	19

in water resource situation (WRS) 150-150-C after the initial period when 6" grain sorghum reverted to dryland production. This resulted in early downward movements in both the number of acres of clay soils irrigated and the number of acres of irrigated grain sorghum.

Major shifts in production patterns occurred after the 1995-99 period, the 2000-09 period, and after the 2010-19 period. Wheat and grain sorghum are the only crops involved in shifts in the earlier periods. There are two types of movement in the production patterns of the water resource situations. First, water resource situations with shallow saturated thicknesses experience rapid increases in water costs as water is pumped. Second, water resource situations with relatively large depths to water have high initial costs and, as the water level declines, water costs need only increase slightly in order to cause shifts in production patterns. Water resource situation (WRS) 75-50-C discontinues irrigation of wheat and grain sorghum after the 1985-89 period, WRS 510-350-C discontinues irrigation of wheat and grain sorghum after the 1995-99 period, while WRS 75-150-C is still irrigating wheat and grain sorghum in the terminal period.

In water resource situations with higher initial water costs, and in the water resource situations when irrigated wheat and grain sorghum are discontinued less water is pumped to irrigate the more profitable crops; alfalfa, corn, and soybeans. As a result, changes in water costs are substantially smaller, and it is not until after the 2010-19 period that these crops are affected by increased water costs.

Sandy Soils

Sandy soils show less movement in production patterns among water resource situations than the shifts that occurred on clay soils. Because of the way water costs are computed, center pivot acre inch costs are less sensitive to declines in the static water level. Like clay soils, there are two types of movement in the production pattern of the water resource situations. On one hand, water resource situations with shallow saturated thicknesses experience quick increases in water costs while water resource situations with larger depths to water have high initial costs and require only slight increases in water costs to shift production patterns. Irrigated wheat is terminated in WRS 75-350-S after the 2010-19 period, and alfalfa production is not affected in any water resource situation throughout the study.

Net Returns

Net returns to the study increase from 19.5 million deflated dollars per year in the initial period up to 28.4 million dollars per year at the conclusion of the study. Since dryland production is profitable, and the production requiremetns increase throughout the study, net income increases. As the model shifts from high levels of irrigation to less intensive levels and finally to dryland, the change in net income indicates a slowdown in growth. Income increases at an increasing rate until 1995. The period 1995-2000 experiences the first annual decline in the rate of growth corresponding to a large decrease in irrigation on clay soils. The following period, 2000-2010, experiences a sharper decline in the rate of growth corresponding to the large decreases in acreage irrigated on both clay and sandy soils.

Results of Scenario II: Projected Changes in Irrigated and Dryland Acreage and the Rate of Decline in the Water Table

Clay Soils

Scenario II reflects a gradual increase in the price of natural gas, all other prices remaining constant. There is a steady decline in irrigated acres until the 2000-09 period with 56,000 acres. There is a small increase of irrigated acreage in the terminal period. This is presented in Table XVI. There are shifts to less intense applications of water as costs increase, resulting in increased acreage, but these increases in irrigated acreage are overshadowed by shifts to dryland production or the cessation of production of those crops without dryland alternatives.

Declines in the static water level by water resource situation are presented in Table XVII. Water resource situations with small depths to water and deep saturated thicknesses exhibit the largest declines for the longest time. WRS 75-150-C, 75-250-C, and 75-350-C have declines of 12.1 feet (2.4 fpy) in the initial period and the declines increase until the 1995-99 period with 14.94 feet (2.9 fpy). The increases are a result of increased pumping on order to meet increased production goals. After the 1995-99 period, declines decrease as irrigated production becomes less economical and less water is pumped.

TABLE XVI

SCENARIO II - ESTIMATES OF TOTAL IRRIGATED AND DRYLAND ACREAGES (1980-2029)

	Period						
Crop	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Clay Soils (Acres)							
Wheat Dryland	212,294	225,038	363,987	493,577	590,477	648,513	706,549
Wheat Irrigated	94,659	95,444	57,196	21,480	-	-	-
Grain Sorghum Dryland	147,137	229,667	395,572	442,541	529,656	583,889	619,492
Grain Sorghum Irrigated	61,053	42,533	10,766	12,705	6,564	-	-
Total Dryland*	372,918	470,016	776,736	955,162	1,141,024	1,256,175	1,352,676
Total Irrigated**	193,607	179,192	113,499	84,062	60,744	55,896	56,274
Sandy Soils (Acres)							
Wheat Dryland	147,728	227,241	255,093	338,332	359,248	394,558	429,867
Wheat Irrigated	36,505	24,777	25,495	-	-	-	-
Grain Sorghum Dryland	100,037	128,055	185,901	234,598	259,498	311,489	330,485
Grain Sorghum Irrigated	18,434	16,407	9,862	5,433	7,116	-	-

TABLE XVI (Continued)

	Period						
Crop	1980-84	1985-89	1990-04	1995-99	2000-09	2010-19	2020-29
Total Dryland*	245,960	-	450,059	582,991	629,802	718,603	774,264
Total Irrigated**	67,088	52,863	47,557	17,379	18,864	3,931	323

*Includes barley.
**Includes alfalfa, corn, and soybeans.

TABLE XVII

SCENARIO II - ESTIMATED DECLINES IN THE STATIC WATER LEVEL BY SOIL AND WATER RESOURCE SITUATIONS (1980-2029)

Soil and Water Resource Situation (WRS)	Static Water Level Decline (ft.)						
	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
75-50-C	12.11	12.54	2.47	2.70	5.88	-	-
75-150-C	12.11	12.97	13.74	14.94	5.87	6.30	6.72
75-150-S	11.86	12.70	12.60	7.03	15.44	.68	.78
75-250-C	12.10	12.97	14.22	14.94	11.99	6.30	6.72
75-250-S	11.86	12.38	12.24	2.80	6.09	6.50	-
75-350-C	12.10	12.97	14.22	12.12	16.24	6.30	6.72
75-350-S	11.57	6.69	2.55	2.79	.58	.68	-
150-150-C	10.31	8.85	8.11	2.70	5.90	6.62	-
150-150-S	11.57	5.64	2.56	2.80	6.01	.68	.78
150-250-C	11.71	11.20	2.46	2.70	5.87	6.29	6.72
150-250-S	5.21	2.32	2.55	.27	.58	-	-
150-350-C	10.45	10.07	2.47	2.70	5.87	6.29	6.72
150-350-S	2.12	.23	-	-	-	-	-
150-450-C	5.47	4.41	2.47	2.70	5.87	6.29	6.72
150-450-S	2.12	.23	-	-	-	-	-
150-550-C	2.06	2.24	2.47	2.70	5.87	6.29	6.72
150-550-S	.22	.23	-	-	-	-	-
225-150-C	5.97	2.24	2.47	2.70	5.87	6.29	6.72
225-150-S	2.13	2.31	2.55	2.79	.58	-	-
225-250-C	2.06	2.24	2.47	2.70	5.87	6.29	.78

TABLE XVII (Continued)

Soil and Water Resource Situation (WRS)	Static Water Level Decline (ft.)						
	1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
225-250-S	.17	.19	-	-	-	-	-
225-350-C	2.06	2.24	2.47	2.70	5.87	6.29	6.72
225-450-C	2.06	2.24	2.47	2.70	5.84	6.29	6.72

Sandy Soils

Acreage irrigated by center pivot systems is 67,000 acres at the outset, and decreases to 48,000 acres in the 1990-95 period. After that there is a large decrease with only 17,000 irrigated acres in the 1995-99 period, 19,000 acres in the 2000-09 period, and a negligible 323 acres irrigated in the terminal period. This unexpected phenomena of irrigated acreage decreasing, increasing and then decreasing can be explained. As the water table decreases, GPM decreases, and the cost of pumping water increases, the profitability of irrigated activities decreases and approaches the profitability of dryland production. Intensively irrigated activities become unprofitable, while lower intensity activities still remain more profitable than dryland. Production goals increase, and more acres of lower intensity activities are required to meet production goals.

Declines in the static water table are presented in Table XVII. There is an increase in the rate of decline after the initial period to meet increase production goals, but after the 1985-89 period, the rate of decline decreases.

Projected Acreages in Irrigated and

Dryland Crop Production

Clay Soils

Irrigated wheat begins with 94,600 acres in the initial period and increases to 95,400 acres in the subsequent 1985-89 period. There is a major decrease to 57,000 acres irrigated in 1990-94 period, followed by another decrease to 21,000 acres in the subsequent period, followed by no irrigated wheat after 1995-99. Irrigated grain sorghum follows a similar pattern but stays in the model in the period 2000-09 before dropping out. Dryland wheat increases steadily with the largest increase occurring after the 1990-94 period. Dryland grain sorghum showed steady increases with the biggest increase occurring after the 1990-94 period. Alfalfa showed a steady increase in irrigated production throughout the study, while corn and soybeans peaked in the 2010-19 period before leveling off. Table XVIII provides the data.

Sandy Soils

There are 36,500 acres of center pivot irrigated wheat in the 1980-84 period, 24,700 acres in the subsequent period, 25,500 acres in the 1990-94 period, and after that there is no irrigated wheat. Irrigated grain sorghum shows a steady decline but there are 7,000 acres being irrigated in the 2000-09 period. Dryland production shows a steady increase for both crops, as shown in Table XIX. Irrigated production of alfalfa, corn, and soybeans were relatively constant over time. With increased energy costs leading to increased cost per acre inch, alfalfa, corn, and soybeans all become more sensitive to irrigation costs. As water resource situations become uneconomical, irrigated acreage is reduced. However, increased production goals tend to counteract the decrease.

TABLE XVIII

SCENARIO II - CLAY SOILS - ESTIMATES OF ANNUAL IRRIGATED AND DRYLAND ACREAGES OF THE VARIOUS CROPS (1980-2029)

Crop		Period						
		1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Wheat	Dry (Acres)	212,294	225,038	363,987	493,577	590,477	648,513	706,549
"	8"	10,368	25,288	-	3,505	-	-	-
"	12"	20,225	13,716	38,769	-	-	-	-
"	18"	64,066	56,440	19,196	17,975	-	-	-
Grain Sorghum	Dry (Acres)	147,137	229,667	395,572	442,541	529,656	583,889	619,492
"	6"	27,681	13,164	-	-	4,857	-	-
"	18"	22,075	20,999	7,756	12,705	1,707	-	-
"	24"	11,297	8,370	3,010	-	-	-	-
Barley	Dry (Acres)	13,487	15,311	17,177	19,044	20,891	23,773	26,635
"	18"	-	-	-	-	-	-	-
Alfalfa	33" (Acres)	2,981	3,236	3,495	3,768	4,003	4,680	5,298
Corn	24" (Acres)	34,805	37,848	41,896	45,946	49,996	51,034	50,794
Soybeans	24" (Acres)	109	131	146	163	181	182	182

TABLE XIX

SCENARIO II - SANDY SOILS - ESTIMATES OF ANNUAL IRRIGATED AND DRYLAND ACREAGES OF THE VARIOUS CROPS (1980-2029)

		Period						
Crop		1980-84	1985-89	1990-94	1995-99	2000-09	2010-19	2020-29
Wheat	Dry (Acres)	147,728	227,241	255,093	338,332	359,248	394,558	429,867
"	8"	-	5,372	-	-	-	-	-
"	12"	-	-	25,495	-	-	-	-
"	18"	36,505	19,405	-	-	-	-	-
Grain Sorghum	Dry (Acres)	100,037	128,055	185,901	234,598	259,498	311,489	330,485
"	18"	11,127	12,239	5,132	6,433	7,116	-	-
"	24"	7,307	4,168	4,736	-	-	-	-
Barley	Dry (Acres)	7,195	8,130	9,065	10,061	11,056	12,556	13,912
"	18"	-	-	-	-	-	-	-
Alfalfa	33" (Acres)	1,358	1,473	905	974	1,042	966	323
Corn	24" (Acres)	10,763	10,173	11,262	10,939	10,686	2,965	-
Soybeans	24" (Acres)	28	33	33	33	20	-	-

Changes in Production Patterns Among Water Resource Situations

Clay Soils

With the increase in the price of natural gas, the model depicts changes in 6 water resource situations after the first 5 year period. High intensity levels of irrigation switch to less intense applications and some of the less intense applications levels move to dryland production. Combined with a decline in the water table, another increase in the price of natural gas accelerates the movement towards dryland production in the shallower saturated-thickness and larger depth to water resource situations. This movement results in wheat and grain sorghum being produced dryland in WRS 75-150-C, 150-250-C, and 150-350-C, after the 1985-89 period. Alfalfa, corn, and soybeans are forced out of production in the later time periods in the shallow saturated thicknesses.

Sandy Soils

The increase in the price of natural gas has a more pronounced effect on center pivot systems than on surface irrigation systems. Consumption of natural gas is a function of brakehorsepower, and center pivot systems require higher brakehorsepower to sustain the pressure necessary to operate. After the first period 1980-84, there are shifts to less intensive water applications is WRS 75-250-S and 75-350-S. There are shifts to dryland production in WRS 75-350-S, 150-150-S, and 150-250-S. Corn drops out of production in WRS 150-350-S, and 150-450-S, and soybeans drop out of WRS 225-150-S. After fulfilling production requirements in the period 1985-89, WRS 150-350-S, 150-450-S, 150-550-S, and 225-250-S were no longer economical to irrigate. Regardless of change in the saturated thickness or decline in the water table, the rise in the price of natural gas curtailed irrigation in water resource situations with large depths to water.

Net Returns

Net returns on an annual basis start at 19.5 million dollars in 1980 and increase up to 27.5 million dollars in the year 2020. The increment of change of annual income increases from 1980 until the year 2000, after which the annual change in the increase of income begins to decline. The fact that production goals are not met as water resource situations become dewatered as a result of the increasing cost of natural gas seems to account for the decline in the rate of increase of income.

Comparison of the Results of the Two Scenarios

Clay Soils

In Scenario I, total irrigated acreage stays relatively constant from the initial period 1980-84 with 194,000 acres until after the period 1995-99 with 200,000 acres. Scenario II begins with 194,000 acres and steadily declines to 84,000 acres after the 1990-94 period. After the 1995-99 period, the total irrigated acreage of Scenario II levels off and stays constant until the end, whereas Scenario I exhibits a steady decline after the period 1995-99. At the conclusion of the study, Scenario I is irrigating 10,000 acres more than Scenario II.

Irrigated wheat in Scenario I follows a pattern similar to the total irrigated acreage of Scenario I. Irrigated wheat begins with 95,000 acres and is relatively constant through the 2000-09 production period when there are 93,000 acres being irrigated. After the 2000-09 period, irrigated wheat declines sharply to 9,000 acres and at the conclusion of the study, there are 5,500 acres of irrigated wheat. In Scenario II, irrigated wheat stays constant for the first two periods and then declines in the next two periods, and drops out after the 1995-99 period.

Irrigated grain sorghum follows a similar pattern in both scenarios for the first two production periods. After the 1985-89 period, irrigated grain sorghum declines sharply in Scenario II and drops out of production after the 2000-09 period. In Scenario I, there are 44,000 acres of irrigated grain sorghum in 1995-99, 19,000 acres in the period 2000-09, and there is 3,400 acres irrigated at the conclusion.

Corn, alfalfa, and soybeans follow the same pattern in both Scenarios up to the period 2000-09. After that period, production levels off in Scenario II while it continues to increase in Scenario I.

Sandy Soils

In Scenario I, total irrigated acreage begins at 68,000 acres, stays relatively constant, and 61,000 acres remain irrigated though the 2000-09 period. After that, total irrigated acreage drops to 23,500 in the 2010-19 period and there are 14,000 acres being irrigated at the conclusion of the study. Scenario II begins with a total of 68,000 acres irrigated, decreases throughout the study, and ends up with 323 acres being irrigated. The biggest decrease occurs after the 1990-94 period, and after the 2000-09 period, when the total irrigated drops from 19,000 acres to 4,000 acres.

Irrigated wheat acreage begins at 36,500 acres in Scenario I, increases to 42,000 acres in the 1985-89 period, and decreases to 30,500 in the 2000-09 period. There are only 7,000 acres irrigated in the 2010-19 period, and at the conclusion of the study, there are no acres of irrigated wheat. The solution of Scenario II begins with 26,500 acres of irrigated wheat, decreases to 24,700 acres in the 1985-89 period, irrigated 25,500 acres in the period of 1990-94, and there is no irrigation of wheat after that. The increase in the price of natural gas results in a substantial shortening of the time horizon for irrigated wheat on sandy soils.

Under Scenario I, there is twice as much irrigated grain sorghum acreage as is irrigated under Scenario II from the 1990-94 period until the 2000-09 period. After that time, there is no longer any irrigated grain sorghum under either scenario.

In Scenario I, alfalfa shows a steady increase in irrigated production throughout the study. Corn and soybeans increase production up to the 2000-09 period after which the two crops begin to decline. In Scenario II, alfalfa acreage declines after the second production period and then stays relatively constant until the conclusion of the study, when there are only 323 acres of alfalfa irrigated. Soybeans irrigated on sandy soils increase after the first period, remain constant until the 1995-99 period, and after the 2000-09 period, production is stopped. Corn production in Scenario II stays relatively constant at 11,000 acres until after the 2000-09 period, and finally production is stopped at the conclusion of the study.

When comparing the results of the two models, certain relationships become apparent that help explain the differences in the two models. The first is that wheat is charged only the variable cost per acre inch versus the total cost per acre inch for the other crops. As mentioned previously, wheat is a spring crop receiving supplemental irrigation whereas summer crops like grain sorghum and corn are the primary crops irrigated intensively. While the cost of fuel is an important component of the total cost per acre inch, it becomes more important when just the variable cost is considered. In Scenario I, irrigation of wheat continues to the 2000-09 period regardless of soil type. In Scenario II, increases in the cost of natural gas significantly reduce irrigated wheat production after the 1990-94 period regardless of soil type.

The other relationship is that center pivot systems are less sensitive to declines in the water table than surface systems, but they are more sensitive to increases in the price of natural gas. The two systems are different in pressure per square inch required at the wellhead discharge, with center pivot systems needing larger engines with greater brake horsepower among other things. In both Scenario I and Scenario II, corn production on clay soils is very similar, while corn production on sandy soils appears to move in different directions. This seems to indicate that natural gas increases are less important on clay soils with surface systems than on soils with center pivot systems.

This chapter presented and analyzed the results of the study. The next chapter presents the summary and conclusions.

CHAPTER V

SUMMARY AND CONCLUSIONS

The acreage of irrigated crop production in the Oklahoma panhandle has increased rapidly in the past two decades. Natural recharge is insignificant relative to the amount of water being pumped from the aquifer. Irrigation is expected to expand in the area for some time to come which implies that the water supply is going to be depleted at a more rapid rate than currently observed. At the present time there is an "energy crisis" which will affect the economic life of the aquifer. However, there are no available estimates of the changes that will take place in the growth of irrigation, depletion of the water supply and the repercussions on the pattern of crop production and income of the area.

The general purpose of this study is to estimate the changes that will take place with respect to these variables: a gradual decline in the water table by itself and with an increasing price of natural gas. The first part of this chapter presents a summary of the objectives of the study and the procedures employed. The second part presents the highlights of the empirical results and draws some conclusions from these results. Finally, the policy implications of the conclusions are discussed and the limitations of the study brought out. The need for further research in the study area is also stated.

Objectives and Procedures

The major objective of this study is to present estimates of 1) the growth of irrigation in the study area and 2) the rate of depletion of the aquifer over time and its effects on a) the pattern of irrigated and dryland crop production and b) the net returns of the study area. More specifically, the first objective is to develop a model that 1) depict's the study areas irrigated and dryland crop production, 2) projects the growth of irrigation, 3) estimates the resulting rate of groundwater withdrawal, and 4) estimates the changes in net return. The second specific objective is to compare results of the model under two sceanrios, the first, a base scenario with a gradual decline in the water level, and the second, a scenario under which the price of natural gas is allowed to increase. The rate of groundwater use and the study area's resulting net returns from the two sceanrios are compared and some policy implications inferred.

The analysis in the panhandle is based on an inventory of the soil and water resource taken from county soil surveys and a geo-gydrological study of the Oklahoma panhandle. The study area was stratified into 26 discrete soil and water resource situations based on soil types, depth to water, and saturated thickness (Thompson). These soil and water resource situations formed the basis of the analysis. Center pivot irrigation takes place on sandy soils and surface irrigation takes place on clay soils. Initial pumping costs are determined by the depth to water and the saturated thickness; changes in pumping costs as the water level declines are a function of the saturated thicknesses. A recursive linear programming (RLP) model was employed to depict the pattern of irrigated crop production over the period 1980-2029, under both scenarios. The model used the study area's historic share of the projected U.S. and Oklahoma's supply of six irrigated crops (wheat, grain sorghum, barley, alfalfa, corn, and soybeans) as production goals.

The model's solution produced the study area's projected supply of the six irrigated crops as long as the net returns were greater than dryland production for those crops with dryland alternatives (wheat, grain sorghum, barley), or as long as net returns were greater than zero for those crops without dryland alternatives (alfalfa, corn, soybeans).

Findings and Conclusions

The recursive linear programming (RLP) model was run for the period 1980-2029 under the two scenarios. The highlights of their results and comparisons are presented.

Clay Soils

In Scenario I, total irrigated acreage stays relatively constant from the initial period 1980-84 with 194,000 acres until after the period 1995-99 with 200,000 acres. Scenario II begins with 194,000 acres and steadily declines to 84,000 acres after the 1990-94 period. After the 1995-99 period Scenario II's total irrigated acreage levels off and stays constant until the end whereas Scenario I exhibits a steady decline after the period 1995-99. At the conclusion of the study, there are 10,000 more irrigated acres in Scenario I than in Scenario II.

Irrigated wheat in Scenario I follows a pattern similar to the total irrigated acreage in Scenario I. Irrigated wheat begins with 95,000 acres and is relatively constant through the 2000-09 production period when there are 43,000 acres being irrigated. After the 2000-09 period, irrigated wheat declines sharply to 9,000 acres and at the conclusion of the study, there are 5,500 acres of irrigated wheat. In Scenario II, irrigated wheat stays constant for the first two periods and then declines in the next two periods, and drops out after the 1995-99 period.

Irrigated grain sorghum follows a similar pattern in both scenarios for the first two production periods. After the 1985-89 period, irrigated grain sorghum declines sharply in Scenario II and drops out of production after the 2000-09 period. In Scenario I, there are 44,000 acres of irrigated grain sorghum in 1995-99, 19,000 acres in the period 2000-09, and there is 3,400 acres irrigated at the conclusion.

Corn, alfalfa, and soybeans follow the same pattern in both Scenarios up to the period 2000-09. After that period, production levels off in Scenario II while it continues to increase in Scenario I.

Sandy Soils

In Scenario I, total irrigated acreage begins at 68,000 acres, stays relatively constant, and 61,000 acres remain irrigated through the 2000-09 period. After that, total irrigated acreage drops to 23,500 in the 2010-19 period and there are 14,000 acres being irrigated at the conclusion of the study. The results of Scenario II begin with a total of 68,000 acres irrigated, decrease throughout the study, and ends up with 323 acres being irrigated. The biggest decrease occurs after the 1990-94 period, dropping from 47,500 acres to 17,400 acres in the 1995-99 period, and after the 2000-09 period, when the total irrigated drops from 19,000 acres to 4,000 acres.

Irrigated wheat acreage begins at 36,500 acres in Scenario I, increases to 42,000 acres in the 1985-89 period, and decreases to 30,500 in the 2000-09 period. There are only 7,000 acres irrigated in the 2010-19 period, and at the conclusion of the study, there are no acres of irrigated wheat. Scenario II begins with 36,500 acres of irrigated wheat, declines to 24,700 acres in the 1985-89 period, irrigates 25,500 acres in the period 1990-94, and there is no irrigation of wheat after that. The increase in the price of natural gas results in a substantial shortening of the time horizon for irrigated wheat on sandy soils.

With grain sorghum, Scenario I is irrigating twice the acreage of Scenario II from the 1990-94 until the 2000-09 period. After that time, there is no longer any irrigated grain sorghum under either scenario.

In Scenario I, alfalfa shows a steady increase in irrigated production throughout the study. Corn and soybeans increase production up to the 2000-09 period after which the two crops begin to decline. In Scenario II, alfalfa acreage declines after the second production period and then stays relatively constant until the conclusion of the study, when there are only 323 acres of alfalfa irrigated. Soybeans irrigated on sandy soils increase after the first period, remain constant until the 1995-99 period, and after the 2000-09 period, production is stopped. Corn production in Scenario II stays relatively constant at 11,000 acres until after the 2000-09 period, when it declines to 3,000 acres in the period 2010-19, and finally production is stopped at the conclusion of the study.

<u>Net Returns</u>

As the price of natural gas increases over time, Scenario II's net returns become a smaller percentage of Scenario I's net returns. In some soil and water resource situations, irrigated production is hastened into dryland production with lower net returns. Crops without any drylnad alternatives drop out of the solution, and the crops that continue to be irrigated have higher water costs with a consequent lower net return. There seems to be a bottoming out of the relationship in the year 2000. At this time, the little irrigation being done has higher water costs as a result of the previous pumpage, and the lion's share of production and net returns are attributable to dryland production, which is large in both models.

Policy Implications

This analysis reveals, as others before it have, that the irrigation water supply in the Oklahoma panhandle has a finite economic life. If input and output prices maintain their relative positions, and yields and technology do not change, the water supply will be exhausted from an economic standpoint in about 40 years. This analysis also reveals that a 2 percent increase in the price of natural gas used to power irrigation engines relative to the price of other inputs or outputs will likely cut the economic life of the water supply in half. The adjustment process will likely involve a gradual conversion of irrigation to less intensive irrigation to dryland production. The economic impact of conversion to dryland production on towns and communities in the Panhandle, while not estimated in this study, is likely to be substantial. Policy makers will need innovative ideas to lengthen the economic life of the water supply or diminish the severity of the adjustment process.

An implicit assumption of this study is that farm operations continue to irrigate, using the same technology, until it is no longer economical to produce under irrigated conditions. Policies may be developed to encourage conservation and efficient use of the existing supply. Support for research to develop low pressure pumping and application equipment will reduce energy use, lower pumping costs and prolong the economic life of the aquifer. Development of additional drought resistent or water stress tolerant crop varities is equally important. Recent research by the Oklahoma Agricultural Experiment Station has disclosed the possibility of significantly reducing the quantity of water applied on grain sorghum by irrigating alternate rows without corresponding reductions in yield per acre. Other research has suggested the possibility of water use reductions through improved timing water applications relative to the stages of plant development. A combination of public and private support for research and a willingness of producers to adopt water conserving technology can significantly prolong the economic life of the aquifer.

Policy makers may wish to play a more direct role in encouraging conservation and the efficient use of water. Oklahoma water law would permit limiting water use to the "safe yield" of the aquifer. The safe yield may be defined to equal the amount recharges from rainfall, a very small number of area-feet relative to recent withdrawals. Other policy alternatives include implementing and enforcing well spacing requirements, monitoring pumping and restricting it to a specified level, and devising a tax structure graduated with water use to encourage conservation. These alternatives are much less palatable to individual producers and would require substantial public investment in regulatory enforcement mechanisms. They would likely prolong the economic life of the water supply, but at perhaps a substantial cost to the public.

Policy makers may also wish to consider the possibility of supplementing the area water supply through interbasin transfers or water importation. Aside from the inherent political difficulties of removing water from one area to transport it to another region, a number of important economic, social and environemntal issues must be carefully evaluated. Important among the beneficiaries will be the producer and communities in the region receiving the imported water. A portion of the cost must be borne by these individuals and communities. Total costs of contruction, maintenance and operation of a transfer mechanism are likely to be very high. The costs may have to be spread among all the people in the state or, perhaps, the nation. Such decisions are likley to be made far from the Oklahoma Panhandle. Considerable additional study of the potential benefits and costs of the policy alternatives is justified.

Limitations and Suggestions for Further Research

Mathematical representation of the real world is always subject to simplification and error. Hydrologic and economic relationships were developed in the course of this study and they have limitations that need to be specified.

Hydrologic Limitations

The hydrology of the area has not been exhaustively studied and important hydrologic parameters have been derived only for a few parts of the study area. Misspecification of parameters such as the coefficient of storage, the average drawdown, or the recirculation coefficient may introduce errors when computations are made of declines in water levels, the changes in well capacities, and pumping costs.

These biases can be minimized only if more is known about the hydrology of the study area and a digital simulator of the entire aquifer is available.

Economic Limitations

The growth of irrigation, the quantities of irrigated crops produced, and the depletion of the aquifer all depend on cost price relationships, technological advances and the availability of labor capital, and energy. Assumptions of these factors need to be specified.

The input output coefficients are held constant through the course of the study. Technological advances are possible in plant breeding and water application. Increased yields from successful plant breeding may allow the study area to produce its share of the national supply with less water, therefore depleting the aquifer at a slower rate. Improved efficiency in water application would reduce the projected rate of depletion. Advances in minimum tillage or superior distribution systems would reduce the energy requirements and result in a longer economic life.

The assumed cost and prices will change in future years. If inputs costs increase and/or product prices decrease, the projected economic life of the water resource situations will be overestimated. The converse will be true if input costs decrease and/or product prices increase in the future.

It is assumed there are adequate supplies of labor, capital and energy which may not be the case and may alter the rate of depletion.

Suggestions for Further Research

A linear programming (LP) model is an effective tool to analyze "what if" questions. For instance, if water use was restricted, what would the prediction patterns be? The first suggestion for further research would be to run the model under a number of different scenarios. Price changes, production goals, labor or water restrictions are possible scenarios to be run by themselves or in combination with each other. A sequential decision model should be incorporated to determine optimal withdrawal rates over time under alternative interest rates.

More efficient pumping and distribution of the water to the roots is a research area that both private and public sectors can work on. The goal would be to reduce or eliminate evapotranspiration, seepage tailwater. The research that seems to offer the most promise for the immediate future is the development and refinement of relationships between soil moisture and atmospheric stress, stage of plant growth and development, and the timing and amount of soil moisture from irrigation and rainfall. Economic research needs to be undertaken to determine the feasibility of coal powered electrical engines if natural gas becomes too expensive or limited in supply.

Despite the limitations discussed above, the results of this study provide upper and lower estimates of the economic life of the aquifer. These estimates are useful to irrigators, landowners, businessmen, policy makers and researchers.

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APPENDIX A

CROP ENTERPRISE BUDGETS

DRYLAND WHEAT

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	18.000	54.00	__________
GRAZING	AUMS	0.0	0.350	0.0	__________
TOTAL RECEIPTS				54.00	__________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	0.750	3.34	__________
CROP INSURANCE	DOL.	0.140	15.000	2.10	__________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	__________
CUSTOM HAULING	BU.	0.100	18.000	1.80	__________
FERT. SPREADER	ACRE	1.350	1.000	1.35	__________
NITROGEN (N)	LBS.	0.170	30.000	5.10	__________
PHOSPH (P205)	LBS.	0.140	30.000	4.20	__________
TRACTOR FUEL & LUBE	ACRE			1.28	__________
TRACTOR REPAIR COST	ACRE			0.71	__________
EQUIP. REPAIR COST	ACRE			0.35	__________
TOTAL OPERATING COST				28.72	__________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				25.28	__________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	13.086	1.31	__________
TRACTOR INVESTMENT		0.100	11.170	1.12	__________
EQUIPMENT INVESTMENT		0.100	10.940	1.09	__________
TOTAL INTEREST CHARGE				3.52	__________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				21.76	__________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.45	__________
EQUIPMENT	HR.			1.78	__________
TOTAL OWNERSHIP COST				3.24	__________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				18.52	__________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.484	1.70	__________
TOTAL LABOR COST			0.484	1.70	__________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				16.83	__________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	__________
LAND TAXES	ACRE			0.0	__________
TOTAL LAND CHARGE				0.0	__________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				16.83	__________

HENDERSON,MAPP

WHEAT, SURFACE IRRIGATION
8" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	39.000	117.00	________
GRAZING	AUMS	0.0	0.500	0.0	________
TOTAL RECEIPTS				117.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	________
NITROGEN (N)	LBS.	0.170	53.000	9.01	________
CROP INSURANCE	DOL.	0.140	42.000	5.88	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	19.000	1.61	________
CUSTOM HAULING	BU.	0.100	39.000	3.90	________
TRACTOR FUEL & LUBE	ACRE			3.39	________
TRACTOR REPAIR COST	ACRE			1.89	________
EQUIP. REPAIR COST	ACRE			1.03	________
TOTAL OPERATING COST				39.66	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				77.34	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	16.221	1.62	________
TRACTOR INVESTMENT		0.100	29.697	2.97	________
EQUIPMENT INVESTMENT		0.100	26.428	2.64	________
TOTAL INTEREST CHARGE				7.23	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				70.10	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.87	________
EQUIPMENT	HR.			4.30	________
TOTAL OWNERSHIP COST				8.17	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				61.93	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.288	4.51	________
OTHER LABOR	HR.	3.500	1.170	4.09	________
TOTAL LABOR COST			2.458	8.60	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				53.33	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				53.33	________

HENDERSON, MAFP

WHEAT, SURFACE IRRIGATION
12" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	46.000	138.00	________
GRAZING	AUMS	0.0	1.000	0.0	________
TOTAL RECEIPTS				138.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	________
NITROGEN (N)	LBS.	0.170	94.000	15.98	________
CROP INSURANCE	DOL.	0.140	52.000	7.28	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	26.000	2.21	________
CUSTOM HAULING	BU.	0.100	46.000	4.60	________
TRACTOR FUEL & LUBE	ACRE			3.39	________
TRACTOR REPAIR COST	ACRE			1.89	________
EQUIP. REPAIR COST	ACRE			1.03	________
TOTAL OPERATING COST				49.33	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				88.67	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	22.263	2.23	________
TRACTOR INVESTMENT		0.100	29.697	2.97	________
EQUIPMENT INVESTMENT		0.100	26.428	2.64	________
TOTAL INTEREST CHARGE				7.84	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				80.83	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.87	________
EQUIPMENT	HR.			4.30	________
TOTAL OWNERSHIP COST				8.17	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				72.66	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.288	4.51	________
TOTAL LABOR COST			1.288	4.51	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				68.15	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				68.15	________

HENDERSON,MAPP

WHEAT, SURFACE IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	55.000	165.00	________
GRAZING	AUMS	0.0	1.000	0.0	________
TOTAL RECEIPTS				165.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	________
NITROGEN (N)	LBS.	0.170	120.000	20.40	________
CROP INSURANCE	DOL.	0.140	52.000	7.28	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	35.000	2.97	________
CUSTOM HAULING	BU.	0.100	55.000	5.50	________
TRACTOR FUEL & LUBE	ACRE			3.39	________
TRACTOR REPAIR COST	ACRE			1.89	________
EQUIP. REPAIR COST	ACRE			1.03	________
TOTAL OPERATING COST				55.41	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				109.59	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	25.946	2.59	________
TRACTOR INVESTMENT		0.100	29.697	2.97	________
EQUIPMENT INVESTMENT		0.100	26.428	2.64	________
TOTAL INTEREST CHARGE				8.21	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				101.38	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.87	________
EQUIPMENT	HR.			4.30	________
TOTAL OWNERSHIP COST				8.17	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				93.21	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.288	4.51	________
TOTAL LABOR COST			1.288	4.51	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				88.70	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				88.70	________

HENDERSON,MAPP

DRYLAND GRAIN SORGHUM

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	11.000	42.02	
SORGHUM STUBBLE	AUMS	0.0	0.750	0.0	
TOTAL RECEIPTS				42.02	
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	3.000	1.44	
NITROGEN (N)	LBS.	0.170	41.000	6.97	
INSECTICIDE	ACRE	6.500	1.000	6.50	
CROP INSURANCE	DOL.	0.080	30.000	2.40	
CUSTOM COMBINE	CWT.	0.300	11.000	3.30	
TRACTOR FUEL & LUBE	ACRE			1.88	
TRACTOR REPAIR COST	ACRE			1.15	
EQUIP. REPAIR COST	ACRE			0.56	
TOTAL OPERATING COST				24.20	
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				17.82	
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	7.070	0.71	
TRACTOR INVESTMENT		0.100	17.987	1.80	
EQUIPMENT INVESTMENT		0.100	12.081	1.21	
TOTAL INTEREST CHARGE				3.71	
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				14.11	
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			2.34	
EQUIPMENT	HR.			1.97	
TOTAL OWNERSHIP COST				4.31	
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				9.80	
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.894	3.13	
TOTAL LABOR COST			0.894	3.13	
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				6.67	
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	
LAND TAXES	ACRE			0.0	
TOTAL LAND CHARGE				0.0	
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				6.67	

HENDERSON,MAPP

GRAIN SORGHUM, SURFACE IRRIGATION
6" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	26.000	99.32	________
SORGHUM STUBBLE	AUMS	0.0	0.500	0.0	________
TOTAL RECEIPTS				99.32	________
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	3.000	1.44	________
NITROGEN (N)	LBS.	0.170	50.000	8.50	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
HERBICIDE	ACRE	8.000	1.000	8.00	________
CROP INSURANCE	DOL.	0.080	49.000	3.92	________
CUSTOM COMBINE	CWT.	0.300	26.000	7.80	________
TRACTOR FUEL & LUBE	ACRE			3.71	________
TRACTOR REPAIR COST	ACRE			2.07	________
EQUIP. REPAIR COST	ACRE			1.23	________
TOTAL OPERATING COST				43.17	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				56.15	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	13.489	1.35	________
TRACTOR INVESTMENT		0.100	32.468	3.25	________
EQUIPMENT INVESTMENT		0.100	25.502	2.55	________
TOTAL INTEREST CHARGE				7.15	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				49.01	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.23	________
EQUIPMENT	HR.			4.15	________
TOTAL OWNERSHIP COST				8.38	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				40.63	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.408	4.93	________
TOTAL LABOR COST			1.408	4.93	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				35.70	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				35.70	________

HENDERSON,MAPP

DRYLAND GRAIN SORGHUM

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	11.000	42.02	__________
SORGHUM STUBBLE	AUMS	0.0	0.750	0.0	__________
TOTAL RECEIPTS				42.02	__________
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	3.000	1.44	__________
NITROGEN (N)	LBS.	0.170	41.000	6.97	__________
INSECTICIDE	ACRE	6.500	1.000	6.50	__________
CROP INSURANCE	DOL.	0.080	30.000	2.40	__________
CUSTOM COMBINE	CWT.	0.300	11.000	3.30	__________
TRACTOR FUEL & LUBE	ACRE			1.88	__________
TRACTOR REPAIR COST	ACRE			1.15	__________
EQUIP. REPAIR COST	ACRE			0.56	__________
TOTAL OPERATING COST				24.20	__________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				17.82	__________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	7.070	0.71	__________
TRACTOR INVESTMENT		0.100	17.987	1.80	__________
EQUIPMENT INVESTMENT		0.100	12.081	1.21	__________
TOTAL INTEREST CHARGE				3.71	__________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				14.11	__________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			2.34	__________
EQUIPMENT	HR.			1.97	__________
TOTAL OWNERSHIP COST				4.31	__________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				9.80	__________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.894	3.13	__________
TOTAL LABOR COST			0.894	3.13	__________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				6.67	__________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	__________
LAND TAXES	ACRE			0.0	__________
TOTAL LAND CHARGE				0.0	__________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				6.67	__________

HENDERSON,MAPP

GRAIN SORGHUM, SURFACE IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	46.000	175.72	________
SORGHUM STUBBLE	AUMS	0.0	1.200	0.0	________
TOTAL RECEIPTS				175.72	________
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	10.000	4.80	________
NITROGEN (N)	LBS.	0.170	91.000	15.47	________
NITROGEN (N)	LBS.	0.170	22.000	3.74	________
HERBICIDE	ACRE	8.000	1.000	8.00	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
CROP INSURANCE	DOL.	0.080	80.000	6.40	________
CUSTOM COMBINE	CWT.	0.300	46.000	13.80	________
TRACTOR FUEL & LUBE	ACRE			3.35	________
TRACTOR REPAIR COST	ACRE			2.04	________
EQUIP. REPAIR COST	ACRE			1.59	________
TOTAL OPERATING COST				65.69	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				110.03	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	21.141	2.11	________
TRACTOR INVESTMENT		0.100	32.003	3.20	________
EQUIPMENT INVESTMENT		0.100	29.180	2.92	________
TOTAL INTEREST CHARGE				8.23	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				101.80	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.17	________
EQUIPMENT	HR.			4.82	________
TOTAL OWNERSHIP COST				8.99	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				92.81	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.591	5.57	________
TOTAL LABOR COST			1.591	5.57	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				87.24	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				87.24	________

HENDERSON,MAPP

GRAIN SORGHUM, SURFACE IRRIGATION
24" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	55.000	210.10	________
SORGHUM STUBBLE	AUMS	0.0	1.400	0.0	________
TOTAL RECEIPTS				210.10	________
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	10.000	4.80	________
NITROGEN (N)	LBS.	0.170	125.000	21.25	________
NITROGEN (N)	LBS.	0.170	28.000	4.76	________
HERBICIDE	ACRE	8.000	1.000	8.00	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
CROP INSURANCE	DOL.	0.080	80.000	6.40	________
CUSTOM COMBINE	CWT.	0.300	55.000	16.50	________
TRACTOR FUEL & LUBE	ACRE			3.35	________
TRACTOR REPAIR COST	ACRE			2.04	________
EQUIP. REPAIR COST	ACRE			1.59	________
TOTAL OPERATING COST				75.19	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				134.91	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	24.286	2.43	________
TRACTOR INVESTMENT		0.100	32.002	3.20	________
EQUIPMENT INVESTMENT		0.100	29.180	2.92	________
TOTAL INTEREST CHARGE				8.55	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				126.36	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.17	________
EQUIPMENT	HR.			4.82	________
TOTAL OWNERSHIP COST				8.99	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				117.37	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.591	5.57	________
TOTAL LABOR COST			1.591	5.57	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				111.80	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				111.80	________

HENDERSON,MAPP

DRYLAND BARLEY

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
BARLEY	BU.	2.160	25.000	54.00	________
GRAZING	AUMS	0.0	0.350	0.0	________
TOTAL RECEIPTS				54.00	________
OPERATING INPUTS:					
BARLEY SEED	BU.	4.100	0.670	2.75	________
CROP INSURANCE	DOL.	0.140	15.000	2.10	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM HAULING	BU.	0.100	20.000	2.00	________
CUSTOM COMBINE	BU.	0.085	5.000	0.42	________
NITROGEN (N)	LBS.	0.170	30.000	5.10	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			1.28	________
TRACTOR REPAIR COST	ACRE			0.71	________
EQUIP. REPAIR COST	ACRE			0.35	________
TOTAL OPERATING COST				24.56	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				29.44	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	3.277	0.33	________
TRACTOR INVESTMENT		0.100	11.170	1.12	________
EQUIPMENT INVESTMENT		0.100	10.940	1.09	________
TOTAL INTEREST CHARGE				2.54	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				26.91	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.45	________
EQUIPMENT	HR.			1.78	________
TOTAL OWNERSHIP COST				3.24	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				23.67	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.484	1.70	________
TOTAL LABOR COST			0.484	1.70	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				21.97	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				21.97	________

HENDERSON,MAPP

BARLEY, SURFACE IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
BARLEY	BU.	2.160	85.000	183.60	________
GRAZING	AUMS	0.0	1.000	0.0	________
TOTAL RECEIPTS				183.60	________
OPERATING INPUTS:					
BARLEY SEED	BU.	4.100	1.000	4.10	________
NITROGEN (N)	LBS.	0.170	150.000	25.50	________
CROP INSURANCE	DOL.	0.140	50.000	7.00	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	65.000	5.52	________
CUSTOM HAULING	BU.	0.100	85.000	8.50	________
TRACTOR FUEL & LUBE	ACRE			3.39	________
TRACTOR REPAIR COST	ACRE			1.89	________
EQUIP. REPAIR COST	ACRE			1.03	________
TOTAL OPERATING COST				65.43	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				118.17	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	23.660	2.37	________
TRACTOR INVESTMENT		0.100	29.697	2.97	________
EQUIPMENT INVESTMENT		0.100	26.428	2.64	________
TOTAL INTEREST CHARGE				7.98	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				110.19	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.87	________
EQUIPMENT	HR.			4.30	________
TOTAL OWNERSHIP COST				8.17	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				102.01	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.288	4.51	________
TOTAL LABOR COST			1.288	4.51	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				97.51	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				97.51	________

HENDERSON,MAPP

ALFALFA, SURFACE IRRIGATION
33" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
ALFALFA HAY	TONS	58.000	6.500	377.00	__________
TOTAL RECEIPTS				377.00	__________
OPERATING INPUTS:					
1/5 EST. COST	ACRE	84.250	0.200	16.85	__________
INSECTICIDE	ACRE	6.500	0.330	2.14	__________
PHOSPH (P205)	LBS.	0.140	100.000	14.00	__________
INSECTICIDE	ACRE	12.750	1.000	12.75	__________
CUTTING & BALING	BL.	0.550	195.000	107.25	__________
CUSTOM HAULING	BL.	0.200	195.000	39.00	__________
SPREADER RENTAL	ACRE	1.350	1.000	1.35	__________
TRACTOR FUEL & LUBE	ACRE			1.40	__________
TRACTOR REPAIR COST	ACRE			0.91	__________
TOTAL OPERATING COST				195.66	__________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				181.34	__________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	5.837	0.58	__________
TRACTOR INVESTMENT		0.100	13.299	1.33	__________
EQUIPMENT INVESTMENT		0.100	0.0	0.0	__________
TOTAL INTEREST CHARGE				1.91	__________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				179.42	__________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.73	__________
EQUIPMENT	HR.			0.0	__________
TOTAL OWNERSHIP COST				1.73	__________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				177.69	__________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.210	4.23	__________
TOTAL LABOR COST			1.210	4.23	__________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				173.46	__________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	__________
LAND TAXES	ACRE			0.0	__________
TOTAL LAND CHARGE				0.0	__________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				173.46	__________

HENDERSON,MAPP

SPENTM SUBROUTINE ENTERED **********************

CORN, SURFACE IRRIGATION
24" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
CORN	BU.	2.290	130.000	297.70	________
PASTURE	AUMS	0.0	1.400	0.0	________
TOTAL RECEIPTS				297.70	________
OPERATING INPUTS:					
CORN SEED					
0.055 250.000 13.75 ________					
NITROGEN (N)	LBS.	0.170	200.000	34.00	________
PHOSPH (P205)	LBS.	0.140	40.000	5.60	________
HERBICIDE	ACRE	12.000	1.000	12.00	________
INSECTICIDE	ACRE	6.000	1.000	6.00	________
CROP INSURANCE	DOL.	0.120	80.000	9.60	________
CUSTOM COMBINE	BU.	0.350	130.000	45.50	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
INSECTICIDE	ACRE	24.750	0.500	12.38	________
TRACTOR FUEL & LUBE	ACRE			4.22	________
TRACTOR REPAIR COST	ACRE			2.35	________
EQUIP. REPAIR COST	ACRE			1.45	________
TOTAL OPERATING COST				154.70	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				143.00	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	50.236	5.02	________
TRACTOR INVESTMENT		0.100	36.920	3.69	________
EQUIPMENT INVESTMENT		0.100	27.723	2.77	________
TOTAL INTEREST CHARGE				11.49	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				131.52	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.81	________
EQUIPMENT	HR.			4.57	________
TOTAL OWNERSHIP COST				9.37	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				122.14	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.601	5.60	________
TOTAL LABOR COST			1.601	5.60	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				116.54	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				116.54	________

HENDERSON,MAPP

SOYBEANS, SURFACE IRRIGATION
24" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
SOYBEANS	BU.	5.400	35.000	189.00	_________
TOTAL RECEIPTS				189.00	_________
OPERATING INPUTS:					
SOYBEAN SEED	LBS.	0.150	60.000	9.00	_________
PHOSPH (P205)	LBS.	0.140	50.000	7.00	_________
CUSTOM COMBINE	ACRE	12.000	1.000	12.00	_________
CUSTOM HAULING	BU.	0.100	35.000	3.50	_________
HERBICIDE	LBS.	10.000	1.000	10.00	_________
INSECTICIDE	ACRE	6.500	1.000	6.50	_________
TRACTOR FUEL & LUBE	ACRE			3.64	_________
TRACTOR REPAIR COST	ACRE			2.03	_________
EQUIP. REPAIR COST	ACRE			0.86	_________
TOTAL OPERATING COST				54.53	_________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				134.47	_________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	13.916	1.39	_________
TRACTOR INVESTMENT		0.100	31.837	3.18	_________
EQUIPMENT INVESTMENT		0.100	17.048	1.70	_________
TOTAL INTEREST CHARGE				6.28	_________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				128.19	_________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.15	_________
EQUIPMENT	HR.			2.78	_________
TOTAL OWNERSHIP COST				6.92	_________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				121.27	_________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.381	4.83	_________
TOTAL LABOR COST			1.381	4.83	_________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				116.44	_________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	_________
LAND TAXES	ACRE			0.0	_________
TOTAL LAND CHARGE				0.0	_________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				116.44	_________

HENDERSON,MAPP

DRYLAND WHEAT

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	18.000	54.00	________
GRAZING	AUMS	0.0	0.350	0.0	________
TOTAL RECEIPTS				54.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	0.750	3.34	________
CROP INSURANCE	DOL.	0.140	15.000	2.10	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM HAULING	BU.	0.100	18.000	1.80	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
NITROGEN (N)	LBS.	0.170	30.000	5.10	________
PHOSPH (P205)	LBS.	0.140	30.000	4.20	________
TRACTOR FUEL & LUBE	ACRE			1.28	________
TRACTOR REPAIR COST	ACRE			0.71	________
EQUIP. REPAIR COST	ACRE			0.35	________
TOTAL OPERATING COST				28.72	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				25.28	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	13.086	1.31	________
TRACTOR INVESTMENT		0.100	11.170	1.12	________
EQUIPMENT INVESTMENT		0.100	10.940	1.09	________
TOTAL INTEREST CHARGE				3.52	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				21.76	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.45	________
EQUIPMENT	HR.			1.78	________
TOTAL OWNERSHIP COST				3.24	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				18.52	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.484	1.70	________
TOTAL LABOR COST			0.484	1.70	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				16.83	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				16.83	________

WHEAT, CENTER PIVOT IRRIGATION
8" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	37.000	111.00	________
GRAZING	AUMS	0.0	0.500	0.0	________
TOTAL RECEIPTS				111.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	________
NITROGEN (N)	LBS.	0.170	40.000	6.80	________
NITROGEN (N)	LBS.	0.170	24.000	4.08	________
PHOSPH (P205)	LBS.	0.140	27.000	3.78	________
CROP INSURANCE	DOL.	0.140	40.000	5.60	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	17.000	1.44	________
CUSTOM HAULING	BU.	0.100	37.000	3.70	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			1.73	________
TRACTOR REPAIR COST	ACRE			0.97	________
EQUIP. REPAIR COST	ACRE			0.43	________
TOTAL OPERATING COST				42.83	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				68.17	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	17.439	1.74	________
TRACTOR INVESTMENT		0.100	15.172	1.52	________
EQUIPMENT INVESTMENT		0.100	14.087	1.41	________
TOTAL INTEREST CHARGE				4.67	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				63.50	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.98	________
EQUIPMENT	HR.			2.29	________
TOTAL OWNERSHIP COST				4.27	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				59.23	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.658	2.30	________
OTHER LABOR	HR.	3.500	1.170	4.09	________
TOTAL LABOR COST			1.828	6.40	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				52.83	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				52.83	________

HENDERSON,HAPP

WHEAT, CENTER PIVOT IRRIGATION
12" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	44.000	132.00	_________
GRAZING	AUMS	0.0	1.000	0.0	_________
TOTAL RECEIPTS				132.00	_________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	_________
NITROGEN (N)	LBS.	0.170	58.000	9.86	_________
NITROGEN (N)	LBS.	0.170	40.000	6.80	_________
PHOSPH (P205)	LBS.	0.140	31.000	4.34	_________
CROP INSURANCE	DOL.	0.140	50.000	7.00	_________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	_________
CUSTOM COMBINE	BU.	0.085	24.000	2.04	_________
CUSTOM HAULING	BU.	0.100	44.000	4.40	_________
FERT. SPREADER	ACRE	1.350	1.000	1.35	_________
TRACTOR FUEL & LUBE	ACRE			1.73	_________
TRACTOR REPAIR COST	ACRE			0.97	_________
EQUIP. REPAIR COST	ACRE			0.43	_________
TOTAL OPERATING COST				51.87	_________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				80.13	_________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	21.496	2.15	_________
TRACTOR INVESTMENT		0.100	15.172	1.52	_________
EQUIPMENT INVESTMENT		0.100	14.087	1.41	_________
TOTAL INTEREST CHARGE				5.08	_________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				75.06	_________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.98	_________
EQUIPMENT	HR.			2.29	_________
TOTAL OWNERSHIP COST				4.27	_________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				70.79	_________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.658	2.30	_________
TOTAL LABOR COST			0.658	2.30	_________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				68.49	_________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	_________
LAND TAXES	ACRE			0.0	_________
TOTAL LAND CHARGE				0.0	_________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				68.49	_________

HENDERSON,MAPP

WHEAT, CENTER PIVOT IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
WHEAT	BU.	3.000	54.000	162.00	________
GRAZING	AUMS	0.0	1.000	0.0	________
TOTAL RECEIPTS				162.00	________
OPERATING INPUTS:					
WHEAT SEED	BU.	4.450	1.000	4.45	________
NITROGEN (N)	LBS.	0.170	65.000	11.05	________
NITROGEN (N)	LBS.	0.170	48.000	8.16	________
PHOSPH (P205)	LBS.	0.140	49.000	6.86	________
CROP INSURANCE	DOL.	0.140	50.000	7.00	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	34.000	2.89	________
CUSTOM HAULING	BU.	0.100	54.000	5.40	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			1.73	________
TRACTOR REPAIR COST	ACRE			0.97	________
EQUIP. REPAIR COST	ACRE			0.43	________
TOTAL OPERATING COST				58.79	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				103.21	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	24.914	2.49	________
TRACTOR INVESTMENT		0.100	15.172	1.52	________
EQUIPMENT INVESTMENT		0.100	14.087	1.41	________
TOTAL INTEREST CHARGE				5.42	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				97.80	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.98	________
EQUIPMENT	HR.			2.29	________
TOTAL OWNERSHIP COST				4.27	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				93.53	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.658	2.30	________
TOTAL LABOR COST			0.658	2.30	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				91.22	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				91.22	________

HENDERSON,MAPP

GRAIN SORGHUM, CENTER PIVOT IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
MILO	CWT.	3.820	51.000	194.82	________
SORGHUM STUBBLE	AUMS	0.0	1.200	0.0	________
TOTAL RECEIPTS				194.82	________
OPERATING INPUTS:					
GRAIN SORG SEED	LBS.	0.480	8.000	3.84	________
NITROGEN (N)	LBS.	0.170	44.000	7.48	________
NITROGEN (N)	LBS.	0.170	45.000	7.65	________
PHOSPH (P205)	LBS.	0.140	27.000	3.78	________
HERBICIDE	ACRE	8.000	1.000	8.00	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
CROP INSURANCE	DOL.	0.080	80.000	6.40	________
CUSTOM COMBINE	CWT.	0.300	51.000	15.30	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			2.75	________
TRACTOR REPAIR COST	ACRE			1.53	________
EQUIP. REPAIR COST	ACRE			0.83	________
TOTAL OPERATING COST				65.41	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				129.41	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	17.687	1.77	________
TRACTOR INVESTMENT		0.100	24.037	2.40	________
EQUIPMENT INVESTMENT		0.100	14.818	1.48	________
TOTAL INTEREST CHARGE				5.65	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				123.76	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.13	________
EQUIPMENT	HR.			2.46	________
TOTAL OWNERSHIP COST				5.59	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				118.16	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.042	3.65	________
TOTAL LABOR COST			1.042	3.65	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				114.52	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				114.52	________

HENDERSON,MAPP

DRYLAND BARLEY

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
BARLEY	BU.	2.160	25.000	54.00	________
GRAZING	AUMS	0.0	0.350	0.0	________
TOTAL RECEIPTS				54.00	________
OPERATING INPUTS:					
BARLEY SEED	BU.	4.100	0.670	2.75	________
CROP INSURANCE	DOL.	0.140	15.000	2.10	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM HAULING	BU.	0.100	20.000	2.00	________
CUSTOM COMBINE	BU.	0.085	5.000	0.42	________
NITROGEN (N)	LBS.	0.170	30.000	5.10	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			1.28	________
TRACTOR REPAIR COST	ACRE			0.71	________
EQUIP. REPAIR COST	ACRE			0.35	________
TOTAL OPERATING COST				24.56	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				29.44	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	3.277	0.33	________
TRACTOR INVESTMENT		0.100	11.170	1.12	________
EQUIPMENT INVESTMENT		0.100	10.940	1.09	________
TOTAL INTEREST CHARGE				2.54	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				26.91	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.45	________
EQUIPMENT	HR.			1.78	________
TOTAL OWNERSHIP COST				3.24	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				23.67	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.484	1.70	________
TOTAL LABOR COST			0.484	1.70	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				21.97	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				21.97	________

HENDERSON,MAPP

BARLEY, CENTER PIVOT IRRIGATION
18" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
BARLEY	BU.	2.160	85.000	183.60	________
GRAZING	AUMS	0.0	1.000	0.0	________
TOTAL RECEIPTS				183.60	________
OPERATING INPUTS:					
BARLEY SEED	BU.	4.100	1.000	4.10	________
NITROGEN (N)	LBS.	0.170	100.000	17.00	________
PHOSPH (P2O5)	LBS.	0.140	40.000	5.60	________
CROP INSURANCE	DOL.	0.140	50.000	7.00	________
CUSTOM COMBINE	ACRE	8.500	1.000	8.50	________
CUSTOM COMBINE	BU.	0.085	65.000	5.52	________
CUSTOM HAULING	BU.	0.100	85.000	8.50	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
TRACTOR FUEL & LUBE	ACRE			1.73	________
TRACTOR REPAIR COST	ACRE			0.97	________
EQUIP. REPAIR COST	ACRE			0.43	________
TOTAL OPERATING COST				60.70	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				122.90	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	26.208	2.62	________
TRACTOR INVESTMENT		0.100	15.172	1.52	________
EQUIPMENT INVESTMENT		0.100	14.087	1.41	________
TOTAL INTEREST CHARGE				5.55	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				117.35	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.98	________
EQUIPMENT	HR.			2.29	________
TOTAL OWNERSHIP COST				4.27	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				113.08	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	0.658	2.30	________
TOTAL LABOR COST			0.658	2.30	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				110.78	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				110.78	________

HENDERSON,MAPP

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CORN, CENTER PIVOT IRRIGATION
24" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
CORN	BU.	2.290	125.000	286.25	________
GRAZING	AUMS	0.0	1.400	0.0	________
TOTAL RECEIPTS				286.25	________
OPERATING INPUTS:					
CORN SEED					
		0.055	250.000	13.75	________
NITROGEN (N)	LBS.	0.170	170.000	28.90	________
PHOSPH (P205)	LBS.	0.140	50.000	7.00	________
HERBICIDE	ACRE	12.000	1.000	12.00	________
INSECTICIDE	ACRE	6.000	1.000	6.00	________
CROP INSURANCE	DOL.	0.120	80.000	9.60	________
CUSTOM COMBINE	BU.	0.350	125.000	43.75	________
FERT. SPREADER	ACRE	1.350	1.000	1.35	________
INSECTICIDE	ACRE	6.500	1.000	6.50	________
INSECTICIDE	ACRE	24.750	0.500	12.38	________
TRACTOR FUEL & LUBE	ACRE			2.76	________
TRACTOR REPAIR COST	ACRE			1.54	________
EQUIP. REPAIR COST	ACRE			0.96	________
TOTAL OPERATING COST				146.49	________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				139.76	________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	43.549	4.35	________
TRACTOR INVESTMENT		0.100	24.145	2.41	________
EQUIPMENT INVESTMENT		0.100	16.691	1.67	________
TOTAL INTEREST CHARGE				8.44	________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				131.33	________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			3.14	________
EQUIPMENT	HR.			2.77	________
TOTAL OWNERSHIP COST				5.91	________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				125.41	________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.047	3.66	________
TOTAL LABOR COST			1.047	3.66	________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				121.75	________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	________
LAND TAXES	ACRE			0.0	________
TOTAL LAND CHARGE				0.0	________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				121.75	________

HENDERSON,MAPP

ALFALFA, CENTER PIVOT IRRIGATION
33" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
ALFALFA HAY	TONS	58.000	6.500	377.00	__________
TOTAL RECEIPTS				377.00	__________
OPERATING INPUTS:					
1/5 EST. COST	ACRE	88.640	0.200	17.73	__________
INSECTICIDE	ACRE	6.500	0.330	2.14	__________
PHOSPH (P205)	LBS.	0.140	98.000	13.72	__________
INSECTICIDE	ACRE	12.750	1.000	12.75	__________
CUTTING & BALING	BL.	0.550	195.000	107.25	__________
CUSTOM HAULING	BL.	0.200	195.000	39.00	__________
SPREADER RENTAL	ACRE	1.350	1.000	1.35	__________
TRACTOR FUEL & LUBE	ACRE			1.40	__________
TRACTOR REPAIR COST	ACRE			0.91	__________
TOTAL OPERATING COST				196.26	__________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				180.74	__________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	5.767	0.58	__________
TRACTOR INVESTMENT		0.100	13.299	1.33	__________
EQUIPMENT INVESTMENT		0.100	0.0	0.0	__________
TOTAL INTEREST CHARGE				1.91	__________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				178.83	__________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			1.73	__________
EQUIPMENT	HR.			0.0	__________
TOTAL OWNERSHIP COST				1.73	__________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				177.10	__________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.210	4.23	__________
TOTAL LABOR COST			1.210	4.23	__________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				172.87	__________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	__________
LAND TAXES	ACRE			0.0	__________
TOTAL LAND CHARGE				0.0	__________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				172.87	__________

HENDERSON,MAPP

SOYBEANS, CENTER PIVOT IRRIGATION
24" WATER COSTS EXCLUDED

CATEGORY	UNITS	PRICE	QUANTITY	VALUE	YOUR VALUE
PRODUCTION:					
SOYBEANS	BU.	5.400	35.000	189.00	_________
TOTAL RECEIPTS				189.00	_________
OPERATING INPUTS:					
SOYBEAN SEED	LBS.	0.150	60.000	9.00	_________
PHOSPH (P2O5)	LBS.	0.140	50.000	7.00	_________
CUSTOM COMBINE	ACRE	12.000	1.000	12.00	_________
CUSTOM HAULING	BU.	0.100	35.000	3.50	_________
HERBICIDE	LBS.	10.000	1.000	10.00	_________
INSECTICIDE	ACRE	6.500	1.000	6.50	_________
TRACTOR FUEL & LUBE	ACRE			3.64	_________
TRACTOR REPAIR COST	ACRE			2.03	_________
EQUIP. REPAIR COST	ACRE			0.86	_________
TOTAL OPERATING COST				54.53	_________
RETURNS TO LAND,LABOR,CAPITAL,MACHINERY, OVERHEAD,RISK,AND MANAGEMENT				134.47	_________
CAPITAL COST:					
ANNUAL OPERATING CAPITAL		0.100	13.916	1.39	_________
TRACTOR INVESTMENT		0.100	31.837	3.18	_________
EQUIPMENT INVESTMENT		0.100	17.048	1.70	_________
TOTAL INTEREST CHARGE				6.28	_________
RETURNS TO LAND, LABOR, MACHINERY, OVERHEAD, RISK AND MANAGEMENT				128.19	_________
OWNERSHIP COST: (DEPRECIATION, TAXES, INSURANCE)					
TRACTOR	HR.			4.15	_________
EQUIPMENT	HR.			2.78	_________
TOTAL OWNERSHIP COST				6.92	_________
RETURNS TO LAND, LABOR, OVERHEAD, RISK AND MANAGEMENT				121.27	_________
LABOR COST:					
MACHINERY LABOR	HR.	3.500	1.381	4.83	_________
TOTAL LABOR COST			1.381	4.83	_________
RETURNS TO LAND, OVERHEAD, RISK AND MANAGEMENT				116.44	_________
LAND CHARGE OR RENT:					
LAND INVESTMENT	ACRE	0.0	0.0	0.0	_________
LAND TAXES	ACRE			0.0	_________
TOTAL LAND CHARGE				0.0	_________
RETURNS TO OVERHEAD, RISK AND MANAGEMENT				116.44	_________

HENDERSON,MAPP

APPENDIX B

MEAN MONTHLY RAINFALL DISTRIBUTION

TABLE XX

STUDY AREA MEAN MONTHLY PRECIPITATION (1967-78)

Month	Beaver County	Cimarron County	Texas County
Jan	.27	.31	.22
Feb	.78	.38	.43
Mar	1.23	.76	1.27
Apr	1.82	1.36	1.64
May	3.10	2.84	3.87
Jun	3.10	2.10	3.12
Jul	2.90	2.79	2.66
Aug	4.18	2.69	3.35
Sep	1.69	2.01	1.82
Oct	1.18	.90	1.00
Nov	1.43	.84	1.13
Dec	.41	.30	.27
Total	22.09	17.28	20.78

Source: Prepared by Sherri Smith, OSU Agricultural Economics Reference Librarian from U. S. Department of Commerce, Weather Bureau, Climatological Data.

APPENDIX C

PUMPING AND DISTRIBUTION COSTS OF WATER

APPENDIX C

PUMPING AND DISTRIBUTION COSTS OF WATER

Presented here are the parameters used and assumptions built that with the aid of the OSU Irrigation Cost Program determine per acre inch costs for both surface and center pivot irrigation systems.

Every irrigation system contains a well, a pump, an engine, and a distribution system. For each of these components there are fixed costs and variable costs. Fixed costs include depreciation, taxes, insurance, and interest. Variable costs include fuel, lubricant, repairs, and labor.

Fixed Costs

Straight line depreciation is used and it is figured as a function of the initial component cost, acre inches per year, and the expected life of the component. The well is expected to last 20 years. The pump life is 30,000 hours, the bowl life is 8 years, column life is 16 years, and the gearhead life is 15 years. Light industrial engines have a life of 30,000 hours and electrical engines have a life of 75,000 hours, or 25 years, whichever occurs first. Main line below ground plastic pipe have a life of 20 years, aluminum lateral pipe a life of 15 years, and a self propelled lateral a life of 15 years.

The property tax rate is 0.010 and the tax assessment rate is 0.200. The insurance rate is 0.005 and the interest rate is 0.100.

Fixed per acre inch costs attributable to taxes, insurance, and interest are figured as a function of the initial component cost, the relevant rate, and acre inches per year.

Variable Costs

Fuel costs are based on natural gas consumption of 0.0110 million cubic feet per brake horsepower hour and 0.8480 kilowatt hours per brake horsepower hour. Lubrication costs are computed as 15% of the fuel costs for natural gas operations and 0.0005 gallons of lubricant per water horsepower hour for electric engines.

Repair costs are a function of the initial cost of the component, hours used per year, a repair coefficient, and acre inches per year. Engine repair is based upon a repair coefficient of .00007 for repairs per hour per dollar of a natural gas engine purchase price. For electric engines, the repair coefficient is .00001 per hour per dollar of the engine purchase price. Pump repair costs are based upon estimated repair costs equal to 1/2 of the new cost divided by its estimated life of 30,000 hours. Repair costs for surface distribution systems are based on the investment in laterals per hour while center pivot distribution systems repair cost are based on the investment in laterals per year.

Labor requirements for applying water were assumed to be 0.49 hours per acre irrigated with a surface system and 0.065 hours per acre irrigated with a self propelled sprinkler system. Labor requirements were charged at the rate of $3.50 per hour.

Component Costs

Well Costs

The cost per foot for drilling and developing a well is $25.50. All wells are assumed to be developed down to the bedrock; the depth of the well is equal to the depth to the static water level plus the saturated thickness. The 4 deepest wells were cut back either 25 feet (150 ft. depth to water, 450 ft. saturated thickness, and 225 ft. depth to water, 350 ft. saturated thickness), or 50 feet (150 ft. depth to water, 550 saturated thickness, and 225 ft. depth to water, 450 ft. saturated thickness). These exceptions reflect the expectation that irrigators in these water resource situations would find it economical to stop short of developing a well to the bedrock.

Pump Costs

Pump costs were determined from the costs of the various components, column pipes, shafts, bowls, and right angles required to maintain a certain level of well discharge of a given total dynamic head, where TDH is a function of pressure required at the wellhead and the feet of lift. Pressure required at the wellhead is substantially higher for center pivot systems. The feet of lift is determined by the depth to static water level and the average drawdown. The length of the column is assumed to be 85% of the well depth.

Engine Costs

Natural gas light industrial engines are assumed to be the original power unit since more than 90% of the engines in the study area operate on natural gas. Light industrial engines are used because they are considered to be more economical than automotive engines in the long run. Engine sizes and costs are based on the following functions:

WHP = f(TDH, GPM)

BHP = g(WHP, DE, PE)

PHP = h(BHP, derate)

Derate = k(altitude, temperature, and accessories)

where:

WHP = water horsepower

TDH = total dynamic head

GPM = gallons per minute

BHP = brake horsepower

DE = drive efficiency, .97

PE = pump efficiency, .75

PHP = purchase horsepower

Derate = a factor to account for continuous operation, .6

Light industrial natural gas engine costs are assumed to be $55.00 per derated horsepower. Electrical engines are assumed to cost $40.00 per non-derated horsepower.

Distribution Costs

The investment cost of the distribution systems includes the cost of (1) the main line, (2) the lateral lines, and (3) the valves between the two lines.

A surface system has 1320 feet of plastic, 10" diamter, main line below ground pipe at a cost of $2.75 per foot. Eight inch aluminum lateral pipe costs $2.40 per foot and the amount needed is dependent on the acreage irrigated. There are 9 underground valves at a cost of $31.50 per valve.

A center pivot system used 1320 feet of 8" diameter, plastic main line below ground pipe at a cost of $2.25 per foot. There is one underground valve at a cost of $30.10, and the cost of a self-propelled lateral is $30,000.00.

APPENDIX D

PAST CROP PRODUCTION FOR THE

COUNTRY, STATE, AND REGION

TABLE XXI

FIVE CENSUS YEAR CROP PRODUCTION

Crop		1954	1959	1964	1969	1974
	U.S.	983,900,000	1,117,735,000	1,283,371,000	1,442,679,000	1,796,187,000
Wheat	Ok.	70,770,000	90,580,000	96,623,000	121,800,000	134,400,000
Bu.	Pan.	8,800,000	12,433,000	5,291,000	11,279,500	8,815,000
	U.S.	235,575,000	555,441,000	489,796,000	729,919,000	629,222,000
Sorghum	Ok.	6,447,000	18,625,000	14,714,000	26,840,000	22,800,000
Bu.	Pan.	3,403,000	4,752,300	4,856,300	15,119,800	12,180,000
	U.S.	379,254,000	420,203,000	386,059,000	427,055,000	304,112,000
Barley	Ok.	5,035,000	14,190,000	13,156,000	18,900,000	3,360,000
Bu.	Pan.	80,500	532,300	70,300	295,100	158,400
	U.S.	107,834,000	110,976,000	118,778,000	126,026,000	127,143,000
Hay	Ok.	2,766,750	1,864,000	2,450,000	2,998,000	3,087,000
Ton	Pan.	27,825	22,200	23,700	79,400	64,800
	U.S.	56,364,000	63,321,000	71,304,000	75,883,000	74,672,000
Alfalfa	Ok.	1,328,800	747,000	1,144,000	1,680,000	1,564,000
Ton	Pan.	18,666	12,100	14,700	34,800	49,420
	U.S.	2,707,913,000	3,824,598,000	3,484,253,000	4,687,057,000	4,663,631,000
Corn	Ok.	4,012,000	6,592,000	2,548,000	3,224,000	8,008,000
Bu.	Pan.	4,800	56,700	5,000	1,751,200	7,146,900

TABLE XXI (Continued)

Crop		1954	1959	1964	1969	1974
	U.S.	341,075,000	532,899,000	700,921,000	1,133,120,000	1,214,802,000
Soybean	Ok.	192,000	1,566,000	2,040,000	3,468,000	5,037,000
Bu.	Pan.				1,900	6,110

TABLE XXII

SHARES OF PRODUCTION BY CENSUS YEAR

Crop		1954	1959	1964	1969	1974
Wheat	Ok. % U.S.	07.19	08.10	07.52	08.44	07.48
	Pan. % Ok.	12.43	13.72	05.47	09.26	06.55
	Pan. % U.S.	00.89	01.11	00.41	00.78	00.49
Sorghum	Ok. % U.S.	02.73	03.35	03.00	03.67	03.62
	Pan. % Ok.	52.78	25.51	33.00	56.33	53.43
	Pan. % U.S.	01.44	00.85	00.99	02.07	01.93
Barley	Ok. % U.S.	01.32	03.37	03.40	04.42	01.10
	Pan. % Ok.	01.59	03.75	00.53	01.56	04.71
	Pan. % U.S.	00.02	00.12	00.01	00.06	00.05
Hay	Ok. % U.S.	02.56	01.67	02.06	02.37	02.42
	Pan. % Ok.	01.00	01.19	00.96	02.64	02.09
	Pan. % U.S.	00.02	00.02	00.01	00.06	00.05
Alfalfa	Ok. % U.S.	02.35	01.17	01.60	02.21	02.09
	Pan. % Ok.	01.40	01.61	01.28	02.07	03.15
	Pan. % U.S.	00.03	00.01	00.02	00.04	00.06
Corn	Ok. % U.S.	00.14	00.17	00.07	00.06	00.17
	Pan. % Ok.	00.11	00.86	00.19	54.31	89.24
	Pan. % U.S.	00.00	00.00	00.00	00.03	00.15

TABLE XXII (Continued)

Crop		1954	1959	1964	1969	1974
Soybean	Ok. % U.S.	00.05	00.29	00.29	00.30	00.41
	Pan. % Ok.				00.05	00.12
	Pan. % U.S.				00.00	00.00

VITA

David Dunn Henderson

Candidate for the Degree of

Master of Science

Thesis: ANALYSIS OF THE ECONOMIC LIFE OF THE IRRIGATION WATER SUPPLY IN THE OKLAHOMA PANHANDLE

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Buffalo, New York, June 24, 1952, the son of Mr. and Mrs. Donald Henderson.

Education: Graduated from Greece Olympia High School, Rochester, New York, in June, 1970; received Bachelor of Arts degree in Political Science from State University of New York at Albany in May, 1974; completed requirements for Master of Science degree at Oklahoma State University in December, 1979.

Professional Experience: Graduate research assistant, Department of Agricultural Economics, Oklahoma State University, 1978-79.