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T. Zacharias
C.R. Taylor
R.D. Lacewell

Texas Water Resources Institute

Texas A&M University

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Tom Zacharias

C. Robert Taylor

Ronald D. Lacewell

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ABSTRACT

The U.S. Army Corps of Engineers (COE) has proposed a project that would reduce the flow from saline springs and seeps within the groundwater alluvium of the Red River Basin. While the amount of salts moving through the alluvium would be controlled by the project, total water quantity would not be appreciably affected. Presently, salinity levels in the basin are quite high, making irrigated agriculture an infeasible alternative. In areas affected by salinity, salts accumulate in the active root zone, thereby restricting the availability of soil moisture to the crop and reducing yield. To counteract the deleterious presence of the salts, extra irrigation water is applied to "leach" the salts below the active root zone thus maintaining the yield at some specified level.

Waters containing over 13,000 parts per million (ppm) salts have been sampled by the COE in the Pease River watershed (a subsector of the entire area to be impacted by the project). It is estimated that installation of the project would reduce this level to approximately 3000 ppm. Although 3000 ppm is not below the tolerance threshold of most plants, rainfall in the area is sufficient to act as a natural leaching agent.

The purpose of this study was to estimate the response of the agricultural sector to the project. A recursive linear program was designed in such a manner that the time path of producer

adjustments to the reclaimed water source could be estimated. The Pease River watershed was chosen due to the sizable reduction in the salinity due to the proposed project, relative to other areas within the basin. By considering only a single watershed, the adoption process could be more closely studied. Two scenarios were considered in the analysis in an attempt to better understand the effects of the initial assumptions on the measure of project benefits. The first scenario applied guidelines established by the Water Resources Council (WRC). WRC guidelines required the use of OBERS SERIES E' yield projections, normalized prices, and an interest rate of 7.125 percent to discount future costs and benefits. The second scenario applied in alternative criteria, which assumed no trend in yield, a three-year average of current prices, and a real interest rate of 2.5 percent.

Since probabilistic estimates indicating the improvement in water quality through time were unavailable from the COE, it was assumed that all improvement in water quality occurred linearly over time, with full water quality improvement in the tenth year. The adjustment process was then evaluated over a twenty year horizon. Several irrigation strategies were considered for each crop, thereby allowing the model to select an optimal leaching policy given the level of water quality for any point in time. The linear programming model maximized expected net returns from representative crop enterprises on the basis of a three-year moving average of past actual yields. This means expected yield in the linear programming model was slightly less than actual yield for any particular year. When all improvements in water quality had taken place and the model achieved steady state, the economically optimal allocation of the water resource had been determined.

Results from the study indicated that a policy of rapid adoption should be undertaken. In the initial year, a 40 percent leaching fraction was economically feasible on limited acreage. Dryland production then shifted quickly to irrigation as water quality improved. Water use also shifted, moving from a 40 percent to a 20 percent leaching fraction. By the ninth year of the analysis, all adjustments had occurred and a 10 percent leaching fraction was economically optimal on all irrigated acreage. Due to its profitability and relative salt tolerance, cotton was the only irrigated activity chosen by the model. An optimal cropping pattern of 55,121 acres of irrigated cotton, 14,437 acres of dryland cotton and 7,728 acres of native pasture was selected by the model under the first scenario. For the second, scenario, the optimal cropping pattern consisted of 55,703 acres of irrigated cotton and 25,583 acres of dryland alfalfa. The estimated net present value of benefits attributable to the project over the 20 year planning horizon was approximately $16 million and $30 million for the first and second scenarios, respectively.

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CHAPTER I

INTRODUCTION

Problem Statement

One-third of the world's irrigable land is faced with the potential accumulation of harmful salts in both its soil and water resources. The Middle East, parts of the Soviet Union, and the Southwestern United States are some of the major areas affected by salinity (Fleck and Howe, 1979). Early civilizations dependent upon irrigation were also affected. Areas such as the Tigris and Euphrates River Valleys were reported to have become unproductive and consequently abandoned due to the accumulation of deleterious salts (Peterson, 1970). Presently, there are several regions in Texas that face a salinity problem. Salinity is a particularly serious problem in the El Paso Valley, the Trans-Pecos, the Lower Rio Grande Valley, and the Red River Basin. Attention was focused on the Red River area in the late fifties through the efforts of the Public Health Service (PHS). A study by the PHS revealed that chloride and sulfate salts were the major sources of natural pollution in the basin. It was estimated that 3300 tons of salts enter Lake Texoma on a daily basis, 1100 tons of this was brine from local oil field activity (Corps of Engineers).

Natural salts in the Red River Basin come from springs located in the upper reaches of the basin above Texoma. Because the salt springs could be readily identified, the U.S. Army Corps of Engineers (COE) designed a proposed project which would substantially curtail the harmful flow from these springs. At the same time, the quantity of water within the basin would not be appreciably affected. Final authorization for the project was completed in 1970 under Public Law 91-611 (P.L. 91-611).

Objectives

The purpose of this study is to estimate the agricultural benefits attributable to the salinity control project in the Pease River area, which is a subsector of the basin that would be impacted by the project. This will be accomplished by the following.

(1) A recursive linear programming model will be constructed which considers irrigable land in three, one-half mile zones on each side of the Pease River exclusive of the immediate floodplain. This model will determine an optimal cropping pattern for the area given present water quality and quantity.

(2) By allowing for the change in water quality through time due to the project, the model will be used to determine the optimal irrigation adoption policy for the watershed and subsequently determine the optimal cropping pattern for land now irrigated as well as potentially irrigable land in the area once all adjustment to the project have been made.

(3) Results from the with and without project analyses will then be used to measure project benefits.

Use of normative economic tools such as linear programming models (LP) are appropriate for this type of analysis since these models determine an economically optimal allocation of resources for a given set of objectives and constraints. Several types of studies can be done within the linear programming framework, one type being a macro analysis of the entire watershed as done by Runkles et al. (1980) which estimated aggregate agricultural benefits attributable to the project. However, a micro analysis, which is the focus of this study, can more closely examine some fundamental aspects of the project. For instance, producers' expectations as they adjust to the project can be incorporated into the study. Also, several alternative irrigation strategies can be considered in order to evaluate how rapidly producers adopt irrigation and quantity of irrigation water that would be applied. By considering these features along with varying assumptions about prices, future technology, and discount rates, a better indication of project benefits will be obtained when both the macro and micro studies are combined.

Description of the Project

In its design memorandum, the COE listed three study objectives:

"a. To control stream pollution from each natural source to the degree that the concentration at major downstream check points would not exceed an upper limit of 250 ml/1 (milligrams per liter) of chlorides.

b. To achieve the desired degree of chloride reduction at selected checkpoints along the major streams in terms of specific quality, based on percent of time the water would be usable.

c. To control as much of the natural chloride pollutant as is practical near the source for the most efficient quality improvement" (Corps of Engineers, 1976).

General project control alternatives considered by COE were: (a) a pipeline to the Gulf of Mexico; (b) desalination; (c) importation of water for dilution; and (d) local collection and disposal systems. Based on political, economic, technological, and environmental considerations, the latter alternative was felt to be the most effective means of control. Within this latter alternative, specific options evaluated were: (1) collection by a subsurface wall which would capture salt flows moving through the alluvium; (2) location of a shallow well system within the emission area that would collect salt flows which would then be pumped to the disposal systems; (3) construction of a total impoundment reservoir which could hold the salt flows and runoff expected in a 100-year period, (4) construction of several smaller 100-year capacity impoundments that would receive salts from various sources, and (5) injection into deep wells. To determine the appropriate level of pollution control within the basin, an optimization procedure was developed by COE to evaluate the cost and level of pollution control for the various project alternatives. Results from this procedure indicated that for the Pease River area, a system of shallow wells would be the most efficient from an engineering and economic standpoint (Corps of Engineers, 1976).

Impacts of Salinity

Salts found in most irrigation water come from the continual weathering and erosion processes of the earth's crust. These dissolved salts are comprised of various ions such as potassium, sodium, magnesium, and calcium. Some of these are essential for plant growth, while sodium is not. Unfortunately, sodium and sodium chlorides usually represent the largest proportion of dissolved salts found in irrigation water. Accumulations of salts in the soil is a result of three general situations: (1) salts present in the soil, (2) high groundwater tables, and (3) salts added by irrigation water, the latter being the most serious condition (Longenecker and Lyerly, 1974) in the Pease River area. As saline water is used for irrigation, salts build up in the soil. Evapotranspiration removes only pure water from the soil and plant surfaces, leaving the salts behind.

At first observation, areas seriously affected by salts may have a white crust on high spots in the field or the crop stand may be irregular. The plant itself will be stunted and leaf color will tend toward a bluish-green. If the situation is more accute, soil permeability will be reduced and seed germination will be poor (Longenecker and Lyerly, 1974). Plant are specifically affected in two ways by salinity. First, the plant absorbs saline ions which are toxic to the plant. Second, as salts build up in the root zone, the osmotic pressure between the roots and available soil water shifts, leaving the plant unable to extract water. An inability to extract water from the soil is the most critical effect of salinity on most plants (Maas and Hoffman, 1977). To prevent this accumulation, extra irrigation water is usually applied to "leach" the salts below the active root zone.

Study Area

The entire watershed for the Red River drains some 93,500 square miles. With its headwaters in New Mexico, the Red River crosses Texas, Oklahoma, Arkansas, and eventually flows into the Mississippi River in Louisiana. The Pease River, which runs primarily through Foard, Hardeman, and Wilbarger counties, Texas, drains only about 2,100 square miles. This is an undulating region of fairly level plains and in places, distinctly eroded valleys. Elevation will vary from 1,200 to 1,800 feet above sea level for the three counties. The area is subject to hot humid summers and dry winters with some snow. Annual average high and low temperatures range from 30° to 100°F. The prevailing wind is south south-easterly and for some soils, wind erosion is a problem. Average rainfall is about 24 inches, with most rain falling in the warm season from April to October.

Agribusiness is the predominant economic activity in the study area. Livestock represents a little more than one-half of the region's agricultural income (Texas Department of Agriculture and U.S. Department of Agriculture, Statistical Reporting Service, 1978). Land use is roughly divided into 60 percent range and 40 percent cropland. Cotton, wheat, and grain sorghum are the major field crops. The growing season is approximately 220 days and rainfall is adequate for dryland production in most years. Presently, there is some irrigation, but the majority of cultivated land is in dryland crop production. Only 16,800 acres were irrigated in Foard, Hardeman, and Wilbarger counties (Texas Department of Agriculture and U.S. Department of Agriculture, Statistical Reporting Service, 1978) in 1977. Salinity levels in the Red River Basin are quite high and the use of alluvium water for irrigation is at present not considered economically feasible. In the Pease River area, water containing over 14,000 parts per million (ppm) of total dissolved salts have been sampled (Corps of Engineers, 1976). The proposed project would reduce salinity in this particular watershed to below 3,000 ppm. Although 3,000 ppm is not below the tolerance threshold of most plants, rainfall in the area is sufficient to act as a natural leaching agent.

CHAPTER II

CONCEPTUAL FRAMEWORK

Irrigation and Salinity

The first agronomic phase of the study involved the determination of crop water requirements. The Food and Agriculture Organization (FAO) (Doorenbos and Pruitt, 1977) defines a water requirement as:

> "The depth of water needed to meet the water loss through evapotranspiration of a disease-free crop, growing in large fields under normal non-restricting soil conditions including soil water and fertility and achieving full production under the given growing environment."

Given the difficulty and cost of performing actual field experiments, several methods have been developed to predict water requirements. These estimation techniques are based on the prediction of evapotranspiration of the crop. A few of the more common methods are Blaney-Criddle (1950), Penman (1948), and recently the Ritchie model (1975). Procedures for estimating evapotranspiration incorporate climatic variables such as humidity, wind speed, solar radiation, pan evaporation rates, and an index referencing the stages of crop growth.

As stated in the first chapter, the plant is critically affected by the lack of soil water in the root zone due to salinity concentrations. Those plants able to withstand this are considered salt tolerant. Tolerance is a relative concept dependent upon environmental variables such as soil characteristics and weather. Mass and Hoffman (1977) have completed an extensive search of the literature concerning the experimental work done in relation to plant tolerance. In general, they note three important findings: (1) that plants react to salinity as a function of total soluble salts in the active root zone; (2) that plant yield does not decline substantially until a soil salinity threshold is achieved and at this threshold, yield declines linearly for increases in salinity; and (3) that commercial crop yield is the only relevant criterion for estimating crop tolerance. With the aid of least squares regression the authors quantified this relationship in the following form.

$$(1) \qquad Y = 100 - B(EC_e - A)$$

for $EC_e > A$, where

Y = percentage reduction in relative crop yield,

B = percentage of yield decrease per unit increase in salinity,

A = salinity threshold in millihos per centimeter,

EC_e = soil salinity in millihos per centimeter.[1/]

[1/] EC_e is defined as the electrical conductivity of the soil saturated extract. It is one of the more common methods of determining soil salinity. The measurement is taken by passing on electric current through a saturated soil paste (Richards, 1954).

To maintain yields at any desired level when $EC_e > A$ from equation (2), leaching is required. If no additional water is applied, then soil salinity increases in proportion to the concentration and amount of total salts present in the irrigation water. The above statement should be somewhat qualified since factors such as effective rainfall and ion exchange among soil elements can influence the leaching requirements (Richards, 1954). Ayers and Wescott (1976) have developed the concept of minimal leaching requirements, defined as:

(2) $$LR = EC_w / ECd_w$$

where

- LR = crop leaching requirement as a fraction of consumptive use,
- EC_w = electrical conductivity of the irrigation water in millihos per centimeter.
- ECd_w = maximum salinity of water in the root zone if all soil water were removed by the crop to meet its requirement (Ayers and Wescott, 1976).

A composite EC_w can be calculated using a weighted average of the concentration of the irrigation water and the concentration of effective rainfall (Richards, 1954). Values for EC_e can then be estimated from EC_w, these relationships are also given by Ayers and Wescott (1976).

Admittedly the foregoing discussion has glossed over a voluminous literature concerning salinity. However, implicit in all this is the opportunity on the part of the irrigation manager to choose among several leaching strategies, not necessarily the threshold value which represents a zero decline in yield. Choices among alternative control measures is the economic problem in terms of salinity management involving the determination of an optimal leaching policy to control excessive salinity accumulation over a given planning horizon.

The Analytical Model

It is of interest here to achieve or at least to consider an allocation of the reclaimed water resource by agriculture in an economically optimal framework. Assuming that the region could act as if it were a firm seeking to maximize profits, resource utilization would be such that benefits resulting from the proposed project would be greatest. The assumption regarding profit maximization is critical and open to debate, however, Friedman (1953) feels that the desire to maximize profits or the difference between receipts and expenses is a strong one and those firms that do not adhere to it at least in principle will not survive in any sort of a competitive framework. A further assumption is now made regarding the region's position in the economy or analogously the firm's position in the industry. That is the firm is one of several similar firms, not necessarily homogenous, and that its actions cannot influence factor and product prices.

The technical relationship between factor and product is given by the production function. The critical observation from the production function is that for an increase in an input, other inputs held constant, output increases to some point and at that point, output decreases for further increases in the variable input. Before this point is reached, constant per unit increases in the variable input lead to successively smaller per unit increases in output. This is known as the law of diminishing marginal returns.

In the most general case, the firm is multi-factor and multi-product. Hicks in Value and Capital (1946) gives the conditions for the profit maximizing firm in equilibrium. These are: price equal to marginal cost, which consists of three relationships: (1) the marginal rates of substitution between any two products equals their respective price ratios, (2) the marginal rates of substitution between any two inputs must equal their respective price ratios, (3) the price ratio between a factor and a product must equal the marginal rate of transformation (marginal physical product) between the factor and the product. The final restrictions are known as the stability conditions and require that marginal product is decreasing and average cost is rising. When these conditions are met, no attempt to increase or decrease inputs and outputs can increase the firm's profits. Relating this to benefit-cost analysis, the economist is interested in a resource allocation from a particular project such that the marginal (incremental) cost of increasing output is just equal to the marginal benefit from that increase. However, the traditionally used benefit-cost methodology denies the marginal concept and evaluates projects based on the discounted ratio of benefits to costs.

To perform a marginal analysis of the multi-factor and multi-product firm requires the existence of several production functions relating all possible factor combinations to the various products. These production functions should be continuous and differentiable. In practice this is rarely the case and an alternative procedure must be sought. Given the analytical model so described, the technique of linear programming provides a very effective means of solving such a problem. In relation to traditional marginal analysis, linear programming considers finite production activities or processes which approximate the production function (Dorfman et al. (1958). These activities define the technical relationship among a given set of inputs and a particular output (Boulding and Spivey, 1960). Thus, the firm makes its production decisions by selecting profit maximizing levels of various output processes. The typical linear programming problem takes the following form:

(3) $$\text{maximize } Z = C_1X_1 + C_2X_2 + \ldots + C_nX_n$$

subject to

$$(4) \quad \begin{aligned} a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n &\leq b_1 \\ a_{21}X_1 + a_{22}X_2 + \ldots + a_{2n}X_n &\leq b_2 \\ &\vdots \\ a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n &\leq b_m \end{aligned}$$

and

$$(5) \quad X_j \geq 0 \; ; \quad b_i \geq 0 \; ; \quad a_{ij} \geq 0 \; ;$$

where

$i=1,\ldots m$ = index of resource restrictions,

$j=1,\ldots n$ = index of decision variables or activities,

z = value of the objective function to be maximized,

x_j = decision variables or activities,

C_j = per unit contribution to the objective function,

b_i = level of the resource restriction,

a_{ij} = technical coefficient associated with the amount of the resource (b_i) to produce a unit of X_j.

To solve this system of inequalities, additional variables known as slack variables are introduced and the problem is transformed to a system of m equations and n unknowns. The slack variable has a C_j value of zero and represents the unused portion of the resource. The algorithm used to solve this system is known as the simplex method (Dantzig, 1963). The simplex method iterates on a series of matrix manipulations which are based on the X_j's contribution to the objective function and its resource requirements (a_{ij}).

Returning to concepts presented earlier in this chapter, the application of a linear programming model allows for the approximation of a production function relating saline water to crop yield when no such formal relation has been previously defined. Individual irrigation strategies or processes can be described by the linear program such that optimal resource combinations can be determined.

CHAPTER III

METHODOLOGY

Implementation of the analytical model outlined in Chapter II required the transformation of the agronomic and economic data into a linear programming format. To incorporate the adjustment to improved water quality, an expectations model was formulated in conjunction with the linear programming model. The following sections present a discussion of the procedures involved in the construction of the overall model.

Data Base

Acreage and yield data were obtained from two COE draft reports, one by Grossman and Keith (1980) and the other by Runkles et al. (1980). Soil acreages were delineated into three zones, each one-half mile wide lying beside the river, excluding the immediate floodplain. These zones represented the alluvial area which would be potentially benefited by the project. Table 1 gives acreage by soil type and recommended irrigation practice by soil. For each soil, irrigated and dryland crop yield were reported by Grossman and Keith (see table 2). Crops considered relevant for the Pease River area were cotton, grain sorghum, wheat, alfalfa, coastal bermuda, and native pasture. Yields reported in table 2 reflect high level management conditions (Soil Conservation Service). To

Table 1. Acreages of Pease River Reach Soil Types by Zone and Recommended Irrigation System

Soil	Name[a/]	Irr. Type[b/]	Acres by Zone		
			Zone 1	Zone 2	Zone 3
Abilene	CL	F	0.0	679.0	1428.0
Clairemont	CL	F	460	239.0	464.0
Colorado	CL	F	323.0	77.0	84.0
Hollister	CL	F	0.0	189.0	514.0
Mangum	CL	F	1844.0	667.0	176.0
Quanah	CL	F	25.0	0.0	0.0
Port	CL	F	0.0	0.0	159.0
Sagerton	CL	F	128.0	197.0	416.0
Spur	CL	F	751.0	172.0	703.0
Tillman	CL	F	441.0	679.0	1666.0
Wichita	CL	F	29.0	143.0	66.0
Bukreek	L	F	123.0	65.0	52.0
Sagerton	L	F	106.0	13.0	66.0
Tipton	L	F	57.0	0.0	0.0
Wichita	L	F	273.0	289.0	292.0
Clairemont	SL	F	124.0	53.0	172.0
Colorado	SL	F	445.0	92.0	0.0
Tipton	SL	F	866.0	2935.0	2818.0
Yomont	VFSL	S	3248.0	550.0	298.0
Lincoln	LFS	S	3515.0	2470.0	1743.0
Miles	LFS	S	0.0	670.0	2742.0
Springer	LFS	S	397.0	1875.0	4198.0
Enterprise	VFSL	F,S	6907.0	8433.0	3407.0
Altus	FSL	F,S	0.0	0.0	135.0
Hardeman	FSL	F,S	1418.0	2268.0	2202.0
Miles	FSL	F,S	684.0	3900.0	5210.0

[a/] CL - clay loam; L - loam; SL - silt loam; VFSL - very find sandy loam; LFS - loamy fine sand; FSL - fine sandy loam.

[b/] F - furrow system or surface system; S - sprinkler system.

Source: Grossman and Keith.

Table 2. High Level Management Crop Yields for the Pease River Area by Soil Type

Soil Name	Cotton (lbs)		Grain Sorghum (cwt)		Wheat (bushels)		Alfalfa (ton)		Coastal Bermuda (ton)		Native Pasture (avm)
	Irr.	Dry	Irr.	Dry	Irr.	Dry	Irr.	Dry	Irr.	Dry	Dry
Abilene	775.0	275.0	65.0	0.0	60.0	25.0	0.0	0.0	3.6	0.0	2.6
Clairemont	1000.0	350.0	65.0	22.4	60.0	25.0	0.0	0.0	5.4	0.0	3.4
Colorado	775.0	300.0	65.0	20.0	60.0	25.0	0.0	0.0	4.5	0.0	3.3
Hollister	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	3.6	0.0	2.4
Mangum	700.0	225.0	45.0	14.0	45.0	20.0	0.0	0.0	3.1	0.0	2.9
Quanah	700.0	200.0	56.0	14.0	50.0	20.0	0.0	0.0	4.5	0.0	2.5
Port	725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	4.5	0.0	3.1
Sagerton	700.0	225.0	56.0	14.0	50.0	20.0	0.0	0.0	5.0	0.0	2.6
Spur	725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	5.0	0.0	3.1
Tillman	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	2.2
Wichita	700.0	225.0	56.0	17.0	50.0	20.0	0.0	0.0	3.6	0.0	2.6
Bukreek	750.0	275.0	56.0	17.0	50.0	20.0	0.0	0.0	5.0	0.0	2.7
Sagerion	750.0	250.0	50.0	17.0	50.0	25.0	0.0	0.0	4.5	0.0	2.6
Tipton	800.0	350.0	60.0	25.0	60.0	30.0	0.0	0.0	4.9	0.0	3.7
Wichita	700.0	225.0	56.0	17.0	50.0	20.0	0.0	0.0	3.6	0.0	2.6
Clairemont	1000.0	350.0	65.0	22.4	60.0	25.0	0.0	0.0	5.4	0.0	3.4
Colorado	775.0	300.0	65.0	20.0	60.0	25.0	0.0	0.0	4.5	0.0	3.3
Tipton	800.0	350.0	65.0	25.0	60.0	30.0	0.0	0.0	5.0	0.0	3.7
Yomont	1000.0	350.0	65.0	22.4	60.0	25.0	7.3	2.8	4.9	2.7	3.5
Lincoln	0.0	0.0	0.0	15.0	0.0	20.0	5.0	2.0	2.5	0.0	3.0
Miles	650.0	250.0	42.0	14.0	35.0	15.0	5.5	2.5	3.6	1.8	3.0
Springer	600.0	225.0	42.0	14.0	30.0	15.0	5.0	2.0	3.6	1.6	3.3
Enterprise	750.0	325.0	55.0	20.0	55.0	25.0	6.5	2.5	4.9	2.7	3.1
Altus	650.0	275.0	45.0	17.0	50.0	20.0	7.0	3.0	4.9	2.8	3.7
Hardeman	600.0	250.0	50.0	17.0	40.0	20.0	6.5	2.5	4.5	2.3	3.1
Miles	750.0	275.0	56.0	20.0	50.0	20.0	5.0	2.0	4.9	2.7	2.9

Source: Grossman and Keith.

make yields more representative of existing conditions, the high level management yields were reduced by 15 percent.

Other data in Grossman and Keith (1979) included the relationships between crop yield, water quantity and water quality. Irrigation water requirements were computed as the difference between a crop's consumptive use and the amount of effective rainfall within the growing season. The procedure used in determining consumptive use for this study was developed by McDaniels (1960). Table 3 gives irrigation water requirements for the various leaching fractions.

The effect of salinity on the various crops was expressed as a percentage reduction in yield. Estimation of crop yield reduction required the conversion from EC_w (salinity of alluvium water) to that of EC_e (soil salinity). Factors of 2.05, 1.5, 1.1, and 0.9 were multiplied by EC_w to obtain soil salinity values for the 10, 20, 30 and 40 percent leaching fractions, respectively (Ayers and Wescott, 1976). Once these EC_e values were estimated, equations such as the one presented in Chapter II were used to determine the yield reduction due to salinity. Table 4 gives the equations by crop used for this analysis.

Leaching requirements were a function of consumptive use and the amount of effective rain not falling in the growing season.

(8) $$LR = (CU * LF) - ER$$

where

Table 3. Crop Irrigation Water Requirements Including the Leaching Requirement

Crop		Irrigation Water Requirements in Acre Inches
Cotton		
	10%	14.0
	20	16.0
	30	18.5
	40	21.1
Grain Sorghum	10%	15.7
	20	16.2
	30	18.7
	40	21.3
Wheat	10%	17.8
	20	21.0
	30	24.0
	40	29.2
Alfalfa	10%	47.8
	20	54.0
	30	60.1
	40	66.2
Coastal Bermuda	10%	41.7
	20	47.2
	30	52.7
	40	58.2

Source: Grossman and Keith.

Table 4. Equations Relating Soil Salinity to the Relative Decline in Yield and the Threshold Level for Representative Crops in the Pease River Area [a]

Crop	Equation [b]	Threshold
Cotton	$Y = 5.21(X) - 40.48$	7.77
Grain Sorghum	$Y = 7.05(X) - 26.83$	3.81
Wheat	$Y = 7.14(X) - 42.86$	6.00
Alfalfa	$Y = 7.42(X) - 15.06$	2.03
Coastal Bermuda	$Y = 5.35(X) - 44.37$	8.29

[a] Source: Ayers and Wescott, 1976.

[b] Y = percentage decline in yield,
X = soil salinity (EC_e) in mmhos/cm.

LR = leaching requirement supplied by irrigation water,

CU = consumptive water use of the crop,

LF = desired leaching fraction,

ER = effective rain not falling in the growing season.

The Model

The model used was a recursive linear programming model that traced out the temporal impacts of improved quality of irrigation water. Its purpose was to maximize expected annual benefits for each individual period in the analysis. Benefits to the project were the net revenues from irrigated crop enterprises, exclusive of any present use or anticipated trend in irrigation without the project. An evaluation horizon of twenty years was chosen so that adjustment in the initial periods could be analyzed. It was assumed that the leaching water applied in each period restored the soil profile to its initial condition in the previous year. For the first ten years water quality was assumed to increase at a rate proportional to that of the control level specified by the COE. At the end of the tenth year, all water quality improvement was assumed to have taken place. This assumption was made for the following reasons: (1) it was unrealistic to expect the alluvial water to improve instantaneously; and (2) even if this were so, it was even more unreasonable to expect producers to adopt irrigation technology instantaneously.

Consideration of several leaching strategies ranging from 10 percent to 40 percent allowed the economic nature of the adjustment process to be modeled. Through time, the model selected those activities which maximized expected net revenues. Improvements in actual returns updated the information available within the system such that producers would adopt irrigation if it became profitable. As the model achieved steady state and all adjustment had occurred, an optimal irrigation policy could be determined.

The recursive nature of the model was due to: (a) the annual improvement in water quality and its effect on producers' expectations of yield; and (b) the conversion of native pasture to cropland on an annual basis. Given an initial estimate of current cropland in the first period, the model transferred range to cropland as it became economically feasible to do so.

Two scenarios were considered in the analysis in order to illustrate the effects of alternative interest rates and yield trends on project benefits. The first scenario applied guidelines set by the Water Resource Council (WRC) and can be considered as an "obligation of contract." Results from this scenario can be interpreted as a direct measure of benefits mandated by the WRC in the evaluation of water resource development projects. WRC guidelines required the use of: (1) OBERS SERIES E' yield projections; (2) state average prices reported in Agricultural Price Standards; and (3) an interest rate of 7.125 percent of discounting future benefits and costs and charging interest on operating capital.

The second scenario applied another set of criteria felt to be more appropriate than the federal standards. In the case of yield projections, OBERS results in unreasonable estimates for the region. A base yield of 250 pounds for dryland cotton trends to 383 pounds in the 20th period of the analysis, which was approximately a 50 percent increase in yield (the OBERS national trend value for cotton was 6.67 pounds of lint per year). Time series analysis for the previous ten years indicated no such regional trend, consequently the second scenario assumed no trend in yield (Texas Department of Agriculture and U.S. Department of Agriculture, Statistical Reporting Service, 1978; Richardson, 1979). With respect to the prices used, a regional three-year average price (1976-1978) was felt to be more representative than the statewide five year average price (1973-1977) reported in Agricultural Price Standards.

To discount future benefits to their present value, an interest rate of 2.5 percent was used for the second scenario. Given the current inflationary experience, the lower rate more nearly reflects a real rate of interest when the market rate is net of inflation. Also, a lower rate serves to counter society's myopic tendencies. Both Mishan (1971) and Dasgupta and Pearce

(1972) argue that government should serve as a "guardian of the future" and prevent society from discounting future wealth at too high of an interest rate. To adequately reflect current production expenses, a 12 percent interest rate was selected for interest on operating capital.

Each scenario required the development of a benchmark model, which was based on present salinity levels (without project conditions) and no future change in water quality. These "with" and "without" analyses were then used to net out dryland crop production and irrigation that would have taken place regardless of the project. The differences between the with and without net returns was the net benefit attributable to the project.

Expectations Model

The linear programming model was based on the assumption that producers in the region maximized their expected net revenues. It was assumed that dryland crop net revenues were known with perfect certainty, i.e., expected revenues equaled actual revenues. Although dryland crop yields traditionally have greater variability than irrigated yields, the purpose here was to analyze the effects of water quality improvement on a regional level rather than be concerned with yield variability per se. Given this objective, the expectations model served two purposes: (1) it allowed production decisions to be based on past information; and (2) it gave the model an implicit adoption policy for using the cleaner water based on an economic criterion.

Actual irrigated yields without trend were assumed to reflect without project conditions then increase at a rate proportional to that of the final control level:

$$(6) \qquad Y_{i,t} = [(wo_i + (\frac{wp_i - wo_i}{10})) * (t-1)] * BASE$$

where

i = leaching fraction subscript for $i = 1, \ldots, 4$,

t = year subscript for $t = 1, \ldots, 20$,

wo_i = without project percentage yield reduction for leaching fraction i,

wp_i = with project percentage yield reduction for leaching fraction i,

BASE = base yield for any irrigated activity.

In the case of trend,

$$(7) \qquad Y_{i,t} = [(wo_i + (\frac{wp_i - wo_i}{10}) * (t-1)] * (BASE + TREND * (t-1))$$

where

TREND = OBERS trend value.

Expected yields were assumed to be a three-year moving average of past actual values which was consistent with the assumption of a three-year average price mentioned earlier. Such a mechanism allowed the producer to observe the water quality phenomenon, update his information set and react accordingly. The expected values were simply characterized by

$$(8) \qquad E(Y_{i,t}) = (Y_{i,t-1} + Y_{i,t-2} + Y_{i,t-3})/3$$

where E is the expectations operator.

Additional assumptions were required in the initial periods of the analysis since there were no historical values upon which expectations of this sort could be based. In the first year, the expected value was assumed to be the reduction for without project conditions.

$$(9) \qquad E(Y_{it=1}) = BASE * wo_i \, .$$

The expected value for the second year was assumed to be:

$$(10) \qquad E(Y_{i,t=2}) = [(wo_i + (\frac{wp_i - wo_i}{10})) * (2-1)] * BASE$$

for the case of no trend in yield.

Third year expectations were the average of the two previous year's actual values, after which the three-year moving average came into effect.

The Linear Programming Model

The Objective Function

In the linear programming model, the objective function consisted of the expected net revenues for the various crop enterprises, defined as the difference between expected gross revenue and actual production cost excluding land rent. Expected gross revenues were the product or price and expected yield. For cotton, grain sorghum, and wheat the model calculated the total revenues for the joint products of these crops. Lint and seed were the joint products of cotton. Livestock grazing was the joint product of both grain sorghum and wheat. For grain sorghum, fixed factors of 0.2 and 0.3 were multiplied by the animal unit (AUM) price for dryland and irrigated activities, respectively. The "graze-out" yield of wheat was assumed to be 0.0746 of the expected grain yield. Total revenue for native pasture was an AUM yield multiplied by the AUM price.

Yields and Prices

Yield trend values were only applied to cotton, grain sorghum, and wheat according to OBERS projections. Trend values are presented in table 5. Prices were to be held constant throughout the evaluation horizon in order to allow the model to respond to changes in yield. Table 6 reports the prices used in the study.

Table 5. OBERS SERIES E' TREND Projections for the Crops Considered in the Analysis

Crop	Annual Trend Estimate
Cotton	6.67 lbs.
Grain Sorghum	1.12 bushels
Wheat	0.33 bushels
Alfalfa	--
Coastal Bermuda	--
Native Pasture	--

Table 6. Crop Prices Used in the Analysis

	Scenario I	Scenario II
Cotton Lint	$0.50/lb.	$0.54/lb.
Cotton Seed	86.12/ton	96.00/ton
Grain Sorghum	3.70/cwt	3.54/cwt
Wheat	2.35/bu.	2.72/bu.
Alfalfa Hay	50.29/ton	57.67/ton
Coastal Bermuda Hay	50.29/ton	57.67/ton
Native Pasture (in Avms)	8.24/Aum	8.24/Aum

Costs

Costs were the summation of all relevant non-land costs incurred by the producer. To account for cost differences due to yield, soil type, irrigation strategy, type of irrigation system, and location in the alluvial zone, it was necessary to modify a set of base budgets. (The set of base budgets used is presented in Appendix A (Texas Agricultural Extension Service, 1980; Jobes, 1979).) Costs falling into the aforementioned categories include: (1) fertilizer cost, variable irrigation cost, and interest on operating capital, (2) per acre harvest cost associated with yield, and (3) per acre irrigation fixed costs. Preharvest variable costs include seed, herbicide, insecticide, crop insurance, labor, and tractor and field machinery use. Items such as herbicide, insecticide, and crop insurance vary by crop. Due to the complexity of the cost component, a FØRTRAN computer program was written to compute net revenues. A description of the program will be given in a later section.

To properly evaluate project benefits, land rent was excluded from the cost calculations. Since the payment of all factors of production except for land was considered, the difference between revenues and costs determined the returns to the fixed factor, land. Benefits attributable to the project were then the increased returns to the land as captured by the landowners.

Total Cost Component

This section presents an example of the total cost computation used in the model. Included in this computation were all variable and fixed costs along with the appropriate interest rates and management charges. Using cotton as an example, equations (11) through (13) represent the total cost component.

(11) CTVC = (CIPVC + CFREQ + Z1FVC) * RATE + (CAHC * YCØT/cwt) + (CYHC * YCØT/BALE)

where

CTVC = per acre total variable cost for cotton,

CIPVC = per acre preharvest variable cost excluding fertilizer and irrigation,

CFREQ = per acre total fertilizer cost,

Z1FVC = per acre variable irrigation cost where Z1F denotes a furrow system in the first zone,

RATE = interest on operating capital; which is one-half the annual rate,

CAHC = cost per hundredweight for stripping and hauling,

CYHC = cost per bale for ginning, bags, and ties.

(12) CTFC = CIFC + Z1FFC

where

CTFC = per acre total fixed cost excluding management charges on total variable cost,

CIFC = per acre tractor and field machinery fixed cost,

Z1FFC = per acre fixed irrigation cost for a furrow system in the first zone.

(13) $$CTTC = CTVC * RMGT + CTVC + CTFC$$

where

CTTC = per acre total cost for cotton,

RMGT = interest rate on management charge (10 percent).

Similar calculations were made for the other crops. The total cost computation was the same for dryland activities except for the omission of irrigation cost.

Fertilizer Costs

Fertilizer rates were based on nutrient requirement recommendations provided by Welch, Gray, and Anderson, (1978). These recommendations are based on expected yield levels. Within the range of specified yields, a fertilizer recommendation was given by interpolating between these values and computing a slope coefficient, a total requirement for each of the major plant nutrients (N-P-K) was derived. Total requirements were then multiplied by the per pound price of each fertilizer to obtain total fertilizer costs. For example, the yield ranges in the fertilizer recommendation tables for cotton were 0 to 480, 480 to 960, and 960 to 1440. Slope coefficients for nitrogen were 0.125, 0.083, and 0.083 for the three yield ranges. The following equation was used to compute nitrogen fertilizer costs for a cotton yield of 1000 pounds.

(14) FREQ = [(480 * .125) + ((960 - 480) * .083)
+ ((1000 - 960 * .083)] * PNIT

where

FREQ = total cost of nitrogen fertilizer applied,

PNIT = per pound price of nitrogen fertilizer.

This computation was made for each crop yield and each type of fertilizer. A table of slope coefficients and fertilizer prices is presented in Appendix A.

Harvest Costs

The FØRTRAN program computed all harvest costs attributable to yield for the applicable crops. In most cases this calculation was simply the custom rate multiplied by the yield. A flat rate of custom combining was in effect for low yielding grain sorghum and wheat crops. As yields increased, variable rates then became effective. (The various custom harvest rates are presented in Appendix A as part of the base budgets.)

Irrigation Costs

Currently there is very little irrigation cost data for the region. Some information was available in existing budgets, but this was inadequate given the emphasis of the study on water use. The Oklahoma State University Cost Program developed by Kletke, Mapp, and Harris (1978) seemed to fill this need for more detailed irrigation cost data. The Irrigation Cost Program is a FØRTRAN computer program that calculates fixed and variable costs on a per acre or per acre inch basis. Input to the program is such that the user can specify parameters for a particular type of irrigation system. The program considers four irrigation systems: center pivot, side-move sprinkler, and hand-move sprinkler, and surface systems. System parameters include items such as application rates, field size, depth of well, type of fuel, fuel cost, labor, type of motor, etc. Specific data input to the program was obtained through interviews with agricultural engineers and area experts.[2/] It was the opinion of these specialists that the side-move sprinkler and surface systems would be the "most-likely" systems for the region. On looser soils, a sprinkler system was considered the only feasible system. For tight soils, which tend to have more of a salinity problem, the surface system was considered as the only feasible system, while for soils of intermediate texture, both were considered. To account for the cost

2/ Personal interview with Wayne Keese, 12 October 1979 and with Dan Reddell, 4 December 1979.

of moving water across the alluvial zones, the program was modified by extending the length of the mainline. Efficiency factors were also derived for the two systems. It was assumed there would be 15 and 25 percent system losses for the side-move and surface systems, respectively.

For greater efficiency in the calculation of net revenues in the main program, it was felt that continuous irrigation cost functions would be more desirable than point costs at discrete application rates. To accomplish this, the cost program was run for application rates ranging from 3 acre inches to 42 acre inches at 3 acre inch intervals. Ordinary least squares regression (OLS) was then used to fit a quadratic function to these generated points. Results from these regressions are presented in tables 7 and 8. Separate functions for fixed and variable irrigation costs were needed so that appropriate interest on operating capital could be charged to the variable cost component.

The divergence between the surface system variable cost functions and those derived for the sprinkler system was due to the computation of repair costs in the cost program. In the program, repair costs for the sprinkler system were a function of total acres irrigated. As application rates increased, the fixed repair cost per acre inch of water declined, resulting in a declining portion of the variable cost function. Surface system repair costs were a function of annual hours used and therefore represented a

Table 7. Variable and Fixed Irrigation Cost Functions Delineated by Zone for Scenario I

Sprinkler	Irrigation Cost Functions
Zone 1	Fixed Cost = WR*(0.0489 + 20.64/WR)
	Variable Cost = WR*(2.377 + 7.993/WR)
Zone 2	Fixed Cost = WR*(0.487 + 29.079/WR)
	Variable Cost = WR*(2.62 + 8.017/WR)
Zone 3	Fixed Cost = WR*(0.0489 + 36.657/WR)
	Variable Cost = WR*(2.86 + 8.012/WR)
Surface	**Irrigation Cost Functions**
Zone 1	Fixed Cost = WR*(0.0287) + 18.3/WR)
	Variable Cost = WR*1.99
Zone 2	Fixed Cost = WR*(0.0268 + 26.769/WR)
	Variable Cost = WR*2.06
Zone 3	Fixed Cost = WR*(0.0279 + 34.293/WR)
	Variable Cost = WR*2.11

Note: WR = irrigation water requirement adjusted for system efficiency.

Table 8. Variable and Fixed Irrigation Cost Functions Delineated by Zone for Scenario II

Sprinkler	Irrigation Cost Functions
Zone 1	Fixed Cost = WR*(0.049 + 26.9/WR)
	Variable Cost = WR*(2.377 + 7.993/WR)
Zone 2	Fixed Cost = WR*(0.053 + 36.155/WR)
	Variable Cost = WR*(2.62 + 8.017/WR)
Zone 3	Fixed Cost = WR*(0.0545 + 45.455/WR)
	Variable Cost = WR*(2.86 + 8.012/WR)

Surface	Irrigation Cost Functions
Zone 1	Fixed Cost = WR*(0.0278 + 23.3/WR)
	Variable Cost = WR*1.99
Zone 2	Fixed Cost = WR*(0.0328 + 33.519/WR)
	Variable Cost = WR*2.06
Zone 3	Fixed Cost = WR*(0.0342 + 42.819/WR)
	Variable Cost = WR*2.11

Note: WR = irrigation water requirement adjusted for system efficiency.

constant at each application rate. A computer printout of the cost program is given in Appendix B.

Native Pasture Transfer

The final variable in the LP model was the transfer of native pasture to cropland. A study by Whitson and Kay (1976) reported a conversion cost from pasture to improved pasture or cropland of $50.27 per acre. Adjusting this by the Index of Prices Paid by Farmers for Tractors and Self Propelled Machinery (Crop Reporting Board) resulted in a 1980 cost of $66.95. This charge was amortized at the two scenario interest rates (WRC guidelines and current situation), 7.125 percent and 12 percent for the twenty-year planning horizon which resulted in objective function values of -$6.38 and -$8.96 per acre, respectively.

Resource Constraints and Requirements

Soil acreages, total acreage cropped and water availability were the only resource constraints in the model. Acreages of the various soil types were used to restrict crop activity levels. The water constraint represented the annual water quantity that can be obtained from the alluvium. Based on COE estimates, 99,000 acre feet of water could be withdrawn annually. The other important constraint in the model is current cropland acres as reported by Grossman and Keith. All crop activities required one acre of current cropland while native pasture did not. If native pasture was transferred to cropland, the acreage transferred was added to current cropland and used as the amount of cropland in the next year. Ideally, such a constraint should have been applied to each soil type, but data of such detail were unavailable.

The matrix of resource requirements or the "A" matrix was simplistic for the model. Aside from the native pasture activity, each crop activity required one acre of a given soil type. The pasture transfer activity supplied one acre of pasture land to the value of current cropland at the amortized per acre cost. The final row of the "A" matrix gave the per acre water requirements inclusive of the various leaching requirements. Figure 1 presents a "picture" of the linear programming matrix.

Discounting

To evaluate total project benefits, results from the linear programming model were discounted back to their net present value which gave a measure of benefits in current dollars. The discounting formula is given in equation (15).

$$(15) \qquad PV = \sum_{t=1}^{20} NR_t/(1 + r)^t$$

where

t = the year subscript, t = 1, ..., 20,

PV = the net present value of the project in current dollars,

	Crop Activities			Pasture Activity	Pasture Transfer	Sign	Resource Constraints
OBJECTIVE FUNCTION ⟶	c_1	$c_2 \cdots$	$c_j \cdots$	c_j	$(-c_j)$		
	1	1	1	1		$\leq$	SOILS
	.	.	.	.			.
	.	.	.	.			.
	.	.	.	.			.
	1	1	1	0.0	-1	$\leq$	CROPLAND
	$WR_{i,1}$	$WR_{i,2}$	$WR_{i,j}$	0.0	0.0	$\leq$	WATER

where c_j = per acre contribution to the objective function from each crop activity, and

$WR_{i,j}$ = acre inch water requirement by crop.

Figure 1. Diagram of the linear programming model used in the analysis.

NR = sum of actual net revenues for year t,

r = interest rate used to discount future returns.

It should be remembered that the objective function value in equation (15) is a value net of dryland activity and future irrigation use without the project. Discount rates of 7.125 percent and 2.5 percent were used for WRC guidelines and the current situation, respectively.

CHAPTER IV

RESULTS

The Benchmark

The benchmark solution reflected optimal resource allocation under existing conditions. Water quality was set at pre-project levels and the analysis was conducted for the twenty year horizon. The model determined optimal land use given the prices, production costs, and physical constraints of the respective scenarios.

Scenario I

Major factors influencing the outcome of this particular analysis were the net revenues of cotton relative to the other field crop and pasture activities as well as the specification of OBERS yield projections. These two factors gave cotton an advantage over all other activities, resulting in a majority of acreage shifting to cotton in each successive period (see table 9).

Initially there was some competition among the dryland hay crops (coastal bermuda and alfalfa), native pasture, and cotton (both irrigated and dryland). Grain sorghum and wheat did not generate sufficient net revenues to enter the optimal solution. Because OBERS projections failed to specify a trend for the hay crops or native pasture, cotton was able to drive these activities out of the optimal solution as the time increment was stepped up. Coastal bermuda dropped out of the solution in the second period

Table 9. Optimal Solution, Assuming Without Project Conditions, Scenario I.

	Crop Acreages for Years 1-20									
	1	2	3	4	5	6	7	8	9	10-20
Dryland Cotton	29,639	40,136	40,321	41,612	53,648	55,616	58,303	64,773	64,773	64,773
Irrigated Cotton	4,760	4,760	4,760	4,760	4,760	4,760	4,760	4,760	4,785	4,785
Dryland Grain Sorghum										
Irrigated Grain Sorghum										
Dryland Wheat										
Irrigated Wheat										
Dryland Alfalfa	9,385	9,385	9,385	9,385	135					
Irrigated Alfalfa										
Dryland Coastal Bermuda	9,794									
Irrigated Coastal Bermuda										
Native Pasture	23,708	23,005	22,820	21,529	18,743	16,910	14,773	7,753	7,728	7,728
Native Pasture Converted	12,388	703	185	1,291	2,786	1,833	2,677	6,480	25	

while alfalfa remained competitive on limited acreage until the end of the fifth period. Native pasture possessed a higher effective net revenue than coastal bermuda or alfalfa due to the cost of converting native pasture to cropland. For an acre of native pasture to be transferred to cropland, the per acre net revenue of any competing activity had to exceed the amortized per acre conversion charge as well as the net revenue of native pasture. By the ninth period all possible acreage had been converted to cotton production, since a cotton yield had not been specified for the 7,728 acres remaining in native pasture.

With water quality at pre-project levels, 4,760 acres of irrigated cotton entered the optimal solution in the first period. Twenty-five additional acres came in during the ninth period; after this, the solution remained stable. In relation to the other irrigated activities, cotton was again at an advantage because of its low water requirements and relatively greater salt tolerance. Cotton acreage coming into the solution required a 40 percent leaching fraction resulting in a 15 percent yield reduction.

To enter the solution, an irrigated activity must have been able to outperform its dryland counterparts. In this sense, dryland net revenues represented the opportunity cost to irrigation. The soils supporting irrigated cotton were the highest yielding and some of these acreages were unable to enter the solution due to the higher cost of transporting water to the outer two one-half mile zones, and the higher per acre inch cost of sprinkler irrigation relative to furrow.

Scenario II

Under the set of prices used in the second scenario, cotton and dryland alfalfa dominated the cropping pattern selected by the model (see table 10). In the analysis, cotton and alfalfa were priced substantially higher relative to the other crops (table 6). The interesting point to note was that for the twenty-six soils, yields for dryland alfalfa were only specified for eight of these soil types (table 1). Even with this limitation, total acreage planted to dryland alfalfa and dryland cotton was very close (25,583 acres of dryland alfalfa versus 29,573 acres of dryland cotton).

Dryland coastal bermuda was profitable on only one soil type and came into the optimal solution at 9,974 acres. A total of 27,474 acres was converted to cropland at an amortized charge of $8.96 per acre while 8,622 acres remained in native pasture. As in the first scenario, grain sorghum and wheat were not profitable enough to enter the solution.

Using a 40 percent leaching fraction, 5714 acres of irrigated cotton came into the benchmark solution for Scenario II. Higher cotton prices contributed to the additional acreage as compared with Scenario I, even though irrigation costs were slightly higher due to the 12 percent interest rate charged against operating expenses. Since the second scenario depicted current conditions with no trend in yield or change in water quality, results from the first year were applicable for the remainder of the 20 period horizon.

Table 10. Optimal Solution Assuming Without Project Conditions, Scenario II

Item	Crop Acreages for Years 1-20
Dryland Cotton	29,573
Irrigated Cotton	5,714
Dryland Grain Sorghum	
Irrigated Grain Sorghum	
Dryland Wheat	
Irrigated Wheat	
Dryland Alfalfa	25,583
Irrigated Alfalfa	
Dryland Coastal Bermuda	9,794
Irrigated Coastal Bermuda	
Native Pasture	8,622
Native Pasture Converted	27,474

With Project Analysis

Under the assumption of improved water quality through time, optimal cropping patterns selected by the linear program were set in motion by the expectations model. In each period, the net revenues of irrigated activities increased, when an irrigated activity represented an economically feasible alternative it was brought into the optimal solution. As the time step was incremented minimal leaching strategies were pursued leading to an economically efficient use of the water resource.

Results from the "with project" analysis indicated that a policy of rapid adoption was in order. Steady state was achieved in the ninth year for each scenario. In both cases, cotton dominated the optimal cropping pattern by virtue of its relative price and salt tolerance. Although the majority of acreage in the watershed went to irrigated cotton, there was not a single period in which the annual availability of water within the alluvium was exhausted.

Scenario I

Scenario I planted acreage did not deviate from the benchmark until the fourth period of the analysis. During the first three periods, the OBERS trend for cotton served to draw acreage away from the hay crops and native pasture (see table 11).

Table 11. Optimal Solution Assuming With Project Conditions, Scenario I

	Crop Acreages for Years 1-20								
	1	2	3	4	5	6	7	8	9-20
Dryland Cotton	29,639	40,136	40,321	40,658	43,197	9,385	9,385	15,855	14,437
Irrigated Cotton	4,760	4,760	4,760	5,714	17,510	53,703	53,703	53,703	55,121
Dryland Grain Sorghum									
Irrigated Grain Sorghum									
Dryland Wheat									
Irrigated Wheat									
Dryland Alfalfa	9,385	9,385	9,385	9,385	135				
Irrigated Alfalfa									
Dryland Coastal Bermuda	9,794								
Irrigated Coastal Bermuda									
Native Pasture	23,708	23,005	22,820	21,529	16,444	14,198	14,198	7,728	7,728
Native Pasture Converted	12,338	703	185	1,291	5,085	2,246		6,470	

Starting in the fourth period, the improvement in water quality began to dramatically influence the optimal solution (see table 13). Leaching fractions of 40 percent were economically feasible and resulted in expected yield reduction of approximately 10 percent and 5 percent for years four and five, respectively. By the sixth period, a 20 percent leaching fraction was obtained, the expected yield reduction being approximately 2 percent. The 20 percent leaching fraction represented a substantial decrease in water use and irrigation costs. Irrigation water requirements including system losses dropped from 28.13 to 21.33 acre inches in the case of furrow irrigated soils and a drop from 24.82 to 18.82 acre inches in the case of sprinkler irrigated soils. In terms of costs, the lower leaching fractions meant a reduction of $13.54 and $14.26 in per acre variable irrigation costs for the furrow and sprinkler system in the first zone, respectively. Because of this decrease in costs, 33,812 of dryland cotton were diverted to irrigated production in the sixth year.

The solution was stable for periods six and seven. In the eighth period, 6,740 acres of native pasture were converted to dryland cotton while irrigated cotton remained the same. The shift occurred on the lower yielding cotton soils reflecting the presence of trend. It was not until the eighth period that the trend projection enhanced cotton's net revenue relative to that of native pasture. Because the shift occurred on the lower yielding soils, irrigated cotton with its higher costs was unable to compete this acreage away from dryland production. Thus, the model had determined the optimal level of dryland and irrigated crop production.

Steady state was attained in the ninth period of the analysis. The 10 percent leaching fraction for cotton became feasible and the optimal cropping pattern selected by the model was composed of 55,121 acres of irrigated cotton at the 10 percent leaching fraction, 14,437 acres of dryland cotton, and 7,728 acres of native pasture.

Scenario II

Annual cropping patterns determined by the Scenario II model are presented in table 12. Similar to the benchmark analysis, the hay crops were competitive with cotton. Dryland alfalfa accounted for 23,583 acres of production throughout the twenty year horizon. Coastal bermuda came into the solution at 9,974 acres, but was driven out by the fifth period. In periods one through four, acreage shifted primarily from native pasture to irrigated cotton. By the fifth period, use of the 40 percent leaching fraction resulted in an expected yield reduction of 5 percent which was significant in pulling acreage out of dryland cotton, dryland coastal bermuda, and native pasture. With the attainment of the 20 percent leaching fraction in period six, a steady state cropping

Table 12. Optimal Solution Assuming With Project Conditions, Scenario II

	Crop Acreages for Years 1-20								
	1	2	3	4	5	6	7	8	9-20
Dryland Cotton	29,573	29,573	29,573	26,709	14,658				
Irrigated Cotton	5,714	5,714	6,471	12,247	31,219	53,703	53,703	53,703	53,703
Dryland Grain Sorghum									
Irrigated Grain Sorghum									
Dryland Wheat									
Irrigated Wheat									
Dryland Alfalfa	23,583	23,583	23,583	23,583	23,583	23,583	23,583	23,583	23,583
Irrigated Alfalfa									
Dryland Coastal Bermuda	9,794	9,794	9,794	9,794	5,210				
Irrigated Coastal Bermuda									
Native Pasture	8,622	8,622	7,865	4,953	2,616				
Native Pasture Converted	27,474		757	2,912	23,370	2,616			

pattern had been determined consisting of 53,703 acres of irrigated cotton, and 23,583 acres of dryland alfalfa. In contrast to Scenario I, the change in water quality and relative prices were the major factors in drawing acreage out of native pasture rather than the effects of trend.

The overall adoption policy was exactly the same for both scenarios in terms of changes in leaching fractions (see table 14). Acreage levels varied somewhat, but this was attributable to the difference in relative net revenues.

Water Use

According to COE estimates, 99,000 acre feet of water could be pumped from the alluvium on an annual basis. Although the results have shown that over 70 percent of the acreage in the watershed would be in irrigation, the demand for alluvium water never depleted the annual flow (see tables 13 and 14). Water use was greatest at the adoption of the 20 percent leaching fraction when (in both scenarios) approximately 95,000 acre feet of water was used. Adoption of the 10 percent leaching fraction resulted in lower total water use of approximately 83,000 acre feet for both scenarios.

Table 13. Irrigated Crop Acreages Coming into the Optimal Solution for Alternative Leaching Strategies and Total Water Use With Project Conditions, Scenario I

Item	Leaching Fraction	Crop Acreages for Years 1-20								
		1	2	3	4	5	6	7	8	9-20
Cotton	10%									55,121
	20%						53,703	53,703	53,703	
	30%									
	40%	4,760	4,760	4,760	5,714	17,510				
Grain Sorghum	10%									
	20%									
	30%									
	40%									
Wheat	10%									
	20%									
	30%									
	40%									
Alfalfa	10%									
	20%									
	30%									
	40%									
Bermuda	10%									
	20%									
	30%									
	40%									
Acre feet of water used		10,253	10,253	10,253	12,254	39,876	94,469	94,469	94,469	85,146
Acre feet of water unused		88,747	88,747	88,747	86,746	59,123	4,530	4,530	4,530	13,854

Table 14. Irrigated Crop Acreages Coming into the Optimal Solution for Alternative Leaching Strategies and Total Water Use, With Project Conditions, Scenario II

Item	Leaching Fraction	Crop Acreages for Years 1-20								
		1	2	3	4	5	6	7	8	9-20
Cotton	10%									53,703
	20%						53,703	53,703	53,703	
	30%									
	40%	5,714	5,714	6,471	12,247	31,219				
Grain Sorghum	10%									
	20%									
	30%									
	40%									
Wheat	10%									
	20%									
	30%									
	40%									
Alfalfa	10%									
	20%									
	30%									
	40%									
Bermuda	10%									
	20%									
	30%									
	40%									
Acre feet of water used		12,253	12,253	14,206	27,551	71,978	94,469	94,469	94,469	82,936
Acre feet of water unused		86,746	86,746	84,973	71,448	27,021	4,530	4,530	4,530	16,073

Net Benefits

Tables 15 and 16 present the estimated annual benefits for Scenario's I and II. Table 15 gives the measure of project net benefits defined as the difference between the "with" and "without" project analyses. Increased project net benefits in Scenario II were explained by the higher relative prices for activities coming into the optimal solution as compared with those of Scenario I. The upward trend for Scenario I was the result of OBERS projections.

From table 16 the effect of varying the interest rate can be seen. The present value of net project benefits was approximately $16 million using an interest rate of 7.125 percent, while a present value of approximately $30 million dollars was estimated using an interest rate of 2.5 percent. Net benefits estimated for each scenario were similar in absolute terms, however, the impact of a change in the interest rate was dramatic. These results re-emphasize the importance of the selection of the interest rate used to discount future incomes. The relative flow of benefits was also similar since identical adoption policies were determined for both scenarios. In years six and nine, the largest increases in benefits were realized, occurring when the 20 percent and 10 percent leaching fractions came into effect, respectively.

Table 15. Net Benefits Attributable to Improved Water Quality in the Pease River Area

Year	Scenario I	Scenario II
1	0.0	0.0
2	27,082.0	52,713.0
3	58,661.0	394,636.0
4	321,330.0	573,790.0
5	585,362.0	1,031,365.0
6	2,101,479.0	2,379,291.0
7	2,133,523.0	2,395,947.0
8	2,125,546.0	2,395,947.0
9	2,477,265.0	2,735,473.0
10	2,486,158.0	2,735,473.0
11	2,495,398.0	2,735,473.0
12	2,504,752.0	2,735,473.0
13	2,513,685.0	2,735,473.0
14	2,523,083.0	2,735,473.0
15	2,520,327.0	2,735,473.0
16	2,527,474.0	2,735,473.0
17	2,715,406.0	2,735,473.0
18	2,740,667.0	2,735,473.0
19	2,568,891.0	2,735,473.0
20	2,577,938.0	2,735,473.0
Total	38,004,027.0	42,049,365.0

Table 16. Discounted Net Benefits Attributable to Improved Water Quality in the Pease River Area

Years	Scenario I	Scenario II
1	0.0	0.0
2	23,599.0	50,173.0
3	47,717.0	366,459.0
4	243,998.0	519,826.0
5	414,925.0	911,577.0
6	1,390,528.0	2,051,656.0
7	1,317,836.0	2,015,627.0
8	1,225,586.0	1,966,466.0
9	1,333,383.0	2,190,371.0
10	1,249,166.0	2,136,947.0
11	1,170,417.0	2,084,827.0
12	1,096,666.0	2,033,977.0
13	1,027,377.0	1,984,368.0
14	962,631.0	1,935,969.0
15	897,623.0	1,888,750.0
16	840,298.0	1,842,683.0
17	842,734.0	1,797,739.0
18	794,001.0	1,753,892.0
19	694,736.0	1,711,114.0
20	650,812.0	1,669,380.0
Total	16,224,033.0	30,911,801.0

CHAPTER V

CONCLUSIONS

Summary of the Research

Arid and semiarid irrigated regions have traditionally faced the problem of salinity and its impact on crop yield. The purpose of this study was to analyze the agricultural sector's response to a proposed Corps of Engineers (COE) salinity control project along the Red River and its tributaries. Within the Red River Basin natural salt springs and seeps contribute heavily to degradation of alluvium water. The project would reduce the salt load thereby allowing irrigation to become a feasible agricultural alternative.

It has been shown in the literature that irrigation decisions involving salinity control measures should be made in an economic context. Use of an economic criteria provides a framework for which various alternatives can be evaluated in order to determine a policy that is in some sense optimal. The model developed in Chapter III was applied in such a manner that a proper relation existed between the principles of salinity management and economic theory. By further incorporating the temporal aspects of the adjustment process to the project, the model determined an optimal adoption policy which considered water quality improving through time and producers' adjustment to the improvement.

Results from the model indicated that a policy of rapid adoption should be undertaken. Irrigation with highly saline irrigation water in the initial periods of the analysis and the ability to sustain yield reductions in order to improve net revenues gave further evidence that maximization of physical yield is not necessarily an economically viable alternative. The policy chosen by the model was insensitive to the scenarios considered since changes in relative product prices reinforced cotton's position as the most profitable activity. Due to cotton's salt tolerance, low water requirements, and limited high quality cotton land, total water use was less than annual availability. Thus, on an aggregate basis the profit maximizing level of water was applied. If relative prices shifted such that crops having higher irrigation water requirements came into the solution, annual availability could possibly become an effective constraint.

With respect to the WRC guidelines, a few points should be mentioned. First, the effect of relative prices was significant in determining optimal cropping patterns. Perhaps several variations of estimates should be used to observe the sensitivity of the results to price parameters. Because market prices can be interpreted as a measure of social value and the future is unknown, a "broader" examination of relative prices might be more meaningful than a single sector of carefully estimated prices.

Second, OBERS projections were not appropriate in the analysis. If factor and product prices are to be held constant as well as technology of production processes, the use of trend for a lengthy planning horizon does not seem to be a legitimate procedure, especially when some crop activities are trended while others are not. It also seems unreasonable to assign aggregate trends to a specific region, particularly when previous research (Richardson, 1979) indicated that such trends were inapplicable.

Third, the fact that selection of the interest rate used to discount future returns is critical, was demonstrated by the results of Scenarios I and II. As Baumol (1968) has stated, economists agree on what the interest rate should measure, but its relative magnitude is a subject of much debate. Despite the requirement that a standard rate by applied to all Federal projects, a better understanding of the nature of project benefits might be achieved by selecting a rate based on project life, initial outlay, and the costs and benefits to human capital. In the latter case, an investment in human capital, i.e., education or health, might have a quite different flow and distribution of benefits than an investment in irrigation projects or flood control.

Limitations

The purpose of an economic analysis is to abstract from reality in order that behavior can be explained or predicted with only those factors which have the most influence on an economic system. In the abstraction process, aggregations are made as well as assumptions concerning behavior. The analysis just presented is subject to these limitations.

Several critical aspects of the project were greatly simplified. Use of probabilistic estimates involving seasonal water availability and its potential effect on water quality would no doubt influence the results. Because of insufficient data, relevant agronomic factors such as soil characteristics and weather, which ultimately determine the relationship between salinity and crop yield, were ignored and represent a gross aggregation over the various plant functions. Additionally, the economic model assumed product and factor prices to be known with perfect certainty and irrigation technology was held constant throughout the analysis. The assumption of profit maximization when used in conjunction with perfect knowledge represents a limitation in the results. The model then selects optimal activity levels with no allowance for risk or random variation in outcome.

Further Research

Two areas of further research evidenced by this study are: (1) the economic evaluation of saline water; and (2) the welfare aspects of project analysis. Substantial efforts have been made in these areas, but further refinement is needed.

Economic studies involving salinity management will only by relevant in a temporal and probabilistic setting. Both the inter seasonal and intra seasonal allocation problems are interesting. Studies attempting to determine optimal timing of application under stochastic environments would aid in developing operational production functions. These in turn would be a contribution on an international level given the growing concern over the salinity issue. Regional analysis, when set in a multiperiod planning horizon, would have implications for groundwater management as well as the management of irrigation return flows within the larger irrigation projects. Welfare aspects of project analysis are also important and interesting problems. More research indicating the distribution of costs and benefits is needed to evaluate the overall impacts of a project.

REFERENCES

Ayers, Robert S. and Dennis W. Wescott. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29, 1976.

Blaney, H. F. and W. D. Criddle. Determining Water Requirements in Irrigated Areas from Climatological and Irrigation Data.

Boulding, Kenneth E. and W. Allen Spivey. Linear Programming and the Theory of the Firm. New York: MacMillan Company, 1960.

Corps of Engineers. Arkansas Red River Basin Chloride Control Design Memorandum. U.S. Dept. of Interior, U.S. Army Corps of Engineers, Tulsa, 1976.

Crop Reporting Board. "Index of Prices Paid by Farmers for Tractor and Self Propelled Machinery." Agricultural Prices, USDA, ESCS, Washington, D.C. (December 31, 1979): 30.

Dasgupta, Ajit K. and D. W. Pearce. Cost-Benefit Analysis, Theory and Practice. New York: Harper and Row, 1972.

Doorenbos, J. and W. O. Pruitt. Crop Water Requirements. FAO Irrigation and Drainage Paper 24, 1977.

Dorfman, Robert, Paul A. Samuelson, and Robert M. Solow. Linear Programming and Economic Analysis. New York: McGraw-Hill, 1958.

Friedman, Milton. Essays in Positive Economics. Chicago: University of Chicago Press, 1953.

Grossman and Keith/Consulting Engineers. "Red River Chloride Study, Analysis of Irrigated Agriculture." Report for Tulsa District Corps of Engineers, 1979.

Hicks, J. R. Value and Capital. Oxford: Oxford University Press, 1946.

Jobes, Raleigh A. Oklahoma Enterprise Budget Book. Oklahoma Extension Service, Oklahoma State University, Stillwater, Oklahoma, 1979.

Keese, Wayne. Personal interview. TAEX-Extension-Ag. Engineer, October 12, 1979.

Kletke, Darrel D., Thomas R. Harris, and Harry P. Mapp, Jr. Irrigation Cost Program Users Reference Manual. Research Report P-770. Stillwater: Oklahoma State University, 1978.

Longenecker, D. E. and P. J. Lyerly. Control of Soluble Salts in Farming and Gardening. Texas Agricultural Experiment Station, College Station, 1974.

McDaniels, L. L. Consumptive Use of Water by Major Crops in Texas. Texas Board of Water Engineers, Bulletin 6019, 1960.

Maas, E. V. and G. J. Hoffman. "Crop Salt Tolerance-Current Assessment." J. Irrig. and Drainage Div. 103(1977): 115-124.

Mishan, E. J. Cost-Benefit Analysis. New York: Praeyer Publishers, 1971.

Penman, H. L. "Natural Evaporation from Open Water, Bare Soil and Grass." Royal Soc., London Proc. Ser. A, 193: 120-416, 1948.

Peterson, Dean F. "Water in the Deserts." Arid Lands in Transition, H. Dregne (ed.), Washington, D.C., American Association for the Advancement of Science (1970): 15-30.

Reddell, Dan. Personal interview. TAES, Ag. Engineering, TAMU, December 4, 1979.

Richards, L. A. (ed.) Diagnosis and Improvement of Saline and Alkalai Soils. USDA Agr. Handbook 60, February 1954.

Richardson, J. Analysis of Crop Yields for Trend. Memorandum, Texas A&M University, College Station, October 25, 1979.

Ritchie, J. T. "Model for Predicting Evaporation from a Row Crop with Incomplete Cover." Water Resources Research, 8(1975): 1204-1212.

Runkles, J. R., R. D. Lacewell, D. H. Laughlin, D. Moore, C. R. Taylor, R. Martin, T. Zacharias, J. Richardson and B. Harris. Analysis of Potential Irrigated Agriculture and Probable Benefits Therefrom Red River Chloride Control Project Oklahoma-Texas. COE draft report, 1980.

Soil Conservation Service. Soil Survey of Foard, Hardeman, and Wilbarger Counties, Texas. USDA-SCS and in cooperation with Texas Agricultural Experiment Station, 1975.

Texas Agricultural Extension Service. Texas Crop Budgets. TAES Extension Economists-Management, MP-1027, 1980.

Texas Department of Agriculture and U.S. Department of Agriculture, Statistical Reporting Service. Texas County Statistics. Compiled by Texas Crop and Livestock Reporting Service, Austin, Texas, 1979.

U.S. Water Resources Council. Agricultural Price Standards. Washington, D.C., October 1978.

U.S. Water Resources Council. OBERS Projections, Series E'. U.S. Government Printing Office, Washington, D.C., 1978.

Welch, Charles D., Carl Gray, and Warren B. Anderson. Fact Sheet-Crop Fertilization on Texas Alluvial Soils. Texas Agricultural Extension Service, L-720, College Station, 1978.

Whitson, Robert E. and Ronald D. Kay. "Beef Cattle Forage Systems Analysis Under Variable Prices and Forage Conditions." Journal of Animal Science, 46(1978): 3.

APPENDIX A: CROP BUDGETS AND FERTILIZER REQUIREMENTS

Table 17. Base Budget for Dryland Grain Sorghum[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain	cwt	\$3.70	17.00	\$62.90
Stubble Grazing	AUM	8.24	.20	1.65
Total				64.55
2. Preharvest Variable Costs				
Seed	lbs	.48	5.00	2.40
Nitrogen	lbs	.18	25.50	4.59
Phos. (P_2O_5)	lbs	.17	25.50	4.34
Tractors	acre	6.47	1.00	6.47
Machinery	acre	3.91	1.00	3.91
Labor	hour	4.50	3.57	16.06
Int. on Op. Cap.	dol	.07125	18.88	1.35
Total Preharvest				39.12
3. Harvest Costs				
Custom Combine[b]	acre	8.00	1.00	8.00
Custom Haul	cwt	.25	17.00	4.25
Total Harvest				12.25
4. Total Variable Costs				51.37
5. Fixed Costs				
Tractors	acre	5.37	1.00	5.37
Machinery	acre	3.07	1.00	3.07
Management	acre	5.48	1.00	5.14
Total				13.58
6. Total Costs				64.95
7. Returns Above Total Costs				-0.40

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

[b] Combining costs are \$8.00 per acre to a yield of about 23 cwt and then are \$.35 per cwt.

Table 18. Base Budget for Irrigated Grain Sorghum[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain	cwt	$3.70	46.73	$172.98
Stubble Grazing	AUM	8.24	.30	2.47
Total				175.45
2. Preharvest Variable Costs				
Seed	lbs	.48	8.00	3.84
Nitrogen	lbs	.18	67.00	12.06
Phos. (P_2O_5)	lbs	.17	67.00	11.39
Potash (K_2O)	lbs	.09	13.50	1.22
Insecticide	appli.	3.00	2.00	6.00
Tractors	acre	7.14	1.00	7.14
Field Mach.	acre	4.06	1.00	4.06
Irrigation (mach. & labor)	ac. in.	1.51	24.90	37.60
Labor (tract. & mach)	hour	4.50	3.75	16.88
Other Labor	hour	2.75	2.00	5.50
Int. on Op. Cap.	dol.	.07125	52.84	3.76
Total Preharvest				109.45
3. Harvest Costs				
Custom Combine	cwt	.35	46.75	16.36
Custom Haul	cwt	.25	46.75	11.69
Total Harvest				28.05
4. Total Variable Costs				137.50
5. Total Costs				
Tractors	acre	5.93	1.00	5.93
Field Mach.	acre	4.61	1.00	4.61
Irrig. Mach.	ac. in.	.74	24.90	18.43
Management	acre	13.75	1.00	13.75
Total				42.72
6. Total Costs				180.22
7. Returns Above Total Costs				-4.77

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 19. Base Budget for Dryland Cotton[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Lint	lbs	$ .50	275.00	$137.50
Seed	ton	86.12	.22	18.95
Total				156.45
2. Preharvest Variable Costs				
Seed	lbs	.40	12.00	4.80
Insecticide	appli.	4.50	1.00	4.50
Herbicide	acre	6.00	1.00	6.00
Nitrogen	lbs	.18	34.00	6.12
Phos. (P_2O_5)	lbs	.17	34.00	5.78
Tractors	acre	6.60	1.00	6.60
Machinery	acre	5.31	1.00	5.31
Labor	hour	4.50	4.25	19.12
Int. on Op. Cap.	dol	.07125	29.12	2.07
Total Preharvest				60.30
3. Harvest Costs				
Gin, Bag, Ties	bale	35.00	.55	19.25
Strip and Haul	cwt	1.00	11.99	11.99
Total Harvest				31.24
4. Total Variable Cost				91.54
5. Fixed Cost				
Tractors	acre	7.62	1.00	7.62
Machinery	acre	3.81	1.00	3.81
Management	acre	9.15	1.00	9.15
Total				20.58
6. Total Costs				112.12
7. Returns Above Total Costs				44.33

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 20. Base Budget for Irrigated Cotton[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Lint	lbs	$ .50	638.00	$319.00
Seed	ton	86.12	.51	43.92
Total				362.92
2. Preharvest Variable Costs				
Seed	lbs	.40	25.00	10.00
Insecticide	appli.	4.50	7.00	31.50
Herbicide	acre	10.00	1.00	10.00
Nitrogen	lbs	.18	71.00	12.78
Phos. (P_2O_5)	lbs	.17	66.00	11.22
Potash (K_2O)	lbs	.09	11.00	.99
Tractors	acre	7.46	1.00	7.46
Field Mach.	acre	4.98	1.00	4.98
Irrig. (mach. & labor)	ac. in.	1.51	24.60	37.15
Labor (trac. & mach.)	hour	4.50	4.11	18.50
Labor (other)	hour	2.75	2.00	5.50
Int. on Op. Cap.	dol	.07125	75.04	5.35
Total Preharvest				155.43
3. Harvest Costs				
Gin, Bag, Ties	bale	35.00	1.28	44.80
Custom Strip and Haul	cwt	1.00	28.07	28.07
Total Harvest				72.87
4. Total Variable Cost				228.30
5. Fixed Cost				
Tractors	acre	7.95	1.00	7.95
Field Mach.	acre	5.30	1.00	5.30
Irrig. Mach.	ac. in.	.77	24.60	18.94
Management	acre	22.83	1.00	22.83
Total				55.02
6. Total Costs				283.32
7. Returns Above Total Costs				79.60

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 21. Base Budget for Dryland Wheat [a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain	bu	$2.35	21.00	$49.35
Grazing	AUM	8.24	1.57	12.94
Total				62.29
2. Preharvest Variable Costs				
Seed	bu	4.50	1.00	4.50
Nitrogen	lbs	.18	21.00	3.78
Phos. (P_2O_5)	lbs	.17	14.00	2.38
Insecticide	appli.	3.50	1.00	3.50
Crop Insurance	acre	3.00	1.00	3.00
Tractors	acre	3.94	1.00	3.94
Field Mach.	acre	3.65	1.00	3.65
Labor	hour	4.50	2.23	10.04
Int. on Op. Cap.	dol	.07125	17.40	1.24
Total Preharvest				36.03
3. Harvest Costs				
Custom Combine [b]	acre	7.00	1.00	7.00
Custom Haul	bu.	.15	21.00	3.15
Total Harvest				10.15
4. Total Variable Cost				46.18
5. Fixed Costs				
Tractors	acre	8.21	1.00	8.21
Machinery	acre	2.67	1.00	2.67
Management	acre	4.34	1.00	4.62
Total				15.50
6. Total Costs				61.68
7. Returns Above Total Costs				0.61

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

[b] Combining costs are $7.00 per acre to a yield of 35 bushels and then are $.20 per bushel.

Table 22. Base Budget for Irrigated Wheat [a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain	bu	$2.35	47.00	$110.45
Grazing	AUM	8.24	3.51	28.92
Total				139.37
2. Preharvest Variable Costs				
Seed	bu	4.50	1.25	5.62
Nitrogen	lbs	.18	65.00	11.70
Phos. (P_2O_5)	lbs	.17	43.00	7.31
Potash (K_2O)	lbs	.09	28.00	2.52
Insecticide	appli.	3.50	1.00	3.50
Crop Insurance	acre	6.60	1.00	6.60
Tractors	acre	5.62	1.00	5.62
Field Mach.	acre	5.33	1.00	5.33
Irrig. (mach. & labor)	ac. in.	1.51	32.30	48.77
Labor (trac. & mach.)	hour	4.50	2.47	11.12
Int. on Op. Cap.	dol	.07125	54.04	3.85
Total Preharvest				111.94
3. Harvest Costs				
Custom Combine [b]	bu	.20	47.00	9.40
Custom Haul	bu	.15	47.00	7.05
Total Harvest				16.45
4. Total Variable Costs				128.39
5. Fixed Costs				
Tractors	acre	11.10	1.00	11.10
Field Mach.	acre	8.39	1.00	8.39
Irrig. Mach.	ac. in.	.60	32.30	19.38
Management	acre	12.84	1.00	12.84
Total				51.71
6. Total Costs				180.10
7. Returns Above Total Cost				-40.73

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

[b] Combining costs are $7.00 per acre to a yield of 35 bushels and then $.70 per bushel.

Table 23. Base Budget for Dryland Alfalfa Establishment[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts	ton		0	$0
2. Variable Establishment Costs				
Seed	lbs	1.25	20.00	25.00
Nitrogen	lbs	.18	25.00	4.50
Phos. (P_2O_5)	lbs	.17	150.00	25.50
Potash (K_2O)	lbs	.09	50.00	4.50
Tractors	acre	2.47	1.00	2.47
Field Mach.	acre	1.83	1.00	1.83
Labor	hour	4.50	1.21	5.44
Int. on Op. Cap.	dol	.07125	19.14	1.36
Total Variable				70.60
3. Fixed Establishment Costs				
Tractors	acre	2.75	1.00	2.75
Field Mach.	acre	2.35	1.00	2.35
Management	acre	7.06	1.00	7.06
Total				12.16
4. Total Establishment Costs				82.76

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 24. Base Budget for Dryland Alfalfa Maintenance[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	2.10	$105.61
2. Preharvest Variable Costs				
Phos. (P_2O_5)	lbs	.17	42.00	7.14
Field Mach.	acre	1.61	1.00	1.61
Labor	hour	4.50	.75	3.38
Int. on Op. Cap.	dol	.07125	6.06	.43
Total Preharvest				12.56
3. Harvest				
Custom	bale	.65	69.72	45.32
4. Total Variable Costs				57.88
5. Fixed Costs				
Field Mach.	acre	1.12	1.00	1.12
Prorated Est. Cost (6 yr.)	acre	13.79	1.00	13.79
Management	acre	5.79	1.00	5.79
Total				20.70
6. Total Costs				78.58
7. Returns Above Total Costs				27.03

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 25. Base Budget for Irrigated Alfalfa Establishment[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts	ton		0	$0
2. Variable Establishment Costs				
Seed	lbs	1.25	20.00	25.00
Nitrogen	lbs	.18	25.00	4.50
Phos. (P_2O_5)	lbs	.17	150.00	25.50
Potash (K_2O)	lbs	.09	50.00	4.50
Tractors	acre	2.73	1.00	2.73
Field Mach.	acre	2.03	1.00	2.03
Irrig. (mach. & labor)	ac. in.	1.51	16.60	25.07
Labor (trac. & mach.)	hour	4.50	1.41	6.34
Int. on Op. Cap.	dol	.07125	26.79	1.91
Total Variable				97.58
3. Fixed Establishment Costs				
Tractors	acre	3.04	1.00	3.04
Field Mach.	acre	2.40	1.00	2.40
Irrig. Mach.	ac.in.	1.13	16.60	18.76
Management	acre	9.76	1.00	9.76
Total				33.96
4. Total Establishment Costs				131.54

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 26. Base Budget for Irrigated Alfalfa Maintenance[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	5.53	$278.10
2. Preharvest Variables Costs				
Phos. (P_2O_5)	lbs	.17	110.00	18.70
Potash (K_2O)	lbs	.09	30.00	2.70
Insecticide	appli.	3.00	3.00	9.00
Misc. Exp.	acre	3.00	1.00	3.00
Field Mach.	acre	1.61	1.00	1.61
Labor (mach.)	hour	4.50	.75	3.38
Irrig. (mach. & labor)	ac. in.	1.51	83.10	125.48
Int. on Op. Cap.	dol	.07125	81.92	5.84
Total Preharvest				169.71
3. Harvest				
Custom	bale	.65	183.60	119.34
4. Total Variable Costs				289.05
5. Fixed Costs				
Field Mach.	acre	1.12	1.00	1.12
Prorated Estab. Cost	acre	21.92	1.00	21.92
Irrig. Mach.	ac. in.	.25	83.10	20.78
Management	acre	28.90	1.00	28.90
Total				72.72
6. Total Costs				361.77
7. Returns Above Total Costs				-83.67

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 27. Base Budget for Dryland Coastal Bermudagrass Establishment [a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts			0	$0
2. Preharvest Variable Costs				
Custom Sprigging	acre	22.50	1.50	33.75
Nitrogen	lbs	.18	16.00	2.88
Phos. (P_2O_5)	lbs	.17	20.00	3.40
Herbicide (cust.)	acre	3.90	1.00	3.90
Tractors	acre	1.28	1.00	1.28
Field Machinery	acre	1.68	1.00	1.68
Labor (trac. & mach.)	hour	4.50	1.06	4.77
Int. on Op. Cap.	dol	.07125	28.66	2.04
Total Preharvest				53.70
3. Harvest Costs				0
4. Total Variable Costs				53.70
5. Fixed Costs				
Tractors	acre	1.24	1.00	1.24
Field Machinery	acre	1.74	1.00	1.74
Management	acre	5.37	1.00	5.37
Total				8.35
6. Total Establishment Costs				62.05
7. Returns Above Total Costs				-62.05

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 28. Base Budget for Dryland Coastal Bermudagrass Maintenance [a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	2.30	$115.67
2. Preharvest Variable Costs				
Nitrogen	lbs	.18	40.00	7.20
Phos. (P_2O_5)	lbs	.17	25.00	4.25
Field Machinery	acre	1.61	1.00	1.61
Labor (mach.)	hour	4.50	.75	3.38
Int. on Cap.	dol	.07125	4.22	.30
Total Preharvest				16.74
3. Harvest Costs				
Custom	bale	.65	76.00	49.40
4. Total Variable Costs				66.14
5. Fixed Costs				
Field Machinery	acre	1.12	1.00	1.12
Prorated Estab. Cost (10 yrs.)	acre	6.19	1.00	6.19
Management	acre	6.61	1.00	6.61
Total				13.92
6. Total Costs				80.06
7. Returns Above Total Costs				35.61

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 29. Base Budget for Irrigated Coastal Bermudagrass Establishment[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts	ton	$50.29	0	$0
2. Preharvest Variable Costs				
Custom Sprigging	acre	22.50	1.00	22.50
Nitrogen	lbs	.18	16.00	2.88
Phos. (P_2O_5)	lbs	.17	20.00	3.40
Herbicide (cust.)	acre	3.90	1.00	3.90
Tractors	acre	1.28	1.00	1.28
Field Mach.	acre	1.68	1.00	1.68
Irrig. (mach. & labor)	ac. in.	1.51	36.30	54.81
Labor (trac. & mach.)	hour	4.50	1.06	4.80
Int. on Op. Cap.	dol	.07125	47.60	3.39
Total Preharvest				98.64
3. Harvest Costs				
4. Total Variable Costs				
5. Fixed Costs				
Tractors	acre	1.24	1.00	1.24
Field Mach.	acre	1.64	1.00	1.64
Irrig. Mach.	ac.in.	.53	36.30	19.24
Management	acre	9.86	1.00	9.86
Total				31.98
6. Total Costs				130.62
7. Returns Above Total Costs				-130.62

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 30. Base Budget for Irrigated Coastal Bermudagrass Maintenance [a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	tons	$50.29	4.20	$211.22
2. Preharvest Variable Costs				
Nitrogen	lbs	.18	300.00	54.00
Phos. (P_2O_5)	lbs	.17	70.00	11.90
Potash (K_2O)	lbs	.085	80.00	6.80
Misc. Exp.	acre	3.00	1.00	3.00
Field Mach.	acre	1.61	1.00	1.61
Labor (mach.)	hour	4.50	.75	3.38
Irrig. (mach. & labor)	ac.in.	1.51	72.60	109.63
Int. on Op. Cap.	dol	.07125	95.15	6.78
Total Preharvest				197.10
3. Harvest				
Custom	bale	.65	139.00	90.35
4. Total Variable Costs				287.45
5. Fixed Costs				
Field Mach.	acre	1.12	1.00	1.12
Prorated Estab. Cost (10 yrs.)	acre	13.06	1.00	13.06
Irrig. Mach.	ac.in.	.28	72.60	20.33
Management	acre	28.74	1.00	28.74
Total				63.25
6. Total Costs				350.70
7. Return Above Total Costs				-139.48

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, furrow irrigation in zone 1, good quality water and typical management in the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 31. Base Budget for Dryland Native Pasture[a]

Item	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grazing	AUM	$8.24	2.30	$18.95
2. Preharvest Variable Costs				
Field Mach.	acre	.53	1.00	.53
Labor (mach.)	hour	4.50	.25	1.12
Int. on Cap.	dol	.07125	.53	.04
Total Preharvest				1.69
3. Harvest Costs				0
4. Total Variable Costs				1.69
5. Fixed Costs				
Field Mach.	acre	.34	1.00	.34
Management	acre	.16	1.00	.16
Total				.50
6. Total Costs				2.19
7. Returns Above Total Costs				16.76

[a] This budget represents Enterprise Very Fine Sandy Loam Soils, and typical management for the Pease River Area. Prices and interest rates reflect WRC guidelines.

Table 32. Fertilizer Recommendation Coefficients for Specified Crop Yield Ranges and Fertilizer Prices [a]

Crop	Unit	Levels 1	2	3
Cotton	lbs.	0–480	480–960	above 960
N		.125	.083	.083
P_2O_5		.125	.0417	.083
K_2O		0	.0833	.0417
Grain Sorghum	cwt.	0–40	40–60	above 60
N		1.5	1.0	2.0
P_2O_5		1.5	1.0	1.0
K_2O		0	0	0
Wheat	bu.	0–30	31–45	above 45
N		1.0	2.0	2.667
P_2O_5		.667	1.333	1.333
K_2O		0	1.667	.667
Alfalfa	ton	0–4	4–6	above 6
N		0	0	0
P_2O_5		20.0	20.0	20.0
K_2O		0	30.0	20.0
Coastal Bermuda	ton	0–4	4–8	above 8
N		30.0	60.0	50.0
P_2O_5		10.0	10.0	10.0
K_2O		5.0	20.0	25.0
Fertilizer Prices	lbs.			
N	0.18			
P_2O_5	0.17			
K_2O	0.09			

[a] Source: Welch, Gray, and Anderson, 1978.

APPENDIX B: IRRIGATION COST PROGRAM OUTPUT

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                                     OKLAHOMA STATE UNIVERSITY
                                      IRRIGATION COST PROGRAM
SAMPLE RUN 2                                                                            SIDE MOVE SYSTEM
SYSTEM 2
                              SYSTEM REQUIREMENTS CHARACTERISTICS AND COSTS

                                              THE FARM

       ACRES COVERED:      80.0         GALLONS PER MINUTE:     325.          INCHES PER ACRE:     24.00
    ANNUAL HOURS USE:    2673.2 PRESSURE/SQ IN. AT DISCHARGE:    30.00     ACRE INCHES PER YEAR:  1920.00
                                         TOTAL DYNAMIC HEAD:    155.98      ACRE INCHES PER SET:     3.00

                                              THE WELL

         WELL DEPTH:       90.0        DEPTH TO WATER LEVEL:     60.0    COST/FOOT DRILL & DEVLP.:    27.00

                                              THE PUMP

 DEPTH SETTING COL. PIPE:     80.       NUMBER OF BOWLS SET:       5            PIPE DIAMETER:     6.000
 IF 1.EXTRA 10 FT SECTION:     0              COST PER BOWL:   100.74           TUBE DIAMETER:     2.500
 # OF 20 FT COLUMN SECT.:      4       SECONDARY BOWL COST:   387.78          SHAFT DIAMETER:     1.500
 PRICE PER 20 FT SECTION:  416.13      TOTAL COST OF BOWLS:  2039.64           GEARHEAD COST:    599.50
        PUMP EFFICIENCY:   0.600             STRAINER COST:    32.67           PUMPBASE COST:    835.65
       DRIVE EFFICIENCY:   1.000              SUCTION COST:    44.89         TOTAL PUMP COST:   5216.86

                                             THE ENGINE

          ELECTRIC ENGINE                       ENGINE COST:  1750.00  BRAKE HORSEPOWER REQUIRED:   21.34
       ELECTRIC FUEL:                      FUEL COST PER UNIT:    0.060          WATER HORSEPOWER:   12.80
                                                   ALTITUDE:  1200.   PURCHASE HORSEPOWER NEEDED:   22.84
                              AVERAGE MAXIMUM TEMPERATURE:     90.0     PURCHASE HORSEPOWER USED:   40.00
   HOURS OF ENGINE LIFE:   50000.

                                        THE DISTRIBUTION SYSTEM

       SECTION ONE                    SECTION TWO               SECTION THREE                SECTION FOUR
   MAIN LINE BELOW GROUND             LATERAL
                FEET:   2640.00               FEET:   660.00             FEET:     0.0               FEET:      0.0
           TYPE PIPE:   PLASTIC          TYPE PIPE:  ALUMINUM        TYPE PIPE:                 TYPE PIPE:
            DIAMETER:      6.00           DIAMETER:     6.00          DIAMETER:     0.0          DIAMETER:      0.0
           COST/FOOT:      2.00          COST/FOOT:     2.10         COST/FOOT:     0.0         COST/FOOT:      0.0
        NUMBER LINES:       1.        NUMBER LINES:      1.       NUMBER LINES:      1.      NUMBER LINES:       1.
  BELOW GROUND VALVES:     44.  ABOVE GROUND VALVES:      0.  LATERAL PIPE COST:  1386.00    MAINLINE COST:  5280.00
COST BELOW GR. VALVES:    30.10COST ABOVE GR. VALVES:    25.75   TOTAL VALVE COST:  1324.40DISTANCE BETWEEN SETS:   60
COST OF DRIVE & MOTOR:   400.00

                                           THE PARAMETERS

       INTEREST RATE:     0.071        LABOR COST PER HOUR:     4.50                 TAX RATE:     0.010
      INSURANCE RATE:     0.005      COST/GAL OIL OR GREASE:     5.00      WELL TAX PER GALLON:     0.0
   YEARS OF WELL LIFE:     20.         YEARS OF COLUMN LIFE:     16.       TAX ASSESSMENT RATE:     0.200
   YEARS OF BOWL LIFE:      8.       YEARS OF GEARHEAD LIFE:     15.
```

THE PER ACRE INCH COST SUMMARY

FIXED COSTS	DEPRECIATION	TAXES	INSURANCE	INTEREST	TOTAL/ACIN	TOTAL/ACRE	TOTAL/YEAR	INVESTMENT COSTS
WELL	0.06	0.0	0.0	0.04	0.11	2.60	207.76	2430.00
PUMP	0.21	0.01	0.01	0.10	0.32	7.76	620.67	5216.86
MOTOR	0.05	0.00	0.00	0.03	0.09	2.10	167.94	1750.00
SYSTEMS	0.25	0.01	0.01	0.16	0.42	10.18	814.67	8390.39
TOTALS	0.57	0.02	0.03	0.33	0.94	22.64	1811.04	17787.26

VARIABLE COSTS	FUEL	LUBRICANTS	REPAIRS	LABOR	TOTAL/ACIN	TOTAL/ACRE	TOTAL/YEAR
WELL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PUMP	0.0	0.0	0.12	0.0	0.12	2.91	232.43
MOTOR	1.51	0.23	0.04	0.19	1.96	47.10	3768.38
SYSTEMS	0.0	0.0	0.33	0.28	0.62	14.84	1187.20
TOTALS	1.51	0.23	0.49	0.47	2.70	64.85	5188.00
COMPLETE TOTALS					3.65	87.49	6999.04

BASIC DATA

SAMPLE RUN 2
SYSTEM 2

SYSTEM TYPE 2
COMPLEMENT NUMBER 0

(CPS) COLUMN, PIPE, AND SHAFT DATA

	ROW/COL	PIPE DIAMETER 2	TUBE DIAMETER 3	SHAFT DIAMETER 4	PIPE LENGTH 5	LIST PRICE 6	SHAFT FRICTION LOSS 7	STRAINER COST 8	SUCTION COST 9
20 FEET	1	6.00	1.50	1.00	20.00	314.60	0.67	32.67	38.35
	2	6.00	2.00	1.25	20.00	348.92	0.91	32.67	38.35
	3	6.00	2.50	1.50	20.00	416.13	1.41	32.67	44.89
	4	6.00	2.50	1.69	20.00	427.57	1.77	32.67	44.89
	5	8.00	2.00	1.25	20.00	416.13	0.91	44.48	49.75
	6	8.00	2.50	1.69	20.00	493.35	1.77	44.48	49.75
	7	8.00	3.00	1.69	20.00	652.08	1.77	44.48	57.92
	8	8.00	3.00	1.94	20.00	642.87	2.26	44.48	57.92
	9	10.00	2.50	1.69	20.00	570.57	1.77	67.16	79.85
	10	10.00	3.00	1.94	20.00	717.86	2.26	67.16	79.85
10 FEET	11	6.00	1.50	1.00	10.00	180.18	0.67	32.67	38.35
	12	6.00	2.00	1.25	10.00	197.34	0.91	32.67	38.35
	13	6.00	2.50	1.50	10.00	233.09	1.41	32.67	44.89
	14	6.00	2.50	1.69	10.00	238.81	1.77	32.67	44.89
	15	8.00	2.00	1.25	10.00	241.67	0.91	44.48	49.75
	16	8.00	2.50	1.69	10.00	281.71	1.77	44.48	49.75
	17	8.00	3.00	1.69	10.00	361.79	1.77	44.48	57.92
	18	8.00	3.00	1.94	10.00	358.93	2.26	44.48	57.92
	19	10.00	2.50	1.69	10.00	333.19	1.77	67.16	79.85
	20	10.00	3.00	1.94	10.00	410.41	2.26	67.16	79.85

(GEAR) GEARHEAD COSTS

COST OF GEARHEAD FOR BRAKEHORSEPOWER

<20	<40	<60	<80	<100	<150	<200	<275	<375	>375
1	2	3	4	5	6	7	8	9	10
544.50	599.50	781.00	1017.50	1094.50	1661.00	1798.50	3652.00	3949.00	4273.50

(PUMP) COST OF PUMPBASES

COLUMN PIPE DIAMETER	6 INCH	6 INCH	8 INCH	10 INCH
SHAFT DIAMETER	>1.5	<1.5	ALL	ALL
	1	2	3	4
	367.20	835.65	808.65	865.35

(BOWL) BOWL COSTS

GALLONS /MINUTE	*	SHAFT SIZE	FIRST STAGE 1	SECOND* STAGE * 3	SHAFT SIZE	FIRST STAGE 2	SECOND * STAGE * 4
200	*	<1 1/4	404.34	100.74*	>1 1/4	427.80	103.50*
400	*	<1 1/4	372.60	100.74*	>1 1/4	387.78	103.50*
600	*	ALL	496.80	155.94*	ALL	496.80	155.94*
800	*	ALL	496.80	155.94*	ALL	496.80	155.94*
1000	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1200	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1400	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1600	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*

(PIPE) PIPE COSTS AND PARAMETERS

	ROW	TYPE 2	DIAMETER INCHES 3	FRICTION LOSS CONSTANT 4	COST/ FOOT 5	EXPECTED LIFE 6
ALLUMINUM LATERAL	1	1.00	2.00	0.40	1.40	15.00
	2	1.00	3.00	0.40	1.50	15.00
	3	1.00	4.00	0.40	1.70	15.00
	4	1.00	5.00	0.40	1.95	15.00
	5	1.00	6.00	0.40	2.10	15.00
	6	1.00	8.00	0.40	2.40	15.00
	7	1.00	10.00	0.40	2.80	15.00
	8	1.00	12.00	0.40	3.20	15.00
	9	1.00	0.0	0.40	0.0	15.00
	10	1.00	0.0	0.40	0.0	15.00
ALLUMINUM MAIN LINE	11	1.00	2.00	0.34	1.80	15.00
	12	1.00	3.00	0.33	1.90	15.00
	13	1.00	4.00	0.32	2.10	15.00
	14	1.00	6.00	0.32	2.50	15.00
	15	1.00	8.00	0.32	2.80	15.00
	16	1.00	0.0	0.32	0.0	15.00
	17	1.00	0.0	0.32	0.0	15.00
	18	1.00	0.0	0.32	0.0	15.00
	19	1.00	0.0	0.32	0.0	15.00
	20	1.00	0.0	0.32	0.0	15.00
ALLUMINUM HIGH PRESSURE LINE	21	1.00	1.50	0.34	1.80	15.00
	22	1.00	2.00	0.34	1.90	15.00
	23	1.00	3.00	0.33	2.00	15.00
	24	1.00	4.00	0.32	2.20	15.00
	25	1.00	6.00	0.32	2.60	15.00
	26	1.00	8.00	0.32	2.90	15.00
	27	1.00	0.0	0.32	0.0	15.00
	28	1.00	0.0	0.32	0.0	15.00
	29	1.00	0.0	0.32	0.0	15.00
	30	1.00	0.0	0.32	0.0	15.00
ASBESTOS PIPE	31	2.00	6.00	0.31	2.25	20.00
	32	2.00	8.00	0.31	2.75	20.00
	33	2.00	10.00	0.31	3.00	20.00
	34	2.00	12.00	0.31	3.25	20.00
	35	2.00	0.0	0.31	0.0	20.00
STEEL PIPE	36	3.00	3.00	0.36	2.80	15.00
	37	3.00	4.00	0.36	3.20	15.00
	38	3.00	6.00	0.36	4.00	15.00
	39	3.00	0.0	0.36	0.0	15.00
	40	3.00	0.0	0.36	0.0	15.00
PLASTIC PIPE	41	4.00	4.00	0.32	1.75	20.00
	42	4.00	6.00	0.32	2.00	20.00
	43	4.00	8.00	0.32	2.25	20.00
	44	4.00	10.00	0.32	2.75	20.00
	45	4.00	12.00	0.32	3.00	20.00
	46	4.00	0.0	0.32	0.0	20.00
	47	4.00	0.0	0.32	0.0	20.00
	48	4.00	0.0	0.32	0.0	20.00
	49	4.00	0.0	0.32	0.0	20.00
	50	5.00	0.0	0.0	0.0	0.0

(ENGI) ENGINE COSTS

	ELECTRIC			GAS.LP.NG		DIESEL	
	HORSE-POWER	MOTOR COST	CONTROL PANEL	HORSE-POWER	MOTOR COST	HORSE-POWER	MOTOR COST
ROW/COL	1	2	3	4	5	8	9
1	20.00	1020.00	0.0	30.00	700.00	30.00	2000.00
2	40.00	1750.00	0.0	52.00	1000.00	40.00	2900.00
3	60.00	2500.00	0.0	78.00	1450.00	60.00	3200.00
4	75.00	3200.00	0.0	0.0	0.0	75.00	3750.00
5	100.00	3900.00	0.0	104.00	1800.00	100.00	4800.00
6	125.00	5450.00	0.0	130.00	1760.00	150.00	5600.00
7	150.00	7000.00	0.0	150.00	3000.00	175.00	7200.00
8	175.00	8300.00	0.0	200.00	4500.00	200.00	8600.00
9	200.00	9600.00	0.0	225.00	5250.00	225.00	10000.00
10	0.0	0.0	0.0	275.00	6200.00	250.00	10750.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(MULT) ENGINE VARIABLE COST DATA

		LP	NATURAL GAS	DIESEL	ELECTRIC
	ROW/COL	1	2	3	4
GALLONS FUEL/HORSEPOWER HOUR	1	0.1220	0.0110	0.0728	0.8480
GALLONS LUBRICANT/WATER HORSEPOWER HOUR	2	0.0010	0.0010	0.0015	0.0005
REPAIRS/HOUR/$ENGINE PRICE	3	0.00006	0.00006	0.00010	0.00001
LABOR ON ENGINE PER HOUR OF USE	4	0.0600	0.0600	0.0600	0.0300

(VC4) DISTRIBUTION SYSTEM DATA

		HAND MOVE	SIDE MOVE	SIDE MOVE TOW	SELF PROP-PELLED	SURFACE	BIG GUN
	ROW/COL	1	2	3	4	5	6
LIFE OF LATERALS	1	15.00	12.00	12.00	15.00	15.00	15.00
REPAIRS(SEE BELOW)	3	5.00	8.00	8.20	0.05	0.00	6.50
HOURS LABOR/ACRE IRRIGATED	4	0.63	0.19	0.14	0.06	0.49	0.25

SURFACE REPAIR COEFFICIENT=REPAIRS/$LATERAL VALUE/HOUR
SELF PROPELLED REPAIR COEF=REPAIRS/$LATERAL VALUE/YEAR
ALL OTHER REPAIR COEF=REPAIRS/ACRE/YEAR

(SPLA) COST OF LATERALS FOR SELF PROPELLED SYSTEMS

ACRES COVERED	<36.4	<71	<105	<131	>131
	1	2	3	4	5
	0.0	0.0	0.0	30000.00	37500.00

OKLAHOMA STATE UNIVERSITY
IRRIGATION COST PROGRAM

SAMPLE RUN 2
SYSTEM 5

SURFACE SYSTEM

SYSTEM REQUIREMENTS CHARACTERISTICS AND COSTS

THE FARM

ACRES COVERED:	80.0	GALLONS PER MINUTE:	325.	INCHES PER ACRE:	24.00
ANNUAL HOURS USE:	2673.2	PRESSURE/SQ IN. AT DISCHARGE:	5.00	ACRE INCHES PER YEAR:	1920.00
		TOTAL DYNAMIC HEAD:	81.90	ACRE INCHES PER SET:	3.00

THE WELL

WELL DEPTH:	90.0	DEPTH TO WATER LEVEL:	60.0	COST/FOOT DRILL & DEVLP.:	27.00

THE PUMP

DEPTH SETTING COL. PIPE:	80.	NUMBER OF BOWLS SET:	2	PIPE DIAMETER:	6.000
IF 1.EXTRA 10 FT SECTION:	0	COST PER BOWL:	100.74	TUBE DIAMETER:	2.500
# OF 20 FT COLUMN SECT.:	4	SECONDARY BOWL COST:	387.78	SHAFT DIAMETER:	1.500
PRICE PER 20 FT SECTION:	416.13	TOTAL COST OF BOWLS:	876.30	GEARHEAD COST:	544.50
PUMP EFFICIENCY:	0.600	STRAINER COST:	32.67	PUMPBASE COST:	835.65
DRIVE EFFICIENCY:	1.000	SUCTION COST:	44.89	TOTAL PUMP COST:	3998.53

THE ENGINE

ELECTRIC ENGINE		ENGINE COST:	1020.00	BRAKE HORSEPOWER REQUIRED:	11.20
ELECTRIC FUEL:		FUEL COST PER UNIT:	0.060	WATER HORSEPOWER:	6.72
		ALTITUDE:	1200.	PURCHASE HORSEPOWER NEEDED:	11.99
		AVERAGE MAXIMUM TEMPERATURE:	90.0	PURCHASE HORSEPOWER USED:	20.00
HOURS OF ENGINE LIFE:	50000.				

THE DISTRIBUTION SYSTEM

SECTION ONE		SECTION TWO		SECTION THREE		SECTION FOUR	
MAIN LINE BELOW GROUND		LATERAL					
FEET:	2640.00	FEET:	660.00	FEET:	0.0	FEET:	0.0
TYPE PIPE:	PLASTIC	TYPE PIPE:	ALUMINUM	TYPE PIPE:		TYPE PIPE:	
DIAMETER:	8.00	DIAMETER:	6.00	DIAMETER:	0.0	DIAMETER:	0.0
COST/FOOT:	2.25	COST/FOOT:	2.10	COST/FOOT:	0.0	COST/FOOT:	0.0
NUMBER LINES:	1.	NUMBER LINES:	1.	NUMBER LINES:	1.	NUMBER LINES:	1.
BELOW GROUND VALVES:	44.	ABOVE GROUND VALVES:	0.	LATERAL PIPE COST:	1386.00	MAINLINE COST:	5940.00
COST BELOW GR. VALVES:	30.10	COST ABOVE GR. VALVES:	25.75	TOTAL VALVE COST:	1324.40	DISTANCE BETWEEN SETS:	60

THE PARAMETERS

INTEREST RATE:	0.071	LABOR COST PER HOUR:	4.50	TAX RATE:	0.010
INSURANCE RATE:	0.005	COST/GAL OIL OR GREASE:	5.00	WELL TAX PER GALLON:	0.0
YEARS OF WELL LIFE:	20.	YEARS OF COLUMN LIFE:	16.	TAX ASSESSMENT RATE:	0.200
YEARS OF BOWL LIFE:	8.	YEARS OF GEARHEAD LIFE:	15.		

THE PER ACRE INCH COST SUMMARY

FIXED COSTS	DEPRECIATION	TAXES	INSURANCE	INTEREST	TOTAL/ACIN	TOTAL/ACRE	TOTAL/YEAR	INVESTMENT COSTS
WELL	0.06	0.0	0.0	0.04	0.11	2.60	207.76	2430.00
PUMP	0.13	0.00	0.01	0.07	0.22	5.25	419.81	3998.53
MOTOR	0.03	0.00	0.00	0.02	0.05	1.22	97.88	1020.00
SYSTEMS	0.24	0.01	0.01	0.16	0.42	10.02	801.83	8650.39
TOTALS	0.46	0.01	0.02	0.30	0.80	19.09	1527.09	16098.92

VARIABLE COSTS	FUEL	LUBRICANTS	REPAIRS	LABOR	TOTAL/ACIN	TOTAL/ACRE	TOTAL/YEAR
WELL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PUMP	0.0	0.0	0.09	0.0	0.09	2.23	178.15
MOTOR	0.79	0.12	0.02	0.19	1.12	26.92	2153.98
SYSTEMS	0.0	0.0	0.04	0.73	0.77	18.57	1485.30
TOTALS	0.79	0.12	0.15	0.92	1.99	47.72	3817.43
COMPLETE TOTALS					2.78	66.81	5344.52

SAMPLE RUN 2
SYSTEM 5

BASIC DATA

SYSTEM TYPE 5
COMPLEMENT NUMBER 0

(CPS) COLUMN, PIPE, AND SHAFT DATA

	ROW/COL	PIPE DIAMETER 2	TUBE DIAMETER 3	SHAFT DIAMETER 4	PIPE LENGTH 5	LIST PRICE 6	SHAFT FRICTION LOSS 7	STRAINER COST 8	SUCTION COST 9
20 FEET	1	6.00	1.50	1.00	20.00	314.60	0.67	32.67	38.35
	2	6.00	2.00	1.25	20.00	348.92	0.91	32.67	38.35
	3	6.00	2.50	1.50	20.00	416.13	1.41	32.67	44.89
	4	6.00	2.50	1.69	20.00	427.57	1.77	32.67	44.89
	5	8.00	2.00	1.25	20.00	416.13	0.91	44.48	49.75
	6	8.00	2.50	1.69	20.00	493.35	1.77	44.48	49.75
	7	8.00	3.00	1.69	20.00	652.08	1.77	44.48	57.92
	8	8.00	3.00	1.94	20.00	642.07	2.26	44.48	57.92
	9	10.00	2.50	1.69	20.00	570.57	1.77	67.16	79.85
	10	10.00	3.00	1.94	20.00	717.86	2.26	67.16	79.85
10 FEET	11	6.00	1.50	1.00	10.00	180.18	0.67	32.67	38.35
	12	6.00	2.00	1.25	10.00	197.34	0.91	32.67	38.35
	13	6.00	2.50	1.50	10.00	233.09	1.41	32.67	44.89
	14	6.00	2.50	1.69	10.00	238.81	1.77	32.67	44.89
	15	8.00	2.00	1.25	10.00	241.67	0.91	44.48	49.75
	16	8.00	2.50	1.69	10.00	281.71	1.77	44.48	49.75
	17	8.00	3.00	1.69	10.00	361.79	1.77	44.48	57.92
	18	8.00	3.00	1.94	10.00	358.93	2.26	44.48	57.92
	19	10.00	2.50	1.69	10.00	333.19	1.77	67.16	79.85
	20	10.00	3.00	1.94	10.00	410.41	2.26	67.16	79.85

(GEAR) GEARHEAD COSTS

COST OF GEARHEAD FOR BRAKEHORSEPOWER

<20	<40	<60	<80	<100	<150	<200	<275	<375	>375
1	2	3	4	5	6	7	8	9	10
544.50	599.50	781.00	1017.50	1094.50	1661.00	1798.50	3652.00	3949.00	4273.50

(PUMP) COST OF PUMPBASES

COLUMN PIPE DIAMETER	6 INCH	6 INCH	8 INCH	10 INCH
SHAFT DIAMETER	>1.5	<1.5	ALL	ALL
	1	2	3	4
	367.20	835.65	808.65	865.35

(BOWL) BOWL COSTS

GALLONS /MINUTE	*	SHAFT SIZE	FIRST STAGE 1	SECOND* STAGE * 3	SHAFT SIZE	FIRST STAGE 2	SECOND * STAGE * 4
200	*	<1 1/4	404.34	100.74*	>1 1/4	427.80	103.50*
400	*	<1 1/4	372.60	100.74*	>1 1/4	387.78	103.50*
600	*	ALL	496.80	155.94*	ALL	496.80	155.94*
800	*	ALL	496.80	155.94*	ALL	496.80	155.94*
1000	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1200	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1400	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*
1600	*	<1 7/8	699.66	230.46*	>1 7/8	868.02	245.64*

(PIPE) PIPE COSTS AND PARAMETERS

	ROW	TYPE	DIAMETER INCHES	FRICTION LOSS CONSTANT	COST/ FOOT	EXPECTED LIFE
		2	3	4	5	6
ALLUMINUM LATERAL	1	1.00	2.00	0.40	1.40	15.00
	2	1.00	3.00	0.40	1.50	15.00
	3	1.00	4.00	0.40	1.70	15.00
	4	1.00	5.00	0.40	1.95	15.00
	5	1.00	6.00	0.40	2.10	15.00
	6	1.00	8.00	0.40	2.40	15.00
	7	1.00	10.00	0.40	2.80	15.00
	8	1.00	12.00	0.40	3.20	15.00
	9	1.00	0.0	0.40	0.0	15.00
	10	1.00	0.0	0.40	0.0	15.00
ALLUMINUM MAIN LINE	11	1.00	2.00	0.34	1.80	15.00
	12	1.00	3.00	0.33	1.90	15.00
	13	1.00	4.00	0.32	2.10	15.00
	14	1.00	6.00	0.32	2.50	15.00
	15	1.00	8.00	0.32	2.80	15.00
	16	1.00	0.0	0.32	0.0	15.00
	17	1.00	0.0	0.32	0.0	15.00
	18	1.00	0.0	0.32	0.0	15.00
	19	1.00	0.0	0.32	0.0	15.00
	20	1.00	0.0	0.32	0.0	15.00
ALLUMINUM HIGH PRESSURE LINE	21	1.00	1.50	0.34	1.80	15.00
	22	1.00	2.00	0.34	1.90	15.00
	23	1.00	3.00	0.33	2.00	15.00
	24	1.00	4.00	0.32	2.20	15.00
	25	1.00	6.00	0.32	2.60	15.00
	26	1.00	8.00	0.32	2.90	15.00
	27	1.00	0.0	0.32	0.0	15.00
	28	1.00	0.0	0.32	0.0	15.00
	29	1.00	0.0	0.32	0.0	15.00
	30	1.00	0.0	0.32	0.0	15.00
ASBESTOS PIPE	31	2.00	6.00	0.31	2.25	20.00
	32	2.00	8.00	0.31	2.75	20.00
	33	2.00	10.00	0.31	3.00	20.00
	34	2.00	12.00	0.31	3.25	20.00
	35	2.00	0.0	0.31	0.0	20.00
STEEL PIPE	36	3.00	3.00	0.36	2.80	15.00
	37	3.00	4.00	0.36	3.20	15.00
	38	3.00	6.00	0.36	4.00	15.00
	39	3.00	0.0	0.36	0.0	15.00
	40	3.00	0.0	0.36	0.0	15.00
PLASTIC PIPE	41	4.00	4.00	0.32	1.75	20.00
	42	4.00	6.00	0.32	2.00	20.00
	43	4.00	8.00	0.32	2.25	20.00
	44	4.00	10.00	0.32	2.75	20.00
	45	4.00	12.00	0.32	3.00	20.00
	46	4.00	0.0	0.32	0.0	20.00
	47	4.00	0.0	0.32	0.0	20.00
	48	4.00	0.0	0.32	0.0	20.00
	49	4.00	0.0	0.32	0.0	20.00
	50	5.00	0.0	0.0	0.0	0.0

(ENGI) ENGINE COSTS

	ELECTRIC			GAS,LP,NG		DIESEL	
	HORSE-POWER	MOTOR COST	CONTROL PANEL	HORSE-POWER	MOTOR COST	HORSE-POWER	MOTOR COST
ROW/COL	1	2	3	4	5	8	9
1	20.00	1020.00	0.0	30.00	700.00	30.00	2000.00
2	40.00	1750.00	0.0	52.00	1000.00	40.00	2900.00
3	60.00	2500.00	0.0	78.00	1450.00	60.00	3200.00
4	75.00	3200.00	0.0	0.0	0.0	75.00	3750.00
5	100.00	3900.00	0.0	104.00	1800.00	100.00	4800.00
6	125.00	5450.00	0.0	130.00	1760.00	150.00	5600.00
7	150.00	7000.00	0.0	150.00	3000.00	175.00	7200.00
8	175.00	8300.00	0.0	200.00	4500.00	200.00	8600.00
9	200.00	9600.00	0.0	225.00	5250.00	225.00	10000.00
10	0.0	0.0	0.0	275.00	6200.00	250.00	10750.00
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0

(MULT) ENGINE VARIABLE COST DATA

		LP	NATURAL GAS	DIESEL	ELECTRIC
	ROW/COL	1	2	3	4
GALLONS FUEL/HORSEPOWER HOUR	1	0.1220	0.0110	0.0728	0.8480
GALLONS LUBRICANT/WATER HORSEPOWER HOUR	2	0.0010	0.0010	0.0015	0.0005
REPAIRS/HOUR/$ENGINE PRICE	3	0.00006	0.00006	0.00010	0.00001
LABOR ON ENGINE PER HOUR OF USE	4	0.0600	0.0600	0.0600	0.0300

(VC4) DISTRIBUTION SYSTEM DATA

		HAND MOVE	SIDE MOVE	SIDE MOVE TOW	SELF PROP-PELLED	SURFACE	BIG GUN
	ROW/COL	1	2	3	4	5	6
LIFE OF LATERALS	1	15.00	12.00	12.00	15.00	15.00	15.00
REPAIRS(SEE BELOW)	3	5.00	8.00	8.20	0.05	0.00	6.50
HOURS LABOR/ACRE IRRIGATED	4	0.63	0.19	0.14	0.06	0.49	0.25

SURFACE REPAIR COEFFICIENT=REPAIRS/$LATERAL VALUE/HOUR
SELF PROPELLED REPAIR COEF=REPAIRS/$LATERAL VALUE/YEAR
ALL OTHER REPAIR COEF=REPAIRS/ACRE/YEAR

(SPLA) COST OF LATERALS FOR SELF PROPELLED SYSTEMS

ACRES COVERED	<36.4	<71	<105	<131	>131
	1	2	3	4	5
	0.0	0.0	0.0	30000.00	37500.00