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The Agricultural Benefits of Salinity Control on the Red River of Texas and Oklahoma

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THE AGRICULTURAL BENEFITS OF SALINITY CONTROL ON THE RED RIVER OF TEXAS AND OKLAHOMA

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ABSTRACT

Salinity of the waters from the Red River and its major tributaries has virtually eliminated its use for irrigation of agricultural crops in Texas and Oklahoma. A chloride control project has been proposed whereby the source salt waters will be captured and diverted to storage facilities. The purpose of this study was to estimate the net direct benefits to agricultural producers attributable to the proposed salinity control project. Further, estimates of project costs, municipal and industrial benefits and benefits from improving the water in Lake Kemp were obtained to complete a benefit-cost analysis.

The procedure used to estimate agricultural benefits was to use a FORTRAN program to develop initial tableaus of a recursive linear programming model representing agricultural production in the study area. Alternative scenarios involving profit maximizing behavior on the part of producers, current cropping patterns, and with and without SAR crop yield effects were developed to provide a range of benefit estimates. The basis for benefit evaluation was to use parameters prescribed by the U.S. Water Resources Council's Principles and Standards and recent proposed changes along with those developed in this study to estimate the increase in net returns to producers in the study area between a with project and a without project condition for a 100 year period of analysis. Benefits were discounted to their present value with discount rates of 7 1/8 percent and 3 1/4 percent for comparative purposes. Benefits estimated herein were used in conjunction with external estimates of project costs and other benefits

to evaluate the economic feasibility of the salinity control project.

In all scenarios considered, cotton emerged as the major irrigated crop. Scenarios involving profit maximizing behavior on the part of producers resulted in benefit estimates of over $65 million and $117 million without and with SAR crop yield effects, respectively, at the 7 1/8 percent discount rate. Under a constrained profit maximization scenario where SAR crop yield effects were included and in which producers were assumed to keep current cropping patterns in 1990, adjust to 50 percent of the optimal land use in 2000, and were fully adjusted to optimal land use by 2010, resulted in agricultural benefit estimates of over $87 million at the 7 1/8 percent discount rate. In a scenario where producers were assumed to maintain current cropping patterns throughout the 100 year period of analysis, benefits were estimated to be $28.8 million and $35.8 million without and with SAR crop yield effects, respectively, at the 7 1/8 percent discount rate.

Benefit-cost analysis performed in this study indicated that the proposed project was economically feasible under assumptions of all scenarios considered except where current cropping patterns were followed for the entire analysis period. B/C ratios of 1.068 and 1.291 resulted for the profit maximization scenarios without and with SAR crop yield effects, respectively. Where benefits from the constrained scenario were included in the benefit-cost analysis, a B/C ratio of 1.162 resulted. Finally, with current cropping patterns maintained through 2090, B/C ratio estimates Of .907 and .938 resulted without and with SAR crop yield effects included, respectively.

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table | Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Salinity of irrigation water and the residual effects of using saline water for crop production are among the more important problems currently facing irrigated agriculture. Salinity limits crop production on approximately one-third of the world's irrigable land. Holland, Sweden, Hungary, the Middle East, parts of the Soviet Union, and the Southwestern United States are major areas facing potential accumulation of harmful salts (Yaron).

Among the regions in the United States experiencing relatively high salinity concentrations of its irrigation water is the Red River Valley of the South. The watershed of 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 Army Corps of Engineers is currently developing plans for a project to control the point source of natural salt pollutants in the Red River that would make its waters more acceptable for irrigation as well as municipal and industrial uses. Thus, the initial presumption is that an improvement of the irrigation waters in the Red River will lead to increased irrigation adjacent to the river

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The style and format of this dissertation follows that of the American Journal of Agricultural Economics.

and hence increased agricultural output for the Red River basin and the nation as a whole.

The effect of salinity on agricultural crops is typically expressed as a decrease in yield associated with a given level of soil salinity as compared with yield under non-saline conditions (Maas and Hoffman). Aside from the toxic effects that salts have on plants, the more important effect is the salt accumulation that occurs with repeated application of highly saline irrigation water; evapotranspiration and evaporation remove pure water, leaving the salts. Increased soil salinity causes significant changes in the osmotic pressure of the soil solution resulting in less water uptake by the plant than is needed for normal growth (Longenecker and Lyerly). Normal crop yields also require satisfactory seed germination and emergence. Often accompanying high salinity levels are SAR (sodium absorption ratio) problems; that is, the high percentage of residual sodium in the soil causes rain and irrigation water puddling, soil crusting, reduced germination, and hence reduced emergence and stand establishments. Thus, as a result of lower and slower plant growth and sometimes reduced stand establishment, crop yields are reduced from using sufficiently saline water and/or sodic soils.

It is clear that reduction of salinity levels of irrigation water in portions of the Southwest can increase agricultural output of that region. Projections of increased worldwide demands for food and fiber through the coming decades increasingly focus attention on the need to increase agricultural output (Oyloe; Brannon; Hjort). There are indications that agriculture throughout the world must operate at or near capacity to meet the food needs of the next decade.

However, to significantly reduce salinity concentrations of irrigation water in the Red River will require substantial capital investment on the part of society, and U.S. taxpayers in particular. Thus, based on the premise that additional agricultural output has some estimable monetary value in the U.S. economy, this analysis of the agricultural economic benefits of the Red River project was undertaken.

The decision about whether or not the project should be undertaken rightly belongs to the social decision makers who presumably have access to all the appropriate project cost and benefit estimates and have some "feel" for relative social values in regards to increased agricultural output, income transfers to the direct beneficiaries of the project, environmental effects, and the like (Beattie, _et_ _al_.). It is, however, the economists' position, and indeed the Federal government's position (Office of the Federal Register), that the economic implications and feasibility of such a project should be explored and that the results enter into the decision making process. Therefore, this research, dealing primarily with the agricultural benefits of the proposed Red River Chloride Control project, is intended to add to the store of information needed to make the appropriate decision and provide a guide for similar analyses.

The Proposed Salinity Control Project

In the late 1950's the Public Health Service initiated studies to determine the causes of natural pollution in the Red River basin and concluded that chlorides and sulfates are the principal pollutants.

Congress then authorized the Corps of Engineers (COE) to develop and submit plans for Chloride Control in the basin and finally authorized the project in 1970 under Public Law 91-611. Natural chloride pollution was found to originate upstream from Lake Texoma, a major multipurpose lake located in the center of the basin (Department of the Army). An average of 3300 tons of salt is estimated entering Lake Texoma daily. About 1100 tons is brine from local oil fields. The remaining salts come from 10 natural salt source areas in the Wichita River basin (about 450 tons daily) and upper Red River basin (about 1750 tons daily) (Department of the Army).

The salinity control project to be selected by the Corps of Engineers was to meet three objectives:

"a. To control stream pollution from each natural source to the degree that the concentration at major downstream checkpoints would not exceed an upper limit of 250 mg/l (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 quantity, 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." (Department of the Army, p. 3).

General project alternatives considered were a pipeline to the Gulf of Mexico, desalination, importation of water for dilution, and local collection and disposal systems. Political, economic, technological, and environmental considerations indicated the latter alternative to be the most effective means of control.

If approved, one type of collection system is to be subsurface cut-off walls near the salt sources. A collection pipe will transfer the salt water to wells where it will later be pumped to a disposal area. A second collection method is to be a series of shallow wells pumping salt water directly to disposal areas. Still another proposed system is a large reservoir located downstream of the salt sources that would serve as both a collection and a disposal site capable of handling maximum flows expected in 100 years. The final disposal system described is a system of deep wells where the salt water could be pumped into a suitable geologic formation for permanent storage (Department of the Army).

Study Area

For the purpose of economic evaluation, the Corps of Engineers originally separated the Red River basin into 15 evaluation reaches along the main stream of the Red River and its major tributaries. Figure 1 illustrates the Corps of Engineers' original study area specification. Below Lake Texoma dilution is sufficient to cause no significant yield reduction due to salinity (Gerard, et al., 1979a). Upstream from Lake Texoma, however, irrigation of major crops (i.e., pasture, cotton, grain sorghum, wheat, and alfalfa) is for the most part precluded by high salinity levels in the alluvium water. There is some irrigation presently using the highly saline water, but predominantly cultivated acres are produced "dryland".

The study area will be limited to areas in Texas and Oklahoma 1.5 miles on each side of the Red River and its major tributaries and having significant crop yield reduction due to highly saline irrigation

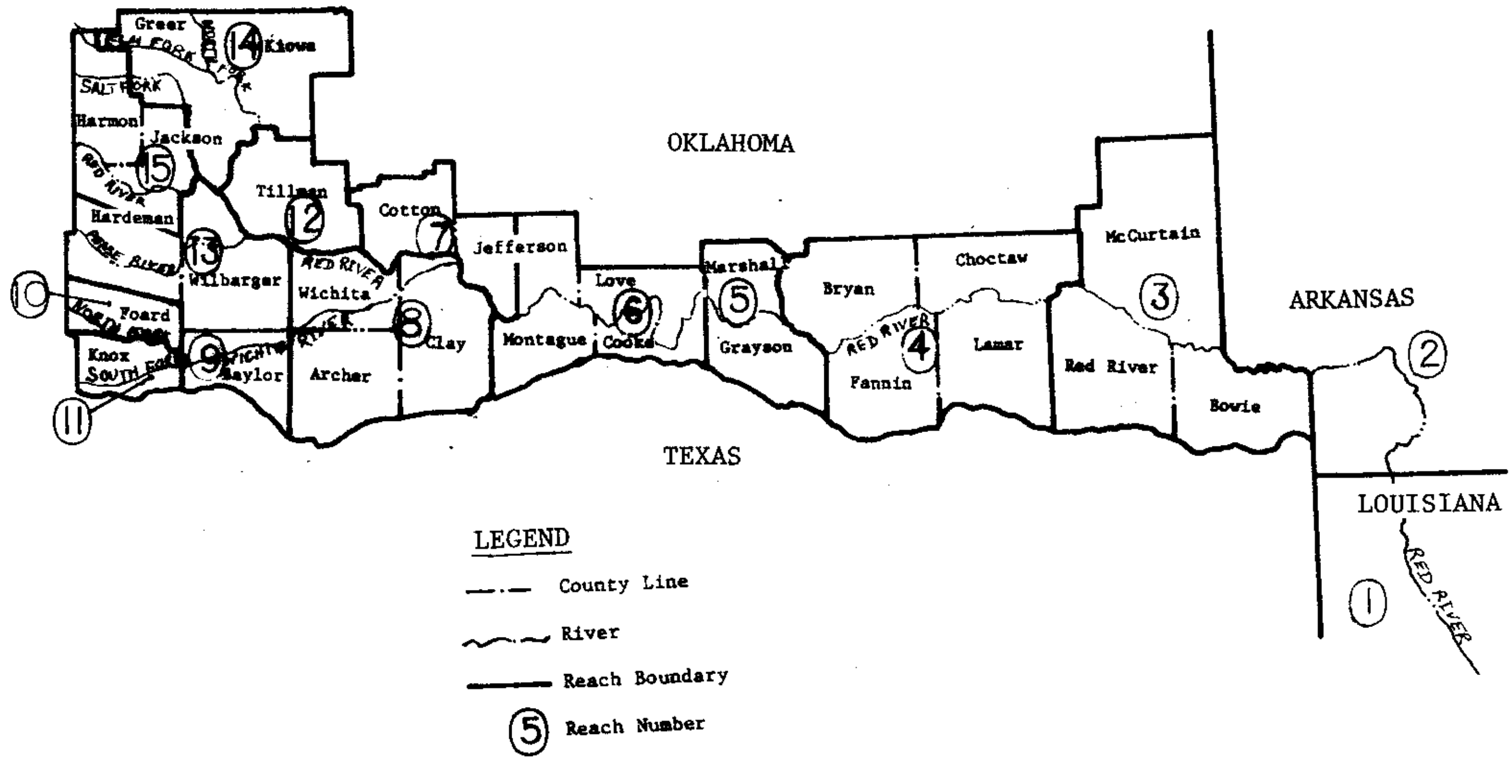


Figure 1. Map of the Study Area

waters. This will include Reaches 5 through 15 of Figure 1. The study area contains over 666,000 acres of potentially irrigable land. Average monthly minimum temperatures in this region range from a low of 30° F to a monthly average maximum of around 100° F. Average rainfall ranges from 16 inches in the western reaches of the study area to 30 inches above Lake Texoma. The majority of this precipitation falls in the warm season from April through October. Thus, irrigation throughout the study area is considered supplemental, but significant in terms of its contribution to stabilizing and increasing crop production (Gerard, et al., 1979a).

Objectives

The overall objective of this study is to quantify the direct net benefits and the resulting changes in the levels of agricultural production that could be attributed to a Red River Chloride Control Project. Specific objectives are as follows:

1. To develop a model for estimating total net revenue to agriculture and the associated cropping patterns along the Red River and its major tributaries for selected scenarios of salinity and SAR induced yield effects.
2. To estimate the net benefits of the chloride control project where:

   a) Profit maximizing cropping patterns are followed.

   b) SAR causes a reduction in crop yields in addition to the reduction from saline irrigation water.

   c) Adoption rate to profit maximizing cropping patterns of irrigation farmers is delayed or not realized immediately.

d) Current cropping patterns are followed in the future.

3. To develop and apply a regional econometric model to estimate the benefits of a chloride control project on the Red River and compare the results to those of the normative model developed in objective one.
4. Develop a price-quantity relationship (demand) for irrigation water in the study area using the model developed in objective one.

Literature Review

The importance of salinity in agricultural production is exemplified by the numerous articles and books dealing with control and management of saline irrigation waters (e.g., Dregne; Shainberg and Oster). Likewise, numerous volumes have been written focusing on economic evaluation of large water resource projects (e.g., Smith and Castle; Haveman). Only a few, however, have brought the technical aspects of salinity together with economic aspects of project evaluation in order to estimate the monetary benefits of salinity control (e.g., Flack and Howe; Anderson and Kleinman). Literature cited is relevant to this study in that it deals with technical aspects of salinity and its effects on agricultural crops as related to (1) measuring benefits from agricultural application of water, (2) evaluation of benefits (or damages) of application of saline irrigation water, and (3) the broader aspects of evaluation of water resource development projects.

Literature concerning the effects of salinity on plant growth is voluminous. Berstein and the U.S. Salinity Laboratory Staff are most often cited as the source of salinity data throughout the world. Maas and Hoffman developed an extensive review and evaluation of the past 30 years of salt related research. They report on physical data relating crop yield to total soluble salts in the root zone. They found an approximate linear relationship between yield reduction and soil water salinity beyond the plant's salt tolerance threshold. Thus, in their review Maas and Hoffman establish the link between crop response to salinity and salt content of irrigation water.

Although the link between salinity and yield reduction has been established, with appropriate management moderately saline water can be used for irrigation without significant yield reduction. Longenecker and Lyerly discuss the application of a "leaching percentage" of 20 to 45 percent of the amount of irrigation water needed for consumptive use to flush the salts beyond the active root zone. Hipp indicated that fall rains could substitute in South Texas for added water application usually needed for leaching. O'Connor and Cull reported that a 20 percent leaching fraction was sufficient in the Pecos River area of Texas. Likewise, Gerard, et al., 1979, have suggested a 20 percent leaching fraction for the Red River area of Texas after a salt control project is in place.

The Gerard, et al., 1979a, study for the Red River region combined much of the published technical information on salinity and information pertaining to a salinity control project on the Red River, i.e., rainfall, and water salinity before and after a salinity control project, to estimate yield reductions and irrigation water requirements for major crops with and without the project for each of the evaluation reaches proposed by the Corps of Engineers. Without the project, irrigation is generally not possible in the upper reaches with the saline water while with the project yield is often reduced for sensitive crops. In the lower reaches, without the project, irrigation is possible but only with reduced yields while with the project yields are not reduced due to salinity.

In that same study, Gerard et al., 1979b, also address the SAR problem by estimating additional yield reduction for each crop if the stand establishment and water absorption is reduced. SAR problems combined with salinity in the region would essentially render the saline water unusable for irrigation throughout the study area without the project according to Gerard, et al., 1979b.

Many studies have dealt with the economics of irrigation and the value of water in crop production for various regions. Moore and Hedges was one of the earlier studies using linear programming to derive normative demand schedules for irrigation water. They developed demands for different sized farms in Calfornia.

The importance of irrigation to the High Plains region of Texas has warranted several studies. Adams, Lacewell and Condra used linear programming to derive short-run input demand schedules and to evaluate the impact of varying input prices on energy and energy related inputs. They derived demand relations for diesel, natural gas, nitrogen fertilizer, and water. Water price in their study was considered as the price producers could afford to pay for water above pumping and distribution costs. Using average level commodity prices, a water price of up to $22 per acre foot caused less than a four percent reduction in water use while at $71.75 per acre foot irrigation ceased.

In a similar but more detailed study on the effects of rising energy and water prices, Lacewell and Condra developed a long-run linear programming model including more of the fixed costs and focusing on the demand for irrigation water on the High Plains. As the price of water was increased wheat production shifted from irrigated to dryland, followed by grain sorghum and cotton, and lastly corn and soybeans went out of production. With all costs considered and at a water price of $55.47 per acre foot, all land shifted to dryland production.

Mapp and Dobbins developed a recursive linear programming model--10 five-year periods--to examine the impact of rising natural gas prices on the pattern of irrigated crop production, net farm income, and quantity of water pumped through time. Their study area was the Oklahoma Panhandle and surrounding area overlaying the central basin of the Ogallala aquifer. Optimal solutions were generated for representative farms under three water resource situations based on aquifer saturated thickness and well yield, two sets of crop prices, and two types of tillage practices--conventional and reduced tillage. They used both constant and increasing natural gas prices in their recursive model to compare results from various scenarios. Mapp and

Dobbins found, not surprisingly, that as pumping costs increase over time, a gradual shift to dryland production occurs. They report that, under constant natural gas prices some irrigated production remains profitable for the entire 50-year period, but rising natural gas price causes at least a 15-year shorter economic life for the aquifer. Reduced tillage practices increased net returns when they were allowed to enter the model, but caused less orderly cropping pattern shifts. Likewise, high product prices encouraged more intensive irrigation practices and more than offset the increased pumping costs over time. They found product price was the most important factor in determining the economic life of an exhaustible water resource.

Casey, Jones, and Lacewell developed a recursive model for the High Plains of Texas and Oklahoma combining linear programming and input-output techniques. The linear programming portion of the model allocated the region's limited water supply so as to maximize producer net returns subject to resource constraints while the input-output section constrained the linear programming portion of the model. This model was used primarily to estimate regional effects of alternative rates of irrigation development in the High Plains. Results indicated that adequate groundwater is available for growth in agricultural output during the next few years, but, that producers should not be optimistic about sustained long term growth in regional agricultural output beyond 1990.

Condra, _et al_. used the MOTAD (Minimization and Total Absolute Deviations) approach to simulate the planning process involving risk for a representative irrigation farm in the Trans Pecos region of Texas. They used a somewhat different formulation than Hazell's original model in that expected net returns were maximized subject to the risk restraint rather than the original minimization formulation. The modified MOTAD linear programming simulation model was used to give estimates of the irrigation farm survival and profitability over time. Alternative future scenarios for inflation rates, energy prices, crop prices, and interest rates were postulated and used to analyze the effects of risk-aversion and tenure situations. Results indicated that survival and profitability of irrigated crop production in the study area depends heavily on favorable input and product prices and that rate of return and survival increased in response to decreased levels of risk-aversion. Further, it was concluded that land purchase provided greater potential return than traditional crop share rental arrangements.

In quite a different type of study, Frank and Beattie used ridge regression to estimate production functions for agricultural production in 11 regions of the Western U.S. and subsequently derived demands for irrigation water in those regions. They estimated demand for irrigation water in general to be slightly elastic. Further, using this technique they estimated the marginal values of irrigation water at mean variable values to vary from a high of $27.79 per acre foot in the long run in Central California to a low of $1.71 in the short run for the Snake-Columbia River Basin.

The problem of salinity in irrigation water and the economic benefits of salinity control were brought together by Yaron and Olian when they used dynamic programming to evaluate long run benefits of water quality improvements (salt control) on citrus production in Israel. They varied leaching levels and salt accumulation within their model to get various levels of decision variables. Decision variables were qualities of water for leaching and irrigation frequency. Their long-run model was generally a micro-level model requiring firm aggregation to a regional level.

McFarland used a combination of dynamic programming and linear programming to determine the optimal intertemporal rate of groundwater use in Mexico. Salt intrusion into a declining fresh water aquifer was the problem. He determined the optimal policies for irrigation and leaching levels in Northwest Mexico.

Damages from salinity were estimated in the Colorado River by Anderson and Kleinman in a 1978 report. They used linear programming to determine optimal cropping patterns and applied yield reduction parameters to establish damages. Further, they used an input-output model to establish the secondary effects throughout the regional economy.

Several works have been written on the theoretical base for water resource development projects in general; Smith and Castle, Haveman, Beattie et al., and Howe and Easter, to name only a few. Likewise, theories of benefit-cost analysis have been investigated in detail by Dasgupta and Pierce, and Mishan. These works are fairly general in that they discuss the theoretical background of benefit-cost analysis and/or public investment, e.g., Pareto conditions, accounting stances, discount rates, externalities, etc. These aspects of project evaluation will be explored more fully in the theoretical discussion to follow in Chapter II.

The U.S. Water Resources Council, operating under provision of the Water Resource Planning Act of 1965, published its "Principles and Standards for Planning Water and Related Resources" specifically to provide standards for evaluating federal water resource projects. Recently--May, 1979--the Water Resources Council proposed additions and changes to the previous rules and regulations that provide even more standardization for project evaluation. For example, irrigation project benefits are now required to be calculated using prescribed crop yield increases over time (OBERS), a prescribed discount rate, a 10 percent of variable cost management charge, etc. (Office of the Federal Register). Thus, these Water Resources Council guidelines will be an important part of this study in that they will determine many parameters of the evaluation and like the basic theory will be discussed more in the next chapter.

The importance of irrigation to agricultural production in the Western U.S. and particularly to Texas and Oklahoma is evidenced by the numerous articles and books written on the subject and briefly reviewed in this section. Certainly, this review is only a brief survey of this voluminous literature. However, it serves to point up the various directions of previous water related research and the techniques used to address the perceived problems. Modeling and analyzing the problem at hand will draw, often very subtly, on many of these works. Thus, the following chapter on the theory involved in this analysis and Chapter III dealing with procedures will bring together many of the ideas and techniques found in the literature just discussed and will point out major problems as they relate to this study. Then, the cropping pattern results of this study will follow in Chapter IV and estimation of agricultural benefits to salinity control on the Red River in Chapter V. Finally, Chapter VI will provide a summary of the study and its limitations.

CHAPTER II

THEORY

Detailed evaluation of water resource development projects has been mandated by Congress and involves analysis of economic efficiency, equity, and environmental impacts (Office of the Federal Register). The goal most often suggested for natural resource management is the maximization of "social welfare" which is usually taken to mean the simultaneous optimization of these three objectives. In the final analysis, this optimization is left to the subjective judgement of the social decision maker since complete quantification of all the variables involved is impossible. Nevertheless, the job of the decision maker can be confined to a large extent to value judgements concerning the weights society gives to efficiency, equity, and environmental effects, by the provision of sound, positive analyses in each of the relevant disciplines associated with water resource planning (Beattie, et al.).

Of the three areas of concern mentioned above, economic efficiency has, through the years, received the most attention. Water resource planning policy has generally dictated that all government financed development projects will be at least economically efficient except in situations designed to assist local economies with high unemployment of resources and transfer income into those economies. That is to say that monetary benefits must be larger than costs and to the extent possible the difference between benefits and costs maximized. This concern for economic efficiency and to a lesser extent for the equity issues has, in the past 40 years, spawned a vast interest and volumonous theory of welfare economics and publically financed project evaluation procedures. Since the focus of this research is on the economic efficiency aspects of a proposed salinity control project, its theoretical underpinning is needed for clarification of the issues involved.

The main theoretical tool of analysis for this research is benefit-cost analysis. The final and seemingly simple result of the benefit-cost theory, the B/C ratio (or other criterion), is couched in a much more encompassing theory of welfare economics, production economics, financial considerations, and quantitative estimation techniques. Thus, to understand the economic efficiency and equity implications of the analysis technique a brief survey of the theoretical background is presented.

The Pareto Criterion

The interrelationships among the various components of the economy suggest that a change in one component will affect many other components in the economy. Thus, the question of whether or not a particular change in one part of the economy, e.g. salinity control on the Red River, will increase or decrease total welfare is the issue of concern. By the Pareto Criterion, an economy is said to be in its optimal state (maximum welfare) when any change in production or consumption that increases the utility of one or more individuals cannot be made without decreasing the utility of at least one individual.

This Pareto optimal position is considered efficient since no change from that position can make one individual better off while leaving all others no worse off. Likewise, a Pareto improvement can be described as a change that moves an economy toward a Pareto optimal. This is not to imply that there is only one Pareto optimal position for an economy. On the contrary, there are an infinite number of optimal positions, each depending on the initial endowment of resources (Henderson and Quandt).

Figure 2 illustrates exchange between two consumers with the standard Edgeworth Box diagram. Pareto movements shown there are in an economy of two consumers, A and B, who have been initially allocated amounts of goods X and Y. If, for example, the initial allocation is at C where B has mostly Y and little X and A has mostly X and little Y and their preferences are represented by the indifference curves as shown, bargaining between A and B will move both individuals to some point between D and E on the contract curve. Neither A nor B would voluntarily move beyond these points to an indifference curve that would give him utility below 10 units since each initially has at least 10 units of utility. Thus, given the initial distribution C, a Pareto optimum or efficient position will be reached between D and E inclusive. If, however, the initial allocation of X and Y were at F, the movement would be to points on the contract curve between G and H inclusive. Thus, the contract curve is the set of all Pareto optimal allocations of X and Y for consumers A and B. Notice that the indifference curves of A are tangent to the indifference curves of B along the contract curve; i.e., A's marginal rate of substitution of X for

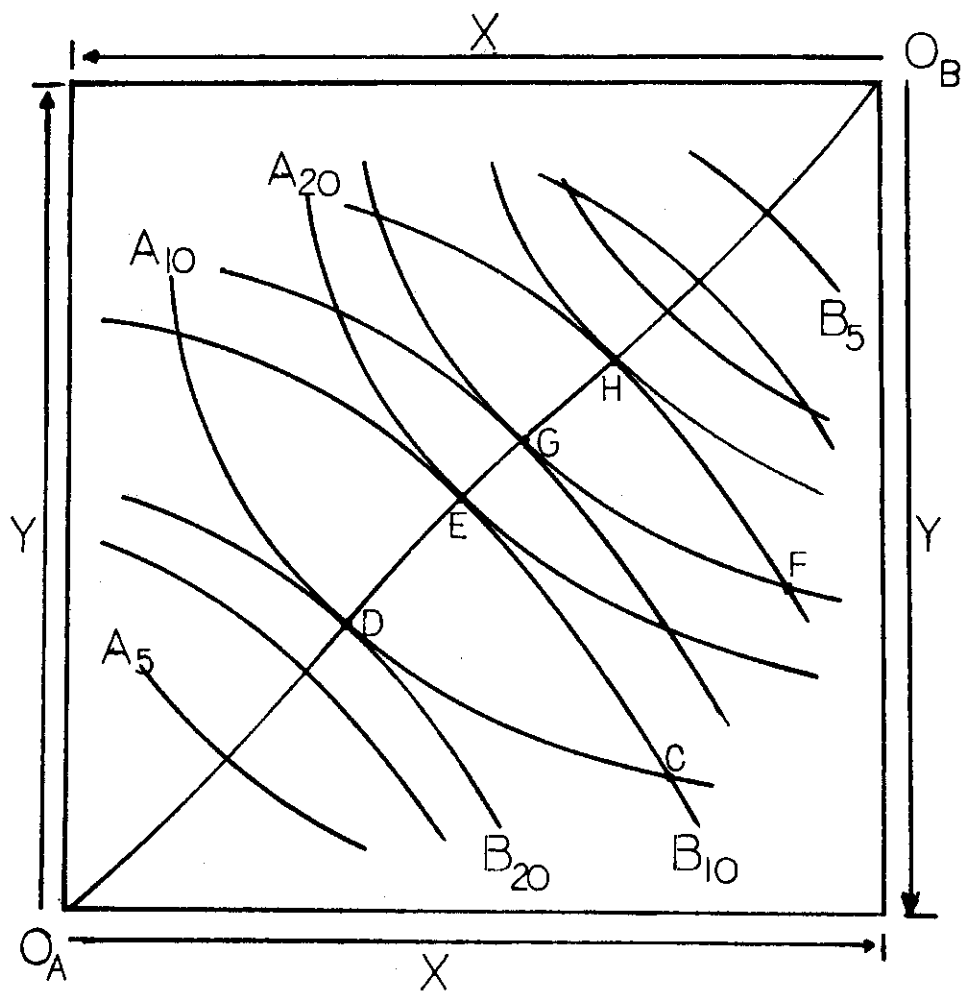


Figure 2. Edgeworth Box Diagram Illustrating Exchange Between Two Consumers

Y equals B's marginal rate of substitution of Y for X. Analogous statements for the relationship between producers and consumers and among any number of producers and consumers can be made (Silberberg). Once the contract curve is reached, however, no further movement will be made voluntarily since at least one individual would be made worse off. That is to say, points on the contract curve involve interpersonal comparison and the Pareto criterion makes no provision for subjective judgements. Thus, the Pareto criterion does not guarantee that social welfare will be maximized, only that given the initial allocation of resources a local optimum is achievable. Indeed, a different initial distribution of resources may be more desirable than the one at which the economy starts. Thus, Pareto optimality is theoretically necessary for social welfare maximization but not sufficient.

The Kaldor-Hicks Principle

The Pareto criterion outlined above would say that a policy or project is acceptable if at least one individual or group is made better off while no one is made worse off. Seldom, however, do projects fit these requirements. Most projects tend to involve gains to some and losses to others. The Kaldor-Hicks principle, based on the Pareto criterion, declares that a change in the economy is acceptable if those who gain from the change can compensate those who lose from the change and still have some gain left over (Dasgupta and Pearce). In terms of the Pareto criterion, if compensation is actually made then the more restrictive conditions of the Pareto criterion are actually fulfilled. In practice, compensation need only be possible and not actually carried out to meet the Kaldor-Hicks criterion.

Benefit-Cost Criterion

It is precisely the aforementioned principle that underlies the benefit-cost analysis. If the monetary benefits to the gainers from the project are larger than the monetary losses incurred by losers from the project, so that in theory gainers could compensate losers, the project is said to be desirable from an economic efficiency standpoint. If compensation does not actually occur, an income transfer to the gainers from the losers is made. Again, the initial or final distributions of gains and losses may be undesirable or the marginal utility of the measuring unit (e.g., the dollar) used in making the interpersonal comparison among participants may not be constant (Dasgupta and Pearce). In these cases both Pareto and Kaldor-Hicks criterion are nullified. However, if one can accept the initial and the resulting final distribution of resources and assume an equal marginal utility of income throughout the economy so that objective analyses can be made, then the Kaldor-Hicks principle provides a firm basis for benefit-cost analysis.

Classification of Benefits and Costs

Once a criterion for project acceptability has been established, i.e., welfare gains greater than welfare losses, the challenge is to accurately quantify both gains and losses attributable to the project under consideration. Quantifiable gains and losses to society take the form of specific monetary benefits and costs that accrue to individuals and/or groups in the society. Thus, within the benefit-cost framework it has become convenient to categorize the different types of benefits and costs and the individuals or groups to whom they accrue. A brief listing and explanation of these categories is given below (taken from and more complete definitions are given in Beattie, et al.).

"Direct benefits and costs:

Direct benefits represent increases in the present and real market value of the immediate products and services attributable to the project. Direct costs represent decreases in this value...

Direct project costs -- decreases in the present and real market value of incremental national output that are incurred in order to build and maintain the development structures (reservoirs, dikes)...

Direct associated benefits -- increases in the present and real market value of incremental national output that are realized from the sale of the immediate products and services attributable to the project...

Direct associated costs -- decreases in the present and real market value of incremental national output that are incurred (beyond direct project costs) in order to realize the direct associated benefit...

Indirect benefits and costs:

Indirect benefits are benefits resulting from the economic activity generated in the process of realizing direct benefits. Indirect benefits (costs) are realized (borne) by those individuals who service direct beneficiaries as well as by individuals interdependent sectors of the economy...

Indirect project benefits -- (1) incremental gross income earned by individuals owning factors (e.g., labor) employed in the construction or maintenance of the project, as well as (b) incremental gross income earned by individuals in other sectors of the national economy that are related to the construction and maintenance sectors...

Indirect project costs -- (a) the opportunity gross income forfeited by individuals owning factors employed in the construction or maintenance of the project, as well as (b) the cost of the factors required to produce the incremental gross income in those other sectors of the national economy that are related to ("induced by") the construction and maintenance sectors.

Indirect associated benefits -- these include (1) increases in gross income (a) earned by individuals in those sectors of the economy that process the incremental output of the project, as well as (b) that earned by individuals in those sectors related to the processing sector ("stemming from"); (2) increases gross income (a) earned by individuals... that provide the necessary input to direct beneficiaries..., as well as (b) that earned by individuals in those sectors related to ("induced by") the providing sectors; and (3) increases in gross income (a) earned by individuals... that provide an outlet for additional consumption expenditures that result from increased income available to primary beneficiaries, as well as (b) that earned by individuals in those sectors related to ("induced by") the consumptive goods sectors.

Indirect associated costs -- these costs include (1)(a) the cost of additional factors employed in those sectors of the economy that process the incremental output of the project as well as (b) the cost of additional factors employed in ("stemming from") those sectors related to the processing sectors; ..." (pp. 63-66).

Thus, to perform an adequate benefit-cost analysis it is necessary to first identify precisely those benefits and costs to include.

Benefits from the Red River Chloride Control Project come primarily from two broadly defined direct sources: (1) municipal and industrial uses, and (2) agricultural irrigation. Costs of the project mainly involve construction and maintenance of the chloride control structures themselves. Estimation of direct and indirect municipal and industrial benefits and direct and indirect project costs is beyond the scope of this study, although, estimates of these components were obtained in order to complete the analysis. Thus, the remaining component of the analysis, net agricultural irrigation benefits, is the focus of this research.

Net agricultural benefits are considered to be a function of direct associated benefits, direct associated costs, indirect associated benefits, and indirect associated costs. One of the most fundamental assumptions of this study, however, is that net national indirect benefits are zero (i.e., indirect associated benefits equal indirect associated costs). It is generally agreed that in an economy of full employment of all resources, perfect competition, and in general equilibrium, the largest net national indirect benefit possible, as well as direct benefits, is by theoretical construction equal to zero. In other words, as Beattie, et al. state: "given this economic utopia, any reinvestment of resources represents only a transfer of income from one user to another, and at best, net national product can be no greater than before the reinvestment" (p. 12).

However, most would also agree that the economy is never at absolutely full employment of resources, and further is extremely dynamic in changing tastes and preferences, production techniques, kinds and quantities of available production resources, etc. Thus, in the case of less than full employment one would expect positive net direct and indirect benefits (exclusive of project costs) to most development projects, i.e., resources actually drawn into production activities associated with the development project must have higher marginal value than their previous use or, as theory would suggest, they would not be pulled from their previous use to a new one. This is not to say that the total net direct or indirect effect, inclusive of project costs, would necessarily be expected positive. Thus, it is the sum of net direct and indirect benefits that must be compared to project costs in order to determine the desirability of any development project.

The reality that net national indirect benefits are probably positive does not, however, necessarily justify their inclusion in the analysis. A more fundamental reason for exclusion is that they are most probably insignificant and would be quite costly to completely quantity. For example, the increased net income that accrued to farmers from an irrigation project that provided irrigation water where before there was none would constitute the net direct agricultural benefit to the irrigation project. However, the net indirect benefit of the increased net incomes of their input suppliers, output processors, and local store owners who benefit from increased sales to the farmers, would likely not be significant in comparison to the total cost of the project. This is because additional resources brought into production as a result of the project must be taken from some other use and thus their opportunity cost in the alternative use must be charged against any benefit. Thus, the net national effect is likely to be small, zero, or even slightly negative if resources are more fully employed in the development region than other parts of the economy and their complete quantification would certainly be difficult. This is not to say that these effects are not important to local economies close to development sites. Indeed, local studies would be very interested in these "multiplier" effects through their local economies. However, at the national level with near full employment of resources, these affects are expected to approach zero and, have generally been excluded from analyses of most water resource development projects. Thus, with the recognition that indirect benefits will probably be positive, they will not be counted in this study based on its national accounting stance and the difficulty in estimation that inclusion would present.

To summarize, agricultural benefits to the Red River Chloride Control project are comprised of direct and indirect benefits. The estimate of direct benefits will be the increased net income of producers that potentially irrigate from the Red River alluvium. All indirect benefits were assumed equal to zero, thus leaving only direct benefits to offset project costs.

The "With and Without Principle"

To appropriately evaluate the benefits and costs of a project, economic development must be estimated for two situations: with the project and without the project. The description of the without project economy provides a baseline situation from which to estimate benefits attributable directly to the project. Certainly the economy in question will develop in some fashion without the project. But, it will probably develop in a quite different way with it. Thus, the "with and without principle" requires projection of the without project economy, not merely the acceptance of the current situation as the baseline from which to contrast the with project economy (Eckstein). In this study, the baseline situation for each scenario is developed similar to its "with project" counterpart, e.g., profit maximizing behavior without the project as well as with the project. In each case benefits are measured as the difference in net returns between the with and without project condition.

Discounting

Public investment in capital projects generally requires the sacrifice of current benefits in favor of a stream of future benefits. However, one unit of current benefits is worth more than one unit of benefits a year from now, etc. Thus, for the purpose of project evaluation, the benefit-cost criterion requires that all future benefits (and costs) attributable to a federal water resource development project be discounted to their present value. The discounting procedure for benefits is:

$$NPV_{\beta} = \sum_{i=0}^{n} \frac{B_i - C_i}{(1+r)^i}$$

where:

NPV_{β} = the net present value of benefits

B_i = the project benefits in year i

C_i = the project costs in year i

r = the rate of discount

i = the discounting period (years).

n = number of years.

This procedure is relatively straightforward, providing that acceptable estimates of annual benefits and costs can be made and project life can be reasonably determined. The only real controversy that arises from this procedure is in the choice of the discount rate. The private opportunity cost rate, a social opportunity cost rate, a social rate of time preference, and the government borrowing rate are some of the rates that have been suggested for public investment projects. However, it is beyond the scope of this study to investigate in detail each of these various rates (Dasgupta and Pearce give a thorough treatment to this issue, pp. 136-156). Suffice it to say here that Congress has prescribed the interest rate to be used in the evaluation of water resource development projects which will be discussed later.

Pricing

In a perfectly competitive economy (with all its implications) and in the absence of externalities, the appropriate (shadow) price for inputs and outputs in the benefit-cost analysis is their marginal cost of production. Pareto optimality theory dictates that social welfare will be maximized (locally) with this marginal cost pricing scheme. In the Pareto economy this price will be reflected by the actual market price since the Pareto economy equilibrates to that point.

However, this utopia seldom exists in the real world. One or more of the conditions for the perfectly competitive economy will be violated; externalities in production or consumption may exist; and institutional constraints will almost certainly exist. Thus, in most cases of benefit cost analysis, some modification of or subjective judgement about the appropriate prices to be used must be made since the theoretically perfect set does not exist in the real world. These prices should reflect as closely as possible the true value of inputs and outputs to society. The pricing scheme used in this study will be discussed more fully in the next chapter.

Benefit Valuation

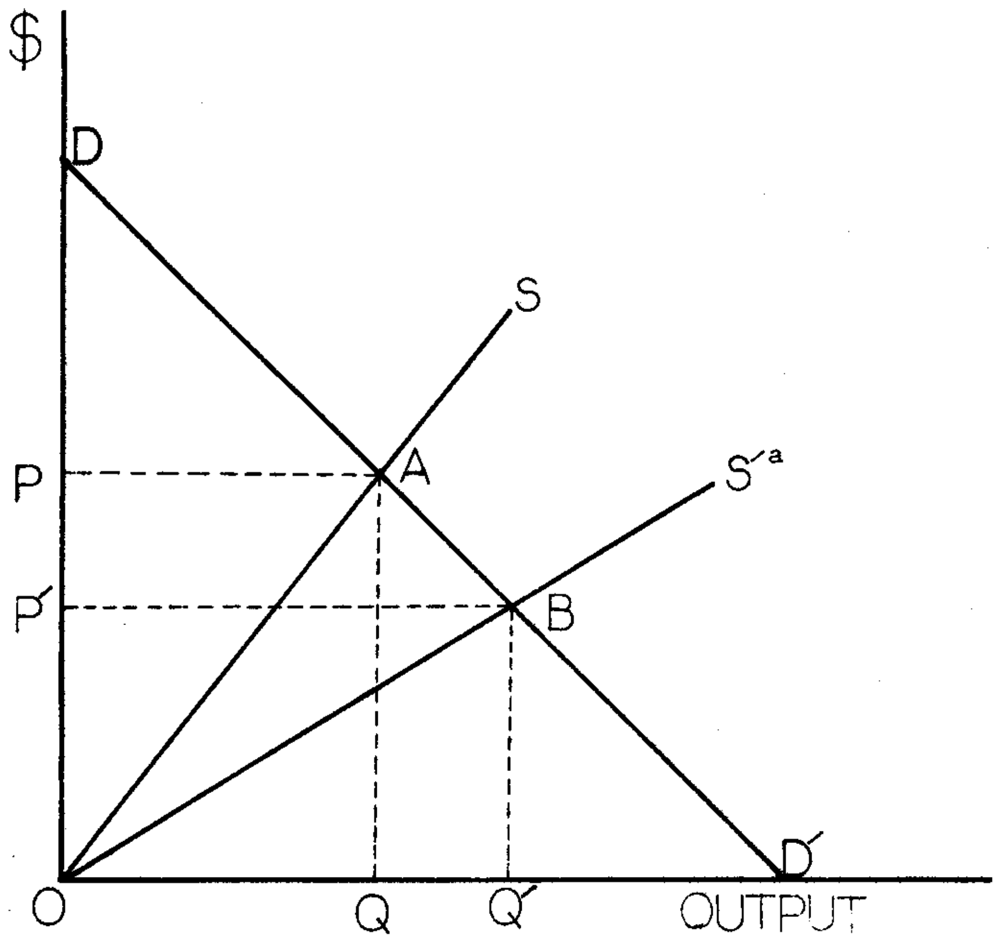
In order to estimate the agricultural benefits to a water resource development project some method of benefit valuation must be devised; i.e., how much is society willing to pay for the project? The theory of consumer and producer surplus made popular by Marshall can be a useful tool in describing the benefits to be measured and in a broad sense, the individual and/or groups to whom they accrue, i.e., producers and consumers.

In recent years much controversy has evolved in relation to the accuracy and appropriateness of consumer surplus as a measure of social welfare. One element of the controversy has been whether or not the area below the ordinary demand curve and above the price line (on the typical demand schedule graph) accurately measures consumer surplus (Silberberg). Another point of argument has been whether or not increases in consumer surplus represent improvements in general welfare and the extent to which they are dependent upon income and distributional effects (Samuelson). However, more recently new approaches have been adopted that have slightly altered the semantics of the conventional welfare theory but have effectively clarified it as useful in measuring changes to gainers and losers of specific policy or project developments (Willig; Just). Thus, following Willig and others, changes in the sum of producers' and consumers' surplus will be taken as meaningful measures of welfare changes.

For the evaluation of all water resource projects for the nation as a whole, economic theory would suggest that the market for agricultural products would have the standard downward sloping demand curve and upward sloping supply curve. Figure 3 illustrates the original situation with demand DD' and partial equilibrium supply OS. The original (without project) condition would result in price P and output Q with consumer surplus DAP and producer surplus PAO. If, however, the nation decided to conduct substantial water resource development projects that provide irrigation water to farmers where before there was none or otherwise lower the unit cost of agricultural output, theory suggests a shift (increase) in the supply of agricultural products to OS'. This results in increased output, from Q to Q', and in a price fall from P to P'. Thus, consumers clearly gain (area PABP'), and would be willing to pay up to the amount represented by PABP' to face the lower price P' and consume quantity Q'.

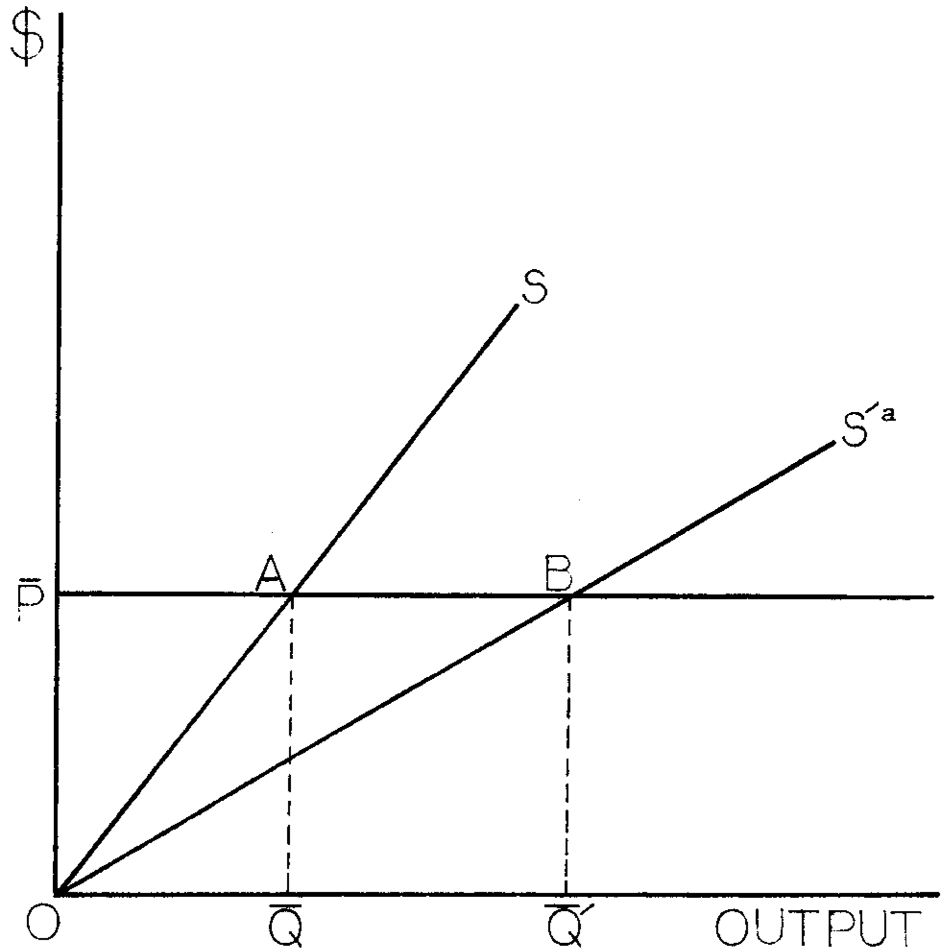
Producers' surplus changes as well, but it is not clear at all whether they gain or lose. Producers' surplus changes from PAO to P'BO and the positive or negative nature of the change is dependent upon the elasticities of demand and supply (Wallace).

On the other hand, for evaluation of any one particular water resource development project, the relevant model changes somewhat. Figure 4 illustrates this model. Again, economic theory suggests that agricultural producers in any one area would have an upward sloping supply (marginal cost) curve, OS, before the development and OS' after development of the project. However, it is likely that any one, relatively small development project would not effect enough producers so that their aggregate output would have an effect on the national price level (i.e., perfectly competitive markets). Thus, if the price for agricultural products does not change for those producers affected,



[a]The exact type of supply shift, whether parallel or otherwise, is unknown. The shift shown is for illustrative purposes.

Figure 3. Example of Demand and Supply for Agricultural Output Before and After Irrigation Project Development.



[a]The exact type of supply shift, whether parallel or otherwise, is unknown. The shift shown is for illustrative purposes.

Figure 4. Example of Supply Shift Resulting from a Relatively Small Irrigation Project.

i.e., they can sell all additional output at price $\bar{P}$, then output of those producers would change from $\bar{Q}$ to $\bar{Q}'$ after the project development. Therefore, producers clearly gain surplus (quasi-rents) from area $\bar{P}$AO to $\bar{P}$BO. Further, in this model construct, there is no change in consumer's surplus. Thus, for any one water resource development project, the appropriate agricultural benefit to be estimated is area OAB, i.e., the increased surplus (quasi-rent) attributable to project.

In the case of any one project, as illustrated above, consumers would have no incentive to pay for (i.e., pay taxes to finance) a water resource project in which they get no additional surplus return. However, as illustrated earlier, water resource projects in general do provide price incentives and the opportunity for increased consumption to consumers. Further, consistent with the Kaldor-Hicks criterion of compensation, Congress does indeed require that federal funding of water resource development projects be predicted on the fact that (or at least the estimate that) agricultural benefits plus any other identifiable benefits are larger than project development costs. In theory, direct beneficiaries should be able to repay project costs. However, this type of repayment is a political issue and not an economic one. Thus, the agricultural benefits, represented by area OAB of Figure 4, may turn out to be simply an income transfer to producers, but, the evaluation procedure of this study nevertheless follows the Kaldor-Hicks theory to determine project desirability.

Production Principles

The agricultural benefits derived from any water resource development project are dependent upon what producers actually do, i.e., how producers organize production in response to the improved availability of irrigation water. In relation to earlier discussion, how much will the supply curve for each commodity actually shift. One of the analytical techniques used to estimate changes in cropping patterns (and thus producer benefit) was the development of a recursive model with its application under alternative scenario specifications. In cases where irrigation is supplemental, as in the Red River area, the actual response to improved irrigation water quantity or quality is often difficult or impossible to accurately ascertain. Thus, in this study, different scenarios were established to represent a wide range of possible responses and provide a basis for analysis. The various scenarios differ in either the assumed effect of salinity on crop yields or the restriction placed on intentions (or capabilities) of producers to follow profit maximizing resource allocation. The different scenarios will be discussed shortly, but first a brief discussion of their similarities is appropriate.

First, producers were always assumed to be cost minimizers in all production activities. Budgets developed for each activity (and thus all technical coefficients) were assumed to reflect the minimum cost associated with production of a given level of output. That is to say that the ratio of marginal productivity of each resource to its marginal factor cost is equal to that ratio for each other resource. This implies technical efficiency in the choice of a production function for each commodity as well as economic efficiency in terms of the specific point on any particular production function that farmers would choose to produce. Further, this assumption is applied to both the with and without project condition. Thus, all of the principles of cost minimization (to attain specified output levels) in resource allocation from micro static production economic theory were involved in the budgeting process.

Second, some scenarios developed for evaluation were centered around assumptions about the objectives (or capabilities) of producers. In some scenarios it was assumed that producers were profit maximizers in addition to being cost minimizers (for each specified output level) and would choose their set of production activities accordingly. That is to say that multi-product firms will organize output so that the rate of product transformation equals the inverse output price ratio (in perfect competition). Thus, in the profit maximization scenarios, multi-product firm economic theory provides a basis for the analysis in addition to the already assumed cost minimization behavior.

Third, alternative scenarios were developed for the entire study area with no regard for individual farmers' land boundaries. Only acreage in the study area was considered. Thus, in scenarios where profit maximization is assumed as the objective, solutions involve the profit maximizing acreage specification as though the entire study area were one large unit. This solution would be identical to profit maximizing solution for each individual producer if only acreage in the study area were included in each producer's plan. However, if acreage, assets, and other production alternatives available to each producer outside the study area were included, i.e., a farm management type study, the solutions could vary significantly from those of the approach taken. However, this effect was not expected to significantly influence the results since production alternatives were included in the model which represent some of those alternatives not considered directly, e.g., livestock grazing wheat pasture.

Fourth, production economic concepts of the relationship between the quantity of a production input used at various prices, i.e., marginal value product equals input price, were employed to derive demand functions for irrigation water in the Red River study area. Thus, the marginal concepts in relation to input use plays and important role in part of the study.

Principles and Standards

The Water Resources Planning Act of 1965 (Pub. Law 89-80) provided for establishment of the Principles and Standards and the May 1979 proposed rule changes Sec. 704.111, 704.122 of the Federal Register, play and important role in the benefit-cost procedure of this study. The Water Resources Council and the U.S. Congress have, through these acts, confirmed in general the benefit-cost theory and specified many of the controversial parameters to be used in the evaluation of water resource development projects. Thus, for analyses to be acceptable to the U.S. Government, strict adherence to these guidelines must be observed.

In general, the procedure outlined by the aforementioned documents follows the theory presented in this chapter. Since these guidelines are common knowledge to water resource analysts, only those changes (or clarifications) recently published in the Federal Register and having relevance for this study will be discussed here.

The proposed changes first clarify the calculation of benefits in relation to project installation time and the actual occurence of benefits. They specify that costs and benefits will be discounted to a common time period by a discount rate published annually by the Water Resources Council. For this project the interest rate was prescribed to be 7 1/8 percent while the common period of comparison was selected as 1990 (Department of the Army). However, some portions of the project were approved at 3 1/4 rate and thus, analysis at this rate was also done. Further, the proposed changes specify that projects will be evaluated on the basis of no more than 100 years of useful life.

Section 704.122 of the Federal Register dealing with irrigation benefits and costs is of particular importance to this study. In that section, the Water Resources Council specifies many of the procedures and parameters to be used in establishing irrigation benefits. They first specify that increased net returns attributable to the project from increased agricultural production will be the measure of benefits. They further specify that only major crops--cotton, wheat, corn, soybeans, milo, hay, pasture, barley, and oats--may be used in national benefit estimations. This is because significant increases in regional production of some minor crops may impact national price levels and lower prices, and thus benefits, for other regions as well. Thus, the net effect would involve a nationwide study and not simply regional analysis.

In regards to costs and returns for these crops, prices are specified to be "projected prices by time periods" that "reflect market clearing conditions...". The Water Resources Council in turn publishes "normalized prices" for these crops which supposedly reflect the long-run market clearing prices to be used for water related projects. Thus, these published prices were adopted in this study. Future yields of the alternative crops are prescribed to be based on current yields plus a "historically derived" rate to be supplied by the Water Resources Council, i.e., OBERS projections. Thus, this yield procedure was also adopted.

Producton costs are prescribed to include the purchased inputs valued at "current market price," family and operated labor at "prevailing labor rates," management charges at 10 percent of variable production expenses, and interest charges at the project discount rate. These costs are specified to increase through time by an index to be provided by the Water Resources Council. However, since a set of constant prices was adopted it would be incorrect to assume cost inflation as well. Indeed, inflation at the same rate in both prices and costs, which is what one would normally assume in the absence of prior information, is offsetting, simply complicates analysis, and adds nothing that helps in the decision making process. Thus, constant prices for inputs as well as outputs were adopted.

Evaluation procedures are specified to include with and without project forecasts of land use patterns as well as the computation of net benefits attributable to the project. Further, a description of current land use patterns is required. Finally benefits are specified as the difference between the discounted flow of net returns with and without the project.

Application of the Theory

Two techniques of benefit estimation were used in this study. One method was to econometrically estimate the actual supply function for major crops in the study area. This method correlates directly to discussion in the previous section and allows for a direct measure of the surplus involved. Another method was a more conventional technique utilizing standard production economic principles of budgeting, least-cost production, profit maximization, etc. Nevertheless, the results of benefit estimation from this method can be interpreted as an indirect measure of the producer surplus gain described in a preceeding section. Thus, a more detailed discussion of the principles involved in these two methods is given below.

The Mathematical Technique

The mathematical technique selected as the base for the model development was a recursive linear program in which a FORTRAN matrix generator was employed to build the initial tableau for each period of the analysis. This technique is particularly desirable for this type of study since large models consisting of many production alternatives, many resource constraints, and multiple time periods can be easily specified and the appropriate objective function optimized. Further, with additional specification, the model can be restricted to include a specified cropping pattern. Thus, very large and often complex problems can be organized, manipulated and solved using linear programming techniques that would otherwise be unmanageable.

The linear programming technique used for solving basin wide resource allocation problems is not without its faults, however. Among the standard criticisms of linear programming to solve production problems is its discrete nature. That is, assumptions about the finiteness, divisibility and proportionality of activities and resources forces the consideration of only specified points on the traditional production function instead of infinite possibilities of resource combinations available for the continuous production function in economic theory (Agrawal and Heady).

One of the most fundamental problems associated with this technique, however, is its inability to predict the actual outcome. An objective to be maximized or minimized is assumed. The linear programming algorithm optimizes that objective, i.e., the technique is strictly a normative one. Further, the evidence available (and indeed in this study) indicates that there is substantial difference between optimal solutions and actual performance (Castle). Thus, if this technique of with and without project analysis is to be used effectively, some consideration of the appropriate models to be compared and/or methods of model restriction must be made. For example, it would not be appropriate to compare the after project results from a basin wide model with a profit maximization objective function to the before project current situation. This would most probably assign substantial benefits to the project due to improved resource allocation and production organization delineated by the after project linear programming solution that would not actually occur. Thus, use of this tool for analysis must also include some subjective judgements about the appropriate comparison and model specifications to be made.

Econometric Technique

Based on favorable results of an econometric simulation model designed to estimate producer and consumer surplus changes in response to major disruptions in the agricultural production sector (Collins), a Leontief indirect function was assumed in order to estimate supply functions for the Red River study area. The Leontief indirect profit function assumed was:

$$(1) \qquad \pi^* (\pi_1, \pi_2, \ldots \pi_n) = \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \, \pi_i^{\frac{1}{2}} \, \pi_j^{\frac{1}{2}}$$

where:

π^* = maximum total profit

π_i = profit of the i^{th} enterprise

α_{ij} = parameters.

This is a slightly different formulation than Diewert's original work in that enterprise profits replace commodity prices. From this indirect formulation the Envelope Theorem results give the acreage behavioral choice functions:

$$(2) \qquad \frac{\partial \pi^*}{\partial \pi_i} = \sum_{j=1}^{n} \alpha_{ij} \left(\frac{\pi j}{\pi_i} \right)^{\frac{1}{2}} = A_i^* (\pi_i, \ldots, \pi_n)$$

Symmetry of the Leontief formulation further implies that $\alpha_{ij}=\alpha_{ji}$ for $i \neq j$ (Diewert). Thus, the acreage response functions to be estimated, $A_i^*(\pi_i, \ldots, \pi_n)$, are given by (2) above comprise a system of equations that can be simultaneously estimated using Restricted Generalized least squares where the α_{ij}, $i \neq j$, are forced to equal each other (Johnston). Hence, total study acreages for each crop can be used as the dependent variable in each respective equation and can be fit simultaneously against the various specifications of net returns (π_i) per acre for each crop as shown in equation 2.

Once the acreage responses are obtained, an estimate of the effect of the salinity control project in shifting the supply must be made. This is done by adjusting the net returns value for each crop that results from salinity control. Since the effect of salinity, and salinity control, varies throughout the study area, a weighted average effect would be appropriate. Upon the assumption of the appropriate salinity effects, the change in producers' surplus (the measure of direct benefits) can easily be calculated as the difference in total profits to producers with and without the project.

CHAPTER III

PROCEDURES

The procedures used to estimate potential benefits to agriculture from the Red River Chloride Control Project using the mathematical modeling technique involved the following steps:

(a) Estimation of current (1979) dryland and irrigated crop yields for each of the soil types in the study area.

(b) Development of crop enterprise budgets (cost and returns budgets), both dryland and irrigated, for each of the crops that are produced in the study area.

(c) Application of a computer model to determine irrigation costs for both sprinkler and furrow irrigation systems for three half-mile zones on each side of the Red River and its major tributaries.

(d) Development and application of a matrix generator and a linear programming model that incorporates both exogenous and endogenous data to determine land use patterns and associated farmer net revenues under both with and without project conditions, over the life of the project, and under alternative scenario specifications.

(e) Calculation of the present value of the net revenue stream under the with and without project conditions and calculations of net project benefits to agriculture for each scenario.

The steps outlined above constitute only a very brief summary of the analytical procedures. Vast amounts of input data and individual calculations are required for the analysis of each reach. Since an understanding of the analytical procedures used may aid in interpreting and evaluating the results, a more detailed discussion of the procedural steps is given in the following discussion. Attention is first focused on the data requirements and sources, then on the model development and operation, and finally on the alternative scenarios.

Exogenous Data Base

Estimation and analysis of potential economic benefits from the Red River project can be considered the second phase of a two phased study. The first phase was designed to estimate some of the physical relationships pertaining to crop yield reductions and water requirements before and after the proposed project (Grossman and Keith). More specifically, data from phase I included:

a) Data relating to chloride concentrations of water from the Red River with and without the project.

b) Relationships of yields for each crop to chloride concentrations; e.g., percent reduction in yield attributable to the chloride concentration, and with and without SAR effects.

c) Total water requirements by crop and by reach. Water requirements for irrigation included allowances for normal precipitation and for leaching requirements.

d) Acreages potentially suitable for irrigation by soil type, slope and land capability class in three 0.5 mile zones on each side of the Red River and its major tributaries, by county and by reach within the study area.

e) Recommended irrigation systems for each soil type (furrow, border or sprinkler).

f) Acreages currently in major crops, by county and reach within the study area, existing irrigation and current management practices and crop rotations in the study area.

Additionally, estimates of the amount of water available for irrigation use for each reach were obtained from the Army Corps of Engineers. Further, estimates of project construction costs, maintenance costs and municipal and industrial benefits were obtained from the Army Corps of Engineers and used in the final project evaluation. These items will be discussed individually as needed in the remaining sections of this and following chapters.

Endogenous Data Base

Crop Yields

The estimation of crop yields involved first the development of current yield estimates by soil types for each of the crops produced in the study area, and second, the projection of the yields over the project life. Yield projections beyond 1990 are based on current yields and on OBERS Series E' increases (U.S. Water Resources Council, OBERS Projections). The procedures for making the projections are described in the discussion of the analytical model in a subsequent section. The discussion here is directed only to the estimation of current yields.

The acreage data supplied by the Grossman and Keith study were classified not only by soil type but also by slope and/or land capability class. This totaled to a very large number of separate soil classifications. In many instances, the acreages for a given soil type fell predominately within one slope or capability class. In such instances, the acreages for this soil type across all slopes were combined under the predominant slope. This procedure greatly reduced the number of calculations involved and due to the very small acreages involved did not have any significant effect on the results of the analysis. If the acreages for a given soil type were substantial and were fairly evenly divided among two or more slopes, the acreages were not combined. The number of soil types for which yield estimates were developed is shown by reach in Table 1.

All initial yield estimates were developed under the assumptions of high level management and, for irrigation, high quality water. The yields were later adjusted to reflect typical management and water quality differentials. These adjustments were handled in a FORTRAN matrix generator and the procedures are discussed in the section on the analytical model. The reasons the yield data were developed initially to reflect high level management was because the "Blue sheets" or "Soil Survey Interpretation" forms prepared by the Soil Conservation Service of the U.S. Department of Agriculture were the major sources of information for developing data on yields, and the yield estimates in these forms were more commonly available for high level management.

Yield estimates, both irrigated and dryland, were developed for Reaches 5 through 15 for cotton, grain sorghum, wheat, alfalfa, and Coastal bermuda. Dryland yields only were developed for native pasture. Guar, oats, barley, soybeans and peanuts were not included, even

Table 1. Number of Soil Types by Reach and Total Acres Within Each Reach

Reach	No. of Soil Types[a]	Total Acres[b]
5	21	66,184
6	57	111,448
7	8	18,175
8	28	138,216
10	8	22,161
11	12	15,865
12	18	37,594
13	26	77,286
14	34	98,456
15	25	47,428
Total	254	666,344

[a]Some soils types appear in more than one reach and are counted separately in each reach which they appear.

[b]Total number of acres in study area that are classified as having possible potential for irrigation.

though there were substantial acreages in these crops in some reaches. This was because these crops are primarily dryland and do not have potential in competing for irrigation water at the yield and price relationships incorporated in this study; or, limited production categorizes these as other than major crops and causes exclusion by the Principles and Standards.

The initial step in developing yield estimates for each reach was to tabulate the yields given in the "Blue sheets" or "Soil Survey Interpretation" forms for each individual soil type and slope or land capability class. These yields were then reviewed by local area soil scientists of the Soil Conservation Service (SCS) for whatever changes or adjustments they felt were needed to make the estimates more indicative of expected yields for the local area.

The resulting yield estimates developed by this procedure are shown for each reach in Appendix A. For the Appendix A tables in instances where the slope was not indicated, the land capability class is shown in the "SLOPE" column. A letter W in the SLOPE column indicates a wetness problem. A number of these soils are on flood plains and subject to occasional to severe flooding. A letter E indicates an erosion problem, while the letter S indicates the productivity of the soil is limited because it is shallow, droughty or stony. A zero appearing in the yield column indicates that the crop would not be produced or was not recommended by the SCS on that particular soil. These yields all reflect high level management and are adjusted to reflect typical management levels in the computer model. This procedure is discussed later.

Crop Enterprise Budgets

A separate cost and returns budget is required for each crop produced in the study area, both dryland and irrigated; for each soil type; and for each 10-year increment over the project life. Separate budgets are required for each 10-year increment because yield changes resulting from application of the OBERS Series E' projections necessitate changes in items such as gross income, fertilizer requirements and harvesting costs. In addition, separate calculations are required in the irrigated crop budgets to account for differences in water transmission costs for the three half-mile zones and for differences in the type of irrigation (furrow or sprinkler). To bring the task of generating budgets within manageable proportions, the procedure was to first develop base budgets, both dryland and irrigated, for each crop produced in the study area to reflect current (1979-80) yields, production practices and costs. Then, adjustments in the base budgets to reflect specific situations were calculated by a FORTRAN matrix generator. The procedures used in the matrix generator are reviewed in the discussion of the analytical model. The discussion in this section pertains only to the base budgets.

The base budgets are shown in Appendix B. The data shown in the base budgets were developed specifically for Enterprise Very Fine Sandy Loam Soils, 0-1% slope in Reach 13. This is one of the most widespread and common soils in the study area. The yields have been adjusted from high level to typical management levels by a 15 percent differential. The yields achieved by typical managers generally approximate 85 percent of the yields achieved by the best managers

(Extension Economists-Management).

Crop enterprise budgets developed for the Texas Rolling Plains and for Southwestern and South Central Oklahoma by the extension services of Texas (Extension Economists-Management) and Oklahoma (Jobes), respectively, were major sources of data, primarily with respect to machinery costs (depreciation, repairs, lubrication, etc.). However, a substantial number of changes and adjustments from the extension budgets were required to reflect local study area conditions.

An initial step in developing the budgets was to delineate common cultural practices in the study area for each crop both dryland and irrigated. These were reviewed with crop scientists of Texas A&M and the U.S. Department of Agriculture who were familiar with the area. These scientists believed there were not enough differences in cultural practices between soil types to warrant differentiation for that reason. Therefore, the same cultural practices were assumed for all soils. Also, double cropping options, i.e., sorghum-wheat, were not considered in the analysis since, as Table B-16 indicates, this alternative is not profitable.

Prices received for crops sold were those given in Agricultural Price Standards issued by the U.S. Water Resources Council. Prices for production inputs (seeds, fertilizer, insecticides, herbicides, fuel, etc.) are area prices as listed in the Oklahoma and Texas extension budgets and pertain to Fall 1979-Spring 1980 cost levels. The amount of fertilizer applied was developed relative to yield based on published fertilizer recommendations for the area from the Texas Agricultural Extension Service.

For most crops, and particularly irrigated crops, harvesting costs vary according to yield. Harvest cost rates per unit of production as used in the analysis are those currently paid by producers in the area. Since both fertilizer and harvesting costs are functions of yield, the costs are calculated separately for each budget in the analytical model. The procedures are discussed in more detail in the section of this report explaining the model. The rates of application for items such as insecticides and herbicides are based on recommendations of crop scientists for the area.

Income from several of the crops comes from the sale of joint products. For example, income from cotton is derived from the sale of both lint and cotton seed. Approximately 1.6 lbs. of seed is produced per lb. of lint. In the matrix generator, a single price is used for cotton which reflects this relationship. That is, the price reflects income from both lint and seed.

Likewise, income from wheat comes from the sale of both grain and from grazing. The production of wheat grazing as well as the production of native pasture is measured in animal unit months of grazing (AUM). An AUM is pasture or grazing required for a cow and her calf for one month or a 1000 pound animal for one month. It was assumed in calculating the budgets that the amount of production of grazing from wheat is related to the level of grain production. An increase or decrease of one bushel in the yield of wheat is associated with an increase or decrease of .0746 AUM of grazing. This estimate is based on relationships between wheat grain yields and grazing rates for the area (Extension Economists-Management). The value of an AUM is based on estimated rates of gain for beef animals from the forage crop involved and normalized prices for beef as given in Agricultural Price Standards. Yields for native pasture were measured in pounds of forage dry weight. This was converted to AUM's by a conversion factor of 1 AUM for each 3120 lbs. of air dried forage. This conversion factor is one generally used by crop and livestock scientists. It involves taking 25 percent of the grass yield, which is the amount of total production typically consumed by animals, and dividing by 780 (Whitson, Hamilton and Scifres). The 780 reflects pounds of air dried forage consumed by one animal in one month.

All costs in the budgets are separated into two major categories, variable and fixed. The variable costs for tractors and field machinery include items such as fuel, repairs and lubrication. These cost estimates were based primarily on the Texas Agricultural Extension Service crop enterprise budgets. The extension budgets in turn were developed mostly on the basis of time requirements per acre for each machine item used, fuel consumption rates, and repair and lubrication costs per unit of time as indicated by tests of agricultural engineers. Irrigation labor was charged at $4.50 an hour, other skilled labor at a rate of $4.50 an hour, while unskilled labor was charged at a rate of $2.75 an hour. These appeared to be the most common wage rates for the area. The rate of interest charged on operating capital was 7 1/8 percent, which is the project discount rate. The amount of operating capital on which interest was charged approximates one-half of total preharvest variable costs, which means the capital is used an average of about 6 months.

Fixed costs on machinery and equipment include depreciation, taxes, insurance and interest on average capital investment. Fixed costs also include a charge for management, which was valued at 10 percent of variable production costs (Office of the Federal Register). No charge was made for land, which means that land is the residual claimant to net returns.

The base budgets are intended only to indicate the general format, approaches and assumptions used in developing all of the crop enterprise budgets required for each reach. A detailed description of model budgets is presented in a later section.

Irrigation Costs

As indicated above, irrigation costs are an integral part of the crop enterprise budgets. Presently, there is very little published information concerning irrigation and irrigation costs for the study area. Budget data from the Texas Agricultural Extension Service considered only irrigated pasture. Although irrigated budget data for most crops were available from the U.S. Department of Agriculture and Oklahoma State University, this information was based primarily on pumping water from an aquifer, not the alluvium, and hence was inadequate for the purpose of this study. For this study, irrigation cost estimates were developed that reflected a well pumping from the alluvium near the river. Other considerations of the overall analysis that irrigation costs had to incorporate were alternative water requirements of a crop, and the incremental leaching fraction. Because of this, specific information related to the irrigation system, the cost of applying various water rates, and system efficiency had to be specified.

The Oklahoma State University Cost Program developed by Kletke, Harris, and Mapp was selected as the appropriate tool for estimating irrigation costs for alternative distribution systems and application rates. This program estimates both fixed and variable costs per acre inch for several types of irrigation systems. The FORTRAN-written program is based upon general engineering computations which consider well capacity, pressure requirements, application rates, hours of operation, fuel, well depth and length of delivery system (laterals). Cost computations include such items as development cost of the well, distribution system costs, engine costs, depreciation, and taxes. The program has standardized input requirements for four systems: (1) center-pivot sprinkler, (2) hand-move sprinkler, (3) side-move sprinkler, and (4) surface irrigation. Based on discussions with scientists and agriculturalists in the Vernon area, the side-move sprinkler and surface system were selected as representative distribution systems for the area. Other input data for the model were obtained from communications with agricultural engineers familiar with the project and experts in irrigation equipment. This resulted in basic assumptions regarding the well, its depth and capacity and the system requirements, either furrow or sprinkler. Sample outputs for the two systems considered are given in Appendix C.

Due to the nature of the economic model, several application rates were required. For this reason, it was felt that continuous cost functions, both fixed and variable, would be appropriate rather than discrete rates as generated by the program. Discrete rates would also require considerable data storage for the economic model.

Several points (per acre application rates) were generated by applying the Oklahoma State cost program. This was done for each of the three zones (.5, 1.0, and 1.5 miles) from the river. A delivery system from the edge of the river to the middle of each zone was assumed. Hence, cost to deliver water to each successive zone away from the river increased for any given application rate. The per acre application rates were fit against their associated fixed and variable costs to produce the functional form. This resulted in the equations as reported in Table 2. It should be noted that the observations used in the regression were not statistically derived, consequently, there was no loss of accuracy in the function versus the discrete point generated by the program.

Notice that the variable cost equation for sprinklers is a function of the same form as fixed costs. This means variable costs per acre inch pumped declines as application rates increase. The reason for this is that in the Oklahoma State program, sprinkler distribution system repair costs are considered as a constant per acre regardless of the application rates. Thus, repair costs per acre inch must decline for greater rates of application.

Fixed and variable costs had to be separated since some calculations used to develop crop enterprise budgets in the economic model were based on variable costs, e.g., the interest on operating capital and the management charge. These equations represent input data to the economic model discussed below.

Table 2. Variable and Fixed Irrigation Costs Per Acre for Alternative Application Rates and Zones[a]

Sprinkler System:

Zone 1 - Fixed Cost = X * (0.0489 + 20.64 * (1/X))[b]

Variable Cost = X * (2.377 + 7.993 * (1/X))

Zone 2 - Fixed Cost = X * (0.0487 + 29.08 * (1/X))

Variable Cost = X * (2.620 + 8.017 * (1/X))

Zone 3 - Fixed Cost = X * (0.0499 + 36.66 * (1/X))

Variable Cost = X * (2.860 + 8.012 * (1/X))

Furrow System:

Zone 1 - Fixed Cost = X * (0.0287 + 18.30 * (1/X))

Variable Cost = X * 1.99

Zone 2 - Fixed Cost = X * (0.0268 + 26.77 * (1/X))

Variable Cost = X * 1.06

Zone 3 - Fixed Cost = X * (0.0279 + 34.29 * (1/X))

Variable Cost = X * 2.11

Where X = quantity of water applied in acre inches.

[a]The zones refer to the 0-.5, .5-1.0, and 1.0-1.5 mile ranges from the river.

[b]Costs are $/acre and X is acre inches of water applied, e.g., $21.81 = 24 x (.0489 + 20.64 x (1/24)).

Analytical Model

The analytical model developed for this study consists of three basic portions: (1) a FORTRAN matrix generator, (2) a mathematical linear programming model and (3) a FORTRAN report writer. The same general analytical model was used for each reach with adjustments made to the input data to appropriately describe each reach.

The model postulated as appropriate for this study was a linear program which included combinations of different crops, soil types and irrigation or dryland production as activities. The postulated model had two basic restrictions, (1) the amount of land in each soil type by reach, and (2) the amount of irrigation water available in each reach. With many reaches to model, many activities and few restrictions, many similarities among activities, compounded by a 10 year recursive analysis, it was necessary to develop a matrix generator for expediency and efficiency.

The matrix generator developed is a FORTRAN program that incorporates exogenous data obtained from the Grossman and Keith report on crops, soils, crop water requirements and water availability, along with crop yields and economic data developed in this study. The matrix generator develops the initial tableau of the linear programming economic model and optionally outputs much of the input and internally calculated data for inspection. The matrix generator creates the model's recursive feature in that it builds an initial "base year" tableau for year 1990 and five additional tableaus corresponding to the five 10-year increments the model is to simulate (2000, 2010, 2020, 2030 and 2040). Beyond 2040 the system was assumed to stabilize to the 2040 condition and remain for the next 50 years. After the base year, OBERS Series E' yield adjustments are used to calculate the new tableaus for each 10-year period. The matrix generator writes the six linear programming tableaus it has generated onto a storage disk in a format that the MPSX linear programming package can directly read. Once the correctly formatted data are on disk storage, the MPSX package reads the tableau data for each period and proceeds to a solution. The MPSX package in turn is signaled to write the solution onto disk storage. The stored linear programming solution is then read by another FORTRAN program, the report writer, which finds the objective function values and cropping pattern variables, does the discounting and writes a summary of cropping patterns and a summary of annual discounted net returns for the 100 year period. Optionally, the matrix generator can be signaled to write much of the input data such as costs of production and yield by soil type by crop as well as many of the resulting internal calculations in the form of a set of one-line but complete enterprise budgets (to be discussed in detail later). Figure 5 gives a diagramatic representation of the model mechanics. The following sections contain a detailed description of these three components, their required inputs, outputs, and general operation.

Mathematical Linear Programming Model

The mathematical portion of the economic model, the linear program, provides a means of estimating changes in net returns of agricultural production that would be brought about by chloride control on

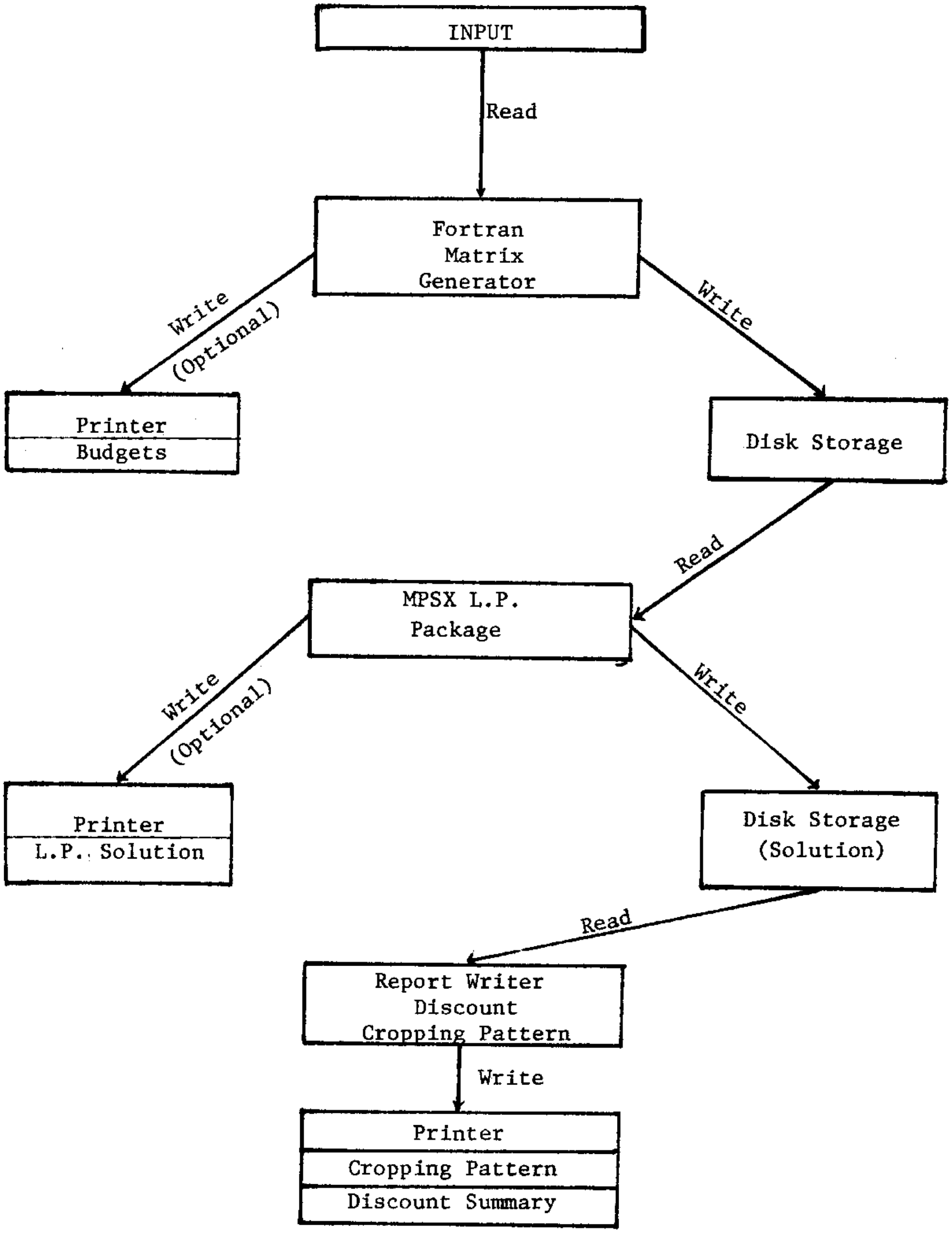


Figure 5. Diagram of the Mechanics of Model Operation

the Red River. The model objective is optimized subject to land and irrigation water constraints. Optimization is performed in 10-year intervals with temporal yield adjustments causing changes in many base calculations thus requiring a new tableau each period.

The mathematical model is essentially created by the matrix generator--by design. It is, however, discussed here in the reverse of its actual operation to make clear the real objective of the matrix generator, i.e., to develop an economic model.

Activities

The linear program includes production activities which are combinations of crop, soil type and irrigated (sprinkler and furrow) or dryland production in each of the three one-half mile zones from the river. Each crop considered is matched with each soil type along with dryland production, sprinkler and furrow irrigation in each zone. Thus, the number of production alternatives considered in each reach is the product of the number of crops considered, the number of soil types in each reach, the number of irrigation systems, sprinkler, furrow, and non-irrigated (three), and the number of zones which is also three. This usually large number of activities for each reach is often reduced significantly for the linear program, however, by elimination of activities because some soil types are not adapted for both sprinkler and furrow irrigation or, in some cases specific crops are not recommended on some soil types.

Native Pasture to Cropland Transfer

One additional activity is included in the mathematical model to account and charge for the expense of converting land currently used as native pasture but changed to crop or improved pasture production in the optimal solutions. The total number of acres currently in cropland in each reach was obtained from the Grossman and Keith report and all other acreage in each reach was assumed to be in native pasture. Thus, if the optimal solution required more cropland or improved pasture than the current situation, a charge for the conversion is made.

Whitson and Kay report a 1976 cost of $50.27 per acre for a similar conversion. This cost was adjusted to a 1980 cost by the index of Prices Paid by Farmers for Tractors and Self Propelled Machinery as published by the Crop Reporting Board. The adjusted cost, $66.95 per acre, was then ammortized into perpetuity at a discount rate of 7.125% for an annual charge of $4.77 per acre. Thus, above current cropland acreages, the optimal solution is charged $4.77 each year for each acre converted from native pasture to cropland or improved pasture.

Resources

Constrained resources included in the model are (1) the amount of land of each soil type in each zone of each reach, and (2) the amount of water available for irrigation in each reach. Each activity in the linear programming model has an input-output coefficient for each of these resources along with its objective function (net revenue) value and some accounting row coefficients to accommodate the possibility of different cropping pattern specifications. Thus, each unit of each crop on a particular soil type in each zone will require one acre from its soil type in that zone, as well as some amount, W_i acre inches (i=no. of the crop), of irrigation water (dryland requires zero water) and has a net return of $ M (objective function).

Figure 6 illustrates a reduced initial tableau of the constrained portion of the model. Note that each activity, X_{ijk} (i=1,2,...,n, n=number of crops, j=1,2,...,m, m=number of soils, k=1,2,3, k=number of the zone) has a coefficient of one in the ST_{jk} (soil type j in zone k) row, and a coefficient of w_i (water requirement of the i^{th} crop) in the irrigation water row. These rows are constrained to S_{jk}, the amount of soil type j in zone k, and W the total amount of irrigation water available to the reach. Note also the "Trans" activity and "T" row are included to charge the $4.47 for each acre converted from native pasture to cropland or improved pasture above C, the current cropland acres. All activities except native pasture have a coefficient of one in the "T" row.

In addition to the constrained portion of the model, accounting rows for each crop by irrigation type, and zone, each crop by irrigation type and reach, and each crop by reach were included to enable a variety of alternative model specifications. By inputing additional data and changing some programming parameters any of these accounting rows can be transformed into constraining rows. For example, this was done to the crop by reach accounting rows to specify current cropping patterns.

The Matrix Generator

The tableau of the economic model seems simple enough since the only restrictions are land and irrigation water. However, development of water requirements, specification of land by soil type and espe-

	X_{111}	X_{211}	$X_{311} \cdots X_{n11}$	X_{121}	$X_{221} \cdots X_{n31} \cdots X_{nm1}$	X_{112}	$X_{122} \cdots X_{n22}$	$X_{132} \cdots X_{nm2}$	X_{113}	$X_{123} \cdots X_{n33} \cdots X_{nmz}$	Trans		RHS
Net Revenue \$	M_{111}	M_{211}	$M_{311} \ldots M_{n11}$	M_{121}	$M_{221} \cdots M_{n31} \cdots M_{nm1}$	M_{112}	$M_{122} \cdots M_{n22}$	$M_{132} \cdots M_{nm2}$	M_{113}	$M_{123} \cdots M_{n33} \cdots M_{nmz}$	-4.47		
ST_{11}	1	1	1 ... 1									$\leq$	S_{11}
ST_{21}				1	1 ...							$\leq$	S_{21}
ST_{31}					... 1 ...							$\leq$	S_{31}
$\vdots$					...							$\leq$	$\vdots$
ST_{m1}					... 1							$\leq$	S_{m1}
ST_{12}						1						$\leq$	S_{12}
ST_{22}							1 ... 1					$\leq$	S_{22}
ST_{23}								1 ...				$\leq$	S_{32}
$\vdots$								...				$\leq$	$\vdots$
ST_{m2}								... 1				$\leq$	S_{m2}
ST_{13}									1			$\leq$	S_{13}
ST_{23}										1 ...		$\leq$	S_{23}
ST_{33}										... 1 ...		$\leq$	S_{33}
$\vdots$										...		$\leq$	$\vdots$
ST_{m3}										... 1		$\leq$	S_{m3}
Water	W_1	W_2	$W_3 \ldots W_n$	W_1	$W_2 \ldots\ldots W_n$	W_1	$W_1 \ldots W_n$	$W_1 \ldots W_n$	W_1	$W_1 \ldots\ldots W_n$		$\leq$	S_{m3}
T	1	1	1 ... 1	1	1 1	1	1 1	1 1	1	1 1	-1	$\leq$	C

Figure 6. A Representation of the Linear Programming Matrix

cially development of the appropriate objective function coefficients for a multitude of possible production alternatives is the real key to the economic model. The matrix generator develops these coefficients from input data derived from the Grossman and Keith report, from the base budgets and yield data previously discussed herein, and properly arranges and formats the results for the MPSX package.

Data

Data required as input to the matrix generator are (1) cropping activity names, (2) irrigation water requirements for each cropping activity, (3) crop yield by soil type, (4) yield adjustments due to irrigation water salinity, (5) costs of production (only specified costs are included and will be discussed shortly), (6) crop prices, (7) acreage of each soil type by zone, (8) acreage of each crop grown currently (optional), (9) total current cropland acres, and (10) total irrigation water available to the reach. Input data specifications are listed in their card column format in Appendix D. It is given there in the order in which the matrix generator reads, not in any order of calculation or importance. Rather, data are ordered, formatted, and inputed only for convenience of operation.

In addition to input data, some data are stored internally since they are assumed to apply uniformly across all reaches. These data include 1) fertilizer recommendations based on yield level, 2) fertilizer prices, 3) water cost equation coefficients, 4) interest rates, and 5) OBERS Series E' yield adjustment coefficients. These data will be discussed more fully in later discussion.

Output to the MPSX linear programming package from the matrix generator takes the form of a properly formatted activity name, net revenue (objective function), irrigation water requirement and accounting row coefficients for each considered activity, properly formatted resource constraints for acreage of each soil type by zone for each reach and water availability in each reach. Further, the matrix generator will output to the printer much of its input data and internal calculations for easy inspection and checking. These features will be discussed shortly.

Matrix Generator Operation

The matrix generator operates as a series of inner loops that make various calculations for each cropping activity considered combined with each soil type to produce one year's matrix; and, two outer loops which combine all reaches into one model formulation and adjust yields according to OBERS Series E' to produce the recursive feature. Thus, the first pass through the matrix generator creates the 1990 initial tableau, yields are adjusted by OBERS projections and another pass through the matrix generator creates the 2000 tableau, etc. Given in the following sections is a generally ordered description of the internal operation of the matrix generator and the sources of data not previously described. Figure 7 gives a diagramatic view of the sequence of the matrix generator operation.

Inputed costs of production. Costs entered as input along with cost calculations made internally by the matrix generator, crop prices and yields, allow the subsequent specification of complete cost and returns budgets for each activity considered and thus the net returns (objective function) value needed for the mathematical model. These

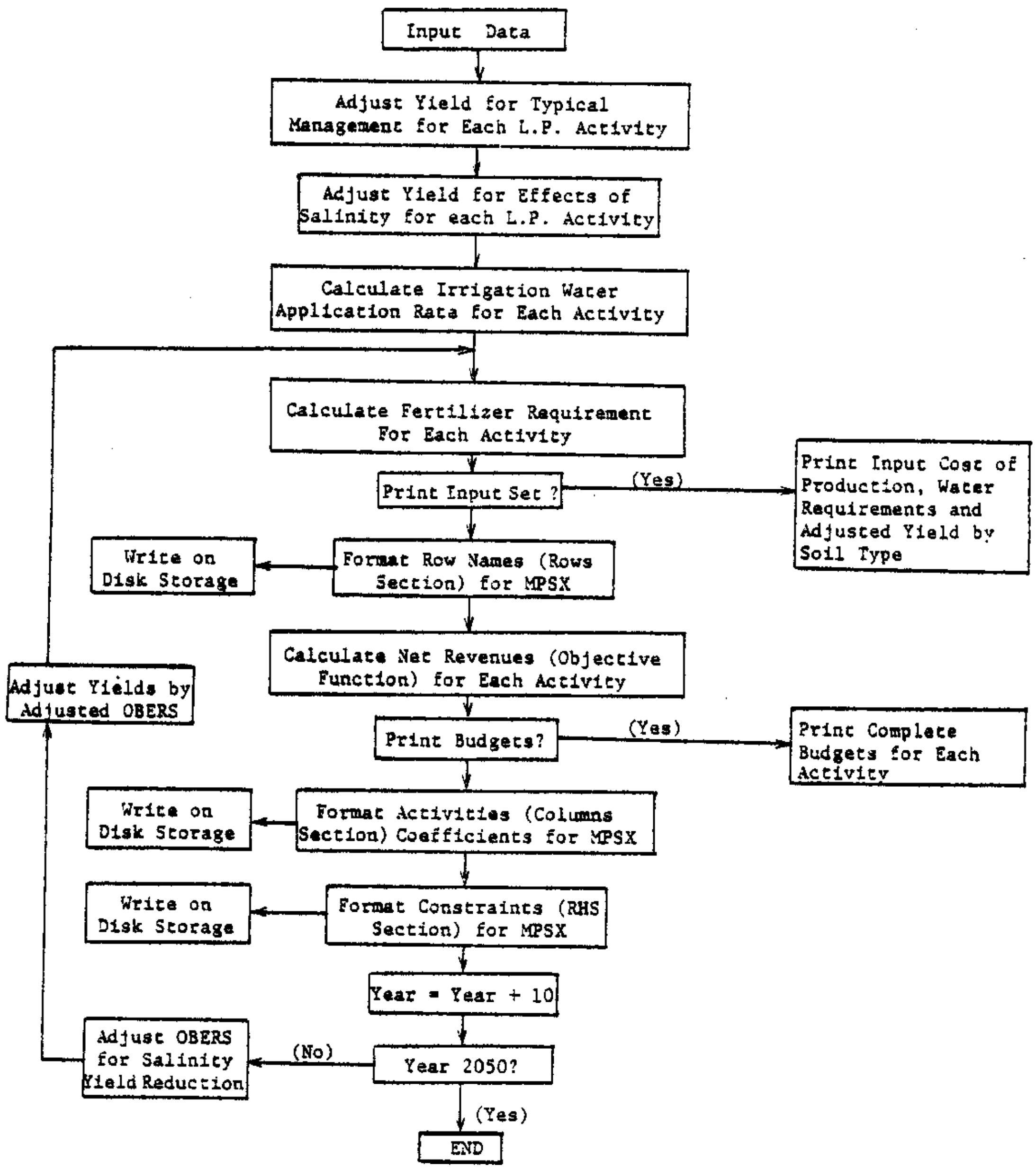


Figure 7. Diagramatic Representation of the Matrix Generator Operation

inputed costs were obtained directly from the base budgets given in Appendix B.

Costs entered as input are broken into three categories: 1) non-land fixed costs, 2) preharvest variable costs, and 3) harvesting costs. Note that these costs do not include all costs but do include all costs not calculated by the matrix generator. Therefore, a precise definition of these costs is very important.

Non-land fixed costs. Included in this category are all costs of a fixed nature, excluding land, and fixed costs of irrigation machinery (fixed cost calculations for irrigation machinery will be made internally by the model). This category will principally include depreciation on tractors and field machinery (given in the fixed cost section of the budgets in Appendix B).

Preharvest variable costs. These costs include all variable costs of production with the exception of fertilizer (N, P_2O_5, and K_2O) costs, variable irrigation costs, interest on operating capital, harvesting costs, and management costs (these cost items are calculated internally and will be discussed in a later section). From the base budgets given in Appendix B, preharvest variable costs for irrigated cotton for example, would include seed, insecticide, herbicide, variable tractor and machinery costs, and labor costs.

Harvesting cost. Harvesting costs were generally assumed to vary with the yield of each crop. Thus, each crop grown on each soil type will have a different harvesting cost. However, the base for the harvesting cost must be input into the model. The base budgets given in Appendix B were chosen to represent somewhat of a typical situation. Thus, the total harvesting cost and yield associated with each crop budget (both irrigated and dryland) in Appendix B is inputed as the base. The matrix generator then calculates the harvest cost per unit of yield by simple division.

Yields. High level management yields by soil type are input into the model (given in Appendix A). Adjustment to reflect typical level management is made by simply taking 85% of the high level management yield. Next, yields of irrigated crops are adjusted to reflect the effects of salinity of the irrigation water and SAR effects for both the modified and natural systems. These effects were obtained from Table 10-23 (Chapter 3) and Tables 22-26 (Chapter 4) of the Grossman and Keith report assuming the 20% leaching fraction condition. Table 3 gives a summary of these yield reductions assuming no SAR effects while Table 4 gives a summary of yield reductions with SAR effects. Hence, the model will represent the with project or without project and the with and without SAR condition depending on the inputed yield reduction for salinity. Yield for each cropping activity for the base year model was obtained by multiplying each typical level management yield by one minus the yield reduction due to salinity for that particular crop. For example, irrigated cotton yielding 800 lbs. of lint that has a yield reduction of 30% due to water salinity would yield 560 lbs. of lint (.7 x 800). There was assumed no yield differential between sprinkler and furrow irrigation systems.

Irrigation water requirements. Irrigation water requirements for crops were obtained from Table 29 (Chapter 3) of the Grossman and Keith report. Inputed irrigation water requirements for each crop represent the effective irrigation water requirements plus its leaching fraction.

Table 3. Summary of Estimated Percentage Yield Reduction of Crops Irrigated With Water From the Red River for Modified and Natural Systems, Without SAR Effects[a]

Reach	Cotton	Grain Sorghum	Wheat	Alfalfa	Coastal Bermuda
5 Nat.	0	0	0	0	0
Mod.	0	0	0	0	0
6 Nat.	0	0	0	7	0
Mod.	0	0	0	0	0
7 Nat.	0	6	0	18	0
Mod.	0	0	0	0	0
8 Nat.	0	10	0	23	0
Mod.	0	0	0	0	0
9 Nat.	0	2	0	16	0
Mod.	0	0	0	0	0
10 Nat.	48	100	82	100	63
Mod.	0	7	0	27	0
11 Nat.	57	100	89	100	70
Mod.	0	11	0	30	0
12 Nat.	0	21	5	38	0
Mod.	0	0	0	9	0
13 Nat.	52	100	79	100	69
Mod.	0	12	0	30	0
14 Nat	11	48	28	78	21
Mod.	0	0	0	6	0
15 Nat.	64	100	100	100	85
Mod.	0	4	0	23	0

[a]Source: Grossman and Keith/Consulting Engineers.

Table 4. Summary of Estimated Percentage Yield Reduction of Crops Irrigated With Water From the Red River for Modified and Natural Systems, With SAR Effects[a]

Reach		Cotton	Grain Sorghum	Wheat	Alfalfa	Coastal Bermuda
5	Nat.	0	0	0	0	0
	Mod.	0	0	0	0	0
6	Nat.	16	19	21	34	0
	Mod.	0	0	0	0	0
7	Nat.	18	29	27	52	0
	Mod.	0	0	0	0	0
8	Nat.	20	35	30	63	0
	Mod.	0	0	0	0	0
9	Nat.	18	24	27	50	0
	Mod.	0	0	0	0	0
10	Nat.	100	100	100	100	100
	Mod.	7	20	19	55	0
11	Nat.	100	100	100	100	100
	Mod.	8	26	20	60	0
12	Nat.	100	100	100	100	100
	Mod.	5	7	11	24	0
13	Nat.	100	100	100	100	100
	Mod.	7	26	18	57	0
14	Nat	100	100	100	100	100
	Mod.	6	7	8	20	0
15	Nat.	100	100	100	100	100
	Mod.	9	16	15	45	0

[a]Source: Grossman and Keith/Consulting Engineers.

These requirements for selected crops are given in Table 5. An efficiency of 75 percent for furrow and 85 percent for sprinkler irrigation systems was used to adjust requirements within the model to reflect the total quantity of irrigation water that must be pumped to account for inefficiencies of the irrigation distribution systems (Keese). Thus, the inputed water requirements for furrow irrigation activities are divided by .75 compared to .85 for sprinkler irrigation activities.

Fertilizer requirements. Fertilizer requirements vary with expected yield for each of the crops included in the analysis. Requirements for N, P_2O_5, and K_2O were determined from Texas Agricultural Extension Service published data (Welch, Gray and Anderson). Existing fertilization levels were assumed to be low nitrogen, low phosphorous and high potassium in order to estimate fertilizer recommendations. These recommendations were used to determine estimation equations that could be applied to the many different yields involved in the study. Equations containing three linear segments were developed for each crop corresponding to the three expected yield levels published by the Texas Agricultural Extension Service (Welch, et al.). Linear interpolation is made between yield levels when appropriate. The segmented fertilizer recommendation equation coefficients for selected crops are given in Table 6. The requirement for any particular crop for N, P_2O_5 or K_2O is the cumulative total of the recommendation for each target yield up to the expected yield of the crop in question. For example,

Table 5. Per Acre Irrigation Water Requirements by Crop and by Reach[a]

Reach	Cotton	Grain Sorghum	Wheat	Alfalfa	Coastal Bermuda
	Acre Inches				
5	6.9	11.3	9.4	32.1	26.8
6	8.1	12.2	12.5	37.4	30.2
7	10.9	16.2	18.6	46.3	40.2
8	11.9	17.1	19.7	47.6	41.8
9	12.1	16.0	21.2	49.9	43.0
10	16.4	16.5	22.1	54.8	44.4
11	16.9	16.9	22.3	54.5	44.8
12	12.3	15.5	21.1	49.3	42.4
13	16.0	16.2	21.0	54.0	47.2
14	15.9	15.8	21.2	53.9	47.2
15	16.7	16.8	22.0	54.9	48.2

[a]Source: Grossman and Keith/Consulting Engineers.

Table 6. Fertilizer Recommendation Equation Coefficients for N, P205, and K20 Calculations in the Matrix Generator[a,b]

Crop Number	Name	Unit	Levels 1	2	3
1	Cotton	Lbs.	0-480	481-960	961 and Up
	N		.125	.083	.083
	P205		.125	.0417	.083
	K20		0	.0833	.0417
2	Sorghum	Cwt.	0-40	41-60	61 and Up
	N		1.5	1.0	2.0
	P205		1.5	1.0	1.0
	K20		0	0	0
3	Wheat	Bu.	0-30	31-45	46 and Up
	N		1.0	2.0	2.667
	P205		.667	1.333	1.333
	K20		0	1.667	.667
4	Coastal	Tons	0-4	4.1-8	8 and Up
	N		30.0	60.0	50.0
	P205		10.0	10.0	10.0
	K20		5.0	20.0	25.0
6	Alfalfa	Tons	0-4	4.1-6	6 and Up
	N		0	0	0
	P205		20.0	20.0	20.0
	K20		0	30.0	20.0
8	Nat.Past.	Aum	0	0	0

[a]Source: Welch, Gray and Anderson.

[b]Recommendations are the accumulated total of the coefficient multiplied by the yield level, e.g., the nitrogen recommendation for cotton yielding 600 lbs. lint is 69.96 lbs. = (480 x .125) + (120 x .083).

the nitrogen fertilizer recommendation for cotton with an expected yield of 800 lbs. would be 87 lbs. calculated as (480 x .125) + (800 - 480) x .0833.

Optional data tables. At this point the matrix generator has all the information needed to proceed in developing the coefficients for the linear programming model. If, however, the matrix generator has been signaled to do so, it will output a series of tables of which the first contains the inputed costs of production and average yield used to compute harvest costs (discussed earlier in the inputed production costs section). The second and third tables give total effective irrigation water requirements and total water application rates by reach, respectively. The fourth table gives yield reduction due to salinity for each reach. The fifth and following tables contain adjusted yields for each cropping activity by soil type for the first year, 1990, and succeeding years through 2040. After 1990, these yields reflect the effects of OBERS E' increases. Examples of these outputs are given in Appendix E. Soil type names are shortened to code names in this output to facilitate condensed printing. Expanded names for the codes can be found in the tables of Appendix F under "L.P. CODE NAMES".

Format row names. At this point in the matrix generator operation, the rows section of the linear program is specified, formatted and written onto disk storage. One row for each soil type in each reach in zones one, two and three are first specified combining the soil type code, the number 1, 2, or 3 and the reach number as row names. Next, accounting rows are added for each cropping activity by irrigation type, and zone by reach using as names a combination of S, F, or N for sprinkler, furrow or non-irrigation, a three letter crop code, 1, 2, or 3 for the zone, and the reach number. Then, an accounting row is specified for each crop by irrigation type and by reach, simply dropping the zone designation from the name above. And finally an accounting row is specified for each crop in the reach by its three letter code name. Finally, an irrigation water row is specified for each reach by the name "WATER" followed by the reach number.

Total costs. Total costs include both fixed and variable costs. Fixed costs are calculated as the sum of the inputed non-land fixed cost (previously described) and the fixed portion of irrigation costs. Equations given in Table 2 (p. 57) of this report were used to calculate the fixed cost for either a furrow or sprinkler system depending on each activity specification. The total water application rate for each cropping activity, i.e., the total crop requirement divided by its efficiency rate, was used as "X" in the fixed cost equations of Table 2. Thus, total fixed costs are the sum of an inputed portion, non-land fixed cost, and an internally calculated portion, irrigation fixed costs.

Total variable costs include variable costs for irrigation, fertilizer, harvesting, inputed preharvest, interest, and management. Variable costs for irrigation were also computed by using the variable cost equation given in Table 2 (p. 57) of this report. Fertilizer costs are calculated as the product of the number of pounds of each fertilizer type, as calculated above, times \$.18, \$.17 and \$.09 for N, P_2O_5 and K_2O respectively (Extension Economists-Management; Jobes).

Harvesting costs were calculated as the product of expected yield for each activity and the per unit harvesting cost for cotton, alfalfa, and Coastal bermuda. The per unit harvesting cost is calculated for each of these crops, both irrigated and dryland, as the total harvest cost divided by the yield from the base budgets given in Appendix B. Thus, for these three crops harvest costs vary directly with expected yield of each activity. For sorghum and wheat, however, harvesting costs are determined in a slightly different manner. For grain sorghum with yields less than 23 cwt. per acre, the harvest cost is calculated by $HC = 8 + .25 x yield (cwt); and for yields above or equal to 23 cwt. harvesting cost is calculated by $HC = .60 x yield (cwt). For wheat, the same general approach is taken with harvest costs for yields less than 35 bu. per acre calculated as $HC = 7 + .15 x yield (bu); and yields equal to or above 35 bu. per acre $HC = .35 x yield (bu).

Interest on operating capital is charged at a rate of 7.125 percent[1] annually for six months of actual use. Interest is charged on total variable costs for irrigation, fertilizer, and the inputed preharvest variable costs. Notice that harvesting cost is excluded from interest charges since these costs would normally occur simultaneously with crop revenue (assuming the crop is sold at harvest) and could be paid at that time.

Management costs are charged at a 10 percent rate on all variable costs as specified by the Water Resources Council (Office of the Federal Register). Thus, management is charged at 10 percent variable

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[1]Current discount rate specified for evaluation of federal program.

costs for irrigation, fertilizer, harvesting, preharvest and interest.

In summary, total variable costs are the sum of variable irrigation costs, fertilizer costs, inputed preharvest costs, interest costs, interest calculated as 3.562 percent (the six month rate) of irrigation, fertilizer and preharvest costs, and management charges calculated as 10 percent of the total of all the above. Likewise, the net revenue (objective function) value for each activity is the difference between total revenue and fixed costs plus total variable costs. Again, there is no charge made for land which is considered the residual claimant to net returns.

Net returns. The matrix generator now makes the net revenue (objective function) calculations for each linear program activity. Net revenue is calculated as the difference between total revenue and total costs. Total revenue is simply calculated as the expected yield for each activity, including all appropriate reductions, multiplied by the inputed price for that crop (which includes the value of all joint products).

Optional budgets. At this point the matrix generator has made all the calculations for one year of the model. If it has been signaled to do so (see the card column format in Appendix D for precise specification) the matrix generator will output a one-line complete budget for each activity it has developed for each 10-year increment, i.e., OBERS Series E' yield adjustments are included after 1990 and will be discussed shortly. Appendix G contains an example of this output which is one page from a set of crop enterprise budgets for 1990 for the modified system in Reach 13. This report, if requested of the matrix generator, includes a budget for each activity of the L.P. matrix for each of the model years 2000, 2010, 2020, etc. Notice in Appendix G that each row is a complete cost and returns budget for that activity. The activity naming convention is given in Figure 8. Costs and returns are specified for each activity along with calculated coefficients for water application, fertilizer, and the specified yield for which many items depend. "NET REVENUE" given there for each activity is the objective function value given to the economic model for that activity. Note that costs and returns are broken into the categories previously discussed. Further, activities that have zero yield or negative net returns simply have their net returns set at zero, although their other coefficients are written for inspection.

Format L.P. columns and RHS. The matrix generator now proceeds to finish the tableau by formatting and writing each activity name along with its objective function, water requirements and accounting row coefficients onto disk storage. If the net revenue value is less than or equal to zero for any activity, however, the matrix generator by-passes the activity for the MPSX model. Upon completion of the columns section of the L.P. model, the matrix generator moves on to format and write on disk storage in the RHS section. Constraints of the model are written in this section and include the inputed acreage by soil type by reach, total water available for irrigation, total current cropland acreage, and optionally, acreage of each cropping activity. These data are discussed below.

Acreage by soil type. The acreage data for zones 1, 2, and 3 are

S	1	E N T	1
Irr. code S-sprinkler F-furrow N-non-irr.	crop[a] no.	soil type code	zone 1, 2 or 3

Sprinkler irrigated cotton on Enterprise soil in zone 1.

[a]Crop numbers are given in Appendix E.

Figure 8. Naming Convention for Activities Developed by the Matrix Generator

taken directly from acreage data given in Table 2-I-9 through 2-I-41 of the Grossman and Keith report. Appendix F gives summary tables of acreage of each soil type by zone in each reach for Reaches 5 through 15. Acreage totals for each reach given in this report may vary slightly from those given in the Grossman and Keith report since some soil types given there were unsuited for irrigation because of extreme slope, complex soil type, etc. The letters B, F, and S appearing in the "REC. IRR. TYPE" (recommended irrigation type) column indicate border, furrow or sprinkler irrigation systems respectively as listed in the Grossman and Keith report for individual soil types.

Irrigation water availability. Irrigation water availability was supplied by the Corps of Engineers for each reach and is listed in Table 7.

Total current cropland acreage. This input is designed as the constraint, C, for the native pasture to cropland or improved pasture transfer activity described in the mathematical model. It is simply the summation of the current cropland acreage above.

Current cropping pattern. This is an optional input category designed to allow specification of current or any other cropping pattern. When the current cropping pattern was desired the proper input was the acreage of each crop given by the 1979 field survey Table 2-II-1 in the Grossman and Keith report. The data in Table 2-II-1 were tabulated by county, and thus pose some problems for counties divided between two reaches. In these cases, the crop acreage was divided between the reaches the county spanned by the percentage of study area land actually in each reach as calculated from the more detailed acreage

Table 7. Water Available for Irrigation by Reach[a]

Reach	Alluvial Storage (acre Feet)
5[b]	79,100
6	79,100
7	58,200
8[c]	46,200
9	18,500
10	12,700
11	11,900
12	51,900
13	99,000
14	71,900
15	46,300

[a]Given by the U.S. Army Corps of Engineers.

[b]None given, assumed equal to Reach 6.

[c]Excludes Lake Kemp water.

specifications of Tables 2-I-1 through 2-I-41 of Grossman and Keith.

Upon completion of the RHS section, the matrix generator checks the year and either ends operation or proceeds to the OBERS Series E' projections and prepares to repeat the entire procedure just described.

OBERS. For each 10-year interval of the model operation, OBERS Series E' projections are used to adjust yields of each considered crop. OBERS annual projections are given in Table 8. Yield changes are given in units per year, thus, the annual change is multiplied by 10 to obtain the 10 year response needed by the model. Yield adjustments are made by the matrix generator only for commodities listed on Table 8 and given by OBERS. For example, no projection is made for alfalfa, thus no increase is assumed for this study or included in the model.

Before the OBERS increases are added to the previous model yields, however, one additional calculation is made. The OBERS projections were assumed subject to the same yield reduction due to irrigation water salinity as yield in the previous decade. Thus, OBERS projections are multiplied by one minus the yield reduction due to salinity for each cropping activity. Once the appropriate OBERS reduction is made, the adjusted yield change is added to the yield of the previous decade and the resulting yield is used in the next iteration of the model.

Successive tableaus. Upon completion of the base year tableau (1990) and the adjusted yields, the matrix generator proceeds exactly as before to develop the 2000 year tableau. After 2040, the model was assumed to stabilize to the 2040 condition and remain for the next 50

Table 8. OBERS Series E' National Per Acre Annual Yield Changes, Selected Crops, Historical and Projected, 1920-2020[a]

Commodity		1920-[b] 1950	1950-[c] 1970	1970-2020 OBERS Baseline
Wheat..........	Bu.	0.10	0.73	0.33
Rice...........	Lbs.	19.40	109.75	59.43
Rye............	Bu.	0.02	0.68	0.30
Corn...........	Bu.	0.24	2.32	1.28
Oats...........	Bu.	0.03	0.70	0.56
Barley.........	Bu.	0.14	0.77	0.49
Grain Sorghum.	Bu.	0.29	1.40	1.12
Cotton.........	Lbs.	2.74	8.60	6.67
Soybeans.......	Bu.	0.36	0.26	0.18

[a]Source: U.S. Water Resources Council, OBERS Projections.

[b]1929 To 1950 for grain sorghum, and 1924 for soybeans.

[c]1950 To 1969 for corn.

years. Therefore, additional tableaus are unnecessary.

Report Writer

The report writer is the final phase of the analytical model. A complete listing of this FORTRAN program is given in Appendix D. Upon solution of the economic problems given the MPSX package, MPSX is signalled to write each solution on disk storage as well as printing each solution. The report writer reads the six solutions (one base and five additional at 10 year increments) and proceeds to summarize the results of the model.

The report writer first gives a cropping pattern summary for each reach. This summary consists primarily of a series of accounting rows from the linear program. First, acreage of each crop, divided into its dryland or irrigated category, is given by each 10 year model solution. Next, the native pasture to cropland or improved pasture transfer row and total irrigated acres are given for each 10 year period. Finally, the nominal net revenue (objective function value) for each of the solutions is given. An example of this output is given in Appendix H.

The discounting procedure is performed for the "NET REVENUE SUMMARY" and is printed following the cropping pattern summary. By this point the report writer has read and stored the net revenue (objective function) for each 10 year solution. For each year between the 10 year solutions this program linearly interpolates a net revenue. By this method each year between 1990 and 2040 is given a net revenue value. The discounting is then performed for discount rates of 7 1/8 percent and 3 1/4 percent for the first 50 years by:

$$PV_{NR} = \sum_{i=1}^{50} \frac{NR_i}{(1+r)^i}$$

where i is the year and r is the discount rate (.07125 or .0325). After 50 years, cropping patterns and thus net revenues were assumed to stabilize. Thus, the 2040 solution was assumed to hold true for the next 50 years. Discounting net revenues from the 50th to 100thyear was calculated by:

$$PV_{NR} = \frac{NR_{50}}{r} \left[\frac{1}{(1+r)^{50}} - \frac{1}{(1+r)^{100}} \right]$$

The net revenue summary, then, gives the nominal net revenues calculated for each year (1990-2040), its calculated present value at the two discount rates, and total present value to date for both rates. Finally, the present value of the 2040 net revenue discounted for the next 50 years is added to the present value of the first 50 years to get the present value of net returns for the 100 year period at the 7 1/8 percent and 3 1/4 percent rates. An example of these net revenue summaries generated by the report writer is presented in Appendix H.

Alternative Scenarios

The linear programming model just described was used to obtain normative estimates of cropping patterns and net returns from agricultural production under various scenarios in the study area. Model evaluation with and without the project formed the basis of analysis in each case. All scenarios were based on a 100 year (years 1990-2090) planning horizon using either OBERS Series E' projection yield adjustments through the first 50 years and the 50th year cropping plan for the remaining years, or in some scenarios, no yield adjustments.

Water Resources Council guidelines call for with and without project conditions to be those "expected to exist in the future" with and without the project (Office of the Federal Register, p. 30203). Thus, a subjective estimate of future cropping patterns is required to precisely meet the guidelines. However, rather than subjectively specifying cropping patterns for the mathematical model the initial base for establishing benefits will be the discounted present value of the difference between the maximized net revenue to agriculture in the region with and without the project. Thus, the subjective assumption for the first scenario is that the producers' objective is to maximize profits.

In the Red River area it is not certain, though highly probable, that SAR is a significant problem (Grossman and Keith). If it is, results of an economic evaluation of the benefits could be quite different than the case where it is not. Thus, a more likely scenario was developed in which high SAR causes yield reduction in addition to reduction caused by application of saline irrigation water. Thus, for this scenario the same objective as the initial scenario was assumed, but with yield reductions that reflect significant SAR problems as reported in Grossman and Keith.

Next, a scenario, somewhat derived from the first two, was developed to establish the effects of the rising yields accounted for with the use of OBERS projections and provide an estimate of benefits with no increased yields assumed. Thus, this scenario involves the benefit estimation with the profit maximization objective without OBERS yield increases.

Still another scenario that provides a lower limit to the benefits estimates is one in which cropping patterns do not change over time from the current situation with and without the project. The cropping pattern was restricted to a 1979 field survey (Grossman and Keith) within the linear programming model for cases with and without SAR effects and with and without the project to establish net benefits for this scenario.

Finally, a scenario was investigated involving the possibility that producers may not immediately undertake irrigation practices. More likely is a situation in which producers make the transformation to irrigation over an extended period. Since about 3/5 of the benefits of such a project would be counted in the first 20 years (at 7 1/8% discount rate), this could seriously impact the calculation of benefits. This delay was incorporated into the linear programming model by limiting the cropping pattern to the current situation in the initial solution, allowing a shift to 50% of the optimal after 10 years, with a complete shift to the optimal by the 20th year. Thus, in this scenario an effort was made to subjectively estimate what cropping patterns might do over time in response to the project and account for a gradual evolvement of agricultural producers toward profit maximization.

Water Demand

Parametric programming techniques were used with the profit maximization scenario of the linear programming model to derive estimates of demand for water in the Red River basin. A "purchase water" column was added to the model and the price of water parameterized to obtain a price-quantity (demand) relationship for irrigation water. Demands were derived for each 10 year period (for the first 50 years). These demands were in turn used to develop the demand relationship for irrigation water in the basin for the entire period of analysis.

Econometric Procedure

The procedure used to estimate potential agricultural benefits from the Red River Chloride control project via the econometric method included:

(a) Procurement of time series data on crop yields and price for both irrigated and dryland crops for each county in the study area.

(b) Estimation of supply response by three-stage least-squares regression.

(c) Direct calculation of benefits.

Annual time series data for irrigated and dryland total crop production, acreages, and prices for each of the Texas counties in the study area were obtained from the Texas Crop and Livestock Reporting Service. These data were available, however, on county basis only for 1968 through 1979 and a relatively short time series resulted. Data for the Oklahoma counties were obtained from the Oklahoma Crop and Livestock reporting service. Data for Oklahoma counties was available for a much longer period, but, dryland and irrigated acreages were separated only in about five year intervals. Further, sufficiently complete series from both sources were available only for cotton, grain sorghum, and wheat. Thus, since cotton was expected to be the most important crop with regards to project benefits from salinity control, grain sorghum and wheat are heavily involved in current cropping patterns, and these data were available, these three crops were selected for this analysis.

The combined acreages of irrigated and dryland production for Texas counties and total production for Oklahoma counties for 1968 through 1979 gave the main data series for the entire study area. Thus, the first econometric estimation was confined to projection of the total acreage response for cotton, grain sorghum and wheat. Subsequent model specifications included only Texas reaches with crop production of the three chosen crops divided between dryland and irrigated production, and, a model confined only to one particular reach of the study area. Hence, models were specified from aggregations of one reach, to aggregation of only Texas reaches, to the aggregation of the entire study area.

Average annual per acre gross revenue estimates for each county were obtained by multiplying the county average yield for each crop by the price received by farmers. However, net revenue estimate for each crop was needed in the supply response estimation. Thus, the gross revenues were inflated by the Index of All Farm Products: Prices Received by Texas Farmers to their 1979 level and the variable cost from the respective crop base budget developed in this study was subtracted to obtain net revenue estimate for each crop and each year of the time series.

Finally, estimation of supply responses were made using acreage of each crop as the dependent variable and the net return specification as explained in the Theory Chapter as independent variables using the Restricted Generalized Least Squares method. Appropriate specification was made initially to force parameters to be equal according to the theoretical model employed. To further analyze the data, additional specifications were made for various model formulations regarding the level of aggregation and releasing parameter restrictions. Results of these estimations will be discussed in Chapter V.

CHAPTER IV

CROPPING PATTERN RESULTS

This chapter is limited to a discussion of cropping pattern estimates obtained from the mathematical model under the various scenarios presented in Chapter III. First, the results of the two profit maximization scenarios, with and without SAR effects, will be presented. Then, the scenario involving a restriction in the movement of producers toward the optimal cropping pattern will be presented. Finally, a note on the model results with acreage restricted to the current cropping patterns in the study area will be presented.

Optimal Land Use

Throughout the study area, with and without SAR effects on crop yield included in the analysis, cotton was usually the most profitable irrigated crop and, therefore, is the only crop which would be irrigated if producers organized production to maximize net income. The only exception was in Reach 6, where small acreages of grain sorghum would be irrigated with and without the project assuming no yield effect due to SAR, and with the project for the case where an SAR effect on crop yields was incorporated. In each of the other reaches, analysis both with and without SAR effects on crop yields included indicates that cotton is the only crop which would be irrigated, either with or without the project. Non-irrigated land in both cases was used in varying mixes of cotton, grain sorghum, alfalfa, Coastal bermuda and native pasture. Wheat production never entered the optimal land use patterns due to its relatively low net returns.

Optimal land use patterns, under the assumptions of the analysis, would not change after 2040, since all yields are held constant thereafter. Optimal land use patterns will, however, change for the first 50 years.

Since prices for all products sold and inputs purchased are assumed constant over the project life and land and water resources fixed, factors that cause changes in optimal cropland use over the project life are those associated with the OBERS Series E' projected yields. The usual changes in land use consisted of shifts from the production of forage crops (alfalfa, Coastal bermuda and native pasture) to dryland cotton. Much more moderate increases in dryland grain sorghum acreages also occurred in several reaches. Differentials among crops in the rates of change in projected yields were such as to cause cotton and grain sorghum to become relatively more profitable over time. By the year 2040 only nominal acreages of forage would remain in optimal land use patterns in a few of the reaches whether or not SAR effects are included. The following contains discussion of the profit maximizing land use patterns with and without SAR effects, and with and without the salinity control project.

Without SAR Effects

Table 9 gives a summary of optimal land use patterns for the entire study area with and without the project. Data in Table 9 indicates that without salinity control, cotton is the major irrigated

Table 9. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, Without SAR Effects, All Reaches (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	274,817	280,658	280,712	282,067	282,067	282,026
Without	166,760	171,228	171,281	171,282	162,669	162,669
Dry Cotton						
With	266,320	342,019	343,727	345,366	345,366	345,407
Without	348,175	451,450	453,158	456,151	464,764	464,764
Irr. Sorghum						
With	---	962	2,200	2,200	1,184	1,231
Without	---	962	2,200	2,200	1,184	1,231
Dry Sorghum						
With	446	375	15,854	33,620	34,636	34,636
Without	446	375	15,854	33,620	34,636	34,636
Dry Alfalfa						
With	57,161	13,020	5,292	---	---	---
Without	57,161	13,020	5,292	---	---	---
Dry Coastal						
With	49,814	21,727	15,467	---	---	---
Without	73,776	21,727	15,467	---	---	---
Native Pasture						
With	17,785	7,582	3,091	3,091	3,091	3,044
Without	20,026	7,582	3,091	3,091	3,091	3,091
Total	666,344	666,344	666,344	666,344	666,344	666,344

crop. Substantial acreage (about 25 percent of the total in 1990) is allocated to irrigated cotton and over twice as much is in dryland cotton. The remaining 25 percent of cropland (in 1990) is allocated to dryland grain sorghum, alfalfa, Coastal bermuda, and native pasture. With the project an additional 100,000 acres is allocated to irrigated cotton in 1990. About 75 percent of this shift comes from dryland cotton with the remaining 25 percent coming from Coastal bermuda and native pasture.

Over the first 30 years both with and without the project, a shift away from forages, alfalfa, Coastal bermuda, and native pasture, and into cotton occurs. This is due entirely to the application of OBERS yield projections. The increased yields for cotton increasingly make that crop more attractive since no yield increase was assumed for forages (as given in Table 8, p. 84). By 2020, only a few acres remain in forage crops (native pasture). Further, the OBERS yield effect also causes the slight intrusion of grain sorghum into the optimal land use patterns over time.

Investigation of optimal land use by reach (given in Tables 10 through 14) in conjunction with Table 3 (p. 70) of the previous chapter on yield reductions due to salinity gives an indication of the expected distribution of benefits within the study area for this scenario of no SAR effects on crop yield. Optimal cropping patterns in Reaches 5 through 9 and 12 are the same with and without the project. As shown in Table 3 (p. 70), without SAR effects, irrigated cotton, usually the most profitable crop, has no yield reduction due to salinity. Only in Reach 6 is there another irrigated crop, grain sorghum, and it too has no

Table 10. Projected Optimal Land Use With and Without the Project, by 10-year Increments, 1990-2040, Without SAR Effects, Reaches 5 and 6 (Acres)[a]

Crop	1990	2000	2010	2020	2030	2040
			Reach 5			
Irr. Cotton	26,265	26,265	26,265	26,265	26,265	26,265
Dry Cotton	37,449	38,691	38,691	38,691	38,691	38,691
Dry Alfalfa	1,242	---	---	---	---	---
Native Pasture	1,228	1,228	1,228	1,228	1,228	1,228
Total	66,184	66,184	66,184	66,184	66,184	66,184
			Reach 6			
Irr. Cotton	46,131	46,131	46,185	46,185	46,185	46,185
Dry Cotton	51,879	52,029	52,271	52,271	52,271	52,271
Irr. Sorghum	---	962	2,200	2,200	1,184	1,184
Dry Sorghum	446	375	2,412	9,460	10,476	10,476
Dry Alfalfa	2,299	2,299	2,299	---	---	---
Dry Coastal	8,986	7,945	4,749	---	---	---
Native Pasture	1,707	1,707	1,332	1,332	1,332	1,332
Total	111,448	111,448	111,448	111,448	111,448	111,448

[a]The acre feet of water available for irrigation in Reach 5 was assumed to be the same in Reach 6. No estimate of the volume of alluvial storage for Reach 5 was provided by the Corps of Engineers. The volume of irrigation water has no effect on project benefits since crop yields in Reach 5 are not affected by salinity problems.

Table 11. Projected Optimal Land Use With and Without the Project, by 10-year Increments, 1990-2040, Without SAR Effects, Reaches 7,8,9 and 12 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 7			
Irr. Cotton	11,989	11,989	11,989	11,989	11,989	11,989
Dry Cotton	6,186	6,186	6,186	6,186	6,186	6,186
Total	18,175	18,175	18,175	18,175	18,175	18,175
			Reach 8			
Irr. Cotton	34,868	34,868	34,868	34,868	34,868	34,868
Dry Cotton	94,494	102,005	102,005	102,005	102,005	102,005
Dry Sorghum	---	---	---	1,343	1,343	1,343
Dry Alfalfa	1,912	---	---	---	---	---
Dry Coastal	6,942	1,343	1,343	---	---	---
Total	138,216	138,216	138,216	138,216	138,216	138,216
			Reach 9			
Irr. Cotton	13,789	13,789	13,789	13,789	13,789	13,789
Dry Cotton	7,565	15,732	15,732	15,732	15,732	15,732
Dry Sorghum	---	---	4,010	4,010	4,010	4,010
Dry Alfalfa	107	---	---	---	---	---
Dry Coastal	555	---	---	---	---	---
Native Past.	11,515	4,010	---	---	---	---
Total	33,531	33,531	33,531	33,531	33,531	33,531
			Reach 12			
Irr. Cotton	13,890	14,818	14,818	14,818	14,818	14,818
Dry Cotton	9,095	18,574	18,574	18,574	18,574	18,574
Dry Sorghum	---	---	---	4,202	4,202	4,202
Dry Coastal	14,609	4,202	4,202	---	---	---
Total	37,594	37,594	37,594	37,594	37,594	37,594

Table 12. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, Without SAR Effects, Reaches 10 and 11 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 10			
Irr. Cotton						
With	6,959	6,959	6,959	6,959	6,959	6,959
Without	---	---	---	---	---	---
Dry Cotton						
With	11,146	15,202	15,202	15,202	15,202	15,202
Without	18,105	22,161	22,161	22,161	22,161	22,161
Dry Coastal						
With	1,409	---	---	---	---	---
Without	1,409	---	---	---	---	---
Native Pasture						
With	2,647	---	---	---	---	---
Without	2,647	---	---	---	---	---
Total	22,161	22,161	22,161	22,161	22,161	22,161
			Reach 11			
Irr. Cotton						
With	6,347	6,347	6,347	6,347	6,347	6,347
Without	---	---	---	---	---	---
Dry Cotton						
With	1,201	3,559	3,559	6,552	6,552	6,552
Without	6,791	9,906	9,906	12,899	12,899	12,899
Dry Sorghum						
With	---	---	---	2,966	2,966	2,966
Without	---	---	---	2,966	2,966	2,966
Dry Alfalfa						
With	2,993	2,993	2,993	---	---	---
Without	2,993	2,993	2,993	---	---	---
Dry Coastal						
With	5,317	2,966	2,966	---	---	---
Without	5,317	2,966	2,966	---	---	---
Native Pasture						
With	7	---	---	---	---	---
Without	764	---	---	---	---	---
Total	15,865	15,865	15,865	15,865	15,865	15,865

Table 13. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, Without SAR Effects, Reaches 13 and 14 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 13			
Irr. Cotton						
With	53,703	55,121	55,121	55,121	55,121	55,121
Without	---	---	---	---	---	---
Dry Cotton						
With	---	14,437	14,437	14,437	14,437	14,437
Without	43,884	69,558	69,558	69,558	69,558	69,558
Dry Sorghum						
With	---	---	7,728	7,728	7,728	7,728
Without	---	---	7,728	7,728	7,728	7,728
Dry Alfalfa						
With	23,583	7,728	---	---	---	---
Without	19,897	7,728	---	---	---	---
Native Pasture						
With	---	---	---	---	---	---
Without	25	---	---	---	---	---
Total	77,286	77,286	77,286	77,286	77,286	77,286
			Reach 14			
Irr. Cotton						
With	40,698	40,812	40,812	40,812	40,812	40,771
Without	19,828	23,368	23,368	23,368	14,755	14,755
Dry Cotton						
With	42,764	53,258	53,283	53,283	53,283	53,324
Without	49,728	70,702	70,727	70,727	79,340	79,340
Dry Sorghum						
With	---	---	1,623	3,830	3,830	3,830
Without	---	---	1,623	3,830	3,830	3,830
Dry Alfalfa						
With	6,265	---	---	---	---	---
Without	6,265	---	---	---	---	---
Dry Coastal						
With	8,173	3,830	2,207	---	---	---
Without	22,079	3,830	2,207	---	---	---
Native Pasture						
With	556	556	531	531	531	484
Without	556	556	531	531	531	531
Total	98,456	98,456	98,456	98,456	98,456	98,456

Table 14. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, Without SAR Effects, Reach 15 (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	20,179	23,560	23,560	24,915	24,915	24,915
Without	---	---	---	---	---	---
Dry Cotton						
With	4,541	22,346	23,787	22,432	22,432	22,432
Without	22,999	45,906	47,347	47,347	47,347	47,347
Dry Sorghum						
With	---	---	81	81	81	81
Without	---	---	81	81	81	81
Dry Alfalfa						
With	18,760	---	---	---	---	---
Without	18,760	---	---	---	---	---
Dry Coastal						
With	3,823	1,441	---	---	---	---
Without	4,085	1,441	---	---	---	---
Native Pasture						
With	125	81	---	---	---	---
Without	1,584	81	---	---	---	---
Total	47,428	47,428	47,428	47,428	47,428	47,428

yield reduction due to salinity. Thus, since salinity control has no effect on the most profitable irrigated crops, optimal land use would not change and there would be no irrigation benefits attributable to the project in reaches 5, 6, 7, 8, 9, and 12.

In the remaining western reaches, however, salinity control would have substantial impact. Only in Reach 14 would irrigation from the Red River occur without the project. The yield reduction on irrigated cotton in Reach 14 is only 11 percent without the project and is not sufficient to make irrigated cotton less profitable than other dryland alternatives. In the other western reaches, however, the yield reduction due to salinity is close to 50 percent or more and reduces irrigated cotton to zero in the optimal land use patterns without the project. Thus, without the project, crop production in western reaches is confined, for the most part, to dryland. With the project, there is no yield reduction on cotton and substantial acreages of irrigated cotton enter the optimal cropping pattern. Only in Reach 14 does dryland cotton occupy more acreage than irrigated cotton with the project. This is because the water is completely utilized in Reach 14, hence there was no more acreage available for irrigated crops.

The irrigated acreage change with and without the project leads to benefits only in the western reaches when an SAR effect is not included. As in the eastern reaches, forage production in the western reaches of the study area ceases over time in favor of cotton and small acreages of grain sorghum due to the application of OBERS yield projections. However, only those acreages that shift to irrigated production, i.e., become more profitable due to salinity control, have potential to produce benefits from the project.

With SAR Effects

Table 15 gives the summary of the optimal land use for the study area for this scenario, with and without the project. Without salinity control, cotton is the only irrigated crop. However, only about 14 percent of the total acreage is allocated to irrigated cotton (in 1990) while over 61 percent is in dryland cotton. The remaining 25 percent (in 1990) again is allocated to dryland grain sorghum, alfalfa, Coastal bermuda and native pasture. With the project, a massive shift occurs from dryland cotton, Coastal bermuda, and native pasture to irrigated cotton--over 142,000 acres shift in 1990.

As in the no SAR case, a shift occurs away from forages and toward cotton and small acreages of grain sorghum in the with project case and only toward cotton in the without project case. Again, this is entirely due to the application of OBERS yield projections and by 2020 only nominal amounts of native pasture remain.

Looking further into the optimal cropping patterns with SAR effects included, by reach (given in Tables 16 through 20), in conjunction with Table 4 (p. 71) of Chapter III, indicates potential for benefits in much more of the study area than without SAR effects included. Table 18 indicates that optimal cropping patterns in Reaches 5, 8 and 9, without the project, would be identical to those with the project with the only irrigated crop being cotton. However, Table 4 (p. 71) shows that Reach 5 has no yield reduction due to salinity and thus optimal land use would not change and no benefits from the project could occur. In Reaches 8 and 9, on the other hand, salinity causes yield reductions

Table 15. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, With SAR Effects, All Reaches (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	235,877	238,341	232,068	230,454	228,989	228,411
Without	93,030	85,396	85,132	78,836	78,836	78,247
Dry Cotton						
With	298,260	384,337	392,372	396,979	398,444	399,022
Without	408,850	537,282	539,308	548,597	548,597	549,186
Irr. Sorghum						
With	---	962	2,200	2,200	1,184	1,184
Without	---	---	---	---	---	---
Dry Sorghum						
With	446	375	15,854	33,620	34,636	34,636
Without	446	375	18,054	35,820	35,820	35,820
Dry Alfalfa						
With	57,161	13,020	5,292	---	---	---
Without	57,161	13,020	5,292	---	---	---
Dry Coastal						
With	56,407	21,727	15,467	---	---	---
Without	86,831	22,689	15,467	---	---	---
Native Pasture						
With	18,193	7,582	3,091	3,091	3,091	3,091
Without	20,026	7,582	3,091	3,091	3,091	3,091
Total	666,344	666,344	666,344	666,344	666,344	666,344

Table 16. Projected Optimal Land Use With and Without the Project, by 10-year Increments, 1990-2040, With SAR Effects, Reaches 5,8 and 9 (Acres)[a]

Crop	1990	2000	2010	2020	2030	2040
			Reach 5			
Irr. Cotton	26,265	26,265	26,265	26,265	26,265	26,265
Dry Cotton	37,449	38,691	38,691	38,691	38,691	38,691
Dry Alfalfa	1,242	---	---	---	---	---
Native Past.	1,228	1,228	1,228	1,228	1,228	1,228
Total	66,184	66,184	66,184	66,184	66,184	66,184
			Reach 8			
Irr. Cotton	34,868	34,868	34,868	34,868	34,868	34,868
Dry Cotton	94,494	102,005	102,005	102,005	102,005	102,005
Dry Sorghum	---	---	---	1,343	1,343	1,343
Dry Alfalfa	1,912	---	---	---	---	---
Dry Coastal	6,942	1,343	1,343	---	---	---
Total	138,216	138,216	138,216	138,216	138,216	138,216
			Reach 9			
Irr. Cotton	13,789	13,789	13,789	13,789	13,789	13,789
Dry Cotton	7,565	15,732	15,732	15,732	15,732	15,732
Dry Sorghum	---	---	4,010	4,010	4,010	4,010
Dry Alfalfa	107	---	---	---	---	---
Dry Coastal	555	---	---	---	---	---
Native Past.	11,515	4,010	---	---	---	---
Total	33,531	33,531	33,531	33,531	33,531	33,531

[a]The acre feet of water available for irrigation in Reach 5 was assumed to be the same in Reach 6. No estimate of the volume of alluvial storage for Reach 5 was provided by the Corps of Engineers. The volume of irrigation water has no effect on project benefits since crop yields in Reach 5 are not affected by salinity problems.

Table 17. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, With SAR Effects, Reaches 6 and 7 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 6			
Irr. Cotton						
With	46,131	46,131	46,185	46,185	46,185	46,185
Without	17,610	9,976	9,712	3,416	3,416	3,296
Dry Cotton						
With	51,879	52,029	52,271	52,271	52,271	52,271
Without	79,860	88,184	88,744	95,040	95,040	95,160
Irr. Sorghum						
With	---	962	2,200	2,200	1,184	1,184
Without	---	---	---	---	---	---
Dry Sorghum						
With	446	375	2,412	9,460	10,476	10,476
Without	446	375	4,612	11,660	11,660	11,660
Dry Alfalfa						
With	2,299	2,299	2,299	---	---	---
Without	2,299	2,299	2,299	---	---	---
Dry Coastal						
With	8,986	7,945	4,749	---	---	---
Without	9,526	8,907	4,749	---	---	---
Native Pasture						
With	1,707	1,707	1,332	1,332	1,332	1,332
Without	1,707	1,707	1,332	1,332	1,332	1,332
Total	111,448	111,448	111,448	111,448	111,448	111,448
			Reach 7			
Irr. Cotton						
With	11,989	11,989	11,989	11,989	11,989	11,989
Without	498	498	498	498	498	29
Dry Cotton						
With	6,186	6,186	6,186	6,186	6,186	6,186
Without	17,677	17,677	17,677	17,677	17,677	18,146
Total	18,175	18,175	18,175	18,175	18,175	18,175

Table 18. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, With SAR Effects, Reaches 10 and 11 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 10			
Irr. Cotton						
With	6,959	6,959	6,959	6,959	6,959	6,959
Without	---	---	---	---	---	---
Dry Cotton						
With	11,146	15,202	15,202	15,202	15,202	15,202
Without	18,105	22,161	22,161	22,161	22,161	22,161
Dry Coastal						
With	1,409	---	---	---	---	---
Without	1,409	---	---	---	---	---
Native Pasture						
With	2,647	---	---	---	---	---
Without	2,647	---	---	---	---	---
Total	22,161	22,161	22,161	22,161	22,161	22,161
			Reach 11			
Irr. Cotton						
With	6,135	6,346	6,346	4,732	4,732	4,732
Without	---	---	---	---	---	---
Dry Cotton						
With	1,201	3,559	3,559	8,167	8,167	8,167
Without	6,791	9,906	9,906	12,899	12,899	12,899
Dry Sorghum						
With	---	---	---	2,966	2,966	2,966
Without	---	---	---	2,966	2,966	2,966
Dry Alfalfa						
With	2,993	2,993	2,993	---	---	---
Without	2,993	2,993	2,993	---	---	---
Dry Coastal						
With	5,317	2,966	2,966	---	---	---
Without	5,317	2,966	2,966	---	---	---
Native Pasture						
With	219	---	---	---	---	---
Without	764	---	---	---	---	---
Total	15,865	15,865	15,865	15,865	15,865	15,865

Table 19. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, With SAR Effects, Reaches 12 and 13 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 12			
Irr. Cotton						
With	8,270	8,660	5,193	5,193	5,193	4,803
Without	---	---	---	---	---	---
Dry Cotton						
With	14,325	24,732	28,199	28,199	28,199	28,589
Without	22,595	33,392	33,392	33,392	33,392	33,392
Dry Sorghum						
With	---	---	---	4,202	4,202	4,202
Without	---	---	---	4,202	4,202	4,202
Dry Coastal						
With	14,999	4,202	4,202	---	---	---
Without	14,999	4,202	4,202	---	---	---
Total	37,594	37,594	37,594	37,594	37,594	37,594
			Reach 13			
Irr. Cotton						
With	39,045	39,045	39,045	39,045	39,045	39,045
Without	---	---	---	---	---	---
Dry Cotton						
With	14,658	30,513	30,513	30,513	30,513	30,513
Without	43,884	69,558	69,558	69,558	69,558	69,558
Dry Sorghum						
With	---	---	7,728	7,728	7,728	7,728
Without	---	---	7,728	7,728	7,728	7,728
Dry Alfalfa						
With	23,583	7,728	---	---	---	---
Without	23,583	7,728	---	---	---	---
Dry Coastal						
With	---	---	---	---	---	---
Without	9,794	---	---	---	---	---
Native Pasture						
With	---	---	---	---	---	---
Without	25	---	---	---	---	---
Total	77,286	77,286	77,286	77,286	77,286	77,286

Table 20. Projected Optimal Land Use With Project Compared With Projected Optimal Land Use Without Project by 10-year Increments, 1990-2040, With SAR Effects, Reaches 14 and 15 (Acres)

Crop	1990	2000	2010	2020	2030	2040
			Reach 14			
Irr. Cotton						
With	33,035	36,539	36,539	36,539	35,074	34,910
Without	---	---	---	---	---	---
Dry Cotton						
With	44,486	57,531	57,556	57,556	59,021	59,185
Without	57,431	94,070	94,095	94,095	94,095	94,095
Dry Sorghum						
With	---	---	1,623	3,830	3,830	3,830
Without	---	---	1,623	3,830	3,830	3,830
Dry Alfalfa						
With	6,265	---	---	---	---	---
Without	6,265	---	---	---	---	---
Dry Coastal						
With	14,114	3,830	2,207	---	---	---
Without	34,204	3,830	2,207	---	---	---
Native Pasture						
With	556	556	531	531	531	531
Without	556	556	531	531	531	531
Total	98,456	98,456	98,456	98,456	98,456	98,456
			Reach 15			
Irr. Cotton						
With	9,391	7,750	4,890	4,890	4,890	4,866
Without	---	---	---	---	---	---
Dry Cotton						
With	14,871	38,156	42,457	42,457	42,457	42,481
Without	22,999	45,906	47,347	47,347	47,347	47,347
Dry Sorghum						
With	---	---	81	81	81	81
Without	---	---	81	81	81	81
Dry Alfalfa						
With	18,760	---	---	---	---	---
Without	18,760	---	---	---	---	---
Dry Coastal						
With	4,085	1,441	---	---	---	---
Without	4,085	1,441	---	---	---	---
Native Pasture						
With	321	81	---	---	---	---
Without	1,584	81	---	---	---	---
Total	47,428	47,428	47,428	47,428	47,428	47,428

of 20 and 18 percent, respectively, for cotton; thus, benefits can occur. However, in both Reaches 8 and 9, available water is completely utilized without the project and thus, no additional acreage could be irrigated even with salinity control. Hence, the only benefit possible in these reaches is the value of the yield increase provided by salinity control.

In the remaining reaches, optimal cropping patterns would not be the same for the with and without project condition. Table 4 (p. 71) indicates substantial yield reduction for all crops, except Coastal bermuda, through Reach 9, without the project. From Reach 10 westward, no irrigated crop production is possible since yields are completely eliminated by salinity and SAR effects. With the project, yield reduction for cotton is five to nine percent in Reaches 10 through 15 with substantial reduction to other irrigated crops, except Coastal bermuda. Thus, a simple comparison of the yield reduction coefficients for the western reaches indicates that benefits may be possible if the small reduction to irrigated cotton yields does not make it less profitable than the other dryland alternatives.

Table 19 indicates that in Reaches 6 and 7 some irrigation of cotton without the project is profitable even with the 16 and 18 percent yield reduction due to salinity, respectively. Evidently, this reduction still does not make irrigated cotton less profitable than other alternatives on some of the better soils. However, much more dryland cotton and other dryland crops enter the optimal cropping pattern in these reaches than irrigated cotton, especially in Reach 7. With the project, substantial irrigated cotton enters the optimal cropping pattern at the expense primarily of dryland cotton. Thus, in these two reaches substantial benefits could occur.

In Reach 10 and westward (Tables 18 through 20) no irrigation occurs without the project. Acreage is divided among dryland production of cotton, grain sorghum, alfalfa, Coastal bermuda and native pasture. With the project substantial acreage of irrigated cotton enters the optimal cropping pattern. This means that even with the slight yield reduction due to salinity in those reaches, irrigated cotton is still the most profitable crop on some soil types.

In several of the western reaches, however, slight to moderate declines in irrigated acreage occur over the period 1990-2040 with the project. For some soil types, the differences in net income among dryland and irrigated crop alternatives are quite small. Where differences are small, changes of a few cents in net income relationships resulting from the yield projections and associated reductions due to salinity can cause shifts in optimal land use patterns.

Without Crop Yield Adjustments

The application of OBERS Series E' yield adjustment has substantial impact on optimal land use estimates for the study area. They cause a shift away from forage production in favor of cotton and grain sorghum over time. More importantly, however, they cause net returns to the region to increase substantially over time since costs are held constant.

Trend analyses conducted primarily as a by-product of the econometric portion with admittedly limited data (1968-1979) indicate little or no significant upward trend in yields for any of the crops considered in this study. Thus, the application of OBERS projections may be questionable for this region.

In order to establish the affect of OBERS projections on the results of this analysis, a simple takeoff of the already discussed profit maximization scenarios was developed in which yields remain constant at their initial levels throughout the period of analysis (1990-2040). All other assumptions of the profit maximization scenarios were maintained. Hence, the optimal land use for the entire analysis period would be the optimal land use developed in each scenario for 1990. Since OBERS yield increases are not applied, cropping patterns do not change. All other results for the 1990 period, i.e., water utilization and irrigated acreage, remain constant for the entire period of analysis. Likewise, the net returns for each year (1990-2090) do not change over time. The resulting benefit estimates will be discussed in the next chapter.

Acres Irrigated

A comparison of the number of acres that would be irrigated in 1990 assuming optimal land use (with and without SAR effects) with actual irrigated acres in 1979 is shown in Table 21. The irrigated acres for 1979 are those reported by Grossman and Keith from their 1979 survey. The acreages that would be irrigated assuming optimal land use are shown by reach both with and without the salinity control project in place.

Without SAR effects considered, total acreage that would be irrigated under an optimal land use pattern based on restrictions of water

Table 21. Comparison of the Number of Acres Irrigated as Reported in the November 1979 Field Survey With the Number of Acres that Would be Irrigated in 1990 With Optimal Land Use, With and Without SAR Effects[a]

	Acres Irrigated				
		Optimal 1990 Without SAR		Optimal 1990 With SAR	
Reach	Nov. 1979 Survey	With Project	Without Project	With Project	Without Project
5	2,377	26,265	26,265	26,265	26,265
6	1,637	46,131	46,131	46,131	17,610
7	845	11,989	11,989	11,989	498
8	15,500	34,868	34,868	34,868	34,868
9	---	13,789	13,789	13,789	13,789
10	472	6,959	---	6,959	---
11	---	6,347	---	6,135	---
12	6,370	13,890	13,890	8,270	---
13	4,812	53,703	---	39,045	---
14	3,373	40,698	19,828	33,035	---
15	3,480	20,179	---	9,391	---
Total	38,866	274,818	166,760	235,877	93,030

[a]Acreage reported in Column 6, Table 2-III-3, of Grossman and Keith.

availability is 274,818 with the project, and 166,760 without the project. With SAR effects included in the analysis total acreage that would be irrigated with the salinity control project is 235,877, and without the project is 93,030. This compares to 38,866 acres irrigated in 1979. With salinity control, some irrigation from the alluvium would occur in each of the 11 reaches, both with and without SAR effects. Irrigation would be profitable in each of the 5 eastern reaches with and without SAR effects but only in two of the western reaches without SAR (Reaches 12 and 14) and none of the western reaches if SAR is a problem.

Of the 38,866 irrigated acres reported in the November 1979 survey, the major source of irrigation water apparently was from sources other than the alluvium. For example, the largest irrigated acreage (15,500) was reported for Reach 8, where Lake Kemp was reported to be the major source of water. Other non-alluvium sources were Lake Altus and the Seymour and Blaine Gypsum aquifer formations. Thus, evidence presented here indicates that although irrigation from the alluvium of the Red River is now profitable, relatively few producers are irrigating from it.

Irrigation Water Utilized

Projections of the amount of water that would be utilized for irrigation in 1990 compared with the amount available are shown by reach in Table 22 for the no SAR condition and in Table 23 for the SAR condition. Estimates of the amount of water that would be utilized for irrigation in 1990 for both situations are based on the assumptions

Table 22. Comparison of the Amount of Water Available for Irrigation With the Projected Amount that Would be Used in 1990 With Optimal Land Use, Without SAR Effects

		Water Utilized		Water Not Utilized	
Reach	Water Available	With Project	Without Project	With Project	Without Project
	Acre Feet				
5[a]	79,100	20,137	20,137	58,963	58,963
6	79,100	41,518	41,518	37,582	37,582
7	58,200	14,487	14,487	43,713	43,713
8	46,200	46,200	46,200	0	0
9	18,500	18,500	18,500	0	0
10	12,700	12,700	0	0	12,700
11	11,900	11,900	0	0	11,900
12	51,900	18,983	18,983	32,917	32,917
13	99,000	94,469	0	4,531	99,000
14	71,900	71,900	35,029	0	36,871
15	46,300	37,499	0	8,801	46,300
Total[b]	495,700	368,156	174,717	127,554	320,983

[a]Reach 5 was assumed equal to Reach 6 because capacity of the alluvium was not given.

[b]Totals do not include Reach 5 because alluvial storage was not given.

Table 23. Comparison of the Amount of Water Available for Irrigation With the Projected Amount that Would be Used in 1990 With Optimal Land Use, With SAR Effects

Reach	Water Available	Water Utilized		Water Not Utilized	
		With Project	Without Project	With Project	Without Project
	Acre Feet				
5[a]	79,100	20,137	20,137	58,963	58,963
6	79,100	41,518	15,849	37,582	63,251
7	58,200	14,487	602	43,713	57,598
8	46,200	46,200	46,200	0	0
9	18,500	18,500	18,500	0	0
10	12,700	12,700	0	0	12,700
11	11,900	11,503	0	397	11,900
12	51,900	11,302	0	40,598	51,900
13	99,000	68,451	0	30,549	99,000
14	71,900	58,362	0	13,538	71,900
15	46,300	17,452	0	28,848	46,300
Total[b]	495,700	300,475	81,151	195,225	414,549

[a]Reach 5 was assumed equal to Reach 6 because capacity of the alluvium was not given.

[b]Totals do not include Reach 5 because alluvial storage was not given.

of each scenario previously mentioned.

Without SAR effects and with salinity control, irrigation water would be completely utilized in Reaches 8, 9, 10, 11, and 14 and almost completely utilized in Reaches 13 and 15. Substantial amounts of water would not be utilized in Reaches 6, 7, and 12. Without salinity control only in Reaches 8 and 9 would water be completely utilized while all other reaches leave large quantities not utilized.

With SAR effects and with salinity control, irrigation water would be completely utilized only in Reaches 8, 9, and 10 and almost fully utilized in Reach 11. Substantial amounts of water from the alluvium would not be used in the four western reaches (12, 13, 14, and 15) as well as in Reaches 6 and 7. Without the project, however, irrigation is not profitable from the alluvium in the six western reaches (10 through 15) and only marginally so in Reach 7.

The large volume of unutilized water and large acreages of dryland crop production in all cases means that irrigation would be profitable only on the more productive and responsive soils. Irrigated yields on the poorer soils is not sufficiently higher than dryland yields so as to make irrigation of crops more profitable than dryland production. As illustrated in Tables 22 and 23, almost 90,000 additional acre feet of water would not be utilized in the study area with the project simply because of the SAR effect. This is because yield reduction in the western reaches would occur even with salinity control. This in turn will have a significant bearing on the amount of benefits that might be realized from the western part of the study area and is discussed in more detail in the next chapter.

Constrained Optimum

Next, a scenario was developed to estimate benefits and cropping patterns given the constraint that producers may not undertake irrigation practices immediately and/or move to the optimal (profit maximizing) land use by the beginning year. Evidence that such a situation might exist comes from (1) the 1979 survey (Grossman and Keith) in which producers were observed not to be following optimal land use, according to this study specification, and (2) a survey conducted by Somerville (1980) and reported to the Corps of Engineers which indicated mixed feelings throughout the study area toward using irrigation water from the Red River after salinity control. However, in neither case does any objective estimate appear as to the rapidity with which producers might move toward a profit maximizing land use. Thus, a subjective scenario was developed in which producers were constrained to current land use for the 1990 period, allowed to adjust by 50 percent of difference between the 2000 year optimal and 1990 (current) land use, and by 2010 to fully adjust to the optimal cropping plan. Table 24 gives a summary of acreages of crops currently grown in the study area.

The resulting cropping pattern for this scenario is summarized for all reaches in Table 25. This scenario was developed only for the case where SAR effects in crop yields are included. The 1990 cropping plan with and without the project is the same as the current cropping pattern given in Table 24 with acreage optimized between dryland and irrigated production. The 2000 cropping plan indicates adjustment from wheat and native pasture and into irrigated cotton, dryland cotton and

Table 24. Current Cropping Pattern Reported in the 1979 Survey for the Study Area, by Reach (Acres)[a]

Reach	Cotton	Grain Sorghum	Small Grains	Alfalfa	Coastal Pasture	Native Pasture
5	---	8,720	1,000	---	---	56,464
6	7,490	18,070	31,490	4,040	5,250	45,108
7	2,430	1,270	7,600	1,270	---	5,605
8	11,500	800	17,050	---	1,750	107,116
9	---	---	---	---	---	33,631
10	2,914	---	193	730	485	17,839
11	920	920	7,370	400	---	6,255
12[b]	21,660	3,610	3,610	3,610	3,610	1,494
13	17,729	610	1,639	10,760	1,875	44,673
14	24,631	7,127	49,081	6,640	---	10,977
15	8,777	4,214	16,397	2,340	---	15,700
Total	98,051	45,341	135,430	29,790	12,970	344,762

[a]Source: Grossman and Keith, Table 2-II-1. County values for counties split between two reaches were adjusted by the percentage of study area land actually in each reach as calculated from Tables 2-I-1 through 2-I-41.

[b]Values in this row reflect 95 percent of those of the 1979 Survey since more acreage was specified in crops than is in the reach.

Table 25. Projected Land Use With Project Compared With Projected Land Use Without Project, a Constrained Optimum for 1990-2000, Optimal Land Use 2010-2040, With SAR Effects, All Reaches (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	66,965	185,031	232,068	230,454	228,988	228,411
Without	11,500	67,456	85,131	78,836	78,836	78,246
Dry Cotton						
With	31,086	175,337	392,372	396,979	398,444	399,022
Without	86,551	292,912	539,308	548,597	548,597	549,187
Irr. Sorghum						
With	4,749	2,357	2,200	2,200	1,184	1,184
Without	888	---	---	---	---	---
Dry Sorghum						
With	40,592	58,808	15,854	33,620	34,636	34,636
Without	44,453	62,475	18,054	35,820	35,820	35,820
Dry Wheat						
With	135,430	78,771	---	---	---	---
Without	135,430	78,288	---	---	---	---
Dry Alfalfa						
With	29,790	54,423	5,292	---	---	---
Without	29,790	52,280	5,292	---	---	---
Dry Coastal						
With	12,970	38,131	15,467	---	---	---
Without	12,970	38,072	15,467	---	---	---
Native Pasture						
With	344,762	73,486	3,091	3,091	3,091	3,091
Without	344,762	74,861	3,091	3,091	3,091	3,091
Total	666,344	666,344	666,344	666,344	666,344	666,344

alfalfa and Coastal bermuda. By 2010 total adjustment to the optimal land use was assumed with most of the acreage devoted to irrigated and dryland cotton, and small acreages of sorghum, alfalfa, Coastal bermuda and native pasture. Similar adjustment occurs without the project under the same assumptions. The only real difference is that many fewer acres are allotted to irrigated cotton and more goes into dryland cotton.

Current Land Use

All crops considered in this analysis are currently being grown in the study area. Most are grown dryland as indicated earlier. Again, Table 24 (p. 118) gives a summary of acreages of these crops currently grown in the study area. These results were taken from the Grossman and Keith report and adjusted to more accurately fit the various reaches. Cultivated crops and forages listed are reported acreages while native pasture was assumed the residual claimant and, in this model, occupies all other acreage of each reach. Thus, native pasture is reported in Table 24 (p. 118) as the difference between total acreage in the reach and the sum of all other crop acreages.

Two models were again developed for this scenario, with and without SAR effects, to establish somewhat of a lower limit for benefits while maintaining the other assumptions specified for the profit maximization scenarios. Current crops were specified to hold through 2040 while the linear program was allowed to optimize between irrigated and dryland production. Table 26 presents the results for the entire study area without SAR effects and Table 27 gives results when SAR is

Table 26. Current Cropping Pattern With Project Compared to Current Cropping Pattern Without Project, 10-year Increments, 1990-2040, Without SAR Effects, All Reaches (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	83,321	83,920	83,920	83,321	83,321	83,321
Without	45,224	45,224	45,224	45,224	44,387	44,387
Dry Cotton						
With	14,730	14,131	14,131	14,730	14,730	14,730
Without	52,827	52,827	52,827	52,827	53,664	53,664
Irr. Sorghum						
With	4,811	5,337	5,030	2,208	2,208	2,208
Without	4,789	5,337	5,030	2,208	2,208	2,208
Dry Sorghum						
With	40,530	40,004	40,311	43,133	43,133	43,133
Without	40,592	40,004	40,311	43,133	43,133	43,133
Dry Wheat						
With	135,430	135,430	135,430	135,430	135,430	135,430
Without	135,430	135,430	135,430	135,430	135,430	135,430
Dry Alfalfa						
With	29,790	29,790	29,790	29,790	29,790	29,790
Without	29,790	29,790	29,790	29,790	29,790	29,790
Dry Coastal						
With	12,970	12,970	12,970	12,970	12,970	12,970
Without	12,970	12,970	12,970	12,970	12,970	12,970
Native Pasture						
With	344,762	344,762	344,762	344,762	344,762	344,762
Without	344,762	344,762	344,762	344,762	344,762	344,762
Total	666,344	666,344	666,344	666,344	666,344	666,344

Table 27. Current Cropping Pattern With Project Compared to Current Cropping Pattern Without Project, 10-year Increments, 1990-2040, With SAR Effects, All Reaches (Acres)

Crop	1990	2000	2010	2020	2030	2040
Irr. Cotton						
With	66,965	66,941	59,916	59,347	59,347	59,347
Without	11,500	11,500	11,500	11,500	11,500	11,500
Dry Cotton						
With	31,086	31,110	38,135	38,704	38,704	38,704
Without	86,551	86,551	86,551	86,551	86,551	86,551
Irr. Sorghum						
With	4,749	5,337	5,030	2,208	2,208	2,208
Without	888	888	581	---	---	---
Dry Sorghum						
With	40,592	40,004	40,311	43,133	43,133	43,133
Without	44,453	44,453	44,760	45,341	45,341	45,341
Dry Wheat						
With	135,430	135,430	135,430	135,430	135,430	135,430
Without	135,430	135,430	135,430	135,430	135,430	135,430
Dry Alfalfa						
With	29,790	29,790	29,790	29,790	29,790	29,790
Without	29,790	29,790	29,790	29,790	29,790	29,790
Dry Coastal						
With	12,970	12,970	12,970	12,970	12,970	12,970
Without	12,970	12,970	12,970	12,970	12,970	12,970
Native Pasture						
With	344,762	344,762	344,762	344,762	344,762	344,762
Without	344,762	344,762	344,762	344,762	344,762	344,762
Total	666,344	666,344	666,344	666,344	666,344	666,344

a factor.

In both cases, with and without SAR, and with and without the project, cotton is the major irrigated crop with small acreages of grain sorghum also irrigated. Wheat, alfalfa, and Coastal bermuda are all produced dryland. Substantial difference is evident in the number of acres allocated to irrigated cotton without the project between the with and without SAR effect. Much less difference in irrigated cotton acreage is noticed with the project. Thus, the appearance of significant irrigated acreages for both conditions and a larger difference between irrigation with and without the project indicates benefits will result even with current cropping pattern specifications. Further, more benefits result with SAR effects than without them. However, with SAR effects and with the project, a small shift (about 7,000 acres) from irrigated cotton to dryland cotton occurs over time. This is due again to application of OBERS yield increases and indicates a relatively small difference between dryland and irrigated cotton net returns for some soil types. This tends to reduce project benefits in the later years of the project.

CHAPTER V

AGRICULTURAL BENEFITS OF SALINITY CONTROL

Estimates of the net direct agricultural benefits of salinity control on the Red River derived by using the mathematical modeling technique will be presented in this chapter for scenarios described in Chapter III, and are associated with the cropping patterns results as presented in Chapter IV. Following the mathematical modeling results will be a presentation of the econometric results. Benefit estimates described in this study will be combined with Corps of Engineers initial cost projections and additional benefit estimates in a brief benefit-cost analysis on the proposed salinity control project. Finally, a section focusses on demand estimates for irrigation water assuming the project is in place.

Net Agricultural Benefits

A comparison of the estimated present values of the net revenue streams over the 100-year life of the project, with and without the salinity control project, and for each scenario is presented. In each scenario the estimate of total net benefits is the difference between the discounted present value of farmers' net revenue with and without the proposed salinity control project. The present values are calculated using the project discount rate of 7 1/8 percent and a lower rate of 3 1/4 percent for comparative purposes.

Benefits Without SAR Yield Effects

Under the assumptions of the first scenario, i.e., profit maximization with and without the project, no SAR yield effect included and application of OBERS yield projections, benefits from salinity control would be realized only in the five western reaches (10, 11, 13, 14, and 15). This is because there is no yield reduction to irrigated cotton in those reaches. Total benefits for this scenario are $65.794 million at the 7 1/8 percent discount rate and $137.058 million at a 3 1/4 percent discount rate. Present values of net revenues and benefits are presented by reach in Table 28 for this scenario.

Under the assumption of constant yields instead of OBERS projections, the total benefit estimate is $55.848 million at a 7 1/8 percent dicount rate and $117.559 at 3 1/4 percent. Benefit results for this scenario are presented by reach in Table 29.

Benefit estimates for the scenario where current cropping patterns are retained throughout the project life are presented by reach in Table 30. Benefits for this scenario are $28.823 million at the 7 1/8 percent discount rate and $60.064 million at the 3 1/4 percent rate.

In all of these scenarios benefits occur only in the five western reaches. The largest benefits, about 45 percent of the total, occur in Reach 13. The application of OBERS yield increases has a $9.2 million effect on benefit estimation with all other parameters held constant. The estimate of benefits is reduced by $36.2 million from the profit maximization case if current cropping patterns are assumed (with OBERS increases). Thus, without SAR effects, benefits to agricultural producers should range from a low of $28.8 million to a

Table 28. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Profit Maximizing Objective, With and Without the Project, and Without SAR Effects

Reach	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	99,396	255,401	99,396	255,401	0	0
6	186,920	464,654	186,920	464,654	0	0
7	32,036	80,100	32,036	80,100	0	0
8	205,322	528,550	205,322	528,550	0	0
9	48,770	123,920	48,770	123,920	0	0
10	21,577	61,610	15,812	49,671	5,765	11,909
11	18,885	48,613	13,047	38,047	5,838	10,528
12	44,783	119,296	44,783	119,296	0	0
13	100,209	263,116	71,609	203,848	28,600	59,243
14	144,598	371,911	126,902	333,139	17,696	38,736
15	51,929	143,300	44,034	126,694	7,895	16,642
Total	954,425	2,460,471	889,375	2,323,320	65,794	137,058

Table 29. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Profit Maximizing Objective, Constant Yields 1990-2090 With and Without Project, and Without SAR Effects[a]

	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
Reach	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	59,558	125,371	59,558	125,371	0	0
6	122,936	258,779	122,936	258,779	0	0
7	20,533	43,223	20,533	43,223	0	0
8	122,863	258,625	122,863	258,625	0	0
9	31,411	66,121	31,411	66,121	0	0
10	9,457	19,906	4,321	9,096	5,135	10,809
11	12,421	26,146	7,942	16,717	4,479	9,428
12	25,017	52,660	25,017	52,660	0	0
13	58,042	122,179	32,368	68,135	25,673	54,043
14	87,622	184,443	73,875	155,508	13,746	28,936
15	26,305	55,373	19,492	41,031	6,813	14,342
Total	576,164	1,212,831	579,875	1,102,266	55,848	117,559

[a]Estimated net benefits if crop yields are held constant over the 100-year life of the project. In all other parts of the study, crop yields are adjusted upward over the first 50 years of the life of the project in accordance with OBERS projections.

Table 30. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Current Cropping Patterns, With and Without the Project, and Without SAR Effects

Reach	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	16,106	37,338	16,106	37,338	0	0
6	59,438	142,213	59,438	142,213	0	0
7	10,702	26,021	10,702	26,021	0	0
8	52,280	119,774	52,280	119,774	0	0
9	1,949	3,960	1,949	3,960	0	0
10	7,115	16,917	4,231	10,997	2,884	5,920
11	5,626	14,391	4,166	11,416	1,460	2,975
12	36,440	94,714	36,440	94,714	0	0
13	44,847	106,476	31,550	79,197	13,297	27,279
14	74,107	186,142	66,743	170,224	7,364	15,918
15	21,769	57,566	17,951	49,594	3,818	7,972
Total	330,379	805,512	301,556	745,448	28,823	60,064

maximum of $65.794 million if OBERS yield increases occur and to a maximum of $55.8 million if they do not.

Benefits With SAR Yield Effects

The assumption of profit maximization with and without the project for the with SAR yield effects included led to the benefit estimates presented by reach in Table 31. Benefits from salinity control would be realized in 10 of the 11 reaches under this scenario. Only in Reach 5 would benefits not occur. This is because there is no yield reduction to irrigated cotton due to salinity or SAR effects in Reach 5. Total agricultural benefit estimates given in Table 31 are $117.395 million at the 7 1/8 percent discount rate and $246.372 million, with substantial benefits coming in Reaches 6, 9, 13, and 14. Most benefits (66.7 percent), however, come from the five eastern reaches (Reaches 6, 7, 8, 9, and 12). This is in contrast to the analysis without SAR yield effects considered where all benefits come from the five western reaches. Hence, much of the total estimated benefits shift from the western region of the study area to the eastern region by including SAR yield effects.

This shift is due primarily to the assumption of increased yield reduction to irrigated cotton without the project in the eastern reaches and with the project in the western reaches. The five to nine percent yield reductions to irrigated cotton in the western reaches even with salinity control results in a much greater proportional reduction in net returns from irrigation than the percentage reduction in yields. This significantly reduces the number of acres it is profitable to irrigate. The reason is that gross revenues are reduced

Table 31. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Profit Maximizing Objective, With and Without the Project, and With SAR Effects

Reach	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	99,396	255,401	99,396	255,401	0	0
6	186,920	464,654	170,198	429,180	16,722	35,473
7	32,036	80,100	26,036	67,683	6,001	12,417
8	205,322	528,550	164,923	440,872	40,399	87,678
9	48,770	123,920	34,812	93,585	13,958	30,335
10	19,390	56,777	15,812	49,671	3,578	7,106
11	16,535	43,453	13,791	38,047	2,744	5,406
12	42,528	114,244	41,221	111,710	1,307	2,534
13	83,575	226,751	71,608	203,848	11,967	22,903
14	133,866	348,103	114,330	307,733	19,536	40,370
15	45,218	128,842	44,034	126,694	1,184	2,147
Total	913,556	2,370,799	796,161	2,124,427	117,395	246,372

by an amount proportionate to the reduction in yield but costs are reduced by a much smaller amount. Some cost reduction does occur, primarily in harvesting costs, but the effect of reduced yields on total costs is slight. This squeeze on net returns reduces the number of acres that otherwise would be irrigated and reduces net benefits significantly compared to what the results would be with higher quality water. This is evidenced in Table 21 of Chapter IV where, in the western reaches, significantly more acreage is irrigated without SAR effects than with SAR effects.

A somewhat more straightforward situation occurs in the eastern reaches. Without the project, salinity/SAR yield reductions are not so great as to preclude irrigation. Thus, with implementation of salinity control, additional irrigated acreage is made profitable. On acreage already allocated to irrigated production yield is significantly increased making all acreage previously irrigated even more profitable. Hence, including the effects of SAR on crop yields large benefits are shifted to the eastern reaches from the western reaches.

In connection with the shift in benefits, the total net benefit increases significantly above those derived without the SAR effect. Although the with project total net revenue estimates between the SAR and no SAR situations is significant ($40.869 million), the without project net revenues between including and not including SAR effects makes the largest impact. Without the project an additional $93,214 million in damages occurs, i.e., a total revenue of $889,375 million without SAR effects to a total net revenue of $796,161 million with SAR yield effects. Thus, a difference of $51.601 million in estimated total benefits ($117.395 million - $65.794 million) results from the change in the assumption about SAR effects.[2]

Without the application of OBERS yield increases, a model similar to that described above results. Results for this model are given in Table 32. Net benefits are not as great, however, $100.627 million at a 7 1/8 percent discount rate and $212,817 at 3 1/4 percent, as with OBERS yield changes. Thus, the effect of OBERS in this scenario is seen to be an increase in project benefits of $16.798 million and $33.555 million at the 7 1/8 percent and 3 1/4 percent discount rates, respectively, over the case where no OBERS increases were applied.

Benefit results from the scenario of current cropping patterns with SAR effects are presented in Table 33. Again, benefits in this situation are higher than the comparable scenario without SAR effects, $35.833 million vs. the previously given $28.328 million at the 7 1/8 percent discount rate.

One additional scenario was developed involving SAR effects. As described earlier, this scenario involved the subjective judgement that producers would retain current cropping patterns in 1990, adjust to 50% of the profit maximizing land use by 2000, and completely adjust to the profit maximizing cropping patterns by 2010. All other assumptions of the profit maximizing scenario were maintained. The resulting benefit estimates are given in Table 34. Total net benfits for this scenario are $87.581 million at a 7 1/8 percent discount rate, $29.814 million less than the profit maximization scenario but $51.748 mil-

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[2]These values occur at the 7 1/8 percent discount rate, but analogous values are observed at the 3 1/4 percent rate.

Table 32. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Profit Maximizing Objective, Constant Yields 1990-2090 With and Without Project, and With SAR Effects[a]

Reach	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	59,558	125,371	59,558	125,371	0	0
6	122,936	258,779	108,843	229,115	14,093	29,664
7	20,533	43,223	15,163	31,718	5,370	11,305
8	122,863	258,625	88,730	186,776	34,133	71,849
9	31,411	66,121	19,615	41,289	11,797	24,832
10	7,637	16,077	4,321	9,096	3,316	6,981
11	10,485	22,070	7,942	16,717	2,543	5,352
12	23,279	49,002	22,008	46,327	1,271	2,674
13	44,232	93,109	32,368	68,135	11,864	24,974
14	79,108	166,522	64,090	134,909	15,018	32,613
15	20,714	43,604	19,492	41,031	1,222	2,573
Total	542,756	1,142,503	442,130	930,684	100,627	212,817

[a]Estimated net benefits if crop yields are held constant over the 100-year life of the project. In all other parts of the study, crop yields are adjusted upward over the first 50 years of the life of the project in accordance with OBERS projections.

Table 33. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Current Cropping Patterns, With and Without the Project, and With SAR Effects

Reach	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	19,106	37,338	16,106	37,338	0	0
6	59,438	142,213	58,235	139,883	1,203	2,330
7	10,702	26,021	9,781	24,155	921	1,866
8	52,280	119,774	38,956	90,856	13,324	28,918
9	1,949	3,960	1,949	3,960	0	0
10	6,120	14,730	4,231	10,998	1,889	3,732
11	5,200	13,467	4,166	11,416	1,034	2,051
12	36,290	89,944	33,000	87,437	1,290	2,507
13	38,691	92,969	31,550	79,197	7,141	13,772
14	69,587	176,407	61,200	160,024	8,387	16,383
15	18,595	50,796	17,951	49,594	644	1,202
Total	312,858	767,619	277,125	695,008	35,833	72,761

Table 34. Estimated Present Value of Total Project Benefits Over the 100-year Period 1990-2090, Current Cropping Patterns for 1990, a Constrained Optimum for 1990-2000, Optimum for 2010-2090, With and Without the Project, and With SAR Effects

	Present Value of Net Revenues With Project		Present Value of Net Revenues Without Project		Present Value of Net Benefits	
Reach	7 1/8%	3 1/4%	7 1/8%	3 1/4%	7 1/8%	3 1/4%
	$1,000					
5	76,777	228,241	76,777	228,241	0	0
6	144,426	412,865	135,804	387,503	8,622	25,362
7	25,223	71,829	21,233	61,782	4,010	10,047
8	167,479	483,986	134,977	404,649	32,502	79,319
9	37,709	111,257	27,558	85,125	10,151	26,132
10	17,105	53,897	14,090	47,437	3,015	6,460
11	12,802	38,943	10,719	34,314	2,083	4,629
12	40,150	111,288	38,847	108,758	1,303	2,530
13	73,810	214,706	64,010	194,375	9,800	20,331
14	114,866	324,972	99,614	289,950	15,252	35,022
15	38,310	120,276	37,467	118,555	843	1,721
Total	748,657	2,172,260	661,086	1,960,689	87,581	211,553

lion higher than the current land use pattern scenario. Thus, although benefits are substantially reduced if producers do not maximize profits immediately after project construction, adjustment toward, and final arrival at, profit maximizating behavior will lead to substantial agricultural benefits from salinity control.

In all of the scenarios where SAR yield effects are included, except the current cropping patterns, benefits occur in each of the Reaches 6 through 15. Benefits do not occur in Reach 12 with current cropping patterns since there are no crops grown in that region currently, hence, no benefits can occur. In each case, Reach 8 has the largest estimated benefits. However, exploratory analysis indicates that benefits in Reach 8 could be substantially higher since a relatively small percentage of its irrigable land is actually irrigated due to its relatively small water availability. Indeed, additional water for irrigation can come from Lake Kemp, a large reservoir located in Reach 8. The Corps of Engineers has estimated additional irrigation benefits can be derived from reducing salinity entering Lake Kemp which will be presented later in this chapter.

Econometric Results

Results from the econometric model developed for this study were disappointing. Little, and more often no, statistical significance in the first stage of analysis could be obtained for several model specifications. Models involving data for irrigated and dryland production of cotton, grain sorghum and wheat for the Texas reaches only were developed as well as those for the entire study area. In most cases R-squares were less than .3 in the linear first stage of the estimation procedure. Subsequently, the restricted model in the third stage analyses were very poor fits. Additional trials using more simple least-squares techniques attempting to identify significance among crop prices, yields and acreages of the various crops in the study area were also fruitless. Thus, the econometric approach was abandoned. The failure of this portion of the study was attributed largely to the lack of accurate and lengthy time series data. Further, this technique seems to be more suited to aggregate analysis and less to the more specific regional situations.

Benefit-Cost Analysis

The Corps of Engineers has developed initial estimates of construction, operation and maintenance costs for the proposed Red River Salinity Control project. They have also estimated municipal and industrial benefits, and additional irrigation benefits that would be derived from improved water quality of Lake Kemp which is currently being used for irrigation. These estimates are combined in this section to determine the project feasibility.

Initial estimates of construction costs were $171 million to $185 million. Operations and maintenance costs were added by Corps of Engineers to bring the total project costs to a present value of $230.556 million. Annual municipal and industrial benefits were estimated to be about $8.0 million (a total of $112.165 million present value). Additional irrigation benefits from the improvement of Lake Kemp water were estimated to be $68.197 million each year. Thus, these estimates in combination with the agricultural benefit estimates developed in this study can be used to determine the economic feasibility of the proposed salinity control project. A summary of the benefits estimated from the various scenarios developed herein and the costs and benefits estimated by the Corps of Engineers is given in Table 35. All estimates presented in Table 35 utilize the 7 1/8 percent discount rate.

The benefit-cost ratios presented in Table 35 indicate that if SAR causes yield reduction in addition to the pure salinity yield effects, the project is economically feasible with B/C ratios of over 1.2 either with or without the OBERS yield increases. If, however, SAR is not a significant problem, the reduction in agricultural benefits reduces the B/C ratio to near one but still leaves the project economically feasible. If current cropping patterns are followed continuously in the future, the project becomes undesirable from an economic efficiency standpoint since the costs exceed benefits which causes a B/C ratio of less than one (.907 and .938 for the without and with SAR effects, respectively). In the case of the subjectively defined scenario where producers were confined to only a 50 percent adjustment toward the optimal land use in 2000 and to complete adjustment to optimal land use by 2010, the project is still economically feasible with a B/C ratio of 1.162. Hence, only in the case that producers fail to adjust to more profitable land use, i.e., current land use throughout the period of analysis, will the project be economically unjustified.

Table 35. Comparison of the Present Value of Net Benefits and Costs of the Proposed Red River Chloride Control Project for Various Scenarios[a]

	Profit Max Without SAR[b]		Profit Max With SAR		Current Crops		Constrained Optimum With SAR
	With OBERS[c]	Without OBERS	With OBERS	Without OBERS	Without SAR	With SAR	
	$ Million						
Benefits[d]							
M & I	112.165	112.165	112.165	112.165	112.165	112.165	112.165
Lake Kemp	68.197	68.197	68.197	68.197	68.197	68.197	68.197
Ag. Irr	65.974	55.847	117.395	100.627	28.823	35.833	87.581
Total	246.156	236.209	297.757	280.989	209.185	216.195	267.943
Project Costs	230.556	230.556	230.556	230.556	230.556	230.556	230.556
B/C	1.068	1.025	1.291	1.219	.907	.938	1.162

[a] The discount rate is 7 1/8 percent.

[b] SAR is a yield reduction used in conjunction with yield reduction caused by salinity.

[c] OBERS is an annual yield increase for specified crops.

[d] Municipal and industrial and Lake Kemp benefits and project costs are preliminary estimates provided by the Corps of Engineers.

Water Demand

The quantity and value of irrigation water utilized in the study area and the amount left for utilization elsewhere and its value could have significant impact on benefits to agricultural producers derived from the salinity control project. To investigate the impacts and determine the water utilization at various water "prices" or alternative use values, parametric programming was used on the linear program developed for this study. The scenario involving the with SAR yield effects and profit maximizing behavior was chosen for this analysis. The "price" of water was varied from zero to $160 per acre foot (in addition to the already included pumping and distribution costs) in each period, 1990-2040, to establish long-run demand schedules. The demands reflect the long-run situation in that profit was maximized while including fixed costs (except land) as well as variable costs. Demand schedules for irrigation water in the study area are shown for 1990 through 2040 in Figures 9 through 14, respectively. The corresponding data points for each period, i.e., price vs. quantity used, are given in Table 36.

The largest quantity of irrigation water used in the study area would be in year 2000 with an external water value of zero. Almost 326,000 acre feet would be utilized for irrigation in that year. After 2000, at the zero water value, utilization would decline. This results from the application of the full OBERS yield increases to dryland production and only partial increases to irrigated production. This partial increase in irrigated yields is due to the yield reduction that occurs even with the salinity control project. This, in effect,

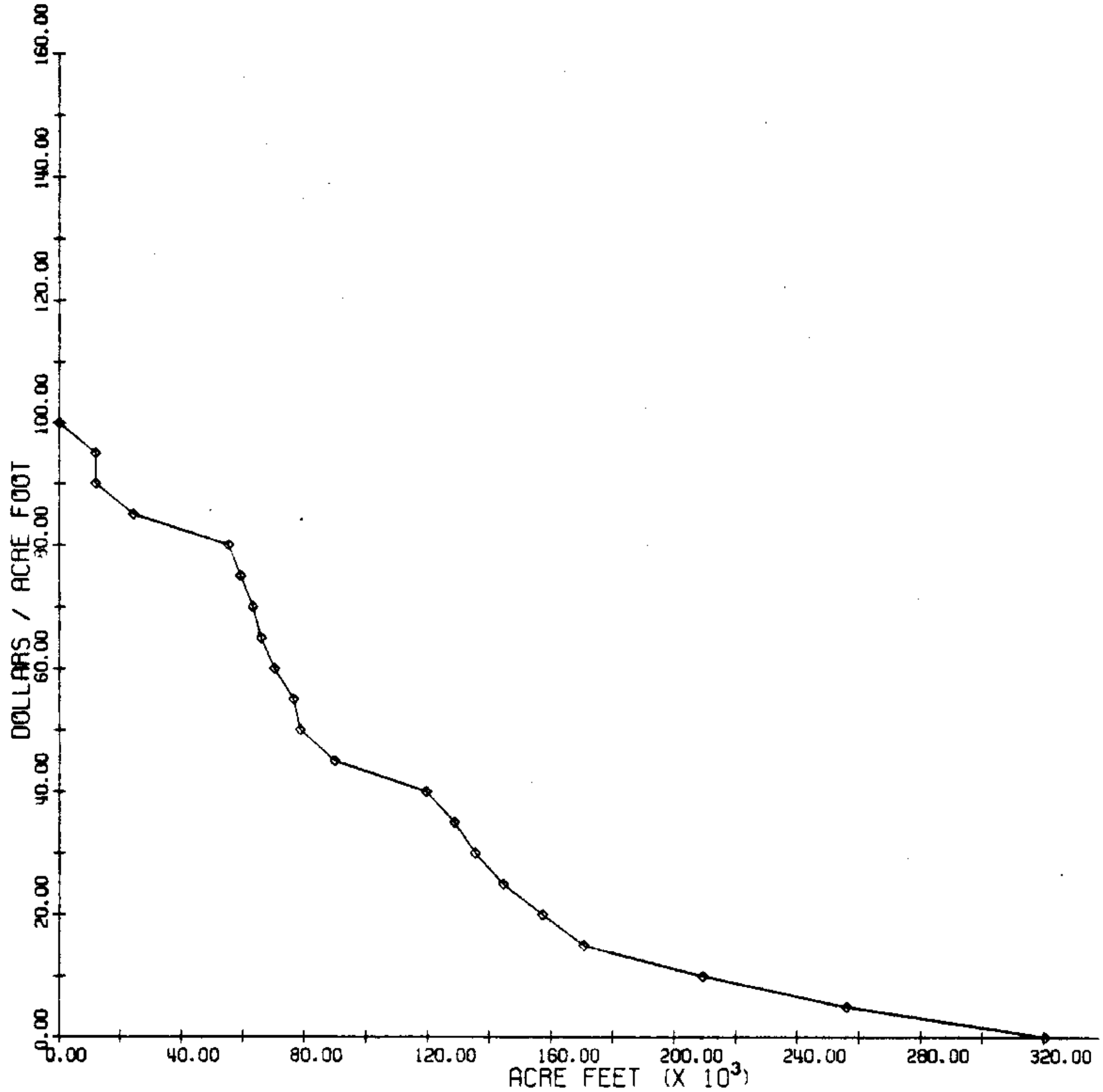

Figure 9. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 1990

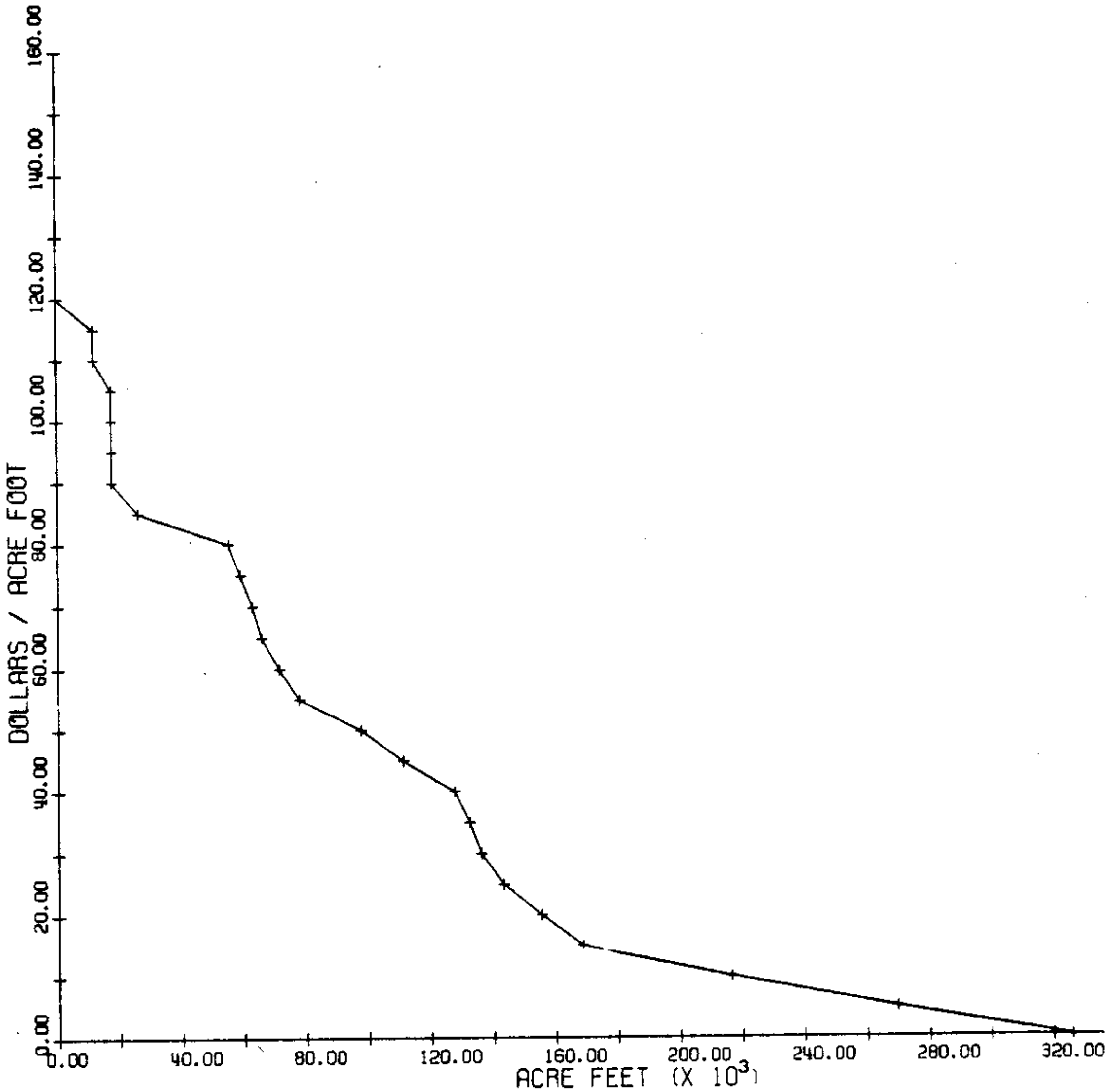

Figure 10. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 2000

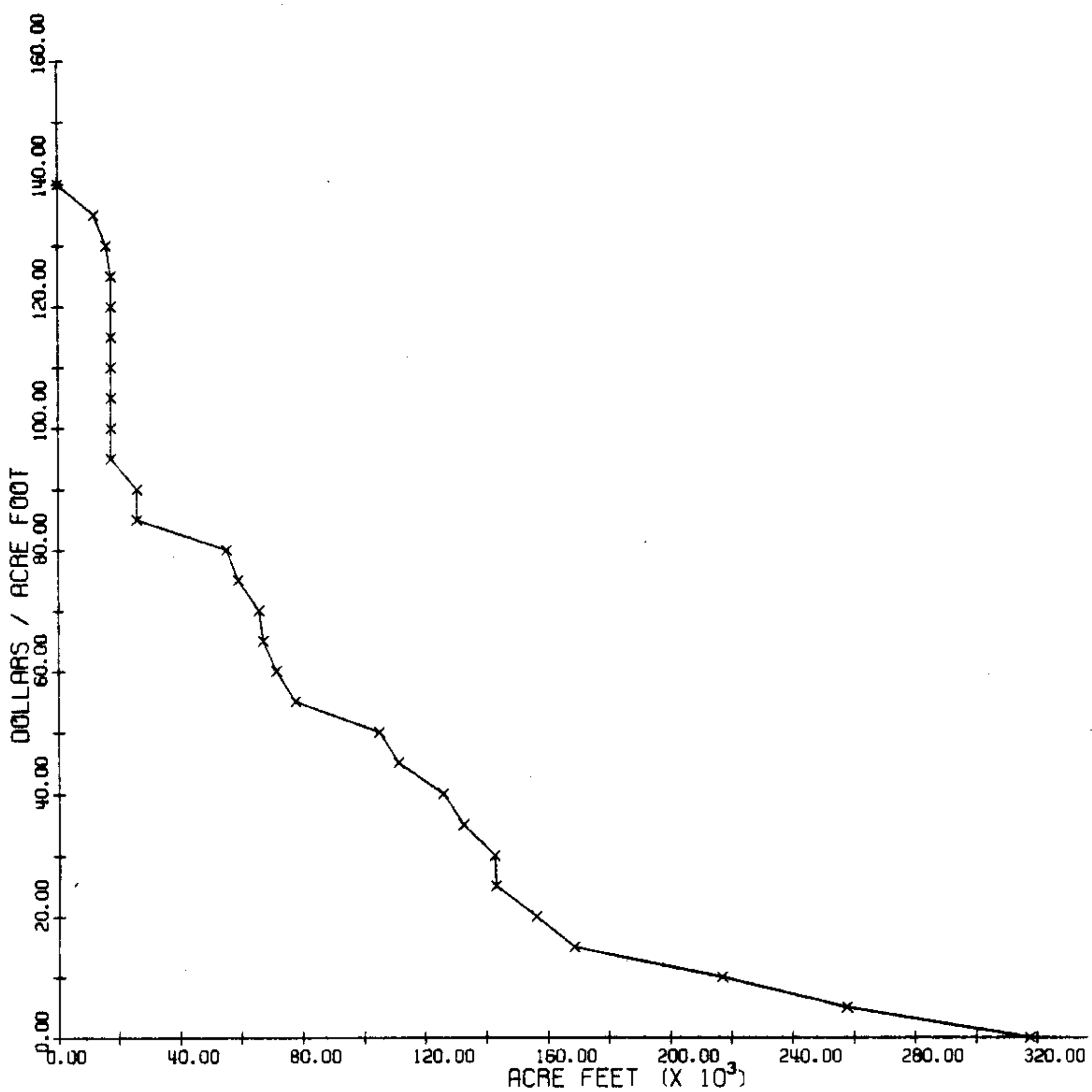

Figure 11. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 2010

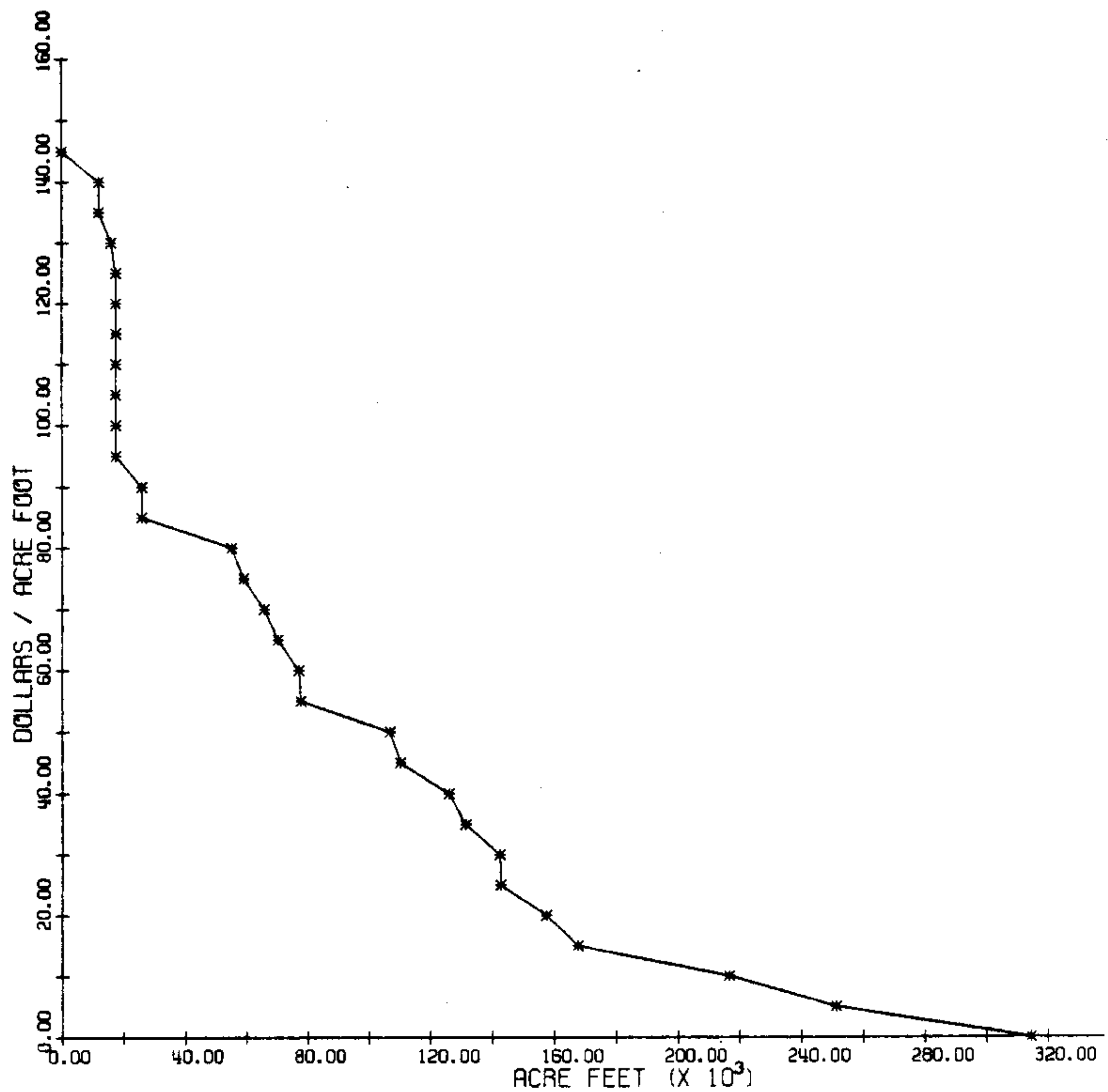

Figure 12. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 2020

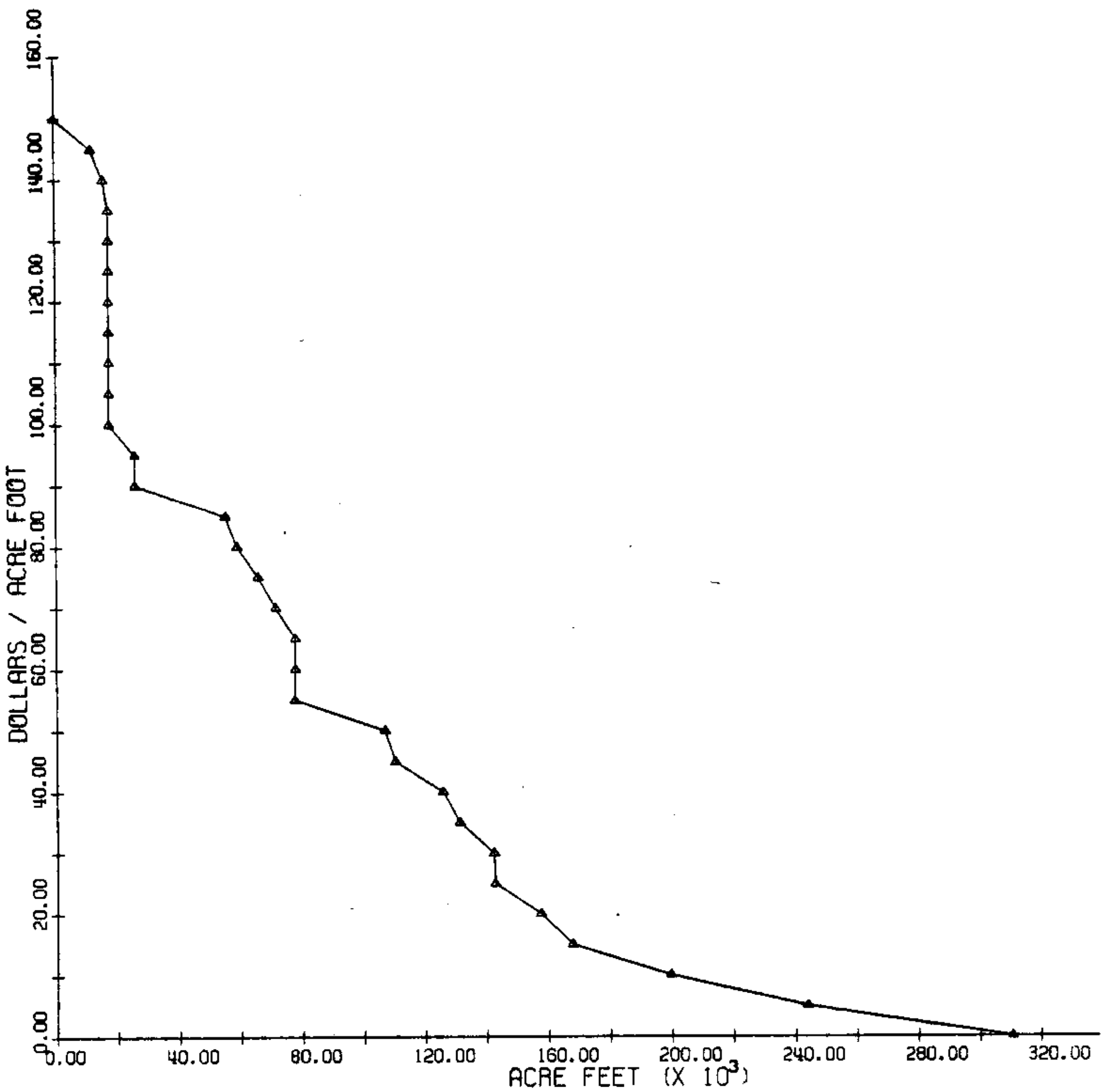

Figure 13. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 2030

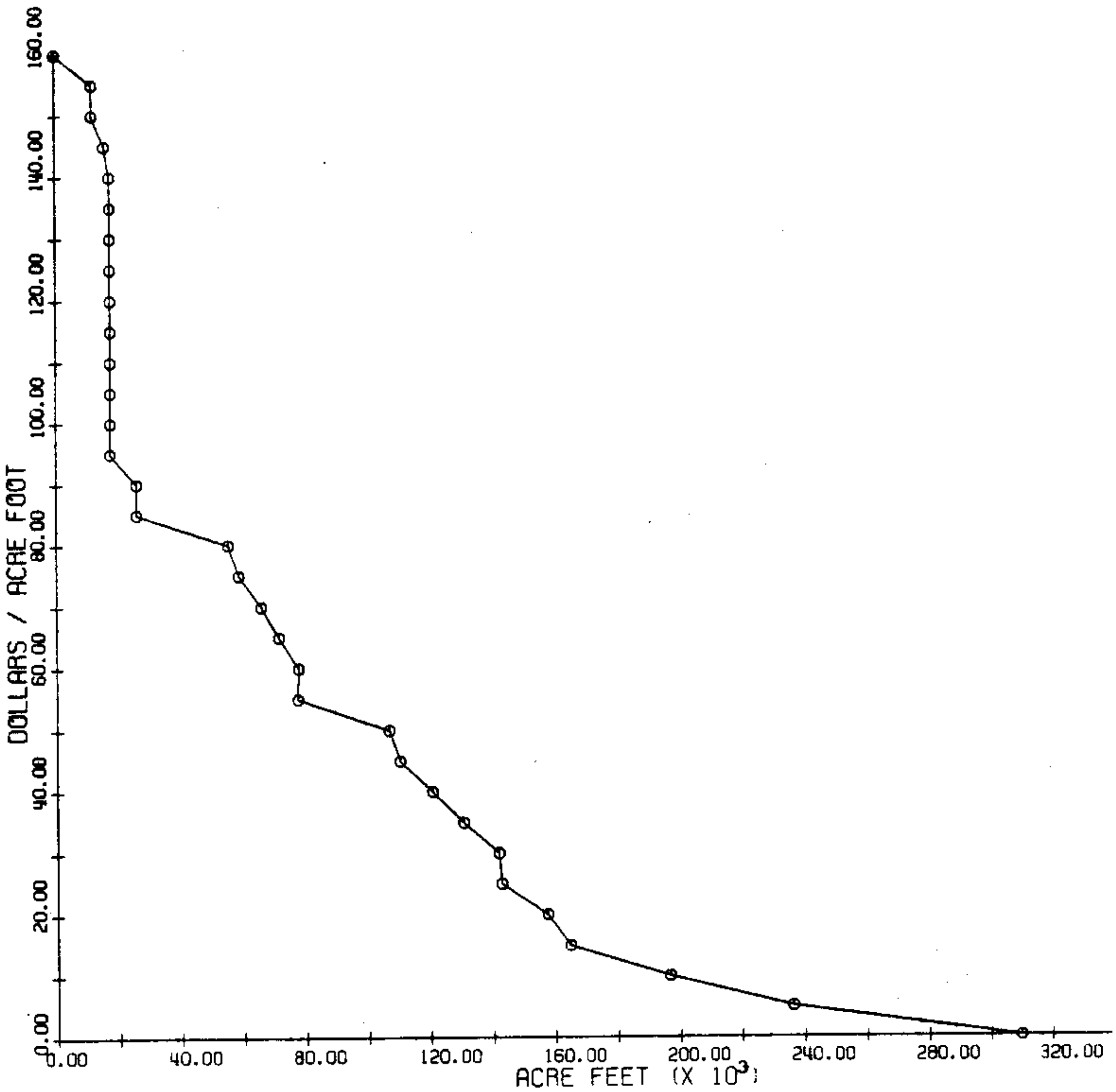

Figure 14. Long-Run Demand Schedule for Irrigation Water in the Red River Alluvium, With Project, and With SAR Effects, 2040

Table 36. Water Utilized at Various Water Values, 1990-2040, Profit Maximization With Project, Without SAR Effects

Value of Water	Water Used					
	1990	2000	2010	2020	2030	2040
$/Ac.Ft.	Acre Feet					
0.00	320,612	325,989	317,666	314,639	310,670	309,803
5.00	255,996	269,610	257,640	251,162	243,751	236,171
10.00	209,248	216,452	217,015	216,605	199,401	196,534
15.00	170,587	168,556	168,556	167,534	167,534	164,559
20.00	157,114	155,422	156,163	157,470	157,470	157,470
25.00	144,537	143,135	143,064	142,573	142,573	142,573
30.00	135,445	136,006	142,573	142,101	142,101	141,876
35.00	128,697	132,319	132,319	131,190	131,190	130,512
40.00	119,410	127,696	125,701	125,701	125,701	120,612
45.00	89,722	111,295	111,295	110,259	110,259	110,259
50.00	78,622	97,658	104,874	106,899	106,899	106,899
55.00	76,455	77,762	77,692	77,692	77,692	77,692
60.00	70,221	71,421	71,421	77,087	77,762	77,762
65.00	65,846	65,880	67,291	70,255	77,762	71,421
70.00	62,913	62,846	65,846	65,846	71,421	65,880
75.00	58,965	58,964	58,964	58,965	65,880	58,695
80.00	55,207	55,207	55,207	55,207	58,965	55,207
85.00	24,443	26,043	26,043	26,043	55,207	26,043
90.00	11,973	17,597	26,043	26,043	26,043	26,043
95.00	11,973	17,597	17,597	17,597	26,043	17,597
100.00	0	17,597	17,597	17,597	17,597	17,597
105.00	0	17,597	17,597	17,597	17,597	17,597
110.00	0	11,973	17,597	17,597	17,597	17,597
115.00	0	11,973	17,597	17,597	17,597	17,597
120.00	0	0	17,597	17,597	17,597	17,597
125.00	0	0	17,597	17,597	17,597	17,597
130.00	0	0	15,997	15,997	17,597	17,597
135.00	0	0	11,973	11,973	17,597	17,597
140.00	0	0	0	11,973	15,997	17,597
145.00	0	0	0	0	11,973	15,997
150.00	0	0	0	0	0	11,973
155.00	0	0	0	0	0	11,973

increases the relative profitability of dryland production over irrigated production. Thus, acreage shifts to dryland production over time in cases where the difference in initial net returns (1990) between the two competing enterprises is small.

From Table 36 and Figure 9, at a price of $100 per acre foot, irrigation ceases in 1990. By 2040, the upper limit to water value has risen to $160 per acre foot. These limits result initially from the profitability of irrigated cotton and increase due to the application of OBERS yield increases over time. More interesting, however, is that at a price of $10 per acre foot, water use is cut to only 65% of its zero price use. At $15 per acre foot use is cut to just over 50% of its zero price use. This implies that if, for example, costs associated directly to water use were to increase by only $15 per acre foot (about half-again as much as the cost of the furrow system given in Appendix C) optimal irrigation in the study area would decline by nearly half. This would in turn cause substantial reduction in agricultural benefits.

Table 37 gives a summary of the discounted present value of total net revenue to agriculture in the study area for various water values charged directly to producers so as to cause the reduction in water use shown in Table 36. It was assumed that producers maximize profits in response to the increased water costs and that the increases begin in 1990 and hold constant through 2090. Thus, as seen in Table 37, an increased cost to producers of $5 per acre foot would cause a $22 million reduction in benefits to the salinity control project while a $15 per acre foot increase would reduce benefits by $53.8 million (at

Table 37. Net Present Value of Net Returns to Agriculture With Various Water Values

Value of Water	Net Present Value of Profits (7 1/8% Rate)	(3 1/4% Rate)
$/Ac.Ft.	$ Million	
0.00	913.57007	2370.81909
5.00	891.50366	2326.71191
10.00	874.11523	2291.84033
15.00	859.73315	2262.99194
20.00	847.53394	2238.26685
25.00	836.25586	2215.24316
30.00	825.59009	2193.54443
35.00	815.58496	2173.13306
40.00	805.96680	2153.56616
45.00	797.50342	2136.07300
50.00	789.85840	2120.05957
55.00	783.33984	2106.49902
60.00	777.66357	2094.83716
65.00	772.43359	2084.05420
70.00	764.86865	2062.76978
75.00	762.84229	2064.30640
80.00	758.88623	2056.21924
85.00	756.17041	2050.64673
90.00	754.34912	2046.82568
95.00	753.13623	2044.22168
100.00	752.19751	2041.96045
105.00	751.29712	2039.74829
110.00	750.44531	2037.60327
115.00	749.66968	2035.56470
120.00	749.20654	2033.96509
125.00	748.76221	2032.40259
130.00	748.35425	2030.91943
135.00	747.99902	2029.54492
140.00	747.80786	2028.54102
145.00	747.66895	2027.70801
150.00	747.57861	2027.05322
155.00	747.53931	2026.68286

the 7 1/8 percent discount rate). Hence, increased costs of irrigation water, e.g., increased fuel costs, and/or decreased values of water in alternative uses (municipal and industrial uses), can substantially reduce project benefits to agriculture if optimal allocation of the water is maintained throughout the region.

The amount of water utilized in the study area leaves substantial amounts not utilized even at the zero price level. Table 38 gives the amount of water not utilized at the various prices for the assumed scenario. Values in Table 38 are based on the total quantity of irrigation water available from the alluvium in Reaches 6 through 15 as given by the Corps of Engineers, plus the amount used in Reach 5 (20,137 acre feet) with optimal land use and no additional price, i.e., a total of 515,837 acre feet. As seen in Table 38, over 195,000 acre feet are not utilized at the zero price level in 1990. At $5 per acre foot in 1990, about half the total remains unutilized. This trend continues for higher prices, of course. Thus, at every price level for water, a substantial quantity is available for alternative uses.

Table 38. Water Not Utilized at Various Water Values, 1990-2040, Profit Maximization With Project, With SAR Effects[a]

Value of Water	Water Not Used					
	1990	2000	2010	2020	2030	2040
$/Ac.Ft.	Acre Feet					
0.0	195,225	189,848	198,171	201,198	205,167	206,034
5.00	259,841	246,227	258,197	264,675	272,086	279,666
10.00	306,589	299,385	298,822	299,232	316,436	319,303
15.00	345,250	347,281	347,281	348,303	348,303	351,278
20.00	358,723	360,415	359,674	358,367	358,367	358,367
25.00	371,300	372,702	372,773	373,264	373,264	373,264
30.00	380,392	379,831	373,264	373,736	373,736	373,961
35.00	387,140	383,518	383,518	384,647	384,647	385,325
40.00	396,427	388,141	390,136	390,136	390,136	395,225
45.00	426,115	404,542	404,542	405,578	405,578	405,578
50.00	437,215	418,179	410,963	408,938	408,938	408,938
55.00	439,382	438,075	438,145	438,145	438,145	438,145
60.00	445,616	444,416	444,416	438,750	438,075	438,075
65.00	449,991	449,957	448,546	445,582	438,075	444,416
70.00	452,924	452,991	449,991	449,991	444,416	449,957
75.00	456,872	456,873	456,873	456,872	449,957	457,142
80.00	460,630	460,630	460,630	460,630	456,872	460,630
85.00	491,394	489,794	489,794	489,794	460,630	489,794
90.00	503,864	498,240	489,794	489,794	489,794	489,794
95.00	503,864	498,240	498,240	498,240	489,794	498,240
100.00	515,837	498,240	498,240	498,240	498,240	498,240
105.00	515,837	498,240	498,240	498,240	498,240	498,240
110.00	515,837	503,864	498,240	498,240	498,240	498,240
115.00	515,837	503,864	498,240	498,240	498,240	498,240
120.00	515,837	515,837	498,240	498,240	498,240	498,240
125.00	515,837	515,837	498,240	498,240	498,240	498,240
130.00	515,837	515,837	499,840	499,840	498,240	498,240
135.00	515,837	515,837	503,864	503,864	498,240	498,240
140.00	515,837	515,837	515,837	503,864	499,840	498,240
145.00	515,837	515,837	515,837	515,837	503,864	499,840
150.00	515,837	515,837	515,837	515,837	515,837	503,864
155.00	515,837	515,837	515,837	515,837	515,837	503,864

[a]Values do not include additional water in Reach 5.

CHAPTER VI

SUMMARY AND LIMITATIONS

The Problem

Salinity of irrigation water and the potential accumulation of harmful salts in the soil is a very important problem to agriculture in the Western United States and in many other parts of the world. The Red River Valley, located in Texas and Oklahoma, is one area where salinity poses a problem to irrigated crop production. Salinity of the water in the Red River and its major tributaries essentially eliminates its use for irrigation in areas west of Lake Texoma, a major multi-purpose lake located in the center of the basin.

An estimated 3300 tons of salt per day enter Lake Texoma from upstream sources. About 1100 tons is brine from local oil fields. The rest is natural salts from 10 springs located in the upper Red River basin in Oklahoma and salt seeps located along the North and Middle Pease River in Texas. About 85 percent of the daily salt load comes from Oklahoma sources and 15 percent from Texas sources.

Congress authorized the Corps of Engineers (COE) to develop and submit plans for chloride control on the Red River in the late 1950's. Final authorization for the project was completed in 1970. The plan selected as most effective from economic, technological, political and environmental standpoints was a system of local collection and disposal of source salt waters. Flow of salt waters near each source was to be interrupted via subsurface cut-off walls and shallow wells and diverted to disposal areas, reservoirs or pumped into suitable geological formations. Reservoirs located downstream of the salt sources were proposed to serve both as collection and disposal units capable of handling flows for a 100 year period.

The COE originally separated the Red River basin into 15 evaluation reaches. Below Lake Texoma dilution is sufficient to cause no significant yield reduction due to salinity. Upstream from Lake Texoma, however, irrigation of major crops, pasture, cotton, grain sorghum, wheat, and alfalfa, is precluded by high levels of salinity in the alluvium water. Thus, the purpose of this study was to quantity net benefits (by reach) resulting from changes in the levels of agricultural production that could be attributed to the proposed Red River Chloride Control Project. Net benefits were determined for the economic life of the project (100 years) and measured as the difference in the discounted present value of net returns to the region with the project as compared to those without the project for several alternative scenarios.

Procedure

The estimation of potential economic benefits to agriculture from the Red River Chloride Control Project was the second component of an overall agricultural study for the project. Soil scientists, agronomists, engineers and irrigation specialists teamed to provide many of the physical relationships necessary for the development of an adequate economic model. Data provided by the first component for each evaluation reach included: (1) percent reduction in yield attributable to the chloride concentration with and without the project; (2) irrigation water requirements adjusted for normal precipitation and leaching requirements; (3) acreages potentially suitable for irrigation by soil type, slope and land capability class; (4) recommended irrigation systems for each soil type (furrow, border or sprinkler); and (5) current acreages of major crops. Further, estimates of the amount of water available for irrigation by reach were provided by the Corps of Engineers.

Estimates of current crop yields by soil type for both irrigated and dryland production were developed for cotton, grain sorghum, wheat, alfalfa, Coastal bermuda and native pasture. Dryland yields only were developed for native pasture. Initial yield estimates were developed under assumptions of high level management and high quality irrigation water. Basic developmental data for yields included "Soil Survey Interpretation" forms for each soil type, slope and land capability class, and county soil survey reports. These yield estimates were reviewed by area soil scientists and agronomists of the Soil Conservation Service for further appropriate adjustments.

Base crop enterprise budgets were developed for each considered crop for both dryland and irrigated production based on a common soil type in the study area. Prices for production inputs (seeds, fertilizer, insecticides, herbicides, fuel, etc.) were area prices listed in the Oklahoma and Texas extension published budgets and pertain to Fall 1979-Spring 1980 cost levels. Prices received for crops were normalized prices issued by the U.S. Water Resources Council.

Irrigation cost estimates for sprinkler (side roll) and furrow (gravity flow) systems were developed to reflect shallow wells pumping from the alluvium near the river. The Oklahoma State University Cost Program was used to estimate the per acre inch cost of water pumped. Incremental application rates were fit against their associated fixed and variable costs estimates to produce estimation equations for irrigation costs.

The Model

The general model developed for this study was a recursive linear program with two FORTRAN components; a matrix generator and a report writer. The matrix generator served to develop a unique enterprise budget for each combination of crop, soil type and irrigation system, and create the initial matrix for the linear programming model for 10 year intervals from 1990 to 2040. The report writer greatly simplifies the analysis by organizing the linear programming solutions and writing a concise report by evaluation reach for the entire period of analysis.

Linear Program

The objective of the linear program for each evaluation reach is to maximize net returns constrained by (1) the amount of land in each soil type, and (2) the amount of water available for irrigation, or additional constraints on cropping patterns that provide for alternative scenarios. Net revenue maximization is performed for each 10-year interval (i.e., for years 1990, 2000, 2010, ..., 2040) with temporal yield adjustments causing changes in many base calculations thus requiring a new tableau in each period. Also incorporated into the LP component is an annual land use conversion charge of $4.77 per acre if pasture is converted to cropland.

Matrix Generator

The matrix generator was needed to develop a complete initial tableau for the linear programming model. Thus, vital elements were either read into the matrix generator or stored internally. Data that change among evaluation reaches were read in while data that remained applicable across all reaches were stored internally. Data required as input to the matrix generator are (1) cropping activity names, (2) irrigation water requirements for each cropping activity, (3) crop yield by soil type, (4) yield reduction due to irrigation water salinity by crop, (5) costs of production for each crop (only specified costs are included as some cost calculations are made internally), (6) crop prices, (7) acreage of each soil type, (8) total current cropland acres, (9) total irrigation water available, and (10) acreage of each crop grown currently (optional). Data stored internally include (1) fertilizer recommendations as a function of yield by crop, (2) fertilizer prices, (3) water cost equations, (4) interest rates to be used on variable capital costs, and (5) OBERS Series E' yield adjustment coefficients.

The matrix generator operates as a series of inner loops to make adjustments to the base budgets for yield differentials by soil type, and irrigation cost differentials due to differences in quantity of water pumped and method of distribution. Outer loops adjust yields according to OBERS Series E' projections for each reach to produce the recursive feature. Thus, the first pass through the matrix generator creates the 1990 initial tableau, yields are adjusted by OBERS projections, and another pass through the matrix generator creates the year 2000 tableau, etc.

Within the inner loops each crop alternative along with its applicable irrigation type (sprinkler, furrow, or nonirrigated) is matched with each soil type to form the activity base for the L.P. model. After this formation the matrix generator proceeds to define enterprise budgets for each crop as follows: (1) adjust inputed high level management yields for each crop to typical level management, (2) adjust yield for each crop for the appropriate salinity level (either with or without project), (3) adjust inputed irrigation water requirement for distribution system efficiency, (4) establish fertilizer application rates on basis of crop yield, (5) calculate irrigation water costs holding fixed and variable costs separate, (6) calculate fertilizer costs, (7) estimate harvesting costs as a function of crop yield, (8) calculate interest on operating capital, (9) calculate management charges, (10) determine total revenue as adjusted yield times price, and finally (11) calculate net revenue. Upon completion of these calculations, the matrix generator formats and writes each entry necessary for the MPSX linear programming package.

Report Writer

The report writer is the final phase of the mathematical model. It reads the linear programming solution of each 10 year period in terms of objective function and cropping pattern. An objective function is linearly interpolated for each year between the 10-year solutions and discounted to a present value basis at 7 1/8 percent and 3 1/4 percent.

Lastly, a summary of cropping patterns and annual discounted net returns for the 100 year period of analysis is printed by the report writer.

Results

Several scenarios of producer behavior were developed to provide a range of potential benefits. Alternative scenarios involve assumptions about producer objectives or capabilities, increases yields over time, or the possibility that SAR is and is not a problem in the study area. The first two scenarios were based on the assumption that producers would maximize profits with and without the salinity control project and with and without SAR crop yield effects. Next, scenarios were developed that involved maintaining current cropping patterns over the entire period of analysis, both with and without SAR crop yield effects included. Then, OBERS yield projections that were used to adjust crop yields through time were deleted and current crop yields were assumed constant throughout the period of analysis. Finally, a scenario was developed in which producers were assumed to maintain current land use in the initial period (1990), adjusted to 50 percent of the optimal cropping pattern in the second period (2000), and were fully adjusted to the optimal land use by the third period (2010). Hence, a wide range of scenarios were evaluated to estimate agricultural implications of the salinity control project.

Cropping Patterns

Throughout the study area and under all scenarios, the major irrigated crop was cotton. Nonirrigated land was allocated in varying mixes of cotton, grain sorghum, alfalfa, Coastal bermuda and native pasture. Wheat production never entered the optimal land use patterns due to its low net returns, although it was forced into the cropping patterns based on current land use scenarios. In all scenarios, a shift out of forages and into cotton was observed. This resulted from the application of OBERS yield projections.

Without SAR crop yield effects and without the salinity control project, optimal land use involved substantial irrigated cotton and dryland cotton. Most of the irrigated cotton occurred in the eastern reaches where relatively little yield reduction is caused by salinity. With the project in place, this study indicates irrigated cotton would move into the western reaches as well. Thus, benefits were experienced only in the western reaches based on the assumption of optimal land use and no SAR crop yield effects.

With SAR crop yield effects included and without the salinity control project much less cotton is irrigated. Yield reduction in the eastern reaches limits irrigation to only the highly productive soils. With the salt control project a sizable increase in irrigated cotton acreage is observed throughout the study area (except Reach 5 where no yield reduction occurs with or without the project). In the eastern reaches, no yield reduction occurs with the project in place. In the western reaches, yield reduction to cotton occurs even with the project but is not sufficient to make irrigated cotton less profitable than other alternatives.

In the scenario without OBERS yield increases over time, the 1990 optimal solution was assumed constant through time under the other alternative assumptions of the study. With the current cropping pattern scenario, a 1979 field survey was used to establish the cropping pattern.

Agricultural Benefits of Salinity Control

Net agricultural benefits were estimated for each scenario developed using the current discount rate for federal project evaluation--7 1/8 percent. However, some portions of the proposed salinity control project were authorized at a 3 1/4 percent discount rate. Thus, benefit estimates using both rates were provided in this study.

In the profit maximizations scenarios, with OBERS yield increases included in the analysis, the present value of agricultural net returns to land attributable to the salinity control project were estimated to be $65.794 million without SAR effects and $117.395 million with SAR effects (at 7 1/8 percent discount rate). With profit maximization but constant crop yields over time, salinity control benefit estimates for the region dropped to $55.848 million and $100.627 million without and with SAR effects included, respectively, discounted at 7 1/8 percent. In the current cropping pattern scenario, project benefits were estimated to be $28.823 million without SAR and $35.833 million with SAR yield reductions using a 7 1/8 percent discount rate. Finally, in the constrained profit maximizing land use scenario and assuming SAR crop yield effects, project benefits of $87.581 million resulted.

Benefit-cost analysis was conducted using preliminary Corps of Engineers estimates on project construction, operation and maintenance costs, municipal and industrial benefits, additional irrigation benefits from improving Lake Kemp water, and, agricultural benefits estimated under the various scenarios developed in this study. The analysis indicated that the proposed salinity control project was economically feasible under each scenario except the case where producers were assumed to maintain current cropping patterns through the 100-year period of analysis. The ratio of benefits to costs (B/C ratio) ranged from 1.025 to 1.219 using scenarios of profit maximization with and without OBERS yield increases, with and without SAR crop yield effects. B/C ratios of .907 and .938 resulted in the current land use scenario without and with SAR crop yield effects, respectively. Hence, only in very limited situations would the salinity control project not be economically infeasible.

Limitations

The results of this study are, of course, a function of the assumptions. Different assumptions were made among scenarios in an effort to minimize the overall effect of making specific assumptions in any one. However, specific assumptions certainly dictate the outcome of each scenario and consequently the salinity control project benefit estimates that result. For example, benefits in some scenarios were estimated as the present value of the increase in returns to land attributable to the project based on optimal land use patterns. Actual land use will almost certainly deviate from the estimated optimum both with and without the project, thus affecting the realized net income of producers. Thus, the real limitation here is how closely these estimated cropping patterns follow the actual outcomes. A major reason that the estimated profit maximizing cropping pattern will not evolve in actuality is the regional approach used in this study without regard to the farm or ranch organization. A farm management analysis by firm in the study area considering all land, other resources, livestock interests, cash flow aspects and goals of the operation could certainly lead to significantly different land use patterns than estimated herein.

The normalized crop prices that were adopted represent another limit to the study. They tend to underestimate current farm prices while costs used represent, as closely as practicable, current production costs. Thus, the net returns estimates in many cases are underestimated.

Irrigated crop yields were estimated by specialists in each area. However, there is limited experience with irrigation on many crops in much of the study area, hence some lack of reliability of the estimates.

Particularly important to the calculation of benefits is the effect of salinity and/or SAR effect on crop yields and the temporal yield increase as dictated by OBERS Series E' projections. Although projections have been made on the effects of SAR on crop yields, it has not clearly been demonstrated the extent to which SAR affects either all or part of the study area. Thus, until the effects can be specifically identified, the value of salinity control must remain in doubt. Further, adjustments in yields through breeding programs for crops and forages, other factors affecting salinity and salinity concentration by period of the year, and the exclusion of yield increases for forage crops could significantly impact the estimates of benefits among the various scenarios.

Another assumption that could have a significant impact on cropping pattern estimates and in turn on benefits to the salinity control project was that water was assumed available on an annual basis and could be utilized to its limit without regard to withdrawal and refill rates or irrigation timing during the year. If, for example, water flow in the alluvium is significantly reduced in mid-summer when irrigation needs are the greatest, or during drought years, cropping patterns would likely change substantially toward more dryland production thus reducing estimated benefits.

Finally, with regard to the overall results of this study, it is essential to recognize that only benefits to agriculture were estimated here. Estimates of project costs, municipal and industrial benefits, and additional benefits derived from improvement of the water in Lake Kemp are preliminary values obtained from the Corps of Engineers. The interrelationships and tradeoffs among all types of benefits and costs especially with regard to the most desirable degree of salinity control and the resulting salinity concentrations of the alluvial waters were not investigated in this study. Thus, benefit estimates herein are limited only to one size project while others may be more or less desirable.

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APPENDIX A

Crop Yields

Table A-1. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 5

			COTTON(LB)		GRAIN SORGHUM(CWT)		WHEAT(BU)		ALFALFA(TON)		COASTAL BERMUDA(TON)		NATIVE PASTURE(AUM)
SOIL NAME	TEXTURE*	SLOPE**	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	DRY
BURLESON	C	1-3	750.0	450.0	65.0	33.6	35.0	30.0	0.0	0.0	5.4	3.6	2.1
HEIDEN	C	1-5	700.0	350.0	60.0	30.8	35.0	30.0	0.0	0.0	4.5	2.7	2.2
CALLISBURG	CL	IIIE	650.0	250.0	60.0	28.0	25.0	25.0	0.0	0.0	6.8	2.5	1.7
REDLAKE	C	IIE	600.0	550.0	40.0	38.2	40.0	35.0	6.0	5.5	4.0	3.1	1.5
NORMANGEE	CL	IIS	600.0	350.0	55.0	30.8	0.0	0.0	0.0	0.0	4.0	2.7	1.5
VANOSS	CL	1-5	800.0	450.0	70.0	28.0	40.0	35.0	7.0	3.5	6.8	3.4	1.2
BASTROP	L	0-1	800.0	400.0	70.0	38.2	0.0	0.0	0.0	0.0	6.8	3.1	1.7
COUNTS	L	0-1W	0.0	450.0	0.0	25.2	0.0	0.0	0.0	0.0	0.0	2.9	0.0
CROCKETT	L	IIIE	600.0	350.0	65.0	30.2	25.0	25.0	0.0	0.0	6.8	3.4	1.9
DURANT	L	1-3	0.0	400.0	0.0	28.0	0.0	35.0	0.0	0.0	0.0	2.7	1.7
SANGER	C	IIE	600.0	350.0	65.0	38.2	30.0	30.0	0.0	0.0	4.0	2.9	1.9
WILSON	SICL	IIIW	600.0	350.0	60.0	30.8	30.0	30.0	0.0	0.0	4.0	2.7	1.7
FRIOTON	SICL	IIW	0.0	400.0	0.0	36.4	0.0	35.0	0.0	0.0	0.0	3.4	0.8
BASTROP	FSL	1-3	0.0	350.0	60.0	23.8	20.0	20.0	0.0	0.0	0.0	3.1	1.7
KONAWA	FSL	1-5	0.0	450.0	0.0	28.0	0.0	30.0	0.0	0.0	0.0	3.1	1.0
KONSIL	FSL	1-5	700.0	300.0	65.0	30.8	30.0	30.0	0.0	0.0	6.3	2.7	1.9
KIOWATIA	FSL	0-3	500.0	330.0	40.0	19.6	25.0	25.0	0.0	3.5	6.8	3.4	1.5
MADILL	FSL	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5
PALUXY	FSL	0-1	0.0	350.0	0.0	33.6	0.0	0.0	0.0	0.0	0.0	3.1	1.7
TELLER	FSL	0-1W	700.0	450.0	70.0	30.8	40.0	35.0	7.0	3.5	6.8	3.4	1.6
DOUGHERTY	LFS	0-3	0.0	300.0	0.0	16.8	0.0	20.0	0.0	0.0	0.0	2.3	1.1

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

** LAND CAPABILITY CLASS IS INDICATED BY ROMAN NUMERALS I, II, III OR IV WHERE SLOPE WAS NOT AVAILABLE. THE LETTER W INDICATES A WATER PROBLEM, E AN EROSION PROBLEM AND S LIMITED PRODUCTIVITY BECAUSE THE SOIL IS SHALLOW, STONEY, OR DROUGHTY. UND AND HUM ARE ABBREVIATIONS FOR UNDULATING AND HUMMOCKY, RESPECTIVELY.

Table A-2. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 6

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
ANOCON		IIIE	0.0	0.0	0.0	19.6	0.0	20.0	0.0	0.0	0.0	2.7	1.9
STONEBURG		1-5	0.0	0.0	0.0	25.2	0.0	20.0	0.0	0.0	0.0	2.0	1.9
BASTROP	L	2-5	750.0	300.0	60.0	25.2	30.0	30.0	0.0	0.0	5.4	2.5	1.7
BASTROP	FSL	1-5	750.0	300.0	60.0	25.2	30.0	30.0	0.0	0.0	5.4	2.5	1.7
BASTROP	L	0-1	800.0	500.0	70.0	39.2	0.0	0.0	0.0	0.0	6.8	3.6	1.9
CALLISBURG	FSL	1-5	650.0	200.0	65.0	25.2	30.0	30.0	0.0	0.0	6.8	2.5	1.7
CLAREMORE	SIL	1-3	0.0	0.0	0.0	19.6	0.0	25.0	0.0	0.0	0.0	2.0	1.3
BREWER		IIS	0.0	500.0	0.0	33.6	0.0	35.0	0.0	4.5	0.0	3.1	2.3
CROKETT	FSL	1-3	600.0	350.0	65.0	30.2	0.0	25.0	0.0	0.0	6.8	3.4	1.9
DENTON	FSL	3-5	550.0	300.0	55.0	30.8	30.0	30.0	0.0	0.0	4.0	2.8	1.9
SAN SABA	FSL	3-5	0.0	300.0	0.0	30.8	0.0	25.0	0.0	0.0	0.0	2.5	1.9
DOUGHERTY	LFS	0-3	0.0	300.0	0.0	16.8	0.0	20.0	0.0	0.0	5.4	2.3	1.1
DUFFAU	LFS	1-3	0.0	0.0	60.0	22.4	25.0	20.0	0.0	0.0	5.4	2.9	1.7
DUFFAU	FSL	2-5	0.0	0.0	65.0	22.4	25.0	20.0	0.0	0.0	5.4	2.7	1.7
FRIO	CL	0-1	0.0	450.0	0.0	25.2	0.0	35.0	0.0	0.0	0.0	3.1	1.5
GADDY	FSL	0-2	0.0	0.0	50.0	16.8	0.0	20.0	0.0	3.0	5.8	2.7	1.0
GOWEN	FSL	0-1	800.0	550.0	70.0	42.0	0.0	30.0	0.0	0.0	6.8	3.6	2.1
GOWEN	CL	0-1	800.0	500.0	70.0	38.2	0.0	30.0	0.0	0.0	6.8	3.6	2.1
GOWEN	L	0-1	800.0	550.0	70.0	42.0	0.0	30.0	0.0	0.0	6.8	3.6	2.1
HARDEMAN	FSL	0-3	600.0	250.0	36.4	16.8	40.0	20.0	5.0	2.0	0.0	0.0	0.0
HENSLEY	L	1-5	0.0	0.0	40.0	14.0	0.0	20.0	0.0	0.0	2.7	1.6	1.5
KONSIL	FSL	2-5	600.0	250.0	60.0	28.0	0.0	25.0	0.0	0.0	6.3	2.5	1.9
KIRKLAND	SIL	1-3	0.0	300.0	0.0	19.6	0.0	25.0	0.0	0.0	0.0	2.3	1.1
LABETTE	L	1-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
LEWISVILLE	CLL	1-5	0.0	500.0	0.0	44.8	0.0	0.0	0.0	0.0	0.0	3.4	2.1
LINCOLN		0-2	0.0	0.0	30.0	14.0	0.0	28.0	0.0	0.0	5.4	2.5	0.9
MILLER	C	0-1	600.0	450.0	60.0	33.6	40.0	35.0	0.0	3.5	4.5	2.9	0.8
MINCO	L	0-1	800.0	500.0	70.0	28.0	40.0	35.0	7.0	3.5	6.8	3.6	1.4
MINCO	FSL	0-1	0.0	500.0	0.0	28.0	0.0	35.0	0.0	3.5	0.0	3.6	1.4
MINCO	VFSL	0-3	0.0	450.0	0.0	25.2	0.0	30.0	0.0	3.0	0.0	3.4	1.4
NORWOOD	CL	0-1	0.0	600.0	67.2	50.4	0.0	0.0	0.0	0.0	6.8	4.5	2.5
PONDCREEK	SIL	0-1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
PORT	L	0-1	0.0	450.0	0.0	25.2	0.0	30.0	0.0	4.5	0.0	3.6	2.3
PORT	SCL	0-1	0.0	450.0	0.0	25.2	0.0	30.0	0.0	4.5	0.0	3.6	2.3
PULASKI	FSL	0-1	0.0	425.0	0.0	28.0	0.0	30.0	0.0	3.5	0.0	3.4	2.3
RENFROW	L	1-4	550.0	250.0	50.0	16.8	30.0	25.0	0.0	0.0	2.7	1.3	1.1
ROEBUCK	C	0-1	0.0	500.0	0.0	33.6	0.0	0.0	0.0	0.0	0.0	3.4	1.7
SLIDELL		1-3	550.0	350.0	55.0	38.2	35.0	30.0	0.0	0.0	0.0	3.1	1.9
SAN SABA	C	1-3	0.0	350.0	0.0	42.0	0.0	30.0	0.0	0.0	4.0	2.7	1.9
STEPHENVILLE	FSL	1-5	0.0	0.0	0.0	16.8	0.0	20.0	0.0	0.0	0.0	2.3	1.2
TELLER	L	0-1	750.0	450.0	65.0	30.8	0.0	35.0	8.0	3.5	6.8	3.4	1.6
TELLER	FSL	1-3	750.0	400.0	65.0	28.0	0.0	30.0	8.0	3.0	6.8	3.1	1.6
VANOSS	L	0-1	750.0	450.0	65.0	28.0	0.0	35.0	8.0	3.5	6.8	3.4	0.0
VENUS	L	2-5	500.0	250.0	60.0	36.4	0.0	0.0	0.0	0.0	4.5	2.9	1.9
WAURIKA		0-1	550.0	350.0	60.0	44.8	30.0	25.0	0.0	0.0	5.4	3.1	1.9
WILSON	CL	0-1	550.0	350.0	55.0	30.8	0.0	30.0	0.0	0.0	5.4	2.7	1.7
WINDTHORST	FSL	0-1	0.0	0.0	60.0	19.6	0.0	20.0	0.0	0.0	5.4	2.5	1.5
YAHOLA	FSL	1-5	500.0	425.0	55.0	28.0	0.0	30.0	0.0	3.5	6.3	3.4	1.8
ZANEIS	L	1-3	0.0	350.0	0.0	22.4	0.0	30.0	0.0	2.6	0.0	2.9	1.4

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

** LAND CAPABILITY CLASS IS INDICATED BY ROMAN NUMERALS I, II, III OR IV.

Table A-3. Crop Yields by Soil Classification for High Level Management And High Qaulity Water for 1990 - Reach 7

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB)		GRAIN SORGHUM(CWT)		WHEAT(BU)		ALFALFA(TON)		COASTAL BERMUDA(TON)		NATIVE PASTURE(AUM)
			IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	DRY
PORT	CL	I-2	0.0	500.0	0.0	33.6	0.0	40.0	0.0	4.5	0.0	3.6	2.3
PORT	L	I-2	0.0	500.0	0.0	28.0	0.0	35.0	0.0	5.0	0.0	3.8	2.3
TIPTON	L	I-3	800.0	375.0	60.0	22.4	60.0	25.0	7.5	3.0	4.9	2.5	1.1
FOARD	SIL	0-1	800.0	250.0	39.2	16.8	40.0	25.0	0.0	0.0	3.1	1.8	0.7
TILLMAN	SIL	I-3	700.0	275.0	36.4	14.0	45.0	20.0	0.0	0.0	0.0	2.0	0.6
ENTERPRISE	VFSL	0-1	800.0	375.0	55.0	25.2	55.0	30.0	6.5	2.5	4.9	2.7	0.9
YAHOLA	FSL	IIW	0.0	425.0	0.0	28.0	0.0	30.0	0.0	3.5	0.0	3.4	1.7
PRATT	LFS	IIIE	0.0	250.0	50.4	23.0	0.0	20.0	5.5	0.0	0.0	1.8	1.3

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

** LAND CAPABILITY CLASS IS INDICATED BY ROMAN NUMERALS I, II, III OR IV WHERE SLOPE WAS NOT AVAILABLE. THE LETTER W INDICATES A WATER PROBLEM, E AN EROSION PROBLEM AND S LIMITED PRODUCTIVITY BECAUSE THE SOIL IS SHALLOW, STONEY, OR DROUGHTY. UND AND HUM ARE ABBREVIATIONS FOR UNDULATING AND HUMMOCKY, RESPECTIVELY.

Table A-4. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 8

			COTTON(LB)		GRAIN SORGHUM(CWT)		WHEAT(BU)		ALFALFA(TON)		COASTAL BERMUDA(TON)		NATIVE PASTURE(AUM)
SOIL NAME	TEXTURE*	SLOPE**	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	DRY
HOLLISTER	CL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	0.0	0.0	0.7
MANGUM	CL	IIIW	700.0	225.0	45.0	14.0	45.0	20.0	0.0	0.0	3.1	0.0	0.8
TILLMAN	CL	1-3	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
WICHITA	CL	1-3	700.0	225.0	56.0	17.0	50.0	25.0	0.0	0.0	3.6	0.0	0.7
WINTERS	L	1-3	750.0	250.0	25.0	7.5	50.0	25.0	0.0	0.0	4.9	0.0	1.0
ASA	SICL	IIW	1000.0	390.0	62.0	28.0	60.0	30.0	0.0	0.0	5.4	0.0	1.2
MANGUM	SICL	IIW	700.0	225.0	45.0	14.0	45.0	20.0	0.0	0.0	3.1	0.0	0.8
BLUEGROVE	L	1-3	650.0	250.0	60.0	25.2	50.0	25.0	5.0	1.5	4.9	0.0	1.0
FRANKIRK	L	0-1	750.0	250.0	56.0	16.8	60.0	25.0	0.0	0.0	4.9	0.0	0.7
MOTLEY	L	1-3	750.0	275.0	58.0	20.0	50.0	25.0	4.5	1.5	4.5	0.0	0.9
RENFROW	L	1-3	700.0	240.0	56.0	16.8	55.0	25.0	0.0	0.0	3.6	0.0	1.1
WINTERS	L	0-1	750.0	275.0	60.0	28.0	50.0	25.0	5.0	2.0	4.9	0.0	1.0
TIPTON	L	0-1	800.0	350.0	60.0	25.0	60.0	30.0	7.5	3.5	4.9	0.0	1.1
CLAIREMONT	SIL		1000.0	390.0	62.0	28.0	60.0	30.0	7.5	3.5	5.4	0.0	1.1
DEANDALE	LS	0-1	450.0	290.0	39.2	16.8	50.0	25.0	0.0	0.0	4.5	0.0	0.8
KAMAY	SIL	1-3	700.0	225.0	42.0	14.0	45.0	20.0	0.0	0.0	3.6	0.0	0.8
KIRKLAND	SIL	1-3	700.0	250.0	58.0	19.6	55.0	25.0	0.0	0.0	3.6	0.0	1.1
PORT	SIL		1000.0	390.0	62.0	28.0	60.0	30.0	0.0	0.0	5.4	0.0	1.2
WESWOOD	SIL		1000.0	0.0	62.0	28.0	60.0	30.0	7.5	3.5	5.4	0.0	1.2
ENTERPRISE	VFSL	1-3	800.0	350.0	55.0	20.0	55.0	30.0	6.5	2.5	4.9	2.7	1.1
MINCO	VFSL	1-3	800.0	350.0	55.0	20.0	55.0	30.0	6.5	2.8	4.9	2.7	1.1
YOMONT	VFSL	IIS	1000.0	390.0	65.0	27.0	60.0	30.0	7.5	3.0	5.4	3.6	1.2
DEVOL	FSL	1-3	650.0	250.0	58.0	24.0	50.0	25.0	5.0	2.0	4.9	2.7	1.1
HARDEMAN	FSL	1-3	600.0	250.0	50.0	17.0	40.0	20.0	6.5	2.5	4.5	2.3	0.9
GRANDFIELD	FSL	1-3	750.0	300.0	60.0	25.0	50.0	25.0	5.0	2.0	4.9	2.7	1.1
LINCOLN	FSL	IIIE	0.0	0.0	0.0	15.0	0.0	20.0	5.0	2.1	0.0	2.5	0.9
TELLER	FSL	1-3	750.0	325.0	62.0	28.0	55.0	30.0	6.5	2.5	4.9	2.9	1.1
DEVOL	LFS	0-3	650.0	250.0	58.0	24.0	50.0	25.0	5.0	2.0	4.5	2.5	1.0

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

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Table A-5. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 9

			COTTON(LB)		GRAIN SORGHUM(CWT)		WHEAT(BU)		ALFALFA(TON)		COASTAL BERMUDA(TON)		NATIVE PASTURE(AUM)
SOIL NAME	TEXTURE*	SLOPE**	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	DRY
HENSLEY	CL	1-3	0.0	0.0	40.0	14.0	45.0	20.0	0.0	0.0	2.7	0.0	0.7
HOLLISTER	CL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	3.6	0.0	0.7
LINDY	CL	1-3	700.0	225.0	56.0	18.0	50.0	20.0	0.0	0.0	4.5	0.0	1.0
MANGUM	C	IIIW	650.0	150.0	40.0	12.0	40.0	15.0	0.0	0.0	2.7	0.0	0.7
MERETA	CL	1-3	450.0	150.0	35.0	12.5	40.0	15.0	0.0	0.0	2.3	0.0	1.0
SAGERTON	CL	1-3	700.0	225.0	56.0	14.0	50.0	20.0	0.0	0.0	4.5	0.0	0.7
TILLMAN	CL	1-3	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
TOBOSA	CL	1-3	600.0	175.0	40.0	15.0	45.0	20.0	0.0	0.0	3.1	0.0	0.7
VERNON	CL	1-3	0.0	0.0	22.4	9.5	30.0	15.0	0.0	0.0	1.8	0.0	0.6
ASPERMONT	SICL	1-3	650.0	200.0	35.0	12.5	40.0	15.0	0.0	0.0	3.6	0.0	0.7
FRIO	SICL	IIW	750.0	325.0	62.0	28.0	60.0	30.0	0.0	0.0	5.4	0.0	1.1
WINTERS	L	0-1	750.0	275.0	55.0	25.0	50.0	25.0	0.0	0.0	4.9	0.0	1.0
CLAIREMONT	SIL	IIE	1000.0	350.0	65.0	22.4	60.0	30.0	0.0	0.0	5.4	0.0	1.1
KAMAY	SIL	0-1	700.0	225.0	42.0	14.0	45.0	20.0	0.0	0.0	3.6	0.0	0.9
ENTERPRISE	VFSL	1-3	750.0	325.0	55.0	20.0	55.0	25.0	6.5	2.5	4.9	2.7	0.9
HARDEMAN	FSL	3-5	500.0	200.0	28.0	14.0	35.0	15.0	4.0	1.5	4.9	2.3	0.9
YAHOLA	FSL	IIW	650.0	300.0	50.4	19.6	60.0	30.0	7.5	3.5	4.9	2.7	1.0

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

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Table A-6. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 10

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
ABILENE	CL	0-1	775.0	275.0	65.0	20.0	60.0	25.0	0.0	0.0	3.6	0.0	0.7
HOLLISTER	CL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	3.6	0.0	0.7
MANGUM	C	IIW	650.0	150.0	40.0	12.0	40.0	15.0	0.0	0.0	2.7	0.0	0.7
SPUR	CL	IIW	725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	4.9	0.0	0.9
TILLMAN	CL	1-3	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
WICHITA	L	0-1	725.0	250.0	56.0	17.0	60.0	25.0	0.0	0.0	3.6	0.0	0.7
YOMONT	VFSL	0-1	1000.0	350.0	65.0	22.4	60.0	25.0	7.3	2.8	4.9	2.7	1.0
MILES	FSL	1-3	650.0	250.0	52.0	18.0	45.0	20.0	5.0	2.0	4.9	2.7	0.8

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Table A-7. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 11

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
HOLLISTER	CL	I	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	3.6	0.0	0.7
MANGUM	C	IIIW	650.0	150.0	40.0	12.0	40.0	15.0	0.0	0.0	2.7	0.0	0.7
SAGERTON	CL	0-1	750.0	250.0	50.0	17.0	50.0	25.0	0.0	0.0	4.5	0.0	0.7
TILLMAN	CL	1-3	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
WICHITA	CL	1-3	700.0	225.0	56.0	17.0	50.0	20.0	0.0	0.0	3.6	0.0	0.7
CLAIREMONT	SIL	IIW	1000.0	350.0	65.0	22.4	60.0	25.0	0.0	0.0	5.4	0.0	1.0
ENTERPRISE	VFSL	1-3	650.0	300.0	50.4	19.6	50.0	25.0	5.0	2.0	4.9	2.7	0.9
COBB	FSL	1-3	500.0	200.0	39.2	11.2	40.0	18.0	4.0	1.5	4.5	2.3	0.9
HARDEMAN	FSL	3-5	500.0	200.0	28.0	14.0	35.0	15.0	4.0	1.5	4.5	2.3	0.9
MILES	FSL	1-3	650.0	250.0	42.0	16.8	45.0	20.0	5.0	2.0	4.9	2.7	0.8
YAHOLA	FSL	IIW	650.0	300.0	50.4	19.6	60.0	30.0	7.5	6.0	4.9	2.7	1.0
LINCOLN		IIIE	0.0	0.0	0.0	15.0	0.0	20.0	5.5	2.0	0.0	2.5	0.9

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

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Table A-8. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 12

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
PORT	SICL	IIW	0.0	500.0	0.0	28.0	0.0	35.0	0.0	4.0	0.0	3.6	2.3
ABILENE	L	I-2	775.0	275.0	64.4	19.6	60.0	25.0	4.5	2.5	0.C	2.5	0.7
TIPTON	L	0-1	800.0	350.0	61.6	25.0	60.0	30.0	6.0	3.5	4.9	2.7	1.1
ASA	SL	IIW	0.0	450.0	0.0	33.6	0.0	35.0	0.0	5.0	0.0	3.6	2.5
MINCO	VFSL	0-1	0.0	500.0	0.0	28.0	0.0	35.0	0.0	3.5	0.0	3.1	1.4
CYRIL	FSL	IIW	0.0	500.0	0.0	28.0	0.0	30.0	0.0	3.5	0.C	3.6	2.3
DEVOL	FSL	0-1	0.0	300.0	0.0	19.6	0.0	20.0	0.0	2.0	0.0	2.7	1.1
GRANDFIELD	FSL	0-1	0.0	350.0	0.0	19.6	0.0	25.0	0.0	2.5	0.0	2.3	1.1
HARDEMAN	FSL	0-1	650.0	275.0	42.0	19.6	45.0	20.0	5.0	2.0	0.0	2.3	0.9
HARDEMAN	FSL	UND	600.0	250.0	33.6	16.8	40.0	20.0	5.0	2.0	0.0	2.5	0.9
TIPTON	FSL	0-1	800.0	350.0	61.6	25.2	60.0	30.0	6.0	3.5	4.5	2.7	1.1
DEVOL	LFS	UND	0.0	250.0	0.0	16.8	0.0	20.0	0.0	0.0	0.0	2.5	1.0
DEVOL	LFS	HUM	0.0	0.0	0.0	14.0	0.0	15.0	0.0	0.0	0.0	2.3	1.0
GRANDFIELD	LFS	0-1	0.0	250.0	0.0	16.8	0.0	20.0	0.0	2.0	0.0	2.0	1.0
GRANDFIELD	LFS	UND	0.0	250.0	0.0	16.8	0.0	20.0	0.0	0.0	0.0	2.0	1.0
LINCOLN		IVS	0.0	0.0	0.0	14.0	0.0	20.0	0.0	0.0	0.0	2.5	0.8
YAHOLA		IIW	0.0	425.0	0.0	28.0	0.0	30.0	0.0	3.5	0.0	3.4	1.8
LINCOLN		W	0.0	0.0	0.0	14.0	0.0	20.0	0.0	0.0	0.0	2.9	0.8

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

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Table A-9. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 13

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
ABILENE	CL	0-1	775.0	275.0	65.0	0.0	60.0	25.0	0.0	0.0	3.6	0.0	0.7
CLAIREMONT	CL	0-1	1000.0	350.0	65.0	22.4	60.0	25.0	0.0	0.0	5.4	0.0	1.0
COLORADO	CL	W	775.0	300.0	65.0	20.0	60.0	25.0	0.0	0.0	4.5	0.0	1.0
HOLLISTER	CL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	3.6	0.0	0.7
MANGUM	CL	W	700.0	225.0	45.0	14.0	45.0	20.0	0.0	0.0	3.1	0.0	0.8
QUANAH	CL	1-3	700.0	200.0	56.0	14.0	50.0	20.0	0.0	0.0	4.5	0.0	0.7
PORT	CL	1-3	725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	4.5	0.0	0.9
SAGERTON	CL	1-3	700.0	225.0	56.0	14.0	50.0	20.0	0.0	0.0	5.0	0.0	0.7
SPUR	CL	W	725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	5.0	0.0	0.9
TILLMAN	CL	1-3	700.0	225.0	45.0	16.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
WICHITA	CL	1-3	700.0	225.0	56.0	17.0	50.0	20.0	0.0	0.0	3.6	0.0	0.7
BUKREEK	L	1-3	750.0	275.0	56.0	17.0	50.0	20.0	0.0	0.0	5.0	0.0	0.8
SAGERTON	L	0-1	750.0	250.0	50.0	17.0	50.0	25.0	0.0	0.0	4.5	0.0	0.7
TIPTON	L	0-1	800.0	350.0	60.0	25.0	60.0	30.0	0.0	0.0	4.9	0.0	1.1
WICHITA	L	1-3	700.0	225.0	56.0	17.0	50.0	20.0	0.0	0.0	3.6	0.0	0.7
COLORADO	SIL	W	775.0	300.0	65.0	20.0	60.0	25.0	0.0	0.0	4.5	0.0	1.0
TIPTON	SIL	0-1	800.0	350.0	65.0	25.0	60.0	30.0	0.0	0.0	5.0	0.0	1.1
ENTERPRISE	VFSL	0-1	750.0	325.0	55.0	20.0	55.0	25.0	6.5	2.5	4.9	2.7	0.9
YOMONT	VFSL	1-3	1000.0	350.0	65.0	22.4	60.0	25.0	7.3	2.8	4.9	2.7	1.0
ALTUS	FSL	SALINE	650.0	275.0	45.0	17.0	50.0	20.0	7.0	3.0	4.9	2.8	1.1
HARDEMAN	FSL	1-3	600.0	250.0	50.0	17.0	40.0	20.0	6.5	2.5	4.5	2.3	0.9
MILES	FSL	0-1	750.0	275.0	56.0	20.0	50.0	20.0	5.0	2.0	4.9	2.7	0.8
LINCOLN	LFS	SALINE	0.0	0.0	0.0	15.0	0.0	20.0	5.0	2.0	2.5	0.0	0.9
MILES	LFS	0-3	650.0	250.0	42.0	14.0	35.0	15.0	5.5	2.5	3.6	1.8	0.9
SPRINGER	LFS	UND	600.0	225.0	42.0	14.0	30.0	15.0	5.0	2.0	3.6	1.6	1.0
CLAIREMONT	SIL	1-3	1000.0	350.0	65.0	22.4	60.0	25.0	0.0	0.0	5.4	0.0	1.0

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

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Table A-10. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 14

SOIL NAME	TEXTURE*	SLOPE**	COTTON(LB) IRR	COTTON(LB) DRY	GRAIN SORGHUM(CWT) IRR	GRAIN SORGHUM(CWT) DRY	WHEAT(BU) IRR	WHEAT(BU) DRY	ALFALFA(TON) IRR	ALFALFA(TON) DRY	COASTAL BERMUDA(TON) IRR	COASTAL BERMUDA(TON) DRY	NATIVE PASTURE(AUM) DRY
ABILENE	CL	0-1	775.0	225.0	65.0	20.0	60.0	25.0	0.0	0.0	0.0	0.0	0.7
ACME	CL	1-3	0.0	125.0	0.0	8.4	0.0	12.0	0.0	0.0	0.0	0.0	0.6
HOLLISTER	CL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	0.0	2.7	0.7
LA CASA	CL	1-3	750.0	275.0	61.6	16.8	60.0	25.0	0.0	0.0	0.0	2.7	1.0
MANGUM	CL	IIIS	700.0	225.0	45.0	14.0	45.0	25.0	0.0	0.0	3.1	1.3	0.8
PORT	CL	IIW	0.0	500.0	0.0	28.0	0.0	35.0	0.0	5.0	0.0	2.9	2.1
SPUR	CL	IIW	900.0	225.0	61.6	14.0	60.0	28.0	0.0	0.0	0.0	3.1	1.8
TILLMAN	CL	1-3	700.0	225.0	36.4	14.0	45.0	20.0	0.0	0.0	0.0	2.6	0.6
HOLLISTER	SICL	0-1	725.0	250.0	50.0	17.0	55.0	25.0	0.0	0.0	0.0	0.0	0.7
PORT	SICL	IIW	0.0	500.0	0.0	28.0	0.0	35.0	0.0	5.0	0.0	3.8	2.3
CAREY	L	1-3	700.0	275.0	56.0	15.8	50.0	20.0	0.0	0.0	0.0	0.0	0.8
CYRIL	L	IIE	0.0	500.0	0.0	28.0	0.0	30.0	0.0	0.0	0.0	3.6	2.3
LAWTON	L	0-1	0.0	350.0	0.0	19.6	0.0	25.0	0.0	0.0	0.0	2.3	1.1
LUGERT	L	IIE	0.0	500.0	0.0	33.6	0.0	35.0	0.0	4.0	0.0	3.6	1.8
SPUR	L	IIW	900.0	225.0	61.6	14.0	60.0	20.0	0.0	0.0	0.0	3.1	1.8
TIPTON	L	0-1	800.0	350.0	61.6	25.0	60.0	30.0	6.0	3.5	4.9	2.9	1.1
WOODWARD	L	3-5	0.0	200.0	0.0	14.0	0.0	15.0	0.0	0.0	0.0	2.8	1.1
CAREY	SIL	1-3	700.0	275.0	56.0	15.8	50.0	20.0	0.0	0.0	0.0	0.0	0.8
FOARD	SIL	0-1	800.0	250.0	39.2	16.8	40.0	25.0	5.0	0.0	3.1	1.8	0.7
ST. PAUL	SIL	0-1	0.0	350.0	0.0	19.6	0.0	25.0	0.0	2.2	0.0	2.5	1.1
ENTERPRISE	VFSL	1-3	650.0	300.0	50.4	19.6	50.0	25.0	5.0	2.0	0.0	2.6	1.1
ALTUS	FSL	0-1	0.0	400.0	0.0	28.0	0.0	30.0	0.0	3.0	0.0	2.7	1.1
GRANDFIELD	FSL	1-3	0.0	300.0	0.0	16.8	0.0	20.0	0.0	2.0	0.0	2.3	1.1
HARDEMAN	FSL	1-3	600.0	250.0	50.0	17.0	40.0	20.0	6.5	2.5	0.0	0.0	0.9
MILES	FSL	1-3	650.0	250.0	42.0	16.8	45.0	20.0	5.4	2.0	0.0	2.4	1.1
YAHOLA	FSL	IIE	0.0	425.0	0.0	28.0	0.0	30.0	0.0	3.5	0.0	3.4	1.5
DEVOL	LFS	0-3	0.0	250.0	0.0	19.6	0.0	20.0	0.0	0.0	0.0	2.5	1.0
BROWNFIELD	LFS	0-3	0.0	0.0	35.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
ENTERPRISE	LFS	0-3	0.0	0.0	50.4	23.0	50.0	23.0	5.5	0.0	0.0	2.5	1.0
LINCOLN	LFS	IIIE	0.0	0.0	0.0	14.0	0.0	20.0	0.0	0.0	0.0	2.5	0.8
MENO	LFS	IIIE	0.0	0.0	0.0	22.4	0.0	25.0	0.0	2.5	0.0	2.9	1.0
MILES	LFS	0-3	650.0	250.0	42.0	14.0	35.0	15.0	5.0	2.5	0.0	2.5	1.0
SPRINGER	LFS	0-3	600.0	175.0	42.0	11.2	0.0	0.0	6.0	2.0	0.0	0.0	0.7
ALTUS	LFS	IIIE	0.0	300.0	0.0	22.4	0.0	2.0	0.0	2.0	0.0	2.3	1.2

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Table A-11. Crop Yields by Soil Classification for High Level Management And High Quality Water for 1990 - Reach 15

			COTTON(LB)		GRAIN SORGHUM(CWT)		WHEAT(BU)		ALFALFA(TON)		COASTAL BERMUDA(TON)		NATIVE PASTURE(AUM)
SOIL NAME	TEXTURE*	SLOPE**	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	IRR	DRY	DRY
ABILENE	CL	0-1	775.0	225.0	65.0	20.0	60.0	25.0	0.0	0.0	3.6	0.0	0.7
HOLLISTER	CL	0-1	725.0	250.0	50.9	17.0	55.0	25.0	0.0	0.0	3.6	0.0	0.7
QUANAH	CL	1-3	700.0	200.0	56.0	14.0	50.0	20.0	0.0	0.0	3.6	0.0	0.7
MANSKER	CL	1-3	350.0	150.0	28.0	10.0	25.0	12.0	0.0	0.0	3.6	0.0	0.7
SPUR	CL		725.0	250.0	65.0	17.0	60.0	25.0	0.0	0.0	4.5	0.0	0.9
TILLMAN	CL	0-1	750.0	250.0	42.0	16.8	50.0	25.0	0.0	0.0	3.6	0.0	0.6
MANGUM	SICL	1-2	700.0	225.0	45.0	14.0	45.0	20.0	0.0	0.0	0.0	3.1	0.8
PORT	SICL	0-2	1000.0	390.0	62.0	28.0	60.0	30.0	0.0	0.0	5.4	0.0	1.2
STANFORD	SICL	2-5	0.0	0.0	28.0	11.2	25.0	15.0	0.0	0.0	1.8	0.0	0.5
TILLMAN	CL	2-5	650.0	200.0	36.4	14.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
TIPTON	L	0-1	800.0	350.0	60.0	25.0	60.0	30.0	0.0	0.0	4.9	0.0	1.1
COLORADO	SIL		775.0	300.0	65.0	20.0	60.0	25.0	0.0	0.0	4.5	0.0	1.0
TILLMAN	SIL	2-5	650.0	200.0	36.4	14.0	45.0	20.0	0.0	0.0	3.6	0.0	0.6
ST. PAUL	SIL	0-2	775.0	300.0	65.0	19.6	60.0	25.0	0.0	0.0	4.5	0.0	1.0
CAREY	VFSL	0-2	750.0	300.0	45.0	15.0	60.0	30.0	0.0	0.0	4.5	2.3	0.8
ENTERPRISE	VFSL	1-3	750.0	325.0	55.0	20.0	55.0	25.0	6.5	2.5	4.9	2.7	0.9
WEYMOUTH	VFSL	2-4	350.0	150.0	28.0	10.0	30.0	15.0	0.0	0.0	3.6	2.5	0.6
YOMONT	VFSL	0-2	1000.0	350.0	65.0	22.4	60.0	25.0	7.3	2.8	4.9	2.7	1.0
ALTUS	VFSL	0-1	650.0	275.0	45.0	17.0	50.0	20.0	7.0	3.0	4.9	3.1	1.1
HARDEMAN	FSL	1-3	600.0	250.0	50.0	17.0	40.0	20.0	6.5	2.5	4.5	2.3	0.9
MILES	FSL	1-3	650.0	250.0	52.0	18.0	45.0	20.0	5.0	2.0	4.9	2.7	0.8
YAHOLA	FSL	0-2	650.0	300.0	50.4	19.6	60.0	30.0	7.5	3.5	4.9	2.7	1.0
ENTERPRISE	LFS	2-6	550.0	250.0	42.0	16.8	45.0	20.0	4.0	1.5	0.0	0.0	0.9
MILES	LFS	0-3	650.0	250.0	42.0	14.0	35.0	15.0	5.5	2.5	3.6	1.8	0.9
SPRINGER	LFS	UND	600.0	225.0	42.0	14.0	30.0	15.0	5.0	2.0	3.6	1.6	1.0

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APPENDIX B

Base Crop Budgets

Table B-1. Base Budget for Dryland Grain Sorghum[a]

	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, 0-1% slope and typical management in Reach 13.

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

Table B-2. Base Budget for Irrigated Grain Sorghum[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain	cwt.	$3.70	46.75	$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	appl.	3.00	2.00	6.00
Tractors	acre	7.14	1.00	7.14
Field Mach.	acre	4.06	1.00	4.06
Irrig. (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 Machinery	acre	4.61	1.00	4.61
Irrig. Machinery	ac.in.	.74	24.9	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, 0-1% slope, furrow irrigation in zone 1, good quality water and typical management in Reach 13.

Table B-3. Base Budget for Dryland Wheat[a]

	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	appl.	3.50	1.00	3.50
Crop Insurance	acre	3.00	1.00	3.00
Tractors	acre	3.94	1.00	3.94
Field Machinery	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, 0-1% slope and typical management in Reach 13.

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

Table B-4. Base Budget for Irrigated Wheat[a]

	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	appl.	3.50	1.00	3.50
Crop Insurance	acre	6.60	1.00	6.60
Tractors	acre	5.62	1.00	5.62
Field Machinery	acre	5.33	1.00	5.33
Irrig. (mach. & labor)	ac.in.	1.51	32.3	48.77
Labor (tract. & 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 Machinery	acre	8.39	1.00	8.39
Irrig. Machinery	ac.in.	.60	32.3	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, 0-1% slope, border irrigation in zone 1, good quality water and typical management in Reach 13.

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

Table B-5. Base Budget for Dryland Cotton[a]

	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	appl.	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, 0-1% slope and typical management in Reach 13.

Table B-6. Base Budget for Irrigated Cotton[a]

	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	appl.	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 Machinery	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 & 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 Machinery	acre	5.30	1.00	5.30
Irrig. Machinery	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 soils, 0-1% slope, furrow irrigation in zone 1, good quality water and typical management in Reach 13.

Table B-7. Base Budget for Dryland Alfalfa Establishment[a]

	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 Machinery	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 Machinery	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, 0-1% slope and typical management in Reach 13.

Table B-8. Base Budget for Dryland Alfalfa Maintenance[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	2.1	$105.61
2. Preharvest Variable Costs				
Phos. (P_2O_5)	lbs.	.17	42.00	7.14
Field Machinery	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 Machinery	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, 0-1% slope and typical management in Reach 13.

Table B-9. Base Budget for Irrigated Alfalfa Establishment[a]

	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 Machinery	acre	2.03	1.00	2.03
Irrig. (mach. & labor)	ac.in.	1.51	16.6	25.07
Labor (tract. & 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 Machinery	acre	2.40	1.00	2.40
Irrig. Machinery	ac.in.	1.13	16.6	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, 0-1% slope, furrow irrigation in zone 1, good quality water and typical management in Reach 13.

Table B-10. Base Budget for Irrigated Alfalfa Maintenance[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	5.53	$278.10
2. Preharvest Variable Costs				
Phos. (P_2O_5)	lbs.	.17	110.00	18.70
Potash (K_2O)	lbs.	.09	30.00	2.70
Insecticide	appl.	3.00	3.00	9.00
Misc. Expense	acre	3.00	1.00	3.00
Field Machinery	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 Machinery	acre	1.12	1.00	1.12
Prorated Estab. Cost	acre	21.92	1.00	21.92
Irrig. Machinery	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, 0-1% slope, furrow irrigation in zone 1, good quality water, and typical management in Reach 13.

Table B-11. Base Budget for Dryland Coastal Bermudagrass Establishment[a]

	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 (tract. & 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, 0-1% slope, furrow irrigation and typical management in Reach 13.

Table B-12. Base Budget for Dryland Coastal Bermudagrass Maintenance[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	ton	$50.29	2.3	$115.67
2. Preharvest Variable Costs				
Nitrogen	lbs.	.18	40.00	7.20
Phos.	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 Op. Cap.	dol.	.07125	4.22	.30
Total Preharvest				$ 16.74
3. Harvest Costs				
Custom	bale	.65	76.0	$ 49.40
4. Total Variable Costs				$ 66.14
5. Fixed Costs				
Field Machinery	acre	1.12	1.00	1.12
Pror. Est. 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, 0-1% slope, and typical management in Reach 13.

Table B-13. Base Budget for Irrigated Coastal Bermudagrass Establishment[a]

	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 Machinery	acre	1.68	1.00	1.68
Irrig. (mach. & labor)	ac.in.	1.51	36.30	54.81
Labor (tract. & 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				$ 98.64
5. Fixed Costs				
Tractors	acre	1.24	1.00	1.24
Field Machinery	acre	1.64	1.00	1.64
Irrig. Machinery	ac.in.	.53	36.3	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, 0-1% slope, furrow irrigation in zone 1, good quality water, and typical management in Reach 13.

Table B-14. Base Budget for Irrigated Coastal Bermudagrass Maintenance[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Hay	tons	$50.29	4.2	$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. Expenses	acre	3.00	1.00	3.00
Field Machinery	acre	1.61	1.00	1.61
Labor (mach.)	hour	4.50	.75	3.38
Irrig. (mach. & labor)	ac.in.	1.51	72.6	109.63
Int. on Op. Cap.	dol.	.07125	95.15	6.78
Total Preharvest				$197.10
3. Harvest				
Custom	bale	.65	139.0	90.35
4. Total Variable Costs				$287.45
5. Fixed Costs				
Field Machinery	acre	1.12	1.00	1.12
Pror. Est. Cost (10 yrs)	acre	13.06	1.00	13.06
Irrig. Machinery	ac.in.	.28	72.6	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 Loam soils, 0-1% slope, furrow irrigation in zone 1, good quality water, and typical management in Reach 13.

Table B-15. Base Budget for Dryland Native Pasture[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grazing	AUM	$8.24	2.3	$18.95
2. Preharvest Variable Costs				
Field Machinery	acre	.53	1.00	.53
Labor (mach.)	hour	4.50	.25	1.12
Int. on Op. Cap.	dol.	.07125	.53	.04
Total Preharvest				$ 1.69
3. Harvest Costs				0
4. Total Variable Costs				$ 1.69
5. Fixed Costs				
Field Machinery	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, 0-1% slope and typical management in Reach 13.

Table B-16. Base Budget for Irrigated Double Crop Grain Sorghum-Wheat[a]

	Unit	Price or Cost/Unit	Quantity	Value or Cost
1. Gross Receipts				
Grain (sorghum)	cwt.	$3.55[b]	46.75	$165.96
Grain (wheat)	bu.	2.35	47.00	110.45
Total				$276.41
2. Preharvest Variable Costs				
Sorghum Seed	lbs.	.48	8.00	3.84
Wheat Seed	bu.	4.50	1.25	5.62
Nitrogen	lbs.	.18	132.00	23.76
Phos. (P_2O_5)	lbs.	.17	110.00	18.70
Potash (K_2O)	lbs.	.09	41.50	3.73
Insecticide	appl.	3.17	3.00	9.51
Crop Insurance	acre	6.60	1.00	6.60
Tractors	acre	12.76	1.00	12.76
Field Mach.	acre	9.39	1.00	9.39
Irrig. (mach. & labor)	ac.in.	1.51	57.20	86.37
Labor (tract. & mach.)	hour	4.50	6.22	27.99
Other Labor	hour	2.75	2.00	5.50
Int. on Op. Cap.	dol.	.07125	106.88	7.61
Total Preharvest				$221.38
3. Harvest Costs				
Cust. Combine (sorghum)	cwt.	.35	46.75	16.36
Cust. Haul (sorghum)	cwt.	.25	46.75	11.69
Cust. Combine (wheat)[c]	bu.	.20	47.00	9.40
Cust. Haul (wheat)	bu.	.15	47.00	7.05
Total Harvest				$ 44.50
4. Total Variable Costs				$265.88
5. Fixed Costs				
Tractors	acre	17.03	1.00	17.03
Field Machinery	acre	13.00	1.00	13.00
Irrig. Machinery	ac.in.	.66	57.20	37.75
Management	acre	26.59	1.00	26.59
Total				$ 94.37
6. Total Costs				$360.25
7. Returns Above Total Costs				$-83.84

[a]This budget represents Enterprise Very Fine Sandy Loam soils, 0-1% slope, border irrigation in zone 1, good quality water and typical management in Reach 13.

[b]Grain sorghum price is $3.70/cwt. Double cropped grain sorghum is harvested at a higher moisture content. The cost of drying and weight loss is $.15/cwt.

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

APPENDIX C

Example of Irrigation Cost Generator

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	801.63	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

BASIC DATA

SYSTEM TYPE 5
COMPLEMENT NUMBER 0

SAMPLE RUN 2
SYSTEM 5

(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	456.80	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*

(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	1.60	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

(ENG1)

ENGINE COSTS

ROW/COL	ELECTRIC HORSE-POWER 1	ELECTRIC MOTOR COST 2	ELECTRIC CONTROL PANEL 3	GAS,LP,NG HORSE-POWER 4	GAS,LP,NG MOTOR COST 5	DIESEL HORSE-POWER 8	DIESEL MOTOR COST 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

	ROW/COL	LP 1	NATURAL GAS 2	DIESEL 3	ELECTRIC 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

	ROW/COL	HAND MOVE 1	SIDE MOVE 2	SIDE MOVE TOW 3	SELF PROP-PELLED 4	SURFACE 5	BIG GUN 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

(SPL4)

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 2

SIDE MOVE 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:	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 MAIN LINE BELOW GROUND		SECTION TWO LATERAL		SECTION THREE		SECTION FOUR	
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:	30.10	COST ABOVE GR. VALVES:	25.75	TOTAL VALVE COST:	1324.40	DISTANCE 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

SAMPLE RUN 2
SYSTEM 2

BASIC DATA

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	642.07	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*

(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

APPENDIX D

Matrix Generator and Report Writer FORTRAN Listing

```
C                    MATRIX GENERATOR LISTING
C
C
C
C                 INPUT DATA CARD COLUMN FORMAT FOR
C                       THE MATRIX GENERATCR
C
C               SECTION ONE (ONE CARD PER CROP)
C      CC
C      1-2  INTEGER CROP NUMBER** +
C      5-24 CROPPING ACTIVITY  NAMES--20 CHARACTER LIMIT
C     25-28 UNIT NAMES
C     30-30 IRRIGATION SYSTEM CODE - S = SPRINKLER,
C           F = FURROW, N = NON-IRRIGATED
C     31-33 3 CHARACTER CROP CODE
C     36-40 NON-LAND FIXED COST*
C     43-47 PRE-HARVEST VARIABLE COST (EXCLUDE FERTILIZER,
C           IRRIGATION, INTEREST, MANAGEMENT CHARGES)*
C     49-54 AVERAGE YIELD PER ACRE.*
C     56-61 HARVEST COST PER ACRE.*
C     63-68 PRICE PER UNIT CROP*
C      ...
C      ...
C      1-2  '99' CARD MARKS END OF THIS SECTION
C
C               SECTION TWO (ONE CARD PER CROP)
C      CC
C      1-4  CONSUMPTIVE WATER USE PLUS LEACHING REQ. FOR
C           FIRST REACH FOR CROP LISTED FIRST IN SECTION 1*
C      6-9  CONSUMPTIVE WATER USE PLUS LEACHING REQ. FOR
C           SECOND REACH FOR CROP LISTED FIRST IN SECTION 1*
C      ...
C      ...
C     10-60 CONSUMPTIVE WATER USE PLUS LEACHING FOR EACH
C           CROP IN FORMAT F5.1,1X *
C      ...
C
C                 SECTION THREE (ONE CARD PER CROP)
C      CC
C      1-5  OBERS YIELD INCREASE FOR EACH CROP IN SECTION 1
C      8-60 YIELD REDUCTION DUE TO SALINITY FOR EACH CROP
C           IN SECTION 1 FOR EACH REACH*
C
C                 SECTION FOUR A (ONE SET CF ALL REMAINING
C                                CARDS FOR EACH REACH)
C       CC
C      1-5   HEADER CARD REACH NAME
C      6-7   HEADER CARD REACH NUMBER**
C      1-2   SOIL TYPE NUMBER
C      4-6   3 CHARACTER USER SPECIFIED SOIL TYPE CODE
```

```
C     10-65  HIGH LEVEL MGT. CROP YIELDS FOR FIRST 9 CROPS
C            SPECIFIED IN SECTION 1 IN FORMAT F6.1,1X *
C      ...
C      ...
C      ...   SECOND CARD FOR NEXT 9 CROPS LISTED IN SECTION 1
C      ...
C      ...   THIRD CARD FOR NEXT 9 CROPS LISTED IN SECTION 1
C            INSERT BLANK CARDS IF SECOND OR THIRD CARD
C            IS NOT NEEDED
C      ...
C      ...
C      1-2  SECTION ENDED BY '99' CARD
C
C              SECTION FOUR B
C     CC
C      2-7  LAND CONSTRAINT FOR SOIL TYPE LISTED FIRST
C           IN SECTION 1
C     9-14  LAND CONSTRAINT FOR SOIL TYPE LISTED SECOND
C      ...
C      ...
C      ...   LIST FIRST 11 SOIL CONSTRAINTS ON CARD 1 THIS
C            SECTION, SECOND 11 ON SECOND CARD, ETC., -- UP
C            TO 5 CARDS -- 1 CARD GROUP (1 TO 5 CARDS) PER
C            ZONE
C
C              SECTION FOUR C
C
C     CC        (CARD 1)
C        2  INEQUALITY SIGNAL FOR MPSX, G,L,N, OR E FOR
C           TOTAL ACREAGE OF CROP LISTED FIRST IN SECTION 1,
C           E.G., COTTON, SORGHUM, WHEAT, ETC.
C        4  INEQUALITY SIGNAL FOR SECOND CROP
C        6  INEQUALITY SIGNAL FOR THIRD CROP
C      ...
C      ...
C      ...  INEQUALITY SIGNAL FOR LAST CROP
C               (CARDS 2,3,4)
C      2-7  CONSTRAINT ACREAGE FOR CROP LISTED FIRST IN
C           SECTION 1*
C     9-14  CONSTRAINT ACREAGE FOR CROP LISTED SECOND
C           IN SECTION 1*
C      ...  .......
C      ...  .......
C           ETC., UP TO 10 CROPS, FORMAT(10F6.0). IF
C           N IS SPECIFIED ON CARD 1, LEAVE BLANK SPACE
C           IN APPRORRIATE POSITION (3 CARDS MUST
C           BE INCLUDED HERE EVEN IF BLANK)*
C                (CARD 5)
C     2-10  TOTAL WATER AVAILABLE FOR IRRIGATION (INS)*
C       13  INEQUALITY SIGNAL L FOR TOTAL CROPLAND ACRES
C    14-21  TOTAL CROPLAND ACRES (VALUE IN SECTION 1
C           WHICH 'TRANS' ACTIVATES)*
C       23  INEQUALITY SIGNAL G,L,N, OR E FOR TOTAL
```

```
C          IRRIGATED ACRES
C     24-31 TOTAL IRRIGATED ACREAGE (OPTIONAL)*
C     34-38 '1' IF INPUT DATA REQUESTED - BLANK OTHERWISE
C     40-44 '1' IF BUDGETS ARE REQUESTED - BLANK OTHERWISE
C
C            * DECIMAL PUNCHED
C           ** RIGHT JUSTIFIED
C            + CROP NUMBERS MUST BE:
C              1 - COTTON        5 - CORN
C              2 - SORGHUM       6 - ALFALFA
C              3 - WHEAT         7 - BARLEY
C              4 - COASTAL BER   8 - NATIVE PASTURE
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      BASIC DATA IN THIS PROGRAM ARE CODED AS FOLLOWS
C
C      C = IRRIGATION CODE --S F, OR-N
C      CC = CROP NAME CODE (3 CHARACTERS)
C      CROP = CROP NAMES (20 CHARACTERS) --UP TO 30 CROPS
C      COST =  ARRAY CONTAINING (IN ORDER)
C        (1) NON-LAND FIXED COST
C        (2) PREHARVEST VARIABLE COST
C        (3) AVERAGE YIELD PER ACRE
C        (4) HARVEST COST PER ACRE
C        (5) CRCP PRICE/ UNIT
C
C      WATER = ARRAY CONTAINING WATER REQUIREMENTS
C      UNIT =  ARRAY CONTAINING UNIT MEASURES
C      CONST = ARRAY CONTAINING SOIL TYPE CCNSTRAINTS
C              FOR EACH REACH
C      YRED = YIELD REDUCTION PARAMETERS
C               FOR EACH LEACHING LEVEL
C      FERT = ARRAY CONTAINING FERTILIZER REQUIREMENTS
C             FOR N, P, AND K
C      SOIL = SOIL NAME CODE (4 CHARACTERS)
C      YIELD = ARRAY WITH YIELD BY SOIL TYPE BY CROP
C      OBJ = OBJECTIVE FUNCTION ARRAY
C      K = NUMBER OF CROPS
C      KK = NUMBER OF SOIL TYPES
C      NR = NUMBER OF REACHES
C      DIMENSIONED DATA = FIN, FINN, FINNN ARE FERTILIZER
C       REQ. COEFICIENTS; FVC, SVC ARE WATER COST EQUATION
C      COEFICIENTS; CHECK CONTAINS CROP CODES; CACRE
C      CONTAINS RHS VALUES PLACED ON CROP ACREAGES;
C
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      DIMENSION YIELD(55,30,12), COST(30,5), WATER(30,12)
      INTEGER  CROP(30,5),C(30),SOIL(55,12),CC(30),UNIT(30)
      DIMENSION FERT(55,30,3,12),NC(30),NS(12),WAPPL(30,12)
      DIMENSION OBJ(30,55,12), CONST(3,55,12), WC(30,3)
      DIMENSION OBERS(30),YRED(30,12),SLOPE(4,3,17)
```

```
      DIMENSION FIN(68), FINN(68), FINNN(68), UPACRE(11,12)
      DIMENSION FVC(12),SVC(12),FWC(4,3),SWC(4,3),TOTWAT(12)
      DIMENSION CLAND(12), XRRACR(12), ICODE(12), IRCODE(12)
      DATA FIN/480.,.125,.125,0.,40.,1.5,1.5,0.,30.,1.,.667,
     *0.,4.,30.,10.,5.,70.,1.143,.857,.286,4.,0.,20.,0.,30.,
     *1.,.667,0.,40*0.0/
      DATA FINN/960.,.083,.042,.083,60.,1.,1.,0.,45.,2.,
     *1.33,1.67,8.,60.,10.,20.,110.,1.,.857,1.25,6.,0.,
     *20.,30.,45.,2.,1.33,1.667,40*0.0/
      DATA FINNN/1440.,.0833,.0833,.0417,80.,2.,1.,1.,60.,
     *2.66,1.33,.667,14.,50.,10.,25.,150.,.5,1.,.75,8.,0.,
     *20.,20.,60.,2.66,1.33,.667,40*0.0/
      INTEGER K,KK,ID,FI,SI,CHECK(30),IRR,DRY,CHK(30)
      INTEGER  CHK(30),GORL(11,12),INPUT(12), BUDGET(12),
      INTEGER  END, REACH(12), LORG(11,12), NAM(10)
      REAL LOACRE(11,12)
      DATA  CHECK/30*0/,CHK/30*0/,CHEK/30*0/,END/'ENDD'/
      DATA  ID/'N'/,FI/'F'/,IRR/'IRR'/,DRY/'DRY'/,SI/'S'/
      DATA FVC/0.,0.,0.,1.99,2.06,2.11,.0287,.0268,.0279,
     *18.302,26.769,34.293/
      DATA SVC/2.377,2.62,2.86,7.993,8.017,8.012,.0489,
     *.0487,.0499,20.644,29.079,36.657/
      J=0
      DO 20 N=1,17
      DO 10 I=1,4
      J= J + 1
      SLOPE(I,1,N)=FIN(J)
      SLOPE(I,2,N)=FINN(J)
      SLOPE(I,3,N)=FINNN(J)
   10 CONTINUE
   20 CONTINUE
      J=0
      DO 25 N=1,4
      DO 50 I=1,3
      J= J + 1
      SWC(N,I)= SVC(J)
      FWC(N,I)= FVC(J)
   50 CONTINUE
   25 CONTINUE
      I=0
      NR=0
      NK=0
      K=0
C     READ CROP NUMBER, NAME, UNITS
  105 J=K
      K=K+1
      READ(5,100) NC(K), (CROP(K,L),L=1,5), UNIT(K),
     *C(K),CC(K),(COST(K,L), L=1,5)
      IF(NC(K)-99) 105,101,101
  100 FORMAT(I2,2X,5A4,A4,1X,
     *A1,A3,2(1X,F6.2),1X,F6.1,1X,F6.2,1X,F7.2)
  101 CONTINUE
      K=J
```

```
      DO 15 I=1,K
      READ(5,112) (WATER(I,J), J=1,12)
  112 FORMAT(12(F4.1,1X))
   15 CONTINUE
      DO 75 I=1,K
      READ(5,85) OBERS(I), (YRED(I,J), J=1,12)
   85 FORMAT(F5.2,1X,12(F4.0,1X))
   75 CONTINUE
      DO 120 I=1,K
      DO 115 J=1,12
      IF(C(I).EQ.ID) GO TO 125
      IF(C(I).EQ.FI) GO TO 116
      WAPPL(I,J)= WATER(I,J)/.85
      GO TO 115
  116 WAPPL(I,J)= WATER(I,J)/.75
      GO TO 115
  125 WAPPL(I,J)= 0.0
  115 CONTINUE
  120 CONTINUE
C     READ SOIL TYPE, YIELDS--UP TO 55 SOILS, 30 CROPS
   51 CONTINUE
      NR=NR+1
      I=0
      READ(5,60) NAME, REACH(NR)
   60 FORMAT(A4,1X,A2)
      IF (NAME.EQ.END) GO TO 133
  110 KK=I
      I=I+1
      READ(5,106) IS, SOIL(I,NR), (YIELD(I,J,NR),J=1,27)
  106 FORMAT(I2,1X,A3,1X,9F7.1/7X,9F7.1/7X,9F7.1)
      IF(IS-99) 110,111,111
  111 CONTINUE
      NS(NR)=KK
      DO 114 J=1,3
      READ(5,113) (CONST(J,I,NR), I=1,11)
      IF (KK.LE.11) GO TO 114
      READ(5,113) (CONST(J,I,NR), I=12,22)
      IF (KK.LE.22) GO TO 114
      READ(5,113) (CONST(J,I,NR), I=23,33)
      IF(KK.LE.33) GO TO 114
      READ(5,113) (CONST(J,I,NR), I=34,44)
      IF(KK.LE.44) GO TO 114
      READ(5,113) (CONST(J,I,NR), I=45,55)
  113 FORMAT(11(1X,F6.0))
  114 CONTINUE
      READ(5,131) (GORL(I,NR),I=2,11),(LORG(I,NR),I=2,11),
     *(UPACRE(I,NR), I=2,11), (LOACRE(I,NR), I=2,11)
  131 FORMAT(10(A1,1X),/,10(A1,1X),/,10(F7.0,1X),/,
     *10(F7.0,1X))
      READ(5,132) TOTWAT(NR),ICODE(NR),CLAND(NR),
     *IRCODE(NR),XRRACR(NR),INPUT(NR),BUDGET(NR)
  132 FORMAT(1X,F9.0,2(1X,A1,F8.0),2(1X,I5))
      GO TO 51
```

```
133 CONTINUE
    NR=NR-1
    DO 99 N=1,NR
    KK=NS(N)
    DO 118 I=1,KK
    DO 119 J=1,K
    YIELD(I,J,N)=YIELD(I,J,N)*.85
    IF(NC(J).EQ.8) YIELD(I,J,N)=YIELD(I,J,N)*.28846
    YIELD(I,J,N)=YIELD(I,J,N) * (1-YRED(J,N)/100.)
119 CONTINUE
118 CONTINUE
 99 CONTINUE
    MN=1980
    DO 500 NN=1,6
    MN=MN+10
    DO 490 JJ=1,NR
    KK=NS(JJ)
    DO 201 I=1,KK
    DO 202 J=1,K
    DO 205 N=1,17
    IF(NC(J)- N) 205,206,205
206 IF(YIELD(I,J,JJ).LE.SLOPE(1,1,N)) GO TO 203
    IF(YIELD(I,J,JJ).LE.SLOPE(1,2,N)) GO TO 204
    DO 510 M=1,3
    MM=M + 1
    FERT(I,J,M,JJ)=(SLOPE(1,1,N)*SLOPE(MM,1,N)) +
   *(SLOPE(1,2,N)-SLOPE(1,1,N))*SLOPE(MM,2,N) +
   *(YIELD(I,J,JJ) - SLOPE(1,2,N))*SLOPE(MM,3,N)
510 CONTINUE
    GO TO 205
203 DO 501 M=1,3
    MM=M + 1
    FERT(I,J,M,JJ)=(YIELD(I,J,JJ)*SLOPE(MM,1,N))
501 CONTINUE
    GO TO 205
204 DO 502 M=1,3
    MM= M + 1
    FERT(I,J,M,JJ)=(SLOPE(1,1,N)*SLOPE(MM,1,N)) +
   * (YIELD(I,J,JJ) - SLOPE(1,1,N))*SLOPE(MM,2,N)
502 CONTINUE
205 CONTINUE
202 CONTINUE
201 CONTINUE
    NK=NK+1
    IF(NK.GT.1) GO TO 251
    WRITE(6,231)
231 FORMAT(1H1,6X,42('-'),T52,'COSTS OF PRODUCTION',T75,
   *42('-'),/,T43,'NON-',T53,'PRE-',T63,'AVG',T73,
   *'HARVEST',T83,'CROP *',T93,'UNIT',T100,
   *'CROP'/,T43,'LAND',T53,'HARVEST',T63,
   *'YIELD',T73,'COST/',T83,'PRICE/',T100,
   *'I.D.',/,T43,'FIXED',T53,'VAR',
   *T73,'ACRE',T83,'UNIT',T100,'NO.',
```

```
   */,T43,'($)',T53,'($)',
   *T63,'(UNITS)',T73,'($)',T83,'($)',
   */,20X,95('-'),/)
    DO 250 I=1,K
    WRITE(6,235) (CROP(I,J),J=1,5), (COST(I,J),J=1,5),
   *UNIT(I),NC(I)
235 FORMAT(1H0,20X,5A4,F6.2,4X,F6.2,3X,F7.1,2(4X,F6.2),
   *T93,A4,T100,I2)
250 CONTINUE
    WRITE(6,249)
249 FORMAT(1H0,/,23X,'* INCLUDES VALUE OF JOINT ',
   *'PRODUCTS, E.G., SEED IN COTTON AND GRAZING',
   *' IN WHEAT.')
    WRITE(6,232) (REACH(I),I=1,NR)
232 FORMAT(1H1,T45,'EFFECTIVE IRRIGATION WATER ',
   *'REQUIREMENTS',/,3X,120('-'),/,T67,'REACH',/,T34,
   *75('-'),/,14X,'CROP',T36,12(A2,4X))
    WRITE(6,334)
334 FORMAT(13X,107('-'))
    DO 246 I=1,K
    WRITE(6,241) (CROP(I,J),J=1,5), (WATER(I,J),J=1,NR)
241 FORMAT(1H0,13X,5A4,12(F4.1,2X))
246 CONTINUE
    WRITE(6,245) (REACH(I),I=1,NR)
245 FORMAT(1H1,T45,'TOTAL IRRIGATION WATER APPLICATION',
   *' RATES',/,3X,120('-'),/,T67,'REACH',/,T34,75('-'),
   */,14X,'CROP',T36,12(A2,4X))
    WRITE(6,334)
    DO 248 I=1,K
    WRITE(6,241) (CROP(I,J),J=1,5), (WAPPL(I,J),J=1,NR)
248 CONTINUE
    WRITE(6,265) (REACH(I),I=1,NR)
265 FORMAT(1H1,T45,'YIELD REDUCTION DUE TO SALINITY',
   *' (PERCENT)',/,3X,120('-'),/,T67,'REACH',/,T34,
   *75('-'),/,14X,'CROP',T36,12(A2,4X))
    WRITE(6,334)
    DO 262 I=1,K
    WRITE(6,241) (CROP(I,J),J=1,5), (YRED(I,J),J=1,NR)
262 CONTINUE
251 CONTINUE
    IF(INPUT(JJ).EQ.0) GO TO 230
    NSS=15
    N=1
    IF(KK.LE.15) NSS=KK
225 WRITE(6,200) REACH(JJ), MN
200 FORMAT(1H1,6X,21('-'),T33,'REACH ',A2,
   *'YIELD BY SOIL TYPE BY CROP -- 20% LEACHING LEVEL--',
   *I4,T98,27('-'),/)
    WRITE(6,211) (SOIL(I,JJ),I=N,NSS)
211 FORMAT(1H ,21X,15(3X,A4))
    DO 216 I=1,K
    WRITE(6,215) (CROP(I,J),J=1,4),UNIT(I),
   *(YIELD(J,I,JJ),J=N,NSS)
```

```
215 FORMAT(1H0,4A4,A4,15(F7.1))
216 CONTINUE
    IF(KK.GT.15.AND.N.EQ.1) GO TO 226
    IF(KK.GT.30.AND.N.EQ.16) GO TO 237
    IF(KK.GT.45.AND.N.EQ.31) GO TO 239
    GO TO 230
226 IF(KK.GT.30.AND.N.EQ.16) GO TO 237
    N=16
    NSS=KK
    IF(KK.GT.30) NSS=30
    GO TO 225
237 N=31
    NSS=KK
    IF(KK.GT.45) NSS=45
    GO TO 225
239 N=46
    NSS=KK
    GO TO 225
230 CONTINUE
490 CONTINUE
    WRITE(8,275) MN
275 FORMAT('NAME',10X,'SALT',I4,/,'ROWS',/,
   *' N  OBJFN')
    DO 272 JJ=1,NR
    WRITE(8,273)  REACH(JJ)
273 FORMAT(' N  OBJ',A2)
272 CONTINUE
    WRITE(8,271)
271 FORMAT(' N  ENDOBJ')
    DO 279 JJ=1,NR
    KK=NS(JJ)
    DO 281 J=1,3
    DO 280  I=1,KK
    WRITE(8,285) SOIL(I,JJ),J,REACH(JJ)
285 FORMAT(' L   ',A3,I1,A2)
280 CONTINUE
281 CONTINUE
279 CONTINUE
    WRITE(8,296)
296 FORMAT(' N  DUMMY')
    II=0
    DO 258 JJ=1,NR
    KK=NS(JJ)
    IK=1
    DO 259 J=1,K
    IJ= IK
    CK=IRR
    CKK=CC(J)
    IF(C(J).EQ.ID) CK=DRY
    DO 260 I=1,IJ
    IF(CK.EQ.CHK(I).AND.CKK.EQ.CHEK(I)) GO TO 260
    IF(I.EQ.IJ) GO TO 269
    GO TO 260
```

```
269 CONTINUE
    IK= I + 1
    CHK(IK)= CK
    CHEK(IK)=CKK
    IF(C(J).EQ.SI.OR.C(J).EQ.FI) WRITE(8,270) IRR,
   *CC(J),REACH(JJ)
    IF(C(J).EQ.ID) WRITE(8,270) DRY,CC(J),REACH(JJ)
270 FORMAT(' G  ',A3,A3,A2)
260 CONTINUE
259 CONTINUE
    WRITE(8,287) REACH(JJ)
287 FORMAT(' N  TRANS',A2)
    WRITE(8,289) IRCODE(JJ), REACH(JJ)
289 FORMAT(1X,A1,'  IRACRE',A2)
    WRITE(8,288) ICODE(JJ), REACH(JJ)
288 FORMAT(1X,A1,'  CRPLND',A2)
    WRITE(8,290) REACH(JJ)
290 FORMAT(' L  WATER',A2)
258 CONTINUE
    WRITE(8,282)
282 FORMAT(' N  ENDCROP')
    DO 283 JJ=1,NR
    JK=1
    DO 343 J=1,K
    JJJ= JK
    DO 342 I=1,JJJ
    IF(CC(J).EQ.CHECK(I)) GO TO 342
    IF(I.EQ.JJJ) GO TO 340
    GO TO 342
340 CONTINUE
    JK= JJJ + 1
    CHECK(JK)= CC(J)
    WRITE(8,341) GORL(JK,JJ), CC(J),REACH(JJ)
341 FORMAT(1X,A1,2X,'UP',A3,A2)
    WRITE(8,338) LORG(JK,JJ),CC(J), REACH(JJ)
338 FORMAT(1X,A1,2X,'LO',A3,A2)
    IF(JJ.LT.NR) GO TO 291
    II=II+1
    NAM(II)=CC(J)
291 CONTINUE
342 CONTINUE
343 CONTINUE
283 CONTINUE
    WRITE(8,268)
268 FORMAT(' N  FINREAD')
    DO 292 I=1,II
    IF(I.EQ.II) GO TO 362
    WRITE(8,293) NAM(I)
293 FORMAT(' N  IRR',A3)
```

```
  362 CONTINUE
      WRITE(8,347) NAM(I)
  347 FORMAT(' N  DRY',A3)
  292 CONTINUE
      WRITE(8,297)
  297 FORMAT(' N  IRRACRE',/,' N  TOTWAT')
      WRITE(8,295)
  295 FORMAT('COLUMNS')
      DO 299 JJ=1,NR
      WRITE(8,294) REACH(JJ),REACH(JJ),REACH(JJ),
     *REACH(JJ),REACH(JJ)
  294 FORMAT(4X,'TCOST',A2,T15,'OBJ',A2,T26,'-4.77',T40,
     *'CRPLND',A2,T54,'-1.0',/,4X,'TCOST',A2,T15,'TRANS',
     *A2,T26,'1.0',T40,'OBJFN',T54,'-4.77')
  299 CONTINUE
      A=1.0
      KKK=0
      DO 435 JJ=1,NR
      KK=NS(JJ)
      DO 330 L=1,3
      DO 310 J=1,KK
      DO 305 I=1,K
      KKK=KKK + 1
      IF (C(I).EQ.ID) GO TO 350
      IF (C(I).EQ.FI) GO TO 355
      TWA=WAPPL(I,JJ)
      WVC= SWC(1,L) + SWC(2,L)*(1./TWA)
      WFC= SWC(3,L) + SWC(4,L)*(1./TWA)
      GO TO 351
  355 CONTINUE
      TWA=WAPPL(I,JJ)
      WVC= FWC(2,L)
      WFC= FWC(3,L) + FWC(4,L)*(1./TWA)
      GO TO 351
  350 CONTINUE
      TWA=0.0
      WVC= 0.0
      WFC= 0.0
  351 CONTINUE
C     HC= HARVEST COST, TR= TOTAL REVENUE
C     TWVC= TOTAL WATER VARIABLE COST
C     FIXC= TOTAL FIXED COST, OBJ= NET REVENUE
C     COST, TWFC= TOTAL WATER FIXED COST
C     FC= FERTITLIZER COST, OPHC= OTHER PREHARVEST COST,
C     CMGT= MANAGEMENT CHARGE, RC= INTEREST CHARGE
      HC = (COST(I,4)/COST(I,3)) * YIELD(J,I,JJ)
      IF(NC(I).EQ.2) GO TO 360
      IF(NC(I).EQ.3) GO TO 380
      GO TO 390
  360 CONTINUE
      HC= 8. + .25 * YIELD(J,I,JJ)
      IF(YIELD(J,I,JJ).GE.23) HC= .6 * YIELD(J,I,JJ)
      GO TO 390
```

```
380 CONTINUE
    HC= 7. + .15 * YIELD(J,I,JJ)
    IF(YIELD(J,I,JJ).GE.35) HC= .35 * YIELD(J,I,JJ)
390 CONTINUE
    RATE= .035625
    TR = (COST(I,5)*YIELD(J,I,JJ))
    TWVC= WVC*TWA
    TWFC= WFC*TWA
    FIXC = COST(I,1) + TWFC
    FC=(FERT(J,I,1,JJ)*.18) + (FERT(J,I,2,JJ)*.17) +
   *(FERT(J,I,3,JJ)*.09)
    OPHC= COST(I,2)
    VC= OPHC + FC + TWVC
    RC= VC * RATE
    PHVC= VC + RC
    VTC=PHVC + HC
    CMGT= VTC * .10
    TVC= VTC + CMGT
    OBJ(I,J,JJ)= TR - (FIXC+TVC)
    IF(OBJ(I,J,JJ).LT.0) OBJ(I,J,JJ)=0.0
    IF(BUDGET(JJ).EQ.0) GO TO 900
    IF(KKK.GT.1) GO TO 601
    WRITE(6,600) REACH(JJ),MN
600 FORMAT(1H1,6X,35('-'),T45,'REACH ',A2,
   *' COSTS AND RETURNS --',1X,I4,T80,40('-'),/,
   *T64,'VARIABLE COSTS',/,3X,'CROP',T16,
   *'NET',T25,
   *'TOTAL',T35,'FIXED',T43,54('-'),T100,'WATER',T109,
   *'FERTILIZER',/,3X,'CODE',T16,'REVENUE',T25,
   *'REVENUE',T35,'COST',T43,'WATER',T51,'FERT.',
   *T59,'HARVEST',T67,'OTHERPH',T76,'INT.',T83,
   *'MGT',T91,'TOTAL',T100,'APPL.',T108,'N',T114,'P205',
   *T122,'K20',T127,'YIELD',/,1X,130('-'))
601 CONTINUE
    WRITE(6,700) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),
   *OBJ(I,J,JJ),TR,FIXC,TWVC,FC,HC,OPHC,RC,CMGT,TVC,
   *TWA,(FERT(J,I,JK,JJ),JK=1,3),YIELD(J,I,JJ)
700 FORMAT(3X,A1,I1,A3,I1,A2,T13,3(2X,F7.2),
   *T40,6(2X,F6.2),2X,F7.2,
   *4(2X,F5.1),2X,F7.1)
    IF(KKK.EQ.55) KKK=0
900 CONTINUE
    IF(YIELD(J,I,JJ).EQ.0) GO TO 305
    WRITE(8,319) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),
   *OBJ(I,J,JJ),CC(I), REACH(JJ), A
319 FORMAT(4X,A1,I1,A3,I1,A2,T15,'OBJFN',T26,F7.2,
   *T40,'UP',A3,A2,T54,F3.0)
    WRITE(8,300) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),
   *REACH(JJ),OBJ(I,J,JJ),SOIL(J,JJ),L,REACH(JJ),A
300 FORMAT(4X,A1,I1,A3,I1,A2,T15,'OBJ',A2,T26,
   *F7.2,T40,A3,I1,A2,T54,F3.0)
    IF(NC(I).NE.8) WRITE(8,309)C(I),NC(I),SOIL(J,JJ),
   *L,REACH(JJ),REACH(JJ),A
```

```
309 FORMAT(4X,A1,I1,A3,I1,A2,T15,'CRPLND',A2,T28,F3.0)
    IF(C(I).EQ.ID) GO TO 307
    WRITE(8,301) C(I),NC(I), SOIL(J,JJ) ,L,REACH(JJ),
   *REACH(JJ),TWA,TWA
301 FORMAT(4X,A1,I1,A3,I1,A2,T15,'WATER',A2,T28,F4.1,
   *T40,'TOTWAT',T54,F4.1)
    WRITE(8,302) C(I), NC(I), SOIL(J,JJ),L,REACH(JJ),
   *REACH(JJ),A, CC(I), REACH(JJ), A
302 FORMAT(4X,A1,I1,A3,I1,A2,T15,'IRACRE',A2,T28,
   *F3.0,T40,'LO',A3,A2,T54,F3.0)
    WRITE(8,303) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),CC(I),
   *REACH(JJ), A
303 FORMAT(4X,A1,I1,A3,I1,A2,T15,'IRR',A3,A2,T28,F3.0)
    WRITE(8,304) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),
   *CC(I),A,A
304 FORMAT(4X,A1,I1,A3,I1,A2,T15,'IRR',A3,T28,F3.0,T40,
   *'IRRACRE',T54,F3.0)
    GO TO 305
307 WRITE(8,312) C(I), NC(I), SOIL(J,JJ),L,REACH(JJ),
   *CC(I),REACH(JJ),A,CC(I),REACH(JJ),A
312 FORMAT(4X,A1,I1,A3,I1,A2,T15,'LO',A3,A2,
   *T28,F3.0,T40,'DRY',A3,A2,T54,F3.0)
    WRITE(8,313) C(I),NC(I),SOIL(J,JJ),L,REACH(JJ),
   *CC(I),A
313 FORMAT(4X,A1,I1,A3,I1,A2,T15,'DRY',A3,T28,F3.0)
305 CONTINUE
310 CONTINUE
330 CONTINUE
435 CONTINUE
    WRITE(8,375)
375 FORMAT('RHS')
    DO 419 JJ=1,NR
    KK=NS(JJ)
    DO 335 L=1,3
    DO 320  I=1,KK
    WRITE(8,315) SOIL(I,JJ),L,REACH(JJ), CONST(L,I,JJ)
315 FORMAT(4X,'CONST',T15,A3,I1,A2,T26,F7.0)
320 CONTINUE
335 CONTINUE
    DO 332 I=2,JK
    WRITE(8,331) CHECK(I),REACH(JJ),UPACRE(I,JJ)
331 FORMAT(4X,'CONST',T15,'UP',A3,A2,T26,F7.0)
    WRITE(8,377) CHECK(I),REACH(JJ),LCACRE(I,JJ)
377 FORMAT(4X,'CONST',T15,'LO',A3,A2,T26,F7.0)
332 CONTINUE
    WRITE(8,352)REACH(JJ), CLAND(JJ)
352 FORMAT(4X,'CONST',T15,'CRPLND',A2,T26,F7.0)
    WRITE(8,333) REACH(JJ),XRRACR(JJ)
333 FORMAT(4X,'CONST',T15,'IRACRE',A2,T26,F7.0)
    WRITE(8,325) REACH(JJ),TOTWAT(JJ)
325 FORMAT(4X,'CONST',T15,'WATER',A2,T26,F9.0)
419 CONTINUE
    WRITE(8,337)
```

```
337 FORMAT('ENDATA')
    DO 429 JJ=1,NR
    KK=NS(JJ)
    DO 450 J=1,KK
    DO 400 I=1,K
    IF(YIELD(J,I,JJ).EQ.0) GO TO 410
    YIELD(J,I,JJ)=YIELD(J,I,JJ)  + ((OBERS(I) * 10.)
   **(1-YRED(I,JJ)/100.))
410 CONTINUE
400 CONTINUE
450 CONTINUE
429 CONTINUE
500 CONTINUE
    STOP
    END
```

```
C                    REPORT WRITER LISTING
C
      INTEGER*4   FILE,LIST,NOCOL,NOCOL2,I,J,L,M,N,P
      REAL*8      NAME,ENDATA,ENDSEC,NOEND,DNE,DUM,STP
      DATA        ENDATA/'ENDATA  '/,ENDSEC/'$ENDSEC$'/
      DATA        DUM/'DUMMY'/,STP/'TOTWAT'/
      REAL*8      COLUMN(11000),VALUES(11000)
      DATA        NOEND/'SOLUTION'/
      REAL*8      START,FIN,RCROP(18,2,6),RVALUE(30,2,6,18)
      DATA        START/'OBJFN'/,DNE/'ENDOBJ'/,FIN/'FINREAD'/
      INTEGER*4   TYPE(1000),VALNUM(1000)
      REAL*4      VALALF(1000)
      DOUBLE PRECISION   OBJFN(6),XOBJ(13,6),ROBJ(13,6)
      DOUBLE PRECISION  TROBJ(6)
      EQUIVALENCE  (VALUES(1),VALNUM(1),VALALF(1))
      FILE= 4
      LIST= 6
C       SKIP THE NAME,XDATA RECORD
C       READ FILE
      K=1
      RATE= .07125
      RATEX= .0325
      NSTART=4
      READ (FILE)
      READ (FILE) NAME,NOCOL
    1 CONTINUE
      KK=0
      NOCOL2=2*NOCOL
      READ (FILE) (COLUMN(N),N=1,NOCOL)
      READ (FILE) (TYPE(N), N=1,NOCOL2)
      J=0
      DO 2 I=2,NOCOL2,2
      J=J+ TYPE(I)
    2 CONTINUE
      J= J/4
      READ(FILE) (VALALF(N), N=1,J)
      J=0
      DC 20 N=1,NOCCL
      L= J/4 +1
      M= L + 1
      P= L + 19
      IF(TYPE(2*N-1)-2) 19,19,12
C     NUMERIC - REAL - VALUE
   12 CONTINUE
   19 J=J+ TYPE(2*N)
   20 CONTINUE
   22 CONTINUE
      I=0
C     SKIP TO THE $ENDSEC$ OF ID ARR AY
      READ (FILE)
```

```
C       GET ROW ANC COLUMNS SECTIONS
   21 READ (FILE) NAME,NOCOL
      IF(NAME.EQ.ENDATA) GO TO 31
      READ(FILE) (COLUMN(N), N=1,NOCOL)
      READ (FILE)
   24 READ (FILE) (VALUES(N), N=1,NOCOL)
      IF(VALUES(8).EQ.DUM) GO TO 100
      IF(VALUES(8).EQ.START) GO TO 125
      IF(VALUES(8).EQ.FIN) GO TO 175
      IF(VALUES(1).EQ.ENDSEC) GO TO 21
      GO TO 24
  125 CONTINUE
      TROBJ(K)=VALUES(1)
  124 CONTINUE
      I=I+1
      READ (FILE) (VALUES(N), N=1,NOCOL)
      IF(VALUES(8).EQ.DNE) GO TO 126
      ROBJ(I,K)=VALUES(1)
      GO TO 124
  126 CONTINUE
      NR=I-1
      GO TO 24
  100 CONTINUE
      JJ=1
  105 READ (FILE) (VALUES(N), N=1,NOCOL)
      KK= KK + 1
      RVALUE(KK,1,K,JJ)= VALUES(8)
      RVALUE(KK,2,K,JJ)= VALUES(1)
      IF(KK.EQ.15) GO TO 112
      GO TO 105
  120 CONTINUE
  112 CONTINUE
      KK=KK+1
      RVALUE(KK,1,K,JJ)= VALUES(8)
      RVALUE(KK,2,K,JJ)= VALUES(4)
      KK=KK + 1
      RVALUE(KK,1,K,JJ)= VALUES(8)
      RVALUE(KK,2,K,JJ)=  - (VALUES(5))
      KK=0
      IF(JJ.EQ.NR) GO TO 24
      JJ=JJ+1
      GO TO 105
  175 CONTINUE
      KK=0
  176 CONTINUE
      READ (FILE) (VALUES(N), N=1,NOCOL)
      KK=KK+1
      RCROP(KK,1,K)= VALUES(8)
      RCROP(KK,2,K)= VALUES(1)
      IF(VALUES(8).EQ.STP) GO TO 179
      GO TO 176
  179 CONTINUE
      GO TO 24
```

```
130 CONTINUE
 31 CONTINUE
    IF(K.EQ.6) GO TO 29
    READ (FILE)
    READ (FILE) NAME,NOCOL
    K= K + 1
    IF(NAME.EQ.NOEND) GO TO 1
 29 CONTINUE
    NTR=NR+1
    DO 155 N=1,6
    ROBJ(NTR,N)= TROBJ(N)
    DO 156 I=1,NTR
    XOBJ(I,N)=ROBJ(I,N)/1000000.
156 CONTINUE
155 CONTINUE
    DO 400 I=1,NTR
    IYEAR=1990
    NN=0
    NRC=NSTART + I
    WRITE(6,210) NRC
    WRITE(7,210) NRC
210 FORMAT(1H1,T17,'TABLE    .   OPTIMAL CROPPING PATTERN',
   *' SUMMARY FOR THE            SYSTEM, REACH ',I2,'.',/,
   *T17,100('-'),/,
   */,T70,'YEAR',/,T32,82('-'),/,T17,'CROP',T32,'1990',
   *T47,'2000',T63,'2010',T78,'2020',T93,'2030',T108,
   *'2040',/,T17,100('-'))
    IF(I.EQ.NTR) GO TO 245
    DO 220 J=1,14
    WRITE(6,330) RVALUE(J,1,1,I), (RVALUE(J,2,K,I), K=1,6)
    WRITE(7,330) RVALUE(J,1,1,I), (RVALUE(J,2,K,I), K=1,6)
330 FORMAT(1H0,T17,A8,T27,6(F12.2,3X))
220 CONTINUE
    WRITE(6,250) (RVALUE(16,2,K,I),K=1,6),
   *(RVALUE(15,2,K,I),K=1,6),(RVALUE(17,2,K,I),K=1,6)
    WRITE(7,250) (RVALUE(16,2,K,I),K=1,6),
   *(RVALUE(15,2,K,I),K=1,6),(RVALUE(17,2,K,I),K=1,6)
250 FORMAT(/,T17,'WATER ',T27,6(F12.2,3X),/,T17,'AVAIL.',
   *//,T17,'WATER',T27,6(F12.2,3X),/T17,,'USED',//,T17,
   *'WATER',T27,6(F12.2,3X),/T17,,'MVP')
    WRITE(6,332) (XOBJ(I,K), K=1,6)
    WRITE(7,332) (XOBJ(I,K), K=1,6)
332 FORMAT(1H0,T17,'NOMINAL NET',T27,6(F12.5,3X),/,T17,
   *'REVENUE ($MIL)')
    GO TO 258
245 CONTINUE
    DO 257 J=1,12
    WRITE(6,247) RCROP(J,1,1),(RCROP(J,2,K),K=1,6)
    WRITE(7,247) RCROP(J,1,1),(RCROP(J,2,K),K=1,6)
247 FORMAT(1H0,T17,A8,T27,6(F12.2,3X))
257 CONTINUE
    WRITE(6,332) (XOBJ(I,K),K=1,6)
    WRITE(7,332) (XOBJ(I,K),K=1,6)
```

```
 258 CONTINUE
     WRITE(6,300) NRC
     WRITE(7,300) NRC
 300 FORMAT(1H1,T17,'TABLE    .  NET REVENUE SUMMARY '
    *'FOR THE OPTIMAL CROPPING PLANS FOR THE',/,T28,
    *'SYSTEM, REACH ',I2,'.',/,T17,82('-'),/,T25,
    *'NOMINAL VALUE',T40,'PRESENT VALUE',T55,
    *'PRESENT VALUE',T70,'PRESENT VALUE',T85,
    *'PRESENT VALUE',/,T17,'YEAR',T25,'THIS YEAR',T40,
    *'THIS YEAR',T55,'TOTAL TO DATE',T70,'THIS YEAR',T85,
    *'TOTAL TO DATE',/,T40,'(7 1/8% RATE)',T55,
    *'(7 1/8% RATE)',T70,'(3 1/4% RATE)',T85,
    *'(3 1/4% RATE)',/,T17,82('-'),/,
    *T25,28('-'),' $ MILLION ',30('-'))
     DO 201 J=1,6
     OBJFN(J)= FOBJ(I,J)
 201 CONTINUE
     TPVOBJ= OBJFN(1)
     TPVX=TPVOBJ
     XTPVOB= TPVOBJ/1000000.
     WRITE(6,275) IYEAR, XTPVOB, XTPVOB, XTPVOB,
    *XTPVOB,XTPVOB
     WRITE(7,275) IYEAR, XTPVOB, XTPVOB, XTPVOB,
    *XTPVOB,XTPVOB
     DO 200 K=2,6
     JJ= K - 1
     IF(OBJFN(K).GT.OBJFN(JJ)) GO TO 225
     YINC= 0.0
     GO TO 230
 225 CONTINUE
     YINC= (OBJFN(K)-OBJFN(JJ))/10.
 230 CONTINUE
     VOBJ= OBJFN(JJ)
     DO 235 N=1,10
     NN= NN + 1
     VOBJ = VOBJ + YINC
     PVOBJ= VOBJ/((1+RATE)**NN)
     XPV=VOBJ/((1+RATEX)**NN)
     TPVOBJ= TPVOBJ + PVOBJ
     TPVX= TPVX + XPV
     XPVOBJ= PVOBJ/1000000.
     XTPVOB= TPVOBJ/1000000.
     XXPV= XPV/1000000.
     XXTPV= TPVX/1000000.
     XVOBJ= VOBJ/1000000.
     IYEAR= IYEAR + 1
     WRITE(6,275) IYEAR, XVOBJ ,XPVOBJ, XTPVOB,XXPV,XXTPV
     WRITE(7,275) IYEAR, XVOBJ ,XPVOBJ, XTPVOB,XXPV,XXTPV
 275 FORMAT(1H ,T17,I4,T21,F12.5,T36,F12.5,T52,F12.5,T66,
    *F12.5,T82,F12.5)
 235 CONTINUE
 200 CONTINUE
C    ANOTHER METHOD TO DISCOUNT NR FROM YEAR 50 TO 100
```

```
C     TEMP= TPVOEJ
C     DO 240 I=51,100
C     PVOBJ=OBJFN(6)/((1+RATE)**I)
C     TEMP=TEMP+PVOBJ
C 240 CONTINUE
      XTPV=(OBJFN(6)/RATE)*((1./(1+RATE)**50.)-
     *(1./(1+RATE)**100.))
      TPVOBJ=(TPVOBJ + XTPV)/1000000.
      TPVXX=(OBJFN(6)/RATEX)*((1./(1+RATEX)**50.)-
     *(1./(1+RATEX)**100.))
      TPVX= (TPVX+TPVXX)/1000000.
C     WRITE(6,350) TEMP
      WRITE(6,350) TPVOBJ,TPVX
      WRITE(7,350) TPVOBJ,TPVX
  350 FORMAT(1H ,T17,'TOTAL PRESENT VALUE (100 YEARS)',
     *T52,F12.5,T82,F12.5,/,T17,82('-'))
  400 CONTINUE
      RETURN
      END
```

APPENDIX E

Example Output of the Matrix Generator

Table E-1. Example of Optional Matrix Generator Output Containing Inputed Costs of Production.

	COSTS OF PRODUCTION						
	NON-LAND FIXED ($)	PRE-HARVEST VAR ($)	AVG YIELD (UNITS)	HARVEST COST/ ACRE ($)	CROP * PRICE/ UNIT ($)	UNIT	CROP I.D. NO.
S IRR COTTON	13.25	87.94	638.0	72.87	0.57	LBS.	1
F IRR COTTON	13.25	87.94	638.0	72.87	0.57	LBS.	1
DRYLND COTTON	11.43	46.33	255.0	28.97	0.57	LBS.	1
S IRR SORGHUM	10.54	43.42	46.8	28.05	3.75	CWT.	2
F IRR SORGHUM	10.54	43.42	46.8	28.05	3.75	CWT.	2
DRYLND SORGHUM	8.44	28.84	17.0	12.25	3.75	CWT.	2
S IRR WHEAT	19.49	37.79	47.0	16.45	3.12	BU.	3
F IRR WHEAT	19.49	37.79	47.0	16.45	3.12	BU.	3
DRYLND WHEAT	10.88	28.63	21.0	10.15	3.12	BU.	3
S IRR ALFALFA	23.32	16.98	6.5	139.75	50.29	TONS	6
F IRR ALFALFA	23.32	16.98	6.5	139.75	50.29	TONS	6
DRYLND ALFALFA	14.91	4.98	2.5	53.95	50.29	TONS	6
S IRR C BERMUDA	19.91	7.98	4.2	90.35	50.29	TONS	4
F IRR C BERMUDA	19.91	7.98	4.2	90.35	50.29	TONS	4
DRYLND C BERMUDA	7.31	4.98	2.3	49.47	50.29	TONS	4
N NATIVE PASTURE	0.34	1.65	2.3	0.0	8.24	AUMS	8

* INCLUDES VALUE OF JOINT PRODUCTS, E.G., SEED IN COTTON AND GRAZING IN WHEAT.

Table E-2. Example of Optional Matrix Generator Output Containing Inputed Irrigation Water Requirements

EFFECTIVE IRRIGATION WATER REQUIREMENTS

	REACH										
CROP	05	06	07	08	09	10	11	12	13	14	15
S IRR COTTON	6.9	8.1	10.9	11.9	12.1	16.4	16.9	12.3	16.0	15.9	16.7
F IRR COTTON	6.9	8.1	10.9	11.9	12.1	16.4	16.9	12.3	16.0	15.9	16.7
DRYLND COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR SORGHUM	11.3	12.2	16.2	17.1	16.0	16.5	16.9	15.5	16.2	15.8	16.8
F IRR SORGHUM	11.3	12.2	16.2	17.1	16.0	16.5	16.9	15.5	16.2	15.8	16.8
DRYLND SORGHUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR WHEAT	9.4	12.5	18.6	19.7	21.2	22.1	22.3	21.1	21.0	21.2	22.0
F IRR WHEAT	9.4	12.5	18.6	19.7	21.2	22.1	22.3	21.1	21.0	21.2	22.0
DRYLND WHEAT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR ALFALFA	32.1	37.4	46.3	47.6	49.9	54.8	54.5	49.3	54.0	53.9	54.9
F IRR ALFALFA	32.1	37.4	46.3	47.6	49.9	54.8	54.5	49.3	54.0	53.9	54.9
DRYLND ALFALFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR C BERMUDA	26.8	30.2	40.2	41.8	43.0	44.4	44.8	42.4	47.2	47.2	48.2
F IRR C BERMUDA	26.8	30.2	40.2	41.8	43.0	44.4	44.8	42.4	47.2	47.2	48.2
DRYLND C BERMUDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N NATIVE PASTURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E-3. Example of Optional Matrix Generator Output Containing Calculated Irrigation Water Application Rates

	TOTAL IRRIGATION WATER APPLICATION RATES										
	REACH										
CROP	05	06	07	08	09	10	11	12	13	14	15
S IRR COTTON	8.1	9.5	12.8	14.0	14.2	19.3	19.9	14.5	18.8	18.7	19.6
F IRR COTTON	9.2	10.8	14.5	15.9	16.1	21.9	22.5	16.4	21.3	21.2	22.3
DRYLND COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR SORGHUM	13.3	14.4	19.1	20.1	18.8	19.4	19.9	18.2	19.1	18.6	19.8
F IRR SORGHUM	15.1	16.3	21.6	22.8	21.3	22.0	22.5	20.7	21.6	21.1	22.4
DRYLND SORGHUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR WHEAT	11.1	14.7	21.9	23.2	24.9	26.0	26.2	24.8	24.7	24.9	25.9
F IRR WHEAT	12.5	16.7	24.8	26.3	28.3	29.5	29.7	28.1	28.0	28.3	29.3
DRYLND WHEAT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR ALFALFA	37.8	44.0	54.5	56.0	58.7	64.5	64.1	58.0	63.5	63.4	64.6
F IRR ALFALFA	42.8	49.9	61.7	63.5	66.5	73.1	72.7	65.7	72.0	71.9	73.2
DRYLND ALFALFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR C BERMUDA	31.5	35.5	47.3	49.2	50.6	52.2	52.7	49.9	55.5	55.5	56.7
F IRR C BERMUDA	35.7	40.3	53.6	55.7	57.3	59.2	59.7	56.5	62.9	62.9	64.3
DRYLND C BERMUDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N NATIVE PASTURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E-4. Example of Optional Matrix Generator Output Containing Inputed Yield Reduction Due to Salinity

	YIELD REDUCTION DUE TO SALINITY (PERCENT)										
	REACH										
CROP	05	06	07	08	09	10	11	12	13	14	15
S IRR COTTON	0.0	0.0	0.0	0.0	0.0	7.0	8.0	5.0	7.0	6.0	9.0
P IRR COTTON	0.0	0.0	0.0	0.0	0.0	7.0	8.0	5.0	7.0	6.0	9.0
DRYLND COTTON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR SORGHUM	0.0	0.0	0.0	0.0	0.0	20.0	26.0	7.0	26.0	7.0	16.0
P IRR SORGHUM	0.0	0.0	0.0	0.0	0.0	20.0	26.0	7.0	26.0	7.0	16.0
DRYLND SORGHUM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR WHEAT	0.0	0.0	0.0	0.0	0.0	19.0	20.0	11.0	18.0	8.0	15.0
P IRR WHEAT	0.0	0.0	0.0	0.0	0.0	19.0	20.0	11.0	18.0	8.0	15.0
DRYLND WHEAT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR ALFALFA	0.0	0.0	0.0	0.0	0.0	55.0	60.0	24.0	57.0	20.0	45.0
P IRR ALFALFA	0.0	0.0	0.0	0.0	0.0	55.0	60.0	24.0	57.0	20.0	45.0
DRYLND ALFALFA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR C BERMUDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P IRR C BERMUDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DRYLND C BERMUDA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N NATIVE PASTURE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table E-5. Example of Optional Matrix Generator Output Containing Adjusted Yield by Soil Type

-------------------- REACH 13 YIELD BY SOIL TYPE BY CROP -- 20% LEACHING LEVEL--1990 --------------------

		ABL	CCL	COC	HOL	HAN	QUA	POR	SAG	SPU	TIL	WCL	BUK	SAL	TPL	WIL
S IRR COTTON	LBS.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F IRR COTTON	LBS.	612.6	790.5	612.6	573.1	553.3	553.3	573.1	553.3	573.1	553.3	553.3	592.9	592.9	632.4	553.3
DRYLND COTTON	LBS.	233.7	297.5	255.0	212.5	191.2	170.0	212.5	191.2	212.5	191.2	191.2	233.7	212.5	297.5	191.2
S IRR SORGHUM	CWT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F IRR SORGHUM	CWT.	40.9	40.9	40.9	31.4	28.3	35.2	40.9	35.2	40.9	28.3	35.2	35.2	31.4	37.7	35.2
DRYLND SORGHUM	CWT.	0.0	19.0	17.0	14.4	11.9	11.9	14.4	11.9	14.4	13.6	14.4	14.4	14.4	21.3	14.4
S IRR WHEAT	BU.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F IRR WHEAT	BU.	41.8	41.8	41.8	38.3	31.4	34.8	41.8	34.8	41.8	31.4	34.8	34.8	34.8	41.8	34.8
DRYLND WHEAT	BU.	21.3	21.3	21.3	21.3	17.0	17.0	21.3	17.0	21.3	17.0	17.0	17.0	21.3	25.5	17.0
S IRR ALFALFA	TONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F IRR ALFALFA	TONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DRYLND ALFALFA	TONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S IRR C BERMUDA	TONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F IRR C BERMUDA	TONS	3.1	4.6	3.8	3.1	2.6	3.8	3.8	4.3	4.3	3.1	3.1	4.3	3.8	4.2	3.1
DRYLND C BERMUDA	TONS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N NATIVE PASTURE	AUMS	0.6	0.8	0.8	0.6	0.7	0.6	0.8	0.6	0.8	0.5	0.6	0.7	0.6	0.9	0.6

-------------------- REACH 13 YIELD BY SOIL TYPE BY CROP -- 20% LEACHING LEVEL--1990 --------------------

		CSL	TSL	ENT	YOH	ALT	HAR	MSL	LIN	MFS	SPR	CLS
S IRR COTTON	LBS.	0.0	0.0	592.9	790.5	513.8	474.3	592.9	0.0	513.8	474.3	790.5
F IRR COTTON	LBS.	612.6	632.4	592.9	0.0	513.8	474.3	592.9	0.0	0.0	0.0	790.5
DRYLND COTTON	LBS.	255.0	297.5	276.2	297.5	233.7	212.5	233.7	0.0	212.5	191.2	297.5
S IRR SORGHUM	CWT.	0.0	0.0	34.6	40.9	28.3	31.4	35.2	0.0	26.4	26.4	40.9
F IRR SORGHUM	CWT.	40.9	40.9	34.6	0.0	28.3	31.4	35.2	0.0	0.0	0.0	40.9
DRYLND SORGHUM	CWT.	17.0	21.3	17.0	19.0	14.4	14.4	17.0	12.8	11.9	11.9	19.0
S IRR WHEAT	BU.	0.0	0.0	38.3	41.8	34.8	27.9	34.8	0.0	24.4	20.9	41.8
F IRR WHEAT	BU.	41.8	41.8	38.3	0.0	34.8	27.9	34.8	0.0	0.0	0.0	41.8
DRYLND WHEAT	BU.	21.3	25.5	21.3	21.3	17.0	17.0	17.0	17.0	12.8	12.8	21.3
S IRR ALFALFA	TONS	0.0	0.0	2.4	2.7	2.6	2.4	1.8	1.8	2.0	1.8	0.0
F IRR ALFALFA	TONS	0.0	0.0	2.4	0.0	2.6	2.4	1.8	0.0	0.0	0.0	0.0
DRYLND ALFALFA	TONS	0.0	0.0	2.1	2.4	2.5	2.1	1.7	1.7	2.1	1.7	0.0
S IRR C BERMUDA	TONS	0.0	0.0	4.2	4.2	4.2	3.8	4.2	0.0	3.1	3.1	4.6
F IRR C BERMUDA	TONS	3.8	4.3	4.2	0.0	4.2	3.8	4.2	2.1	0.0	0.0	0.0
DRYLND C BERMUDA	TONS	0.0	0.0	2.3	2.3	2.4	2.0	2.3	0.0	1.5	1.4	0.0
N NATIVE PASTURE	AUMS	0.8	0.9	0.8	0.9	0.9	0.8	0.7	0.7	0.7	0.8	0.8

APPENDIX F

Soil Classification and Acreage by Reach

Table F-1. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 5

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
BURLESON	C	1-3	B,F	BUR	13.	160.	424.	597.
HEIDEN	C	1-5	B,F	HEI	784.	1278.	1705.	3767.
CALLISBURG	CL	IIIE	B,F	CAL	1521.	2372.	2344.	6237.
REDLAKE	C	IIE	B,F	RED	1272.	481.	273.	2026.
NORMANGEE	CL	IIS	B,F	NOR	374.	682.	569.	1625.
VANOSS	CL	1-5	B,F	VAN	581.	422.	279.	1282.
BASTROP	L	0-1	F	BAS	1795.	1306.	864.	3965.
COUNTS	L	0-1W	F	COU	668.	0.	0.	668.
CROCKETT	L	IIIE	F	CRO	288.	526.	439.	1253.
DURANT	L	1-3	F	DUR	984.	1397.	1547.	3928.
SANGER	C	IIE	B,F	SAN	233.	1076.	1357.	2666.
WILSON	SICL	IIIW	B,F	WIL	578.	1039.	800.	2417.
FRIOTON	SICL	IIW	B,F	FRI	520.	549.	686.	1755.
BASTROP	FSL	1-3	F,S	BAF	2763.	1780.	531.	5074.
KONAWA	FSL	1-5	F,S	KON	4236.	1651.	1202.	7089.
KONSIL	FSL	1-5	F,S	KOR	3866.	3714.	3261.	10841.
KIOWATIA	FSL	0-3	F,S	KRO	780.	295.	167.	1242.
MADILL	FSL	0-1	F,S	MAD	603.	368.	257.	1228.
PALUXY	FSL	0-1	B,F	PAL	264.	192.	127.	583.
TELLER	FSL	0-1W	F,S	TEL	307.	196.	0.	503.
DOUGHERTY	LFS	0-3	S	DOU	2336.	2822.	2280.	7438.
				TOTAL	24766.	22306.	15112.	66184.

* CL= CLAY LOAM, C=CLAY, SICL= SILT CLAY LOAM, SIL= SILT LOAM, L= LOAM, FSL= FINE SANDY LOAM, VFSL= VERY FINE SANDY LOAM, LFS= LOAMY FINE SAND.

** LAND CAPABILITY CLASS IS INDICATED BY ROMAN NUMERALS I, II, III OR IV WHERE SLOPE WAS NOT AVAILABLE. THE LETTER W INDICATES A WATER PROBLEM, E AN EROSION PROBLEM AND S LIMITED PRODUCTIVITY BECAUSE THE SOIL IS SHALLOW, STONEY, OR DROUGHTY. UND AND HUM ARE ABBREVIATIONS FOR UNDULATING AND HUMMOCKY, RESPECTIVELY.

*** B = BORDER, F = FURROW, S = SPRINKLER

Table F-2. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 6

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
ANOCON		IIIE	B.F.S	ANO	0.	0.	78.	78.
STONEBURG		1-5	B.F.S	STO	0.	0.	79.	79.
BASTROP	L	2-5	B.F.S	BAL	1411.	3904.	6399.	11714.
BASTROP	FSL	1-5	B.F.S	BAF	1848.	2392.	1619.	5859.
BASTROP	L	0-1	B.F.S	BUN	201.	501.	145.	847.
CALLISBURG	FSL	1-5	B.F.S	CAL	37.	120.	264.	421.
CLAREMORE	SIL	1-3	B.F.S	CLA	41.	12.	11.	64.
BREWER		IIS	B.F	BRE	106.	462.	812.	1380.
CROKETT	FSL	1-3	B.F	VAN	0.	9.	70.	79.
DENTON	FSL	3-5	B.F	DEN	0.	13.	96.	109.
SAN SABA	FSL	3-5	B.F	SAN	0.	13.	97.	110.
DOUGHERTY	LFS	0-3	B.F.S	DOU	97.	437.	2184.	2718.
DUFFAU	LFS	1-3	B.F.S	DUF	0.	48.	146.	194.
DUFFAU	FSL	2-5	B.F.S	DFF	165.	782.	1016.	1963.
FRIO	CL	0-1	B.F.S	FRI	91.	179.	83.	353.
GADDY	FSL	0-2	S	GAD	1359.	762.	178.	2299.
GOWEN	FSL	0-1	B.F.S	GOW	0.	86.	34.	120.
GOWEN	CL	0-1	B.F.S	GCL	0.	0.	31.	31.
GOWEN	L	0-1	B.F	GOL	47.	99.	348.	494.
HARDEMAN	FSL	0-3	B.F.S	HAR	361.	726.	675.	1762.
HENSLEY	L	1-5	B.F	HEN	69.	172.	134.	375.
KONSIL	FSL	2-5	B.F.S	KOR	8.	87.	61.	156.
KIRKLAND	SIL	1-3	B.F	KIR	0.	0.	555.	555.
LABETTE	L	1-3	B.F	LAB	0.	10.	159.	169.
LEWISVILLE	CLL	1-5	B.F.S	LEW	205.	92.	73.	370.
LINCOLN		0-2	B.F	LIN	4543.	206.	0.	4749.
MILLER	C	0-1	B.F	MIL	1619.	871.	107.	2597.
MINCO	L	0-1	B.F.S	MIN	4466.	5955.	4391.	14812.
MINCO	FSL	0-1	B.F.S	MIF	3605.	3782.	1459.	8846.
MINCO	VFSL	0-3	B.F.S	MIV	2183.	1220.	184.	3587.
NORWOOD	CL	0-1	B.F	NOR	1525.	330.	0.	1855.
PONDCREEK	SIL	0-1	B.F.S	PON	121.	500.	542.	1163.
PORT	L	0-1	B.F.S	POR	28.	0.	32.	60.
PORT	SCL	0-1	B.F.S	POS	71.	208.	18.	297.
PULASKI	FSL	0-1	B.F.S	PUL	318.	427.	649.	1394.
RENFROW	L	1-4	B.F	REN	0.	54.	292.	346.
ROEBUCK	C	0-1	B.F	ROE	20.	148.	0.	168.
SLIDELL	[illegible]	1-3	B.F	SLI	0.	68.	101.	169.
SAN SABA	C	1-3	B.F	SAS	0.	68.	100.	168.
STEPHENVILLE	FSL	1-5	B.F.S	STE	210.	265.	898.	1373.
TELLER	L	0-1	B.F.S	TEL	1828.	4741.	3732.	10301.
TELLER	FSL	1-3	B.F.S	TEF	2006.	2909.	3057.	7972.
VANOSS	L	0-1	B.F.S	VAL	314.	241.	484.	1039.
VENUS	L	2-5	B.F.S	VER	23.	52.	221.	296.
WAURIKA		0-1	B.F	WAU	0.	0.	150.	150.
WILSON	CL	0-1	B.F	WIL	59.	33.	0.	92.
WINDTHORST	FSL	0-1	B.F	WIN	15.	222.	249.	486.
YAHOLA	FSL	1-5	B.F	YAH	9542.	5191.	473.	15206.
ZANEIS	L	1-3	B.F.S	ZAN	36.	145.	1842.	2023.
				TOTAL	38578.	38542.	34328.	111448.

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Table F-3. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 7

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
PORT	CL	I-2	B,F	POR	180.	439.	364.	983.
PORT	L	I-2	B,F,S	POT	0.	176.	483.	659.
TIPTON	L	1-3	B,F,S	TIP	10.	1086.	2737.	3833.
FOARD	SIL	0-1	B,F	FOA	0.	29.	469.	498.
TILLMAN	SIL	1-3	B,F	TIL	0.	0.	156.	156.
ENTERPRISE	VFSL	0-1	B,F,S	ENT	833.	3263.	3406.	7502.
YAHOLA	FSL	IIW	B,F,S	YAH	1434.	589.	92.	2115.
PRATT	LFS	IIIE	S	PRA	347.	1538.	544.	2429.
				TOTAL	2804.	7120.	8251.	18175.

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Table F-4. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 8

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
HOLLISTER	CL	0-1	B.F	HOL	0.	73.	155.	228.
MANGUM	CL	IIIW	B.F	MAN	6754.	3168.	1319.	11241.
TILLMAN	CL	1-3	B.F	TIL	434.	1054.	643.	2131.
WICHITA	CL	1-3	B.F	WIC	0.	0.	157.	157.
WINTERS	L	1-3	B.F	WIN	174.	136.	0.	310.
ASA	SICL	IIW	B.F.S	ASA	35.	174.	78.	287.
MANGUM	SICL	IIW	B.F	MAG	2757.	2539.	1003.	6299.
BLUEGROVE	L	1-3	B.F.S	BLU	1029.	3070.	3436.	7535.
FRANKIRK	L	0-1	B.F.S	FRA	38.	342.	612.	992.
NOTLEY	L	1-3	B.F.S	NAT	1823.	3349.	3234.	8406.
RENFROW	L	1-3	B.F.S	REN	0.	10.	184.	194.
WINTERS	L	0-1	B.F.S	WIS	1135.	3525.	3279.	7939.
TIPTON	L	0-1	B.F.S	TIP	0.	161.	387.	548.
CLAIREMONT	SIL		B.F.S	CLA	9284.	1945.	975.	12204.
DEANDALE	LS	0-1	B.F	DEA	71.	1376.	2090.	3537.
KAMAY	SIL	1-3	B.F	KAM	919.	2023.	3303.	6245.
KIRKLAND	SIL	1-3	B.F	KIR	0.	38.	0.	38.
PORT	SIL		B.F.S	POR	0.	73.	184.	257.
WESWOOD	SIL		B.F	WES	9036.	3037.	1208.	13281.
ENTERPRISE	VFSL	1-3	B.F.S	ENT	2636.	7120.	7675.	17431.
MINCO	VFSL	1-3	F.S	MIN	1823.	3332.	2616.	7771.
YOMONT	VFSL	IIS	B.F.S	YOM	9288.	858.	389.	10535.
DEVOL	FSL	1-3	F	DEV	1270.	2190.	2059.	5519.
HARDEMAN	FSL	1-3	B.F.S	HAR	51.	305.	1556.	1912.
GRANDFIELD	FSL	1-3	B.F.S	GRA	23.	217.	301.	541.
LINCOLN	FSL	IIIE	S	LIN	264.	701.	378.	1343.
TELLER	FSL	1-3	B.F.S	TEL	2641.	4826.	3788.	11255.
DEVOL	LFS	0-3	B.F.S	DEL	0.	0.	80.	80.
				TOTAL	51485.	45642.	41089.	138216.

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Table F-5. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 9

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
HENSLEY	CL	1-3	B.F	HEN	114.	412.	134.	660.
HOLLISTER	CL	0-1	B.F	HOL	27.	158.	78.	263.
LINDY	CL	1-3	B.F	LID	547.	0.	60.	607.
MANGUM	C	IIIW	B.F	MAN	2917.	1235.	683.	4835.
MERETA	CL	1-3	B.F	MER	271.	156.	14.	441.
SAGERTON	CL	1-3	B.F	SAG	425.	360.	337.	1122.
TILLMAN	CL	1-3	B.F	TIL	1191.	1617.	1755.	4563.
TOBOSA	CL	1-3	B.F	TOB	27.	297.	660.	984.
VERNON	CL	1-3	B.F	VER	1222.	1142.	986.	3350.
ASPERMONT	SICL	1-3	F	ASP	756.	356.	133.	1245.
FRIO	SICL	IIW	F	FRI	59.	0.	0.	59.
WINTERS	L	0-1	F	WIN	0.	0.	42.	42.
CLAIREMONT	SIL	IIE	F	CLA	6295.	3361.	2801.	12457.
KAMAY	SIL	0-1	B.F	KAM	85.	433.	211.	729.
ENTERPRISE	VFSL	1-3	F.S	ENT	1093.	380.	39.	1512.
HARDEMAN	FSL	3-5	F.S	HAR	450.	46.	59.	555.
YAHOLA	FSL	IIW	S	YAH	107.	0.	0.	107.
				TOTAL	15586.	9953.	7992.	33531.

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Table F-6. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 10

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
ABILENE	CL	0-1	B,F	ABL	0.	273.	15.	288.
HOLLISTER	CL	0-1	B,F	HOL	151.	345.	1172.	1668.
MANGUM	C	IIW	B,F	MAN	1610.	938.	99.	2647.
SPUR	CL	IIW	B,F	SPU	4916.	689.	73.	5678.
TILLMAN	CL	1-3	B,F	TIL	1090.	2648.	3512.	7250.
WICHITA	L	0-1	F	WIC	976.	799.	442.	2217.
YOMONT	VFSL	0-1	F,S	YOM	1004.	0.	0.	1004.
MILES	FSL	1-3	S	MIL	1309.	100.	0.	1409.
				TOTAL	11056.	5792.	5313.	22161.

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Table F-7. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 11

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
HOLLISTER	CL	I	B.F	HOL	0.	0.	323.	323.
MANGUM	C	IIIW	B.F	MAN	545.	219.	0.	764.
SAGERTON	CL	0-1	B.F	SAG	0.	9.	202.	211.
TILLMAN	CL	1-3	B.F	TIL	757.	540.	697.	1994.
WICHITA	CL	1-3	B.F	WIC	292.	422.	602.	1316.
CLAIREMONT	SIL	IIW	B.F.S	CLA	1746.	0.	0.	1746.
ENTERPRISE	VFSL	1-3	B.F.S	ENT	1007.	194.	0.	1201.
COBB	FSL	1-3	B.F.S	COB	0.	84.	55.	139.
HARDEMAN	FSL	3-5	B.F.S	HAR	857.	609.	213.	1679.
MILES	FSL	1-3	B.F.S	MIL	0.	74.	459.	533.
YAHOLA	FSL	IIW	B.F.S	YAH	2968.	0.	25.	2993.
LINCOLN		IIIE	S	LIN	2941.	0.	25.	2966.
				TOTAL	11113.	2151.	2601.	15865.

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Table F-8. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 12

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
PORT	SICL	IIW	B.F.S	POR	0.	47.	71.	118.
ABILENE	L	I-2	B.F	ABL	0.	0.	144.	144.
TIPTON	L	0-1	B.F.S	TFL	17.	1427.	1423.	2867.
ASA	SL	IIW	B.F.S	ASA	189.	195.	166.	550.
MINCO	VFSL	0-1	B.F.S	MIN	251.	1079.	1552.	2882.
CYRIL	FSL	IIW	B.F.S	CYR	0.	130.	513.	643.
DEVOL	FSL	0-1	B.F.S	DEV	0.	176.	730.	906.
GRANDFIELD	FSL	0-1	B.F.S	GRA	13.	326.	470.	809.
HARDEMAN	FSL	0-1	B.F.S	HAR	1054.	3467.	5230.	9751.
HARDEMAN	FSL	UND	B.F	HAU	390.	928.	2620.	3938.
TIPTON	FSL	0-1	B.F.S	TFS	35.	45.	658.	738.
DEVOL	LFS	UND	S	DEU	1553.	2550.	2756.	6859.
DEVOL	LFS	HUM	S	DEH	388.	804.	621.	1813.
GRANDFIELD	LFS	0-1	S	GRL	0.	54.	120.	174.
GRANDFIELD	LFS	UND	S	GRS	0.	60.	212.	272.
LINCOLN		IVS	S	LIN	1324.	220.	0.	1544.
YAHOLA		IIW	B.F.S	YAB	1513.	1170.	58.	2741.
LINCOLN		W	S	LIF	521.	324.	0.	845.
				TOTAL	7248.	13002.	17344.	37594.

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Table F-9. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 13

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
ABILENE	CL	0-1	B,F	ABL	0.	679.	1428.	2107.
CLAIREMONT	CL	0-1	B,F	CCL	460.	239.	464.	1163.
COLORADO	CL	W	B,F	COC	323.	77.	84.	484.
HOLLISTER	CL	0-1	B,F	HOL	0.	189.	514.	703.
MANGUM	CL	W	B,F	MAN	1844.	667.	176.	2687.
QUANAH	CL	1-3	B,F	QUA	25.	0.	0.	25.
PORT	CL	1-3	B,F	POR	0.	0.	159.	159.
SAGERTON	CL	1-3	B,F	SAG	128.	197.	416.	741.
SPUR	CL	W	B,F	SPU	757.	172.	203.	1132.
TILLMAN	CL	1-3	B,F	TIL	441.	679.	1666.	2786.
WICHITA	CL	1-3	B,F	WCL	29.	143.	66.	238.
BUKREEK	L	1-3	F	BUK	123.	65.	52.	240.
SAGERTON	L	0-1	F	SAL	106.	13.	66.	185.
TIPTON	L	0-1	B,F	TFL	57.	0.	0.	57.
WICHITA	L	1-3	F	WIL	273.	289.	292.	854.
COLORADO	SIL	W	B,F	CSL	445.	92.	0.	537.
TIPTON	SIL	0-1	F	TSL	866.	2935.	2818.	6619.
ENTERPRISE	VFSL	0-1	F,S	ENT	6907.	8433.	3407.	18747.
YOMONT	VFSL	1-3	S	YOM	3248.	550.	298.	4096.
ALTUS	FSL	SALINE	F,S	ALT	0.	0.	135.	135.
HARDEMAN	FSL	1-3	F,S	HAR	1413.	2268.	2207.	5888.
MILES	FSL	0-1	F,S	MSL	684.	3900.	5210.	9794.
LINCOLN	LFS	SALINE	S	LIN	3515.	2470.	1743.	7728.
MILES	LFS	0-3	S	MFS	0.	620.	2742.	3362.
SPRINGER	LFS	UND	S	SPR	397.	1875.	4198.	6470.
CLAIREMONT	SIL	1-3	F	CLS	124.	53.	172.	349.
				TOTAL	22170.	26605.	28511.	77286.

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Table F-10. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 14

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
ABILENE	CL	0-1	B.F	ABL	267.	932.	1039.	2238.
ACME	CL	1-3	B.F.S	ACM	11.	14.	0.	25.
HOLLISTER	CL	0-1	B.F	HCL	275.	1843.	3234.	5352.
LA CASA	CL	1-3	B.F	LAC	69.	399.	179.	647.
MANGUM	CL	IIIS	B.F	MAN	751.	540.	185.	1476.
PORT	CL	IIW	B.F	PCL	560.	701.	544.	1805.
SPUR	CL	IIW	B.F	SPU	2609.	1325.	697.	4631.
TILLMAN	CL	1-3	B.F	TIL	589.	1707.	3504.	5800.
HOLLISTER	SICL	0-1	B.F	HSL	0.	321.	782.	1103.
PORT	SICL	IIW	B.F	PSL	209.	707.	485.	1401.
CAREY	L	1-3	B.F.S	CAR	10.	82.	11.	103.
CYRIL	L	IIE	F	CYR	1941.	1152.	0.	3093.
LAWTON	L	0-1	B.F.S	LAW	1383.	3022.	2988.	7393.
LUGERT	L	IIE	F	LUG	170.	865.	678.	1713.
SPUR	L	IIW	B.F.S	SPL	5445.	577.	140.	6162.
TIPTON	L	0-1	F	TIP	3803.	2646.	1465.	7914.
WOODWARD	L	3-5	B.F.S	WOO	152.	450.	443.	1045.
CAREY	SIL	1-3	F	CAL	0.	82.	313.	395.
FOARD	SIL	0-1	B.F.S	FOA	0.	0.	40.	40.
ST. PAUL	SIL	0-1	B.F.S	STP	1309.	2913.	3681.	7903.
ENTERPRISE	VFSL	1-3	B.F.S	ENT	2411.	1621.	694.	4726.
ALTUS	FSL	0-1	F.S	ALT	1559.	3227.	3152.	7938.
GRANDFIELD	FSL	1-3	F.S	GRL	0.	83.	302.	385.
HARDEMAN	FSL	1-3	F.S	HAR	791.	433.	124.	1348.
MILES	FSL	1-3	F.S	MSL	1002.	2437.	2449.	5888.
YAHOLA	FSL	IIE	F.S	YAH	6855.	576.	105.	7536.
DEVOL	LFS	0-3	S	DEV	203.	559.	87.	849.
BROWNFIELD	LFS	0-3	S	BRO	47.	202.	282.	531.
ENTERPRISE	LFS	0-3	F.S	EFS	838.	516.	0.	1354.
LINCOLN	LFS	IIIE	S	LIN	1438.	38.	731.	2207.
MENO	LFS	IIIE	B.F.S	MEN	8.	126.	135.	269.
MILES	LFS	0-3	S	MFS	617.	650.	975.	2242.
SPRINGER	LFS	0-3	S	SPR	347.	972.	1356.	2675.
ALTUS	LFS	IIIE	B.F.S	ALS	7.	127.	135.	269.
				TOTAL	35676.	31845.	30935.	98456.

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Table F-11. Acreage by Zone (.5, 1.0, and 1.5 Miles from the River) for Each Soil Classification - Reach 15

SOIL NAME	TEXTURE*	SLOPE**	REC.*** IRR. TYPE	L.P. CODE NAME	ACRES ZONE 1	ZONE 2	ZONE 3	TOTAL
ABILENE	CL	0-1	B,F	ABL	0.	0.	12.	12.
HOLLISTER	CL	0-1	B,F	HOL	0.	100.	675.	775.
QUANAH	CL	1-3	B,F	QUA	11.	393.	859.	1263.
MANSKER	CL	1-3	B,F	MAN	44.	0.	0.	44.
SPUR	CL		B,F	SPU	62.	381.	982.	1425.
TILLMAN	CL	0-1	B,F	TIL	41.	259.	990.	1290.
MANGUM	SICL	1-2	B,F	MAG	185.	13.	0.	198.
PORT	SICL	0-2	B,F	POR	0.	13.	0.	13.
STANFORD	SICL	2-5	F	STA	0.	0.	81.	81.
TILLMAN	CL	2-5	B,F	TIC	0.	0.	118.	118.
TIPTON	L	0-1	F	TIF	777.	2079.	2492.	5348.
COLORADO	SIL		B,F	COL	61.	0.	49.	110.
TILLMAN	SIL	2-5	B,F	TIS	0.	0.	78.	78.
ST. PAUL	SIL	0-2	B,F	STP	0.	24.	0.	24.
CAREY	VFSL	0-2	F,S	CAR	223.	182.	231.	636.
ENTERPRISE	VFSL	1-3	F,S	ENT	2860.	3695.	1784.	8339.
WEYMOUTH	VFSL	2-4	F,S	WEY	90.	539.	812.	1441.
YOMONT	VFSL	0-2	F,S	YOM	365.	121.	0.	486.
ALTUS	VFSL	0-1	F,S	ALT	0.	0.	99.	99.
HARDEMAN	FSL	1-3	F,S	HAR	2027.	2903.	2412.	7342.
MILES	FSL	1-3	F,S	MIL	64.	558.	1824.	2446.
YAHOLA	FSL	0-2	F,S	YAH	796.	378.	319.	1493.
ENTERPRISE	LFS	2-6	F,S	ENS	525.	1948.	2068.	4541.
MILES	LFS	0-3	S	MIS	0.	326.	1070.	1396.
SPRINGER	LFS	UND	S	SPR	537.	3128.	4765.	8430.
				TOTAL	8668.	17040.	21720.	47428.

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APPENDIX G

Example of Budgets Developed by the Matrix Generator

COSTS AND RETURNS -- 1990

CROP CODE	NET REVENUE	TOTAL REVENUE	FIXED COST	VARIABLE COSTS WATER	FERT.	HARVEST	OTHERPH	INT.	MGT	TOTAL	WATER APPL.	FERTILIZER N	P205	K20	YIELD
S1ABL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
F1ABL113	63.14	349.20	32.16	42.45	24.92	69.97	87.94	5.53	23.08	253.90	21.3	71.0	65.6	11.0	612.6
M1ABL113	28.17	133.24	11.43	0.0	10.23	26.56	46.33	2.01	8.51	93.64	0.0	29.2	29.2	0.0	233.7
S2ABL113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
F2ABL113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2ABL113	0.0	0.0	8.44	0.0	0.0	8.00	28.84	1.03	3.79	41.65	0.0	0.0	0.0	0.0	0.0
S3ABL113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
F3ABL113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3ABL113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6ABL113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
F6ABL113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6ABL113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4ABL113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
F4ABL113	0.0	153.89	40.02	125.24	23.10	65.83	7.98	5.57	22.77	250.49	62.9	91.8	30.6	15.3	3.1
M4ABL113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8ABL113	3.03	5.25	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.6
S1CCL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
F1CCL113	136.19	450.58	32.16	42.45	30.18	90.29	87.94	5.72	25.66	282.23	21.3	85.8	73.0	25.8	790.5
M1CCL113	53.36	169.57	11.43	0.0	13.02	33.80	46.33	2.11	9.53	104.78	0.0	37.2	37.2	0.0	297.5
S2CCL113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
F2CCL113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2CCL113	4.68	71.40	8.44	0.0	10.00	12.76	28.84	1.38	5.30	58.28	0.0	28.6	28.6	0.0	19.0
S3CCL113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
F3CCL113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3CCL113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6CCL113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
F6CCL113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6CCL113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4CCL113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
F4CCL113	0.0	230.83	40.02	125.24	38.64	98.74	7.98	6.12	27.67	304.39	62.9	155.4	45.9	31.8	4.6
M4CCL113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8CCL113	4.65	6.87	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.8
S1COC113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
F1COC113	63.14	349.20	32.16	42.45	24.92	69.97	87.94	5.53	23.08	253.90	21.3	71.0	65.6	11.0	612.6
M1COC113	36.57	145.35	11.43	0.0	11.16	28.97	46.33	2.05	8.85	97.35	0.0	31.9	31.9	0.0	255.0
S2COC113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
F2COC113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2COC113	0.0	63.75	8.44	0.0	8.93	12.25	28.84	1.35	5.14	56.50	0.0	25.5	25.5	0.0	17.0
S3COC113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
F3COC113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3COC113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6COC113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
F6COC113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6COC113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4COC113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
F4COC113	0.0	192.36	40.02	125.24	28.88	82.28	7.98	5.77	25.02	275.17	62.9	114.7	38.2	19.1	3.8
M4COC113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8COC113	4.45	6.67	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.8
S1HOL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
F1HOL113	46.91	326.67	32.16	42.45	23.75	65.46	87.94	5.49	22.51	247.60	21.3	67.7	63.9	7.7	573.1
M1HOL113	19.77	121.12	11.43	0.0	9.30	24.14	46.33	1.98	8.18	89.93	0.0	26.6	26.6	0.0	212.5

COSTS AND RETURNS -- 1990

CROP CODE	NET REVENUE	TOTAL REVENUE	FIXED COST	VARIABLE COSTS WATER	FERT.	HARVEST	OTHERPH	INT.	MGT	TOTAL	WATER APPL.	FERTILIZER N	P205	K20	YIELD
S1ABL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
P1ABL113	63.14	349.20	32.16	42.45	24.92	69.97	87.94	5.53	23.08	253.90	21.3	71.0	65.6	11.0	612.6
M1ABL113	28.17	133.24	11.43	0.0	10.23	26.56	46.33	2.01	8.51	93.64	0.0	29.2	29.2	0.0	233.7
S2ABL113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
P2ABL113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2ABL113	0.0	0.0	8.44	0.0	0.0	8.00	28.84	1.03	3.79	41.65	0.0	0.0	0.0	0.0	0.0
S3ABL113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
P3ABL113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3ABL113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6ABL113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
P6ABL113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6ABL113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4ABL113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
P4ABL113	0.0	153.89	40.02	125.24	23.10	65.83	7.98	5.57	22.77	250.49	62.9	91.8	30.6	15.3	3.1
M4ABL113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8ABL113	3.03	5.25	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.6
S1CCL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
P1CCL113	136.19	450.58	32.16	42.45	30.18	90.29	87.94	5.72	25.66	282.23	21.3	85.8	73.0	25.8	790.5
M1CCL113	53.36	169.57	11.43	0.0	13.02	33.80	46.33	2.11	9.53	104.78	0.0	37.2	37.2	0.0	297.5
S2CCL113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
P2CCL113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2CCL113	4.68	71.40	8.44	0.0	10.00	12.76	28.84	1.38	5.30	58.28	0.0	28.6	28.6	0.0	19.0
S3CCL113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
P3CCL113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3CCL113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6CCL113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
P6CCL113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6CCL113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4CCL113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
P4CCL113	0.0	230.83	40.02	125.24	38.64	98.74	7.98	6.12	27.67	304.39	62.9	155.4	45.9	31.8	4.6
M4CCL113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8CCL113	4.65	6.87	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.8
S1COC113	0.0	0.0	34:81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
P1COC113	63.14	349.20	32.16	42.45	24.92	69.97	87.94	5.53	23.08	253.90	21.3	71.0	65.6	11.0	612.6
M1COC113	36.57	145.35	11.43	0.0	11.16	28.97	46.33	2.05	8.85	97.35	0.0	31.9	31.9	0.0	255.0
S2COC113	0.0	0.0	32.12	53.30	0.0	8.00	43.42	3.45	10.82	118.98	19.1	0.0	0.0	0.0	0.0
P2COC113	0.0	153.32	29.46	42.98	21.31	24.53	43.42	3.84	13.61	149.69	21.6	60.9	60.9	0.0	40.9
M2COC113	0.0	63.75	8.44	0.0	8.93	12.25	28.84	1.35	5.14	56.50	0.0	25.5	25.5	0.0	17.0
S3COC113	0.0	0.0	41.34	66.72	0.0	7.00	37.79	3.72	11.52	126.76	24.7	0.0	0.0	0.0	0.0
P3COC113	0.0	130.48	38.60	55.72	17.51	14.64	37.79	3.95	12.96	142.57	28.0	53.6	35.7	19.7	41.8
M3COC113	4.50	66.30	10.88	0.0	6.23	10.19	28.63	1.24	4.63	50.92	0.0	21.3	14.2	0.0	21.3
S6COC113	0.0	0.0	47.07	159.00	0.0	0.0	16.98	6.27	18.23	200.48	63.5	0.0	0.0	0.0	0.0
P6COC113	0.0	0.0	43.69	143.28	0.0	0.0	16.98	5.71	16.60	182.57	72.0	0.0	0.0	0.0	0.0
M6COC113	0.0	0.0	14.91	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
S4COC113	0.0	0.0	43.27	139.99	0.0	0.0	7.98	5.27	15.32	168.56	55.5	0.0	0.0	0.0	0.0
P4COC113	0.0	192.36	40.02	125.24	28.88	82.28	7.98	5.77	25.02	275.17	62.9	114.7	38.2	19.1	3.8
M4COC113	0.0	0.0	7.31	0.0	0.0	0.0	4.98	0.18	0.52	5.67	0.0	0.0	0.0	0.0	0.0
M8COC113	4.45	6.67	0.34	0.0	0.0	0.0	1.65	0.06	0.17	1.88	0.0	0.0	0.0	0.0	0.8
S1HOL113	0.0	0.0	34.81	52.74	0.0	0.0	87.94	5.01	14.57	160.26	18.8	0.0	0.0	0.0	0.0
P1HOL113	46.91	326.67	32.16	42.45	23.75	65.46	87.94	5.49	22.51	247.60	21.3	67.7	63.9	7.7	573.1
M1HOL113	19.77	121.12	11.43	0.0	9.30	24.14	46.33	1.98	8.18	89.93	0.0	26.6	26.6	0.0	212.5

APPENDIX H

Example of Report Writer Output

Table H-1. Optimal Cropping Pattern Summary For The Modified System, Reach 13.

CROP	YEAR 1990	2000	2010	2020	2030	2040
IRRCOT13	39045.00	39045.00	39045.00	39045.00	39045.00	39045.00
DRYCOT13	14658.00	30513.00	30513.00	30513.00	30513.00	30513.00
IRRSOR13	0.0	0.0	0.0	0.0	0.0	0.0
DRYSOR13	0.0	0.0	7728.00	7728.00	7728.00	7728.00
IRRWHT13	0.0	0.0	0.0	0.0	0.0	0.0
DRYWHT13	0.0	0.0	0.0	0.0	0.0	0.0
IRRALF13	0.0	0.0	0.0	0.0	0.0	0.0
DRYALF13	23583.00	7728.00	0.0	0.0	0.0	0.0
IRRCST13	0.0	0.0	0.0	0.0	0.0	0.0
DRYCST13	0.0	0.0	0.0	0.0	0.0	0.0
DRYNAP13	0.0	0.0	0.0	0.0	0.0	0.0
TRANS13	44673.00	44673.00	44673.00	44673.00	44673.00	44673.00
IRACRE13	39045.00	39045.00	39045.00	39045.00	39045.00	39045.00
CRPLND13	32613.00	32613.00	32613.00	32613.00	32613.00	32613.00
WATER AVAIL.	1188000.00	1188000.00	1188000.00	1188000.00	188000.00	1188000.00
WATER USED	821418.50	821418.50	821418.50	821418.50	821418.50	821418.50
WATER MV	0.0	0.0	0.0	0.0	0.0	0.0
NOMINAL NET REVENUE ($MIL)	3.15484	4.83746	6.67043	8.59325	10.52937	12.48805

Table H-2. Net Revenue Summary For The Optimal Cropping Plans For The Modified System, Reach 13.

YEAR	NOMINAL VALUE THIS YEAR	PRESENT VALUE THIS YEAR (7 1/8% RATE)	PRESENT VALUE TOTAL TO DATE (7 1/8% RATE)	PRESENT VALUE THIS YEAR (3 1/4% RATE)	PRESENT VALUE TOTAL TO DATE (3 1/4% RATE)
	----	----	$ MILLION	----	----
1990	3.15484	3.15484	3.15484	3.15484	3.15484
1991	3.32310	3.10208	6.25691	3.21850	6.37334
1992	3.49136	3.04238	9.29929	3.27503	9.64837
1993	3.65962	2.97690	12.27619	3.32481	12.97318
1994	3.82788	2.90667	15.18286	3.36822	16.34138
1995	3.99615	2.83262	18.01546	3.40560	19.74698
1996	4.16441	2.75555	20.77101	3.43728	23.18427
1997	4.33267	2.67621	23.44722	3.46360	26.64786
1998	4.50093	2.59523	26.04245	3.48486	30.13271
1999	4.66919	2.51319	28.55563	3.50135	33.63406
2000	4.83746	2.43058	30.98622	3.51334	37.14740
2001	5.02076	2.35489	33.34109	3.53170	40.67909
2002	5.20406	2.27852	35.61961	3.54541	44.22450
2003	5.38735	2.20189	37.82150	3.55476	47.77925
2004	5.57065	2.12537	39.94685	3.56001	51.33926
2005	5.75394	2.04930	41.99615	3.56140	54.90065
2006	5.93724	1.97393	43.97008	3.55918	58.45982
2007	6.12054	1.89953	45.86960	3.55357	62.01338
2008	6.30383	1.82630	47.69588	3.54479	65.55817
2009	6.48713	1.75440	49.45029	3.53305	69.09120
2010	6.67042	1.68399	51.13426	3.51852	72.60973
2011	6.86271	1.61730	52.75156	3.50601	76.11572
2012	7.05499	1.55203	54.30359	3.49080	79.60651
2013	7.24728	1.48829	55.79189	3.47307	83.07956
2014	7.43956	1.42616	57.21803	3.45299	86.53255
2015	7.63184	1.36572	58.58376	3.43074	89.96329
2016	7.82412	1.30700	59.89075	3.40647	93.36975
2017	8.01640	1.25006	61.14079	3.38033	96.75008
2018	8.20869	1.19490	62.33569	3.35246	100.10252
2019	8.40097	1.14156	63.47723	3.32300	103.42551
2020	8.59325	1.09002	64.56726	3.29206	106.71758
2021	8.78686	1.04045	65.60771	3.26028	109.97784
2022	8.98047	0.99265	66.60034	3.22724	113.20508
2023	9.17409	0.94661	67.54694	3.19304	116.39812
2024	9.36770	0.90229	68.44922	3.15780	119.55591
2025	9.56131	0.85969	69.30890	3.12162	122.67752
2026	9.75492	0.81876	70.12766	3.08458	125.76210
2027	9.94853	0.77947	70.90714	3.04679	128.80888
2028	10.14214	0.74179	71.64891	3.00831	131.81720
2029	10.33575	0.70567	72.35457	2.96925	134.78642
2030	10.52936	0.67108	73.02563	2.92965	137.71608
2031	10.72524	0.63810	73.66374	2.89022	140.60628
2032	10.92110	0.60654	74.27026	2.85037	143.45665
2033	11.11697	0.57635	74.84660	2.81017	146.26682
2034	11.31284	0.54749	75.39409	2.76967	149.03647
2035	11.50871	0.51993	75.91400	2.72893	151.76540
2036	11.70458	0.49361	76.40761	2.68802	154.45341
2037	11.90044	0.46849	76.87608	2.64698	157.10039
2038	12.09631	0.44453	77.32060	2.60585	159.70624
2039	12.29218	0.42168	77.74228	2.56470	162.27092
2040	12.48805	0.39991	78.14218	2.52355	164.79448
TOTAL PRESENT VALUE (100 YEARS)			83.57512		226.75075