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A Model for Estimating Demand for Irrigation Water on the Texas High Plains

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ABSTRACT

With rapidly changing conditions in production agriculture, the need for highly flexible and quickly applicable methods of analysis is emphasized. The purpose of this study was to develop such a model for a homogeneous production region in the Texas High Plains.

A linear programming model was constructed whereby crop or input prices are readily adjustable. In addition, limitations on quantities of inputs available can easily be evaluated. The model contains cotton, grain sorghum, corn, wheat and soybeans. Inputs that can be evaluated include irrigation water, natural gas, diesel, nitrogen fertilizer and herbicides. The primary focus of this work was to estimate the demand for irrigation water in the study area.

The model was applied using alternative crop prices and input prices. Assuming average crop prices, current input prices and only variable costs of production, as the price of water was increased wheat shifted from irrigated to dryland production, then grain sorghum, cotton, corn and soybeans, in that order. The price of water was $71.75 per acre foot plus current pumping cost when all land shifted to dryland production.

The same analysis, except variable and fixed costs both included, gave similar results relative to the sequence of crops that shift to dryland production as the price of water was increased. However, the shifts occurred at much lower water prices; i.e., at $24.47 per acre foot plus current pumping costs, all land had shifted to dryland production. This suggests that over the long run, irrigation in the Texas High Plains is quite sensitive to the price of energy used in pumping water. Further, there are strong implications relative to farmer's "ability to pay" for

water imported to the High Plains from other regions.

In this report, several scenarios including low, high and average crop prices and average and high input prices were evaluated.

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Introduction

Agricultural producers, policy-makers, and consumers are aware today, as never before, of the critical importance of U.S. agricultural production in meeting national and world food and fiber requirements. Texas producers play a vital role in this endeavor, leading the nation in 1973 in production of upland cotton, grain sorghum, several vegetables, beef cattle, and sheep (Texas Crop and Livestock Reporting Service). Texas production has been significantly increased in several of the semi-arid regions through irrigation of crops from groundwater aquifers. In fact, in 1973, irrigated production accounted for 50 percent of all grain sorghum and 46 percent of all cotton produced in Texas. These two crops alone represented 26 percent of cash receipts from the sale of farm commodities in Texas in that year (Texas Crop and Livestock Reporting Service).

Statement of the Problem

Groundwater supplies in some regions of Texas are being exhausted rapidly because rates of irrigation pumpage greatly exceed rates of recharge from percolation and other sources. These exhaustible aquifers underlie some of the most productive agricultural regions in the State, such as the Texas High Plains, which is underlain by the Ogallala Aquifer. State planners have been aware of this problem for many years; however, there have been no simple solutions. One solution which has been put forth is the transfer of water into Texas from out-of-state sources for the purpose of sustaining irrigated crop production in these areas (Texas Water Development Board).

The current concern in national policy circles regarding national and world food supplies in the future has certainly provided justification for investigation of measures to prevent the return to dryland production of large areas of Texas. However, the planning environment which faces water planners today has many variables which may greatly affect the outcome of their proposals. First, output prices for farm products have fluctuated dramatically under the effects of simultaneous removal of federal farm programs and entrance of the U.S. into many new export markets. This fluctuation alone has generated uncertainty for producers regarding cropping patterns and level of production decisions. Secondly, input prices have risen rapidly under the influence of general inflation and the energy crisis. Fuel and fertilizer prices in many cases have doubled in recent years. This situation coupled with the uncertainty regarding output prices has generated an entirely new decision framework within which neither the producer, nor the water planner has sufficient experience.

Past studies of the demand for irrigation water in Texas (Harman, et.al.) were not developed under this new decision framework, and could not foresee the situation as it is today. Further, it seems reasonable to expect that the decision framework of the future will differ from that of today. Therefore a critical problem faced by water planners today is the development of a model which will allow the planning process to adjust rapidly to changes in the decision making environment. It is imperative that the effects of variables such as fuel and fertilizer input prices and crop output prices on derived demand for irrigation water be estimated in a timely manner. Only then can effective and efficient plans be developed for dealing with the depletion of ground water supplies in Texas.

Objectives of the Study

The general purpose of this study was to develop the capability to estimate the demand for irrigation water in a timely manner under a situation of changing input and output prices. The specific objective of this study was to develop a model of a subregion of the Texas High Plains with the capability of estimating the quantities of irrigation water which will be demanded at alternative prices for water, based on current and expected future levels of prices for agricultural products and production inputs.

The Study Area

The "hardlands" or Pullman clay soils area south of the Canadian River in the Texas High Plains was selected as the study area (see Figure 1). This area is identified in the Texas Crop Budgets (Area Economists-Management, TAEX) as Texas High Plains, Subregion II.[1] It encompasses about 14,000 square miles or nine million acres of fairly level land with elevations ranging up to 4,000 feet above sea level. The region has a growing season of about 200 days with 16 to 20 inches of annual rainfall (Texas Almanac). Approximately 4.5 million acres are currently in cultivation with 2.8 million of these acres under irrigation (New, 1973).

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[1] The study area consists of the following counties: Armstrong, Briscoe, Carson, Castro, Crosby, Deaf Smith, Floyd, Gray, Hale, Oldham, Parmer, Potter, Randall, and Swisher.

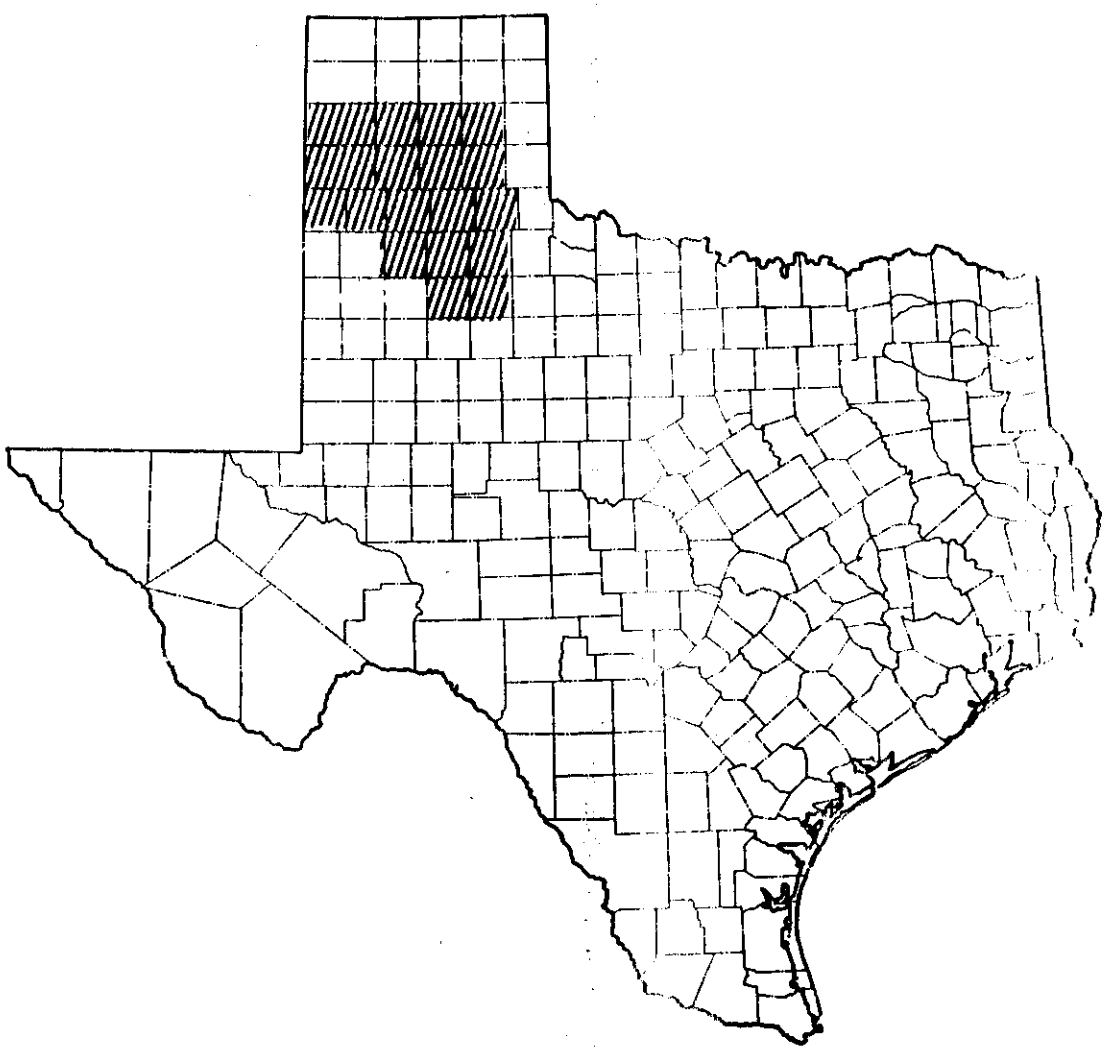

Figure 1. The Study Area

Major crops in the area are cotton, grain sorghum, wheat, corn, and soybeans. Other crops such as sugar beets and vegetables are grown; however, in 1973 the five major crops accounted for over 96 percent of the planted acreage. During this year the region produced over 600 thousand bales of cotton, 67 million hundredweight of grain sorghum, 31 million bushels of corn, 3 million bushels of soybeans, and 33 million bushels of wheat (Texas Crop and Livestock Reporting Service).

Methodology

Linear Programming

Linear programming (LP) was selected as the analytical technique since it provides an effective tool for allocating a given quantity of land, water and other inputs so as to maximize net returns to the producer. Basically the LP model developed in this study maximizes aggregate producer net returns subject to resource restraints.

There are several assumptions which underlie the LP technique. The brevity of the following discussion of these assumptions should not lead to the conclusion that they are unimportant in interpretation of model solutions. If more detailed discussion is desired the reader should consult Heady and Agrawal (pp. 30-33) or any standard operations research text. The basic assumptions are as follows:

1. All resources and activities are assumed to be additive allowing no complementarity between cropping activities, i.e., particular rotational patterns.

2. The objective function is assumed to be linear, suggesting that demand for regional outputs is completely elastic.

3. All activities must be non-negative, i.e., greater than or equal to zero.

4. Activities and resources are assumed to be completely divisible.

5. Activities and resources restrictions are assumed to be finite in number hence all points on crop production functions will not be considered.

6. Activity levels are assumed to be proportional to resource use, which implicitly assumes linearity of crop production functions.

7. It is assumed that prices and technical coefficients are known and fixed for a given solution (excluding parametric procedures).

Previous Studies

Moore and Hedges reported in 1963 on the application of the LP technique in estimation of static-normative demand for irrigation water in Tulare County, California. Derived demand schedules for irrigation water were developed for a series of representative farms using a parametric objective function approach. These schedules were then aggregated on a weighted basis to approximate the regional demand for irrigation water.

In 1973, Shumway reported on a study conducted for the west side of the San Joaquin Valley of California. This model, unlike that of Moore and Hedges, was based on the least cost pattern of production of a given level of outputs. The parametric objective function approach was used to generate a derived demand curve for the region directly, rather than for a series of representative farms.

A study of the Yanco irrigation area was reported by Flinn in 1969 in which farms were stratified by acreage allotments and irrigable area. Separate constraints were imposed on institutionally and market allocated water. Emphasis was also placed on intertemporal demands for water and the effects of varying prices in different periods of water use.

Yaron's analysis of the demand for irrigation water by Israeli agriculture in 1967 has been used as a model for several of the studies reviewed; however, it differs from those previously described in its approach to generation of the demand schedule. A variable resource approach was applied to yield the marginal value product or shadow price of water.

Kelso, Martin, and Mack reported in 1973 on the results of an extensive project to analyze the water resource situation in Arizona. This study was quite thorough and embodied strong points from several of the previously reviewed studies.

Gisser developed a model for forecasting demand for imported water to the Pecos River Basin. Constraints were specified for local water use based on salinity conditions. He pointed out that estimation of groundwater pumping cost functions is critical in any study dealing with stabilization of groundwater levels. Conclusions concerning ultimate outcomes will not likely be affected, but time schedules may be grossly biased.

Harmon, Hughes, and Martin estimated the individual High Plains producer's long run demand for irrigation water in 1970. This study was based on alternative assumptions about required net returns and 1964 input price levels. Several output price levels were analyzed, however, no provision was made for updating this study to changing conditions.

Gray and Trock studied the effect of varying water prices on quantities of water used, cropping patterns, and enterprise combinations in the Lower Rio Grande Basin. This study was very thorough and has provided the basic methodological foundation for development of the High Plains model reported herein. The Rio Grande model did not, on the other hand, extend to the analysis of changing input and output prices.

Development of the HPII Model

One of the primary considerations in development of the HPII model was maintenance of a high degree of flexibility. LP is primarily a static technique, therefore maximum flexibility is required to adapt the model to a dynamic environment. The areas in which flexibility has been emphasized are output prices, cropping patterns, water prices, groundwater pumping costs, fuel and fertilizer input prices, and long run versus short-run perspectives.

Major crops were specified as production enterprises based on their importance in the region and their degree of relationship to irrigation water demand. Production from these enterprises is transferred to output selling activities which allow adjustment of product prices with a minimun of effort. Separate selling activities were provided for each crop.

Changing output prices and the diminishing influence of federal farm programs can be expected to result in shifts in cropping patterns from those currently in practice. Crop acreage flexibility restraints were estimated using linear regression analysis for each of the study crops following procedures developed in several other studies (Day; Henderson; Miller; Nerlove; Sahi and Craddock; Schaller; Condra and Lacewell). Restraints were based on historical time series data and reflect the maximum "expected" increase or decrease in acreage of a given crop in a year. The particular level of a given restraint is jointly determined by the base acreage and the flexibility coefficient. In most cases the base acreage used was an average of the past three years' acreage. The flexibility coefficient (B) is the percentage increase or decrease in acreage allowable in a given year. Mathematically the relationship appears as follows:

$$\bar{X}_t = (1+\bar{B}) \left[\frac{\sum_{n=1}^{3} (X_{t-n})}{3} \right]$$

$$\underline{X}_t = (1-\underline{B}) \left[\frac{\sum_{n=1}^{3} (X_{t-n})}{3} \right]$$

where

$\bar{X}_t$ = upper crop acreage flexibility restraint

$\underline{X}_t$ = lower crop acreage flexibility restraint

$\bar{B}$ = upper crop acreage flexibility coefficient

$\underline{B}$ = lower crop acreage flexibility coefficient

Flexibility coefficients ($1+\bar{B}$; $1-\underline{B}$) were estimated using linear regression through the origin with a slope dummy variable to differentiate between years of increase and decrease. Three year averages (1972-74) were used in all cases where sufficient data were available since use of 1973 or 1974 acreage as a base might result in the use of an atypical base due to recent adjustments to fluctuating crop prices and weather conditions on the High Plains.

Utilization of the crop acreage flexibility restraint approach has removed many of the normative characteristics of LP models. The effect of this approach is constaint of the optimum solution to a subset of solutions which might be reasonably expected within the relevant time frame, given a certain historic behavior pattern of producers in selection of crop enterprises. Thus, the assumption that the producer will allocate resources in order to maximize net returns is relaxed such that he will tend to adjust his decisions over time toward the 'optimum' cropping pattern with some lag between changes in the production cost and returns situation and total adjustment.

Purchasing activities were constructed for consideration of price level changes for water, pumping costs, and fuel and fertilizer inputs. These prices may be changed individually for analysis of specific situations or parametrically to generate derived demand schedules for the particular input (i.e., water, natural gas). All other input costs (except a dryland renting activity) were included in the objective function for the particular crop enterprise.

The planning horizon is also a variable which seriously affects the producer's reactions to changes in his decision environment. It has been assumed in this study that the producer, in the short run, tends to consider only variable (out-of-pocket) costs in his resource allocation decisions. Depreciation, management charges, land charges, and other fixed costs are typically disregarded as "sunk" costs in the short run, but in the long run these costs must be covered. Therefore, the long run planning horizon will include fixed costs since field machines and pumping equipment deteriorate and must be replaced. The HPII model was developed with two objective functions -- one which includes only owner operator variable costs of production, and one which includes all costs of production for the owner-operator (except returns to water and risk). The net returns of the short run objective function include returns to water, risk, management, dryland, and fixed factors of production. The net returns of the long run objective function include only returns to water and risk-bearing. This allows selection of the relevant planning horizon in application of the model.

The HPII model is applicable in many specific situations; however, it is felt that these generally fall within three categories. First, it can serve as a tool to generate derived demand schedules for inputs. Input prices can be varied individually or simultaneously and assumptions regarding output price levels can be altered to analyze the effect upon derived input demand.

Secondly, output prices can be varied to estimate quasi-output supply response functions. It should be noted that both the derived demand and output response functions are "stepped". This is a characteristic which results from the LP technique and its attendant assumptions. Regression analysis has also been applied to the "stepped" functions by some researchers, yielding "smooth" curves for estimation of price elasticities of demand for inputs and supply of outputs (Moore and Hedges).

The third major category of application lies in the area of agricultural and natural resources policy research. The flexibility which has been provided within the model will allow policy makers to adjust price assumptions or other parameters to investigate policy implications in terms of agricultural output, input usage, land use patterns, etc. These applications have had particular relevance in recent years with controversial issues of federal farm programs, land use planning, water use planning, and energy allocation.

Model Characteristics

The LP matrix for the HPII model is presented in Appendix B. The specific coefficients will not be given in this discussion, however, they can be easily determined by reference to the matrix.

Crop Enterprises

Crop enterprise budgets were developed for cotton, grain sorghum, and wheat produced dryland and with different levels of irrigation. Only single-level irrigated alternatives were considered for corn and soybeans. It has been assumed that all irrigated enterprises are under furrow irrigation and management for all crop enterprises is typical or average.

Production Input-Output Coefficients

The production input-output coefficients were developed by modifying the Texas Crop Budgets (Extension Economists-Management) using the Oklahoma State University Crop Budget Generator Program (Walker and Kletke). These modifications included assumptions that all machinery operations are performed with owner-operator machinery and that all groundwater pumping units utilize natural gas. All fuel use other than natural gas was converted to diesel equivalents. Intermediate levels of irrigation for cotton, grain sorghum and wheat were developed (Sartin) since they were not available in the Texas Crop Budgets.

Production Costs

All production costs were included in the objective function for the crop enterprise except those associated with input purchasing activities. The latter category will be discussed separately in the section dealing exclusively with these activities. The costs of production included in the crop enterprise objective function values were divided into variable and fixed costs of production. These costs were derived from the Texas Crop Budgets (Extension Economists-Management) and other sources described in the discussion of production coefficients. Variable costs were included in the first objective function and total costs were included in the second objective function (see Matrix in Appendix B for OBJF1 and OBJF2). The first objective function (OBJF1) was designed for analysis of short run decisions where the producer considers only out-of-pocket expenses, whereas, the second objective function (OBJF2) is more relevant in situations involving capital investment, such as a water project feasibility study.

Input Purchasing Activities

Separate input purchasing activities were specified for water, natural gas, diesel, herbicide, and nitrogen fertilizer. These activities were developed under the assumption that supplies to the producer are limited only by his willingness to pay the market price. The objective function coefficients of these activities were specified per unit. Current input prices were used (Sartin; Osborn; Grubb) unless specified otherwise in the particular application. These prices are as follows:

Water	No charge beyond current pumping costs
Natural gas	\$.88 per thousand cubic feet
Diesel	\$.40 per gallon
Nitrogen fertilizer -	\$.20 per pound

Nitrogen fertilizer prices are currently above \$.20 per pound for dry or granular mixes. However, the HPII region of Texas utilizes anhydrous ammonia as a source of nitrogen for the vast majority of its needs with dry mixes only comprising a small part of total use. Anhydrous is currently priced at $.16 per pound and typical dry fertilizer costs about $.28 per pound. Weighting the prices of anhydrous and dry fertilizer proportionately for quantities of each used, yields an average price of approximately $.20 per pound of nitrogen.

Water pumping costs per acre foot water applied for current levels were developed using information from Sartin and partitioned into variable and fixed costs of pumping (based on natural gas power units). The assumption was made that all wells in the area can be represented by a typical well 250 feet in depth yielding 800 gallons of water per minute. The costs associated with this type of well were specified as follows (Sartin):

Variable:

Fuel	-	$ 4.80/acre foot of water applied
Maintenance	-	$ 3.60/acre foot of water applied
Fixed	-	$12.60/acre foot of water applied

Fuel costs were charged via the natural gas input purchasing activity. Variable maintenance and fixed costs of pumping irrigation water were charged by means of a transfer row as a dollar cost per unit of production of the particular crop production enterprise. Again, only variable costs were imposed in OBJF1 and total costs in OBJF2. No allowance was made in this model for use of surface delivered irrigation water. The assumption was made that any agumentation of current groundwater supplies would occur through stabilization of current groundwater levels. This limitation will be eliminated from a refined version of the HPII model which is being developed under a current Texas Water Resources Institute project at Texas A&M University.

Herbicide input purchases were handled in the same manner as water pumping costs. The production coefficient in each crop production enterprise is a dollar equivalent of herbicide purchased per unit of production of that enterprise based on price levels at the time the budget was constructed. The assumption was made that the price relationship between diesel fuel and herbicide is such that price movements will occur at a ratio of about 3 to 1 (herbicide: diesel prices). Therefore based on budget adjustments for increases to current diesel price levels, the dollar equivalent of herbicide was also increased simultaneously to maintain the same price ratio between diesel and herbicide.

Dryland rent of $15 per acre was charged against both irrigated and dryland crop production enterprises. This procedure was followed in order to allow residual returns to water to remain as net returns to the producer. This charge was based on a one-fourth crop share rental for dryland cotton which is typical for the region (MP-1027).

A management charge of 5 percent of gross revenue was imposed in all long run applications of the HPII model. This charge, while somewhat arbitrary, is not without justification. Certainly the producer must be paid at least opportunity cost for his managerial functions in the long run, or he will not continue to produce, provided he has alternatives. Professional management firms generally charge 7-10 percent of gross revenue for providing a similarly comprehensive management service. Elimination of a required return of 2-5 percent to meet non-farm business expenses which would be incurred by the professional firm, but not the owner-operator, was considered as reasonable. Opportunity costs may actually be lower in the long run but this will depend on labor supply and demand conditions. Therefore, the 5 percent management charge was assessed through a direct reduction in output transferred to the output selling activities. This was accomplished by adjusting the output transfer coefficients to reflect a transfer of only 95 percent of the production to gross returns in the objective function. It is very important to note that this characteristic of the model requires adjustment of output production values in solutions for long run situations, if crop output schedules are desired. Otherwise all outputs will be physically underestimated by about 5 percent. This limitation is being corrected in current refinements of the model.

Output Selling Activities

Output selling activities were provided in the model for each selected crop. These activities represent the sale of physical units of crop output at a specified price per unit. Table 1 shows the alternative crop prices which were specified in this study. These prices were based on monthly price data from the High Plains during the period 1971-74 (Canion). Average prices represent the simple, unweighted averages of these data. High and low prices are the extremes for the period and are intended to define the range of possible prices. All of these product prices are used in application of the model. Correlation coefficients between Texas crop prices are shown in Table 2 (Texas Crop and Livestock Reporting Service) for the period 1969-73. While the correlations are not perfectly positive, they are certainly high enough to justify the

Table 1. Prices Received by Farmers, Texas High Plains, 1971-74[a]

Crop	Unit	Low	Average[b]	High
Corn	$/bu.	1.12	1.95	3.46
Cotton	$/lb.	.18	.31	.67
Grain Sorghum	$/cwt.	1.86	3.10	5.96
Soybeans	$/bu.	2.30	4.27	7.75
Wheat	$/bu.	1.34	2.60	5.35

[a]Source: Telephone conversation with Larry Canion, Agricultural Statistician, Texas Crop and Livestock Reporting Service.

[b]Forty-eight month average, not weighted by volume sold.

Table 2. Correlation Between Product Prices, Texas High Plains, 1969-73[a]

	Cotton	Grain Sorghum	Soybeans	Wheat
Cotton	1.00	.96	.88	.98
Grain Sorghum	.96	1.00	.92	.99
Soybeans	.88	.92	1.00	.91
Wheat	.98	.99	.91	1.00

[a]Source: Texas Crop and Livestock Reporting Service, Texas Prices Paid and Received, Selected bulletins for 1969-73. Although the price correlation between grains and other crops was high for this period, 1974 was a year of wide divergence with relatively low cotton price and relatively high grain prices. Corn was not considered when this analysis was made in the initial stages of the study. However, corn and grain sorghum are close substitutes and prices are expected to move together.

assumption that crop prices will likely move in the same direction in proportionate amounts over the long run. It remains to be seen if these relationships will hold under decreased federal farm program influence and changes in the structure of export markets.

Resource Restraints

It has been assumed that supply of all production inputs except irrigated land, and land in total, is unrestricted. The model does not include other capital, labor, or input restrictions. The limitation which this assumption imposes on the model is that of aggregation bias of the solution. More simply stated -- the solution provided by the HPII model should be expected to differ somewhat from that which would be derived if each farm in the region were modeled individually and the solutions summed to provide a regional solution. It is rather difficult to measure the extent of this bias, however, Paris and Rausser provide a detailed discussion of the implications.

Groundwater was also assumed to be limited only implicitly by constraints on irrigated acreage. This implies that every irrigated acre developed in HPII will have sufficient or economically optimum groundwater supplies available. Although this assumption can be somewhat unrealistic in both the short run and long run, it is not limiting in the analysis of derived demand for water. However, it may lead to over estimation of derived demand for other inputs. Additional refinements will separate current and additional supplies of water allowing an improved representation of the current situation for analyses other than derivation of water demand.

Total cropland and irrigated cropland available to the crops considered in this model were restrained for all short run applications to the levels planted to these crops in 1973. Nineteen seventy three, with favorable product and input prices and release of federal government acreage restrictions, represents a transition year in which nearly all available acres were cropped in this area. Total cropland was estimated to be 3.686 million acres and total irrigated cropland was estimated to make up 2.570 million of the cropland acres (New).[2] Data for 1974 were not used for reasons previously discussed. Some acreage remained in set-aside programs in 1973; however, it is likely that most of this acreage is marginal in productivity and should not be expected to enter production for more than one or two consecutive years. At this time it is impossible to determine what the most likely "idle" acreage will be in the future as producers adjust to the lack of acreage controls. Therefore, 1973 data seem to provide the best estimate available with idle cropland of 717 thousand acres or 16 percent of total cropland in the region.

Dry and irrigated acres planted to minor crops in 1973 made up about 127 thousand acres or less than 4 percent of total planted acreage. It was assumed that this acreage would be retained in these crops in the future. Acreage was reserved for this use and not included as available cropland in the model.

Long run applications of the model included the assumption that irrigated acreage was restrained only by the level of total cropland available to the study crops (3.686 million acres).

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[2] Available cropland and irrigated acreages were taken from statistics published by Leon New because acreages under alternative irrigation systems were provided. Regional acreage estimates were consistent among sources; i.e., Estimates by New were comparable to Texas Crop Reporting Service published statistics.

Crop Acreage Flexibility Restraints

Flexibility restraints were established for cropping pattern shifts between crops included in the model. Essentially these restraints are upper and lower bounds on planted acreage for a particular crop. They are not, however, referred to as "bounds" because they are not 'fixed' in the long run and have their basis of origin in statistical probability rather than arbitrary judgement of the researcher. Details surrounding the estimation of these parameters will be outlined by Condra and Lacewell in a forthcoming publication, "Establishing Crop Acreage Flexibility Restraints for Subregions of the Texas High Plains."

The short run and long run crop acreage flexibility restraints for the HPII model are shown in Tables 3 and 4, respectively. The lower restraint for corn and soybeans were arbitrarily set at zero because no dryland alternative was provided for these crops in the model. Realistically, acreages of these crops should not be expected to fall to zero in the short run or even in the near future. But, under alternative assumptions for prices of water and natural gas it would be equally unrealistic to assume that historical patterns of behavior necessarily be a binding determination of the producer's reaction. This situation does not apply to the other crops because the producer can avoid high water or natural gas charges by shifting to dryland production.

The long run restraints (Table 4) differ from the short run restraints (Table 3) in that the assumption has been made that producers could conceivably select a continuing series of maximum short run increases or decreases in acreage. Thus the long run restraints become $(1+\bar{B})^t X$ base acreage for upper the restraint and $(1-\underline{B})^t X$ base acreage for the lower restraint, where 'B' is the short run flexibility coefficient and 't'

Table 3. Short Run Flexibility Restraints on Crop Acreages, Texas High Plains, Subregion II[a]

Restraints	Crop Acres				
	Corn	Cotton	Grain Sorghum	Soy-beans	Wheat
	1,000				
Upper (Max)	730	684	1,315	120	1,529
Lower (Min)	-0-	544	1,028	-0-	1,127

[a]Source: Condra, Gary D. and Ronald D. Lacewell, "Establishing Crop Acreage Flexibility Restraints for Subregions of the Texas High Plains," forthcoming Texas Water Resources Institute Technical Report.

Table 4. Long Run[a] Flexibility Restraints on Crop Acreages, Texas High Plains, Subregion II[b]

Restraints	Crop Acres			
	Corn	Cotton	Grain Sorghum	Soy-beans
	1,000			
Upper (Max)	2,676[c]	808	1,673	316
Lower (Min)	-0-	407	800	-0-

[a]The long run in this case is three years.

[b]Source: Condra, Gray, Ronald D. Lacewell, "Establishing Crop Acrea... Flexibility Restraints for Subregions of the Texas High Pl... forthcoming Texas Water Resources Institute Technical Repo...

[c]The 'effective' maximum acreage of corn in the model is actually 1,6... million since lower acreage bounds for other crops must first be sati...

is the number of short run periods that comprise the long run. For purposes of this study the long run was specified as three years (t=3) which is a somewhat shorter period of time than is normally considered as the long run. There were several factors which led to the selection of this time period. First, the base acreages used in all crops except soybeans and corn were averages of the past three years acreages[3] (cotton - 565,000 acres, grain sorghum - 1,166,000 acres, and wheat - 1,331,000 acres). Corn and soybean 1974 acreages, 381,000 and 74,000 respectively, were used for base acreages because insufficient data were available for statistical analysis based on historical averages (Texas Crop and Livestock Reporting Service). Therefore, in the case of cotton, grain sorghum, and wheat, the compounding of short run flexibility coefficients implies the requirement that base acreages be recalculated at the end of each short run period. This was not done but the deviation should not be great so long as the period considered does not exceed the period of the average. Secondly, the opportunity for technological and institutional change in periods greater than three years would seem to seriously bias any results based entirely on current production costs and practices. Thirdly, the long run period was chosen as the minimum length of time in which it can be expected that current producers will consider fixed costs of field machinery and pumping equipment in their decision process. This period is certainly not identical for all producers and may exceed three years for the average; however, it certainly will not be much less than three years.

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[3] County acreage estimates were used for all years except 1974. Published county data were unavailable for this year hence regional values were based on estimates for Crop Reporting District 1-N.

It is necessary in interpretation of results generated under any set of flexibility restraints to remember that these restraints are not forecasts. They are behavioral restrictions designed to be representative of the effects of risk aversion, habit, and non-monetary goals in the producer's crop selection decision. It has been assumed that within the period of consideration of this model these effects are more restrictive than any resource or market restraints on a given crop. If the period of analysis is lengthened this assumption will not be valid. There are real resource, institutional, and/or market restrictions which probably will prevent a complete shift to one crop in HPII. This situation is mentioned only as a caution to users of this model that short run flexibility coefficients cannot be compounded indiscriminately, without addition of other restraints to the model.

Application and Results

The HPII model was applied to a series of scenarios which included alternative assumptions about input and output price levels and planning horizons. These scenarios are outlined in Table 5. Unless it is specified otherwise, the price levels described refer to previous discussions under the section on model characteristics. The price of water was varied parametrically from zero (which is equivalent to current conditions) to the price at which irrigation water was no longer demanded by the producer and all cropland had reverted to dryland crop enterprises. It is emphasized that in this analysis, the price of water refers to a cost that is 'in addition to' pumping and distribution costs; i.e., at a zero price of water the cost of pumping and distribution is still included in the model. For example, when the price of water is zero, the producer actually incurs $23.88 per acre-foot of water applied which is the current pumping cost.

Long Run versus Short Run Derived Demand for Water

Scenario A was developed with average output prices and current input prices (Table 5). This scenario was defined as the expected long run situation and, based on these assumptions an expected long run derived demand schedule for irrigation water was generated (Table 6). Corn was extremely sensitive to increases in the price of water. There was a large shift in acreage from corn to dryland wheat at a price of $11.08 per acre-foot of water and corn left the solution at $16.12 per acre-foot. Cotton remained at the lower flexibility restraint (minimum permitted acreage) throughout the analysis. At a price of $16.60 per acre-foot cotton production shifted to dryland. Grain sorghum also remained under irrigation at its lower acreage restraint until the price of water reached $14.12 and then it shifted to dryland production. At water prices beyond $14.12 per acre-foot irrigated corn shifted to dryland grain sorghum production. Dryland wheat production increased to its upper restraint at a price of $11.08 for water. Soybeans were produced at the upper restraint until the price of water reached $24.47 per acre-foot, when this acreage shifted to dryland grain sorghum.

Based on these cropping pattern shifts it would appear that the long run demand for irrigation water in HPII varies from 3.8 million acre-feet at a price of zero to none at $24.47 per acre-foot. Quantity of water demanded decreased about 48 percent when the price of water reached $11.08 per acre-foot. As the price was increased to $14.12 per acre-foot quantity of water demanded decreased another 47 percent. By the time the price reached $16.60 per acre-foot less than 400 thousand acre-feet of water were demanded. Although some irrigation continued throughout the range, it

Table 5. Alternative Scenarios for Application of the Model, Texas High Plains, Subregion II.

Item	Scenario							
	A	B	C	D	E	F	G	H
Crop Prices[a]								
Corn	Average	Average	High	Low	Average	Average	High	Average
Cotton	Average	Average	High	Low	Average	High	Average	Average
Grain Sorghum	Average	Average	High	Low	Average	Average	High	Average
Soybeans	Average	Average	High	Low	Average	Average	Average	High
Wheat	Average	Average	High	Low	Average	Average	High	Average
Input Prices								
Diesel	Current	Current	Current	Current	Current	Current	Current	Current
Herbicide	Current	Current	Current	Current	Current	Current	Current	Current
Natural Gas	Current	Current	Current	Current	High	Current	Current	Current
Nitrogen	Current	Current	Current	Current	Current	Current	Current	Current
Water[b]	Parametric	Parametric	Parametric	Parametric	Parametric	Parametric	Parametric	Parametric
Pumping Costs	Total	Variable	Total	Total	Total	Total	Total	Total
Period	Long Run	Short Run	Long Run	Long Run	Long Run	Long Run	Long Run	Long Run
Irrigated Acreage	Total	Current	Total[c]	Total[c]	Total[c]	Total[c]	Total[c]	Total[c]

[a] Crop prices are presented in Table 1.

[b] Varied parametrically from a price of zero for irrigation water to price at which water is no longer used in irrigation of crops. This is a cost inaddition to pumping and distribution costs of irrigation water.

Table 6. Expected Long Run Derived Demand for Irrigation Water, Texas High Plains, Subregion II, Scenario A[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Costs					
		0	$11.08	$14.12	$16.12	$16.60	$24.47
		1,000					
Water applied	ac.-ft.	3,812.9	1,997.9	1,061.9	845.9	369.7	-0-
Land Use							
Irrigated:	acres	2,877.0	1,677.0	867.0	723.0	316.0	-0-
Corn	acres	1,354.0	144.0	144.0	-0-	-0-	-0-
Cotton	acres	407.0	407.0	407.0	407.0	-0-	-0-
Grain Sorghum	acres	800.0	800.0	-0-	-0-	-0-	-0-
Soybeans	acres	316.0	316.0	316.0	316.0	316.0	-0-
Wheat	acres	-0-	-0-	-0-	-0-	-0-	-0-
Dryland:	acres	809.0	2,019.0	2,819.0	2,963.0	3,370.0	3,686.0
Cotton	acres	-0-	-0-	-0-	-0-	407.0	407.0
Grain Sorghum	acres	-0-	-0-	800.0	944.0	944.0	1,260.0
Wheat	acres	809.0	2,019.0	2,019.0	2,019.0	2,019.0	2,019.0
Total Crops	acres	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0

[a]Scenario A is described in Table 5 Assumptions are based on average prices for crops, current input prices, and irrigated acreage unrestrained, all costs included and the least restrictive crop acreage flexibility restraints.

should be noted that quantity demanded was reduced by almost half at a level of $11.08 per acre-foot. Irrigated acreage at this price level was 1.667 million acres or about 65 percent of current irrigated acreage. The estimated demand for irrigation water is a total for the region and does not consider current groundwater supplies separately from possible supplementary supplies. This has strong implications for irrigation from current groundwater supplies in the face of rapidly increasing input prices.

The expected schedule of output associated with Scenario A is shown Table 7. As the price of water increased the output of wheat increased because it was the most profitable dryland alternative. It also seems significant that increasing the price of water to $11.08 resulted in a 53 percent reduction in grain production (corn, grain sorghum, soybeans, and wheat). For purposes of comparison, the production output levels associated with an $11.08 price per acre-foot of water are approximately 65 percent of 1973 levels for both cotton and grains (Texas Crop and Livestock Reporting Service).

If the assumptions of Scenario A hold, i.e., prices will average near the last four years' average and input prices will be near current levels, and groundwater remains unpriced, the HPII model has some clear implications. Corn acreage will continue on its increasing trend, soybean acreage will increase, but cotton and grain sorghum acreage will decrease from recent historical levels. As the water supply is exhausted and pumping costs increase, acreage will tend to move directly to dryland production of wheat rather than lower levels of irrigation on cotton or grain sorghum.

Table 7. Expected Long Run Schedule of Crop Output at Alternative Prices for Irrigation Water. Texas High Plains, Subregion II, Scenario A[a]

Crops	Units	Price Per Acre-foot of Water above Current Pumping Cost					
		-0-	$ 11.08	$ 14.12	$ 16.12	$16.60	$24.47
		- - - - - - - - 1,000,000 - - - - - - - -					
Corn	bu.	148.94	15.84	15.84	-0-	-0-	-0-
Cotton	lb.	203.50	203.50	203.50	203.50	61.05	61.05
Grain Sorghum	cwt.	40.01	40.01	12.00	14.16	14.16	18.90
Soybeans	bu.	11.06	11.06	11.06	11.06	11.06	-0-
Wheat	bu.	12.14	30.28	30.28	30.28	30.28	30.28

[a]Scenario A is described in detail in Table 5. Assumptions are based on average prices for crops, current input prices, and irrigated acreage unrestrained, all costs included and less restrictive crop acreage flexibility restraints.

Scenario B was developed to represent the short run decision making situation for producers in HPII. Again average crop prices and current prices for inputs were assumed (Table 5). The results from this scenario are shown in Tables 8 and 9. As would be expected the quantity of water demanded at the current price of zero was about a half million acre-feet less than the long run Scenario A because irrigated acreage was restrained to current acreage. Also the price at which no water was demanded ($7[illegible] per acre-foot) was much higher than the Scenario A. Scenario A included total costs while B considered only variable costs of production. This scenario was presented primarily to show the effect of different costs (total versus variable) on the demand for irrigation water. It is expected that producers would react in accordance with the results indicated from Scenario B in the short run if they were presented with the decision to pay for irrigation water or to do without it for the coming production year. It is highly unlikely that they would commit themselves for more than one season at prices and quantities shown in Table 8, assuming average crop prices.

There are two short run trends implied by the results from Scenario B at zero price for water (i.e., only pumping costs are included) which are contrary to long run trends in Scenario A. First, irrigated grain sorghum acreage came into the solution at an intermediate point between its upper and lower acreage restraints as opposed to the lower level in Scenario A. This implies that in the short run grain sorghum acreage will not decline but hold steady near 1973 and 1974 levels. This implication is certainly closer to the situation as viewed in 1975. However the long run trend in grain sorghum acreage may still be declining as

Table 8. Expected Short Run Derived Demand for Irrigation Water, Texas High Plains, Subregion II, Scenario B[a]

Item		Price per Acre-foot of Water above Current Pumping Cost										
		0	$9.10	$33.78	$34.09	$36.90	$41.74	$43.11	$46.28	$50.15	$61.89	$71.75
		-1,000-										
Water Applied	ac-ft	3,253.3	3,234.9	3,074.6	2,889.7	2,492.2	1,289.0	858.9	407.4	197.4	140.4	-0-
Land Use												
Irrigated	acres	2,570.0	2,559.0	2,422.0	2,422.0	2,157.0	1,129.0	842.0	298.0	158.0	120.0	-0-
Corn	acres	730.0	730.0	730.0	730.0	465.0	465.0	178.0	178.0	38.0	-0-	-0-
Cotton	acres	544.0	544.0	544.0	544.0	544.0	544.0	544.0	-0-	-0-	-0-	-0-
Grain sorghum	acres	1,165.0	1,165.0	1,028.0	1,028.0	1,028.0	-0-	-0-	-0-	-0-	-0-	-0-
Soybean	acres	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	120.0	-0-
Wheat	acres	11.0	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Dryland	acres	1,116.0	1,127.0	1,264.0	1,529.0	1,529.0	2,557.0	2,844.0	3,388.0	3,528.0	3,528.0	3,528.0
Cotton	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-	544.0	684.0	684.0	684.0
Grain sorghum	acres	-0-	-0-	-0-	-0-	-0-	1,028.0	1,315.0	1,315.0	1,315.0	1,315.0	1,315.0
Wheat	acres	1,116.0	1,127.0	1,264,0	1,264.0	1,529.0	1,529.0	1,529.0	1,529.0	1,529.0	1,529.0	1,529.0
Total Crops	acres	3,878.0	3,686.0	3,686.0	3,868.0	3,686.0	3,868.0	3,868.0	3,868.0	3,686.0	3,648.0	3,528.0

[a]Scenario B is described in Table 5. Assumptions are based on average prices for crops. Current input prices, irrigation restricted to current irrigated acreage, only variable costs included and the more restrictive crop acreage flexibility restriants.

Table 9. Expected Short Run Schedule of Crop Output at Alternative Prices for Irrigation Water, Texas High Plains, Subregion II, Scenario B[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost										
		-0-	$9.10	$33.78	$34.09	$36.90	$41.74	$43.11	$46.38	$50.15	$61.89	$71.75
		1,000,000										
Corn	bu.	80.30	80.30	80.30	80.30	51.15	51.15	19.58	19.58	4.20	-0-	-0-
Cotton	lb.	272.00	272.00	272.00	231.20	231.20	231.20	231.20	81.60	102.60	102.60	102.60
Grain sorghum	cwt.	58.25	58.25	51.40	51.40	51.40	15.42	19.72	19.72	19.72	19.72	19.72
Soybeans	bu.	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	4.20	-0-
Wheat	bu.	17.18	16.91	18.96	18.96	22.94	22.94	22.94	22.94	22.94	22.94	22.94

[a]Scenario B is described in detail in Table 5. Assumptions are based on average prices for crops, current input prices, irrigation restricted to current irrigated acreage, only variable costs included and the more restrictive crop acreage flexibility restraints.

producers replace equipment and shift to corn. Secondly, the short run solution included a small acreage of irrigated wheat whereas, the long run solution had wheat acreage in as dryland. This situation is actually not seriously contradictory to the long run trend to dryland wheat because it represents only about .5 percent of the wheat acreage planted in the long run scenario. This analysis indicates that irrigated wheat becomes less profitable compared to other crops when fixed costs are considered.

A comparison of the derived demand curves for water generated from Scenarios A and B is shown in Figure 2. The curves cross at an irrigation water price of $11.08 per acre-foot water. This indicates that if water can be delivered to the Ogallala Aquifer for a cost of $11.08 per acre-foot or less there will be an increase in irrigated acreage over time. At prices higher than $11.08 per acre-foot of water and lower than $33.78 per acre-foot there would be no significant short run adjustment in water usage. However, in the long run as reinvestment became necessary adjustment would be dramatic both in terms of water usage and irrigated acreage. Over the long run (where fixed costs must be covered) water prices above $11.08 per acre-foot result in severe reductions in quantity of water than can be profitably applied. Again, this water cost is above pumping and distribution costs and assumes average product and current input price levels. This indicates that irrigation on the Texas High Plains is sensitive to input and product price changes.

Effect of Crop Price on Demand for Irrigation Water

Scenario C (Table 5) includes the assumptions that all crop prices will be at the highest possible levels of the past four years (Table 1)

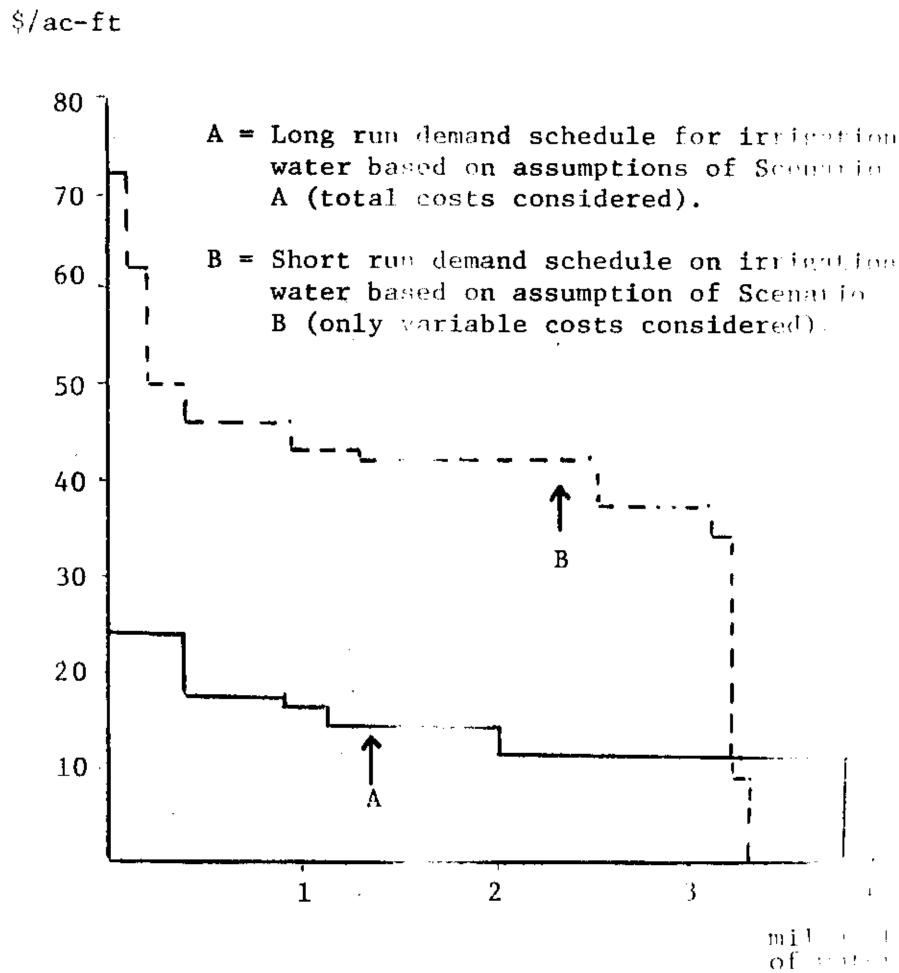

Figure 2. Long Run and Short Run Derived Demand for Irrigation Water, Texas High Plains, Subregion II.

and input prices will be at current levels. The price per unit for all crops considered was increased simultaneously with justification provided by the high positive correlation of crop prices shown in Table 2. This scenario is not intended to represent a likely situation. It was, in fact, developed to represent one of the two most unlikely, but possible situations (the other being low crop prices — Scenario D). Thus Scenario C defines the upper bound on demand for irrigation water (Table 10 and 11).

The long run derived demand for irrigation water, as shown in Table 10, is very sensitive to output price levels. Analysis based on the assumption of maximum crop prices indicates irrigation remains profitable to a water price of $129.79 per acre-foot. The latter price compares with zero quantity demanded at $24.47 per acre-foot in Scenario A (Table 6). At the current water price of zero (i.e., no costs above current pumping and distribution costs), the quantity demanded was 5.5 million acre feet which is the projected pumpage for the entire 45 county area of the Texas High Plains by 1980 (Walker and Taylor). All cropland was irrigated with corn at its upper restraint and all others at the lower restraint (soybean acreage was zero). Higher crop prices allowed shifts to lower levels of irrigation for a given crop as the price of water increased. This is in contrast to the abrupt shifts in Scenario A from higher levels of irrigation directly to dryland production. Under the assumptions of this scenario it was possible to charge up to $31.77 per acre-foot for irrigation water and still retain all available cropland under irrigation. Even with prices up to $91.05 per acre-foot irrigated acreage remained higher than current irrigated levels. At a price of $91.05 per acre-foot of water, irrigated acreage was abruptly reduced

Table 10. Expected Long Run Derived Demand for Irrigation Water, High Crop Prices, Texas High Plains, Subregion II, Scenario C[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost									
		0	$24.30	$31.77	$33.22	$91.05	$93.04	$93.23	$95.60	$123.90	$129.79
		1,000									
Water Applied	ac-ft	5,532.2	5,399.9	4,048.9	3,784.9	1,969.9	1,950.4	1,675.7	670.6	337.8	-0-
Land Use											
Irrigated	acres	3,686.0	3,686.0	2,877.0	2,877.0	1,667.0	1,667.0	1,667.0	808.0	407.0	-0-
Corn	acres	1,670.0	1,269.0	1,269.0	1,269.0	59.0	-0-	-0-	-0-	-0-	-0-
Cotton	acres	407.0	808.0	808.0	808.0	808.0	808.0	808.0	808.0	407.0	-0-
Grain sorghum	acres	800.0	800.0	800.0	800.0	800.0	859.0	859.0	-0-	-0-	-0-
Soybean	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Wheat	acres	809.0	809.0	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Dryland	acres	-0-	-0-	809.0	809.0	2,019.0	2,019.0	2,019.0	2,878.0	3,279.0	3,686.0
Cotton	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	407.0
Grain sorghum	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-	859.0	1,260.0	1,260.0
Wheat	acres	-0-	-0-	809.0	809.0	2,019.0	2,019.0	2,019.0	2,019.0	2,019.0	2,019.0
Total Crops	acres	3,868.0	3,868.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0

[a]Scenario C is described in Table 5. Assumptions are based on high crop prices and current price for inputs, irrigated acreage unrestrained, all costs included and less restrictive crop acreage flexibility restraints.

Table 11. Expected Long Run Schedule of Crop Ouptut at Alternative Prices for Irrigation Water with High Crop Prices, Texas High Plains, Subregion II, Scenario C[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost									
		-0-	$24.30	$31.77	$33.22	$91.05	$93.04	$93.23	$95.60	$123.90	$129.79
		1,000,000									
Corn	bu.	183.70	139.59	139.59	139.59	6.49	-0-	-0-	-0-	-0-	-0-
Cotton	lb.	203.50	404.00	404.00	404.00	404.00	404.00	343.40	343.40	172.98	61.05
Grain sorghum	cwt.	45.60	45.60	45.60	40.01	40.01	42.95	42.95	12.88	18.90	18.90
Soybeans	bu.	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Wheat	bu.	32.36	32.36	12.14	12.14	30.28	30.28	30.28	30.28	30.28	30.28

[a]Scenario C is described in detail in Table 5. Assumptions are based on high crop prices and current price for inputs, irrigated acreage unrestrained, all costs included and less restrictive crop acreage flexibility restraints.

to 65 percent of current level and production of grain (Table 11) was reduced to 57 percent of 1973 levels. However, cotton output still exceeded 1973 levels by 35 percent.

Contrary to the implications of Scenario A, for zero water prices, Scenario C shows that as crop price levels increase corn will tend to replace soybean acreage. Wheat acreage will still tend to decrease but more wheat will be irrigated. These conclusions are contingent, however, on the assumption that irrigated acreage can be expanded to total cropland with supplemental water provided at zero price. This asumption would be highly unrealistic, therefore another scenario (for which the solutions are not presented) was developed in which high crop prices were assumed and irrigated acreage restrained to current levels. Wheat acreage still entered the solution at its lower restraint, but the dryland wheat enterprise replaced the irrigation alternative for wheat. This solution is an estimate assuming no supplemental water; i.e., pumping from existing groundwater supplies.

Scenario D was constructed under the same reasoning as Scenario C except that low crop prices were assumed (Table 5). The results of this scenario are shown in Tables 12 and 13. At low crop prices the lower bound on long run derived demand for irrigation water is zero at all water prices including "no cost." Thus, if crop prices move to (and are expected to stay at) levels approximating the extreme lows of the past four years, acreage will tend to move from irrigated to dryland production and planted acreage will tend to decrease -- assuming current input price levels.

Table 12. Expected Long Run Derived Demand for Irrigation Water, Low Crop Prices, Texas High Plains, Subregion II, Scenario D[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost -0-
		(1,000)
Water applied	ac.-ft.	-0-
Land Use		
Irrigated	acre	-0-
Corn	acre	-0-
Cotton	acre	-0-
Grain sorghum	acre	-0-
Soybean	acre	-0-
Wheat	acre	-0-
Dryland	acre	2,016.0
Cotton	acre	407.0
Grain sorghum	acre	800.0
Wheat	acre	809.0
Total Irrigation	acre	-0-
Total Crops	acre	2,016.0

[a]Scenario D is described in Table 5. Assumptions are based on low crop prices and current input prices, irrigated acreage unrestrained, all costs considered and less restrictive crop acreage flexibility restraints.

Table 13. Expected Long Run Schedule of Crop Output at Alternative Prices for Irrigation Water with Low Crop Prices, Texas High Plains, Subregion II, Scenario D[a]

		Price per Acre-foot of Water above Current Pumping Cost
Crops	Units	-0-
		(1,000,000)
Corn	bu.	-0-
Cotton	lb.	61.05
Grain Sorghum	cwt.	12.00
Soybeans	bu.	-0-
Wheat	bu.	12.14

[a]Scenario D is described in detail in Table 5. Assumptions are based on low crop prices and current input prices, irrigated acreage unrestrained, all costs considered and less restrictive crop acreage flexibility restraints.

A comparison of the derived demand curves for irrigation water with alternative assumptions of Scenarios A, C, and D is shown in Figure 3. Irrigation water demand curve C is the maximum expected long run demand for irrigation water. Demand curve A is the most likely demand for water and curve (point) D is the minimum expected demand for water. All three curves are based on the assumption of current input price levels.

Scenarios were not developed for downward variations of individual output prices since there is no demand for irrigation water by any crop when crop prices are at the low level.

Demand for irrigation water was estimated where the high price level of cotton, grain, and soybeans were considered individually with all other crops set at their average prices. These results are not discussed but assumptions and results have been presented in Table 5 and Appendix A, Tables 16 through 21.

Effect of Input Price on Demand for Irrigation Water

Increases in input prices with crop prices unchanged reduces the demand for irrigation. During the past 2-3 years there have been significant price adjustments both in crops and inputs. A major input to irrigation is natural gas. In addition, this input will likely increase substantially in price. Therefore, this analysis is restricted to estimating the effect of a price increase on the demand for irrigation water assuming average crop prices.

The price of natural gas was assumed to increase from the current level of $.88 per thousand cubic to $1.25 per thousand cubic feet in Scenario E (Table 5). This increased price has been referred to as the

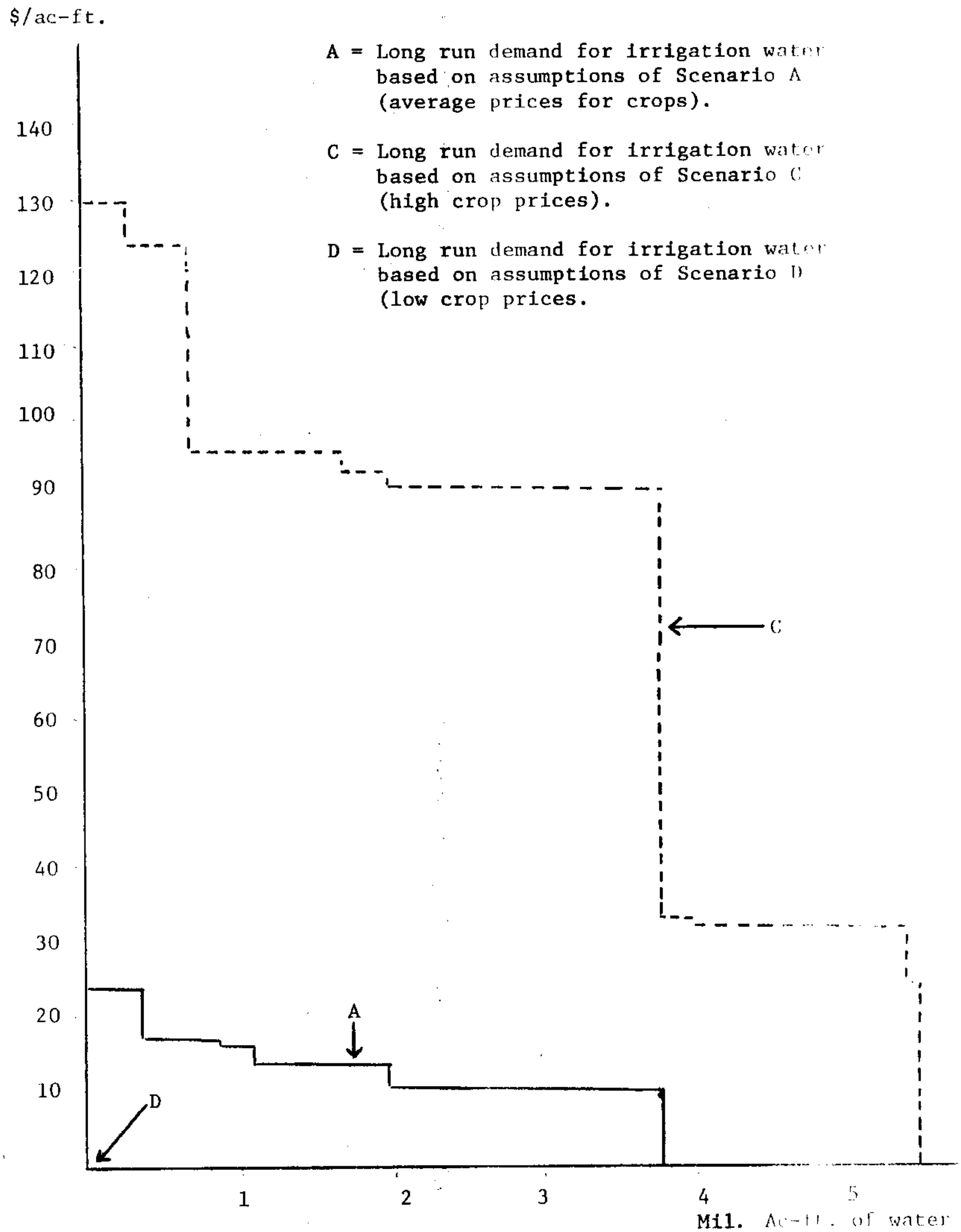

Figure 3. Long Run Derived Demand for Irrigation Water With Alternative Assumptions Concerning Crop Prices, Texas High Plains, Subregion II.

"high" price, however, it is not intended to represent a bound in the sense of high crop prices. This price level for natural gas is a strong possibility in the short run (Osborn) and may be exceeded in a few years. Table 14 presents the long run derived demand schedule for water under the assumptions of Scenario E (which includes average crop prices). Table 15 presents the expected output schedule associated with this scenario and Figure 4 compares Scenario E to Scenario A results. Examination of Figure 4 shows that the increased price for natural gas simply shifted the demand curve straight downward. The solutions in Table 6 are identical to those in Table 14 except that the corresponding price of water in the latter is lower in each case. This can be explained easily since all natural gas in the model has been assumed to be used in pumping water and only one typical well depth and yield has been assumed. Therefore, any increase in the price of natural gas is effectively a direct charge against water usage. The implications of this relationship are two-fold. First, as long as the effective increase in the cost of water resulting from natural gas price increases is less than $11.08 per acre-foot over current levels, increasing natural gas prices _will not_ materially affect current water usage. The only effect will be a reduction in net returns to the producer. However, if natural gas prices increase to a level of $2.15 per thousand cubic feet (an effective increase[4] in water cost of $11.08 per acre-foot) the reduction in irrigated acreage and output will be large. This situation is equivalent to that shown in Table 6 corresponding to a water price of $11.08 per acre-foot.

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[4] Calculated as 8.727 thousand cubic feet of natural gas per acre foot of water applied @ a price of $2.15/thousand cubic feet less the current price.

Table 14. Expected Long Run Derived Demand for Irrigation Water, High Natural Gas Prices, Texas High Plains, Subregion II, Scenario E[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost					
		0	$7.85	$10.90	$12.89	$13.38	$21.25
		- - - - - - -	- - - - - - -	- - - 1,000	- - - - - - -	- - - - - - -	- - - - - - -
Water Applied	ac.-ft.	3,812.9	1,997.9	1,061.9	845.9	369.7	-0-
Land Use							
Irrigated	acres	2,877.0	1,667.0	867.0	723.0	316.0	-0-
Corn	acres	1,354.0	144.0	144.0	-0-	-0-	-0-
Cotton	acres	407.0	407.0	407.0	407.0	-0-	-0-
Grain Sorghum	acres	800.0	800.0	-0-	-0-	-0-	-0-
Soybean	acres	316.0	316.0	316.0	316.0	316.0	-0-
Wheat	acres	-0-	-0-	-0-	-0-	-0-	-0-
Dryland	acres	809.0	2,019.0	2,819.0	2,963.0	3,370.0	3,686.0
Cotton	acres	-0-	-0-	-0-	-0-	407.0	407.0
Grain Sorghum	acres	-0-	-0-	800.0	944.0	944.0	1,260.0
Wheat	acres	809.0	2,019.0	2,019.0	2,019.0	2,019.0	2,019.0
Total Crops	acres	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0

[a]Scenario E is described in Table 5. Assumptions are based on average crop prices, high natural gas prices, and current prices for other inputs, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

Table 15. Expected Long Run Schedule of Crop Output at Alternative Prices for Irrigation Water with High Natural Gas Prices, Texas High Plains, Subregion II, Scenario E[a]

Crops	Units	Price per Acre-foot of Water above Current Pumping Cost					
		-0-	$ 7.85	$ 10.90	$ 12.89	$13.38	$21.25
		- - - - 1,000,000 - - - -					
Corn	bu.	148.94	15.84	15.84	-0-	-0-	-0-
Cotton	lb.	203.50	203.50	203.50	203.50	61.05	61.05
Grain Sorghum	cwt.	40.10	40.10	12.00	14.16	14.16	18.90
Soybeans	bu.	11.06	11.06	11.06	11.06	11.06	-0-
Wheat	bu.	12.14	30.28	30.28	30.28	30.28	30.28

[a]Scenario E is described in detail in Table 5. Assumptions are based on average crop prices, high natural gas prices, and current prices for other inputs, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

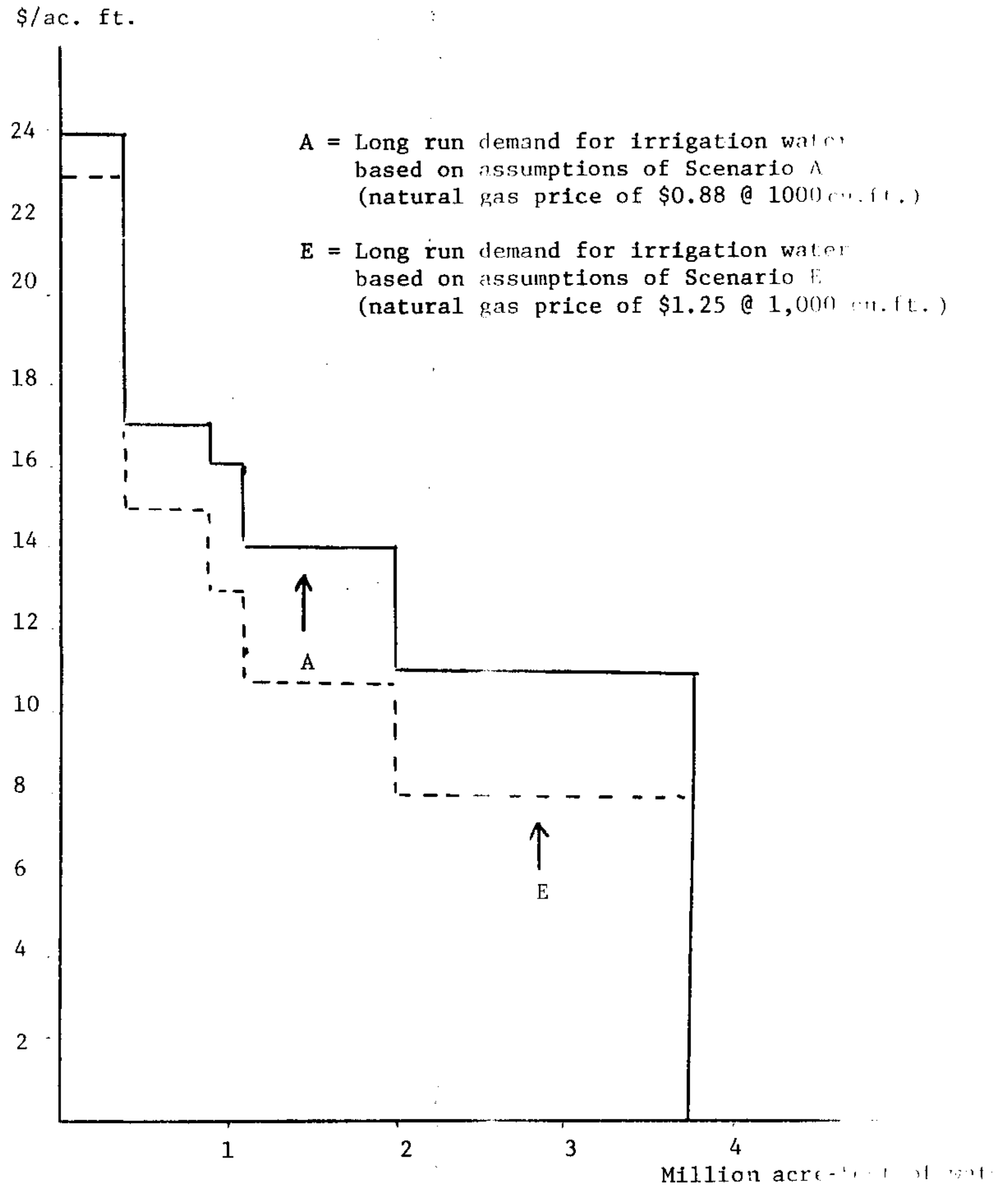

Figure 4. Long Run Derived Demand for Irrigation Water with Alternative Assumptions Concerning natural Gas Prices, Texas High Plains, Subregion II.

Conclusions and Limitations

1. The HPII model possesses the basic characteristics required to estimate the derived demand for irrigation water in Subregion II of the Texas High Plains. These characteristics do not, however, include the capability of analyzing and accurately forecasting the validity of assumptions which were employed in its application. Therefore, the solutions generated will only be valid, given the assumptions.
2. Short run demand for irrigation water was found to exceed the long run demand greatly at all prices of water above $11.08 per acre-foot.
3. In the long run some quantities of water were still demanded for irrigation at prices up to $24.47 per acre-foot under conditions of average crop prices and current input prices. The effective limit on prices which could be changed for irrigation water, however, was about $11.08 per acre-foot. There are two primary objectives in discussion of water importation. One is the maintenance of a high level of food productivity in semi-arid regions. The other is the maintenance of the regional economies which have been founded on irrigated agriculture. If a price of $11.08 per acre-foot of water or higher were charged given the assumption of average crop prices, irrigated acreage would be reduced by about 35 percent from 1973 levels. Output of grains and cotton would also be reduced by about 35 percent from 1973 levels. The period of irrigation could probably be extended, but at the expense of a reduction in current levels of irrigation, an alternative which is available without importation of water.
4. The upper water price limit under conditions of maximum crop prices was increased to $129.79 per acre-foot with an effective limit of

$91.05 per acre-foot of irrigation water. As in the case of the previous conclusion under average crop prices, the upper limit refers to the price of water at which all land reverts to dryland crops. The effective limit is the price above which augmentation of current groundwater supplies would seem to have detrimental rather than beneficial effects.

5. Natural gas price increases had no effect on irrigated acreage, levels of water usage, or cropping patterns under conditions of average crop prices until the price of natural gas reached $2.15 per thousand cubic feet. At that price, derived demand for irrigation water was severely reduced. Thus, it was concluded that short run effects of natural gas price increases will be reflected only in reduced net returns to producers. Should these prices reach levels near the $2.15 per thousand cubic feet level there will still be no short run effect, but an abrupt shift to reduced irrigated acreages and water usage will occur as producers adjust to long run conditions.

6. Subject to the assumption that prices of crops will hold around the last four year averages and input prices will continue at current levels, the HPII model with no irrigated acreage restrictions indicated the following long run trends at the current water price of zero:

   a. Increasing irrigated acreage
   b. Increasing irrigated corn and soybean acreage
   c. Increasing total wheat acreage and decreasing irrigated wheat acreage
   d. Decreasing total cotton and grain sorghum acreage.

7. All results and conclusions from this study and the HPII model are subject to and limited by the following assumptions and conditions:

A. Linear Programming

- There is no complementarity between crop enterprises from particular rotational patterns, nitrogen carryover etc.

- There is no diminishing marginal productivity in increasing levels of production of particular crops.

- Demand for regional crop output is completely elastic.

- Producers will tend to move toward the profit maximizing combination of crop enterprises over time.

B. Enterprise Activities

- Technical production coefficients, costs of production, and yields are estimated to represent those associated with a typical level of management under typical resource situations for the region.

- The aggregation effects of a typical level of management and costs of production are not considered.

- All irrigation takes place under furrow application with pumping costs for water representative of well and pumping unit typical for the region in depth and yield.

- All water requirements and usage are expressed as acre feet of water applied rather than water pumped.

- All fuel used in the pumping of water is natural gas.

- All non-pumping fuel is diesel.

- All management in the long run has a required return of five percent of gross returns to the enterprises.

- Cropping enterprises which were not considered in this study are fixed in land use patterns at 1973 levels.

- Enterprise selection behavior of producers in the short run will tend to approximate that exhibited in the past.

C. Resource Situation

- Current and future water supplies are restricted only by the given irrigated acreage restrictions.

- Water requirements for crop enterprises are calculated on an annual basis, therefore, intertemporal or seasonal effects on water usage are not considered.

- Irrigable land in the long run is restricted only by cropland available for production of crops considered in this study.

- Irrigable land in the long run is not restricted by soil characteristics or topographical features of the land.
- All current and future water supplies in the region are from the Ogallala Aquifer and hence must incur pumping costs before use in irrigation of crops (i.e., no surface delivery of imported water).
- The effects of restrictions on the supply of inputs to the region or individual producers are not considered.
- Water supplies are homogeneous throughout the region and adequate to support any of the alternative crop enterprises.

D. Validation

- Formal validation of the model has been limited to comparison with historical water pumpage in the area. Solutions with increased water availability are extrapolations and should be considered as such.

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APPENDIX A

Selected Model Applications

Table 16. Expected Long Run Derived Demand for Irrigation Water, High Cotton Prices, Texas High Plains, Subregion II, Scenario F[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost						
		0	$11.08	$14.12	$18.01	$24.47	$93.24	$129.78
		- - - - - - - - -	- - - - - - - - -	- - - - - - - - -	1,000	- - - - - - - - -	- - - - - - - - -	- - - - - - - - -
Water Applied	ac.-ft.	3,680.6	2,251.1	1,315.1	1,014.4	945.4	670.6	-0-
Land Use								
Irrigated	acres	2,877.0	1,924.0	1,124.0	867.0	808.0	808.0	-0-
Corn	acres	953.0	-0-	-0-	-0-	-0-	-0-	-0-
Cotton	acres	808.0	808.0	808.0	808.0	808.0	808.0	-0-
Grain Sorghum	acres	800.0	800.0	-0-	-0-	-0-	-0-	-0-
Soybean	acres	316.0	316.0	316.0	316.0	59.0	-0-	-0-
Wheat	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Dryland	acres	809.0	1.762.0	2,562.0	2,819.0	2,878.0	2,878.0	3,686.0
Cotton	acres	-0-	-0-	-0-	-0-	-0-	-0-	808.0
Grain Sorghum	acres	-0-	-0-	800.0	800.0	859.0	859.0	859.0
Wheat	acres	809.0	1,762.0	1,762.0	2,019.0	2,019.0	2,019.0	2,019.0
Total Crops	acres	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0

[a]Scenario F is described in Table 5. Assumptions are based on high prices for cotton, average prices for other crops, and current input prices, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

Table 17. Expected Long Run Schedule of Crop Output with Alternative Prices for Irrigation Water with High Cotton Price, Texas High Plains, Subregion II, Scenario F[a]

Crops	Units	Price per Acre-foot of Water Above Current Pumping Cost						
		-0-	$ 11.08	$ 14.12	$ 18.01	$ 24.47	$ 93.24	$129.78
		1,000,000						
Corn	bu.	99.84	-0-	-0-	-0-	-0-	-0-	-0-
Cotton	lb.	384.76	384.76	384.76	384.76	384.76	327.05	115.43
Grain Sorghum	cwt.	38.10	38.10	11.43	11.43	12.27	12.27	12.27
Soybeans	bu.	10.53	10.53	10.53	1.97	-0-	-0-	-0-
Wheat	bu.	11.56	25.17	25.17	28.84	28.84	28.84	28.84

[a]Scenario F is described in detail in Table 5. Assumptions are based on high prices for cotton, average prices for other crops, and current input prices, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

Table 18. Expected Long Run Derived Demand for Irrigation Water, High Grain Prices, Texas High Plains, Subregion II, Scenario G[a]

Item	Unit	Price per Acre-foot of Water above Current Pumping Cost						
		0	$16.60	$31.77	$33.22	$91.05	$93.04	$95.60
		- - - - - - - - - - - - - - - - - - - 1,000 - - - - - - - - - - - - - - - - - - -						
Water Applied	ac.-ft.	5,532.2	5,056.1	3,705.0	3,441.0	1,626.0	1,474.2	-0-
Land Use								
Irrigated	acres	3,686.0	3,686.0	2,470.0	2,470.0	1,260.0	1,260.0	-0-
Corn	acres	1,670.0	1,670.0	1,670.0	1,670.0	460.0	-0-	-0-
Cotton	acres	407.0	-0-	-0-	-0-	-0-	-0-	-0-
Grain Sorghum	acres	800.0	800.0	800.0	800.0	800.0	1,260.0	-0-
Soybeans	acres	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Wheat	acres	809.0	809.0	-0-	-0-	-0-	-0-	-0-
Dryland	acres	-0-	407.0	1,216.0	1,216.0	2,426.0	2,426.0	2,686.0
Cotton	acres	-0-	407.0	407.0	407.0	407.0	407.0	407.0
Grain Sorghum	acres	-0-	-0-	-0-	-0-	-0-	-0-	1,260.0
Wheat	acres	-0-	-0-	809.0	809.0	809.0	2,019.0	2,019.0
Total Crops	acres	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	2,686.0

[a]Scenario G is described in Table 5. Assumptions are based on high prices for grain, average prices for other crops, and current prices for inputs, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

Table 19. Expected Long Run Schedule of Crop Output at Alternative Prices for Irrigation Water with High Grain Prices, Texas High Plains, Subregion II, Scenario G

Crops	Units	Price per Acre-foot of Water above Current Pumping Cost						
		-0-	$ 16.60	$ 31.77	$ 33.22	$91.05	$93.04	$95.60
		1,000,000						
Corn	bu.	174.95	174.95	174.95	174.95	48.19	-0-	-0-
Cotton	lb.	193.81	58.14	58.14	58.14	58.14	58.14	58.14
Grain Sorghum	cwt.	43.43	43.43	43.43	38.10	38.10	60.00	18.00
Soybeans	bu.	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Wheat	bu.	30.82	30.82	11.56	11.56	28.84	28.84	28.84

[a] Scenario G is described in detail in Table 5. Assumptions are based on high prices for grain, average prices for other crops, and current prices for inputs, irrigated acreage unrestrained, all costs considered, and less restrictive crop acreage flexibility restraints.

Table 20. Expected Long Run Derived Demand for Irrigation Water, High Soybean Prices, Texas High Plains, Subregion II, Scenairo H[a]

Item	Unit	Price per Acre-foot of Water Above Current Pumping Cost					
		0	$11.08	$14.12	$16.12	$16.60	$123.61
		- - - - - - - - - - - - - - - -		- 1,000 -		- - - - - - - - - - - - - - - -	
Water Applied	ac.-ft.	3,812.9	1,997.9	1,061.9	845.9	369.7	-0-
Land Use							
Irrigation:	acres	2,8770.0	1,667.0	867.0	723.0	316.0	-0-
Corn	acres	1,354.0	144.0	144.0	-0-	-0-	-0-
Cotton	acres	407.0	407.0	407.0	407.0	-0-	-0-
Grain Sorghum	acres	800.0	800.0	-0-	-0-	-0-	-0-
Soybean	acres	316.0	316.0	316.0	316.0	316.0	-0-
Wheat	acres	-0-	-0-	-0-	-0-	-0-	-0-
Dryland:	acres	809.0	2,019.0	2,819.0	2,963.0	3,370.0	3,686.0
Cotton	acres	-0-	-0-	-0-	-0-	407.0	407.0
Grain Sorghum	acres	-0-	-0-	800.0	944.0	944.0	1,260.0
Wheat	acres	809.0	2,019.0	2,019.0	2,019.0	2,019.0	2,019.0
Total Irrigation:		2,877.0	1,667.0	867.0	723.0	316.0	-0-
Total Crops:	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0	3,686.0

[a]Scenairo H is described in Table 5. Assumptions are based on high prices for soybeans, average prices for other crops, and current input prices, irrigated acreage unrestrained, all costs considered and less restrictive crop acreage flexibility restraints.

Table 21. Expected Long Run Schedule of Crop Output at Alternative Prices for Irrigation Water with High Soybean Prices, Texas High Plains, Subregion [illegible], Scenario H[a]

Crops	Units	Price per Acre-foot of Water above Current Pumping Cost					
		-0-	$ 11.08	$ 14.12	$ 16.12	$16.60	$123.61
		- - - - - - - - - - -	- - 1,000,000 - - - - -				
Corn	bu.	141.85	15.09	15.09	-0-	-0-	-0-
Cotton	lb.	193.81	193.81	193.81	193.81	58.14	58.14
Grain Sorghum	cwt.	38.10	38.10	11.43	13.49	13.49	18.00
Soybeans	bu.	10.53	10.53	10.53	10.53	10.53	-0-
Wheat	bu.	11.56	28.84	28.84	28.84	28.84	28.84

[a]Scenario H is described in detail in Table 4. Assumptions are based on high prices for soybeans, average prices for other crops, and current input prices, irrigated acreage unrestrained, all costs considered and less restrictive crop acreage flexibility restraints.

APPENDIX B

The Analytical Model

Definition of Each Linear Programming Activity

Columns (Activities or Enterprises)

C2CRNFW3 - Corn production, 1 preplant plus 3 postplant furrow irrigations.

C2COTDRY - Cotton production, dryland.

C2COTFW1 - Cotton production, 1 preplant plus 1 postplant furrow irrigations.

C2COTFW2 - Cotton production, 1 preplant plus 2 postplant furrow irrigations.

C2GSODRY - Grain sorghum production, dryland.

C2GSOFW2 - Grain sorghum production, 1 preplant plus 2 postplant furrow irrigations.

C2GSOFW3 - Grain sorghum production, 1 preplant plus 3 postplant furrow irrigations.

C2SOYFW3 - Soybean production, 1 preplant plus 2 postplant furrow irrigations.

C2WHTDRY - Wheat production, dryland.

C2WHTFW3 - Wheat production, 1 preplant plus 3 postplant furrow irrigations.

C2WHTFW4 - Wheat production, 1 preplant plus 4 postplant furrow irrigations.

CXBUYDSL - Diesel fuel purchasing activity.

CXBUYNGS - Natural gas fuel purchasing activity.

CXBUYNIT - Nitrogen fertilizer purchasing activity.

CXBUYHBC - Herbicide purchasing activity.

CXBUYWXG - Activity for charging variable costs of pumping ground water (less fuel costs).

CXBUYWXF - Activity for charging fixed costs of pumping ground water.

CXSELCOT - Cotton lint selling activity.

CXSELCOS - Cotton seed selling activity.

CXSELGSO - Grain sorghum selling activity.

CXSLECOY - Soybean selling activity.

CXSELWHT - Wheat selling activity.

CXSELBEF - Activity for selling wheat pasture grazing.

CXSELCRN - Corn selling activity.

C2RNTLND - Activity for charging rent on land.

Rows (Resource or Crop Acreage Flexibility Restraints and Activity Transfers)

OBJF1 - Objective function used in short run scenarios.

OBJPARA - CHROW used in parameterizing prices.

OBJF2 - Objective function used in long run scenarios.

RXDIESEL - Diesel fuel required per acre (gallons).

RXCHGDSL - CHROW used in simultaneous parameterization of diesel and herbicide prices.

RXNATGAS - Natural gas required per acre (thousand cubic feet).

RXNITROF - Nitrogen required per acre (pounds).

RXHERBCD - Herbicide required per acre (dollars).

RXWATERQ - Irrigation water required per acre (acre feet).

RXWTRXNG - Variable costs (less fuel cost) per acre of pumping ground water (dollars).

RXWTRFIX - Fixed costs per acre of pumping ground water (dollars).

R2LIRRIG - Irrigated land restraint (acres).

R2LTOTAL - Total cropland restraint (acres).

R2LCOTMX - Upper cotton acreage flexibility restraint (acres).

R2LCOTMN - Lower cotton acreage flexibility restraint (acres).

R2LGSOMX - Upper grain sorghum acreage flexibility restraint (acres).

R2LGSOMN - Lower grain sorghum acreage flexibility restraint (acres).

R2LSOYMX - Upper soybean acreage flexibility restraint (acres).

R2SOYMN - Lower soybean acreage flexibility restraint (acres).

R2LWHTMX - Upper wheat acreage flexibility restraint (acres).

R3LWHTMN - Lower wheat acreage flexibility restraint (acres).

R2LCRNMX - Upper corn acreage flexibility restraint (acres).

R2LCRNMN - Lower corn acreage flexibility restraint (acres).

RXSELCOT - Cotton lint production per acre (pounds).

RXSELCOS - Cotton seed production per acre (tons).

RXSELGSO - Grain sorghum production per acre (hundred weight).

RXSELSOY - Soybean production per acer (bushels).

RXSELWHT - Wheat production per acre (bushels).

RXSELBEF - Wheat pasture grazing production per acre (pounds of beef).

RXSELCRN - Corn production per acre (bushels).

R2COTACR - Cotton acreage accounting row (acres).

R2GSOACR - Grain sorghum acreage accounting row (acres).

R2SOYACR - Soybean acreage accounting row (acres).

R2WHTACR - Wheat acreage accounting row (acres).

R2CRNACR - Corn acreage accounting row (acres).

R9CRNACR - Not used.

R9COTACR - Not used.

R9GSOACR - Not used.

R9SOYACR - Not used.

R9WHTACR - Not used.

R9LITTIG - Not used.

R9LTOTAL - Not used.

RZLNDRNT - Land rent per dryland acre (dollars).

Linear Programming Matrix

	C2CRNFW3	C2COTDRY	C2COTFW1	C2COTFW2	C2GSODRY	C2GSOFW2	C2GSOFW3	C2SOYFW2	
OBJF1	65.41000-	31.20000-	80.06000-	89.96000-	9.83000-	35.85000-	48.66000-	40.15000-	OBJF1
OBJF2	86.93000-	43.40000-	101.63000-	111.54000-	17.71000-	56.18000-	68.99000-	55.58000-	OBJF2
RXDIFSEL	20.59000	9.60000	18.72000	18.72000	6.25000	20.91000	20.91000	15.48000	RXDIFSEL
RXNATGAS	13.09000	.	7.27000	10.13000	.	10.18000	13.09000	10.18000	RXNATGAS
RXNITROG	150.00000	.	20.00000	40.00000	30.00000	80.00000	120.00000	.	RXNITROG
RXHERBCD	.	4.88000	7.32000	7.32000	.	3.85000	3.85000	[illegible]	RXHERBCD
RXWATERQ	1.50000	.	.83000	1.17000	.	1.17000	1.50000	1.17000	RXWATERQ
RXWTRXNG	5.40000	.	3.00000	4.20000	.	4.20000	5.40000	4.20000	RXWTRXNG
RXWTRFIX	18.90000	.	10.50000	14.70000	.	14.70000	18.90000	14.70000	RXWTRFIX
R2LIRRIG	1.00000	.	1.00000	1.00000	.	1.00000	1.00000	1.00000	R2LIRRIG
R2LTOTAL	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	R2LTOTAL
R2LCOTMX	.	1.00000	1.00000	1.00000	.	.	.	.	R2LCOTMX
R2LCOTMN	.	1.00000	1.00000	1.00000	.	.	.	.	R2LCOTMN
R2LGSOMX	.	.	.	.	1.00000	1.00000	1.00000	.	R2LGSOMX
R2LGSOMN	.	.	.	.	1.00000	1.00000	1.00000	.	R2LGSOMN
R2LSOYMX	.	.	.	.	.	.	.	1.00000	R2LSOYMX
R2LSOYMN	.	.	.	.	.	.	.	1.00000	R2LSOYMN
R2LCRNMX	1.00000	.	.	.	.	.	.	.	R2LCRNMX
R2LCRNMN	1.00000	.	.	.	.	.	.	.	R2LCRNMN
RXSELCOT	.	150.00000	425.00000	500.00000	.	.	.	.	RXSELCOT
RXSELCOS	.	.12000	.34000	.40000	.	.	.	.	RXSELCOS
RXSELGSD	.	.	.	.	15.00000	50.00000	57.00000	.	RXSELGSD
RXSELSOY	.	.	.	.	.	.	.	35.00000	RXSELSOY
RXSELCRN	110.00000	.	.	.	.	.	.	.	RXSELCRN
R2COTACR	.	1.00000	1.00000	1.00000	.	.	.	.	R2COTACR
R2GSOACR	.	.	.	.	1.00000	1.00000	1.00000	.	R2GSOACR
R2SOYACR	.	.	.	.	.	.	.	1.00000	R2SOYACR
R2CRNACR	1.00000	.	.	.	.	.	.	.	R2CRNACR
R9CRNACR	1.00000	.	.	.	.	.	.	.	R9CRNACR
R9COTACR	.	1.00000	1.00000	1.00000	.	.	.	.	R9COTACR
R9GSOACR	.	.	.	.	1.00000	1.00000	1.00000	.	R9GSOACR
R9SOYACR	.	.	.	.	.	.	.	1.00000	R9SOYACR
R9LIRRIG	1.00000	.	1.00000	1.00000	.	1.00000	1.00000	1.00000	R9LIRRIG
R9LTOTAL	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	R9LTOTAL
R2LNORNT	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	R2LNORNT

Linear Programming Matrix

	C2WHTDRY	C2WHTFW3	C2WHTFW4	CXBUYDSL	CXBUYNGS	CXBUYNIT	CXBUYHBC	CXBUYWTR	
OBJF1	15.86000-	36.97000-	46.20000-	.40000-	.88000-	.20000-	1.20000-	.	OBJF1
OBJPARA	.	.	.	.	.	.	.	1.00000-	OBJPARA
OBJF2	24.99000-	48.57000-	57.80000-	.40000-	.88000-	.20000-	1.20000-	.	OBJF2
RXDIESEL	9.15000	11.29000	11.29000	1.00000-	.	.	.	.	RXDIESEL
RXCHGDSL	.	.	.	1.00000-	.	.	3.00000-	.	RXCHGDSL
RXNATGAS	.	11.63000	14.55000	.	1.00000-	.	.	.	RXNATGAS
RXNITROF	.	80.00000	100.00000	.	.	1.00000-	.	.	RXNITROF
RXHERBCD	.	1.50000	1.50000	.	.	.	1.00000-	.	RXHERBCD
RXWATERO	.	1.33000	1.67000	.	.	.	.	1.00000-	RXWATERO
RXWTRXNG	.	4.80000	6.00000	.	.	.	.	.	RXWTRXNG
RXWTRFIX	.	16.80000	21.00000	.	.	.	.	.	RXWTRFIX
R2LIRRIG	.	1.00000	1.00000	.	.	.	.	.	R2LIRRIG
R2LTOTAL	1.00000	1.00000	1.00000	.	.	.	.	.	R2LTOTAL
R2LWHTMX	1.00000	1.00000	1.00000	.	.	.	.	.	R2LWHTMX
R2LWHTMN	1.00000	1.00000	1.00000	.	.	.	.	.	R2LWHTMN
RXSELWHT	15.00000	33.00000	40.00000	.	.	.	.	.	RXSELWHT
RXSELBEF	.90000	1.50000	2.00000	.	.	.	.	.	RXSELBEF
R2WHTACR	1.00000	1.00000	1.00000	.	.	.	.	.	R2WHTACR
R9WHTACR	1.00000	1.00000	1.00000	.	.	.	.	.	R9WHTACR
R9LIRRIG	.	1.00000	1.00000	.	.	.	.	.	R9LIRRIG
R9LTOTAL	1.00000	1.00000	1.00000	.	.	.	.	.	R9LTOTAL
R2LNDRNT	1.00000	1.00000	1.00000	.	.	.	.	.	R2LNDRNT

Linear Programming Matrix

	CXBUYWXG	CXBUYWXF	CXSELCOT	CXSELCOS	CXSELGSO	CXSELSOY	CXSELWHT	CXSELBEF	
OBJF1	1.00000-	.	.31000	100.00000	3.10000	4.27000	2.60000	20.00000	OBJF1
OBJF2	1.00000-	1.00000-	.18000	100.00000	1.86000	2.30000	1.34000	20.00000	OBJF2
RXWTPXNG	1.00000-	.	.	.	.	.	.	.	RXWTPXNG
RXWTRFIX	.	1.00000-	.	.	.	.	.	.	RXWTRFIX
RXSELCOT	.	.	1.05000-	.	.	.	.	.	RXSELCOT
RXSELCOS	.	.	.	1.05000-	.	.	.	.	RXSELCOS
RXSELGSO	.	.	.	.	1.05000-	.	.	.	RXSELGSO
RXSELSOY	.	.	.	.	.	1.05000-	.	.	RXSELSOY
RXSELWHT	.	.	.	.	.	.	1.05000-	.	RXSELWHT
RXSELBEF	.	.	.	.	.	.	.	1.05000-	RXSELBEF

Linear Programming Matrix

	CXSELCRN	C2RNTLND	QTR	
OBJF1	1.94000	.	.	OBJF1
OBJF2	1.12000	15.00000-	.	OBJF2
R2LIRRIG	.	.	3686000.0	R2LIRRIG
R2LTOTAL	.	.	3686000.0	R2LTOTAL
R2LCOTMX	.	.	808000.00	R2LCOTMX
R2LCOTMN	.	.	407000.00	R2LCOTMN
R2LGSOMX	.	.	1673000.0	R2LGSOMX
R2LGSOMN	.	.	800000.00	R2LGSOMN
R2LSOYMX	.	.	316000.00	R2LSOYMX
R2LWHTMX	.	.	2019000.0	R2LWHTMX
R2LWHTMN	.	.	809000.00	R2LWHTMN
R2LCRNMX	.	.	2676000.0	R2LCRNMX
RXSELCRN	1.05000-	.	.	RXSELCRN
R2LNDRNT	.	1.00000-	.	R2LNDRNT