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WATER RESOURCES EVALUATION OF THE SOUTHERN HIGH PLAINS OF NEW MEXICO

Technical Completion Report
Project No. B-037-NMEX

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New Mexico Water Resources Research Institute

in cooperation with

Department of Agricultural Economics and Agricultural Business,
Agricultural Experiment Station, NMSU

and

Department of Geoscience, NMIMT

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This study was part of an interdisciplinary-interuniversity research project entitled "An Interdisciplinary Evaluation of the Water Resources of the High Plains of New Mexico."

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ABSTRACT

An interdisciplinary approach to the solution of the water resource problems of the Southern High Plains in New Mexico was made possible by the integration of hydrology and geology with economics. Research procedures developed to carry out this study were closely coordinated by the investigators to achieve the primary objective of evaluation of the social and economic impacts of alternative water-use policies.

A linear programming model was developed to represent the Southern High Plains economy. Inputs into the model were obtained from separate studies covering the hydrological, agricultural, municipal, and industrial areas.

Three sets of alternatives were considered: (1) growth without a water constraint; (2) growth, decreasing pumpage 10 percent after 1966; (3) growth, increasing pumpage 10 percent after 1966.

Without a water constraint, both production and depletions are expected to exhibit the largest increase (54.5 percent and 66.9 percent, respectively). When a 10 percent decrease in pumpage constraint is imposed in the year 2020, the value of production is reduced by $19.02 million; employment by 2931 employees; and water depletions decreased about 62 percent. When a 10 percent increase in pumpage constraint is imposed, the value of production is decreased $47.09 million below that expected when compared to a 10 percent decrease in pumpage, and water depletions are reduced only slightly (31,900 acre-feet).

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Robert R. Lansford, Willem Brutsaert
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CHAPTER I

INTRODUCTION

The Southern High Plains of New Mexico--Curry, Roosevelt, and Lea Counties in eastern New Mexico--contain productive, groundwater-irrigated agricultural areas (Figure 1). These counties are rapidly depleting their irrigation water supply--groundwater sources which have little or no recharge. The Portales Valley in northern Roosevelt County, with irrigation experience predating statehood, has already felt the pinch of a declining water supply and some irrigated cropland has been abandoned. Irrigation development has been more recent in the other counties. For example, there was no irrigation in Curry County in 1940, but by 1970 about 190,000 acres had been developed; Lea County increased from 3,200 to 113,500 acres, and Roosevelt County from 11,300 to 103,700 acres (Lansford and Sorensen, 1972). Some of the more recently developed areas are also discontinuing irrigation.

The groundwater-irrigated acreage of the Southern High Plains region represents about 35 percent of the irrigated acreage in New Mexico (Lansford and Sorensen, 1971). It is estimated that in 50 years the irrigated acreage in the area will drop significantly (Stucky, et al. 1971).

A series of regional "Citizens' Conferences on Water" was held throughout the State of New Mexico, sponsored by the New Mexico Water Resources Research Institute (Stucky, Lansford, and Creel, 1971). Participants discussed important water-related problems of the different regions. The participants in the Southern High Plains region ranked the following problem

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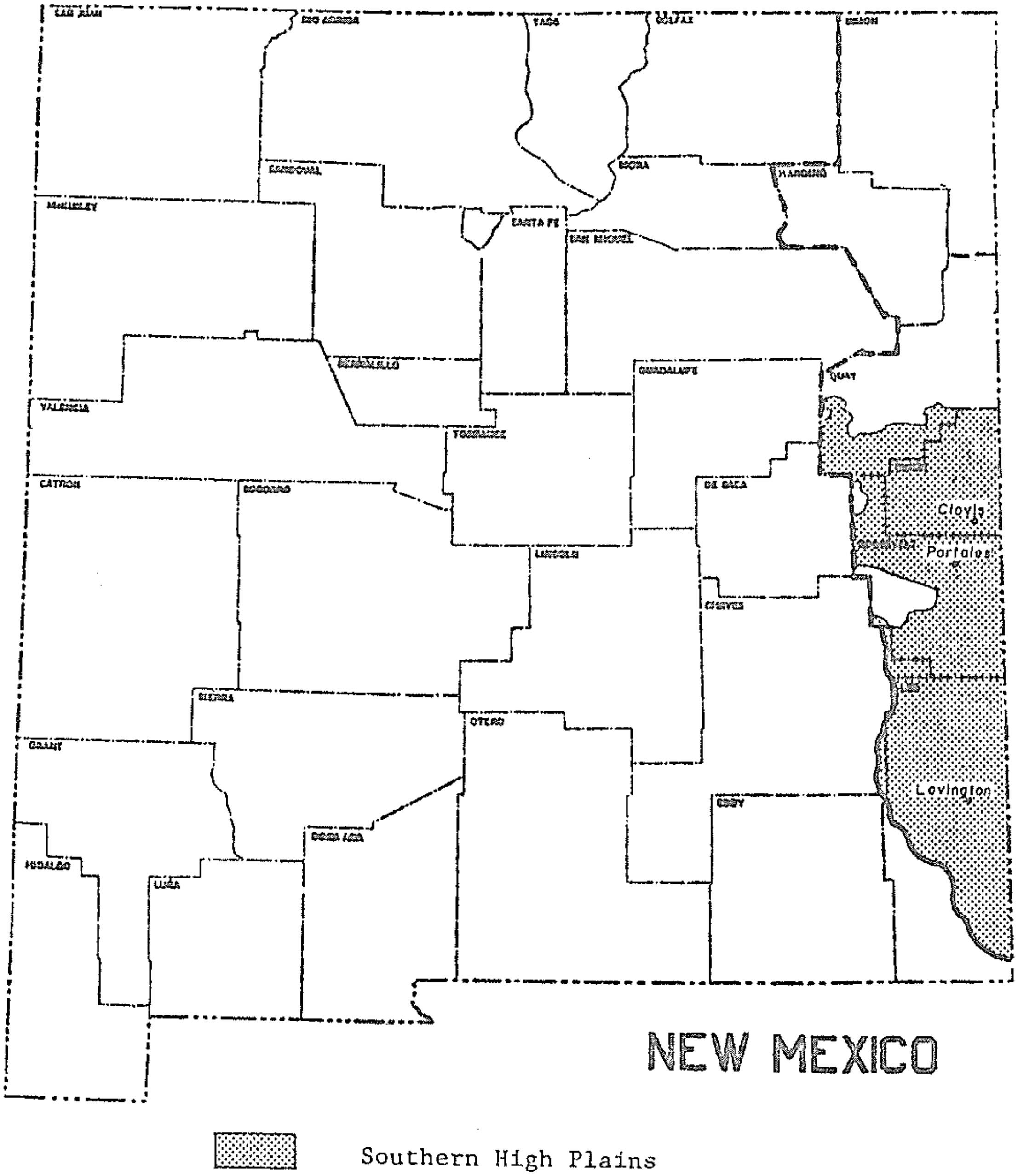


Figure 1. Location of the Southern High Plains in New Mexico.

areas as being most important: (1) declining ground-water table; (2) pollution of ground water; (3) improvements in water-use efficiency in agriculture.

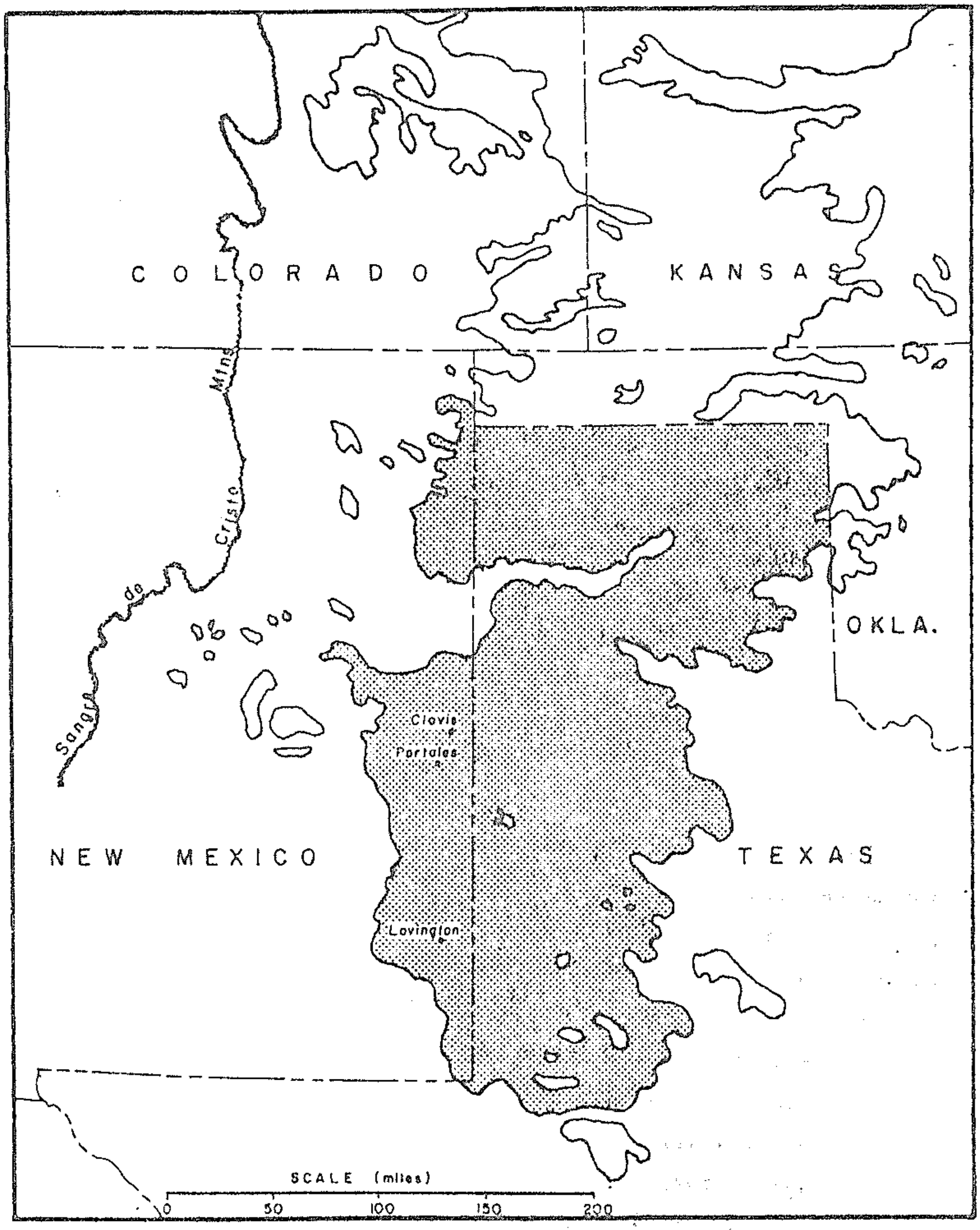
In a recent study supported by the Office of Water Resources Research, Bittinger and Associates (1970) recognized the eastern High Plains of New Mexico and Texas as an interstate ground-water problem between New Mexico and Texas. It involves a severe depletion situation in conjunction with widely varying legal doctrines. New Mexico's ground-water law is based on public ownership (prior appropriation) with controlled development. Texas ground-water law is based on riparian doctrine with little regulation of ground-water development. As a consequence, there is a pronounced disparity between New Mexico and Texas in irrigated agricultural development in the High Plains region.

The Ogallala formation, the common source of water for the High Plains (Figure 2), dips downward from New Mexico into Texas. The gradient of water movement in the Ogallala is largely from west to east. A common solution cannot be derived unless both states agree to a common management of the water resource in the Ogallala. Since New Mexico and Texas tap a common water source, any hydrologic analysis of the High Plains area should disregard artificial state boundaries.

Objectives

The primary objective of this study was to evaluate the economic impacts of alternative water-use policies in the Southern High Plains of New Mexico. To persue this objective it was necessary to develop an economic model for the estimation of alternative water-use patterns. The following sub-objectives were required to carry out the overall objective:

1. Hydrology - To estimate availabilities and interchanges of ground water and surface water in the Southern High Plains by mathematical model analysis.
2. Agriculture = To estimate current and future water use for irrigated agriculture in the Southern High Plains of New Mexico.
3. Municipal and Industrial - To estimate current and future water uses for municipal and industrial purposes.



Ogallala Formation

(Source: Merriam, 1963)

Figure 2. Geographic extent of the Ogallala formation in New Mexico and Texas

The economic model utilizes mathematical programming input-output analyses with regional income as the basis for economic comparison. Constraints on the model are water availability, labor force availability, and population.

CHAPTER II

GENERAL DESCRIPTION

The Southern High Plains of New Mexico is an elevated plateau located on the east-central margin of the State. The area is elongate (Figure 1), bounded on the east by Texas, and the north, west, and south by erosional escarpments facing the drainage basins of the Pecos and Arkansas Rivers. The plateau is approximately 170 miles long and 45 miles wide at its widest point; total area is about 5,880 square miles. The Southern High Plains includes most of Lea, Roosevelt, Curry, and small portions of Quay and Chaves Counties.

The principal towns in the area are Hobbs, Lovington, and Tatum in Lea County, Portales in Roosevelt County, and Clovis in Curry County. Although not situated on the Plains proper, the communities of House and Melrose (and the irrigated lands adjacent to both) are considered to be part of the Southern High Plains even though the surface drainage is to the Pecos River Basin.

Topography and Climate

The surface of the Southern High Plains slopes gently to the east and southeast and, with few exceptions, is remarkably smooth. The nearly featureless grassy surface is characteristically dotted with many broad, shallow depressions called playa lakes, and in the northern part of the area a number of broad shallow draws follow the slope of the plains. The latter, which include Fio Draw, Running Water Draw, Blackwater Draw, Tierra Blanca Draw, and Portales Valley, carry water only at times of heavy precipitation and, together with the playa lakes, constitute the only semblance of surface drainage in the area.

Minor sand dunes are found throughout the area and several extensive areas of dune development exist that are worthy of mention. One strip of dunes lies between Portales Valley and Blackwater Draw. It is two to five miles in width, rises from 50 to 100 feet above the draws, and completely spans the Southern High Plains in New Mexico. Other areas of dune development include a belt north of Blackwater Draw, a small tract east of McDonald in Lea County, and scattered areas in southern Roosevelt and northern Lea Counties.

The Southern High Plains is in the Great Plains physiographic province which consists of broad intervalley remnants of smooth fluviatile plains (Fenneman, 1931).

The climate of the Southern High Plains is predominantly semi-arid. It is characterized by clear and sunny days, large diurnal temperature ranges, low humidity, and moderately low rainfall. The mean annual precipitation averages about 15 inches. The summer months are, in general, the wettest ones when tropical air masses from the Gulf of Mexico predominate over the area and cause thundershowers. Occasionally these thundershowers are accompanied by hail which may cause severe damage to crops and property. The high temperatures and low relative humidity result in the rainfall being quickly evaporated or transpired. The mean annual precipitation, mean annual temperature, and average frost-free period for the stations are summarized in Table 1.

Temperatures in the area average about 58 degrees Fahrenheit. Winters are usually mild and dry, and temperatures above 100 degrees Fahrenheit are not uncommon in the summer months. The growing season usually begins in early April and lasts about 192 days until late October (Table 1). Average evaporation rates at Clovis and Portales are listed in Table 2 and amount to about 97 inches per year.

Drainage Area

The Southern High Plains region in New Mexico consists of three drainage areas. The Red River drainage area, in Quay and Curry Counties, is 685 square miles in extent; the Brazos River drainage area, in Curry and Roosevelt Counties, encompasses 695 square miles; Lea Plateau, in Roosevelt, Lea, and Chaves Counties, extends for some 4,500 square miles.

The plains area has no permanent streams. A few intermittent streams may flow following thunderstorms, which are common during July and August. Most precipitation, however, soon infiltrates into the soil or evaporates.

Table 1. Long-term average annual temperature, total precipitation, and frost-free period for Clovis, Portales, Tatum, and Hobbs, New Mexico

City	Average Temperature (degrees F)	Total Precipitation (inches)	Frost-free Period Length (days)	Frost-free Period Dates
Clovis	57.9	17.48	193	April 16 - Oct. 26
Portales	57.7	16.94	182	April 21 - Oct. 20
Tatum	58.8	15.82	190	April 17 - Oct. 24
Hobbs	61.2	15.12	214	April 5 - Nov. 9
Average	58.2	15.07	192	April 16 - Oct. 25

Source: New Mexico State Engineer Office, *Computed Consumptive Use Requirement and Temperature Data for New Mexico*, Open File Report, Santa Fe, March 1970.

Table 2. Average evaporation rates, in inches, at Clovis and Portales, New Mexico

Month	Station: Clovis 13N (1951-62)	Station: Portales 7WNW (1934-62)
January	4.08	3.05
February	4.57	4.29
March	7.52	7.73
April	9.95	9.33
May	11.85	10.92
June	13.74	12.56
July	13.31	11.74
August	11.54	10.49
September	9.76	8.48
October	6.71	6.22
November	4.57	4.36
December	3.84	3.15
Annual	101.44	92.32

Source: Blaney, H. F., and E. G. Hanson, *Consumptive Use and Water Requirements in New Mexico*, N. Mex. State Engineer Office Tech. Rept. 32, Santa Fe, 1965, 85 pp.

Hydrogeology

Rocks of Precambrian to Quaternary age underlie the Southern High Plains in New Mexico. The rocks of Precambrian age, mostly of igneous and metamorphic origin, lie in depths considerably below 10,000 feet. Rocks of the Ordovician to Permian Systems, having an aggregate thickness roughly estimated at 14,000 feet (Ash, 1963), overlie the Precambrian rocks but do not crop out in the area.

Red shale and sandstone of the Dockum Group of Triassic age underlie the entire area and are exposed locally, especially in the central part of the area and around the perimeter of the High Plains. The group has a maximum thickness of about 1,800 feet in Lea County (Ash, 1963). Overlying the Triassic rocks unconformably are yellow clay, blue shale, and sandstone of the Tucumcari Shale of Cretaceous age. The Tucumcari Shale underlies the central part of the area and crops out locally. It reaches a maximum thickness of about 180 feet in Roosevelt County.

The Ogallala Formation of Tertiary (Pliocene) age crops out or is covered only by thin alluvial deposits over the entire area of the Southern High Plains; it has a maximum thickness of about 400 feet except in the Portales basin. In the Portales basin, erosion during early Pleistocene time removed the Ogallala Formation, and the resulting valley was subsequently filled with a deposit of alluvium that attains a thickness of 200 feet or more. Elsewhere on the Southern High Plains the alluvium covering the Ogallala Formation is thin.

A preliminary geologic map of the southeastern quarter of New Mexico has been published by the U. S. Geological Survey (Bachman and Dane, 1958). An index and bibliography show the source of data used in compiling the map. A geologic map index of New Mexico (Boardman et al., 1956), also published by the Geological Survey, indicates reports and maps available for New Mexico.

Surface water. The Southern High Plains region has had only one streamflow-gaging station, on Running Water Draw near Clovis for the period 1950-1964. The drainage area for this station is 109 square miles. Peak discharge for the short period of record, measured to September 6, 1957, amounted to 7,090 cubic feet per second (cfs), which is 65.0 cfs per square mile of drainage area. There are no permanent streams on the Southern High Plains. Infrequent thunderstorms may cause some draws to flow for a short period; however, most of the precipitation soon infiltrates into the soil or evaporates.

Ground water. Only rocks of the Triassic, Cretaceous, Tertiary, and Quaternary systems are known to contain potable ground water. Permeable rocks of the Ordovician to Permian systems contain saline ground water. The only water known to have been pumped from these rocks has been saline water produced along with oil.

Rocks of Triassic and Cretaceous age yield small to large quantities of generally potable water to many wells on the Southern High Plains. Small quantities of water are obtained by wells tapping the upper part of the Dockum group of Triassic age in the central and northern parts of the area. The water comes from lenticular sandstones interbedded with red shale which constitutes the major part of the stratigraphic sequence. The Tucumcari shale of Cretaceous age in the Causey-Lingo area of Roosevelt County yields as much as 1,000 gallons per minute (gpm) to irrigation wells from sand and gravel at its base (Cooper, 1960). The formation underlies the central part of the Southern High Plains area, but elsewhere the coarse basal member is thin and the formation generally yields only small quantities of water.

The Ogallala formation and the overlying deposit of Quaternary alluvium constitute the Cenozoic stratigraphic sequence in the area. In most of the Southern High Plains area the two formations form a hydrologic unit. They are similar lithologically, and frequently it is difficult to distinguish one formation from the other. In the vicinity of Lovington, in the southern part of the area, yields as great as 1,700 gpm have been pumped from this composit aquifer (Ash, 1963). Yields of 1,000 gpm are common in the vicinity of Clovis to the north (Howard, 1954).

In the Portales basin, one of the more intensively irrigated parts of the Southern High Plains, ground water for irrigation is derived solely from a thick section of the Quaternary alluvium where alluvium fills the valley of an ancient stream that flowed east-southeastward across the High Plains

(Galloway, 1956). The alluvium in the Portales basin yields more than 1,000 gpm to many wells.

The rock units constituting the important aquifers of the High Plains have been cut off from surrounding areas by Recent erosion of the valleys of the Pecos and Canadian Rivers. Any recharge to the ground-water body can come only from infiltration of precipitation that falls on the High Plains (Theis, 1937).

The quality of ground water varies in accordance with the solubility of the constituents of the various rocks through which the water flows. For this reason the quality of water varies from aquifer to aquifer and also, to a lesser extent, from one locality to another in the same aquifer. Table 3 indicates the general chemical quality of water yielded by selected wells in the Southern High Plains in New Mexico.

Potable ground water is generally available throughout the area of the Southern High Plains. At a few localities, however, ground water from Triassic or Cretaceous age rocks may contain somewhat more than the recommended drinking water standard of 250 parts per million (ppm) of either sulfate or chloride.

Table 3. Analyses of water from selected wells in the Southern High Plains, New Mexico

Geologic Source and location	Sulfate (ppm)	Chloride (ppm)	Conductance (microhoms at 25° C)	Total hardness (as $CaCo_3$, ppm)
Ogallala Formation north of Clovis	42	8	428	169
Ogallala Formation southwest of Clovis	*	32	543	207
Valley fill northwest of Portales	675	168	1,920	955
Triassic red beds southeast of Arch	1,860	3,290	12,700	395
Ogallala Formation near Rogers	32	24	564	316
Cretaceous rocks	317	84	1,730	66
Ogallala Formation near Lovington	80	37	601	230
Ogallala Formation near Hobbs	112	82	795	298

*Not reported.

Source: New Mexico State Engineer Office in cooperation with New Mexico Interstate Stream Commission and the U. S. Geol. Survey, *Water Resources of New Mexico: Occurrence, Development, and Use*, State Planning Office, Santa Fe, 1967.

Water Management

Water management in the Southern High Plains of New Mexico is primarily a private entity function wholly concerned with ground water.

Declared underground basins. When the State Engineer finds that the waters of an underground stream channel, artesian basin, reservoir, or lake have reasonably ascertainable boundaries, and when he so proclaims, he assumes jurisdiction over the appropriation and use of such waters.

In 1931, the State Engineer declared the Lea County Underground Water Basin which covers a large portion of Lea County and small portions of Eddy and Chaves Counties (Figure 3). Subsequently, a 1952 extension to the original basin was declared, and the total declared area is about 2,180 square miles. Also, the State Engineer has declared the Portales Underground Water Basin, comprising about 628 square miles in Roosevelt and Curry Counties (Figure 3).

In the remainder of the Southern High Plains, the pumpage is not limited. All of the irrigated cropland within the Southern High Plains is irrigated with only ground-water sources. All municipal and industrial diversions are from ground-water sources.

Resources

Population. Table 4 presents a summary, based on data from the Bureau of the Census, of the population of the Southern High Plains from 1950 to 1970. Urban population refers to that part of the total population which resides in places of over 2,500 in number. Rural population refers to that part of the total which either resides in communities of less than 2,500 or in the "rural" portion of the county.

Of the State's total 1960 population, 102,318 (10.8 percent) were residents of the Southern High Plains. In 1970, the population of the Southern High Plains was 105,550: 80.2 percent were urban and 19.8 percent were rural residents. During the 20-year period between 1950-1970, urban inhabitants of the region increased almost 200 percent while rural population decreased almost 25 percent (Table 4).

Lea County experienced the greatest population growth of the three counties during the 20-year period, 1950-1970. In 1970, Lea County accounted

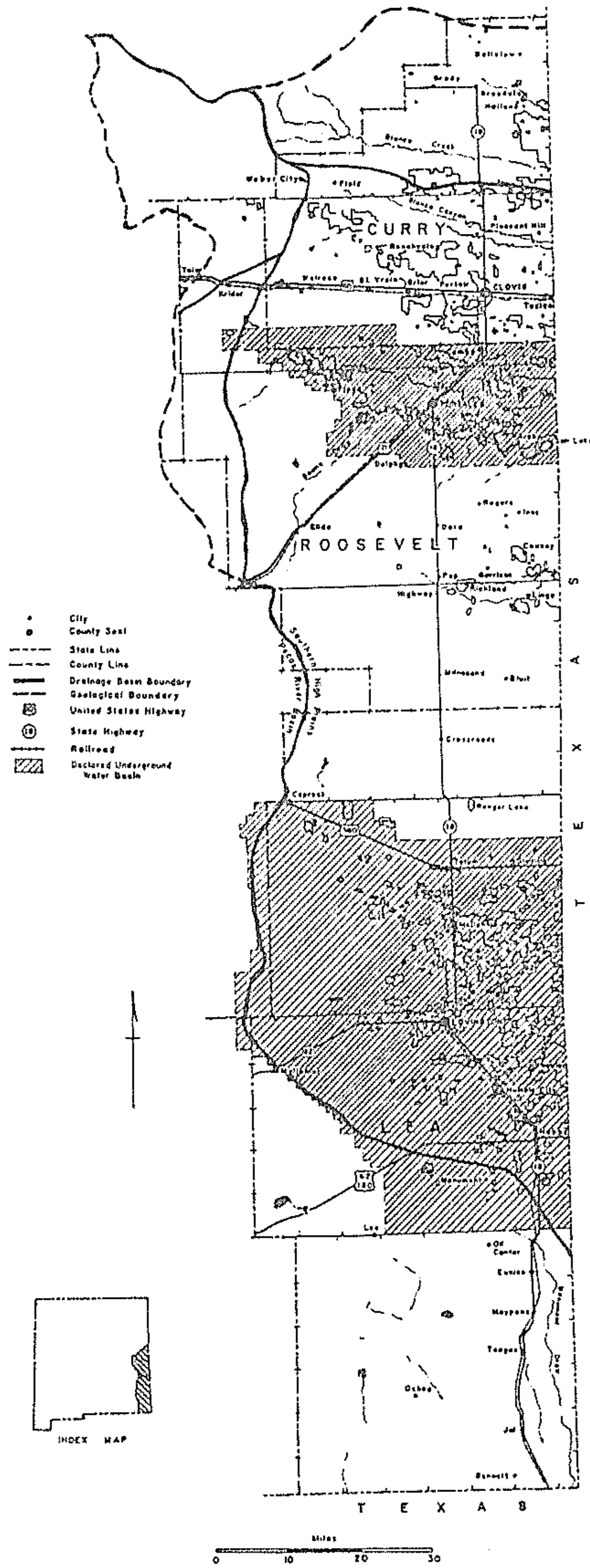


Figure 3. Location of declared groundwater basins in the Southern High Plains, New Mexico.

Table 4. Urban and rural population* for the Southern High Plains Region, New Mexico, 1950-1970

Year and County	Urban	Percent Urban	Rural	Percent Rural	Total	Percent Change from Previous Census
1970						
Lea	40,183	81.1	9,371	18.9	49,554	-7.2
Roosevelt	10,554	64.1	5,925	35.9	16,479	1.7
Curry	33,956	85.9	5,561	14.1	39,517	20.9
Total	84,693	80.2	20,857	19.8	105,550	3.2
1960						
Lea	42,476	79.5	10,953	20.5	53,429	73.9
Roosevelt	9,686	59.8	6,512	40.2	16,198	-1.3
Curry	23,701	72.5	8,990	27.5	32,691	40.0
Total	75,863	74.1	26,455	25.9	102,318	45.2
1950						
Lea	17,017	55.4	13,700	44.6	30,717	
Roosevelt	8,106	49.4	8,303	50.6	16,409	
Curry	17,309	74.1	6,042	25.9	23,351	
Total	42,432	60.2	28,045	39.8	70,477	

Major Cities	1950	1960	Percent Change	1970	Percent Change
Hobbs	13,875	26,288	89.0	26,025	-1.0
Lovington	3,134	9,659	208.2	8,915	-8.3
Portales	8,112	9,691	19.5	10,554	8.1
Clovis	17,318	23,706	36.9	28,495	16.8

*County definition.

Source: United States Bureau of the Census, "Number of Inhabitants, New Mexico," *United States Census of Population: 1950*, Vol. I, Chapter 31, U. S. Government Printing Office, Washington, D.C., 1951.

United States Bureau of the Census, "General Population Characteristics, New Mexico," *United States Census of Population: 1960*. Final Report PC (1) - 33B, U.S. Government Printing Office, Washington, D. C., 1961.

United States Bureau of the Census, "Final Population Counts, New Mexico," *United States Census of Population: 1970*. Advance Report, PC(V1)-33: U.S. Government Printing Office, Washington, D.C., 1970.

for 47 percent of the total region's population, down from the 56 percent figure in 1960 but up from the 40 percent figure in 1950. The primary reason for the loss in population from 1960 to 1970 was the reduced activity in the county's two basic industries, mining and agriculture. During the 1960 decade both of these industries accounted for a steadily decreasing share of the county's employment and personal income.

Curry County experienced a steady growth during the 20-year period, with almost a doubling of urban population and a 69 percent increase in rural population. A major factor in population growth in Curry County was the expansion of Cannon Air Force Base.

Roosevelt County's population changed very little, by only 70 people in the 20-year period. However, the urban-rural make-up changed substantially. Urban population increased from 49.4 percent in 1950 to 64.1 percent in 1970.

In 1970 the Southern High Plains encompassed approximately 12 percent of the urban population, 7 percent of the rural, and 10 percent of the total state population: in 1960 it contained approximately 12 percent of the urban, 8 percent of the rural, and 11 percent of the total population in the State of New Mexico.

Of the four major cities in the Southern High Plains, Hobbs and Lovington in Lea County exhibited the largest percentage growth from 1950 to 1970. However, both cities lost population between 1960 and 1970. Clovis and Portales exhibited relatively stable growth during the 20-year period.

Industrial Development. Lea County is one of the wealthiest and most productive areas in New Mexico. It accounts for nearly two-fifths of the State's value of mineral production and for two-thirds of its production of crude petroleum. Lea County's agricultural production is well balanced and has experienced significant growth in recent years. Other activities, particularly government, trade, and manufacturing, have provided increased employment and income. Lea County has a strong and diversified economy with 52 manufacturing firms (Table 5). Lea County increased its trade and service industries during the 1960's while oil and gas sectors were tapering off.

Much of the industrial activity in Curry and Roosevelt Counties depends directly upon agriculture, with manufacturers employing more than 100 persons being meat processors. The other agriculturally-dependent manufacturers include livestock feed dealers, peanut processors, dairy products, meat products, tankage, and irrigation. The major manufacturers not directly dependent upon agriculture are fabricated metal products, publishers, and a soft-drink bottling company.

Industrial development within the Southern High Plains has hinged primarily upon oil and gas and agriculture. However, with the decrease in economic activity in oil and gas and the expected decline in irrigated agriculture, the growth experienced over the past 10 years will be affected unless a new base can be developed.

Employment. The increase in employment in the Southern High Plains from 1960 to 1970 can be attributed primarily to wholesale and retail trade, services and miscellaneous, and government (Table 6). Mining, agriculture, contract construction, and all other non-agriculture employment decreased during the decade. However, an increase of approximately 10 percent in total employment was recorded from 1960 to 1970, which compares closely to the growth in population.

Lea County has had some recent economic setbacks related to its two basic industries, agriculture and mining. During the 1960 decade both of these industries accounted for a steadily decreasing share of the county's employment and personal income. In 1960, there were 5,990 persons employed in mining and 1,650 persons employed in agriculture. By 1970, only 4,546 persons were employed in mining and 1,240 persons employed in agriculture. The combined employment decrease of 1,864 in these two industries compares with an overall gain of 669 jobs by the rest of the county's economic sectors (Table 6).

The declining employment in agriculture and mining is largely the result of technological gains and other secular changes in the national economy. Productivity gains, which have been particularly significant in these two activities, have made increased production possible with fewer

Table 5. Type and number of manufacturing firms in the Southern High Plains, New Mexico, 1970

Type of Manufacturing	County Lea	County Roosevelt	County Curry	Southern High Plains
Food & kindred products	9	12	19	40
Apparel & other finished products			2	2
Lumber & wood products	2	2		4
Furniture & fixtures	1	2	4	7
Printing, publishing, and allied industries	12	5	4	21
Chemical & allied products	2	1	2	5
Petroleum refining and related industries	3			3
Stone, clay, & glass products	5	1		6
Fabricated metal products	4	1	6	11
Machinery	7	1	3	11
Electrical machinery, equipment, and supplies	2		1	3
Transportation equipment	3	1		4
Miscellaneous manufacturing industries	2	2	2	6
Total	52	28	43	123

Source: New Mexico State Engineer Office, *County Profile--Curry, Roosevelt, and Lea Counties*, Open File Reports, Santa Fe, October 1973.

Table 6. Employment[a] in the Southern High Plains, New Mexico, 1960-1970

(County Definition) - ESC	Lea County			Roosevelt County			Curry County			Southern High Plains		
	1960	1970	Percent Change	1960	1970	Percent Change	1960	1970	Percent Change	1960	1970	Percent Change
Total civilian work force	21,387	20,392	-4.6	5,880	6,270	6.6	10,180	12,164	19.5	37,397	38,826	3.8
Unemployment	790	847	-[b]	297	248	-[b]	301	431	-[b]	1,388	1,526	9.9
Rate	3.7	4.2	-[b]	5.1	4.0	-[b]	3.0	3.5	-[b]	3.9	3.9	-[b]
Employment	20,597	19,545	-5.1	5,533	6,022	8.8	9,879	11,733	18.8	36,009	37,300	3.6
Non-ag. wage and salary	16,156	16,060	-0.6	2,608	3,599	38.0	6,754	8,711	29.0	25,518	28,376	11.2
Manufacturing	611	691	14.1	208	258	24.0	415	635	53.0	1,234	1,584	28.4
Contract construction	906	809	10.7	143	79	-44.8	514	416	-19.1	1,563	1,304	-16.6
Mining	5,993	4,546	-24.1	-[c]	-[c]	-[c]	19	-[c]	-[c]	6,012[c]	4,546[c]	-[c]
Public utilities and transportation	2,102	2,051	-2.4	202	191	-5.4	1,321	1,166	-11.7	3,625	3,408	-6.0
Wholesale & retail trade	3,296	3,556	7.9	712	750	5.3	1,692	2,552	50.8	5,700	6,858	20.3
Real estate, finance, and insurance	404	467	15.6	72	130	80.6	301	432	43.5	777	1,038	33.6
Services and miscellaneous	1,162	1,717	47.8	190	320	68.4	886	1,245	40.5	2,238	3,282	46.5
Government	1,683	2,220	31.9	1,081	1,871	73.1	1,606	2,265	41.0	4,370	6,356	45.4
All other non-ag.	3,145	2,239	-28.8	884	863	-2.4	1,784	1,647	-7.7	5,813	4,749	-18.3
Agriculture	1,295	1,240	-4.2	2,041	1,560	-23.6	1,340	1,375	2.6	4,676	4,175	-10.7

a. Derived from ESC data.
b. Unemployment and associated rate are used for illustrative purposes; therefore, no percentage changes were needed.
c. Undisclosed information; therefore, percentage changes not calculable.

Source: New Mexico Employment Security Commission, Research and Analysis Section, *Labor Information Series, Estimated Civilian Work Force, Unemployment, and Employment by Industry*, Open File Rept. Albuquerque, New Mexico, 1950, 1960, and 1970, 32 pp.

workers. In addition, reductions in exploration activity for new petroleum and natural gas reserves have adversely affected employment levels in the oil and gas field services sector.

The major areas of employment growth during the 1960's in Lea County have been government, wholesale and retail trade, and manufacturing. This trend away from employment in basic industries has been more evident and rapid in Lea County than most other counties in New Mexico, but the county's economy is still largely dependent on agriculture and mining.

Employment in Curry and Roosevelt Counties increased about 15 percent from 1960 to 1970. Much of the employment in Curry and Roosevelt Counties depends directly upon agriculture. In both counties, agriculturally related manufacturers account for 75 percent of the firms and thus a large share of the employment. There are four major employers for the two counties who are neither manufacturers nor services: they are Eastern New Mexico University in Portales; Cannon Air Force Base in Clovis; the Atchison, Topeka and Santa Fe Railway in Clovis; and the tourism industry. As in Lea County, trade and services had significant increases in employment in Curry and Roosevelt Counties while contract construction, public utilities, and transportation had decreases in employment. Direct agricultural employment declined in Roosevelt County but increased moderately in Curry County (Table 6).

Land. Within the Southern High Plains there are approximately 5.3 million acres, with Lea County accounting for slightly over 50 percent (Table 7). Land ownership in the Southern High Plains is reported in Table 7, and land use is reported in Table 8. Federal and state ownership account for about 31 percent, and private ownership accounts for the other 69 percent (Table 7). The Bureau of Land Management (BLM) administers about 75 percent of the federal ownership, and defense controls the remaining 5 percent.

In Lea County more than 50 percent of the land is in private ownership, 31 percent is owned by the state, and 17 percent is owned by the federal government. All of the federal ownership is managed by BLM. In Roosevelt County, about 84 percent of the land is in private ownership, 13 percent is

Table 7. Land ownership and administration (in acres) in the Southern High Plains, New Mexico, 1972

	County*			Total Southern High Plains
	Lea	Roosevelt	Curry	
	. . . . acres			
Indian lands	0	0	0	0
Federal lands	466,952	38,517	3,862	509,331
Forest Service	(0)	(0)	(0)	(0)
BLM	(466,952)	(16,397)	(391)	(483,740)
Defense	(0)	(22,120)	(3,471)	(25,591)
Miscellaneous	(0)	(0)	(0)	(0)
State lands	873,748	211,140	60,667	1,145,555
Private and other miscellaneous	1,471,460	1,322,823	834,031	3,628,314
Total area	2,812,160	1,572,480	898,560	5,283,200

*Total county land area.

Source: New Mexico State Engineer Office, *County Profile--Lea, Roosevelt, and Curry Counties*, Open File Report, Santa Fe, October 1973.

owned by the state, and about 2 percent is owned by the federal government. In Curry County, private ownership accounts for about 93 percent of the land, state ownership 7 percent, and federal ownership less than 1 percent.

In the Southern High Plains, agricultural use of the land accounts for about 93 percent of the total. Grazing is by far the highest single use of land, accounting for about 75 percent of total use (Table 8). The next greatest use, 22 percent, is for crop production. This trend follows in all three counties, with agriculture accounting for 98 percent in Lea, 95 percent in Roosevelt, and 96 percent in Curry County (Table 8). However, crop production accounts for about 65 percent of agricultural land use in Curry County, 30 percent in Roosevelt County, and only 4 percent in Lea County. The predominant cropping use is for dry cropland production in Curry and Roosevelt Counties and irrigated crop production in Lea County.

Table 8. Land use (in acres) in the Southern High Plains, New Mexico, 1972

	County*			Total Southern High Plains
	Lea	Roosevelt	Curry	
	. . . . acres			
Inland waters	2,640	3,243	100	5,983
Urban and built up	40,275	18,000	17,500	75,775
Roads	20,777	15,460	14,543	50,780
Cropland (total)	122,810	461,700	583,800	1,168,310
irrigated	(101,500)	(103,700)	(187,900)	(393,100)
dry	(21,310)	(358,000)	(395,900)	(775,310)
Defense	0	22,120	3,471	25,591
Parks, fish, and wildlife	0	19,571	0	19,571
Commercial timber	0	0	0	0
Grazing lands (total)	2,625,658	1,032,386	279,146	3,937,190
Non-comm. timber	(0)	(0)	(5,638)	(5,638)
Range lands	(2,625,658)	(1,032,386)	(273,508)	(3,931,552)
Total Area	2,812,160	1,572,480	898,560	5,283,200

*Total county land area.

Irrigated cropland. The irrigated cropland is located in the central and northern part of Lea County, the Portales Valley and the Causey-Lingo area in Roosevelt County, and primarily in the southern and certral portion of Curry County (Figure 4). Nearly all of the irrigated cropland lies within the Southern High Plains in the three counties. Only a very small acreage lies outside the Southern High Plains in Lea County, and a small acreage in the House area in Quay County is within the Southern High Plains.

The acreages of various crops produced are reported by county in Table 9. In terms of acres, sorghum was the most important irrigated crop, accounting for 36 percent of the total irrigated cropland. The next most important crop was wheat at 19 percent, followed by diverted acreage at 15 percent, idle or fallow at 14 percent, and cotton at 9.5 percent. Cotton was relatively more important in Lea County, accounting for 20 percent of the total irrigated cropland, with sorghum 29 percent, alfalfa 10 percent, and diverted, idle,

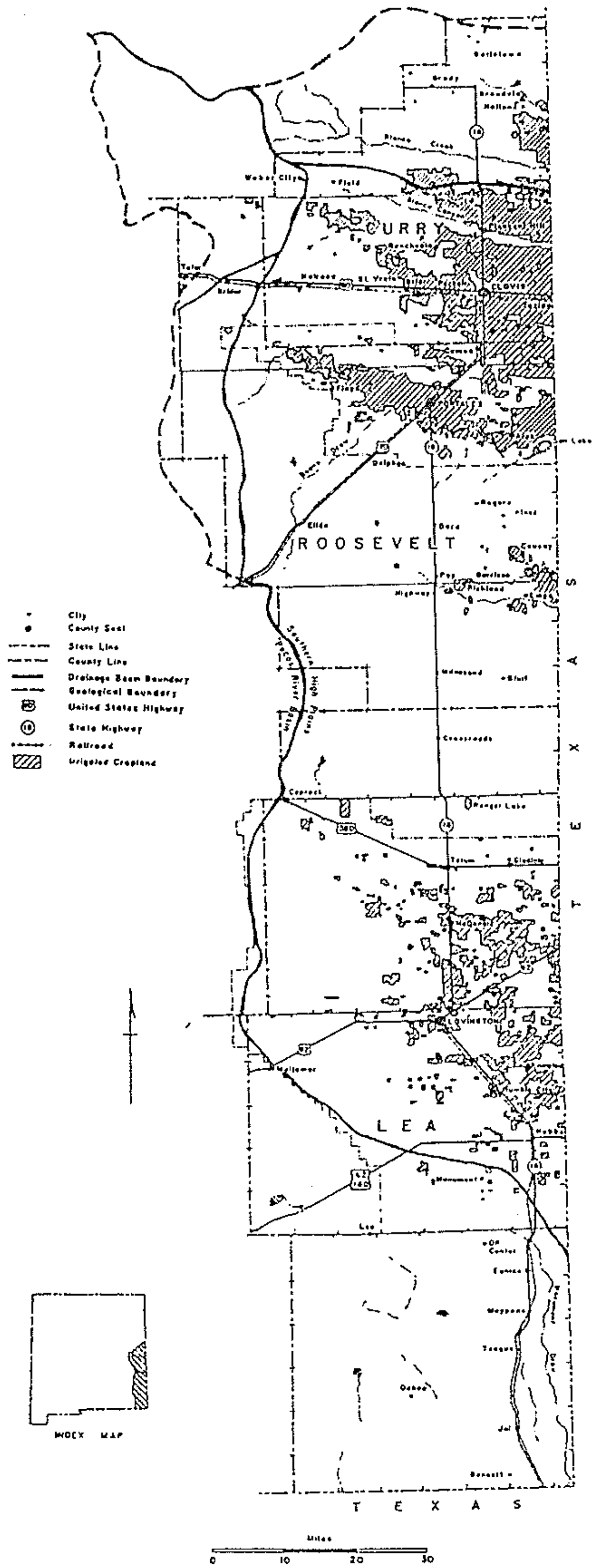


Figure 4. Location of irrigated cropland in the Southern High Plains, New Mexico.

Table 9. Use of irrigated cropland, (in acres), Southern High Plains, New Mexico, average of 1969-1972

Crop	County: Lea	County: Roosevelt	County: Curry	Total Southern High Plains: Acres	Total Southern High Plains: Percent
	. . . .	.Acres.			
Corn	608	1,350	3,350	5,308	1.47
Sorghum	30,600	34,750	65,000	130,350	36.03
Broomcorn	0	2,000	138	2,138	0.59
Wheat	175	10,800	58,050	69,025	19.08
Barley	643	420	1,700	2,763	0.76
Other small grain	3,980	4,763	9,855	18,598	5.14
Cotton	21,443	11,663	1,123	34,229	9.46
Peanuts	198	7,660	40	7,898	2.18
Sugar beets	0	0	1,825	1,825	0.50
Dry beans	0	23	98	121	0.03
Other field crops	75	130	1,500	1,705	0.47
Potatoes	0	763	325	1,088	0.30
Onions	170	83	3	256	0.07
Chile	3	20	0	23	0.01
Miscellaneous vegetables	605	418	18	1,041	0.29
Orchards	65	10	0	75	0.02
Alfalfa	11,075	4,850	2,925	18,850	5.21
Other hay	1,650	9,500	8,250	19,400	5.36
Irrigated planted pasture	3,350	2,900	5,800	12,050	3.33
Irrigated native pasture	1,000	283	65	1,348	0.37
Subtotal All Crops	75,640	92,386	160,065	328,091	90.68
Double cropped	(250)	(8,250)	(20,748)	(29,248)	(8.08)
Total Area in Crops	75,390	84,136	139,317	298,843	82.59
Diverted acreage planted	(4,240)	(8,783)	(28,875)	(41,898)	(11.58)
Diverted acreage fallow	15,165	5,358	34,375	54,898	15.17
Idle or fallow	19,632	12,820	17,528	49,980	13.81
Total Cropland	105,947	93,531	162,345	361,823	100.00

Source: Lansford, Robert R. and Earl F. Sorensen, "Trends in Irrigated Agriculture, 1970 and 1971," *New Mexico Agriculture--1971*, Agricultural Experiment Station Research Rept. 235, New Mexico State University, 1972, pp. 42-43.

Lansford, Robert R., "Planted Cropland Acreage in New Mexico in 1970 and 1971," *New Mexico Agriculture--1971*, Agricultural Experiment Station Research Rept. 235, New Mexico State University, 1972, pp. 31-37.

Lansford, Robert R., "Planted Cropland Acreage in New Mexico in 1971 and 1972," *New Mexico Agriculture--1972*, Agricultural Experiment Station Research Rept. 260, New Mexico State University, 1973, pp. 18-24.

or fallow at 33 percent. In Roosevelt County sorghum was the most important crop, accounting for 37 percent of the total irrigated cropland, cotton 12.5 percent, wheat 11.5 percent, peanuts 8 percent, and diverted, idle, or fallow 19 percent of the total. In Curry County, sorghum accounted for the highest percentage of irrigated cropland use at 36 percent, diverted acreage, idle, or fallow at 29 percent, and wheat at 16 percent.

Dry cropland. The dry cropland in the Southern High Plains is located primarily in northern Lea County, central Roosevelt, and western and northern Curry Counties. Another large acreage lies in southern Quay County within the Southern High Plains of New Mexico.

The acreages of various dry crops produced in the Southern High Plains are reported in Table 10. In terms of acreages, the most important dry crop was wheat which accounted for 19.6 percent of the total dry cropland acreage, followed by sorghum at 17.6 percent; diverted acreage (under government programs) accounted for 35.4 percent, and idle or fallow accounted for 18 percent of the total dry cropland acreage. Curry County accounts for 53 percent of the region's dry cropland, Roosevelt 44 percent, and Lea County about 3 percent.

Water Resources. There are no regularly flowing streams in the Southern High Plains: ground water is the only source of water. Ground water is used for agriculture, for the municipal supply for towns and cities within the region, for an industrial supply of water, and for rural domestic use. Most of the water use is from the Ogallala formation. In most of the Portales Valley of northern Roosevelt County, water is produced from alluvial fill of a broad, shallow, abandoned valley developed by an ancient eastward-to-southeastward flowing stream.

Essentially all water problems of the Southern High Plains are concerned with ground-water supplies with very little natural recharge. As early as 1937, C. V. Theis estimated the ground-water recharge of the Southern High Plains to be less than 0.5 inches into the Ogallala formation, the primary aquifer of the study area. Since then, large-scale pumping

Table 10. Use of dry cropland, (in acres), Southern High Plains, New Mexico, average of 1969-1972

Crop	County: Lea	County: Roosevelt	County: Curry	Total Southern High Plains: Acres	Total Southern High Plains: Percent
	. . . . Acres.	. . . . . .		Acres	Percent
Corn	0	200	50	250	0.03
Sorghum	3,750	72,250	55,250	131,250	17.63
Broomcorn	0	12,190	713	12,903	1.73
Wheat	48	42,200	103,625	145,873	19.59
Barley	0	10	138	148	0.02
Other small grain	0	1,825	675	2,500	0.34
Cotton	145	3,988	25	4,158	0.56
Dry beans	0	338	0	338	0.05
Alfalfa	0	0	0	0	0.00
Pasture and other hay	4,650	41,555	3,000	49,205	6.61
Subtotal All Crops	8,593	174,556	163,476	346,625	46.56
Double cropped	(0)	(0)	(0)	(0)	(0.00)
Diverted acreage	5,635	100,860	157,250	263,745	35.43
Idle or fallow	6,255	52,095	75,725	134,075	18.01
Total Cropland	20,483	327,511	396,451	744,445	100.00

Source: Lansford, Robert R., and Earl F. Sorensen, "Planted Cropland Acreage in New Mexico in 1969 and 1970," *New Mexico Agriculture--1970*, Agricultural Experiment Station Research Rept. 195, New Mexico State University, 1971, pp. 6-12.

Lansford, Robert R., "Planted Cropland Acreage in New Mexico in 1970 and 1971," *New Mexico Agriculture--1971*, Agricultural Experiment Station Research Rept. 235, New Mexico State University, 1972, pp. 31-37.

Lansford, Robert R., "Planted Cropland Acreage in New Mexico in 1971 and 1972," *New Mexico Agriculture--1972*, Agricultural Experiment Station Research Rept. 260, New Mexico State University, 1973, pp. 18-24.

of ground water for irrigation of the rapidly increasing acreage and for industrial, municipal, domestic, stock, power production, and recreational uses has resulted in a rapid lowering of the water table. Agriculture accounts for approximately 97 percent of these uses.

Ground-water level declines were as much as 30 feet over the period 1961-1965 in the Clovis area and were as much as 9 feet from 1967 to 1968.

In the Portales area, water-level declines resulting from pumping were as high as 10 feet over the five-year period 1961-1965, and 4 feet from 1967 to 1968 (Busch and Hudson, 1969). Irrigation water in the Portales Valley is the exception, where the primary source is the valley fill. Ground-water development in the Portales area has been under control of the State Engineer since 1950 when the area was declared an underground-water basin. In the Causey-Lingo area, in east-central Roosevelt County, water-level declines during the five-year period 1961-1965 averaged about 7 feet and were as high as 6 feet from 1967-1968 (Busch and Hudson, 1969).

The Lea County underground-water basin was declared in 1931 and extended in 1952. The largest water-level declines in the Lea County area occurred southeast of Lovington, where the decline was about 13 feet over the five-year period 1961-1965: the decline for the 1967-1968 period was about 3 feet. This area is one of New Mexico's major petroleum producing areas; in recent years, demand for water for use in oil-field waterflooding operations has been increasing, and projections indicate that the demands will continue to increase. Contamination of the ground water by surface disposal of oil-field brines and from leaky oil-well casing has been partially corrected in recent years by subsurface disposal of brine and periodic testing of oil-well casing.

Ground water in the Southern High Plains is normally encountered at reasonably shallow depths. In general, the saturated thicknesses are usually less than 200 feet. Irrigation wells yield an average of 700 gallons per minute (gpm) in Curry County, 600 gpm in the Portales Valley, 500 gpm in the Causey-Lingo area of Roosevelt County, and 900 gpm in Lea County.

CHAPTER III

METHOD AND PROCEDURES

An interdisciplinary approach to the solution of the water resource problems of the Southern High Plains in New Mexico was made possible by the integration of hydrology and geology with economics. Research procedures developed to carry out this study were closely coordinated by the investigators to achieve the stated objectives. Inputs into the economic model were obtained from separate studies covering the hydrological and agricultural areas.

Economic Model

The economic model is essentially a linear programming model designed to represent the Southern High Plains economy. It consists primarily of an input-output table of technical coefficients for the region and a set of constraints placed upon water-connected resources. These constraints include:

(1) Water resources available

  (a) Ground supplies

(2) Human resources available

  (a) Labor force

  (b) Population types.

The year 1967 was chosen as the base year for the coefficients in the model because it was the latest year for which output figures could be derived.

Model description. A mathematical programming model incorporating input-output coefficients for the production sectors of the economy, patterned after Ben-David's model (Lansford, et al., 1972) was developed. The model incorporates the outputs of the individual subinvestigations in the Southern High Plains and is utilized to project future water-use patterns and economic development under alternative assumptions.

An optimal solution of the model for a given set of economic and demographic conditions can be obtained by maximizing the model's objective function. Each production sector contributes to the total value added according to its level of production, while negative impacts on the labor force, such as unemployment, impose a cost to the system. The optimal solution will provide the optimal mix of production sectors which satisfies the region's final demands and resource availabilities.

A major component of the model is the interregional input-output model developed for this study utilizing the 1967 High Plains of Texas Input-Output Table developed by Osborn and McCray (1967).

The classification of major sectors within the Southern High Plains economic description used the 1967 I-O study's breakdown which included 94 sectors. The original 94-sector model was then aggregated into a 13-sector matrix (Table 11). The aggregation became necessary for two main reasons: (1) there was a lack of reliable secondary sources from which a good analysis could proceed with all 94 private sectors; and (2) the logistics problem and the time required to assimilate all the necessary data would be exorbitant and would make any economic analysis and policy implications take a secondary priority.

Aggregation of the sectors into a 13-sector matrix was based primarily on three criteria. First, the procedure accounted for labor skill patterns among the original sectors and attempted to insure whole and comparable SIC codes. Second, water-use patterns and similarity in water cofficients (national studies) were relied upon to aggregate. Third, a similar set of input structures was strived for in the aggregation process.

The objective function is constructed to maximize value added within the region subject to several separate cost components. Typically, value added per unit measures the payment to households as wages, payments to governments as taxes, and payments to business as profits. The goal, therefore, is to maximize this "net addition" to the region. The cost components serve as mechanisms to encourage the system to use as little as possible of the "resources" that these cost components reflect.

The cost assigned to the system for "allowing" unemployment within the region becomes a component. Unemployment insurance, welfare payments, etc., are just a few of the elements considered in the cost to the State as a whole. The objective function is thus concerned with maximizing value

Table 11. Definition and classification of production sectors

Production Sector	West Texas I-O Study*	Production Sector Description
Agriculture		
1	1	Irrigated cotton
2	2, 3, 4	Irrigated food and grain crops
3	5, 6, 7, 8	Dry land crops
4	9	Range livestock
5	10, 11	Other livestock
6	12, 13	Agricultural services
Mining		
7	14, 15, 16	Mining, oil and gas
Construction		
8	17, 18, 19, 20, 21	Contract construction
Manufacturing		
9	22 - 38	Manufacturing
Trades and Services		
10	39-52	Transportation, communications, and utilities
11	53-72	Wholesale and retail trade
12	73, 74, 75	Finance
13	76-94	Services

*Source: Osborn, J. E. and McCray, *The Structure of the Texas High Plains Economy*, Technical Report T-1-108, Department of Agricultural Economics, Texas Tech University, Lubbock, Texas, August 1972, 57 pp.

added, subject to the following cost: Under-utilization of the labor force (unemployment).

The actual value of the objective function is not really important: only the relative differences when various transfers, movements, and additions of resources are used in solving the model. In addition, differential pricing in the cost components can be considered and weighted by using the mechanism of the objective function to assign relative weights to all activities.

Model components. Results and interpretations from the economic model are only as good as the assumptions within the model and the reliability of the basic input data. Consequently, a major proportion of the time and effort of this study went into the preparation of the basic hydrologic, agricultural, and economic data.

Hydrologic Data

Before an economic evaluation of water use can be made, the availability of water must be determined. Within the Southern High Plains there is only ground water. Therefore, a model of the ground water is necessary if a good description of the pumping effects is desired. In addition, the diversions and depletions must be known in order to have a reliable model.

For a comprehensive alternative water-use analysis it is necessary to know both the ground-water availability and the behavior of the aquifer under projected stresses. Since historical records of the hydrologic system, in most instances, are inadequate to permit direct analysis of basin behavior under projected stresses, it was decided that a ground-water system simulator be developed. The most efficient and practical simulator for this study appeared to be a mathematical analogue of the hydrologic basin, solved by digital computer. Such a hydrologic system can be schematically represented as in Figure 5. For a more detailed description of a similar model, see Brutsaert and Way (1973).

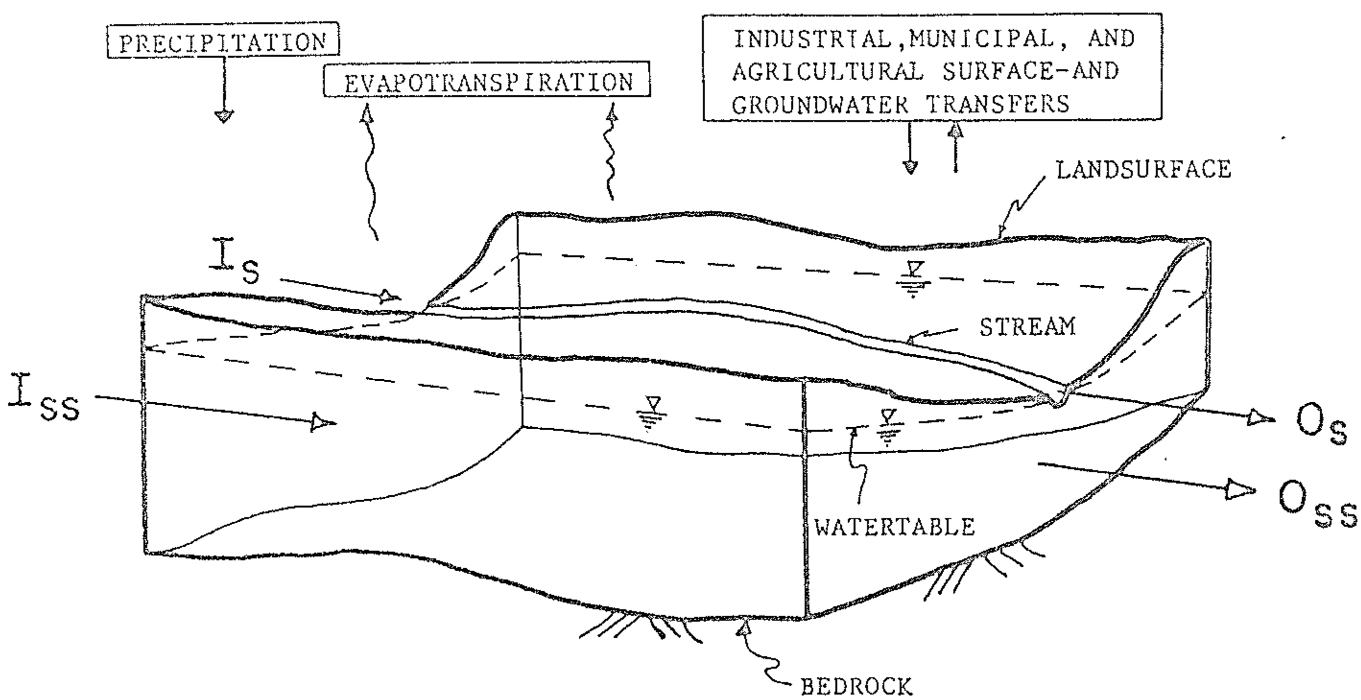


Figure 5. Schematic representation of hydrologic basin.

In this Figure, I = inflow, O = outflow, and the subscripts s and ss, respectively, stand for surface and subsurface. Figure 5 is simply a representation of the statement of continuity.

The fundamental flow equation being utilized for this study is the non-linear partial differential equation describing transient, incompressible, isothermal, two-dimensional flow in an unconfined aquifer which is:

$$\frac{\partial}{\partial x}\left(Kh\frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(Kh\frac{\partial H}{\partial y}\right) = S\frac{\partial H}{\partial t} + \frac{Q}{\delta x \delta y} \qquad (1)$$

where K = hydraulic conductivity; h= saturated thickness: H = water table elevation (total head) above datum; S = effective porosity (storage coefficient); Q = net withdrawal rate from aquifer; x, y = space dimensions; t = time dimensions; δx, δy = surface area of element.

The above equation is a nonlinear partial differential equation obtained by combining Darcy's law with the continuity principle and is applicable to transient, two-dimensional flow in heterogeneous, anisotropic, incompressible, unconfined, saturated, porous media.

This equation represents the ground-water-surface-water simulator used in this study. It was solved by an implicit finite difference scheme on an IBM system 360 Model 44 computer. The method requires the study area to be divided up by a grid system. The memory capacity of the computer allowed for a maximum of 15 x 26 grid blocks to cover the entire New Mexico portion below the Canadian River and approximately two-thirds of the Texas Panhandle; finer spacing of blocks was designed for the New Mexico portion in order to get better resolution. The smallest size of a block in the grid system is 6 x 6 miles.

With respect to boundary conditions, the escarpment of the Ogallala was considered an impervious boundary with the exception of the eastern boundary condition (in Texas) which was treated as a ground-water boundary outflow. The eastern boundary of the model did not reach to the end of the Ogallala formation.

For the mathematical model, various hydrological data of the Southern High Plains of New Mexico and Texas were collected. These data were required for each grid block and included water level elevations, precipitation, irrigation acreage, pumping test analysis, bedrock elevations, and other hydrogeologic information.

The water-level elevations were obtained from publications of the Texas Water Development Board (1966) and the New Mexico State Engineer Office in Roswell open file reports. Continuous annual water-level records from 1950-1966 were available.

Information related to precipitation was obtained from climatological data published by the U. S. Department of Commerce Weather Bureau. Annual precipitation in the period 1956-1966 was collected for this study.

Irrigation acreage of New Mexico was available from water-right allocations and open file reports of the State Engineer Office; for Texas, pumpage volume was obtained from the High Plains Irrigation Survey (New, 1971).

With respect to hydraulic conductivity, a compilation of aquifer tests published by the Texas Water Development Board (1969) gave a reasonably good idea of the distribution of hydraulic conductivity. For New Mexico, hydraulic conductivity data were obtained from technical reports of the State Engineer Office.

A Hydrological Investigation Atlas (Cronin, 1969) published by the United States Geological Survey (U.S.G.S.) was the main source of bedrock elevations and saturated thickness. The location of wells was made on maps of the U.S.G.S., some on 7-1/2 and others on 15-minute quadrangle maps. Many publications related to the hydrogeology of the area were also obtained.

A period of 11 years of calibration from 1956-1966 was selected as reasonable, with time increments of 3 months. In order to help the calibration, detailed water-level maps of 1956 and 1967 were constructed.

The values of hydraulic conductivity for each grid block were obtained from a map showing hydraulic conductivity distributions. These values were based on pumping test data and specific capacity data. However, with New Mexico, the task was difficult owing to lack of information, and some interpolations based on water-table contour spacing were necessary.

An average value of storativity of .15 was assumed for the whole area. This decision was based on long-term pumping test results and personal communication with engineers of the New Mexico State Engineer Office in Roswell and of the Texas District I Office.

Average annual pumpage figures for all blocks were estimated from the actual water-level declines or rises throughout the calibration period 1956-1966, as well as from irrigated acreage distribution patterns.

Annual average precipitation data for selected weather reporting stations were used in the model. A coefficient of 0.025 was used as the recharge of the ground-water system from precipitation.

Annual consumptive use of phreatophytes was considered negligible. Leakage into or out of the underlying bedrock was not considered due to lack of evidence.

All this information was used as input data to the computer model. The model was considered calibrated when computed and actual 1967 water levels were matched. A forward-extrapolation period of 40 years was run for the purpose of this study after the eleven year simulation period. Pumpage was stopped in those nodes where a saturated thickness of 5 feet or less was reached.

Agricultural. Ground water is the only source for irrigating 362,000 acres of cropland in the region. Since records of ground-water pumpage were not available, a theoretical approach was used for their determination. A technique developed by Blaney and Criddle (1962), known as the Blaney-Criddle formula, was used to determine the consumptive irrigation requirements for the region. This formula has been used extensively in New Mexico and is considered to provide reasonable estimates of water use.

Briefly, this procedure was developed by correlating measured consumptive-use data with monthly temperature, monthly percentages of yearly daytime hours, precipitation, and growing or irrigation season. The coefficients thus developed allowed for the computation of consumptive use of each crop if the monthly temperature, the latitude, and the growing period of the crop were known, and if the computed monthly percent of annual daytime hours was available. After total consumptive use was computed, the net amount of irrigation water necessary to satisfy consumptive use was found by subtracting the amount of effective precipitation from the total consumptive water requirement. This net requirement, or consumptive irrigation requirement for any period divided by the irrigation efficiency, results in the irrigation requirement of the crop for that period.

To provide the climatological data necessary, four weather stations (Hobbs, Tatum, Portales, and Clovis) were selected as representative of the climatic conditions in specific irrigated agricultural areas in the Southern High Plains. Monthly temperature, precipitation, percent of annual daytime hours, and the latitude for each station were used with the acreages of each crop, consumptive use coefficients, and crop-growing season in a computer model developed to arrive at the per-unit consumptive use, consumptive irrigation requirement (CIR), and irrigation requirement (IR). The total consumptive irrigation requirements and irrigation requirements for each region were computed by multiplying acreages by CIR and IR.

Municipal and rural domestic. Water-use estimates for both diversions (new water intake) and depletions (consumptive use) were made, utilizing data from the State Engineer Office and the Bureau of the Census. Their estimates are on a per capita basis and adjustments were made to reflect only the actual withdrawal by the urban population.

Industrial. Estimates of production diversion and depletion per unit or industrial water originated from several sources, primarily Lansford, et al., 1973. Mining sector coefficients were adapted from Stotelmeyer, 1972.

Population and Employment Data

Population figures and coefficients were obtained from the U. S. Bureau of the Census for the years 1950, 1960, and 1970.

Employment data were derived from the data published by the Employment Security Commission (NMESC, 1960, 1970). Although on a statewide basis the information is fairly detailed, figures for counties are limited due to disclosure laws and regulations. The NMESC data was supplemented by unpublished data. A coefficient was derived for all 13 major sectors within the region, including estimates for the governmental, nonagricultural, and miscellaneous service sectors. Both NMESC and Bureau of Census data were used to develop the past and present labor force make-up in the description of each region.

CHAPTER IV

RESULTS AND IMPLICATIONS

A linear programming model utilizing input-output coefficients was used to simulate long-run production and water utilization patterns in the Southern High Plains under alternative assumptions. Because of the difficulty of obtaining population, industrial activity, and employment data by drainage basin they were incorporated into the regional model on a county basis. Therefore, the results from the model reflect economic activity and water depletions for all of Lea, Curry, and Roosevelt Counties: portions of Lea, Roosevelt and Curry Counties outside of the Southern High Plains are included, but economic activity and water depletions for the small portion of Quay County that is within the Southern High Plains are excluded.

Each simulation process starts with the same basic optimal solution to the model, and continues with annual changes to satisfy the alternative conditions for a period of 50 years. The basic solution used 1970 conditions, and closely approximates the actual production levels attained and resources used in the base year 1970. Differences between the basic solution of the model and the actual production levels in 1970 result from the optimization procedures used. The optimal use of resources in the model allows for social considerations such as unemployment levels. This basic optimal solution of the model was used as a point of departure for the alternative solutions; hence, a description of the basic solution will be presented first.

Basic Optimal Solution of the Model

The economy of the region was represented in the model by thirteen production sectors (Table 11). All sectors were defined in the model in units of one million dollars of production. Each sector had its own demands for resources such as water, labor, etc., and its contribution to the total benefits to the region's economy, measured by the value added of each one-million-dollar unit. Some of the major results of the basic model and their relationship to water utilization are presented in the following Tables.

Table 12 presents levels of production for all 13 sectors measured in terms of output. *Mining, Oil and Gas* generated the largest value of

Table 12. Production, value added, employment, and water use by production sector in the Southern High Plains, New Mexico, 1970--basic optimal solution

Sector	Value of Production ($1 million)	Value Added ($1 million)	Water Depletions (acre-feet)	Employment
Agriculture				
Irrigated cotton	2.59	1.59	40,520	70
Other irrigated crops	18.30	10.98	341,294	629
Dryland crops	5.58	3.75	0	135
Range livestock	48.87	33.87	2,800	1,274
Other livestock	46.67	16.01	700	2,139
Agricultural services	12.19	7.45	183	1,118
Subtotal	134.20	73.65	385,497	5,365
Mining				
Mining, oil & gas	397.60	288.26	4,799	4,549
Construction				
Contract construction	24.79	10.31	437	1,374
Manufacturing				
All manufacturing	24.39	10.17	279	1,804
Trade & Services				
Transporation, communications, & utilities	86.52	59.10	4,750	3,968
Wholesale & retail trade	225.69	148.73	1,108	6,125
Finance, insurance, & real estate	25.45	18.69	249	1,038
Services	93.57	45.34	2,505	13,107
Subtotal	431.23	271.86	8,612	24,238
Municipal	--	--	7,200	--
Rural	--	--	876	--
Total	1,012.21	654.25	407,700	37,330

production at $397.6 million, and *cotton* generated the smallest value of production at $2.595 million. Within the *Agriculture* sector, *range livestock* accounted for about 36 percent of the agricultural value of production, followed closely by *other livestock* at about 35 percent, *dryland crops* about 4 percent, *other irrigated crops* about 14 percent, and *agricultural services* about 9 percent. The *Mining* sector accounted for about 39 percent of the total value of production for the region. *Construction* accounted for 2.4 percent of the regional value of production ($24.39 million). The *trade* sector accounted for about 22 percent of the total value of production; *Service*, about 9 percent; *Transportation, communications, and utilities* sector about 9 percent; *Finance, insurance, and real estate* about 2.5 percent.

The value added generated by each sector ranges from 34.3 percent of the total value of output in the *other livestock* sector to 73.4 percent in the *Finance, insurance, and real estate* sector. The weighted average-value-added in the Southern High Plains was 65 percent of total output. The large coefficients of output per unit of water in the nonagricultural sectors are a result of the low water consumption in these sectors.

The *Trades* and *Services* sectors represent about 66 percent of the employment within the Southern High Plains. *Services* represents about 35 percent of the total employment. Employment in *Manufacturing* accounts for about 5 percent of those employed in the region, *Construction* about 4 percent, and *Mining* about 12 percent. *Agriculture* represents about 14 percent of the regional employment force, with about 40 percent employed in *other livestock*, about 24 percent in *range livestock*, and about 21 percent employed in *agricultural services*.

Agricultural production accounted for 95 percent of the water depleted in the region with *other irrigated crops* accounting for about 84 percent of the total depletions, and *cotton* accounting for another 10 percent. *Mining* sectors accounted for about 1.2 percent, *Construction* only 0.1 percent, *Manufacturing* sectors only 0.1 percent, and *Trades* and *Services* 2.1 percent.

Table 13 magnifies the differences between the *Agriculture* sectors and all other producing sectors. While the *Agriculture* sectors produced only 13.3 percent of the total output, 11.3 percent of the total value added, and provided only 13.8 percent of the total employment, they consumed 96.5 percent of all the water used in production in the Southern High Plains. The

Table 13. Production, value added, employment, and water use by major sector in the Southern High Plains, New Mexico--basic optimal solution

Major Sector	Production	Value Added	Employment	Water Depletions
	($1 million)	($1 million)		(acre-feet)
Agriculture	134.20	73.65	5,365	385,497
Mining	397.60	288.26	4,549	7,799
Construction	24.79	10.31	1,374	437
Manufacturing	24.39	10.17	1,804	279
Trade & Services	431.23	271.86	24,238	8,612
Municipal & Rural	--	--	--	8,076
Total	1,012.21	654.25	37,330	407,700
	(percent)	(percent)	(percent)	(percent)
Agriculture	13.3	11.3	14.4	94.6
Mining	39.3	44.1	12.2	1.2
Construction	2.4	1.6	3.7	0.1
Manufacturing	2.4	1.5	4.8	0.0*
Trade & Services	42.6	41.5	64.9	2.1
Municipal & Rural	--	--	--	2.0
Total	100.0	100.0	100.0	100.0

*Less than 0.05 percent

Trade and *Services* sectors played the opposite role, using only 2.2 percent of all water depleted by the production sectors, but producing 42.6 percent of the total value of output and accounting for 41.5 percent of the total value added. The *Mining* sector produced 39.3 percent of the total value of production, 44.1 percent of value added, and required only 1.2 percent of the water depletions.

Three Water Management Alternatives

The linear programming model was used to estimate the effects of population growth on the distribution of production and water requirements in the Southern High Plains for the period 1970-2020. Regional population projections used in the model were based on the New Mexico Bureau of Business Research county projections (BEA Projections) (Table 14). An increase in population affects the final demand for consumer products, the labor force, as well as the direct demand for water for municipal and rural use.

Table 14. Population projections by county, Southern High Plains, New Mexico, 1970-2020

		County			
Year		Lea	Curry	Roosevelt	Southern High Plains
1970	Urban	40,183	33,956	10,554	84,693
	Rural	9,371	5,561	5,925	20,857
	Total	49,554	39,517	16,479	105,550
1980	Urban	44,200	38,000	11,200	93,400
	Rural	9,400	5,600	6,000	21,000
	Total	53,600	43,600	17,200	114,400
2000	Urban	53,800	46,400	13,700	113,900
	Rural	9,400	5,600	6,000	21,000
	Total	63,200	52,000	19,700	134,900
2020	Urban	64,600	56,200	16,800	137,600
	Rural	9,400	5,600	6,000	21,000
	Total	74,000	61,800	22,800	158,600

Source: Based on county projections by the New Mexico Bureau of Business Research (BEA projections)

An increase in the final demand will affect all 13 sectors according to the interrelationships of the Input-Output table. Because of these predetermined relationships, any change in the final product mix produced within the region will require a change in the model constraints.

Three alternative solutions of long-run production and water-use patterns, utilizing the BEA population projections at an average rate of 1.01 percent annually or 50.3 percent for the period 1970-2020, are presented below. The three alternatives differ only in water constraints.

In the first alternative, water availability was not constrained. The production sectors were permitted to grow as required in order to supply the products demanded. Thus, additional water would become available for use as needed: for example, by water importation or water-saving technological developments. Ground-water sources were assumed to be sufficient to permit the required increases in pumpage.

The assumption that water can be imported to satisfy all future demands is not a realistic assumption. There are only limited opportunities for water importation to the Southern High Plains: i.e., the Mississippi River importation plan. It is more likely that no additional water will be available in the foreseeable future. The second and third alternatives reflect this assumption and place constraints on water availability: i.e., the amount of ground water in storage. Any increase in water demand is required to be satisfied within the region.

The two alternatives explored were: one, decreasing pumpage 10 percent after 1966, and the other, increasing pumpage 10 percent after 1966. The results of these alternatives on ground-water storage are presented in Figures 6, 7, and 8 for each of the counties for the time period 1956 to 2006, and are summarized in Table 15. The numbers in the Figures are on a county-wide basis, which means that some areas are more drastically depleted than others.

Table 15. Percentage reduction of ground-water storage with a 10 percent decrease in pumpage and with a 10 percent increase in pumpage, Southern High Plains, New Mexico, 1970-2020

	10 percent Decreage in Pumpage				10 percent Increase in Pumpage			
Year	Lea	Curry	Roosevelt	Region	Lea	Curry	Roosevelt	Region
	. . . . . . percent				. . . . . . percent			
1970	0	0	0	0	0	0	0	0
1980	8.2	13.6	5.6	7.7	10.0	16.3	7.5	12.1
2000	21.6	28.1	13.6	22.4	27.1	42.3	18.3	31.7
2020	36.3	44.4	22.6	36.4	44.3	52.9	29.1	44.2

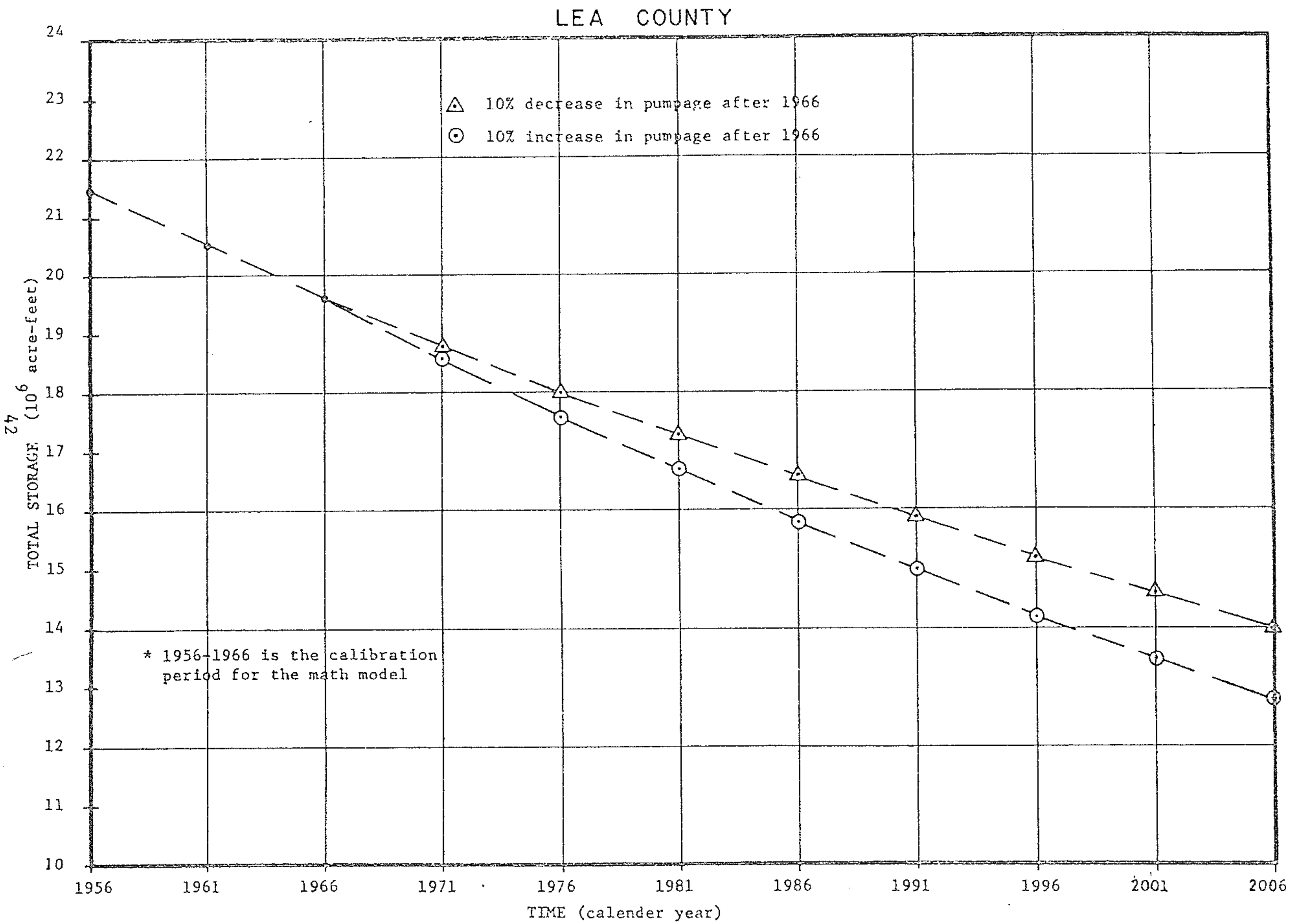


Figure 6. Average Pumpage Effects in Lea County as a Function of Time.

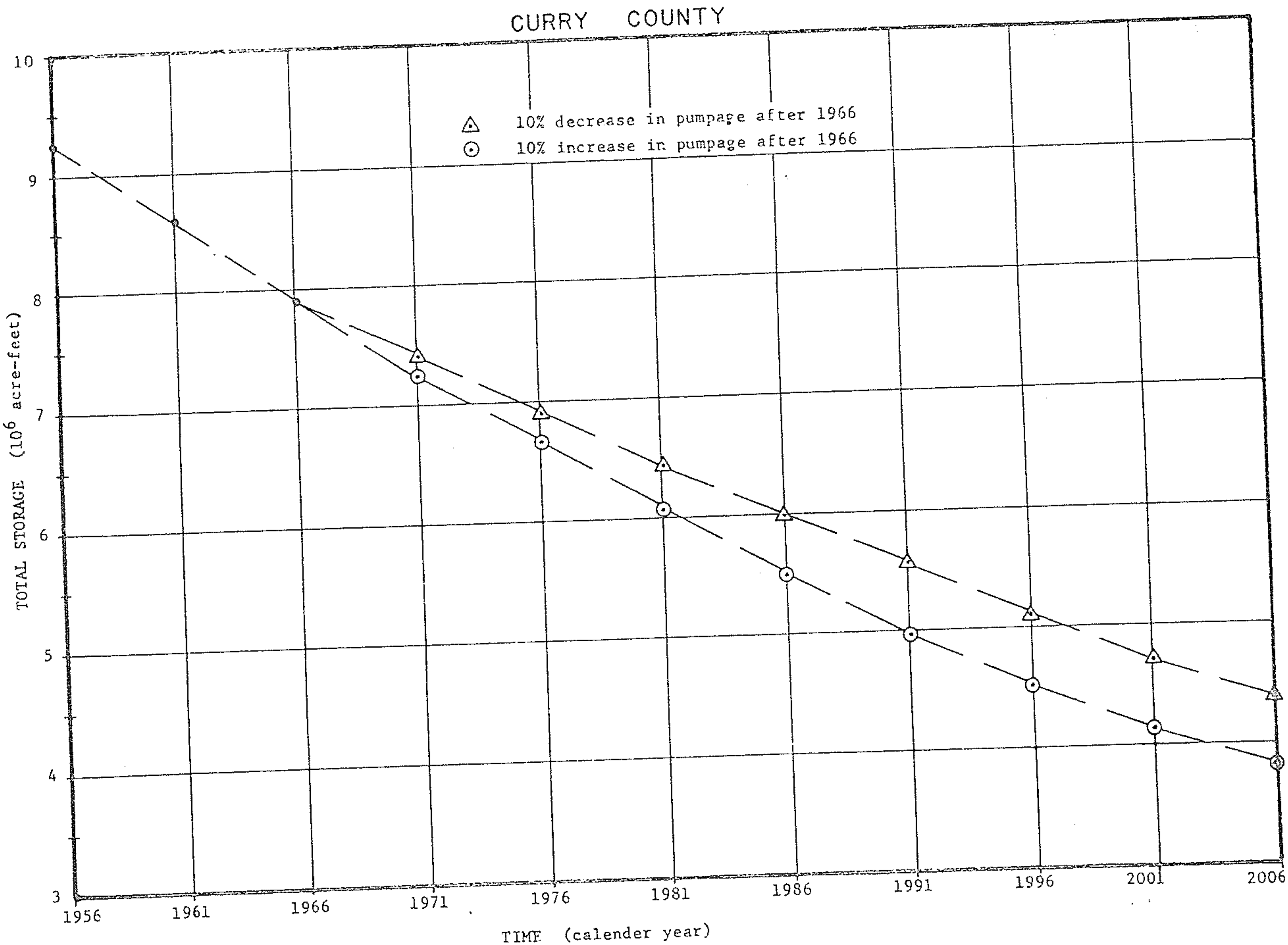


Figure 7. Average Pumpage Effects in Curry County as a Function of Time.

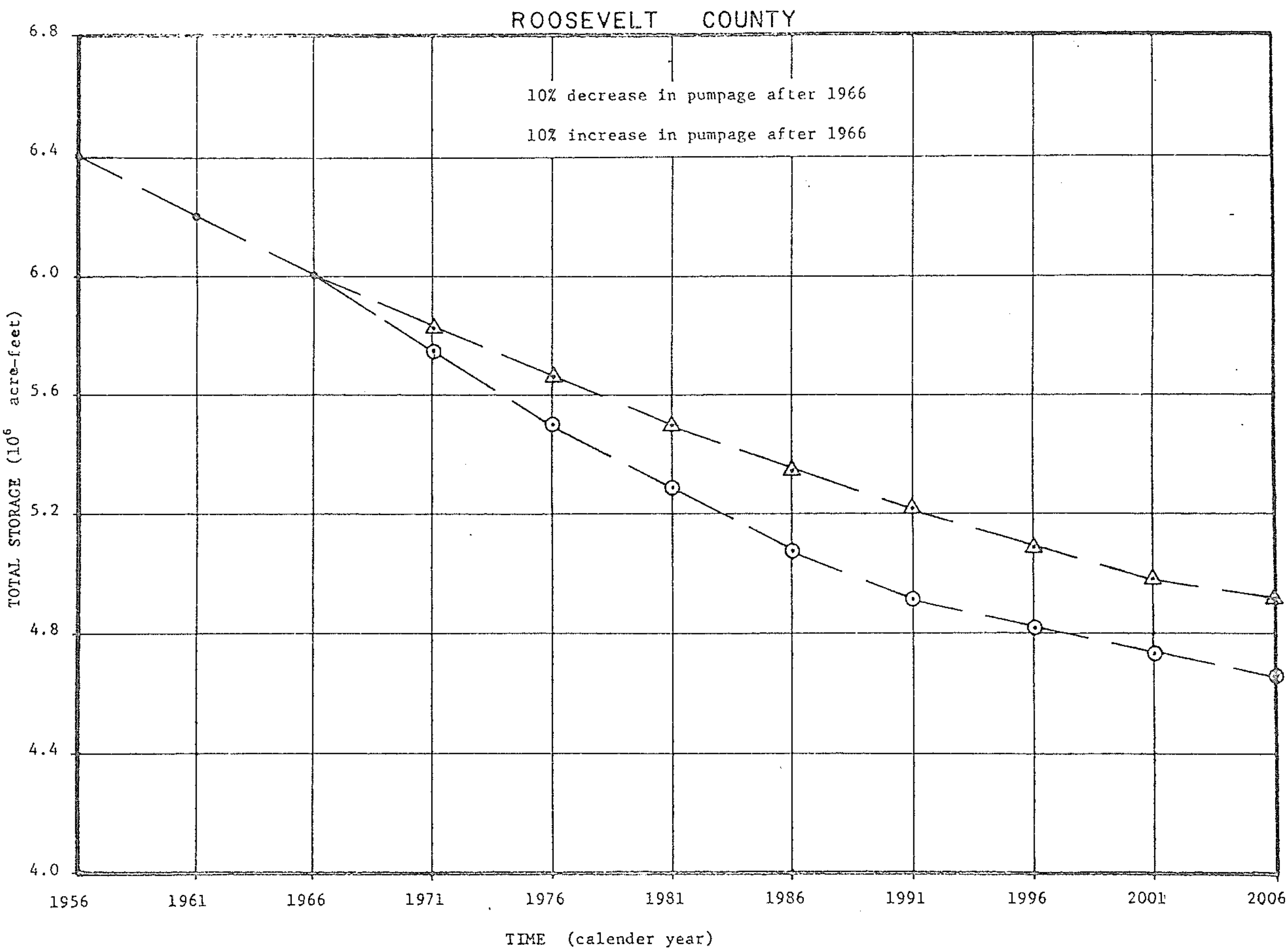


Figure 8. Average Pumpage Effects in Roosevelt County as a Function of Time.

Alternative 1: No water constraint. The long-run effects of population growth under the above assumptions are presented in Table 16 for 2020, and summarized in Table 17. Table 16 presents the production levels, value added, water depletions, and employment required to satisfy the increases in non-agricultural out-of-region sales. Total value of production in the Southern High Plains is expected to increase at approximately the same rate as the population. This amounts to an increase of more than $551 million (54 percent) in the total value of production for the period 1970-2020.

Agricultural production is expected to increase 51 percent ($69.02 million). The expected increase varies from 70 percent for *other irrigated crops* to 14 percent for *agricultural services*, with *irrigated cotton, dryland crops, range livestock,* and *other livestock* up 53 percent respectively.

The total nonagricultural production is expected to increase by $482 million. The expected increase in agricultural production represents only 12.5 percent of the total increase in the value of production while it represents 95.6 percent of the additional water depletions required. The value of production for the *Mining* sectors is expected to increase about 53 percent from 1970 to 2020, *Contract construction* about 58 percent, *Manufacturing* about 57 percent, and *Trade* and *Services* are expected to increase about 57 percent (Table 17).

Water depletions in the year 2020 for the Southern High Plains are expected to reach 680,000 acre-feet. This increase of 272,596 acre-feet over the depletions in 1970 will be required to meet the projected population needs in 2020. Of the 272,596 acre-feet, the agricultural sectors will require 260,693 acre-feet, the remaining production sectors 7,401 acre-feet, and domestic needs 4,502 acre-feet.

Employment is expected to increase 50 percent from 1970 to 2020, with *Agricultural* employment increasing 47 percent, *Mining* up 53 percent, *Construction* up 58 percent, *Manufacturing* up 57 percent, and *Trade* and *Services* up 49 percent. In 2020, *Trade and Services* is expected to account for 66 percent of the total employment. The primary reason *Trade and Services* employment does not increase as rapidly as the other production sectors during the 1970 to 2020 period is because of the inclusion of unemployment in the *Services* sector in 1970; unemployment is reduced drastically in 2020.

Table 16. Production, value added, employment, and water use by production sector in the Southern High Plains, New Mexico, 2020--no water constraint

Sector	Value of Production ($1 million)	Value Added ($1 million)	Water Depletions (acre-feet)	Employment
Agriculture				
Irrigated cotton	3.95	2.43	61,869	107
Other irrigated crops	31.04	18.24	578,772	1,067
Dryland crops	8.53	5.50	0	206
Range livestock	74.57	51.68	4,272	1,944
Other livestock	71.20	24.42	1,068	3,264
Agricultural services	13.93	8.10	209	1,277
Subtotal	203.22	110.37	646,190	7,865
Mining				
Mining, oil, & gas	606.62	439.80	7,321	6,940
Construction				
Contract construction	39.25	16.33	692	2,176
Manufacturing				
All manufacturing	38.19	15.93	437	2,825
Trade and Services				
Transportation, communications, & utilities	133.80	91.33	7,253	6,136
Wholesale & retail trade	359.12	236.66	1,763	9,747
Finance, insurance, & real estate	38.24	28.34	376	1,560
Services	144.95	76.60	3,686	21,136
Subtotal	676.11	432.93	13,078	38,579
Municipal	--	--	11,696	--
Rural	--	--	882	--
Total	1,563.39	1,015.36	680,296	58,385

Table 17. Production, value added, employment, and water use by major sector in the Southern High Plains, New Mexico, 1970-2020-- no water constraint

Year	Major Sector	Value of Production ($1 million)	Value of Production Change from 1970 (percent)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Water Depletions Change from 1970 (percent)
1970	Agriculture	134.20		73.65	5,365	385,497	
	Mining	397.60		288.26	4,549	4,799	
	Construction	24.79		10.31	1,374	437	
	Manufacturing	24.39		10.17	1,804	279	
	Trade & Services*	431.23		271.86	25,764	8,612	
	Municipal & Rural	--		--	--	8,076	
	Total	1,012.21		654.25	38,856	407,700	
2020	Agriculture	203.22	51.4	110.37	7,865	646,190	67.6
	Mining	606.62	52.6	439.80	6,940	7,321	52.6
	Construction	39.25	58.3	16.33	2,176	692	58.4
	Manufacturing	38.19	56.6	15.93	2,825	437	56.6
	Trade & Services*	676.11	56.6	432.93	38,579	13,078	51.9
	Municipal & Rural	--		--	--	12,578	55.7
	Total	1,563.39	54.5	1,015.36	58,385	680,296	66.9

* Includes unemployment
-- Not applicable

Alternative 2: 10 percent decrease in pumpage after 1966. The long-run effects of population growth under the above assumption are presented in Table 18 for 2020, and summarized in Table 19. The Southern High Plains 50-year regional value of production is expected to increase $551.18 million (53.5 percent) without a water constraint, and increase $532.16 million (52.6 percent) with a constraint of 19-percent-decrease in pumpage. Thus, the cost of reducing pumpage by 10 percent is only $19.02 million (1.2 percent reduction). Direct *Agriculture* production would decrease $15.07 million; *Mining* would remain unchanged; *Construction, Manufacturing,* and *Trade and Services* would decrease $3.95 million. The *other irrigated crops* value of production would be decreased $22.58 million; *dryland crops* increased $8.53 million; *irrigated cotton* increased $0.02 million; *agricultural services* decreased $1.04 million; *range livestock* and *other livestock* would remain unchanged.

The level of employment in the Southern High Plains is expected to decrease by 2,931 employees in 2020 when pumpage is restricted by 10 percent as compared to the alternative of no water constraint. *Agriculture* production sectors are expected to account for 663 employees. Employment in *other irrigated crops* will be reduced by 776 employees and *agricultural services* reduced by 95 employees; *dryland crops* and *cotton* employment would be increased by 208 employees. The *Trade and Services* sectors employment level would be decreased 2,244 employees with 96 percent in the *service* sector.

When a pumpage restriction of 10 percent is imposed, water depletions would be decreased in 2020 by 420,812 acre-feet compared to no water constraint. *Agriculture* accounts for 420,745 acre-feet of this reduction. The remaining 67 acre-feet reduction is in the *Services* sectors, 61 acre-feet, *Construction*, 4 acre-feet, and *Manufacturing*, 2 acre-feet. *Other irrigated crops* water depletions are expected to decrease 421,094 acre-feet, *agricultural services* to decrease 16 acre-feet, but *cotton* water depletions are expected to increase 365 acre-feet in 2020 over the no-water-constraint alternative.

The demand for agricultural products which could not be satisfied in this case is allowed to be supplemented by agricultural imports or by reduction of exports.

Table 18. Production, value added, employment, and water use by production sector in the Southern High Plains, New Mexico, 2020--10 percent decrease in pumpage

Sector	Value of Production ($1 million)	Value Added ($1 million)	Water Depletions (acre-feet)	Employment
Agriculture				
Irrigated cotton	3.97	2.44	62,734	108
Other irrigated crops	8.46	5.07	157,678	291
Dryland crops	17.06	11.00	0	413
Range livestock	74.57	51.68	4,272	1,944
Other livestock	71.20	24.42	1,068	3,264
Agricultural services	12.89	7.73	193	1,182
Subtotal	188.15	102.34	225,445	7,202
Mining				
Mining, oil & gas	606.62	439.80	7,321	6,940
Construction				
Contract construction	39.07	16.26	688	2,165
Manufacturing				
All manufacturing	38.01	15.86	435	2,812
Trade and Services				
Transportation, communications, & utilities	133.18	90.91	7,220	6,108
Wholesale & retail trade	357.47	235.57	1,755	9,702
Finance, insurance, & real estate	38.06	28.21	374	1,552
Services	143.81	68.69	3,668	18,973
Subtotal	672.52	423.38	13,017	36,335
Municipal	--	--	11,696	--
Rural	--	--	882	--
Total	1,544.37	997.64	259,484	55,454

Table 19. Production, value added, employment and water use, by major sector in the Southern High Plains, New Mexico, 1970-2020--10 percent decrease in pumpage

Year	Major Sector	Value of Production ($1 million)	Value of Production Change from 1970 (percent)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Water Depletions Change from 1970 (percent)
1970	Agriculture	134.20		73.65	5,365	385,497	
	Mining	397.60		288.26	4,549	4,799	
	Construction	24.79		10.31	1,374	437	
	Manufacturing	24.39		10.17	1,804	279	
	Trade & Services	431.23		271.86	25,764	8,612	
	Municipal & Rural	--		--	--	8,076	
	Total	1,012.21		654.25	38,856	407,700	
2020	Agriculture	188.15	40.2	102.34	7,202	225,445	-44.7
	Mining	606.62	52.6	439.80	6,940	7,321	52.6
	Construction	39.07	57.6	16.26	2,165	688	57.4
	Manufacturing	38.01	55.8	15.86	2,812	435	55.9
	Trade & Services	672.52	56.0	423.38	36,335	13,017	51.1
	Municipal & Rural	--		--	--	12,578	55.7
	Total	1,544.37	52.6	997.64	55,454	259,484	-36.4

-- Not applicable

Alternative 3: 10 percent increase in pumpage. Production, value added, employment, and water depletions in this alternative for the Southern High Plains are presented in Table 20 for 2020, and summarized in Table 21. The cost of permitting a 10 percent increase in pumpage starting in 1966 would be $66.11 million in 2020 compared to no water constraint, and $47.09 million compared to a 10 percent decrease in pumpage. Direct *Agricultural* production would decrease $3.27 million. *Trade and Services* value of production is expected to decrease $41.60 million with the *service* sector decreasing $25.16 million. While value of production is expected to decrease $47.09 million, water depletions are expected to decrease 31,891 acre-feet. Nearly all of the cecreased water depletions (97 percent) are expected to occur in *other irrigated crops*. *Services* decrease 816 acre-feet, *Construction* and *Manufacturing* decrease 13 and 5 acre-feet respectively, and *Mining* increases one acre-foot.

Employment is expected to decrease by 1,912 employees compared to the alternative of a 10 percent decrease in pumpage. The *Trade and Services* sector is expected to account for 1,561 of the employees. The *service* sector alone would account for about 56 percent of the reduced employment.

Summary. In the previous discussion, three sets of water management alternatives were presented for the Southern High Plains. The first was an analysis of the region's growth without a water constraint. The second was an analysis of growth with a 10 percent decrease in pumpage after 1966. The third was an analysis of growth with a 10 percent increase in pumpage after 1966. A summary of the solutions for these alternatives is presented in Table 22.

Without a water constraint, value of production, employment, and water depletions in the Southern High Plains are expected to exhibit the largest increase (54.5 percent, 50.3 percent, and 66.9 percent, respectively). The expected increase in value of production varies from 51.4 percent for *Agriculture* to 58.3 percent for *Construction*. Water depletions are expected to increase 67.6 percent for *Agriculture*, 52.6 percent for *Mining*, 58.4 percent for *Construction*, 56.6 percent for *Manufacturing*, 51.9 percent for *Trade and Services*, and 55.7 percent for *Municipal and Rural* domestic purposes.

Table 20. Production, value added, employment, and water use by production sector in the Southern High Plains, New Mexico, 2020--10 percent increase in pumpage

Sector	Value of Production ($1 million)	Value Added ($1 million)	Water Depletions (acre-feet)	Employment
Agriculture				
Irrigated cotton	3.97	2.44	62,234	108
Other irrigated crops	6.80	4.08	126,644	237
Dryland crops	17.06	11.00	0	413
Range livestock	74.57	51.68	4,272	1,944
Other livestock	71.20	24.42	1,068	3,264
Agricultural services	11.28	6.88	169	1,034
Subtotal	184.88	100.50	194,387	7,000
Mining				
Mining, oil, & gas	606.62	439.80	7,322	6,940
Construction				
Contract construction	38.27	15.92	675	2,121
Manufacturing				
All manufacturing	36.59	15.40	430	2,707
Trade and Services				
Transportation, communications, & utilities	131.57	89.81	7,132	6,034
Wholesale & retail trade	343.03	226.06	1,684	9,310
Finance, insurance & real estate	37.67	27.92	370	1,536
Services	118.65	51.35	3,015	17,894
Subtotal	630.92	395.14	12,201	34,774
Municipal	--	--	11,696	--
Rural	--	--	882	--
Total	1,497.28	966.76	227,593	53,542

Table 21. Production, value added, employment, and water use by major sector in the Southern High Plains, New Mexico, 1970-2020--10 percent increase in pumpage

Year	Major Sector	Value of Production ($1 million)	Value of Production: Change from 1970 (percent)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Water Depletions: Change from 1970 (percent)
1970	Agriculture	134.20		73.65	5,365	385,497	
	Mining	397.60		288.26	4,549	4,799	
	Construction	24.79		10.31	1,374	437	
	Manufacturing	24.39		10.17	1,804	279	
	Trade & Services	431.23		271.86	25,764	8,612	
	Municipal & Rural	--		--	--	8,076	
	Total	1,012.21		654.25	38,856	407,700	
2020	Agriculture	184.88	40.7	100.50	7,000	194,387	-49.6
	Mining	606.62	52.6	439.80	6,940	7,322	52.6
	Construction	38.27	54.4	15.92	2,121	675	54.6
	Manufacturing	36.59	50.0	15.40	2,707	430	54.1
	Trade & Services	630.92	46.3	395.14	34,774	12,201	41.6
	Municipal & Rural	--	--	--	--	12,578	55.7
	Total	1,497.28	49.5	966.76	53,542	227,593	-44.2

Table 22. Summary of alternative solutions for the Southern High Plains, New Mexico, 1970-2020.

Alternative	Sector	Value of Production	Value Added	Employment	Water Depletions
		($1 million)	($1 million)		(acre-feet)
BASIC OPTIMAL SOLUTION - 1970	Agriculture	134.2	73.6	5,365	385,497
	Mining	397.6	288.3	4,549	7,799
	Construction	24.8	10.3	1,374	437
	Manufacturing	24.4	10.2	1,804	279
	Trade & Services	431.2	271.9	24,238	8,612
	Mun. & Rural				8,076
	Total	1,012.2	654.3	37,330	407,700
NO WATER CONSTRAINT	Agriculture	203.2	110.4	7,865	646,190
	Mining	606.6	439.8	6,940	7,321
	Construction	39.3	16.3	2,176	692
	Manufacturing	38.2	15.9	2,825	437
	Trade & Services	676.1	432.9	38,579	13,078
	Mun. & Rural				12,578
	Total	1,563.4	1,015.3	58,385	680,296
10 PERCENT DECREASE IN PUMPAGE	Agriculture	188.2	102.3	7,202	225,445
	Mining	606.6	439.8	6,940	7,321
	Construction	39.1	16.3	2,165	688
	Manufacturing	38.0	15.9	2,812	435
	Trade & Services	672.5	423.4	36,335	13,017
	Mun. & Rural				12,578
	Total	1,544.4	997.6	55,454	259,484
10 PERCENT INCREASE IN PUMPAGE	Agriculture	184.9	100.5	7,000	194,387
	Mining	606.6	439.8	6,940	7,322
	Construction	38.3	15.9	2,121	675
	Manufacturing	36.6	15.4	2,707	430
	Trade & Services	630.9	395.1	34,774	12,201
	Mun. & Rural				12,578
	Total	1,497.3	966.7	53,542	227,593

With a 10 percent decrease in pumpage constraint, the expected value of production would be reduced by $19.02 million in 2020, employment by 2,931 employees, and water depletions by 420,812 acre-feet (61.9 percent) below the alternative of no water constraint (Table 22). Reduced *Agriculture* production would account for $15.07 million of the reduced value of production. The level of employment in the Southern High Plains is expected to decrease by 2,931 employees in 2020. *Agriculture* production sectors are expected to account for about 23 percent and *Trade and Services* sectors about 70 percent. *Agriculture* water depletions are expected to represent almost all (99.99 percent) of the total water-depletion reduction when a 10 percent decrease in pumpage constraint is imposed.

In 2020, when a 10 percent increase in pumpage constraint is imposed, value of production in the Southern High Plains is expected to be reduced to $1,497.28 million, decreased $47.09 million below the value obtained when a 10 percent decrease in pumpage constraint is imposed, and decreased by $66.11 million below the no-water-constraint alternative (Table 22). The level of employment is expected to decrease by 1,912 employees compared to the 10 percent decrease in pumpage alternative. *Trade and Service* sectors account for 82 percent of the reduced employment.

Water depletions in the Southern High Plains are expected to decrease from 680,296 acre-feet without any water constraints to 227,593 acre-feet with a 10 percent decrease in pumpage constraint, a 66 percent reduction. *Agricultural* production sectors would account for over 99 percent of the reduction in water depletions.

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