AN ANALYTICAL INTERDISCIPLINARY EVALUATION OF THE UTILIZATION OF THE WATER RESOURCES OF THE RIO GRANDE IN NEW MEXICO: MIDDLE RIO GRANDE REGION

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This study was part of an interdisciplinary-interuniversity research project entitled "An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico."

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These consultants were included in the research effort and made contributions both in advice to the study group and in data development. The architectural consultant provided information on landscape architecture and aesthetic functions of the environment as related to alternative settlement patterns. Sociological and population problems in the Rio Grande region were considered by the Development Sociologist and included in the interregional models. The law consultant served on

legal phases which developed as the investigations proceeded, and his advice was considered in the final analysis of the study. The Industrial Engineer helped in the development of industrial water-use coefficients. Robert R. Lansford served as the coordinator for all phases of the project.

Although the research team is solely and totally responsible for statements and conclusions in this report, many people helped in the work: Fred Roach, Graduate Assistant at the University of New Mexico, helped with the development of the socio-economic model. One of the key elements of this study was the use of a Technical Advisory Committee composed of representatives from state and federal agencies. The willingness of this advisory committee to work with the study group was outstanding. Many of the changes in the study reflected the advice offered by members of the Technical Advisory Committee. Membership of the Technical Advisory Committee was:

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Mr. T. A. Garrity	U.S. Bureau of Indian Affairs
Mr. William E. Hale	U.S. Geological Survey
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ABSTRACT

An interdisciplinary approach to the solution of the water resource problems of the Middle Rio Grande Region in New Mexico was centered around a socio-economic model, developed to represent the New Mexico economy, with special emphasis placed upon the Rio Grande region. Inputs into the socio-economic 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, with a surface-water constraint; 3) growth, with both surface- and ground-water constraints.

Without a water constraint, in the Rio Grande region, both production and depletions are expected to exhibit the largest increase (59.7 percent and 47.4 percent, respectively). When a surface-water constraint is imposed, the value of production is reduced by $18.1 million in 2020 and water depletions are expected to decrease about 18.1 percent by 2020. When a total water constraint is imposed, the value of production is decreased $4.1 million below that expected when using only a surface-water constraint, and water depletions are reduced about 8.4 percent.

The Middle Rio Grande Region is expected to follow the general trend of the total Rio Grande region but at a higher growth rate. The expected increase in total value of production from 1970 to 2020 is 62.0 percent, employment 62 percent, and water depletions about 61 percent.

When a surface-water constraint is imposed, production is expected to be reduced $3.2 million in 2020, employment by 154 employees, and water depletions by 51,633 acre-feet. When an additional constraint is imposed on ground water in the MRGR, production would be decreased $2.0 million in 2020, employment by an additional 99 employees, and water depletions by 38,390 acre-feet.

*KEYWORDS: *New Mexico, *Rio Grande Basin, *Water resources, *Socio-economic model, Interdisciplinary, Ground water appropriation, Water law, Compacts, Treaties, Litigation, Adjudication of water rights, Water quality, Water utilization, Population, Employment, Industrial, Recreation, Water management, Input-output coefficients, Linear programming model, Surface-ground-water conjunctive-use model, Economic land classification, Irrigation diversions and depletions.*

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MIDDLE RIO GRANDE REGION

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INTRODUCTION

This report represents an in-depth look at the water and related resources in the Middle Rio Grande Region (MRGR) of New Mexico (Figure 1). Other reports have been prepared for the Upper Rio Grande Region (WRRI Report No. 021), the Socorro Region (WRRI Report No. 023), and the Lower Rio Grande Region (WRRI Report No. 024). These reports are viewed as basic data reports to supplement the overall report (WRRI Report No. 020, *An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico*, March 1973).

The Upper Rio Grande Region extends from the New Mexico-Colorado state line to Otowi Bridge and includes the counties of Rio Arriba, Taos, and Santa Fe; the Middle Rio Grande Region from Otowi Bridge to the Socorro-Valencia county line includes the counties of Sandoval, Bernalillo, and Valencia; the Socorro Region, which includes Socorro County; and the Lower Rio Grande Region from the Socorro-Sierra county line to the New Mexico-Texas state line. This differs from other previous divisions in that the Middle Rio Grande Basin generally includes the designated Socorro Region. A distinction was made primarily because the Socorro Region, even though served by the Middle Rio Grande Conservancy District, is essentially a separate area in relation to the type of agriculture, hydrology, geology, and the influence of the Albuquerque metropolitan area.

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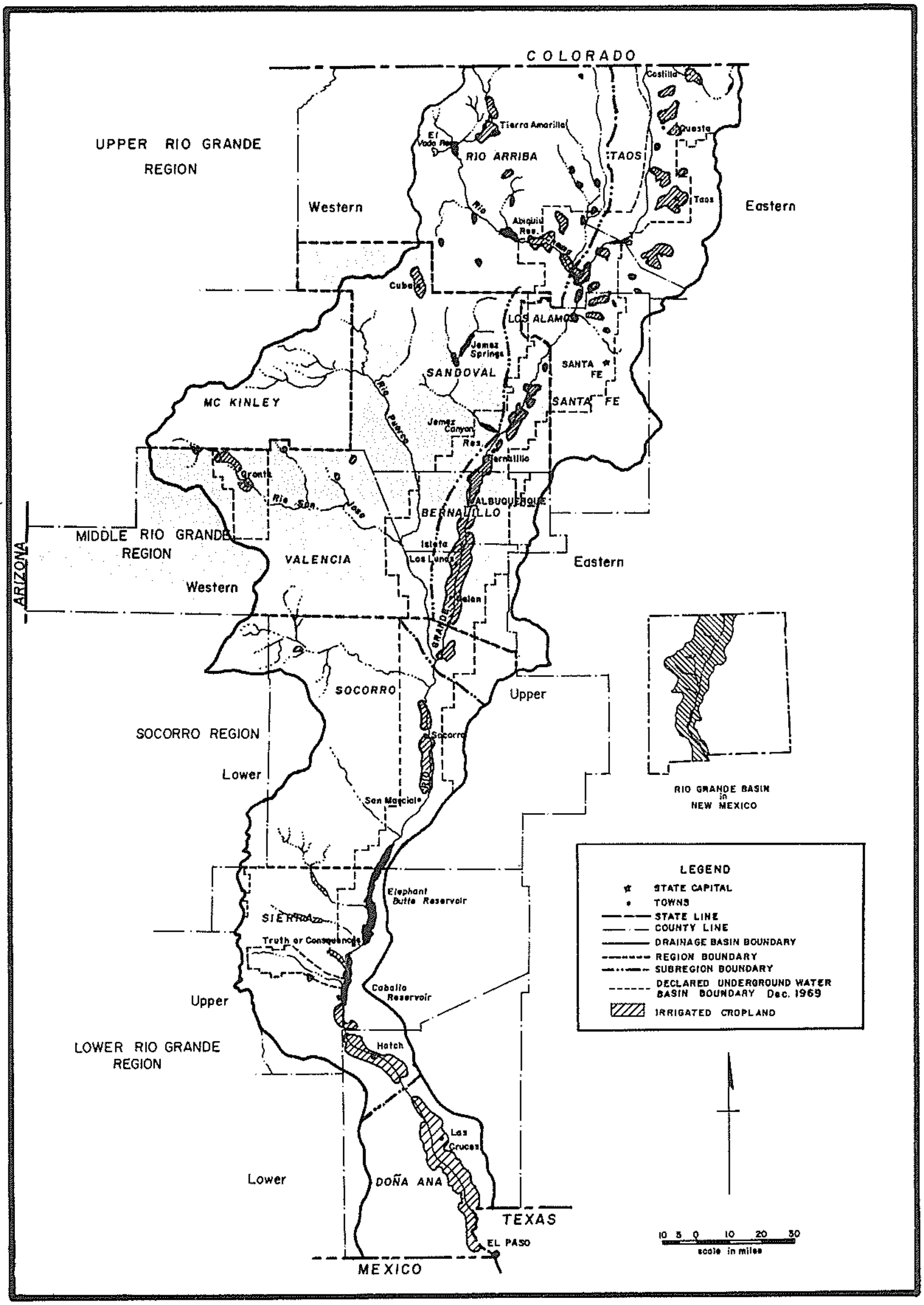

Figure 1. Rio Grande drainage basin in New Mexico, for this study.

GENERAL DESCRIPTION

The Middle Rio Grande Region includes all or portions of the following counties in New Mexico: Sandoval, Bernalillo, Valencia, Torrance, and McKinley (Figure 1). The Middle Rio Grande Region was divided, for portions of this study, into a western subregion and an eastern subregion. The western subregion encompasses the drainage basin of the Jemez River, Rio Puerco, and Rio San Jose (Figure 2). The eastern subregion includes the drainage area associated with the Rio Grande in the Middle Rio Grande Region.

The western subregion includes a large, sparsely populated area in western Sandoval, eastern McKinley, and central Valencia counties. The principal irrigated areas are along the Rio San Jose in central Valencia County with scattered irrigated cropland on tributaries of the Rio San Jose, the Rio Puerco near Cuba in northern Sandoval County, and the sparsely populated Jemez River area in Sandoval County. The principal population centers are Grants in central Valencia County and Cuba in Sandoval County.

The eastern subregion includes the heavily populated area along the Rio Grande in Sandoval, Bernalillo, and eastern Valencia counties. The principal irrigated areas are along the Rio Grande in southern Sandoval, Bernalillo, and Valencia counties. The major population center is Albuquerque, with smaller population centers at Bernalillo, Los Lunas, and Belen.

Topography and Climate

The topography of the Middle Rio Grande Region varies widely from mountains to broad, relatively featureless plains. The eastern subregion is bounded on the east by the Sandia and Manzano Mountains; on the west, from north to south, by the Jemez Mountains which decrease to a sandy ridge that separates the eastern from the western subregion; on the north by White Rock Canyon, a narrow tortuous gorge; and on the south by the Socorro Region. The western subregion is bounded on the west, from north to south, by the Continental Divide, Zuni Mountains, and lava flows; on the north by the Jemez Mountains; and on the south by the Socorro Region.

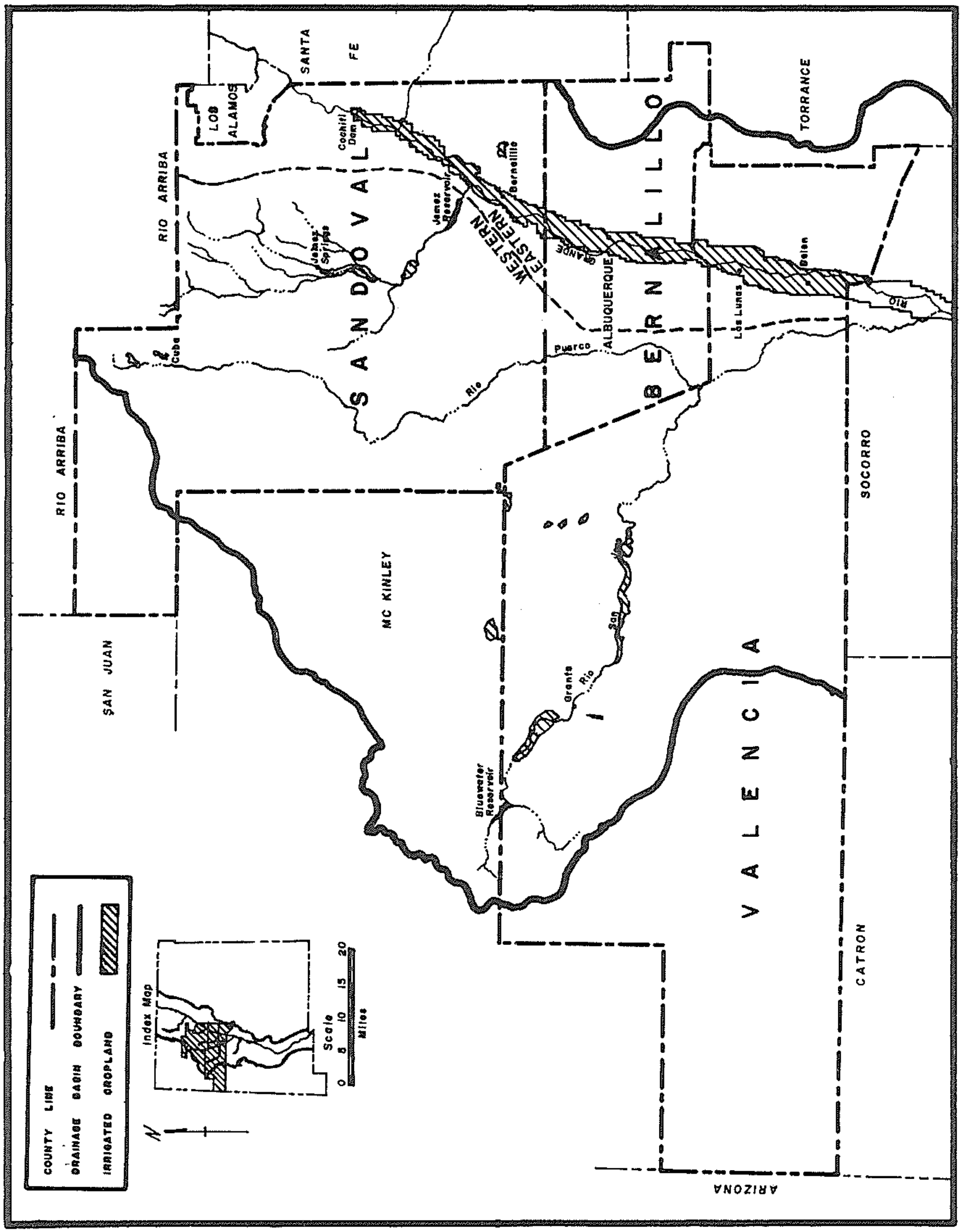

Figure 2. Map of the Middle Rio Grande Region in New Mexico.

The climate of the Middle Rio Grande Region is predominantly semi-arid in the lower elevations and semi-humid in the mountainous regions. The mean average temperatures range from 46 degrees Fahrenheit at Cuba to 54 degrees in the Albuquerque area, with a regional average of about 52 degrees Fahrenheit (Table 1). Annual precipitation ranges from over 20 inches in the mountains to about 8 inches at Los Lunas, with an average of about 11 inches. Precipitation averages about 8.5 inches in the eastern portion of the MRGR. The average frost-free period is from May 13 to October 8, 150 days, but ranges from 113 days at Cuba to 160 days in the Bernalillo-Belen area (Table 1).

Table 1. Eleven-year average of annual average temperature, total precipitation, and frost-free period for Cuba, Jemez Springs, Laguna, Bernalillo, and Los Lunas, New Mexico, 1960-1970.

Year	Average Temperature (degrees F)	Total Precipitation (inches)	Frost-free Period Length (days)	Frost-free Period Dates
Cuba	46.38	14.26	113	June 2 - Sept. 24
Jemez Springs	51.44	16.14	160	May 7 - Oct. 14
Laguna	52.9	8.96	155	May 12 - Oct. 10
Bernalillo	54.4	8.67	160	May 5 - Oct. 12
Los Lunas	54.38	7.60	160	May 6 - Oct. 10
Average	51.9	11.12	150	May 13 - Oct. 8

Source: United States Weather Bureau, *Climatological Data, New Mexico* (Annual Summaries), Vols. 64-74, 1960-1970.

Drainage Area

The drainage area of the Rio Grande Basin from the headwaters to San Bernardo, the southern limit of the Middle Region, is approximately 19,230 square miles, including 2,940 square miles of the San Luis closed basin in Colorado. The only perennial stream is the Rio Grande river. Its flow averages 776,100 acre-feet per year, and consists of spring snowmelt in Colorado and northern New Mexico, and runoff from summer rainfall. All its tributaries are ephemeral and flow only during torrential summer rains. The Jemez is the largest tributary and flows southeastward into the Rio Grande near Algodones.

The Rio Puerco in the western subregion does not affect the Rio Grande river flow within the eastern subregion. The Puerco, with an average of 39,960 acre-feet per year, drains an area of approximately 7,350 square miles; at least 1,130 square miles do not contribute directly to surface runoff. The Puerco flows into the Rio Grande about 50 miles south of Albuquerque near San Bernardo.

Many arroyos drain the east and west mesas along the Rio Grande river. Those on the west side discharge directly into the river north of Arroyo de la Barranca. The arroyos south of Arroyo de la Barranca, as well as the ones on the east side, are mostly intercepted by canals or drains or simply filtrate into alluvial fans (Bjorklund and Maxwell, 1961).

Hydrogeology

The MRGR is located within the Albuquerque basin which is the largest of a series of basins that make up the Rio Grande depression. The Albuquerque basin extends for 90 miles from La Bajada escarpment and the Jemez uplift on the north to the San Acacia constriction on the south. The basin is roughly 30 miles wide; it is bounded to the east by the Sandia-Manzano uplift and to the west by the Puerco Platform, Lucero uplift, and Ladron uplift (Kelley, 1952). The eastern uplifts (Sandias, Manzanos) are generally higher than the western bounding structures which consist mainly of the Puerco Platform. The Puerco Platform is low and considerably faulted. Small volcanoes and fissure flows mark the boundaries at several localities.

The basin-fill sediments are generally classed together as the Santa Fe formation or Santa Fe group. The thickness of the underlying sedimentary rocks is unknown, but Precambrian rocks may be 10,000 feet below sea level in parts of the basin whereas they are about 9,000 feet above sea level in the Sandia uplift and about sea level in the Puerco Platform (Joesting, et al., 1961).

Based on estimated rock densities obtained from gravity anomaly maps across the Rio Grande trough north of Albuquerque (Joesting, et al., 1961), the total thickness of sedimentary rocks (Santa Fe group) in the trough is about 15,000 feet. The total relief of the Precambrian basement along the Sandia front is about 20,000 feet. These results are in general agreement with the aeromopnetic profiles across the trough. Magnetic anomalies are related to variations in both the magnetization and uplift of the Precambrian rocks.

The sediments of primary concern are the Santa Fe group alluvial fans and valley alluvium. The Santa Fe group consists of beds of unconsolidated to loosely consolidated sediments and interbedded volcanic rocks. The deposits range from boulders to clay and from well-sorted stream channel deposits to poorly sorted slopewash deposits (Reeder, et al., 1967). The permeability of the Santa Fe group is generally high: properly constructed wells easily yield several hundred gallons per minute.

Alluvial fans cover the Santa Fe deposits and extend westward from the base of the Sandia and Manzano Mountains. They are usually above the water table, so they are not aquifers; however, in places they consist of well-sorted stream gravel and permit the infiltration and downward percolation of the flood flows.

Valley alluvium of Recent age overlies the Santa Fe group in the Rio Grande flood plain. It is approximately 80 to 120 feet thick, but in general is hard to differentiate from the underlying Santa Fe group. Most of the irrigation wells along the Rio Grande are developed within this alluvium and yield up to 3000 gpm.

The Santa Fe group combined with the valley alluvium make up the aquifer system of the eastern MRGR. This aquifer is unconfined and is hydrologically connected with the Rio Grande river. Locally, "artesian" pressures have been observed (Reeder, et al., 1967). These artesian pressures are to be understood as strong upward movement of ground water from deeper layers in the central portion of the basin due to natural recharge in the higher areas along the Valley. The eastern boundary of the aquifer is spectacularly defined by the Sandia and Manzano uplifts. The less spectacular upfaulted blocks near the Rio Puerco form the western boundary. The lower boundary of the reservoir is not so clearly defined: saturated thickness may be as much as 12,000 to 16,000 feet.

WATER MANAGEMENT

Management of water and related lands involves several federal and state agencies, municipal and county governments, irrigation districts, conservancy districts, and innumerable private entities. The New Mexico statutes provide for irrigation districts which are formed in cooperation with the United States. Once a conservancy or irrigation district is formed it is a legally stable institution with broad powers to perform the purposes for which it was organized. The districts are able to borrow money, tax lands for the indebtedness, and charge for the water they deliver.

Surface Water

Since the early 1900's, surface-water irrigation in the Rio Grande basin in New Mexico has been under the jurisdiction of irrigation districts, conservancy districts, and community ditch systems. The principal organized districts in the MRGR are as follows: Middle Rio Grande Conservancy District, formed in 1925 and serving 81,610 acres; and the Bluewater-Toltec Irrigation District, formed in 1923 and serving 5,500 acres.

In addition to the above, there are numerous community and private ditch systems on the tributaries of the Rio Grande. The acreages served by these individual ditch systems vary in size from a few acres to over 200 acres.

Most of the surface-water irrigated cropland in the reach of the main stem from Otowi Bridge to San Marcial, excluding tributaries, comprises the Middle Rio Grande Conservancy District. This District is divided into four divisions: Cochiti, Albuquerque, Belen, and Socorro. The District also furnishes surface water to the Indian Pueblos of Cochiti, Santo Domingo, San Felipe, Santa Ana, Sandia, and Isleta, and has contracted with the Bureau of Reclamation to maintain and operate the system which consists of 180 miles of main canals, 587 miles of laterals, and 399 miles of open and concrete pipe drains.

The Bluewater-Toltec Irrigation District in western Valencia County is the only irrigation district in the tributary units of the MRGR. Most of the irrigation water of the district has been leased to uranium companies. The remaining surface-water-supplied land receives water from community ditches.

Ground Water

The management of the ground-water resources in the Rio Grande drainage basin is primarily a private entity function. However, the New Mexico State Engineer can control the use of ground water in an area by defining and declaring a ground-water basin. Nearly all of the irrigated cropland in the MRGR is in a declared ground-water basin with only isolated tributary units outside of these basins (Figure 1). Therefore, the development of ground water is under the jurisdiction of the New Mexico State Engineer.

RESOURCES

Population

Table 2 presents a summary of the population of the MRGR from 1950 to 1970, utilizing data from the Bureau of the Census. Presently, the MRGR represents more than a third of the state's total population, with over eighty-three percent of this amount urban in make-up. The population increased substantially from 1950-1960, but during the sixties the increase became modest in comparison. Between 1950-1960, the urban population grew much faster than the rural, but during the sixties a balanced growth occurred in both the urban and rural make-up.

Bernalillo County experienced a tremendous growth from 1940 to 1960. However, from 1960 to 1970 it increased only 20 percent over the previous periods of over 100 percent growth (1940-1950) and 80 percent growth (1950-1960). The percentage of urban population continues to increase each enumeration year.

Sandoval County has shown some growth during the past two decades, primarily from the spill-over effects of the growth of Albuquerque and Bernalillo County. Because of the method used by the Bureau of the Census to classify types of population, Sandoval County recorded only a small urban population in 1960, and none in 1970. Even though the 17,942 people are

Table 2. Urban and rural population* for the Middle Rio Grande Region, New Mexico, 1950-1970

Year and County	Urban	Percent Urban	Rural	Percent Rural	Total	Percent Change from Previous Census
1970						
Bernalillo	297,451	94.2	18,323	5.8	315,774	20.4
Sandoval	0		17,492	100.0	17,492	23.2
Valencia	13,591	33.5	26,948	66.5	40,539	3.7
MRGR	311,042	83.2	62,763	16.8	373,805	18.5
1960						
Bernalillo	241,216	92.0	20,983	8.0	262,199	80.0
Sandoval	2,574	18.1	11,627	81.9	14,201	14.2
Valencia	17,963	46.0	21,122	54.0	39,085	73.9
MRGR	261,753	83.0	53,732	17.0	315,485	74.7
1950						
Bernalillo	111,571	76.6	34,102	23.4	145,673	109.0
Sandoval	0		12,438	100.0	12,438	- 10.5
Valencia	4,495	20.0	17,986	80.0	22,481	11.0
MRGR	116,066	64.3	64,526	35.7	180,592	74.4

Major Cities	1950	1960	Percent Change	1970	Percent Change
Albuquerque (B)	96,815	201,189	107.8	243,751	21.2
Bernalillo (B)	1,922	2,574	33.9	2,016	-21.7
Belen (V)	4,495	5,031	11.9	4,823	- 4.1
Grants (V)	2,251	10,274	356.4	8,768	-14.7
Milan (V)	0	2,658		2,185	-17.8

* County definition.

classified as rural, a significant number of them live within incorporated and unincorporated communities.

Valencia County showed a very low growth during the 1960's in both absolute and relative terms (3.7 percent). However, during the 1950's, the growth was very close to that of its larger neighbor, Bernalillo County. Even though only 33.5 percent of the population was urban according to the 1970 census classification, there are substantially more people living in incorporated villages and suburbs of the larger cities. A number of residents live along the Rio Grande belt south of Albuquerque to Belen. Thus, the reported rural percentage for Valencia County is deceptively high.

In the last decade there has been an appreciable slowing down in the MRGR's growth rate, but with the upsurge in industry and real-estate interest within the last year or so, there exists now a tremendous potential for growth along this portion of the Rio Grande Valley.

Table 3 summarizes the relationship between the MRGR and the entire state.

Table 3. Middle Rio Grande Region's percentage of New Mexico's urban and rural population, 1950-1970

MRGR	Percent of Urban	Percent of Rural	Percent of Total
1950	33.9	19.0	26.5
1960	41.7	16.5	33.1
1970	43.8	20.4	36.7

Industrial Development

A major portion of the industrial base of the State of New Mexico lies within the MRGR, and is centered in Bernalillo County and Albuquerque.

Manufacturing has shown a substantial gain over recent years, and the commercial and trade sectors have shown even more significant growth for the MRGR. Increased tourism has accounted for some of the gains in these two sectors, for with this increase came a tremendous expansion in hotel and motel construction. Land values and sales have increased greatly and, with the continuing rise in population, will continue to show healthy signs of growth. Several national companies have set up offices in all three counties. In Bernalillo County, commercial and residential land comprise the bulk of sales. In both Valencia and Sandoval counties, speculative development has now surpassed the residential sales.

With the presence and growth of the government sector--federal (both military and non-military), state, and local--in the eastern MRGR came the Research and Development industries. During the past decade this sector was one of the leading growth industries. This sector has declined with the recent slow-down in the general economy, but as business conditions improve, this industry will again demonstrate its growth capacity.

Several large manufacturing firms have recently moved into Bernalillo and Sandoval counties. These include Levi-Strauss, Singer-Frieden, and Lenkurt Industries. As these types of industries move into and expand in the eastern MRGR, the commercial and trade sectors will follow suit.

Valencia County has shown some manufacturing activity recently with several medium-sized firms locating within the County. Government continues to be the largest overall business, and is expected to be so for some time. The commercial and trade sectors will continue to develop along with the increasing population. Mining has declined over the last decade, and its future growth, of most concern to the central portion of Valencia County, will depend upon the government's demand for uranium.

Sandoval County has experienced recent manufacturing growth in several industrial park areas, due mainly to the economic growth of Bernalillo County and the cost differentials inherent in Sandoval County.

In the past both the railroad and agriculture were the prime components of Valencia County's economic base. Recently, both of these have begun to decline somewhat in importance. Many of the large ranches have been sold for sub-division and speculative purposes. Land sales (residential and speculative) and recreational trade and services are becoming prime industries, and will continue as such in the future.

Employment

Table 4 gives employment data for the counties of the MRGR for 1960 and 1970. As would be expected in a region with a large and growing urban population, employment in most sectors of the non-agricultural area is increasing steadily while agricultural employment is decreasing steadily. The largest gains for the Region as a whole were made in government employment, trade, services, and manufacturing. Contract construction employment decreased in Bernalillo and Valencia counties, but there was a dramatic increase in Sandoval County due primarily to the development of Rio Ranchos Estates, a large suburban development northwest of Albuquerque.

The only non-agricultural sector which showed a marked decline in employment is the mining sector. The major portion of this decrease is borne by Valencia County, where mining was once the chief occupation.

Land

Within the Rio Grande region there are approximately 16.9 million acres but only 1.7 percent, or 280,785 acres, are irrigated. The land ownership of the Rio Grande drainage basin is reported in Table 5. Federal and state ownership account for about 43 percent of the total land area in the Rio Grande region (Table 5).

The MRGR accounts for approximately 6.18 million acres (about 26 percent of the total land area within the Rio Grande region), of which 71,600 are irrigated. Within the MRGR, federal ownership accounts for about 24 percent of the total land area. Within the Region the acreage of forest land controlled by the Forest Service accounts for about 13 percent of the total land area; land administered by the Bureau of Land Management (BLM) accounts for about 9 percent; defense less than 1 percent; and other federal ownership about 3 percent. State ownership accounts for about 5 percent. Private ownership accounts for about 42 percent. Indian ownership accounts for about 26 percent. Inland water accounts for less than 1 percent of the total land area.

Irrigated Cropland. The irrigated cropland is located in a somewhat narrow strip along the rivers in the Middle Rio Grande Region (Figure 2). In the eastern subregion there are approximately 56,500 acres of irrigated

Table 4. Employment[a] in the Middle Rio Grande Region, New Mexico, 1960-1970

Employment (County Definition) - ESC	Bernalillo			Sandoval			Valencia			Middle Rio Grande Region		
	1960	1970	Percent Change	1960	1970	Percent Change	1960	1970	Percent Change	1960	1970	Percent Change
Total civilian work force	97,500	126,500	29.7	1,952	3,472	77.9	8,134	8,643	6.3	107,586	138,615	28.8
Unemployment	4,200	6,900	b	349	422	b	493	551	b	5,042	7,873	b
Rate	4.3	5.5	b	17.9	12.2	b	6.1	6.4	b	4.7	5.7	b
Employment	93,300	119,600	28.2	1,603	3,050	90.3	7,641	8,092	5.9	102,544	130,742	27.5
Non-ag. wage and salary	80,400	107,400	33.6	969	2,335	141.0	5,840	6,708	14.9	87,209	116,443	33.5
Manufacturing	7,600	9,200	21.1	169	438	159.2	178	308	73.0	7,947	9,946	25.2
Contract construction	7,200	7,000	- 2.8	36	328	811.1	484	355	-26.6	7,720	7,683	- .5
Mining	c	c	c	16	c	c	1,180	865	-26.4	1,180	865	c
Public utilities and transportation	6,800	6,800	0.0	94	79	-15.9	983	976	- .7	7,877	7,855	- .3
Wholesale & retail trade	18,500	26,300	42.2	102	133	30.4	1,084	1,260	16.2	19,686	27,693	40.7
Real estate, finance, and insurance	5,000	6,400	28.0	c	104	c	185	219	18.4	5,185[c]	6,723	c
Services & miscellaneous	18,100	25,200	39.2	183	551	201.1	579	907	56.6	18,862	26,658	41.3
Government	17,200	26,500	54.1	369	701	90.0	1,168	1,818	55.7	18,737	29,019	54.9
All other non-ag.	12,300	11,700	- 4.9	273	454	66.3	1,067	878	-17.7	13,640	13,032	- 4.5
Agriculture	700	500	-28.6	361	245	-32.1	734	506	-31.1	1,795	1,251	-30.3

[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.

cropland. In the western subregion there are about 15,000 acres of irrigated cropland, of which over 60 percent is along the Rio San Jose in central Valencia County. The acreages of the various crops produced are reported by subregion in Table 6. In terms of acres, alfalfa was the most important, accounting for 13 percent of the total irrigated cropland in the western subregion and 44 percent in the eastern subregion. The next most important crops were small grains and pastures. Nearly all of the crops in the Middle Rio Grande Region were low income-generating crops with the exception of vegetables and orchards. However, in the western subregion nearly 60 percent of the irrigated cropland was idle or out-of-production (Table 6). In the eastern subregion, idle and out-of-production accounted for about 18 percent of the irrigated cropland.

Soil Productivity. The soils in the valley floor of the eastern subregion consist primarily of stratified alluvial deposits of mixed origin. There are two general sources from which most were derived. The recent alluvial soils of the river flood-plain were formed by material of mixed origin brought down by the Rio Grande and its tributaries. The other soils owe their origin to the weathering of material from the adjacent mesa and plateau country, and are found upon the gently sloping alluvial fans that extend from the mesas down into the Recent valley fill material.

The largest percentage of the agricultural lands in the eastern subregion are on the alluvial soils of the Rio Grande flood-plain. These relatively young soils, located adjacent to the river, are generally fertile, with varying amounts of organic matter, and are suited to irrigated agriculture. The principal soils are of the Gila and Anthony series, varying in texture from sand to clay. The Gila clays are the most extensive and account for over one-half of the soils in the valley. Soils of the Anthony series account for a smaller portion and generally occupy the alluvial fans adjacent to the river flood-plain. They are generally lighter in texture. Most of the remaining soils are accounted for by the more desirable intermediate textured, clay loams, sandy clay loams, loams, and fine sandy loams. The soils of this series contain a fair amount of organic matter and are, in general, reasonably productive.

Table 5. Land ownership, in acres, in the Rio Grande drainage basin, New Mexico, 1971

Region and County[1]	Federal					State[2]	Private	Indian[3]	Total Land Area	Inland Water	Total Area
	Forest	BLM	Defense	Other	Total						
Upper Rio Grande											
Taos	461,200	199,800	--	24,300	685,300	102,700	545,200	110,300[4]	1,443,500	400	1,443,900
Rio Arriba	1,154,200	215,000	--	45,600	1,414,800	181,400	816,500	185,000	2,597,700	10,000	2,607,700
Mora	9,900	--	--	--	9,900	--	--	--	9,900	--	9,900
San Miguel	6,900	300	--	--	7,200	600	1,900	--	9,700	--	9,700
Santa Fe	158,600	61,000	--	35,200	254,800	38,400	409,800	75,700	778,700	300[5]	779,000
Los Alamos	--	--	--	68,300	68,300	--	3,700	--	72,000	--	72,000
Subtotal	1,790,800	476,100	--	173,400	2,440,300	323,100	1,777,100	371,000	4,911,500	10,700	4,922,200
Middle Rio Grande											
Sandoval	418,400	192,580	2,600	177,400	790,980	93,060	903,730	516,740	2,304,510	1,200[6]	2,305,710
Bernalillo	53,100	17,520	45,800	140	116,560	28,500	271,020	268,230	684,310	--	684,310
Torrance	49,140	2,400	--	--	51,540	19,800	53,600	16,400	141,340	--	141,340
Valencia	262,620	211,100	--	--	473,720	102,260	1,008,540	626,380	2,210,900	1,300	2,212,200
McKinley	15,370	149,520	--	35,500	200,390	65,300	398,580	173,800	838,070	480	838,550
Subtotal	798,630	573,120	48,400	213,040	1,633,190	308,920	2,635,470	1,601,550	6,179,130	2,980	6,182,110
Socorro region											
Socorro	598,050	556,000	3,800	80,300	1,238,150	277,780	1,129,570	65,700	2,711,200	13,900[7]	2,725,100
Catron	75,400	15,500	--	--	90,900	14,900	51,000	--	156,800	--	156,800
Subtotal	673,450	571,500	3,800	80,300	1,329,050	292,680	1,180,570	65,700	2,868,000	13,900	2,881,900
Lower Rio Grande											
Sierra	403,500	450,500	--	1,900	855,900	218,700	434,700	--	1,509,300	36,100	1,545,400
Dona Ana	--	915,670	21,640	7,800	945,110	230,120	232,700	--	1,407,930	--	1,407,930
Subtotal	403,500	1,366,170	21,640	9,700	1,801,010	448,820	667,400	--	2,917,230	36,100	2,953,330
Basin Total	3,666,380	2,986,890	73,840	476,440	7,203,550	1,373,520	6,260,540	2,038,250	16,875,860	63,680	16,939,540

[1] Includes only county area lying within the Rio Grande Drainage Region (Figure 2)

[2] Includes state trust and deeded land and lands administered by other state agencies.

[3] Includes both trust and deeded Indian lands.

[4] Includes transfer of 48,000 acres from Forest Service to Taos Indian Pueblo.

[5] Includes 56 acres for proposed Nambe Falls Reservoir.

[6] Includes 1,200 acres for Cochiti Lake under construction.

[7] Includes 1,801 acres for La Joya and Bosque del Apache Lakes.

Source: Estimated from Bureau of Land Management Quadrangle Maps; acreage of lakes and reservoirs from New Mexico State Engineer Office Preliminary Report, "Reservoirs and Lakes in New Mexico with 40 or more surface acres," February 8, 1971.

Table 6. Acres of irrigated cropland by use in the middle Rio Grande drainage basin, New Mexico, 1970

	Western Region				Eastern Region				Middle Rio Grande Region	
Land Use	Valencia	McKinley	Sandoval	Total	Valencia	Bernalillo	Sandoval	Total	Total	Percent
	. . . . acres				. . . . acres				(acres)	
Cotton	--	--	--	--	--	--	--	--	--	--
Alfalfa	1,207	--	711	1,918	15,052	5,569	4,173	24,794	26,712	37.3
Sorghum	5	--	--	5	268	149	45	462	467	0.7
Corn	135	--	141	276	1,071	669	337	2,077	2,353	3.3
Small grains	590	--	106	696	4,026	1,038	200	5,264	5,960	8.3
Improved pasture	194	--	460	654	3,631	1,366	497	5,494	6,148	8.6
Other hay and native pasture	230	222	182	634	--	2	13	15	649	0.9
Chile	--	--	--	--	104	58	10	172	172	0.2
Orchards	6	--	30	36	251	368	462	1,081	1,117	1.6
Spring lettuce	--	--	--	--	(200)[a]	(40)[a]	(20)[a]	(260)[a]	(260)[a]	(0.4)[a]
Fall lettuce	--	--	--	--	218	--	--	218	218	0.3
Spring onions	--	--	--	--	--	--	--	--	--	--
Fall onions	--	--	--	--	19	8	--	27	27	0.0
Misc. vegetables and family gardens	40	--	88	128	455	398	103	956	1,084	1.5
Subtotal cropped acreage[b]	2,407	222	1,718	4,347	25,095	9,625	5,840	40,560	44,907	62.7
Diverted and fallow[c]	1,564	33	291	1,888	1,876	1,143	2,047	5,066	6,954	9.7
Prepared land	5	--	--	5	299	176	39	514	519	0.7
Subtotal cultivated acreage[d]	3,976	255	2,009	6,240	27,270	10,944	7,926	46,140	52,380	73.2
Idle[e]	1,429	--	345	1,774	2,790	1,318	1,785	5,893	7,667	10.7
Out of production[f]	4,460	--	2,591	7,051	2,975	978	544	4,497	11,548	16.1
Total irrigated cropland[g]	9,865	255	4,945	15,065	33,035	13,240	10,255	56,530	71,595	100.0

a. Double cropped acreage, not included in total.

b. Irrigated cropland on which crops were growing at the time the field survey was conducted, and on which crops had been produced during the current crop year.

c. Acreage of irrigated cropland which was not cropped under provisions of the Agricultural Adjustment Programs or had been tilled in the past two years.

d. Irrigated cropland to which cultural practices were actively applied during the preceding two years, including the year in which this study was conducted. (Includes cropped, fallow, and diverted acreage.)

e. Irrigated cropland not actively farmed for the past two consecutive years but farmed within the past five years. (Includes suspended land which was not serviced by ground water.)

f. Irrigated cropland not actively farmed within the past five years.

g. Irrigated cropland: Land on which water is artificially applied for the production of agricultural products, on which the owner has the physical facilities or right to engage in such practices.

Source: Adjusted from: Lansford, R.R., and E.F. Sorensen, "Planted Cropland Acreage in New Mexico in 1969, 1970," *New Mexico Agriculture--1970*, Agricultural Experiment Station Research Report 195, New Mexico State Univ., Las Cruces, N.Mex., pp. 6-12, Tables 6 and 8; and Lansford, R.R., "Planted Cropland Acreage in New Mexico in 1970 and 1971," *New Mexico Agriculture--1971*, Agricultural Experiment Station Research Report 235, New Mexico State Univ., Las Cruces, N.Mex., pp. 31-37, Tables 17 and 18.

The soils in the western subregion range from light alluvial soils of the Prewitt and San Jose series in the Bluewater-Grants-Laguna area to the heavier mountain soils in the Cuba and Jemez areas. In the Bluewater-Grants-Laguna area the soils are generally deep, young, and of alluvial origin. They are calcareous and low to very low in organic matter. Most of these alluvial soils are of mixed origin and have not been in place long enough to have developed distinct profiles. The primary soils in this area are the San Jose loams and Prewitt clay loams.

The soils in the Cuba, Jemez, and other tributary areas are generally shallow soils of more recent alluvial origin. They are generally higher in organic matter, but consist primarily of the coarser sands and gravels.

A base map was drawn showing the location of the irrigated cropland acreage. Soils with the same characteristics were designated on the map by means of SCS soil survey symbols. A further designation was made according to the SCS capability classification for each of the different soils. It was considered desirable for purposes of this study to group the soils in such a way as to reflect differences in productivity, managerial requirements, and responsiveness to intensive cultural practices. After consulting with SCS personnel and county agents, and interviewing farmers, the soils were assigned to one of three groups depending on the degree of limitation of the above characteristics. A productivity index was used to reflect 100-percent expected yields of eight major crops produced on these different soils. Group I soils were considered to be those with only slight, if any, limitations; Group II, those with moderate limitations; and Group III, those with severe limitations. Such a grouping was considered to reflect the long-run economic potential of different soils in the MRG drainage basin. A detailed description of the soils is given in Appendix A.

About 10 percent of the irrigated cropland in the eastern subregion is Group I soil (Table 7). It occurs primarily in scattered tracks through the Valley (Figure 3). These soils are primarily loams and clays of the Gila series. They are level and deep and are considered to be highly productive. They are moderate to slightly stratified, have moderate permeability, moderate to good drainage, and good water-holding capacity. About 10 percent of the soils in the western subregion are Group I soils (Table 7). They occur primarily in the Bluewater-Grants area. These soils are of the San Jose series and are well-drained, calcareous, alluvial soils which occupy the flood plains and low terraces. Some stratification exists, but they are predominantly medium-textured.

The Group II soils account for the largest portion of the soils in the eastern subregion (about 58 percent) and a much smaller portion in the western subregion (about 30 percent) (Table 7). These soils are similar to the soils in Group I, but are characterized by low permeability and are affected by shallow water-tables and the accumulation of alkali. The soils in Group II consist primarily of the heavier textured soils of the Gila, Anthony, Pima, and Prewitt series and the lighter-textured soils of the Gila and Anthony series. In general, they do not respond as favorably to the use of improved management practices as the soils in Group I. Lower crop yields and incomes can be expected on farms with a large percentage of these soils.

Group III soils account for about 32 percent of the soils in the eastern subregion and about 61 percent in the western subregion (Table 7 and Figures 3 and 4). The primary limitations of these soils are the sandy textures, the extremely heavy textures, their shallow depths, and the existence of heavy or impervious layers. Common problems also include moderate slope, high water-tables, and accumulation of alkali. These soils are primarily of the Gila, Anthony, Puerco, Pima, and San Mateo series. They occur primarily along the river and the sides of the Valley in the eastern subregion, and in the Laguna and Cuba areas of the western subregion. A large percentage of the idle and out-of-production acreage is Group III soil.

Table 7. Acreage of irrigated cropland by soil productivity groups, middle Rio Grande drainage basin, New Mexico, 1969

Soil Productivity Group*	Western Subregion		Eastern Subregion		Total	
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
Group I	1,484	9.8	5,686	10.0	7,170	10.0
Group II	4,453	29.6	32,593	57.7	37,046	51.8
Group III	9,128	60.6	18,251	32.3	27,379	38.2
Total	15,065	100.0	56,530	100.0	71,595	100.0

* Soils included in each Group are described in Appendix A.

Figure 3. Soil productivity map, eastern Middle Rio Grande subregion.

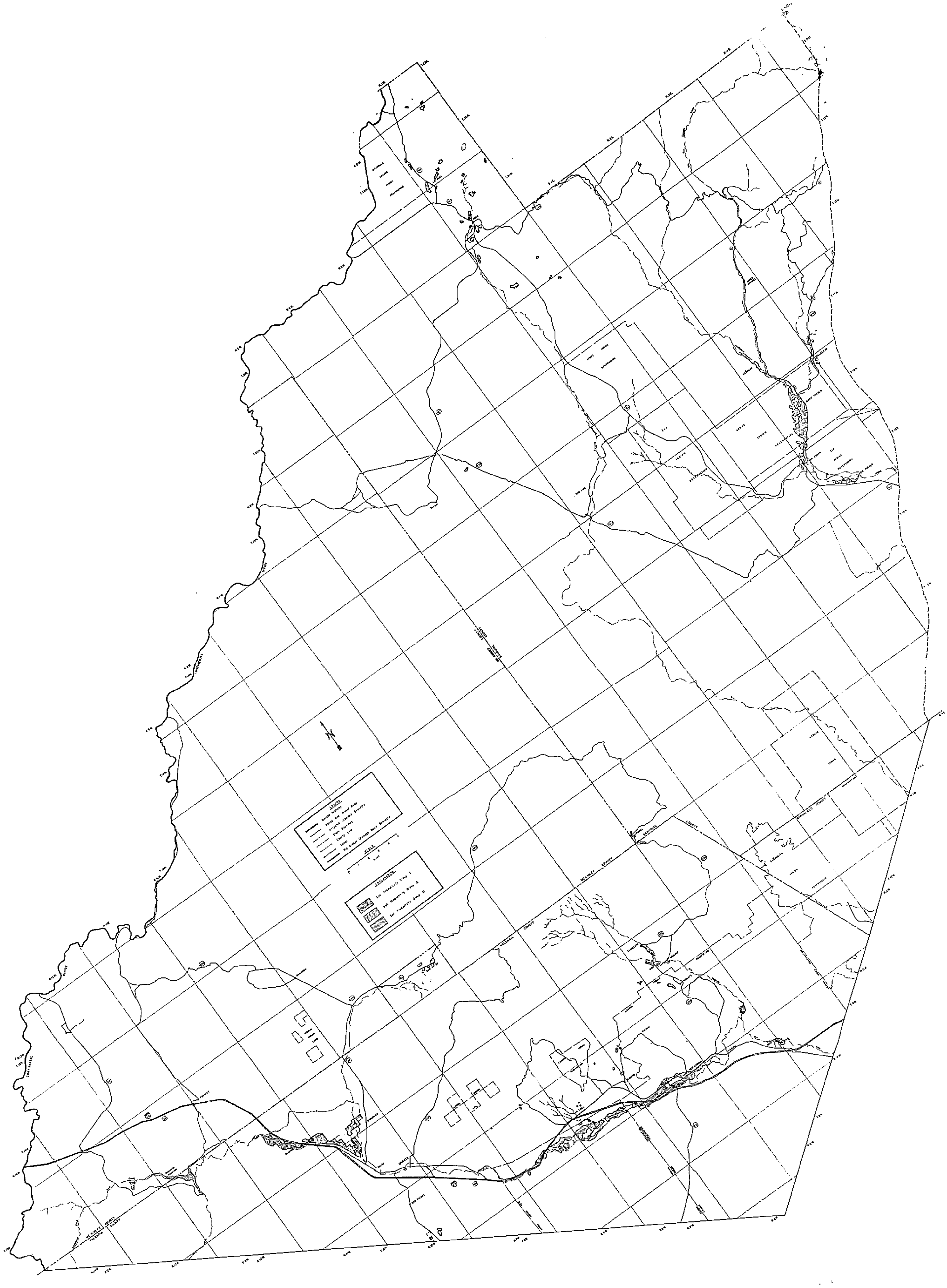

Figure 4. Soil productivity map, western Middle Rio Grande subregion.

HYDROLOGIC DATA

Nearly all of surface water of the Middle Rio Grande Region is supplied by the runoff from the Upper Rio Grande Region. The MRGR is an area of water consumption and not of water generation.

Surface Water

Most of the Region's water supply and use is along the main stem of the Rio Grande (i.e., the eastern subregion as shown in Figure 2 which includes most of the Middle Rio Grande Conservancy District). The water supply of the MRGCD comes primarily from the flow of the Rio Grande as measured at Otowi. The western subregion includes the drainage areas of the Jemez River, and the Rio Puerco and its tributary the Rio San Jose. Much of the water generated by these tributaries is used with the tributary basin.

Tables 8 and 9 present the average monthly flows for the Rio Grande at both Otowi and Bernardo. The historical flows of the Rio Grande are presented in Figures 5 and 6 for the Rio Grande at Otowi and the Rio Grande near Bernardo, respectively. Tables 10 and 11 present the average monthly flows for the Rio Puerco and Jemez River, measured at Bernardo and Bernalillo, respectively. There is no apparent drastic change of monthly averages in the flow of the Rio Grande as measured at Bernardo: this is in contrast to the monthly averages reported for the other stations. Table 12 is a comparison of the monthly averages for the Rio Grande as measured at Otowi and Bernardo. The consumption of water in this reach is apparent. Surface-water availability within this Middle Rio Grande Region is reported in Table 13.

Ground Water

The MRGR ground-water system is, to a large extent, affected by the urban development of the city of Albuquerque. Ground-water use is expected to increase rapidly and affect ground-water levels (Reeder, et al., 1967).

Due to differences in permeability, saturated thickness, and recharge or discharge of ground water, the water table slopes irregularly at a low gradient, diagonally down-valley (Reeder, et al., 1967). The water table

Table 8. Average monthly flows for the Rio Grande at Otowi Bridge, New Mexico

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . .	acre-feet	. . . .
1916-1939	106,425	136,817	45,641
1940-1957	83,099	102,867	43,562
1958-1968	68,171	76,949	50,614
1916-1968	90,564	112,862	45,967
1940-1968	77,437	93,036	46,237

Table 9. Average monthly flows for the Rio Grande at Bernardo, New Mexico, including Floodway, Conveyance Channel, Bernardo Interior Drain, and San Juan Riverside Drain (La Joya Eastside Drain)

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . .	acre-feet	. . . .
1944-1957	54,044	59,531	43,070
1958-1968	54,710	56,432	51,267
1944-1968	54,337	58,167	46,677

Note: Records prior to 1944 are incomplete.

Table 10. Average monthly flows for the Rio Puerco at Bernardo, New Mexico

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . .	acre-feet	. . . .
1940-1957	3,817	5,573	305
1958-1968	2,131	3,110	175
1940-1968	3,178	4,639	256

Table 11. Average monthly flows for the Jemez River near Bernalillo, New Mexico

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . . acre-feet	. . . .	
1944-1947	2,537	3,200	1,210
1958-1968	3,330	4,280	1,430
1944-1968	2,886	3,676	1,307

Table 12. Average monthly flows for the Rio Grande at Otowi Bridge and for the Rio Grande at Bernardo, New Mexico, 1958-1968

Month	Otowi	Bernardo	Gain	Loss
	. . . .		acre-feet	
January	38,568	43,341	4,773	
February	41,965	45,220	3,255	
March	62,499	49,939		12,560
April	119,279	95,402		23,877
May	173,943	146,120		27,823
June	107,605	82,681		24,924
July	43,338	21,337		22,001
August	53,375	32,056		21,319
September	28,434	11,311		17,123
October	27,120	12,606		14,514
November	68,607	58,398		10,209
December	53,316	58,110	4,794	
Total	818,049	656,521	12,822	174,350

Net consumption between Otowi and Bernardo is 161,528 acre-feet.

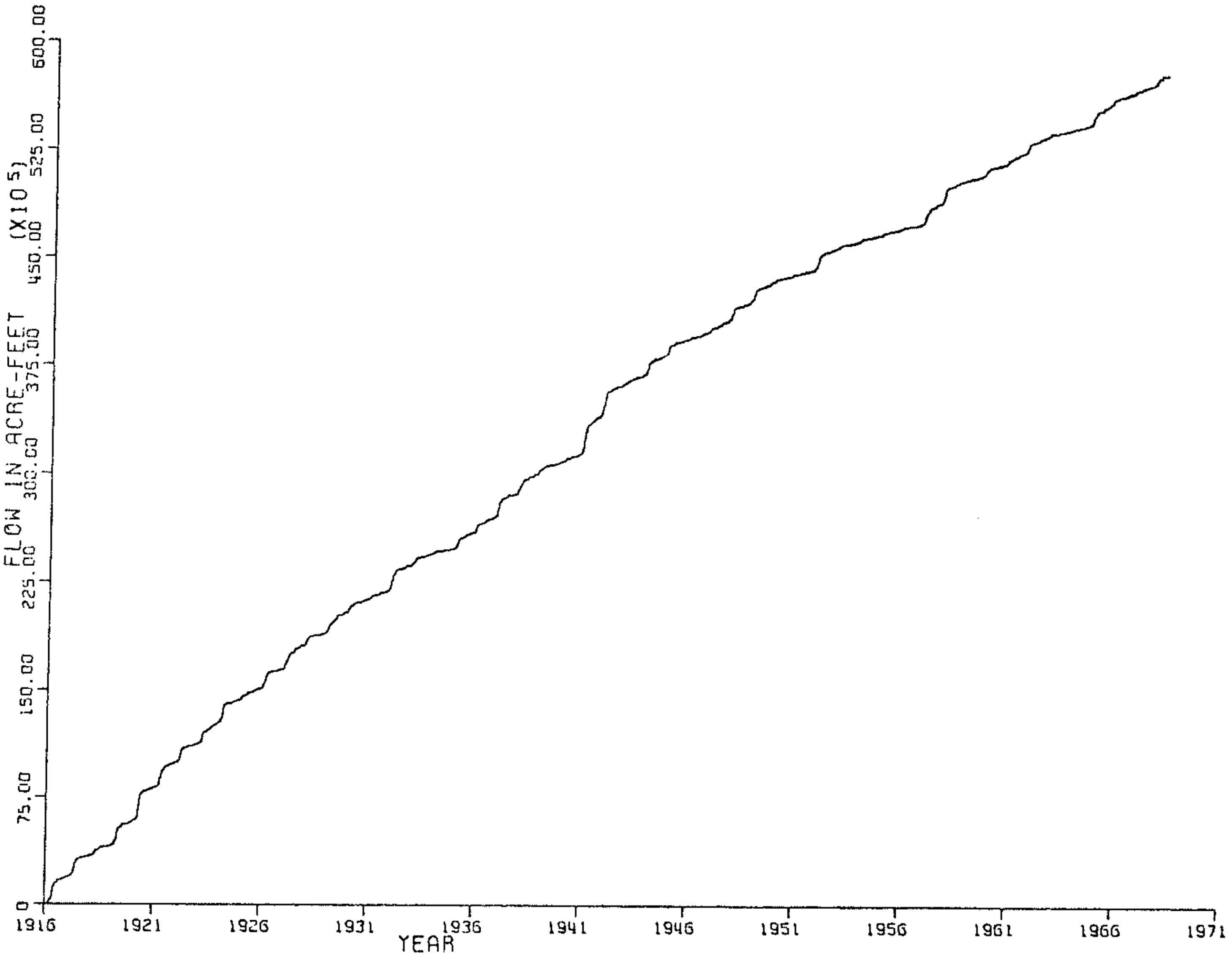

Figure 5. Mass flow curve for the Rio Grande at Otowi Bridge near San Ildefonso, New Mexico, 1916-1968

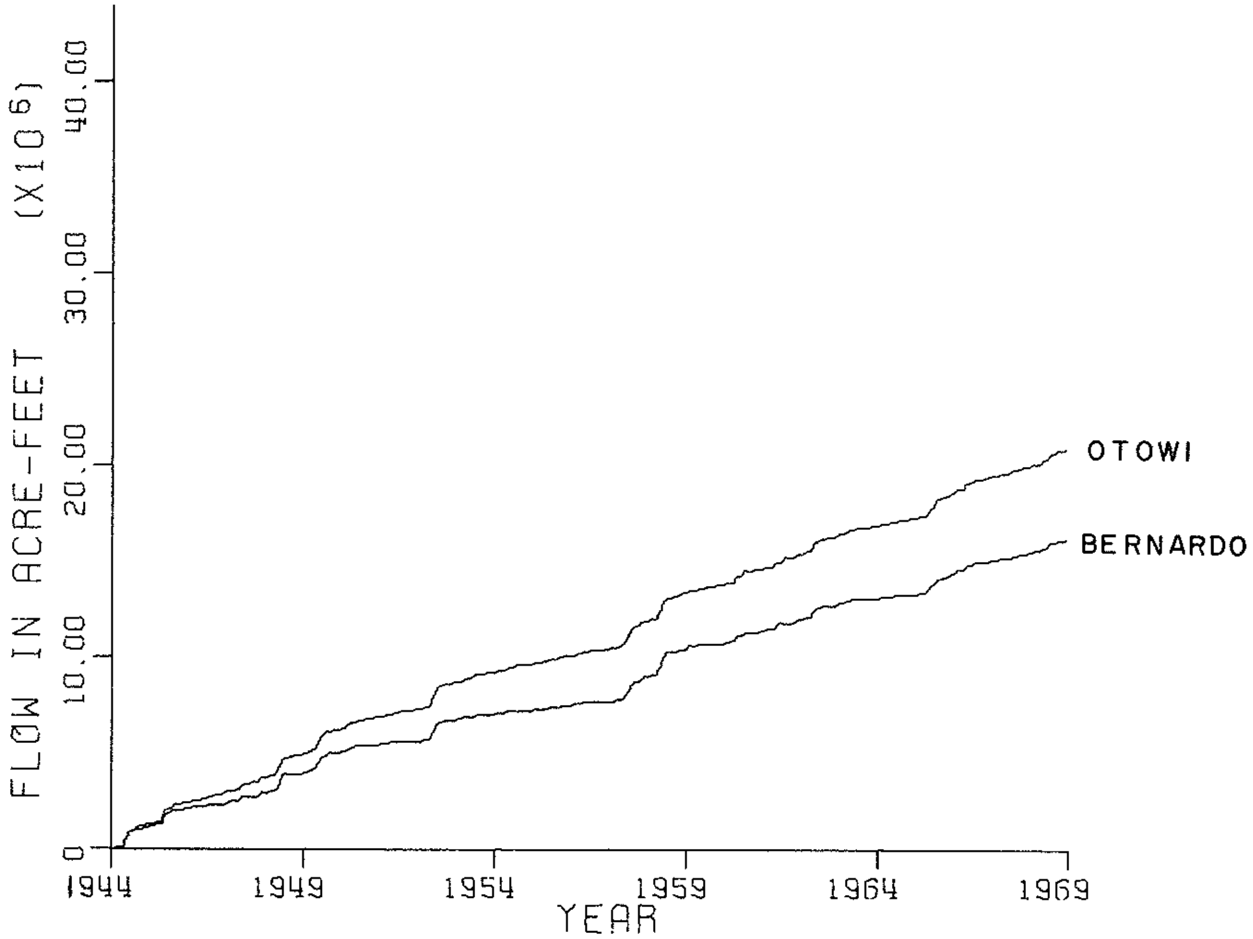

Figure 6. Mass flow curve for the Rio Grande at Otowi Bridge near San Ildefonso, New Mexico and for the Rio Grande at Bernardo, New Mexico, including Floodway, Conveyance Channel, Bernado Interior Drain, and San Juan Riverside Drain (La Joya Eastside Drain) 1944-1968

Table 13. Total surface-water available for the Middle Rio Grande Region, New Mexico

	March-October	November-February	Yearly
	. . . .	acre-feet	. . . . . .
Surface water outflow--main stem	451,452	205,069	656,521
Surface water outflow--tributaries	59,120	6,416	65,536
Agricultural depletion	101,622	1,541	103,163
Total surface-water available	612,194	213,026	825,220

slopes from the bases of the Sandia and Manzano Mountains on the east and from the Rio Puerco on the west toward a generally southward-trending zone about eight miles west of the Rio Grande.

Precipitation, and seepage from the river and drainage and irrigation canals are the main sources of recharge. Discharge is mainly due to pumpage; evapotranspiration is of little significance except to the north and south of the city of Albuquerque.

The Rio Grande river channel in most of its reach throughout the MRGR is not entrenched into the Valley floor (Reeder, et al., 1967). There has been some aggradation in some places which has raised the river channel slightly above the Valley floor. Moreover, pumping of ground water and low irrigation drains keep the water table substantially below the average river level. As a consequence, the river loses water to the ground-water system in most of the Albuquerque area. This trend of increasing induced recharge from the river is expected to continue.

The conjunctive-use surface- ground-water model of the MRGR uses a 16 x 10 grid system (a total of 160 rodes). This covers an area of 20 miles (transversal) by 64 miles (longitudinal) as shown in Figure 7.

Transmissivities range from 6000 gpd per foot in the alluvial fans along the mountains to 600,000 gpd per foot near the Rio Grande river (Reeder, et al., 1967). From estimated saturated thicknesses (Joesting, et al., 1961), hydraulic conductivities were calculated and ranged from 11.7 to 112 ft/day. The estimated specific yield (storage coefficient) is 0.2 for both sides of the river (Bjorklund and Maxwell, 1961).

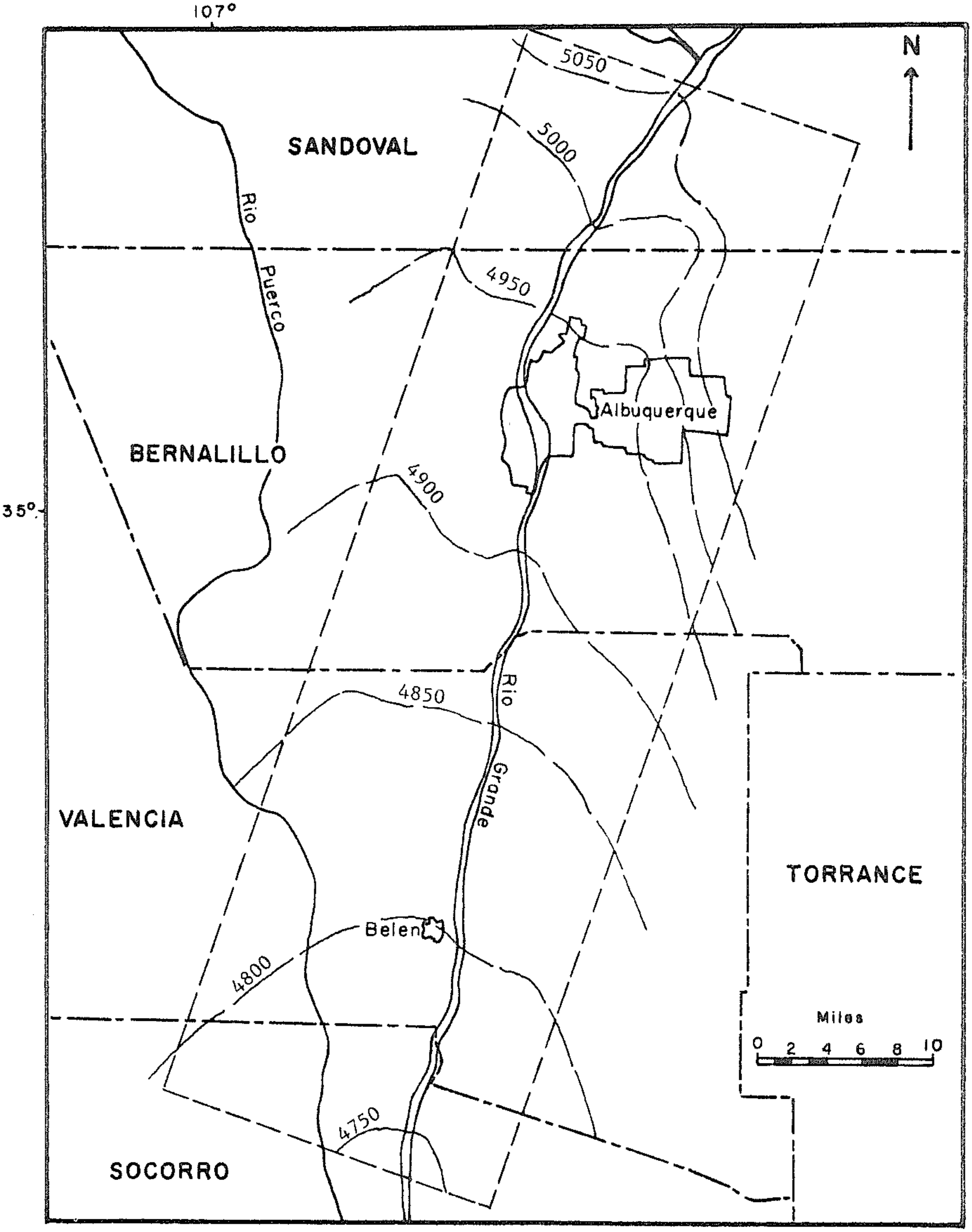

Figure 7. The Middle Rio Grande Region study area with 1968 water-table contours.

Historical conditions from 1962 to 1968 were simulated to verify and adjust model parameters. Major outputs (or inputs) are industrial and municipal water demands for the Albuquerque area. Agricultural groundwater usage, mainly to the north and to the south of the city, was estimated from consumptive-use data and irrigated acreage patterns reported in a later section of this report.

Ground-water velocities are characteristically slow in the Albuquerque area, ranging from 0.2 to 0.3 ft/day. Aquifer response due to pumpage should, therefore, be quite pronounced on a short-term basis. On the other hand, ground-water withdrawal in the Albuquerque area will increase induced recharge from the river and will also increase the gradient to the north, thereby increasing flow into the area from the north.

Analysis of the Albuquerque ground-water basin behavior is based on fifteen simulation runs (20 years each) with the computer model. Pumping patterns, precipitation, and river stages were combined to represent varying hydrologic conditions. The following surface- ground-water interrelationship was obtained by stepwise multiple regression analysis of the Albuquerque simulation data:

$$\Delta d = -113.1 - 28.4 \ \mathrm{EXP}(d_n/200) + 21.4 \log_{10}(L + 3 \times 10^6)$$

where Δd = decline (-) or rise (+) of the water table in any year (feet), d_n = depth (feet) to the water table in antecedent year with respect to river level considered as zero, and L = a lump factor in acre-feet per year. The lump factor consists of the following: river inflow (+), river outflow (-), 5% of annual average precipitation (+), nonbeneficial evapotranspiration losses (-), and the agricultural, municipal, and industrial water needs supplied by the ground-water systems (-).

The application of the above relationship can be demonstrated in different ways. Figure 8 assumes, for example, a present water-table elevation at river level and a normal projected growth for the Albuquerque area. Water levels are expected to drop about 50 feet during the next 30 to 40 years, at which time virtual equilibrium conditions are reached: i.e., hydrology in balance with Albuquerque water demands. The equation gives only average

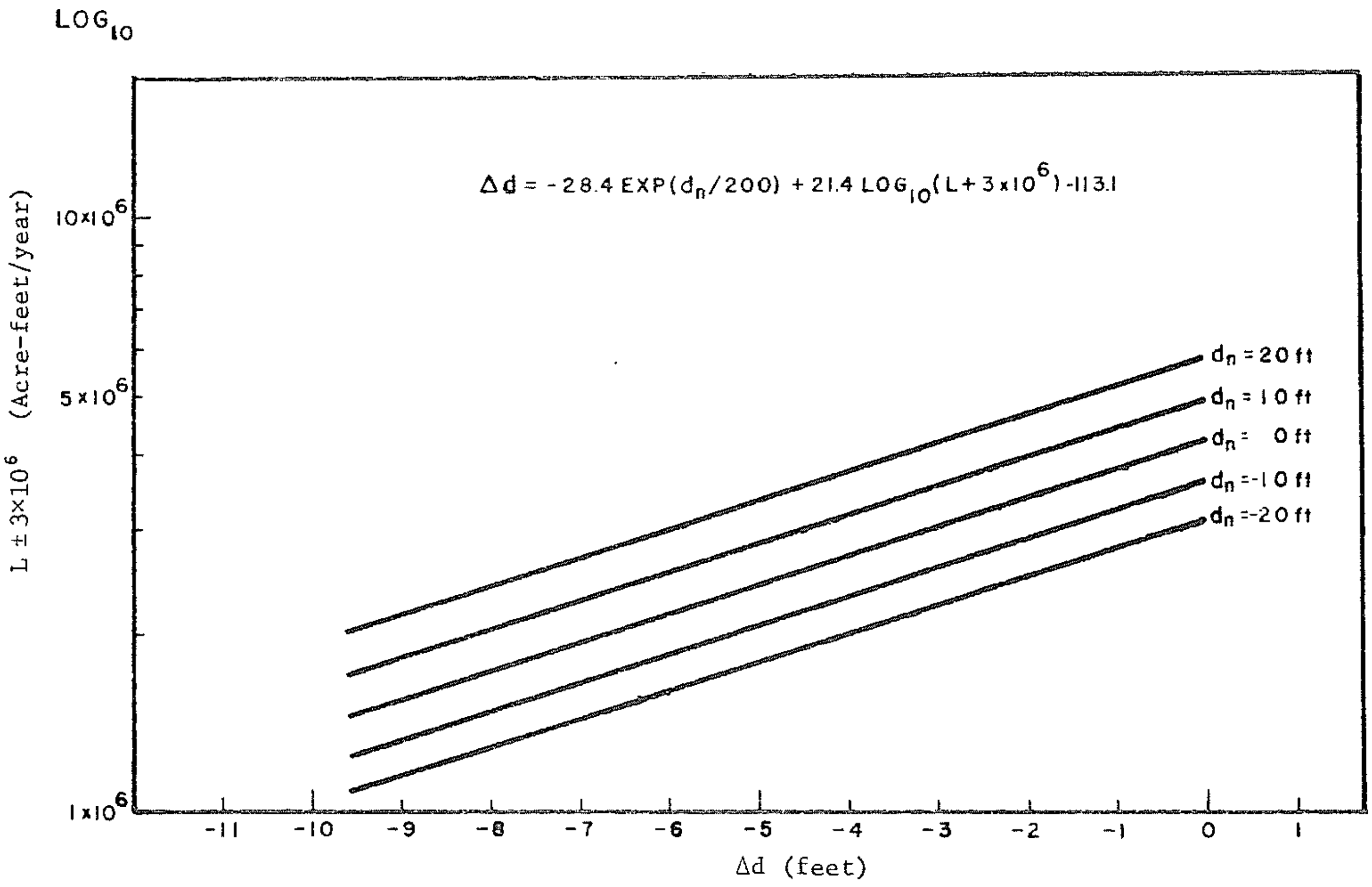

Figure 8. Expected declines in the water-table level in the Albuquerque area utilizing varying depths to water, Middle Rio Grande Region, New Mexico.

water levels (no spatial variation); however, it is easily understood that the largest water-table drop is expected in the vicinity of the city of Albuquerque, which could be on the order of 80 feet tapering off to the north and south to about 30 feet, as well as to the east and west.

Figure 9 demonstrates the effects of a sudden doubling of the water demand. Entering this graph from the ordinate with a particular value, different values for Δd (+ or -) are obtained, depending upon the water-table elevation of a previous year (d_n).

It is interesting to note that the results of this study closely agree with the predictive calculations for the year 2000 by Bjorklund, et al., in Reeder, et al. (1967), shown in Figure 10.

Water Quality

Surface water. The quality of the surface water of the Rio Grande reflects the use of the water upstream. Table 14 illustrates the general decline of the water quality along the Rio Grande in the MRGR during a recent year. Below Otowi Bridge, all ionic constituents increase and flow decreases. The consumption of water by agriculture tends to concentrate constituents. In addition, deep percolation and return flows to drains tend to compound the problem. Many of the drains are used for irrigation canals further down-stream; this results in lower quality water than that of the river. Electrical conductivity (FC x 10^6 @ 25°C) and Sodium Adsorption Ratio (SAR) are used to define the salinity and sodium hazards, and are also used in determining the economic classification of land.

Large concentrations of sediment in the Rio Grande constitute another major water-quality problem. Table 15 presents total loads of suspended sediment as measured at selected gaging stations during 1967. Substantial loads are carried by the Rio Grande to be deposited in Elephant Butte Reservoir. Sediment management and control is a major problem throughout the Middle Rio Grande Conservancy District. Heavy silt loads carried by the Rio Grande below its confluence with the Rio Puerco at Bernardo have settled and caused the river bed to become aggraded. Most of the sediment is produced by the collapse of channel walls where tributaries flow through deep gorges in silty soil, and by the surface erosion of lands with sparse vegetation.

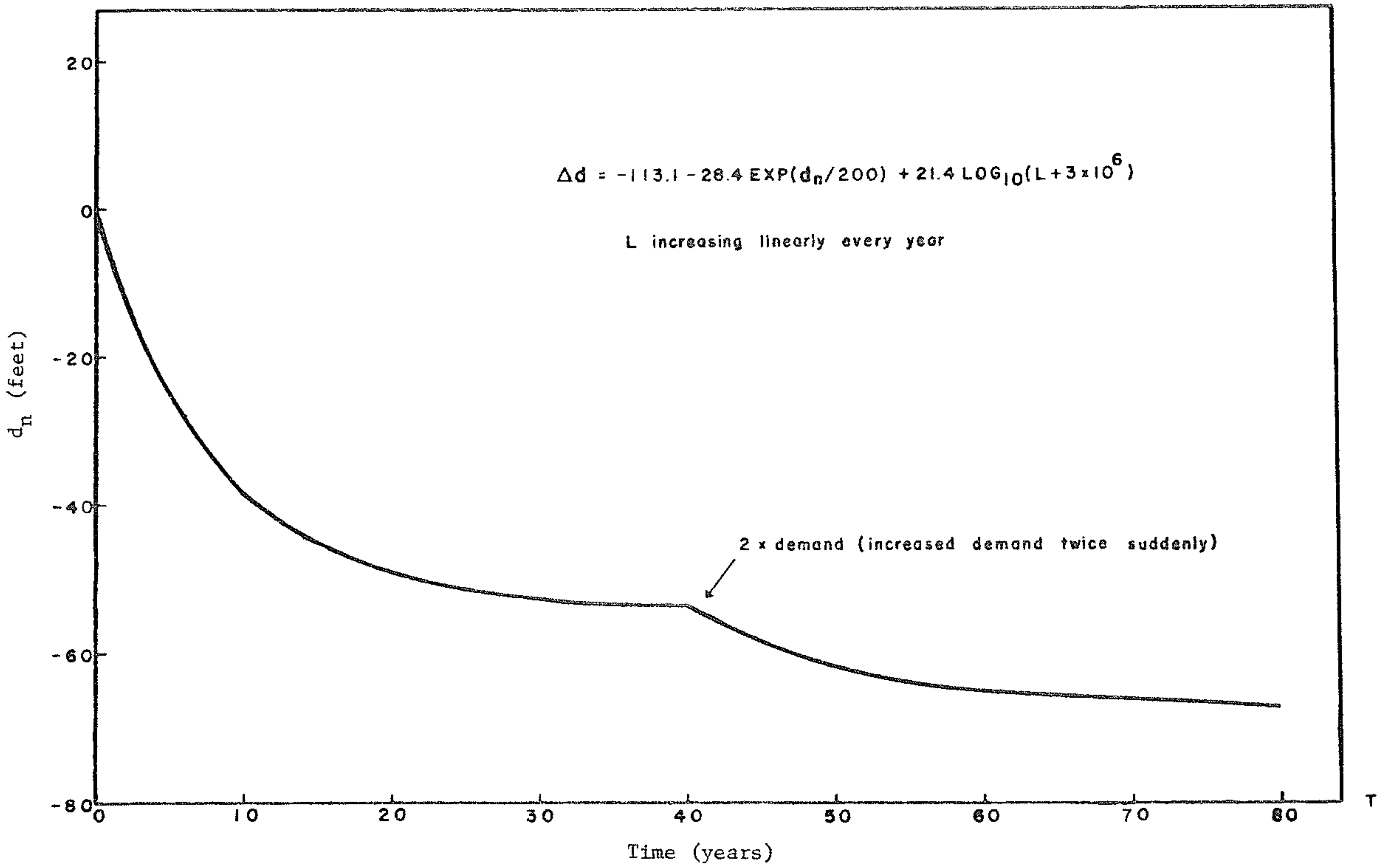

Figure 9. Depth (feet) to the water table [d_n] with respect to time for the Albuquerque area, Middle Rio Grande Region, New Mexico.

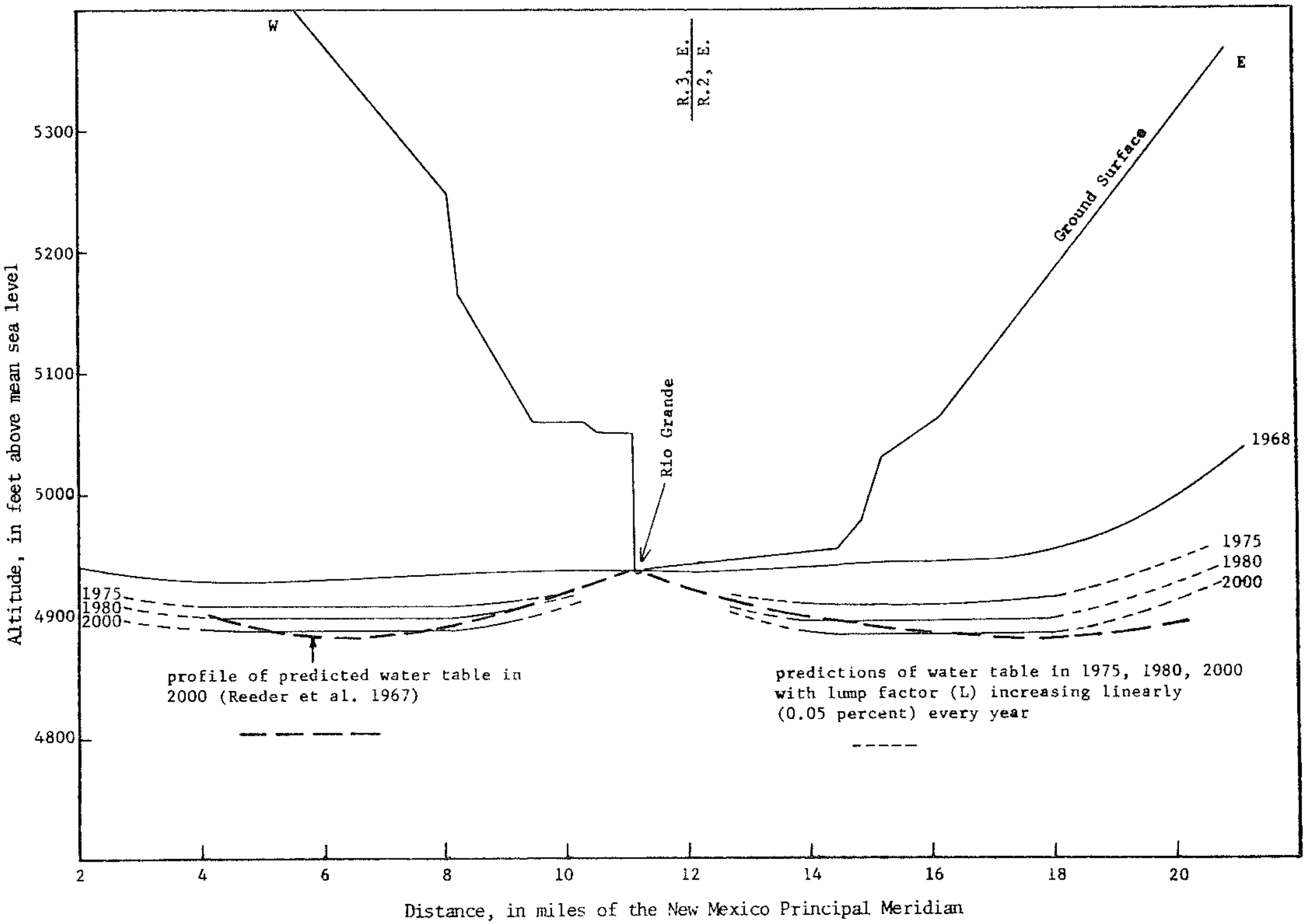

Figure 10. Comparison of predicted water-table levels for 1975, 1980, and 2000 with Reeder et al., 1967, for 2000, Albuquerque section, Middle Rio Grande Region, New Mexico

Table 14. Surface water quality of the Rio Grande at selected gaging stations, 1967

Station	Average Discharge CFS	Ca mg/e	Ma mg/e	Na mg/e	Cl mg/e	SO_4 mg/e	HCO_3 mg/e	Dissolved Solids mg/e	Electrical Conductivity Ec x 10^6 at 25^oC
Rio Grande at Otowi Bridge 1967 Water Year.	802	49	8.0	29	8.6	81	150	276	429
Rio Grande Conveyance Channel at San Marcial 1967 Water Year.	454	90	16	99	--	--	218	632	972
Rio Grande at El Paso, Texas 1967 Calendar Year.	321	87	19	151	130	262	--	809	1,220

Note: Discharge and quality parameters are time averaged. Parameters not measured or reported are identified by --.

Table 15. Total suspended sediment loads at selected gaging stations, 1967 Water Year

Station	Suspended Sediment (tons/year)
Rio Chama near Chamita 3 miles upstream from mouth	3,016,743
Rio Grande at Otowi Bridge	2,650,962
Galisteo Creek at Domingo 4 miles upstream from mouth	1,251,818
Rio Grande near Bernalillo	4,379,253
Rio Puerco near Bernardo 3 miles upstream from mouth	12,257,979
Rio Grande Conveyance Channel at San Marcial	10,502,515
Rio Grande Floodway at San Marcial	2,633,789
Rio Grande at El Paso, Texas	208,112*

*Reported for Calendar Year 1967.

Ground water. Ground-water quality in the eastern subregion is suitable for domestic, agricultural, and industrial purposes. Bjorklund et al. (1961) report the results of the chemical analysis of 94 usable samples of ground water collected in the Albuquerque area. Assuming that the dissolved solids content is 2.7 times the specific conductance, 82 of the samples would be classified as fresh water (less than 1000 ppm), 10 as slightly saline (1000 to 3000 ppm), 2 as moderately saline (> 10,000 ppm).

Ground water in the Santa Fe group, the largest and most productive aquifer of the area, is of good quality in most places (Figure 11). Near Albuquerque, the average total dissolved solids content seems to increase slightly, possibly due to induced recharge from the overlying alluvium because of heavy pumping in the Santa Fe formation. Valley alluvium water is usually more mineralized than water in the underlying Santa Fe group because of evapotranspiration, although this condition has improved greatly since 1930 when the Middle Rio Grande Conservancy District began the construction of drains.

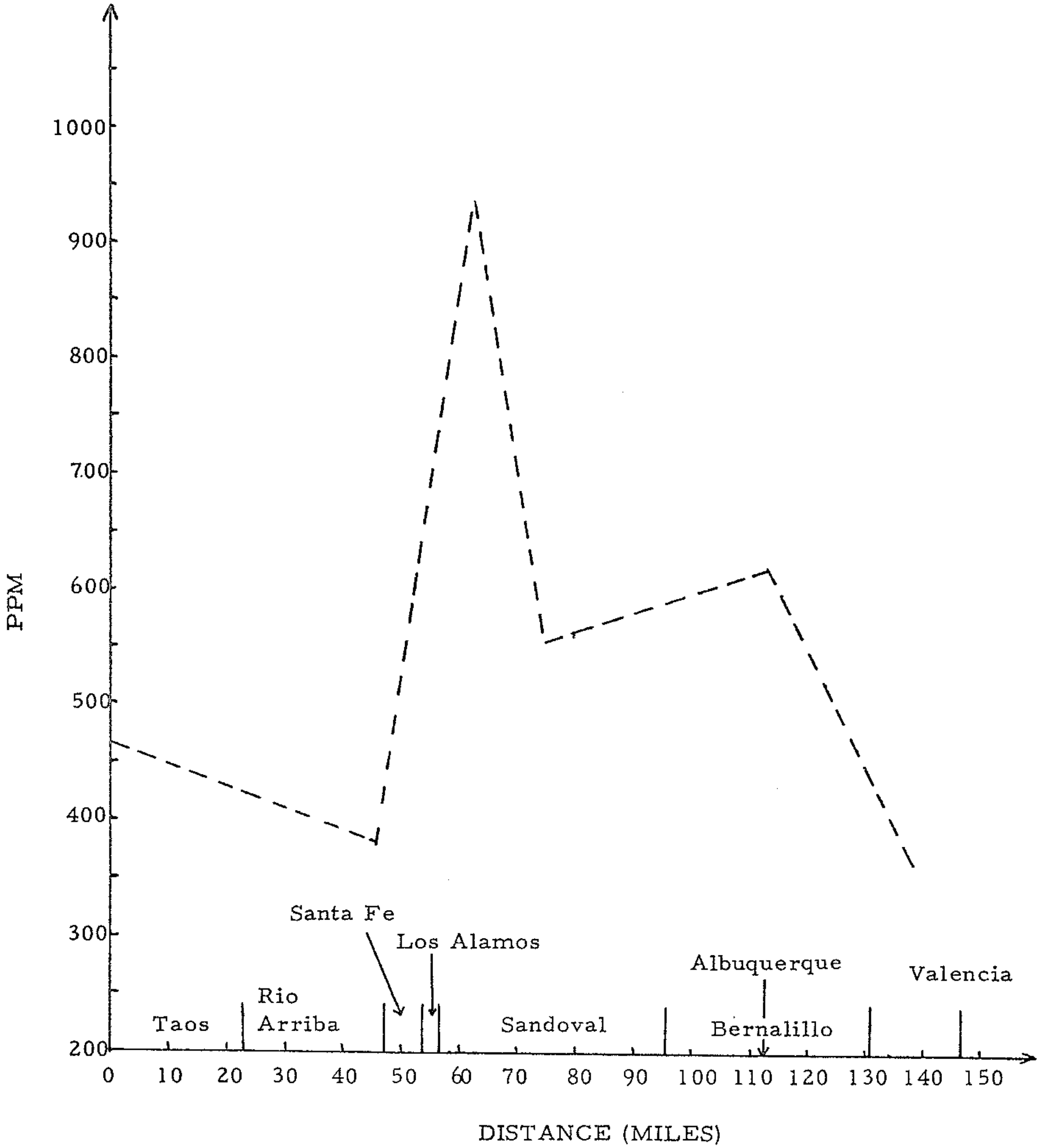

Figure 11. Average total dissolved solids content (ppm) for ground water in the Santa Fe group at selected locations, New Mexico

Locally, especially underneath the West Mesa, water may contain relatively large amounts of dissolved minerals related to volcanic activity and faulting. High silica content, for example, would indicate mixing of hydrothermal solutions with ground water. Ground water beneath the East Mesa is usually fresh since it is in contact with sediments derived largely from the hard rocks of Precambrian and Paleozoic Age of the Sandia and Manzano Mountains.

It is believed that the Santa Fe group ground-water quality deteriorates with depth. According to Kelly et al. (1970), fresh water extends to a depth of 3,500 feet in the Albuquerque basin. However, pumping the Rio Grande aquifer over an extended period of time in a concentrated area around Albuquerque may lead to impairment of water quality; in particular, it may affect the groundwater quality of the Albuquerque area as well as the downstream ground-water users due to upconing of the lower-quality water. Not only does this upconing have an effect on available water, but potential chemical reactions due to water-mass mixing may lead to future changes in water quality and aquifer characteristics.

WATER DIVERSIONS AND DEPLETIONS

Irrigation

Irrigation water for the MRGR comes from both surface and ground sources. Most of the surface water is supplied through the facilities of the Middle Rio Grande Conservancy District. Small quantities, however, are diverted from tributaries in the western portion of the Region. Ground water is used as a supplemental source in most cases, but is the primary source of irrigation water for about 300 acres in the eastern subregion and about 2000 acres in the western subregion.

The eastern subregion was divided into an upper and lower section because of the physical facilities for irrigation, availability of information, and type of agriculture.

Surface-water quantity. The quantity of surface water diverted to the project lands has varied widely from year to year, dependent upon the stream runoff in the higher elevations. In the Middle Rio Grande Conservancy

District, surface water is diverted by three main structures: the Cochiti, Angostura, and Isleta Diversion Dams. Cochiti Diversion Dam, at the head of the project, diverts water to the Cochiti East Side Main Canal and the Sili Main Canal. The Angostura Diversion Dam diverts water to the Albuquerque Main Canal, Corrales Main Canal, Arenal Canal, and the Barr Canal. The Isleta Diversion Dam diverts water to the Belen High Line Canal, Peralta Main Canal, and the San Juan Canal.

A large portion of the water diverted by the Cochiti Diversion is returned to the river by drains and wasteways before reaching the Angostura Diversion. The Angostura and Isleta Diversions also divert water in excess of needs, and a large portion is returned to the river before reaching the San Acacia Diversion in the Socorro Region.

The eleven-year average annual diversion for the Cochiti division is 45,423 acre-feet; for the Albuquerque and Belen divisions, which include the upper Socorro Region, it is 281,756 acre-feet (Table 16). These diversions are the gross diversions, a large portion of which are returned to the river or the drainage ditches and are again diverted, along with the return drain water, by the next lower unit. This excess diversion is of an operational nature for irrigation head, and in some cases results because of cancellation of water orders after water has already been diverted. Other specific losses from the canals include seepage losses, evaporation from the water surface in the canals, and transpiration by plants along the banks of the canals.

Monthly surface-water deliveries to the lands in the Middle Rio Grande Conservancy District in the MRGR are reported in Table 17. These deliveries* are the net deliveries to the farm headgates. (Canal wastage, canal seepage, and the unaccounted-for losses have been deducted.)

Ground-water quantity. The ground water used for supplemental and full service irrigation in the eastern MRGR is primarily from the valley fill. The water results from seepage from the river, canals and laterals, irrigation

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*United States Department of the Interior, Bureau of Reclamation, Middle Rio Grande Project, Albuquerque Office (unpublished data), 1960-1970, 11 pp.

Table 16. Gross annual diversions of irrigation water from the Rio Grande in the Middle Rio Grande Conservancy District, Middle Rio Grande and Socorro Regions, New Mexico, 1960-1970

Year	Middle Rio Grande Region[a]		Socorro Region[b]	
	Cochiti Division[c]	Albuquerque and Belen Divisions[d]	Socorro Division[e]	Total
	. . . .	acre-feet	. . . .	
1960	42,280	269,590	64,910	376,780
1961	38,660	300,100	84,190	422,950
1962	43,910	285,170	83,280	412,360
1963	46,550	203,950	55,640	306,140
1964	49,020	255,610	55,490	360,120
1965	52,560	355,800	94,570	502,930
1966	48,950	265,090	80,200	394,240
1967	43,230	285,830	79,280	408,340
1968	38,750	271,530	98,200	408,480
1969	43,310	315,560	114,000	472,870
1970	52,430	291,090	85,640	429,160
Average	45,423	281,756	81,400	408,579

[a] Includes upper Socorro Region diversions.

[b] Does not include upper Socorro Region diversions.

[c] Diversion at Cochiti Diversion Dam to Cochiti Eastside Main Canal and Sili Main Canal.

[d] Diversion at Angostura Diversion Dam to Albuquerque Main Canal and Atrisco Feeder Canal, and at Isleta Diversion Dam to Belen High Line Canal, Chical Lateral, Chical Acequia, Cacique Acequia, and Peralta Main Canal.

[e] Diversion at San Acacia Diversion Dam to Socorro Main Canal North.

Source: United States Department of Interior, Bureau of Reclamation, Albuquerque Office (unpublished data) 1960-1970, 10 pp.

Table 17. Monthly deliveries[a] of surface water to the lands in the Middle Rio Grande Region, Middle Rio Grande Project, Rio Grande Basin, New Mexico, 1960-1970

Year	MONTH												TOTAL
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
	acre-feet												
1960	0	0	6,280	19,890	25,170	24,250	13,520	12,140	12,640	8,390	0	0	122,280
1961	0	0	6,300	16,590	25,220	22,320	15,070	19,440	14,970	14,290	0	0	134,200
1962	0	0	7,680	17,850	23,570	23,690	14,240	11,920	13,330	14,400	0	0	126,680
1963	0	0	1,190	12,000	16,520	7,700	4,860	9,060	10,370	7,800	0	0	69,500
1964	0	0	7,500	15,710	21,010	9,700	6,630	9,970	8,840	6,560	0	0	85,920
1965	0	0	10,340	17,940	21,080	19,930	23,630	18,530	15,840	19,580	1,010	0	147,880
1966	0	0	5,610	13,560	16,250	15,210	9,540	12,970	7,100	8,590	0	0	88,830
1967	0	0	6,870	10,490	16,790	13,810	10,690	12,680	14,090	11,670	0	0	97,090
1968	0	0	5,020	13,130	18,800	18,620	12,880	16,170	10,590	12,580	0	0	107,790
1969	0	0	7,380	16,680	22,050	22,430	21,960	21,650	19,760	17,150	0	0	148,060
1970[b]	0	0	7,110	14,520	18,940	16,560	14,370	12,410	15,270	13,800	0	0	112,980
Average[b]	0	0	6,480	15,305	20,491	17,656	13,308	14,267	12,982	12,255	92	0	112,837

a Amount of water delivered to the farm headgate; excludes canal wastage, diversions for head, and other unaccounted-for losses (sum of Cochiti, Albuquerque, and Belen Divisions).

b Excludes deliveries calculated for upper Socorro Region.

water applied to the lands, ground-water flow from the bordering mesa lands, precipitation upon the valley floor and adjacent mesas, and from runoff in arroyos from the mesas to the valley.

Ground water used for irrigation in the western MRGR is primarily in the Grants-Bluewater area and is obtained principally from limestone, sandstone, and alluvial sand and ground deposits.

Consumptive irrigation requirements calculated by the Blaney-Criddle formula (1962) on the basis of the 1970 cropping pattern are reported in Tables 18 and 19. Table 18 includes requirements calculated for the Middle Rio Grande Conservancy District. The upper Middle Rio Grande valley tabulations correspond to the area serviced by the Cochiti division of the Middle Rio Grande Conservancy District, and the lower Middle Rio Grande valley tabulations correspond to the remaining MRGCD-serviced area in the MRGR. Table 19 reports requirements for the MRGR not serviced by the MRGCD, and is divided into the eastern and western subregions. These requirements were calculated for the summer (March through October) and winter (November through February) seasons. They are the quantities of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, required consumptively for crop production. They do not include surface evaporation or other economically unavoidable wastes normally associated with irrigation. The surface-water deliveries to the MRGCD were estimated at the farm headgate and, to be comparable, the irrigation requirements were calculated using the appropriate farm-irrigation efficiency. These requirements are also reported in Tables 18 and 19.

The irrigation requirements and the surface-water deliveries are summarized in Table 20 for the various sub-areas of the MRGR. The total irrigation requirement for the MRGR for the summer season was about 214,000 acre-feet. Surface-water deliveries by the MRGCD for the same season were about 123,000 acre-feet.

Surface water is also used for irrigation outside of the MRGCD in areas such as the Bluewater-Toltec Irrigation District in McKinley and Valencia Counties in the western MRGR. Surface-water deliveries were not available for this area, but were estimated to supply about 80 percent of the lands in the western MRGR: the remainder was supplied by ground water.

Table 18. Seasonal and total consumptive irrigation requirements and irrigation requirements by crop for lands serviced by the Middle Rio Grande Conservancy District, Middle Rio Grande Region, New Mexico, 1970

	Consumptive Irrigation requirements[a]			Irrigation requirements[b]		
Crop	Summer[c]	Winter[d]	Total	Summer[c]	Winter[d]	Total
	........acre-feet.......			........acre-feet........		
			UPPER MIDDLE RIO GRANDE VALLEY			
Cotton	--	--	--	--	--	--
Alfalfa	3,297	0	3,297	7,326	0	7,326
Sorghum	--	--	--	--	--	--
Corn	287	0	287	637	0	637
Small grains	133	9	142	296	20	316
Improved pasture	399	4	403	867	9	876
Other hay and native pasture	15	0	15	33	0	33
Chile	--	--	--	--	--	--
Orchards	69	1	70	153	2	155
Spring lettuce	--	--	--	--	--	--
Fall lettuce	--	--	--	--	--	--
Spring onions	--	--	--	--	--	--
Fall onions	--	--	--	--	--	--
Misc. vegetables and family gardens[e]	74	0	74	164	0	164
Total	4,274	14	4,288	9,476	31	9,507
Weighted average	1.88	0.01	1.89	4.17	0.01	4.19[f]
			LOWER MIDDLE RIO GRANDE VALLEY			
Cotton	--	--	--	--	--	--
Alfalfa	55,683	0	55,683	123,739	0	123,739
Sorghum	521	0	521	1,158	0	1,158
Corn	2,753	0	2,753	6,117	0	6,117
Small grains	6,658	808	7,466	14,796	1,796	16,592
Improved pasture	12,419	177	12,596	27,597	394	27,991
Other hay and native pasture	4	0	4	10	0	10
Chile	272	0	272	1,815	0	1,815
Orchards	1,622	19	1,641	3,604	42	3,646
Spring lettuce	--	--	--	--	--	--
Fall lettuce	--	--	--	--	--	--
Spring onions	--	--	--	--	--	--
Fall onions	--	--	--	--	--	--
Misc. vegetables and family gardens[e]	1,794	0	1,794	3,987	0	3,987
Total	81,726	1,004	82,730	182,823	2,232	185,055
Weighted average	2.14	0.03	2.16[f]	4.78	0.06	4.84

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a. The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production (Blaney and Hanson, 1965, p. 5).

b. The quantity of water, exclusive of precipitation, that is required for crop production or the consumptive irrigation requirement divided by the irrigation efficiency (45 percent), (Blaney and Hanson, 1965, p. 5).

c Months of March through October.

d. Months of November through February.

e. Also includes crops for which consumptive-use values were not available.

f. Does not add because of rounding.

Table 19. Seasonal and total consumptive irrigation requirements and irrigation requirements by crop for lands not serviced by the Middle Rio Grande Conservancy District, Middle Rio Grande Region, New Mexico, 1970

Crop	Consumptive Irrigation requirements[a]			Irrigation requirements[b]		
	Summer[c]	Winter[d]	Total	Summer[c]	Winter[d]	Total
	........acre-feet........			........acre-feet.........		
			EASTERN MIDDLE RIO GRANDE REGION			
Cotton	--	--	--	--	--	--
Alfalfa	123	0	123	246	0	246
Sorghum	130	0	130	260	0	260
Corn	92	0	92	184	0	184
Small grains	26	3	29	52	6	58
Improved pasture	--	--	--	--	--	--
Other hay and native pasture	--	--	--	--	--	--
Chile	--	--	--	--	--	--
Orchards	104	1	105	208	2	210
Spring lettuce	--	--	--	--	--	--
Fall lettuce	--	--	--	--	--	--
Spring onions	--	--	--	--	--	--
Fall onions	--	--	--	--	--	--
Misc. vegetables and family gardens[e]	23	0	23	46	0	46
Total	498	4	502	996	8	1,004
Weighted average	1.66	0.01	1.67	3.32	0.03	3.35[f]
			WESTERN MIDDLE RIO GRANDE REGION			
Cotton	--	--	--	--	--	--
Alfalfa	4,523	0	4,523	11,308	0	11,308
Sorghum	7	0	7	18	0	18
Corn	398	0	398	995	0	995
Small grains	874	103	977	2,185	258	2,443
Improved pasture	1,292	15	1,307	3,230	38	3,268
Other hay and native pasture	981	8	989	2,453	20	2,473
Chile	--	--	--	--	--	--
Orchards	60	1	61	150	3	153
Spring lettuce	--	--	--	--	--	--
Fall lettuce	--	--	--	--	--	--
Spring onions	--	--	--	--	--	--
Fall onions	--	--	--	--	--	--
Misc. vegetables and family gardens[e]	137	0	137	343	0	343
Total	8,272	127	8,399	20,682	319	21,001
Weighted average	1.91	0.03	1.93[f]	4.76	0.07	4.83

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[a] The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production (Blaney and Hanson, 1965, p. 5).

[b] The quantity of water, exclusive of precipitation, that is required for crop production or the consumptive irrigation requirement divided by the irrigation efficiency (50 percent for Middle Rio Grande Valley, 40 percent for Western MRGR), (Blaney and Hanson, 1965, p. 5).

[c] Months of March through October.

[d] Months of November through February.

[e] Also includes crops for which consumptive-use values were not available.

[f] Does not add because of rounding.

Table 20. Total irrigation requirements for crop consumption, average annual surface-water deliveries, and estimated ground-water pumpage in the Middle Rio Grande Region, New Mexico, 1970

Area	Irrigation Requirements			Surface water deliveries			Ground water pumpage		
	Summer	Winter	Total	Summer	Winter	Total	Summer	Winter	Total
	........acre-feet........			........acre-feet........			........acre-feet........		
Eastern Middle Rio Grande Region									
Upper Middle Rio Grande Valley									
Serviced by MRGCD	9,476	31	9,507	6,040	0	6,040	3,436	31	3,467
Not serviced by MRGCD	100	1	101	0	0	0	100	1	101
Subtotal	9,576	32	9,608	6,040	0	6,040	3,536	32	3,568
Lower Middle Rio Grande Valley									
Serviced by MRGCD	182,823	2,232	185,055	117,060	0	117,060	65,763	2,232	67,995
Not serviced by MRGCD	896	7	903	0	0	0	896	7	903
Subtotal	183,719	2,239	185,958	117,060	0	117,060	66,659	2,239	68,898
Total Eastern Middle Rio Grande Region									
Serviced by MRGCD	192,299	2,263	194,562	123,100	0	123,100	69,199	2,263	71,462
Not serviced by MRGCD	996	8	1,004	0	0	0	996	8	1,004
Total	193,295	2,271	195,566	123,100	0	123,100	70,195	2,271	72,466
Western Middle Rio Grande Region									
Total	20,682	319	21,001	16,546*	255*	16,801*	4,136*	64*	4,200*
Total Middle Rio Grande Region									
Total	213,977	2,590	216,567	139,646	255	139,901	74,331	2,335	76,666

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* Estimated (80% surface-water supplied, 20% ground-water supplied).

Total pumpage of ground water for irrigation in the MRGR was thus arrived at as the residual of requirements minus deliveries or, as in the eastern MRGR, by estimating the area supplied by source of water. The ground-water pumpage for the MRGR was estimated to be about 74,300 acre-feet in the summer season and about 2,300 acre-feet in the winter season for a total of about 76,700 acre-feet (Table 20). This is about 1.70 acre-feet per cropped acre in the MRGR.

Municipal and Industrial

Municipal water-use depends primarily upon two factors: the number of urban water users, and the per capita use of water. Industrial water-use depends partially on the number of employees and the per employee use of water in the production of goods and services. Using figures from the State Engineer Office, an estimate was made of water use for the urban population in 1960 and 1970. Municipal use includes more than urban population: light industrial as well as commercial activities within a region are dependent upon the municipal water supply. An estimate was made separately for this type of user, which includes the public sector composed of government and associated enterprises. Due to the lack of reliable primary data, these estimates should serve only as crude approximations to the actual water use within the MRGR.

Over 90 percent of the municipal and industrial water users obtained their supplies from ground-water systems. Very little surface water is diverted or depleted by any user other than agriculture.

Rural Domestic

Rural use of water is dependent upon the same two factors, population size (rural only) and the per capita use of water, as the urban population use. All the water diverted or consumed by the rural domestic population was assumed to be derived from ground water.

Livestock

Livestock use of water depends upon both use per animal within the region, and the number of, and evaporation from, stock ponds located in the region. To obtain an estimate of the use of water by livestock, an inventory by Capener and Sorensen (1971) for both the number of livestock and the number of stock ponds was used.

Stock ponds are primarily supplied from surface water, but some livestock water comes from the ground supply. However, the most significant portion of water used can be assumed to be from surface supplies.

Between 1960 and 1970, there was no appreciable change in water consumption by livestock, but since 1960 the number of stock ponds increased. Consequently, only an estimate of livestock use was made for 1970.

The actual consumption by livestock was estimated to be 1,700 acre-feet in 1970 for the MRGR: stock-pond evaporation was estimated to be 1,200 acre-feet. Irrigated pasture, for which no sale of commodity is involved, must be added to these figures. Approximately 25,500 acre-feet of water was used to irrigate pasture land for grazing by livestock. Therefore, in the MRGR approximately 28,400 acre-feet was consumed each year in the late 60's by the livestock sector.

Recreation

There are no reservoirs in the MRGR maintained solely for recreational use. Bluewater Reservoir does have recreational use and activity but was constructed for irrigation, flood control, and sediment abatement. The State Game and Fish Department has leased a minimum pool for the Reservoir from the Bluewater-Toltec Irrigation District to insure a minimal amount of water for fish survival in the Reservoir. However, the evaporation losses are charged to purposes other than recreation.

Non-beneficial

Each year a large portion of the water supply of the MRGR is lost through non-beneficial depletions. These losses are primarily in the form of evaporation from the surface-water areas and from evapotranspiration by phreatophytes.

Phreatophytes. The phreatophyte classification describes a distinct ecological group of desert plants that have adapted their root systems to survive in arid areas where the water table is between 5 and 30 feet below ground. The phreatophytes, which include salt cedar, saltgrass, cottonwood trees, and willow are found in areas such as the lower flood-plain of arid river basins where it is difficult to account for the sources and interaction of surface and ground-water flow.

Phreatophytes, as defined by Blaney and Hanson (1965), are plants that habitually grow where they can send their roots down to the water table or to the capillary fringe immediately overlying the water table. Saltgrass and salt cedar are the two most common phreatophytes in the MRGR. Blaney and Hanson (1965) listed consumptive use of ground water by saltgrass as 29.3 inches per year, and for salt cedar 57.2 inches per year. The flood-plain areas of the Rio Grande in the MRGR are generally covered with saltgrass and areas of salt cedar and cottonwood (Figure 12). Cottonwood is the predominant type of phreatophyte in the MRGR. The Bureau of Reclamation, in 1971, reported phreatophyte consumptive use in the MRGR at over 63,300 acre-feet annually. The total area of phreatophytes in the MRGR was estimated (U.S. Department of Interior, Bureau of Reclamation, 1971) at 17,750 acres.

<u>Evaporation</u>. Losses due to evaporation from reservoirs, lakes, and ponds affect the net water supply available. Studies of evaporation from storage reservoirs indicate that during long periods of deficient streamflow, reservoirs may yield, for useful purposes, as little as 50 percent of the total water supply. The primary evaporation loss in the MRGR comes from open canals and drains. Phreatophyte losses, however, are far greater than evaporation losses.

ECONOMIC LAND CLASSIFICATION

An economic land classification of the 71,595 acres of irrigated cropland in the Middle Rio Grande Region was based on an adaptation of the Cornell system using soil productivity and irrigation water quality and quantity as the primary variables. This classification was conducted, primarily for use with the socioeconomic model, to provide basic information on the relative economic productivity of the irrigated cropland areas within the Region. The delineation of areas with slight, if any, moderate, and severe limitations provided information for the water and land resource reallocation criteria used in the model.

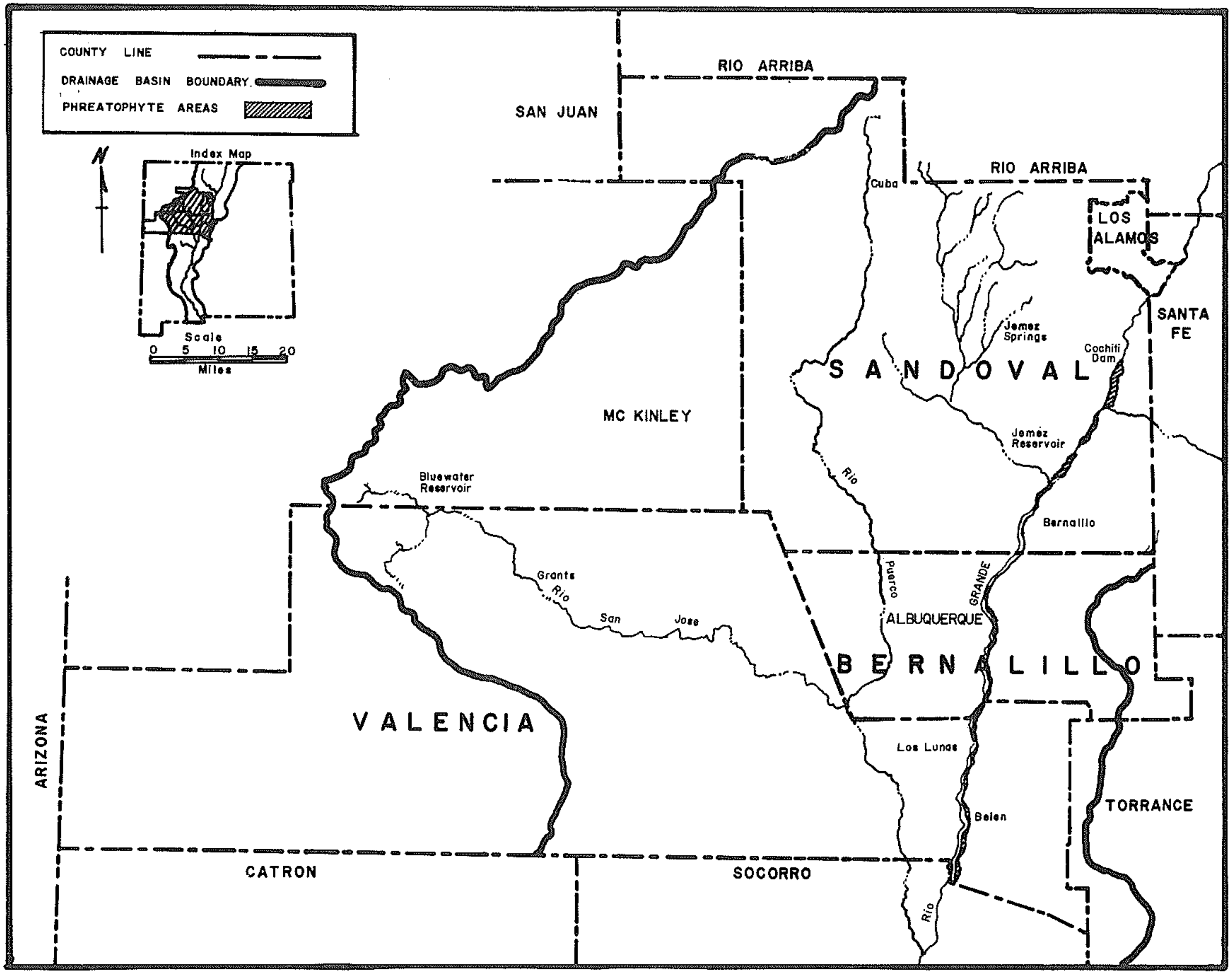

Figure 12. Major phreatophyte areas in the Middle Rio Grande Region, New Mexico, 1964

Source: United States Department of the Interior, Bureau of Reclamation, Albuquerque, New Mexico, March 1964.

None of the irrigated cropland acreage in the MRGR was considered to have only the minor income expectancy limitations required for classification as Economic Class I (Table 21). The primary reasons for lower classification of some of the cropland were lower soil productivity, reduced water quantity, small farm size, and problems associated with urban encroachment.

Only about 5 percent of the irrigated cropland in the MRGR was classified as Economic Class II (Table 21). Soil productivity and irrigation water quantity were the primary limiting factors associated with these lands.

These Economic Class II lands were located in the eastern subregion, primarily in the southern section (Figure 13). Most of this acreage is used for full-time commercial farming. Inputs are relatively high, buildings and equipment are in reasonably good condition but seldom comparable with Class I lands in other sections of the basin. The farms in this Class were larger and fields were larger and better situated for more efficient use of machinery and better irrigation practices than those in Class III.

Table 21. Acreage of irrigated cropland by economic land classes, Middle Rio Grande Region, New Mexico

Economic Land Classification	Western Middle Rio Grande Region		Eastern Middle Rio Grande Region		Total	
	(acres)	(percent)	(acres)	(percent)	(acres)	(percent)
Class I	0	0	0	0	0	0
Class II	0	0	3,720	6.6	3,720	5.2
Class III	15,065	100.0	52,810	93.4	67,875	94.8
Total	15,065	100.0	56,530	100.0	71,595	100.0

Almost 95 percent of the irrigated cropland acreage in the MRGR had severe limitations and was classified as Economic Class III. Most of the farms were small and were operated on a part-time basis, many in the category of hobby farms and rural residences. The fields were irregular in shape as a result of terrain and irrigation systems. Farmsteads and buildings on many of the farms in the eastern subregion indicated a much larger investment than typically could be supported by the farm, thereby limiting

Figure 13. Economic land classification map, eastern Middle Rio Grande subregion.

the value of this economic indicator in the classification. Existing machinery and equipment was generally old and small, and in many instances it was apparent that much of the machinery and equipment was provided through custom, rental, or other arrangements. Deficiencies in soil productivity, water quantity (and in some cases water quality), unfavorable topography, small farm-size, and the likelihood of urban encroachment were the primary limitations imposed on these lands. The Economic Class III lands were located throughout the MRGR, but included all of the western subregion and most of the northern part of the eastern subregion (Figures 13 and 14).

Income expectancies measured in terms of crop yields for selected crops in the MRGR were estimated from enterprise budgets developed for selected farms on the different land classes (Table 22). Extreme differences in the yields or returns between the two economic land classes were not found in all cases because of the limited number of farms interviewed and differences in managerial ability of the farmers.

Table 22. Expected yields for selected crops on different economic land classes, Middle Rio Grande Region, New Mexico

Economic Land Class	Crop Yield per Acre			
	Alfalfa	Small Grains*	Corn	Lettuce
	tons	bu.	bu.	cwt.
Class I	--	--	--	--
Class II	6.5	50	30	160
Class III	4.5	40	25	140

* Includes primarily barley, oats, and wheat.

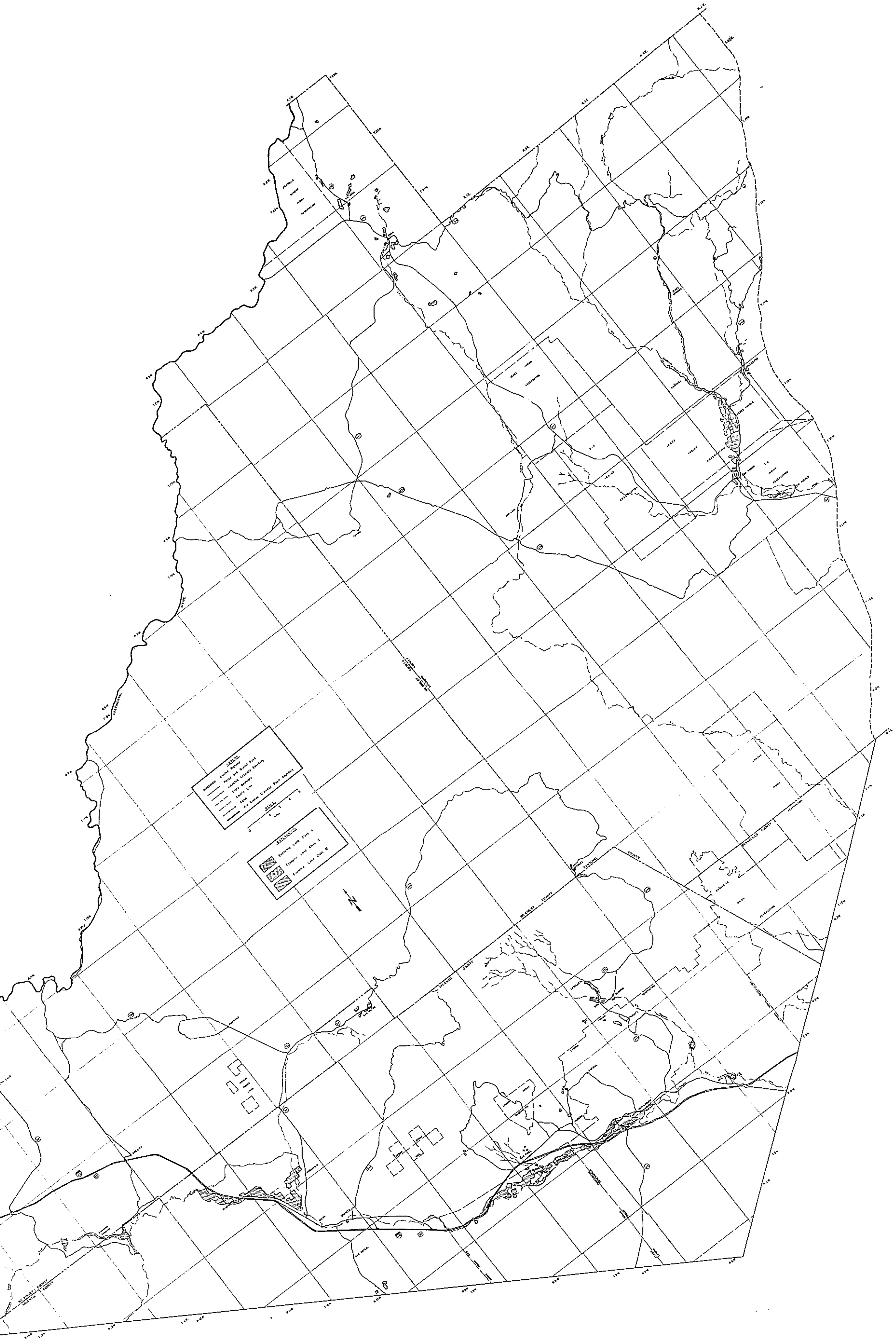

Figure 14. Economic land classification map, western Middle Rio Grande subregion.

THE SOCIO-ECONOMIC MODEL

The socio-economic model was used to simulate long-run production and water utilization patterns in the Rio Grande Basin under alternative assumptions. Because of the difficulty of obtaining population, industrial activity, and employment data by drainage basin they were incorporated into the socio-economic model on a county basis. Therefore, the results from the socio-economic model reflect economic activity and water depletions for all of Sandoval, Bernalillo, and Valencia counties: portions of Sandoval, Bernalillo, and Valencia counties outside of the Rio Grande drainage basin are included, but economic activity and water depletions for the portions of McKinley and Torrance counties that are within the Rio Grande drainage basin are excluded.

The MRGR and the other three Regions constitute the total socio-economic simulation model. Direct interpretations of the results for only the MRGR do not take into account the interactions with the other Regions; therefore, the MRGR will be highlighted as a part of the total Rio Grande region analysis.

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 recreation demands and 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 New Mexico was represented in the model by twenty-four production sectors (Table 23). All sectors were defined in the model in units of one million dollars of production. Each sector had its own demands

Table 23. Definition and classification of production sectors

Production Sector	1960 I-O Study *	Major SIC Codes **	Production Sector Description
Agriculture			
1	1,2		Meat animals, farm dairy products and poultry
2	3		Food grains and feed crops
3	4		Cotton and cottonseed
4	5		Vegetables, fruits and nut trees, miscellaneous food products
5	6	7	Agricultural services
Mining			
6	7,8,11,12	10,12,14	Metals and non-metals
7	9,10	13	Crude petroleum and natural gas, oil and gas field services
Manufacturing			
8	13	201	Meat packing and other meat products
9	14	202	Dairy products
10	15	204,205	Grain mill and bakery products
11	16	remainder of 20	Miscellaneous food products
12	17,21	24,25,32	Lumber and wood products, concrete and stone products
13	19,20	28,29	Chemicals and petroleum refining
14	22,23	19,34,35,36,38, 371-373	Electrical machinery and equipment, scientific instruments, fabricated metal products
15	18,24	22,23,27,31,39	Printing and publishing, miscellaneous manufacturing
Transportation Communications Utilities			
16	25,26	40,41,42,45,47	Railroads and all other transportation
17	27	46,4924	Gas and oil pipelines
18	28,29,30	48,49	Communications, electric and gas utilities
Trade			
19	31,34	50,52,53,54,56,57,59	Wholesale trade and most retail trade
20	32,33	55,58	Retail auto dealers and gas stations, eating and drinking places
Finance, Insurance, and Real Estate			
21	35,36	60,61,62,63,64,65,67	Finance, insurance, and real estate
Services			
22	37,38,39,40	70,72,73,75,76,78,79	Hotels, motels, personal services, business services
23	41,42	80,81,82,88,89,37(p)	Medical and professional services, research and development
Construction			
24	47	15,16,17	Contract construction

*Source: New Mexico Bureau of Business Research, 1965

**Standard Industrial Classification

for resources such as water, labor, etc., and its contribution to the total benefits to the state's economy, measured by the value added of each one-million-dollar unit. Tables 24 and 25 present some of the major results of the basic model and relate them to water utilization for both the total Rio Grande region and for the MRGR. Table 24 presents levels of production for all 24 sectors measured in terms of output. *Medical and professional services* and *research and development* (sector 23) generated the largest value of production at $517.96 million, and *agricultural services* (sector 5) generated the smallest value of production at $4.95 million. Within the agricultural sector, *meat animals*, *dairy products*, *and poultry* (sector 1) accounted for about 49 percent of the agricultural value of production; *fruits and vegetables* (sector 4) about 23 percent; *cotton* (sector 3) about 10 percent; *food grains and feed crops* about 12 percent; and *agricultural services* about 6 percent. The *metals* sector (sector 6) accounted for about 76 percent of the total value of production for the mining industry, and *oil and gas* (sector 7) accounted for the remaining 24 percent. In the manufacturing sectors, *electrical, scientific instruments, and fabricated metal products* (sector 14) accounted for 27 percent of the value of production ($70.345 million); *lumber and wood products*, *concrete and stone products* (sector 12) 22 percent; *printing and publishing, miscellaneous manufacturing* (sector 15) 20 percent; *meat packing* and *dairy products* (sectors 8 and 9) 18 percent; and the remaining 13 percent included *grain mill and bakery products* (sector 10) 5 percent, *miscellaneous food* (sector 11) 5 percent, and *chemicals and petroleum refining* (sector 13) 3 percent. The *Services* sectors (sectors 22 and 23) accounted for about 40 percent of the total value of production; *Trade* (sectors 19 and 20) about 25 percent; *Transportation, communications, and utilities* (sectors 16, 17, and 18) about 14 percent; *Finance, insurance, and real estate* (sector 21) about 10 percent; and *Construction* (sector 24) about 10 percent.

The value added generated by each sector ranges from 17.7 percent of the total value of output in the *meat packing industry* (sector 8) to 71.2 percent in *retail auto, gas stations, and eating places* (sector 20). The weighted average value added in the Rio Grande region was 58 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.

Table 24. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Middle Rio Grande Region, 1970--basic optimal solution

Sector		Total Rio Grande Region				Middle Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	41.839	14.351	2,346	79,888	14.804	5.078	1,263	17,642
	2	9.886	6.357	1,424	224,748	4.038	2.596	163	98,091
	3	8.574	5.264	233	134,180	0.000	0.000	0	0
	4	19.526	15.406	2,739	58,393	1.077	0.850	118	10,023
	5	4.950	3.024	454	59	3.284	2.007	255	39
Mining, Oil & Gas	6	81.785	52.342	1,731	2,977	38.523	24.655	599	1,106
	7	26.277	19.051	189	1,594	6.569	4.763	30	394
Manufacturing	8	20.651	3.655	273	62	20.370	3.605	270	61
	9	25.948	6.798	504	111	22.287	5.839	430	95
	10	14.277	4.183	537	20	14.096	4.130	488	19
	11	13.071	4.902	539	189	9.550	3.581	390	136
	12	56.155	26.730	2,332	854	41.796	19.895	1,874	652
	13	7.931	1.753	109	297	7.931	1.753	109	297
	14	70.345	29.615	4,018	157	63.857	26.884	3,485	146
	15	50.456	26.691	2,139	137	34.140	18.060	1,428	80
Trade & Services	16	109.842	72.935	5,004	274	62.476	41.484	4,169	156
	17	13.501	9.316	152	34	8.981	6.197	140	22
	18	104.925	68.201	4,518	4,484	73.618	47.852	3,356	2,844
	19	325.258	214.345	22,071	1,597	260.519	171.682	16,999	1,279
	20	98.281	69.976	11,298	579	68.991	49.122	7,877	375
	21	177.302	131.381	7,230	1,742	138.902	102.926	5,568	1,364
	22	151.463	88.303	13,158	1,940	98.225	57.265	7,431	1,236
	23	517.957	286.430	17,474	6,371	345.810	191.233	11,806	4,253
	24	172.462	71.744	9,559	3,039	123.630	51.430	6,603	2,178
	Total	2,122.660	1,232.753	110,030	523,722	1,463.473	842.885	74,851	142,489

The *Trades* and *Services* sectors represent about 82 percent of the employment within the Rio Grande region. *Wholesale trade, retail trade, gas stations, restaurants,* and *Services* (sectors 19, 20, 22, and 23) represent almost 60 percent of the total employment. Employment in *Manufacturing* accounts for about 10 percent of those employed in the RGR, primarily in *lumber and wood products*, and *concrete and stone products* (sector 12), *electrical machinery and equipment, scientific instruments, fabricated metal products* (sector 14), and *printing and publishing* and *miscellaneous manufacturing* (sector 15). These three sectors account for over 80 percent of the employment within the *Manufacturing* sectors. *Agriculture* represents about 7 percent of the RGR employment force, with about 38 percent employed in *vegetables and fruits* (sector 4), and about 33 percent in *meat animal and dairy production*.

Agricultural production accounted for 95 percent of the water depleted in the RGR with *food grains and feed crops* (sector 2) accounting for about 45 percent of the total depletions, and *cotton* (sector 3) accounting for another 27 percent. *Mining* sectors accounted for less than 1 percent, *Manufacturing* sectors only 0.3 percent, and *Trades and Services* 3.8 percent.

Table 25 magnifies the differences between the *Agriculture* sectors and all other producing sectors. While the *Agriculture* sectors produced only 4.1 percent of the total output, 3.9 percent of the total value added, and provided only 6.7 percent of the total employment, they consumed 95 percent of all the water used in production in the Rio Grande region. The *Trade and Services* sectors played the opposite role, using only 3.8 percent of all water depleted by the production sectors, but producing 78 percent of the total value of output and accounting for 81.9 percent of the total value added.

In the MRGR the agricultural sectors produced the smallest portion of the subregion's total output (1.6 percent) and total value added (1.2 percent) percent), and also provided for one of the lowest employment rates (2.4 percent). *Agriculture* consumed the largest portion of the water used in production (88.3 percent of the MRGR total). *Mining* (sectors 6 and 7), is less important in the MRGR than in the total Rio Grande region, producing 3.1 percent of the total output, 3.5 percent of the total value added, and

Table 25. Production, employment, and water use for major sectors in the Rio Grande region, and in the Middle Rio Grande Region, New Mexico--basic optimal solution

	Total Rio Grande Region				Middle Rio Grande Region			
Major Sector	Total Output ($1 million)	Total Value Added ($1 million)	Employment	Total Water Depletions (acre-feet)	Total Output ($1 million)	Total Value Added ($1 million)	Employment	Total Water Depletions (acre-feet)
1. Agriculture	84.775	44.402	7,196	497,268	23.203	10.530	1,800	125,796
2. Mining, Oil & Gas	108.062	71.393	1,920	4,571	45.092	29.417	629	1,500
3. Manufacturing	258.834	104.327	10,451	1,826	214.027	83.748	8,473	1,486
4. Trade & Services	1,670.991	1,012.630	90,463	20,059	1,181.152	719.190	63,949	13,708
Total	2,122.660*	1,232.753*	110,030	523,722*	1,463.473	842.885	74,851*	142,489*
	(Percent)	(Percent)	(Percent)	(Percent)				
1. Agriculture	4.0	3.6	6.5	94.9	1.6	1.2	2.4	88.3
2. Mining, Oil & Gas	5.1	5.8	1.8	0.9	3.1	3.5	0.8	1.1
3. Manufacturing	12.2	8.5	9.5	0.4	14.6	11.6	11.3	1.0
4. Trade & Services	78.7	82.1	82.2	3.8	80.7	83.7	85.5	9.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Does not add due to Rounding

providing for 0.8 percent of the employment. The *Manufacturing* sectors are more important in the MRGR than in the total Rio Grande region. The *Trade and Services* sectors in the MRGR were similar to the total Rio Grande region, and the general relationships that exist for the total Rio Grande region are also expressed in the Middle Region; i.e., *Trade and Services* sectors were responsible for the largest portion of the total value of output (80.7 percent), but used only 9.6 percent of the water depleted. The single most important industry is *medical and professional services, research and development* (sector 23) accounting for almost 25 percent of the total value of production in the MRGR.

In the agricultural sectors, *meat animal and dairy production* (sector 1) accounted for 64 percent of the value of production, 48 percent of the value added by *Agriculture*, provided 70 percent of the agricultural employment, but consumed only about 14 percent of the agricultural water. *Food grains and feed crops* (sector 2) accounted for about 17 percent of the value of agricultural production, 25 percent of value added, 10 percent of agricultural employment, and 78 percent of the agricultural water consumed.

The single most important manufacturing sector in the MRGR is *electrical machinery and equipment, scientific instrument, fabricated metal products* (sector 14), followed by *lumber and wood products* and *concrete and stone products* (sector 12), followed by *printing and publishing* and *miscellaneous manufacturing* (sector 15). These three manufacturing sectors account for 65 percent of the manufacturing value of production, 80 percent of value added, 64 percent of manufacturing employment, but only 16 percent of the manufacturing depletions.

The single most important *Trade and Services* sector is *medical and professional services, research and development* (sector 23) comprising almost 30 percent of the value of production of *Trades and Services*, 27 percent of value added, but only 18 percent of the employment, and 31 percent of the water depletions used in *Trades and Services*. The location of the military installations and Albuquerque in the MRGR contributes significantly to sector 23. The next closest sector in value of production is *wholesale trade* and most *retail trade* (sector 19), and contributes about 22 percent of the *Trades and Services* value of production followed by *finance, insurance,* *and real estate* (sector 21) at 12 percent, and *contract construction* (sector 24) at about 10 percent. These four *Trade and Services* sectors account for about 74 percent for the *Trade and Services* total value of production, 72 percent of the value added, 64 percent of the employment, and combined account for 94 percent of the *Trades and Services* water depletions.

The regional distribution of water depletions by major production sectors and municipal and rural uses is presented in Table 26. The significance of the agricultural sectors as major water users was maintained in all Regions, although their share is reduced in the Middle Rio Grande Region to 74.0 percent, where 16.5 percent of the total water use was for domestic purposes. The Middle Region was responsible for the second highest water depletions in the Rio Grande region, utilizing 30 percent of the total water available.

Water recreation demands in the Rio Grande region in the base year (1970) and the distribution of supply by origin are presented in Table 27. The major supply area for water skiing and boating is the Lower Rio Grande. Recreationers from the Middle, Socorro, and Lower Regions, as well as out-of-state visitors, utilize the availability in the Lower Region.

In the concentrated population centers of the Middle Rio Grande Region, demands exceed supply of water-based recreation by 453,235 (551,654-98,419) activity-occasion days (AOD) in water skiing, 146,210 activity-occasion days in boating, and 807,318 activity-occasion days in fishing. The Lower Region supplies 589,672 activity-occasion days of water skiing but demands only 67,719, resulting in a difference of 521,953 AOD (Table 27); in boating there is a net supply of 293,943 AOD (Table 27); and in fishing there is a net supply of 382,904 AOD (Table 27). The Middle Rio Grande Region supplies about 48 percent of the Middle Rio Grande Region's demand for water skiing, boating, and fishing.

Three Water Management Alternatives

The socio-economic model was used to estimate the effects of population growth on the distribution of production and water requirements in the Rio Grande region for the period 1970-2020. Regional population projections used

Table 26. Summary of depletions by major sector in the Rio Grande region (acre-feet)--basic optimal solution

Major Sector	Region Upper	 Middle	 Socorro	 Lower	Total Rio Grande Region
			. . . . . acre-feet		
Agriculture	111,084	125,795	38,061	222,328	497,268
Mining, Oil & Gas	2,852	1,500	108	111	4,571
Manufacturing	225	1,486	29	87	1,826*
Commercial Trade & Services	4,199	13,708	202	1,950	20,059
Municipal	3,862	25,568	407	4,362	34,199
Rural	2,042	2,527	203	1,051	5,823
Total	124,264	170,581	39,010	229,889	563,746*
			. . . . . percent		
Agriculture	89.39	73.74	97.57	96.71	88.21
Mining, Oil & Gas	2.30	0.88	0.28	0.05	0.81
Manufacturing	0.18	0.87	0.07	0.04	0.32
Commercial Trade & Services	3.38	8.04	0.52	0.85	3.56
Municipal	3.11	14.99	1.04	1.90	6.07
Rural	1.64	1.48	0.52	0.46	1.03
	100.00	100.00	100.00	100.00*	100.00

*Does not add due to rounding.

Table 27. Water-based recreation by Region, Rio Grande region--basic optimal solution

	Demanding Region					
Supplying Region	Upper	Middle	Socorro	Lower	Out of State	Total Supply
	(activity-occasion days)					
		WATER SKIING				
Upper	121,402				8,281	129,683
Middle		98,419				98,419
Socorro						
Lower		255,459	13,897	67,719	252,597	589,672
Total Rio Grande region	121,402	353,878	13,897	67,719	260,878	817,714
Rest of State	18,643	154,768				173,411
Out of State		43,008	1,544			44,552
Total Demand	140,045	551,654	15,441	67,719	260,878	1,035,737
		BOATING				
Upper	64,012				15,673	79,685
Middle		78,616				78,616
Socorro						
Lower		74,923	5,639	28,145	213,381	322,088
Total Rio Grande region	64,012	153,539	5,639	28,145	229,054	480,389
Rest of State		74,923				74,923
Out of State		16,364	1,023			17,387
Total Demand	64,012	244,826	6,662	28,145	229,054	572,699
		FISHING				
Upper	380,437	250,258			162,706	793,401
Middle		365,600				365,600
Socorro			30,760		9,371	40,131
Lower				264,910	408,909	673,819
Total Rio Grande region	380,437	615,858	30,760	264,910	580,986	1,872,951
Rest of State		549,268	3,230	26,005		578,503
Out of State		7,792				7,792
Total Demand	380,437	1,117,918	33,990	290,915	580,986	2,459,246

in the model were based on the New Mexico Bureau of Business Research county projections (BEA Projections) (Table 28). An increase in population affects the final demand for consumer projects, the labor force, as well as the direct demand for water for municipal and rural use. The model assumes government employment to be a function of population; therefore, it was determined but not reported in the following analyses.

An increase in the final demand will affect all 24 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 a linear population growth at an average rate of 1.19 percent annually or 59.5 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 surface-water for agricultural use would become available 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 but not to substitute for surface sources.

The assumption that surface water can be imported to satisfy all future demands is not a realistic assumption. There are only limited opportunities for water importation to the Rio Grande Basin, i.e., the San Juan-Chama diversion. It is more likely that no additional surface-water will be available in the foreseeable future. The second alternative reflects this assumption and places a constraint on surface-water availability: i.e., the 1970 surface water supplies plus the San Juan-Chama diversion water. Any increase in water demands is required to be satisfied within the region. In the model, surface and ground water are used in fixed proportions in the agricultural sectors, thus ground water cannot be substituted for surface water. The effect of limiting surface-water availability to 1970 levels (basic optimal solution) implies that growth in agricultural production can be expected only in areas where the availability of surface water exceeds depletions. No effect should be expected in the nonagricultural sectors because ground-water depletions have not been restricted. Under the legal

Table 28. Population projections by Region, Rio Grande region, New Mexico, 1970-2020

Year	Region								Total Rio Grande Region
	Upper		Middle		Socorro		Lower		
	Total Population	% of Total	Total Population	% of Total	Total Population	% of Total	Total Population	% of Total	
1970	111,610	19.5	373,355	65.3	9,763	1.7	76,962	13.5	571,690
1980	123,372	19.3	4.9,897	65.6	10,870	1.7	85,630	13.4	639,769
1990	135,133	19.1	466,440	65.9	11,978	1.7	94,297	13.3	707,848
2000	146,895	18.9	512,982	66.1	13,085	1.7	102,965	13.3	775,927
2010	158,656	18.8	559,525	66.3	14,193	1.7	111,632	13.2	844,006
2020	170,418	18.7	606,067	66.4	15,300	1.7	120,300	13.2	912,085
Average Annual Percent Growth	1.054		1.247		1.134		1.126		1.191

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

constraints imposed by the water laws of New Mexico, the mining of ground water may be restricted by authority of the State Engineer to declare a ground-water basin and close it to future development. Most of the Rio Grande region in New Mexico lies within declared basins. To maintain the base flow of the Rio Grande, increased pumping effects on the river must be offset by retiring surface-water rights. This alternative approximates the current administration of water resources in the Rio Grande region.

The third alternative is much more restrictive than the second alternative of imposing a constraint only on the surface water. This alternative reflects constraints placed on both surface and ground-water resources. Total surface-water availability for use in the Rio Grande region was restricted to the average surface flow in the Rio Grande, including the supplementary flow from the San Juan-Chama project. Ground-water pumpage was initially restricted in this set to the total pumpage in 1970. It was assumed that any future growth will require the transfer of surface-water rights from agriculture to other production sectors, rural, domestic, and municipal uses. A transfer mechanism was added to the model to allow the transfer of surface rights to ground-water rights. Additional pumpage was permitted only to the extent that surface-water depletions were reduced.

Additional diversions refer to the effect of pumpage upon the flows of the river. Within the alluvial deposits of the Rio Grande the surface water and ground water are connected, and pumpage either diverts water from the river or intercepts water destined for the river.

In order to maintain interregional deliveries over time, the total surface-water availability in each Region was reduced annually to compensate for the additional effects of pumping upon the flow of the river.

Alternative 1: No water constraint. The long-run effects of population growth under the above assumptions are presented in Table 29 for the RGR and for the MRGR. Table 29 presents the production levels, value added, employment, and water depletions required to satisfy the increases in local demand and expected increases in nonagricultural out-of-state sales. Total value of output in the Rio Grande region is expected to increase at approximately the same rate as the population. This amounts to an increase of more than

Table 29. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Middle Rio Grande Region, 2020--no water constraint

Sector		Total Rio Grande Region				Middle Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	55.812	19.144	3,302	102,831	23.509	8.064	2,005	28,016
	2	14.502	9.325	2,004	332,144	6.634	4.266	269	161,154
	3	13.530	8.307	368	211,735	0.000	0.000	0	0
	4	25.812	20.366	3,629	77,802	1.370	1.081	150	12,749
	5	7.588	4.636	693	91	5.103	3.118	397	61
Mining, Oil & Gas	6	129.705	83.011	2,731	4,699	62.529	40.019	973	1,795
	7	41.219	29.884	296	2,499	10.663	7.731	49	640
Manufacturing	8	33.501	5.930	442	101	33.065	5.853	438	100
	9	41.866	10.969	814	179	36.168	9.476	697	154
	10	22.792	6.678	854	32	22.516	6.597	779	31
	11	20.971	7.864	864	303	15.493	5.810	632	221
	12	89.420	42.564	3,721	1,360	67.146	31.961	3,010	1,048
	13	12.868	2.844	177	482	12.868	2.844	177	482
	14	113.719	47.876	6,485	254	103.591	43.612	5,654	236
	15	80.783	42.734	3,424	219	55.393	29.303	2,318	129
Trade & Services	16	175.304	116.402	8,068	437	101.384	67.319	6,766	252
	17	21.588	14.896	245	54	14.576	10.057	227	36
	18	168.080	109.252	7,250	7,164	119.426	77.627	5,444	4,613
	19	522.722	344.473	35,423	2,567	422.250	278.263	27,552	2,073
	20	157.470	112.119	18,097	925	111.953	79.711	12,783	609
	21	284.080	210.503	11,577	2,791	224.596	166.426	9,003	2,206
	22	242.044	141.112	20,955	3,099	159.310	92.878	12,053	2,004
	23	838.294	463.576	28,442	10,311	561.213	310.351	19,159	6,903
	24	276.625	115.076	15,316	4,874	200.668	83.478	10,718	3,536
	Total	3,390.292	1,969.539	175,178	766,950	2,371.422	1,365.841	121,251	229,048

$1,267.6 million (59.7 percent) in the total value of output for the period 1970-2020.

Agricultural production is expected to increase only 38.3 percent ($32.5 million) in the Rio Grande region compared to an increase of 59.7 percent in total value of output. This smaller increase results from the assumption that additional surface water will not be made available for agricultural exports and will be used only for local increases in demand for agricultural products. The major increases in agricultural products are expected in the Middle Rio Grande Region which also expects the largest population increase. This results from the interregional Input-Output matrix structure which does not allow for changes in the interregional transfer coefficients. The expected increase varies from 58 percent for *cotton* (sector 3) to 32 percent for *vegetables and fruits* (sector 4), with *agricultural services* up 53 percent (sector 5), 47 percent for *food grains and feed crops* (sector 2), and *meat animals, dairy, and poultry* up only 33 percent (sector 1).

The total nonagricultural production is expected to increase by $1,235 million. The expected increase in agricultural production represents only 2.6 percent of the total increase in the value of production while it represents 85.2 percent of the additional water depletions required. The value of production for the *Mining* sectors is expected to increase about 58 percent from 1970 to 2020, *Manufacturing* about 61 percent, and *Trades and Services* are expected to increase about 60 percent (Table 30).

Water depletions in the year 2020 for the Rio Grande region are expected to reach almost 830,000 acre-feet. This increase of 266,743 acre-feet over the depletions in 1970 will be required to meet the projected population needs in 2020. However, by 2020 an additional 83,000 acre-feet of surface water will be required to maintain the base flow of the river out of the region to Texas. Of the 266,743 acre-feet, the agricultural sectors will require 227,336 acre-feet, the remaining production sectors 15,769 acre-feet, and domestic needs 23,516 acre-feet. The increase in agricultural depletions will be met by utilizing 191,720 acre-feet of surface water and 35,616 acre-feet of ground water. All increases in surface water will be used by agriculture.

Table 30. Production, value added, employment and water use for major sectors in the Rio Grande region, and in the Middle Rio Grande Region, New Mexico, 1970-2020--no water constraint

		Total Rio Grande Region						Middle Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,195	497,268		23.203		10.530	1,800	125,796	
	Mining	108.062		71.393	1,920	4,571		45.092		29.417	629	1,500	
	Manufacturing	258.834		104.327	10,451	1,826		214.027		83.748	8,473	1,486	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		1,181.152		719.190	63,949	13,708	
	Municipal & Rural	--		--	--	39,144		--		--	--	27,780	
	Total	2,122.660*		1,232.753*	110,030*	562,866*		1,463.473		842.885	74,851*	170,269	
2020	Agriculture	117.244	38.3	61.778	9,997	724,603	45.7	36.616	57.8	16.528	2,821	201,980	60.6
	Mining	170.924	58.2	112.895	3,027	7,199	57.5	73.192	62.3	47.749	1,021	2,435	62.3
	Manufacturing	415.920	60.7	167.459	16,781	2,928	60.3	346.240	61.8	135.456	13,706	2,401	61.6
	Trade & Services	2,686.207	60.8	1,627.409	145,374	32,221	60.6	1,915.375	62.2	1,166.108	103,703	22,233	62.2
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	45,095	52.7
	Total	3,390.292*	59.7	1,969.539*	175,178*	829,610*	47.4	2,371.422	62.0	1,365.841	121,251	274,143	61.0

*Does not add because of rounding.

In 1970, the Middle Rio Grande Region accounted for slightly under 70 percent of the total Rio Grande region's value of production and is estimated to remain fairly constant at slightly under 70 percent in 2020. *Trade and Services* accounted for about 81 percent of the value of production in 1970, *Agriculture* 2 percent, *Manufacturing* 14 percent, and *Mining* approximately 3 percent of the value of production in the Middle Rio Grande Region (Table 30). In the year 2020, *Trade and Services* are expected to remain constant at 81 percent, *Agriculture* constant at about 2 percent, *Manufacturing* constant at about 15 percent, and *Mining* to remain constant at about 3 percent of the value of production.

The economy of the MRGR is expected to grow at a higher rate than that for the total Rio Grande region. The expected increase in total value of production from 1970 to 2020 is 62.0 percent compared to 59.7 percent for the total RGR. *Agriculture* is expected to increase at a higher percentage rate of growth, 57.8 percent for the MRGR and 38.3 percent for the RGR, and the remaining sectors at a rate of about 62 percent for the MRGR.

Employment in the MRGR is expected to increase 62 percent from 1970 to 2020, with agricultural employment increasing 57 percent and the other sectors increasing about 62 percent.

Water depletions in the Middle Rio Grande Region in 1970 accounted for about 30 percent of the total Rio Grande region's water depletions but are expected to increase slightly to about 33 percent in 2020. *Agriculture* is the largest water user, accounting for 74 percent of total depletion in the Middle Rio Grande Region in 1970 and in 2020 (Table 30).

Alternative 2: Surface-water constraint. Table 31 presents production levels, value added, employment, and expected water depletions by sector under the surface-water constraints for the Rio Grande region and for the MRGR, and is summarized by major sector in Table 32. The Rio Grande regional value of production with a constraint would be $3,390.3 million, and $3,372.2 million without a surface-water constraint; thus the cost of imposing a surface-water constraint is $18.1 million (0.53 percent reduction). Direct *Agriculture* production would decrease $6.9 million, *Manufacturing* production would decrease $0.3 million, and *Trade and Services* are expected

Table 31. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Middle Rio Grande Region, 2020--surface-water constraint

Sector		Total Rio Grande Region				Middle Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	55.813	19.144	3,303	102,835	23.509	8.064	2,005	28,016
	2	8.127	5.226	1,261	196,466	4.509	2.899	183	109,533
	3	13.357	8.201	364	209,026	0.000	0.000	0	0
	4	25.812	20.366	3,629	77,802	1.370	1.081	150	12,749
	5	7.196	4.397	657	86	4.818	2.944	375	58
Mining, Oil & Gas	6	129.704	83.011	2,731	4,699	62.528	40.018	973	1,795
	7	41.218	29.883	296	2,499	10.662	7.730	49	640
Manufacturing	8	33.500	5.929	442	101	33.064	5.852	438	100
	9	41.866	10.969	814	179	36.168	9.476	697	154
	10	22.788	6.677	854	32	22.512	6.596	779	31
	11	20.971	7.864	864	303	15.493	5.810	632	221
	12	89.368	42.539	3,719	1,359	67.110	31.944	3,009	1,048
	13	12.849	2,840	177	481	12.849	2.840	177	481
	14	113.515	47.790	6,474	253	103.388	43.526	5,642	236
	15	80.772	42.728	3,423	219	55.386	29.299	2,317	129
Trade & Services	16	175.294	116.395	8,067	437	101.382	67.318	6,766	252
	17	21.582	14.892	245	54	14.571	10.054	277	36
	18	168.010	109.206	7,247	7,161	119.383	77.599	5,442	4,612
	19	522.539	344.353	35,411	2,566	442.119	278.176	27,543	2,073
	20	157.350	112.033	18,083	925	111.891	79.666	12,776	607
	21	283.816	210.308	11,566	2,788	224.420	166.295	8,996	2,204
	22	241.851	140.999	20,936	3,096	159.217	92.824	12,046	2,003
	23	828.282	458.040	27,955	10,188	561.203	310.345	19,159	6,903
	24	276.618	115.073	15,316	4,874	200.662	83.475	10,717	3,536
	Total	3,372.196	1,958.862	173,833	628,426	2,368.212	1,363.831	121,097	177,417

Table 32. Production, value added, employment, and water use for major sectors in the Rio Grande region, and in the Middle Rio Grande Region, New Mexico, 1970-2020--surface-water constraint

		Total Rio Grande Region						Middle Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,196	497,268		23.203		10.530	1,800	125,796	
	Mining	108.062		71.393	1,920	4,571		45.092		29.417	629	1,500	
	Manufacturing	258.834		104.327	10,451	1,826		214.027		83.748	8,473	1,486	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		1,181.152		719.190	63,949	13,708	
	Municipal & Rural	--		--	--	39,144		--		--	--	27,780	
	Total	2,122.660*		1,232.753*	110,030	562,866*		1,463.473		842.885	74,851*	170,269	
2020	Agriculture	110.305	30.1	57.334	9,213	586,215	17.9	34.206	47.4	14.988	2,713	150,356	19.5
	Mining	170.922	58.2	112.894	3,027	7,199	57.5	73.190	62.3	47.748	1,021	2,435	62.3
	Manufacturing	415.629	60.6	167.336	16,767	2,926	60.2	345.970	61.6	135.344	13,692	2,399	61.4
	Trade & Services	2,675.342	60.1	1,621.299	144,827	32,088	60.0	1,914.847	62.1	1,165.752	103,670	22,227	62.1
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	45,095	62.3
	Total	3,372.196*	58.9	1,958.862*	173,833*	691,086	22.8	2,368.212	61.8	1,363.831	121,097	222,512	30.7

*Does not add because of rounding.

to decrease $10.9 million. The *meat animal, dairy, and poultry* sector (sector 1) would not be affected by surface-water constraint, but the value of production for *food grains and feed crops* (sector 2) would be decreased $6.4 million, *cotton* (sector 3) reduced $0.2 million, *fruits and vegetables* (sector 4) would be unchanged, and *agricultural services* (sector 5) down about $0.4 million. In the *Services* sectors, *medical and professional*, and *research and development* (sector 23) is expected to decrease about $10 million.

The level of employment in the Rio Grande region is expected to decrease by 1,344 employees in 2020 when a surface-water constraint is imposed. *Agriculture* production sectors (sectors 2, 3, and 5) are expected to account for 784 of these employees, with *food grains and feed crops* accounting for 88 percent of the decrease. *Services* production sectors are expected to account for 546 employees with sector 23 accounting for all employees.

Surface-water depletions in the Socorro and Lower Regions in the base year 1970 approached the average annual availability for these Regions. The Upper and Middle Regions are expected to benefit from the additional surface water to be supplied by the San Juan-Chama diversion project. Thus the long-run average annual availability in these two Regions exceeds their 1970 depletions. Total surface-water availability is reduced over time because of the increased effect of ground-water pumping over time and the increases in pumpage necessary to satisfy growth requirements, and it is expected that 83,000 acre-feet of surface rights will be retired by 2020. Because of the additional San Juan-Chama diversion water, surface-water depletions are expected to increase until about the year 2000 and then decrease. However, the Socorro and Lower Regions are expected to have reductions in surface-water depletions well before the Upper and Middle Regions because they do not benefit from the San Juan-Chama project. The surface-water usage decreases in the 50-year period due to the effect on the river of continued pumpage at an increasing rate, even though the total average flow in the Rio Grande is increased by 111,000 acre-feet (from the San Juan-Chama).

The decrease in ground-water depletions for agricultural use in the same years results from the fixed ground-surface water relationship assumed for agricultural production. This assumption was necessary in order to avoid further surface-flow depletions which would take place if ground water were substituted for surface water in agricultural production.

Total water depletions are expected to increase only 22.8 percent and reach 691,086 acre-feet in 2020. This is 138,524 acre-feet less than the amount required where no water constraint was imposed. *Agriculture* accounts for 136,388 acre-feet of this reduction. The remaining 136 acre-feet reduction includes 2 acre-feet in *Manufacturing* and 134 acre-feet in *Trades and Services*.

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.

The value of production in the Middle Rio Grande Region in 2020 would be $2,371.4 million without a water constraint and $2,368.2 million when a surface-water constraint is imposed (Table 31). Direct agricultural production would decrease $2.4 million, and the indirect effects of agricultural production would account for about $0.8 million decrease in services associated with agriculture. *Food grains and feed crops* (sector 2) account for 77 percent of the decrease in agricultural production.

Employment in the MRGR would decrease from 121,251 with no water constraint to 121,097 with a surface-water constraint. Again, *Agriculture* would account for nearly all (70 percent) of the reduction in employment. The reduction in *food grains and feed crops* is expected to account for 56 percent of the total reduction in employment.

Surface-water depletions in the Middle Rio Grande Region in the base year 1970 did not approach the average annual availability because of the San Juan-Chama diversion project that is expected to supply additional surface water tothe MRGR. The average annual depletions in 2020 with a surface-water constraint would be 51,633 acre-feet less than under the condition of no water constraint. Reduced agricultural depletions account for nearly all (51,624 acre-feet) of the reduced depletions.

Alternative 3: Surface and ground-water constraint. Production, value added, employment, and water depletions in this alternative for the Rio Grande region and the MRGR are presented in Table 33 and summarized by major sector in Table 34. The cost of imposing the additional constraint on ground water is $4.1 million in 2020 compared with a surface-water only

Table 33. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Middle Rio Grande Region, 2020--total water constraint

Sector		Total Rio Grande Region				Middle Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	55.813	19.144	3,303	102,835	23.509	8.064	2,005	28,016
	2	5.990	3.852	989	144,070	2.929	1.883	119	71,151
	3	12.989	7.975	354	203,262	0.000	0.000	0	0
	4	25.812	20.366	3,629	77,802	1.370	1.081	150	12,749
	5	6.812	4.162	625	82	4.487	2.742	349	54
Mining, Oil & Gas	6	129.704	83.011	2,731	4,699	62.528	40.018	973	1,795
	7	41.217	29.882	296	2,499	10.661	7.729	49	40
Manufacturing	8	33.500	5.929	442	101	33.064	5.852	438	100
	9	41.866	10.969	814	179	36.167	9.476	697	154
	10	22.786	6.676	854	32	22.510	6.595	779	31
	11	20.971	7.864	864	303	15.493	5.810	632	221
	12	89.353	42.532	3,718	1,359	67.097	31.938	3,008	1,047
	13	12.836	2.837	176	480	12.836	2.837	176	480
	14	113.713	47.873	6,484	254	103.586	43.610	5,653	236
	15	80.769	42.727	3,423	219	55.383	29.298	2,317	129
Trade & Services	16	175.279	116.385	8,067	437	101.380	67.316	6,766	252
	17	21.578	14.889	245	54	14.567	10.051	227	36
	18	167.978	109.186	7,246	7,159	119.357	77.582	5,441	4,611
	19	522.462	344.302	35,406	2,565	422.051	278.132	27,539	2,072
	20	157.299	111.997	18,077	924	111.849	79.636	12,771	608
	21	283.706	210.226	11,562	2,787	224.330	166.229	8,992	2,203
	22	240.775	140.372	20,826	3,082	159.157	92.789	12,041	2,002
	23	828.277	458.036	27,955	10,188	561.198	310.342	19,159	6,903
	24	276.613	115.071	15,316	4,874	200.658	83.474	10,717	3,536
	Total	3,368.097	1,956.264	173,402	570,242	2,366.166	1,362.482	120,998	139,027

Table 34. Production, value added, employment and water use for major sectors in the Rio Grande region, and in the Middle Rio Grande Region, New Mexico, 1970-2020--total water constraint

		Total Rio Grande Region						Middle Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,196	497,268		23.203		10.530	1,800	125,796	
	Mining	108.062		71.393	1,920	4,571		45.092		29.417	629	1,500	
	Manufacturing	258.834		104.327	10,451	1,826		214.027		83.748	8,473	1,486	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		1,181.152		719.190	63,949	13,708	
	Municipal & Rural	--		--	--	39,144		--		--	--	27,780	
	Total	2,122.660*		1,232.753*	110,030	562,866*		1,463.473		842.885	74,851*	170,269	
2020	Agriculture	107.416	26.7	55.499	8,900	528,050	6.2	32.295	39.2	13.769	2,623	111,971	-11.0
	Mining	170.921	58.2	112.894	3,027	7,199	57.2	73.189	62.3	47.748	1,021	2,435	62.3
	Manufacturing	415.794	60.6	167.407	16,776	2,926	60.2	346.136	61.7	135.416	13,702	2,399	61.4
	Trade & Services	2,673.967	60.0	1,620.464	144,699	32,070	59.9	1,914.547	62.1	1,165.550	103,652	22,224	62.2
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	45,095	62.3
	Total	3,368.097*	58.7	1,956.264	173,402	632,904*	12.4	2,366.166	61.7	1,362.483	120,024	184,122	8.1

*Does not add because of rounding.

constraint, and $22.2 million compared with the alternative without any constraint on water. Direct *Agriculture* production would decrease $2.9 million as a result of imposing the additional ground-water constraint, but *Mining* (sector 6) is expected to remain constant, and the indirect effects of reduced *Agriculture* production would account for the other $1.2 million in *Manufacturing, Trade,* and *Services* associated with agriculture. The affected *Agriculture* sectors are expected to be *food grains and feed crops*, $2.14 million; *cotton*, $0.37 million; and *agricultural services*, $0.38 million. However, annual agricultural production in 2020 is expected to be $22.6 million more than in 1970, and nonagricultural production is expected to be $1,225.8 million above the 1970 level.

The level of employment is expected to decrease by 481 employees when the additional constraint is placed on ground water. *Agriculture* production sectors (sectors 2, 3, and 5) are expected to account for 314 of these employees, with *food grains and feed crops* production accounting for 71 percent of the total decrease.

The increased demand for water by the nonagricultural sectors required a transfer of 47,166 acre-feet from surface rights to ground-water pumpage. The average annual depletion with a total water constraint is expected to be 58,182 acre-feet less than under the condition of a surface-water constraint only, and 196,706 acre-feet less than the alternative of no water constraint. *Agriculture* depletions are expected to decrease 58,165 acre-feet, and *Trade and Services* water depletions are expected to decrease 18 acre-feet when the additional ground-water constraint is added.

The cost of imposing the additional constraint on ground water in the Middle Rio Grande Region would be $2.0 million in 2020 compared with a surface-water constraint only, and $5.3 million compared with the alternative of no constraint on water. *Agriculture* production would account for $1.9 million of the $2.0 million of reduced production in 2020. *Food grains and feed crops* account for about 80 percent of the total reduction in production.

Employment in the MRGR would decrease an additional 99 employees when the additional ground-water constraint is added. *Agriculture* employment would account for 90 of the employees, with 71 percent in the *food grains and feed crops* sector.

Total depletions in 2020 in the MRGR are expected to decrease 38,390 acre-feet below that of a surface-water constraint only, and 90,021 acre-feet when compared with the alternative of no constraint on water. *Agriculture* depletions would account for 38,385 of the 38,390 acre-feet reduction in 2020.

Summary. In the previous discussion, three sets of water management alternatives were presented for the Rio Grande region. The first was an analysis of the region's growth without a water constraint. The second was an analysis of growth with a surface-water constraint. The third was an analysis of growth with both surface- and ground-water constraints. A summary of the solutions for these alternatives is presented in Table 35 for the total Rio Grande region and for the Middle Rio Grande Region.

Without a water constraint, value of production, employment, and water depletions in the Rio Grande region are expected to exhibit the largest increase (59.7 percent, 59.2 percent, and 47.4 percent, respectively.) The expected increase in value of production varies from 38.3 percent for *Agriculture* to 60.8 percent for *Trades and Services.* Water depletions are expected to increase 45.7 percent for *Agriculture*, 57.5 percent for *Mining*, 60.3 percent for *Manufacturing*, 60.6 percent for *Trades and Services*, and 60.1 percent for *Municipal and Rural* domestic purposes.

When a surface-water constraint is imposed, the expected value of production would be reduced by $18.1 million in 2020, employment by 1,344 employees, and water depletions by 138,523 acre-feet (16.7 percent) below the alternative of no water constraint (Table 35). Reduced *Agriculture* production would account for about 38 percent ($6.9 million) of the reduced value of production, and *Trades and Services* about 60 percent ($10.9 million). The level of employment in the RGR is expected to decrease by 1,344 employees in 2020. *Agriculture* production sectors are expected to account for about 58 percent and *Trades and Service* sectors about 41 percent. *Agriculture* water depletions are expected to represent about 85 percent of the total water depletion reduction when a surface-water constraint is imposed.

In 2020, when a total water constraint is imposed, value of production in the RGR is expected to be reduced to $3,368.1 million, decreased $4.1

Table 35. Summary of alternative solutions by major sectors in the Rio Grande region, and in the Middle Rio Grande Region, New Mexico, 1970-2020

			Total Rio Grande Region						Middle Rio Grande Region					
			Value of Production				Water Depletions		Value of Production				Water Depletions	
Alternative	Year	Major Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
			($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
BASIC OPTIMAL SOLUTION	1970	Agriculture	84.775		44.402	7,196	497,268		23.203		10.530	1,800	125,796	
		Mining	108.062		71.393	1,920	4,571		45.092		29.417	629	1,500	
		Manufacturing	258.834		104.327	10,451	1,826		214.027		83.748	8,473	1,486	
		Trade & Services	1,670.001		1,012.630	90,463	20,059		1,181.152		719.190	63,949	13,708	
		Municipal & Rural	--		--	--	39,144		--		--	--	27,780	
		Total	2,122.660*		1,232.753*	110,030	562,866*		1,463.473		842.885	74,851*	170,269*	
NO WATER CONSTRAINT	2020	Agriculture	117.244	38.3	61.778	9,997	724,603	45.7	36.616	57.8	16.528	2,821	201,980	60.6
		Mining	170.924	58.2	112.895	3,027	7,199	57.5	73.192	62.3	47.749	1,021	2,435	62.3
		Manufacturing	415.920	60.7	167.459	16,781	2,928	60.3	346.240	61.8	135.456	13,706	2,401	61.6
		Trade & Services	2,686.207	60.8	1,627.409	145,374	32,221	60.6	1,915.375	62.2	1,166.108	103,703	22,233	62.2
		Municipal & Rural	--		--	--	62,660	60.1	--	--	--	--	45,095	52.7
		Total	3,390.292*	59.7	1,969.539*	175,178*	829,610*	47.4	2,371.442	62.0	1,365.841	121,251	274,143	61.0
SURFACE WATER CONSTRAINT	2020	Agriculture	110.305	30.1	57.334	9,213	586,215	17.9	34.206	47.4	14.988	2,713	150,356	19.5
		Mining	170.922	58.2	112.894	3,027	7,199	57.5	73.190	62.3	47.748	1,021	2,435	62.3
		Manufacturing	415.629	60.7	167.336	16,767	2,926	60.2	345.970	61.6	135.344	13,692	2,399	61.4
		Trade & Services	2,675.342	60.1	1,621.299	144,827	32,088	60.0	1,914.847	62.1	1,165.752	103,670	22,227	62.1
		Municipal & Rural	--		--	--	62,660	60.1	--	--	--	--	45,095	62.3
		Total	3,372.196*	58.9	1,958.862*	173,833*	691,086	22.8	2,368.212	61.8	1,363.831	121,097	222,512	30.7
TOTAL WATER CONSTRAINT	2020	Agriculture	107.416	26.7	55.499	8,900	528,050	6.2	32.295	39.2	13.769	2,623	111,971	-11.0
		Mining	170.921	58.2	112.894	3,027	7,199	57.2	73.189	62.3	47.748	1,021	2,435	62.3
		Manufacturing	415.794	60.6	167.407	16,776	2,926	60.2	346.136	61.7	135.416	13,702	2,399	61.4
		Trade & Services	2,673.967	60.0	1,620.464	144,699	32,070	59.9	1,914.547	62.1	1,165.550	103,652	22,224	62.2
		Municipal & Rural	--		--	--	62,660	60.1	--	--	--	--	45,095	62.3
		Total	3,368.097*	58.7	1,956.264	173,402	632,904*	12.4	2,366.166	61.7	1,362.483	120,024	184,122	8.1

*Does not add because of rounding

million below the value obtained when only a surface-water constraint is imposed, and decreased by $22.2 million below the no-water-constraint alternative (Table 35). The level of employment is expected to decrease by 481 employees when a constraint is imposed on ground water. Again, *Agriculture* sectors account for 82 percent of the reduced employment.

Water depletions in the RGR are expected to decrease from 829,610 acre-feet without any water constraints to 632,904 acre-feet with a total water constraint, a 24 percent reduction. The Middle Rio Grande Region is expected to deplete for nonagricultural uses all of the surface-water rights by the year 2075. Without water imports, increased pumpage restrictions will have to be placed on *Manufacturing, Trades and Services,* and *Municipal* water usage at this time. Any allocation of surface-water rights to *Agriculture* will require these changes at an earlier date. Another alternative might be interregional transfer of water rights. The other Regions are expected to have enough surface-water rights to last for many years. The Albuquerque metropolitan area has about 90 percent of the expected population increase in the total Rio Grande region, and the pumpage necessary to sustain its growth increases its effect on the Rio Grande flow by more than 1,000 acre-feet annually.

The Middle Rio Grande Region is expected to follow the general trend of the total Rio Grande region but at a higher growth rate. The expected increase in total value of production from 1970 to 2020 is 62.0 percent. Employment is expected to increase 62 percent. Water depletions are expected to increase about 61 percent in 2020, with *Agriculture* accounting for 74 percent of total depletions in the MRGR at that time.

When a surface-water constraint is imposed, the value of production is expected to be reduced $3.2 million in 2020, employment by 154 employees, and water depletions by 51,633 acre-feet. *Agriculture* production sectors would account for nearly all of the reduction in production, employment, and water depletions.

When an additional constraint is imposed on ground water in the MRGR, value of production would be decreased $2.0 million in 2020, employment by an additional 99 employees, and water depletions by 38,390 acre-feet. *Agriculture* production sectors would account for over 95 percent of the expected reductions in production, employment, and water depletions.

The supply of water for water-based recreation is expected to be the highest under the alternative of no water constraint (Table 36), and reduced about 5 percent when a constraint is placed on the importation of surface water or mining of ground water. The major effect occurs on surface water where all of the water-based recreation occurs.

Table 36. Estimated water-based recreation by type in the Rio Grande region

	Water Skiing	Boating	Fishing
	. . . . .(activity-occasion days).		
No Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,247	504,584	1,904,992
2000	939,195	552,975	2,591,525
2020	1,132,085	596,668	2,643,000
Surface Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,347	504,625	2,015,576
2000	939,285	553,210	2,595,245
2020	1,160,546	596,894	2,643,000
Surface & Ground Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,273	504,624	1,904,542
2000	939,332	553,356	2,592,460
2020	1,134,160	596,919	2,643,000

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APPENDIX A

SOIL PRODUCTIVITY GROUPS IN THE MIDDLE RIO GRANDE REGION, NEW MEXICO

Group I.

Soils in productivity Group I have few limitations that restrict their use for irrigated crop production and are suited to a wide range of crops, especially those common to the Middle Rio Grande Region. The soils are deep and of desirable texture, which combined with a favorable structure makes them relatively easy to till; and under cultivation a good tilth can be obtained if properly handled. They are sufficiently drained and free from toxic concentrations of soluble salts. The soils in this Group are naturally productive and practically free of gravel and stones. The water holding capacity is good, and consequently the amount of water required to produce crops is not excessive. The surface of the land in this Group is level or very gently sloping, which makes it susceptible to easy irrigation. There is no accelerated erosion of any type on these lands, and they are not subject to overflow from arroyos which would tend to deposit detrimental material. The productive capacity is high since they either have a high fertility level or they respond well to fertilizer inputs. Permeability is generally moderate.

Some of these soils have certain slight limitations which require more careful management practices; however, in most cases these corrective management practices are easy to apply. The smallest portion of the irrigated acreage in the Region occurs as Group I. The largest portions of the Group I acreage occur in the Rio Grande Valley proper, generally as isolated tracts. A relatively small percentage occur in the western portion of the Region in the Bluewater-Grants area.

Group II.

Soils in Group II have certain moderate restrictions that reduce their productive capabilities, require special management practices, or both. The conservation and management practices required are usually more difficult to apply and maintain on these soils than on the Group I soils. These soils are fairly well adapted to irrigated agriculture, but were classified in this Group because their productive capabilities were somewhat limited for general farming. These conditions are due to moderate amounts of alkali, unfavorable soil characteristics, topography, erosion, or impeded drainage. Soils with light-textured subsoils and sandy textures were included in this Group. The amount of irrigation water required to produce crops is comparatively high as these soils have a low water holding capacity. They require frequent and light irrigations, and if water is not always available for these needed frequent irrigations, crop failures are apt to result.

In some areas of the Region, part of the soils in this Group have limited use because of high water-tables and low permeability. Each distinctive kind of soil in Group II has one or more special managerial requirements for successful use. This Group accounts for the largest portion of the irrigated acreage in the region.

Group III.

The soils in productivity Group III have limitations which restrict their use for agricultural production. The character and properties of the soil itself were given the greatest consideration. Alkali was also an important factor in the classification of lands in this Group. In general, however, alkali was usually associated with other limiting factors, such as unfavorable soil characteristics and impeded drainage. Where alkali is the only limiting factor, these lands can be improved to Group II by the leaching out of excess salts under favorable water-table and drainage conditions.

This Group also included lands mapped as nonagricultural, but which were being farmed. These soils include shallow, unproductive soils in areas subject to overflow from arroyos, and very heavy, compact,and moderately impervious clay soils which have a high content of salts and a rather high alkaline reaction.

This Group includes about 38 percent of the irrigated cropland in the Middle Rio Grande Region. They are located primarily along the river and near the sides of the Valley in the Rio Grande Valley area, but are widespread in the western part of the Region in the tributary areas, and account for a larger percentage of the irrigated cropland in the western area than in the eastern Valley area of the Middle Rio Grande Region.

The above-described soil productivity groups and those described in Tables A-1, A-2, and A-3, were defined for purposes of this study and are not necessarily consistent with Soil Conservation Service classifications.

APPENDIX A

Table A-1. Principal soils in productivity Group I, Middle Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
Sa	San Jose loam, 0-1 percent slopes	These soils are well-drained, reddish-brown, calcareous, alluvial soils that developed on flood plains and low terraces. The parent material is stratified, but predominantly medium-textured, calcareous alluvium. These soils have moderate to rapid permeability, low salinity hazard, and good workability.
Sb	San Jose loam, sandy substratum, 0-1 percent slopes	
+/A-(2)1	Anthony clay, 0-1%	These soils are level to gently sloping. They have no apparent erosion or drainage problems, and the subsoils are predominately of poorly stratified, light-textured materials. Strata of porous gravelly materials are also quite common in the subsoil. Typically, a slight lime accumulation zone is found at depths of 2 to 3 feet. Excellent drainage conditions exist over the major part of these soils.
+/AA-(2)1	Anthony clay, 1-3%	
+/A-(1)4	Gila clay loam, 0-1%	The surface of these soils is relatively level or very gently sloping. The surface soils are distinctly calcareous, and because of their age, little profile development has taken place. The subsoil consists of alternate layers of stratified materials which are also variable in texture. The distribution of this soil is very irregular, but in general it parallels either the present or former stream channels. These soils contain a fair amount of organic matter and are, in general, reasonably productive.
+/A-(2)2	Anthony sandy clay, 0-1%	These soils are similar to Anthony clay soils described above, with the exception of the sandy surface-texture.
+/A-(1)1	Gila clay, 0-1%	This soil is similar to the Gila clay loam described above, with the exception of the heavier surface-texture.
+/A-(1)5	Gila sandy clay loam, 0-1%	This soil is similar to the other soils of the Gila series. It is a medium-textured soil which is, in general, highly productive.

APPENDIX A

Table A-2. Principal soils in productivity Group II, Middle Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
Pd	Prewitt clay loam, 0-1 percent slopes	Soils of this group are well-drained, reddish-brown, calcareous, alluvial soils developing on flood plains and low terraces. The parent material is stratified, but predominantly moderately fine-textured, calcareous alluvium. The soils resemble those of the San Jose series but differ from them in having moderately fine-textured materials. They are coarser-textured than the Ladrillo soils. These soils generally have low permeability, moderate to slight salinity hazard, and fair workability.
Pe	Prewitt clay loam, sandy substratum. 0-1 percent slopes	
$\frac{2221}{A}$	(unnamed)	These soils are moderately heavy-textured, deep (over 36 inches), with low permeability. Slopes are less than 1 percent.
$\frac{3221}{A}$	(unnamed)	These soils are medium-textured, deep (over 36 inches), with low permeability. Slopes are less than 1 percent.
$^{+}$/A-(1)1-S	Gila clay, 0-1%, saline	These soils are similar to the Gila clay soils described in Group I, but exhibit saline conditions, slight erosion, or have a light-textured subsoil phase, or a heavy-textured subsoil phase.
^{o}/A-(1)1	Gila clay, 0-1%	
$^{+}$/A-L(1)1	Gila clay, 0-1%, light-textured subsoil phase	
$^{+}$/A-H(1)1	Gila clay, 0-1%, heavy-textured subsoil phase	

APPENDIX A

Table A-2, continued

Map Symbol	Soil Name	Soil Description
+/A-(1)3-S	Gila silty clay, 0-1%, saline	These soils are similar to other soils of the Gila series, but are typically saline.
+/A-(1)4-S	Gila clay loam, 0-1%, saline	These soils are similar to other Gila soils, but are saline or experience steeper slopes.
+/AA-(1)4	Gila clay loam, 1-3%	
+/A-(1)5-S	Gila sandy clay loam, 0-1%, saline	These soils are similar to other Gila soils, with the exception of being saline, having steeper slopes, experiencing slight erosion, and having gravelly subsoil phases.
+/AA-(1)5	Gila sandy clay loam, 1-3%	
⊕/AA-0(1)5	Gila sandy clay loam, 1-3%, gravelly subsoil phase	
+/A-(1)10-S	Gila fine sandy loam, 0-1%, saline	These soils are lighter textured, than those in Group I, experience saline conditions, steeper slopes, and slight erosion.
+/AA-(1)10	Gila fine sandy loam, 1-3%	
⊕/A-(1)10	Gila fine sandy loam, 0-1%	
+/A(1)11-S	Gila sandy loam, 0-1%, saline	These soils are similar to those of the Gila series, with the exception of being saline and having a light subsoil phase.
+/A-L(1)11	Gila sandy loam, 0-1%, light-textured subsoil phase	

Table A-2, continued

May Symbol	Soil Name	Soil Description
^{3}/AA-(2)1	Anthony clay, 1-3%	These soils are similar to the soils described in Group I, but experience moderate erosion hazards.
$^{+}$/AA-(2)2-S	Anthony sandy clay, 1-3%	These soils are similar to those described in Group I, but have steeper slopes and experience slight saline conditions.
^{0}/A-(2)4	Anthony clay loam, 0-1%	These soils are similar to those described in Group I, but have experienced from slight to moderate wind and water erosion.
^{2PK}/AA-(2)4	Anthony clay loam, 1-3%	
$^{\oplus}$/AA-(5)5	Algodones sandy clay loam, 1-3%	These soils range in color from a reddish-brown to red in both the surface soil and subsoil. They occupy sloping to nearly level alluvial fans and intermittent stream bottoms just above the first bottom lands. They are low in organic matter but highly calcareous. The lime is disseminated throughout with no apparent accumulations. Visible specks and streaks of gypsum are quite common in the subsoil. They are well-drained and free from harmful concentrations of alkali. In general, they have high fertility, but are susceptible to erosion hazards.
$^{\oplus}$/A-(5)11	Algodones sandy loam, 0-1%	These soils are similar to the soil described above, but experience slight erosion hazards.

APPENDIX A

Table A-3. Principal soils in productivity Group III, Middle Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
Pc	Prewitt clay, 0-1 percent slopes	These soils resemble those of the Prewitt soils of Group II, but differ from them in having fine-textured materials. They have lower permeability, moderate salinity hazard, and poor workability.
Pg	Puerco clay, 0-1 percent slopes	These soils were derived largely from argillaceous shales but also from some sandstones. Both soils have slopes of 0 to 1 percent. The Puerco soils occur on the flood plains of intermittent streams. They have unusually hard, dense subsoils, which often have pronounced vertical shrinkage cracks. The subsoils are normally uniform in texture, but in places they contain thin strata of darker-colored coarser materials. They have low to very low permeability, may have moderate to severe or slight to moderate salinity hazard depending upon the substratum, and generally poor workability.
Ph	Puerco clay, sandy substratum, 0-1 percent slopes	
Pb	Preston-San Mateo complex	In this unit the Preston and San Mateo soils are so intricately mixed it was not practical to map them separately. A description of each follows: The Preston series, represented by Preston fine sand, 0 to 5 percent slopes, are sandy soils without developed profiles. The soils are porous, calcareous, and grayish brown; they consist of transported material of mixed geological origin that has been deposited by wind. The San Mateo series consists of well-drained, calcareous, stratified alluvial soils occurring on the flood plains and low terraces along streams and rivers. They show little evidence of soil development, other than slightly darker surface horizons, weak structure, or very weak and discontinuous horizons of lime accumulation.

Table A-3, continued

Map Symbol	Soil Name	Soil Description
3331/B-1	(unnamed)	These soils are medium-textured, have moderate permeability, and are usually considered deep (over 36 inches). They are limited by slight to moderate slopes, with slight erosion.
3331/C-1	(unnamed)	
3321/C-1	(unnamed)	
3231/C-1	(unnamed)	These soils are medium-textured, have low to moderate permeability, and are deep (over 36 inches). They are limited by moderate to severe slopes.
4411/B-1	(unnamed)	These soils are fine-textured, have rapid permeability in the subsoil, but have very low permeability in the substratum. They are generally deep to moderately deep. Slopes are generally slight.
44M2/B-1	(unnamed)	
$^{+}$/A-(1)1-W	Gila clay, 0-1%	These soils are similar to those described in Groups I and II, but experience shallow-water tables, light-textured subsoil phases, heavy subsoil phases, and slight to moderate erosion hazards. In many cases these soils have experienced deposition of materials, primarily silt, from irrigation waters, and some have experienced detrimental deposits from tributary arroyos.
$^{+}$/A-L(1)1-W	Gila clay, 0-1%, light-textured subsoil phase	
$^{+}$/A-H(1)1-W	Gila clay, 0-1%, heavy-textured subsoil phase	
$^{+}$/A-L(1)2-W	Gila sandy clay, 0-1%	
$^{+}$/A-(1)3-W	Gila silty clay, 0-1%	
$^{+}$/A-(1)4-W	Gila clay loam, 0-1%	
$^{+}$/A$_1$-(1)4	Gila clay loam, 0-1%	
$^{+}$/A-L(1)4	Gila clay loam, 0-1%, light	
$^{+}$/A$_1$-L(1)4	Gila clay loam, 0-1%, light	
$^{+}$/A-(1)5-W	Gila sandy clay loam, 0-1%	
$^{+}$/AA-H(1)5	Gila sandy clay loam, 1-3%, heavy phase	
^{PF}/A$_1$-(1)5	Gila sandy clay loam, 0-1%	
$^{+}$/A-(1)7-W	Gila loam, 0-1%	
$^{+}$/A-(1)10	Gila fine sandy loam, 0-1%	
$^{+}$/A$_1$-(1)10	Gila fine sandy loam, 0-1%	

APPENDIX A

Table A-3, continued

Map Symbol	Soil Name	Soil Description
$^{+}/A_{1}$-L(1)10	Gila fine sandy loam, 0-1%, light phase	(See above)
$^{⊕PF}/AA_{1}$-(1)10	Gila fine sandy loam, 1-3%	
$^{+}$/A-(1)11-W	Gila sandy loam, 0-1%	
$^{⊕}$/AA-⊕(1)11	Gila sandy loam, 1-3%	
$^{+}/A_{1}$-L(1)11	Gila sandy loam, 0-1%, light phase	
$^{+RL}/A_{1}$(1)13	Gila fine sand, 0-1%	
$^{+\hat{N}}$/AA-(1)14	Gila sand, 1-3%	
$^{⊕}$/AA-0(1)14	Gila sand, 1-3%, gravelly phase	
$^{⊕}/AA_{1}$-⊕(1)14	Gila sand, 1-3%	
$^{⊕PF}/A_{1}$-0(1)14	Gila sand, 0-1%	
^{WU}/A-(1)UN	Gila undifferentiated, 0-1%	
^{o}/A-(2)1	Anthony clay, 0-1%	These soils are similar to those of the Anthony series described in Groups I and II, with the exception of having erosion problems, shallow water-tables, and steeper slopes.
^{37}/AA-(2)1	Anthony clay, 1-3%	
^{o}/A-(2)5	Anthony sandy clay loam, 0-1%	

Table A-3, continued

Map Symbol	Soil Name	Soil Description
2RL/AA-0(2)11	Sandoval sandy loam, 1-3%	These soils have the same general range in color, the same general conditions of relief and drainage, and a similar mode of formation as those of the Anthony series. They differ primarily in that they have been derived from finer-textured materials which have formed heavier-textured subsoils. The subsoils consist predominantly of clay and sandy clay, with an occasional strata of lighter-textured material. Since the subsoils are of comparatively heavy texture, the permeability is rather low and the water holding capacity good. These soils are generally well adapted to irrigated agriculture, and with careful management, including weed eradication, crop rotations, and the incorporation of organic matter, good to excellent crop yields are possible. They are, in general, well drained and alkali concentrations are negligible. The soils described in these mapping units are affected by high water-tables and slight to moderate erosion hazards.
2RM̂/AA-0(2)11	Sandoval sandy loam, 1-3%	
$^+$/A-(3)1-W	Pima clay, 0-1%	The soils of the Pima series differ primarily from those of the Gila series in the color of the surface soil and content of organic matter. The surface soil of the Pima series is a dark grayish-brown or nearly black, very often having a purplish and olive-green cast. This difference in color is due mainly to the development of this series under swampy and extremely poorly drained conditions, resulting in the accumulation of organic matter in the surface soil which
$^+$/A-H(3)1	Pima clay, 0-1%, heavy phase	

Table A-3, continued

Map Symbol	Soil Name	Soil Description
		extends to depths varying from 6 to 30 inches or more. This is underlain by the typical stratified Gila subsoil as described in other Gila series descriptions. This soil represents areas variously affected by alkali and drainage. Where it is well-drained and free from harmful concentrations of alkali, it has high fertility and the yields of crops are good. However, a large percentage of this series is so affected and has resulted in from fair to poor crop conditions. Still other areas in this series have such a high water-table, which is usually associated with toxic concentrations of alkali, that it has a low agricultural value.