UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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Part 5

CARBON BACKS

Rio Grande basin

By

George A. Dinwiddie

(A contribution for incorporation in a
State Planning Report to be prepared
by the New Mexico State Engineer Office.)

Prepared in cooperation with
the New Mexico State Engineer

December 1964

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Albuquerque, New Mexico

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Note: Corrections to copy have been made on orange-backs

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Rio Grande basin

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Description

The Rio Grande basin in New Mexico extends southward from Colorado to **Mexico** and is outlined on figures 1 and 2. Sub-basins

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Figure 2.--(caption on next page) belongs near here.

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within this major drainage area are Rio Grande, Costilla Creek, and Rio San Antonio. Counties and parts of counties included within the area are Bernalillo, Catron, Dona Ana, Los Alamos, McKinley, Mora, Rio Aribba, Sandoval, San Miguel, Santa Fe, Sierra, Socorro, Taos, Torrance, and Valencia. The principal cities and villages in the area are Albuquerque in Bernalillo County; Hatch, Las Cruces, and Mesilla in Dona Ana County; Los Alamos in Los Alamos County; Chama and Espanola in Rio Arriba County; Bernalillo in Sandoval County; Santa Fe in Santa Fe County; Truth or Consequences in Sierra County; Magdalena and Socorro in Socorro County; Questa, Ranchos de Taos, and Taos in Taos County; and Belen, Grants, Los Lunas, and Milan in Valencia County.

Figure 1.--Drainage basins of New Mexico.

Figure 2.--Map of Rio Grande basin in New Mexico.

Geography

The Rio Grande basin in New Mexico consists of three drainage areas. The Rio Grande drainage area, 5-1 on figure 1, is 25,225 sq. mi. (square miles); the Rio San Antonio drainage area, 5-2, is 230 sq. mi.; and the Costilla Creek drainage area, 5-3, is 260 sq. mi. The total area of the Rio Grande basin in New Mexico is 25,715 sq. mi. The principal streams in this area are Rio Grande, Rio Puerco, Rio San Jose, Jemez River, Santa Fe River, Rio Chama, Red River, Costilla Creek, and Rio San Antonio.

The Rio Grande basin includes parts of several physiographic provinces; these provinces are the Southern Rocky Mountains, the Navajo and Datil sections of the Colorado Plateaus, and the Mexican Highland section of the Basin and Range. The Southern Rocky Mountains province in New Mexico includes complex mountains, intermontane basins, and deep canyons. The Colorado Plateaus province in New Mexico includes plateaus, buttes, mesas, lava flows, and broad valleys. The Basin and Range province in New Mexico includes isolated ranges which are separated by plains and broad valleys. Topographically, the Rio Grande basin varies from precipitous mountains to broad, relatively featureless plains.

Most of the Rio Grande basin has been topographically mapped. Some phase of topographic mapping is progressing in all but a few small areas. Figure 3 indicates the areas that have been previously mapped,

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the areas in which mapping is progressing, and the areas in which no mapping has been done.

Figure 3.--Status of topographic mapping in New Mexico.

Geology

Rocks that crop out in the Rio Grande basin are of sedimentary, igneous, and metamorphic origin and range in age from Precambrian to Quaternary. All three rock types are represented throughout the area; however, rocks of all ages do not crop out in all parts of the Rio Grande basin. In Sunshine Valley, western Taos County, the Sangre de Cristo Formation of Permian and Pennsylvanian age is the only formation that is between Precambrian age and Tertiary age; other rocks in that time interval are missing (Winograd, 1959). ~~(State Engineer Technical Report No. 12)~~. The only area in which rocks of the lower Paleozoic Era (Cambrian, Ordovician, Silurian, and Devonian ages) are known to be present in the Rio Grande basin is in the mountains in the southern part of the basin (Kelley, 1952); refer to the generalized stratigraphic section of the Rio Grande basin (table 1). The largest exposure of rocks of Cretaceous, Jurassic, and Triassic ages in the Rio Grande basin is in the San Juan (structural) Basin in Rio Arriba, Sandoval, McKinley, and Valencia counties (Dinwiddie, 1964, and Renick, 1931). These rocks are of primarily sedimentary types, both marine and continental. Igneous rocks of Tertiary and Quaternary ages, consisting mainly of lava flows, dikes, and sills, occur at many places in the basin. Lava flows cap mesas and fill valleys near centers of volcanic activity, and sills are in the subsurface interbedded with sedimentary rocks. Volcanic rocks consisting of rhyolite, andesite, latite, tuff, and pumice occur in the Jemez Mountains near Los Alamos (Griggs, 1964). Igneous and metamorphic rocks of Precambrian age crop out or underlie all of the Rio Grande basin.

note

Table 1.-- Generalized stratigraphic section in the Rio Grande basin, New Mexico

(* Known or probable aquifer, regardless of areal extent or production potential.)

System	Stratigraphic Unit	(feet) Thickness	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	Generally thin; less than 100 ~~feet.~~	Perennial stream channels, flood plains, and locally in dry arroyos.	Unconsolidated silt, sand, and gravel.	Recharged from streamflow; generally yields small to moderate quantities of water to wells; may yield large quantities locally.
	*Pediment, terrace, and bajada deposits	May be as much as 200 ~~feet~~.	Along streams and adjacent to mountains. Terraces are prominent along the Santa Fe River.	Generally unconsolidated silt, sand, gravel, and boulders. Gravel and boulder deposits may be lenticular.	Recharged by surface flow and by direct precipitation. Water generally is less abundant than in stream alluvium; may yield small to large quantities of water to wells.
Quaternary and Tertiary	*Volcanic complex	0 to 2,600+	Caps many mesas and occurs as channel deposits, dikes, sills, and interbedded with sedimentary rocks in most of the Rio Grande basin.	Basalt, andesite, rhyolite, latite, pumice, and tuff.	May yield small to large quantities of water to wells; yield depends primarily on fracture permeability and saturated thickness. Generally is not a principal or reliable aquifer.
	*Santa Fe Group	0 to 9,000± ~~feet.~~	Fills the Rio Grande trough.	Clay, silt, sand, and gravel conglomerate; mostly unconsolidated. Contains volcanic material locally.	Yields large quantities of water (as much as 2,500 gpm, locally) to deep wells. This is the most extensive and reliable aquifer in the Rio Grande basin.
Tertiary	Galisteo Formation	900 to 4,500 ~~feet.~~	Exposed in valleys near Cienega in Santa Fe County; probably underlies Albuquerque area at great depth.	Sandstone, sand, clay, and shale; also may contain some conglomerate.	Low permeability where tested south of Santa Fe. Formation lies at great depth elsewhere in the basin and is uneconomical to tap.
	*Other sedimentary rocks of Tertiary age	0 to 6,000+ ~~feet.~~	Sedimentary rocks that are present throughout the Rio Grande basin; however, abundant nomenclature prohibits extensive treatment here.	Sandstone, siltstone, shale, and some conglomerate.	Generally yield small quantities of water to wells; locally, beds of sandstone might yield moderate quantities; and cumulative yield from many beds of sandstone could be large.

Table 1.--Generalized stratigraphic section in the Rio Grande basin, New Mexico - Continued

System	Stratigraphic Unit	(feet) Thickness	Distribution	Physical properties	Water-bearing characteristics
Cretaceous	* Ojo Alamo Sandstone	70 to 200 ~~feet.~~	San Juan (structural) Basin.	Coarse-grained, conglomeratic sandstone.	Known to yield from 2 to 30 gpm.
	Fruitland Formation and Kirtland Shale	100± to 600± ~~feet.~~	do.	Shale, sandy shale, siltstone and interbedded sandstone.	Beds of sandstone of low permeability might yield small quantity of water. Generally not considered as an aquifer.
	* Pictured Cliffs Sandstone	35 to 75 ~~feet.~~	do.	Thin- to thick-bedded sandstone with interbedded siltstone and shale.	Low porosity and low permeability. Generally not considered as an aquifer; however, may yield small quantities of water locally.
	Lewis Shale	600 to 1,400 ~~feet.~~	do.	Fissile clay shale with interbedded siltstone, sandstone, and limestone.	Generally does not yield water; thin beds of sandstone in lower part might yield small amount of water, but it probably is saline.
	* Mesaverde Group	250 to 2,500± ~~feet.~~	Primarily in the San Juan (structural) Basin; underlies most of the Rio Grande basin at great depth.	Shale with interbedded sandstone and coal.	Sandstone may yield small to moderate quantities of water; not tapped in many areas because of great depth.
	* Mancos Shale	350 to 2,500 ~~feet.~~	Crops out at edge of San Juan (structural) Basin and underlies most of the Rio Grande basin at great depth.	Dark-gray, marine shale; sandstone interbedded near the base locally.	Beds of sandstone might yield small quantities of water.
	* Dakota Sandstone	25 to 245 ~~feet.~~	San Juan (structural) Basin and most of Rio Grande basin.	Sandstone with interbedded carbonaceous shale.	Yields small to moderate quantities of water to wells; not tapped at many places because of great depth. Water quality probably best near outcrops.

Table 1. -- Generalized stratigraphic section in the Rio Grande basin, New Mexico - Continued

System	Stratigraphic Unit	(feet) Thickness	Distribution	Physical properties	Water-bearing characteristics
Jurassic	* Morrison Formation	210 to 910 ~~feet.~~	San Juan (structural) Basin; may underlie other parts of the Rio Grande basin, but probably at great depth.	Variegated shale, claystone, and siltstone with interbedded sandstone.	Yields small to moderate quantities of water to wells; depends on saturated thickness of sandstone.
	* Bluff Sandstone	75 to 150 ~~feet.~~	San Juan (structural) Basin; this formation or its equivalent may underlie other parts of the Rio Grande basin.	Sandstone.	May yield small quantities of water to wells where saturated. Generally has low permeability.
	Summerville Formation	60 to 120 ~~feet.~~	do.	Sandstone, siltstone, and sandy shale.	Not known to yield water to wells.
	Todilto Limestone	0 to 100 ~~feet.~~	do.	Gypsum and fissile limestone.	Yields very little water to wells. Water generally has high sulfate content.
	* Entrada Sandstone	150 to 250 ~~feet.~~	do.	Cross-bedded sandstone.	May yield small quantities of poor quality water to wells.
Triassic	* Chinle Formation	600 to 1,600 ~~feet.~~	do.	Mudstone and siltstone with interbedded sandstone.	Sandstone may yield small to moderate quantities of generally poor quality water; quality is best close to the outcrops.
Permian	* San Andres Limestone	50 to 1,000 ~~feet.~~	Probably widespread and crops out in or underlies most of Rio Grande basin.	Limestone, sandstone, siltstone, and gypsum.	Fracture or solution-channel permeability. May yield large quantities of water to wells. (Yields as much as 3,000 gpm near Grants.) Water quality is variable and is best close to the outcrops.
	* Glorieta Sandstone	70 to 300 ~~feet.~~	San Juan (structural) Basin. This formation or its equivalent may underlie other parts of the Rio Grande basin.	Thick-bedded to massive sandstone.	May yield moderate quantities of water to wells.
	* Yeso Formation	200 to 1,100 ~~feet.~~	Widespread; crops out in or underlies most of Rio Grande basin.	Siltstone, sandstone, and shale.	May yield small to moderate quantities of water to wells.
	* Abo Formation	300 to 1,100 ~~feet.~~	do.	Arkosic sandstone, siltstone, and shale.	Generally low permeability, but yield of water to wells may range from small to large.

Table 1.--Generalized stratigraphic section in the Rio Grande basin, New Mexico - Concluded

System	Stratigraphic Unit	(feet) Thickness	Distribution	Physical properties	Water-bearing characteristics
Permian - Continued	* Sangre de Cristo Formation	250 to 1,800 ~~feet.~~	Sangre de Cristo Mountains; may underlie Santa Fe area.	Arkosic shale, sandstone, and conglomerate.	Generally not an aquifer in the basin because depth to water is too great.
Pennsylvanian	* Magdalena Group	0 to 2,500 ~~feet.~~	Widespread; crops out in or underlies most of the basin.	Limestone, sandstone, and interbedded shale.	May yield small quantities of water to wells.
Mississippian	Lake Valley Formation	0 to 60 ~~feet.~~	Mountains in southern part of the basin.	Limestone and some shale.	Unknown.
Devonian	Percha Formation	20 to 105 ~~feet.~~	do.	Shale, claystone, and some sandstone and siltstone.	Unknown.
Silurian	Fusselman Dolomite	Less than 20 to about 50 ~~feet.~~	do.	Cherty dolomite.	Unknown.
Ordovician	Montoya Group	200 to 450± ~~feet.~~	do.	Massive dolomite, chert limestone, claystone, and a basal sandstone.	Unknown.
	El Paso Group	350 to 450± ~~feet.~~	do.	Thin-bedded limestone; basal unit is laminated, cherty limestone.	Unknown.
Cambrian	Bliss Formation	0 to 400 ~~feet.~~	do.	Thin- to thick-bedded sandstone with some conglomerate and limestone.	Unknown.
Precambrian	* Precambrian rocks	-	Underlies all of the Rio Grande basin.	Granite, schist, gneiss, and other metamorphic rocks.	Yields small quantities of water to wells, generally near the outcrops.

Mineral deposits of the Rio Grande basin include precious, semiprecious, radioactive, and ore minerals. Deposits of precious minerals such as gold and silver have been found or reported at places in almost all parts of the Rio Grande basin. Gold occurs as both placer and vein deposits; silver is found as wire or in veins. Turquoise, a semiprecious mineral used extensively in Indian jewelry, has been mined in greater quantities in New Mexico than in any other State. One of the most important turquoise deposits is near Cerrillos in Santa Fe County (Northrop, 1959). Uraninite, an important radioactive mineral, is mined in large quantities from the Todilto Limestone and beds of sandstone of the Morrison Formation in Valencia County. Lead, copper, manganese, iron, and molybdenum ores are found at many places in the Rio Grande basin. Galena, lead sulfide, is found in notable quantities in the mountains of Bernalillo and Dona Ana, Santa Fe, Sierra, and Socorro Counties. Copper ore has been found in the mountains along the Rio Grande basin from Colorado to Mexico, but the largest deposit is at Santa Rita, in Grant County, west of the Rio Grande basin. Manganese ore, albandite, has been found in the Kingston area of Sierra County. Iron ore is not mined extensively in New Mexico; however, iron ore, as hematite and magnetite, is widespread throughout the Rio Grande basin. Molybdenite, a molybdenum ore, is mined in the Questa area near the center of Taos County. This deposit is presumably one of the largest in the world. The San Juan (structural) Basin yields large quantities of gas and oil; some of this production is from the western part of the Rio Grande basin.

Geologic maps for all of New Mexico are compiled into four generalized reference maps, one for each quarter of the State. These maps are referred to as Miscellaneous Geologic Investigations (Dane and Bachman, 1957, 1958, 1961, and Bachman and Dane, 1962) and are published by the U.S. Geological Survey. Each quarter map lists the more detailed maps from which it was compiled. A geologic map index of New Mexico (Boardman and others, 1956) is also published by the Geological Survey and indicates reports and maps available for New Mexico.

Soils and vegetation

Soil surveys have been made by the U.S. Department of Agriculture in four areas in the Rio Grande basin. These areas are the middle Rio Grande valley area, the Socorro and Rio Puerco area, the Rincon area, and Mesilla Valley area. The reports are published by the Bureau of Chemistry and Soils in cooperation with the New Mexico Agricultural Experiment Station. Climate, agriculture, irrigation, erosion, soils, and crops are discussed.

Agricultural soils in the Rio Grande basin are primarily in lowlands adjacent to the Rio Grande and its principal tributaries where meandering streams have deposited soil. In general, soils near mountains or near outcrops of sandstone are light and soils away from mountains, in broad valleys, or near outcrops of clay and shale, are relatively heavy. Caliche (secondary carbonate) is frequently found in soils near outcrops of carbonate rock. The soils resource map of New Mexico (fig. 4) indicates zones of soil types.

Figure 4.--(caption on next page) belongs near here.

Figure 4.--Soils resource map of New Mexico.

Plant life zones in the Rio Grande basin range from lower Sonoran to Hudsonian and Arctic. The lower Sonoran zone is found only in that part of the basin south of Socorro, and the Hudsonian and Arctic zone is found only in the high mountains north of Santa Fe. Most of the Rio Grande basin is in the upper Sonoran and Transition zones. Irrigated crops are grown along the Rio Grande and its main tributaries. Adjacent to the irrigated lands along the Rio Grande and south of Bernalillo is found semi-desert brush, chiefly creosote bush, tarbush, and mesquite. The next highest zone and south of Santa Fe is found grassland, chiefly blue grama, black grama, galleta, western wheat grass, beardgrasses, dropseeds, threeawns, tobosa, and burro grass. Woodlands, chiefly piñon, juniper, oak and mountain mahogany, with and without an understory of shrubs and grasses are on the higher southern mountains and on most of the mountain slopes in the central and north part of the basin. Forests, chiefly ponderosa pine, douglas fir, and spruce are on the high mountains in the north part of the basin. Tundra, chiefly grasses, sedges, herbs, and low shrubs are above timberline in the Sangre de Cristo Mountains. Big sagebrush is dominant in western Taos County, west of Questa, and in McKinley County, west of the Rio Puerco. Natural vegetation is zoned rather than spotty and depends on elevation, latitude, moisture, and soil condition. The vegetative-type map of New Mexico (fig. 5) indicates zones of vegetation.

Figure 5.--(caption on next page) belongs near here.

Figure 5.--Vegetative type map of New Mexico.

Hydrology

Climatology

Weather stations are located throughout the Rio Grande basin; see map of weather station locations and climatologic divisions ~~zones~~ (fig. 6).

Figure 6 .--(caption on next page) belongs near here.

The Rio Grande basin includes parts of the Northern Mountains, Southwestern Mountains, Central Valley, Central Highlands, and Southern Desert climatologic divisions ~~zones~~. Mean temperatures and precipitation at selected places in the Rio Grande basin are listed in the accompanying table (table 2). More detailed climatological information is given in the monthly climatologic reports by the U.S. Weather Bureau, Department of Commerce.

Figure 6.--Weather stations ~~locations~~ and climatologic divisions in New Mexico.

(U.S. Weather Bureau, 1959)

Table 2.--Mean temperature and precipitation at places in Rio Grande basin, New Mexico

Station		January Temp. (°F)	January Prec. (inches)	February Temp.	February Prec.	March Temp.	March Prec.	April Temp.	April Prec.	May Temp.	May Prec.	June Temp.	June Prec.	July Temp.	July Prec.	August Temp.	August Prec.	September Temp.	September Prec.	October Temp.	October Prec.	November Temp.	November Prec.	December Temp.	December Prec.	Annual Temp.	Annual Prec.
Bandelier NM	Northern Mountains	-	0.76	-	0.80	-	0.92	-	0.87	-	1.40	-	0.85	-	2.47	-	2.49	-	1.64	-	1.17	-	0.80	-	0.90	-	15.07
Bateman Ranch		-	1.78	-	1.90	-	2.14	-	1.47	-	1.80	-	1.23	-	2.57	-	2.98	-	2.39	-	1.70	-	1.16	-	1.73	-	22.85
Cerró		-	.59	-	.62	-	.61	-	1.00	-	1.34	-	.86	-	1.68	-	1.98	-	1.54	-	1.09	-	.59	-	.62	-	12.52
Chama		-	1.67	-	1.69	-	1.52	-	1.30	-	1.40	-	.95	-	1.65	-	2.21	-	2.03	-	1.42	-	.93	-	1.77	-	18.54
Gavilan		-	1.04	-	1.35	-	1.21	-	1.18	-	1.17	-	.92	-	1.97	-	2.47	-	1.91	-	1.14	-	.90	-	1.23	-	16.49
Jemez Springs		32.5	.84	36.3	.89	41.9	1.06	50.7	1.01	58.0	1.41	66.2	1.44	70.6	2.56	69.2	3.12	63.7	2.28	53.8	1.40	42.0	.81	34.7	.85	51.6	17.67
Los Alamos		-	.78	-	.65	-	.84	-	.95	-	1.43	-	1.31	-	2.82	-	3.85	-	2.09	-	1.34	-	.65	-	.84	-	17.55
Penasco RS		-	.97	-	1.10	-	1.23	-	1.18	-	1.40	-	.99	-	2.02	-	2.10	-	1.48	-	1.24	-	.83	-	.83	-	15.37
Red River		19.2	1.01	22.2	1.14	28.2	1.42	37.9	1.63	45.2	1.78	53.3	1.28	58.2	2.61	57.4	3.06	51.6	1.63	42.4	1.30	29.3	.97	21.7	.95	38.9	18.78
Regina		24.2	1.02	28.2	1.22	34.8	1.23	44.0	1.34	52.0	1.13	61.0	.79	66.6	2.21	64.9	2.58	58.2	1.69	47.5	1.20	34.7	.83	26.9	1.10	45.3	16.34
Santa Fé		29.6	.66	33.8	.67	39.2	.72	48.3	.85	56.7	1.45	66.1	1.15	70.4	2.26	68.8	2.21	62.8	1.59	52.2	.87	39.2	.62	31.9	.67	49.9	13.72
Taos		-	.74	-	.73	-	.78	-	.94	-	1.18	-	.78	-	1.52	-	1.64	-	1.15	-	1.01	-	.72	-	.56	-	11.75
Tierra Amarilla 6-SSE		-	1.32	-	1.09	-	1.04	-	1.12	-	1.10	-	.99	-	1.87	-	2.26	-	1.84	-	1.07	-	.90	-	1.31	-	15.91
Tres Piedras		-	.91	-	.92	-	.80	-	.81	-	1.11	-	.68	-	1.89	-	2.29	-	1.53	-	.89	-	.58	-	.87	-	13.28
Truchas		-	.85	-	1.14	-	.94	-	1.10	-	1.20	-	.91	-	1.95	-	2.32	-	1.67	-	1.14	-	.85	-	.86	-	14.93
Bluewater	Southwestern Mountains	27.2	.42	32.2	.35	38.1	.42	46.9	.46	55.3	.50	64.1	.63	69.2	1.75	66.8	2.53	59.6	1.19	49.3	.47	36.1	.46	29.3	.46	47.8	9.64
Winston		-	.59	-	.62	-	.39	-	.46	-	.55	-	.87	-	2.21	-	2.55	-	2.09	-	.86	-	.33	-	.58	-	12.10
Albuquerque WB-AP	Central Valley	33.7	.28	39.5	.33	46.0	.44	55.5	.53	65.3	.87	74.9	.72	79.0	1.43	76.9	1.38	69.9	1.05	58.2	.64	44.0	.42	36.0	.59	56.6	8.68
Bosque del Apache		-	.41	-	.43	-	.23	-	.27	-	.39	-	.80	-	1.04	-	1.51	-	1.34	-	.76	-	.21	-	.38	-	7.77
Elephant Butte Dam		41.0	.40	46.3	.45	52.3	.30	60.9	.32	69.2	.37	78.1	.73	80.3	1.47	78.6	1.82	73.0	1.34	63.0	.62	49.7	.20	42.7	.42	61.3	8.44
Socorro		37.3	.48	43.0	.47	49.7	.26	58.7	.43	66.7	.77	75.7	.69	79.2	1.33	77.3	1.55	70.7	1.46	59.5	.62	45.9	.24	38.6	.44	58.5	8.74
Mountainair (Central Highlands)		-	.84	-	.60	-	.65	-	.66	-	.93	-	.97	-	2.67	-	2.47	-	1.52	-	.97	-	.58	-	.91	-	13.77
Agricultural College	Southern Desert	40.5	.47	45.2	.44	50.9	.26	59.3	.19	67.1	.32	75.9	.57	79.4	1.31	77.7	1.57	71.5	1.28	61.0	.71	47.6	.31	41.9	.50	59.8	7.93
Hatch		-	.48	-	.42	-	.25	-	.38	-	.31	-	.58	-	1.59	-	1.62	-	1.40	-	.81	-	.23	-	.56	-	8.63
Hillsboro		-	.68	-	.58	-	.44	-	.34	-	.44	-	.72	-	1.80	-	1.89	-	1.95	-	.91	-	.32	-	.66	-	10.73

Mean evaporation rates at selected places are listed in the following table (table 3); if further or more detailed information is desired, refer to the monthly climatologic reports by the U.S. Weather Bureau, Department of Commerce.

Table 3.--Mean evaporation rates, in inches; 1960 (U.S. Weather Bureau, 1960)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
*Bosque del Apache	1.80	3.86	7.79	10.79	12.10	13.00	11.66	11.99	9.39	5.35	3.52	-	-
Caballo Dam	3.19	5.35	8.86	11.44	15.64	16.96	13.96	12.16	10.34	7.32	4.97	3.07	114.26
El Vado Dam	-	-	-	-	8.42	10.08	9.35	7.86	6.48	-	-	-	-
Elephant Butte Dam	2.98	4.61	8.07	11.03	13.88	15.20	13.02	10.78	9.30	7.44	4.49	-	-
*Jemez Dam	-	-	-	10.62	12.73	13.89	13.93	13.60	10.90	6.59	3.80	-	-
*Narrows	2.25	4.70	8.68	11.97	13.97	13.94	12.86	12.72	10.16	7.33	4.70	-	-
Santa Fe	-	-	-	-	-	10.30	8.92	7.66	6.39	4.56	2.44	-	-
State University	2.98	4.44	7.62	9.88	11.87	12.87	11.87	10.24	8.20	6.16	3.87	2.66	92.66

*Figures for 1960, only.

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Surface water

The Rio Grande basin contains more streamflow-gaging stations than any other basin in New Mexico. These stations, drainage areas, average annual runoff, and peak discharges are listed in ~~the following~~ table 4.

Table 4.--Streamflow gaging stations in the Rio Grande basin, New Mexico

Sta. No.	Gaging station	Drainage area (sq mi)	Average runoff acre-feet per year through 1963	Peak discharge		
				Date	cfs	cfs per sq mi
	RIO GRANDE BASIN: Part 8					
2475	San Antonio River at Ortiz, Colo.	110	19,260	4-15-37	1,750	15.9
2480	Los Pinos River near Ortiz, Colo.	167	90,500	5-12-41	3,160	18.9
2515	Rio Grande near Lobatos, Colo.	7,700	453,200	6- 8-05	13,200	1.71
2525	Costilla Creek above Costilla Dam	26	d	7-22-54	3,870	149
2530	Casias Creek near Costilla	19	d	6-11-57	122	6.42
2535	Santistevan Creek near Costilla	2.5	d	8-11-41	18	7.20
2540	Costilla Creek below Costilla Dam	55	12,310	5- 9-42	286	5.20
2545	Costilla Creek near Amalia	140	d	4-25-58	689	4.92
2550	Ute Creek near Amalia	12	d	6- 8-55	69	5.75
2555	Costilla Creek near Costilla	195	32,720	5-11-42	1,150	5.90
2605	Costilla Creek below diversion dam, at Costilla	197	d	7-22-54	525	2.66
2610	Costilla Creek at Garcia, Colo.	200	d	5-11-42	h1,000	5.00
2625	Costilla Creek near Jaroso, Colo.	290	1,650	5-19-58	360	1.24
2630	Latir Creek near Cerro	10	4,610	6- 3-42	121	12.1
2635	Rio Grande near Cerro	8,440	249,000	6-22-49	9,740	1.15
2640	Red River near Red River	19.1	12,960	6-12-52	264	13.8
2645	Red River below Zwergle damsite, near Red River	25.7	-	-	-	-
2650	Red River near Questa	113	40,830	5-25-42	j886	7.84
2660	Cabresto Creek near Questa	36.7	7,210	5-25-42	h200	5.45
2665	Red River below Questa	180	61,470	-	-	-
2670	Red River at mouth, near Questa	190	59,660	1-18-52	647	3.41
2675	Rio Hondo near Valdez	36.2	26,420	5-13-41	541	14.9
2680	Rio Hondo at Valdez	38	19,760	-	-	-
2682	Rio Hondo at damsite, at Valdez	40.3	-	-	-	-
2685	Rio Hondo at Arroyo Hondo	65.6	21,140	8-23-35	h1,200	18.3
2690	Rio Pueblo de Taos near Taos	66.6	23,380	5-14-41	970	14.6
-	Rio Pueblo de Taos and North Channel at Taos	80	18,390	5-14-41	950	11.9
2710	Rio Lucero near Arroyo Seco	16.6	17,160	5-13-41	300	18.1
2745	Rio Lucero below diversions, near Arroyo Seco	25	5,610	5-14-41	273	10.9
2750	Rio Fernando de Taos, near Taos	71.7	6,760	-	-	-
2753	Rio Pueblo de Taos near Ranchito	199	22,880	5-13-57	600	3.02
2755	Rio Grande de Ranchos near Talpa	83	13,970	5-19-58	342	4.12
2756	Rio Chiquito near Talpa	37.0	6,330	5-13-58	144	3.89
2760	Rio Pueblo de Taos at Los Cordovas	359	42,710	5-14-41	1,830	5.10
2763	Rio Pueblo de Taos below Los Cordovas	380	39,890	8-24-57	2,380	6.26
2765	Rio Grande below Taos Junction Bridge, near Taos	9,730	542,300	6- 7-48	9,730	1.00
2780	Pueblo Creek near Peñasco	-	43,360	5-13-41	1,440	-
2785	Rio Santa Barbara near Llano	38	21,070	8-23-57	377	9.92
2790	Embudo Creek at Dixon	305	39,150	8-22-46	2,180	7.15
2795	Rio Grande at Embudo	10,400	757,300	6-19-03	16,200	1.56
2815	Rio Chama near Chama	-	-	5- 7-16	k2,040	-
2820	Rio Brazos near Brazos	-	-	5-14-15	k3,240	-
2835	Rio Chama at Park View	405	248,300	5-21-26	k10,000	24.7
2841	Rio Chama near La Puente	480	233,800	6- 7-57	k8,040	16.8
2842	Willow Creek above Heron Reservoir, near Park View	112	-	-	-	-
2843	Horse Lake Creek above Heron Reservoir, near Park View	45	-	-	-	-
2845	Willow Creek near Park View	193	15,850	4-23-42	k4,500	23.3
2855	Rio Chama below El Vado Dam	877	278,000	5-22-20	k9,000	10.3
2865	Rio Chama above Abiquiu Reservoir	1,600	-	8- 3-63	1,800	1.12
2870	Rio Chama below Abiquiu Dam	2,147	-	4-20-62	1,960	0.91
2875	Rio Chama near Abiquiu	2,284	293,200	7-28-52	k7,870	3.45
2880	El Rito near El Rito	50.5	13,180	4-23-42	1,240	24.6
2885	Rio Vallecitos at Vallecitos	-	-	5-21-12	970	-
2890	Rio Ojo Caliente at La Madera	419	53,280	4-21-58	3,140	7.49
2900	Rio Chama near Chamita	3,144	404,000	5-22-20	k15,000	4.78
2910	Santa Cruz River at Cundiyo	86	21,570	9-24-31	2,420	28.1
2915	Santa Cruz River at Riverside	188	7,020	7- 8-50	891	4.74
2920	Santa Clara Creek near Espanola	36.7	3,320	9-22-41	970	26.4
2943	Rio Nambe at Nambe Falls, near Nambe	25.1	-	-	-	-
2950	Rio Nambe near Nambe	38.2	7,670	7-31-55	5,580	146
3010	Pojoaque Creek at Pojoaque Bridge, near Nambe	-	9,560	7-31-55	10,300	-
3022	North Fork Tesuque Creek near Santa Fe	1.60	-	-	-	-
3023	Middle Fork Tesuque Creek near Santa Fe	.44	-	-	-	-
3024	South Fork Tesuque Creek near Santa Fe	.47	-	-	-	-
3025	Tesuque Creek above diversions, near Santa Fe	11.6	2,320	8-24-57	632	54.5
3041	Little Tesuque Creek near Santa Fe	.37	-	-	-	-
3044	Little Tesuque Creek Tributary No. 2 near Santa Fe	.45	-	-	-	-
3050	Little Tesuque Creek near Santa Fe	8	927	7-19-38	186	23.2
3055	Rio Tesuque at Tesuque	-	-	8-24-57	1,490	-
3130	Rio Grande at Otowi Bridge near San Ildefonso	14,300	1,137,000	5-23-20	24,400	1.71
3133	Rito de Los Frijoles near Los Alamos	8.9	-	4- 7-60	13	1.46
3145	Rio Grande at Cochiti	14,600	968,700	5-15-41	23,400	1.60
3160	Santa Fe River near Santa Fe	18.2	6,040	8-14-21	1,500	82.4
3180	Galisteo Creek at Domingo	640	7,230	8-20-35	m24,300	38.0
3190	Rio Grande at San Felipe	16,100	1,032,000	6-26-37	27,300	1.70
3195	Rito San Antonio near Los Alamos	-	-	7-10-50	-	-
3200	Jemez River near Jemez Springs	-	-	7-23-49	86	-
3205	East Fork Jemez River near Los Alamos	-	-	3- 6-50	4.0	-
3210	East Fork Jemez River near Jemez Springs	-	-	3-18-50	41	-
3215	Jemez River below East Fork near Jemez Springs	173	d	4-21-58	2,520	14.6
3220	Rio Las Vacas near Cuba	-	-	5-13-41	1,530	-
3230	Rio Guadalupe at Box Canyon, near Jemez	235	d	4-21-58	1,440	6.13
3235	Rio Guadalupe near Jemez Springs	239	51,620	5-13-41	3,190	13.3
3240	Jemez River near Jemez	470	46,330	5- -41	h6,000	12.8
3265	Jemez River at San Ysidro	834	-	7-28-39	4,100	4.80
3280	Jemez River above Jemez Canyon Dam	999	48,870	11-5,19-57	23,100	23.1
3290	Jemez River below Jemez Canyon Dam	1,040	37,280	8-29-43	16,300	15.7
3295	Rio Grande near Bernalillo	17,300	800,700	5-16-41	25,400	1.47

Table 4.--Streamflow gaging stations - Continued

3300	Rio Grande at Albuquerque	17,440	792,000	4-24-42	25,000	1.43
3305	Tijeras Arroyo near Albuquerque	76.3	1,050	7-19-44	6,410	84.0
3310	Rio Grande near Isleta	17,900	1,383,000	6-27-37	n14,200	.79
3315	Rio Grande near Belen	18,[illegible]30	587,100	4-24-42	23,100	1.27
3320	Rio Grande near Bernardo	[illegible]30	760,200	4-25-42	21,100	1.10
3325	La Jara Creek near La Jara	-	-	6- 5-32	19	-
3330	Rio Puerco near Cabezon	360	6,640	6-28-43	4,400	12.2
3335	Rio Puerco at Cabezon	397	7,010	8- 2-46	2,440	6.15
3340	Rio Puerco above Chico Arroyo, near Gundalupe	420	10,060	8-18-61	4,540	10.8
3405	Chico Arroyo near Gundalupe	1,390	17,380	7-17-53	12,200	8.78
3415	Bluewater Creek below Bluewater Dam	201	1,560	7-1,3-52	58	.29
3420	Bluewater Creek near Bluewater	209	7,150	7- -19	p4,000	19.1
3430	Bluewater Creek at Grants	1,020	3,560	8-28-52	p1,760	1.73
3435	Rio San José near Grants	1,070	4,910	9-20-63	1,400	1.31
3455	Rio San Jose near San Fidel	1,080	4,990	5-1,4-41	418	39
3480	Rio San Jose near Casa Blanca	-	5,660	7-26-37	1,330	-
3485	Encinal Creek near Casa Blanca	-	-	-	-	-
3495	Paguate Creek near Laguna	-	-	8- 1-37	174	-
3505	Rio San Jose near Laguna	-	-	8- 1-37	3,400	-
3515	Rio San Jose at Correo	2,530	8,400	8-21-35	q11,000	d.35
3525	Rio Puerco at Rio Puerco	5,460	44,740	9-23-29	37,700	6.90
3530	Rio Puerco near Bernardo	6,220	37,790	9-23-29	35,000	5.62
3540	Rio Salado near San Acacia	1,380	9,700	8-12-29	27,400	19.9
3550	Rio Grande at San Acacia	26,770	795,600	9-23-29	h50,000	1.87
3555	Rio Grande at San Antonio	27,400	391,700	10-11-04	50,000	1.82
3585	Rio Grande at San Marcial	27,700	970,800	10-11-04	50,000	1.81
3595	Rio Grande at narrows in Elephant Butte Reservoir	28,500	479,300	9- 3-57	r8,500	.30
3600	Alamosa River near Monticello	403	5,920	8-21-36	10,300	25.6
3610	Rio Grande below Elephant Butte Dam	29,450	758,700	5-22-42	r8,220	.28
3625	Rio Grande below Caballo Dam	30,700	675,500	5-20-42	r7,650	.25
3636	Las Cruces Arroyo near Las Cruces	13.5	65.2	8-23-59	1,060	78.5
3640	Rio Grande at El Paso, Texas	32,207	636,400	6-12-05	24,000	.75

Virgin streamflows at the inflow point were taken as the recorded average flow at Lobatos, Colorado, for the 1920-1950 period. At various gaging points along the river in New Mexico the virgin flow was estimated as the recorded flow plus man-made depletions above the station. The virgin streamflows based on the assumptions above are listed in table 5. ~~as follows:~~

Table 5.--Virgin streamflows in the Rio Grande basin, New Mexico

Gaging station	Average annual flow, in acre-feet
Rio Grande near Lobatos (Inflow station)	457,700
Rio Grande below Taos Junction Bridge	747,400
Embudo Creek at Dixon	13,400
Rio Grande at Embudo	322,600
Rio Chama near Chamita	460,100
Rio Grande at Otowi Bridge	1,367,400
Rio Grande at San Marcial	1,288,700
Rio Grande below Elephant Butte Dam	1,323,300
Rio Grande below Caballo Dam	1,353,700
Rio Grande at El Paso (Outflow point)	1,311,900

Total water production in the Rio Grande basin within New Mexico, based on this study, averages 1,377,200 acre-feet which compares with 1,474,900 acre-feet estimated for the Rio Grande joint investigation. Their study covered the 1890-1935 period and showed the average outflow at El Paso as 744,500 acre-feet which indicates a depletion of 1,178,400 acre-feet in New Mexico, which compares with 1,228,000 acre-feet estimated in this study.

Base flow and runoff is regulated by several methods in the Rio Grande basin. Large reservoirs are probably the most obvious means of regulation. Reservoirs, in the Rio Grande basin, that have a usable capacity of 30,000 acre-feet or more are listed in table 6. ~~below.~~

Table 6.--Reservoirs, in the Rio Grande basin, that have a usable capacity of 30,000 acre-feet or more

Name of reservoir and stream	Type of dam	Original capacity (acre-feet)	Dead storage (acre-feet)	Present capacity (acre-feet)	Usable capacity (acre-feet)	Use
Abiquiu (Rio Chama)	Earthfill	1,225,000	0	1,225,000	1,225,000	FS
Bluewater Lake (Bluewater Creek)	Concrete	-	3.4	38,510	38,510	IR
Caballo (Rio Grande)	Earthfill	345,900	0	344,000	344,000	FIR
Elephant Butte (Rio Grande)	Concrete	2,639,000	0	2,195,000	2,195,000	IPR
El Vado (Rio Chama)	Rockfill	198,800	0	194,500	194,500	IR
Jemez Canyon (Jemez River)	Earthfill	117,200	0	113,100	113,100	FS

Use: F, flood control; I, irrigation; P, power production; R, recreation; S, sediment retention.

Many small reservoirs are used to control sediment and the rate of runoff in areas subject to flooding. Other means of regulation used in the Rio Grande basin include channelization and dikes, to control channel position; canals, for water distribution; and drains, to alleviate flooding or swamping in low areas of flood plains.

Some areas in the Rio Grande basin have been subjected to spectacular flooding in the past. Probably the most notable flood was at San Marcial in September 1929 (oral communication, G.L. Oakland). During this flood, the town of San Marcial was destroyed, and many parts of the San Acacia-Socorro area were inundated. This area had been flooded before but destruction of personal property was never so great. The lowlands adjacent to the Rio Grande near Albuquerque have been flooded several times in the past. The most destructive flood near Albuquerque is reported to have been in May 1874 when "Old Town" was left as an island. The town of Bernalillo has been damaged frequently by flash floods from Piedra Lisa Arroyo; this danger has been eliminated by Bernalillo Reservoir No. 1, a small flood-control and sediment-retention dam. The methods of runoff and streamflow regulation, discussed previously, have essentially eliminated the possibility of flooding in areas where large amounts of personal property could be damaged. Locally, areas can be damaged by flash floods in arroyos when a large amount of water is discharged quickly and the water spreads on lowlands; however, flow in many of these arroyos is now or will be controlled by small reservoirs such as the one at Bernalillo.

Sedimentation in streams of the Rio Grande basin are studied at observation and sampling sites from central Taos County to El Paso, Texas. These sites are located at places along the Rio Grande and its main tributaries as well as along conveyance channels and floodways. Suspended-sediment concentration and suspended-sediment load are computed from samples obtained at these sites. In addition, studies are being made to determine bed movement and bed configuration at places in the stream system. Sediment studies are vital to the determination of sediment deposition (quantity, method, and place) in channels and in reservoirs. ~~The following~~ table 7 lists the name and location of the sediment stations in the Rio Grande basin, the maximum and minimum daily suspended-sediment concentration, and the maximum and minimum suspended-sediment load during the period of record at each site. More detailed information can be found in water-supply papers published by the U.S. Geological Survey.

Table 7.--Summary of sediment-analysis stations records in Rio Grande basin, New Mexico

Period of record Water years (1900 1910 1920 1930 1940 1950 1960 1970)	Sta. No.	Station	Frequency of sampling	Daily suspended-sediment concentration (ppm) Max.	Daily suspended-sediment concentration (ppm) Min.	Suspended-sediment load (tons/day) Max.	Suspended-sediment load (tons/day) Min.
		RIO GRANDE BASIN: Part 8					
	2755	Rio Grande de Ranchos near Talpa	M	338	3	99.4	.04
	2795	Rio Grande at Embudo	D	10,200	4	51,000	4
	2845	Willow Creek near Park View	M	6,120	7	15,300	.028
	2865	Rio Chama above Abiquiu Reservoir	D	-	-	-	-
	2870	Rio Chama below Abiquiu Dam	D	-	-	-	-
	2875	Rio Chama near Abiquiu	D	58,000	3	248,000	<.5
	2900	Rio Chama near Chamita	D	55,500	NF	209,000	0
	2943	Rio Nambe at Nambe Falls, near Nambe	M	-	-	-	-
	2950	Rio Nambe near Nambe	M	986	1	57.4	.01
	3130	Rio Grande at Otowi Bridge, near San Ildefonso	D	42,600	11	366,000	3
	3145	Rio Grande at Cochiti	W	44,700	6	186,000	<.5
	3180	Galisteo Creek at Domingo	D	96,300	NF	1,600,000	0
	3190	Rio Grande at San Felipe	W	38,300	84	86,200	22
	3290	Jemez River below Jemez Canyon Dam	D	118,000	NF	167,000	0
	3291	Piedra Lisa Arroyo near Bernalillo	D	13,600	NF	570	0
	3295	Rio Grande near Bernalillo	D	75,000	NF	1,680,000	0
	3300	Rio Grande at Albuquerque	W	62,300	11	610,000	<.5
	3315	Rio Grande near Belen	W	23,900	24	88,200	1
	3320	Rio Grande near Bernardo	D	-	-	348,000	0
	3340	Rio Puerco below Cabezon	D	166,000	NF	730,000	0
	3405	Chico Arroyo near Guadalupe	D	113,000	NF	1,220,000	0
	3513	Rio San Jose at Correo	D	120,000	NF	364,000	0
	3525	Rio Puerco at Rio Puerco	D	210,000	NF	1,800,000	0
	3530	Rio Puerco near Bernardo	D	230,000	NF	2,240,000	0
	3540	Rio Salado near San Acacia	D	182,000	NF	795,000	0
	3548	Rio Grande Conveyance Channel at San Acacia	D	131,000	NF	423,000	0
	3549	Rio Grande Floodway at San Acacia	D	196,000	NF	1,760,000	0
	3555	Rio Grande at San Antonio	D	122,000	NF	1,200,000	0
	3580	Rio Grande Conveyance Channel below heading near San Marcial	D	138,000	NF	294,000	0
	3581	Rio Grande (Tiffany Channel) at San Marcial	D	41,700	NF	40,600	0
	3583	Rio Grande Conveyance Channel at San Marcial	D	122,000	NF	356,000	0
	3584	Rio Grande Floodway at San Marcial[a]	D	117,000	NF	966,000	0
	3637	Tortugas Arroyo near Las Cruces	D	-	-	-	-
	3640	Rio Grande at El Paso	D	-	-	-	-

Dissolved-solids content of surface water in tributaries depends mainly on the type of rock over which the water runs. Dissolved- solids content of surface water in the Rio Grande depends primarily on the tributary from which most of the flow was derived. For instance, the dissolved-solids content of water in the Rio Puerco generally is very high; therefore, during runoff in the Rio Puerco, the dissolved-solids content in the Rio Grande at San Acacia probably is higher than when the Rio Puerco is not flowing. Sulfate is the main chemical constituent in surface water because it is available from widespread rocks and because it is readily soluble. ~~The following~~ table 8 lists the names and locations of chemical-quality monitoring stations in the Rio Grande basin and includes the maximum and minimum daily dissolved-solids concentration and maximum and minimum daily dissolved-solids load during the period of record at each station. More detailed information may be found in water-supply papers published by the U.S. Geological Survey.

Table 8.--Summary of chemical-quality stations records in Rio Grande basin, New Mexico

Period of record Water years (1900 1910 1920 1930 1940 1950 1960 1970)	Sta. No.	Station	Frequency of sampling	Daily dissolved-solids concentration (ppm)		Daily dissolved-solids load (tons)	
				Max.	Min.	Max.	Min.
		RIO GRANDE BASIN: Part 8					
	2492	Rio Grande above Culebra Creek near Lobatos, Colo.	D	805	100	2,690	.34
	2900	Rio Chama near Chamita	M	-	-	-	-
	3130	Rio Grande at Otowi Bridge near San Ildefonso	D	1,030	137	4,730	95.4
	3200	Jemez River near Jemez Springs	M	184	117	7.6	2.8
	3210	East Fork Jemez River near Jemez Springs	M	133	76	4.3	1.3
	3215	Jemez River below East Fork near Jemez Springs	M	-	-	-	-
	-	Jemez River above Rio Guadalupe near Jemez	D	587	256	-	-
	3235	Rio Guadalupe near Jemez Springs	D	295	103	21	2.6
	3240	Jemez River near Jemez	M	459	170	-	-
	3300	Rio Grande at Albuquerque	M	361	119	2,130	42.4
	3320	Rio Grande near Bernardo	D	1,780	207	8,270	3.86
	3330	Rio Puerco near Bernardo	M	4,150	1,180	11,080	25
	3350	Rio Grande at San Acacia	D	2,950	183	16,100	.2
	3581	Rio Grande Tiffany Channel at San Marcial	D	1,730	220	2,840	.24
	3583	Rio Grande Conveyance Channel at San Marcial	D	2,010	240	4,430	.58
	3584	Rio Grande Floodway at San Marcial[a/]	D	1,950	233	16,400	.4
	3610	Rio Grande below Elephant Butte Dam	W	1,170	426	3,790	5.2
	3625	Rio Grande below Caballo Dam	D	912	375	7,710	2.3
	-	Rio Grande below Leasburg Dam	D	1,260	419	7,770	53.2
	3640	Rio Grande at El Paso, Tex.	D	3,830	426	8,290	22.8

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Ground water

Aquifers in the Rio Grande basin may in general be separated into two groups; ~~either~~ valley fill or bedrock. Valley fill includes the sediments that have been deposited along streams and that have filled the Rio Grande trough. Valley-fill deposits generally are stream connected and are recharged mainly from streamflow. The Rio Grande trough is filled with silt, sand, gravel, and conglomerate which is unconsolidated to moderately consolidated (Conover, 1954, and Spiegel, 1963). This sediment along the Rio Grande is very thick (as much as 9,000 feet) and is the most reliable aquifer for large quantities of water in the Rio Grande basin (Bjorklund, 1961). The yield of water at 83 large-discharge wells in the Albuquerque area ranged from 240 to 2,000 gpm and averaged 860 gpm. ~~(State Engineer Technical Report 21).~~ The valley fill along tributary streams is a less reliable aquifer. For instance, wells that tap valley fill along the Rio San Jose yield from less than 10 gpm to more than 100 gpm, and wells that tap valley fill along the Pojoaque River in Santa Fe County may yield from less than 10 gpm to more than 300 gpm.

Bedrock aquifers in the Rio Grande basin are beds of sandstone, ~~or~~ conglomerate, and ~~beds of~~ limestone. Generally, beds of shale, mudstone, siltstone, clay, or shale yield little or no water directly to wells. Lava flows may yield moderate amounts of water to wells at places where the flow is saturated and where fractures may be tapped. A well that taps basalt of Tertiary age near Mount Taylor, in Valencia County, produces water at a rate of about 200 gpm. Most lava flows in the basin are not reliable aquifers. Bedrock aquifers are used mainly for small supplies of water for domestic and stock use at places in the Rio Grande basin away from the principal drainage system where there is no saturated valley fill. Bedrock aquifers generally yield only small to moderate amounts of water to wells; however, some bedrock aquifers, principally limestone, may yield large amounts of water to wells, locally. It is reported that some wells that tap the San Andres Limestone near Grants could yield as much as 3,000 gpm (Gordon, 1961). ~~(State Engineer Technical Report 20).~~ The San Andres Limestone is an areally extensive formation; and someday may be tapped at many places in the basin; however, the dissolved-solids content increases away from the recharge areas, and the chemical quality of the water may prohibit use for many purposes. Most of the bedrock aquifers are recharged from precipitation on the outcrops; however, these aquifers may be recharged locally from streamflow at places where a stream crosses an outcrop or where the aquifer receives water from overlying, stream-connected strata.

Refer to the stratigraphic section in the Rio Grande basin (table 1) for generalized physical properties and water-bearing characteristics of formations. Known and probable aquifers are designated by asterisks in the stratigraphic-unit column.

The amount of water in storage in the valley fill cannot be computed accurately with available data; however, a general estimate was made using some assumed storage characteristics. The estimated average value of the coefficient of storage of the valley fill in the Albuquerque area is 0.2 (Bjorklund, 1961) ~~(State Engineer Technical Report 21).~~ If this value is assumed applicable to the valley fill throughout the Rio Grande valley, and if the average saturated thickness is assumed to be 4,000 feet, an area of 8,000 square miles (estimated from figure 7 ~~the map~~

Figure 7.-- (caption on next page) belongs near here.

showing the ground-water reservoir in the Rio Grande depression) would indicate that there is about 4 billion acre-feet of water available from storage in the valley fill of the Rio Grande basin. The coefficient of storage is variable throughout the Rio Grande basin, the saturated thickness is not actually known, and the areal extent of saturated valley fill is, at best, only estimated. Variation in any of these factors will greatly influence the value of the amount of water available from storage in the valley fill in the Rio Grande trough. In a discussion of available storage in an aquifer such as this, other factors are critical; for instance, the economic feasibility of deep drilling for water, and the change in chemical quality of the water with depth. The available storage in the valley fill in the Rio Grande trough might be only half of the computed value if it is economically feasible to drill only to 2,000 feet or if the chemical quality of water below 2,000 feet prohibits the use of the water. Available storage would be considerably less if, for instance, it is only economical to lift to water from a depth of 500 feet or less.

Figure 7.--Map showing ground-water reservoir in the Rio Grande depression in New Mexico.

There is no formal statewide program of monitoring quality of water in wells; however, during ground-water studies, samples of water are obtained and analyzed. A reasonable concept about the quality of ground water is possible through the accumulation and synthesis of these data. ~~The following~~ table 9 indicates the general quality of water that is obtained from wells at a few places in the Rio Grande basin in New Mexico:

Table 9.--Analyses of water from selected wells in the Rio Grande basin, New Mexico

Aquifer and location	Sulfate (ppm)	Chloride (ppm)	Conductance (micromhos at 25°C)	Total hardness (as $CaCO_3$)
Alluvium in Sunshine Valley north of Questa	43	18	190	98
Santa Fe Group near Santa Fe	30	8.0	354	150
Santa Fe Group near Albuquerque	111	17	556	108
Santa Fe Group near Las Cruces	227	153	1,210	441
San Andres Limestone near Grants	380	70	1,460	613
Ojo Alamo Sandstone west of Cuba	202	25	715	276

~~The following three~~ figures 8, 9, and 10 indicate the general distribution of quality of ground water in the Rio Grande basin in New Mexico:

Figure 8.-(caption on next page) belongs near here.

Figure 9.-(caption on next page) belongs near here.

Figure 10.-(caption on next page) belongs near here.

Figure 8.--General availability of relatively fresh ground water in New Mexico.

Figure 9.--General quality of shallow ground water in New Mexico.

Figure 10.--General occurrence of saline ground water in New Mexico.

Ground-water studies, either areal or well-site studies, have been made in many areas in New Mexico. These studies were designed, in general, to analyze and evaluate ground-water reserves and hydrologic systems both quantitatively and qualitatively. ~~The following~~ figure 11 shows the areas in New Mexico that have been

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Figure 11--(caption on next page) belongs near here.

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studied by the U.S. Geological Survey and the New Mexico Institute of Mining and Technology. Other areas will be studied when they become important for economic development, and some previously studied areas may be re-evaluated as technology and knowledge of hydrology advance.

Figure 11.--Areas in New Mexico in which ground-water studies have been made.

Changes in water levels in stream-connected aquifers are ~~brought about~~ controlled by amount and frequency of runoff in the streams, return of irrigation water, precipitation, transpiration, evaporation, and amount and concentration of pumping from wells. Changes in water levels in non-connected aquifers are brought about mainly by precipitation and pumping. The U. S. Geological Survey observes and records changes of water levels in many strategic areas; these areas are shown on ~~the following~~ figure 12. Data concerning observed

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Figure 12.--(caption on next page) belongs near here.

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water-level changes in these areas are published in State Engineer technical reports.

Figure 12.--Areas of observation of water-level fluctuation in New Mexico.

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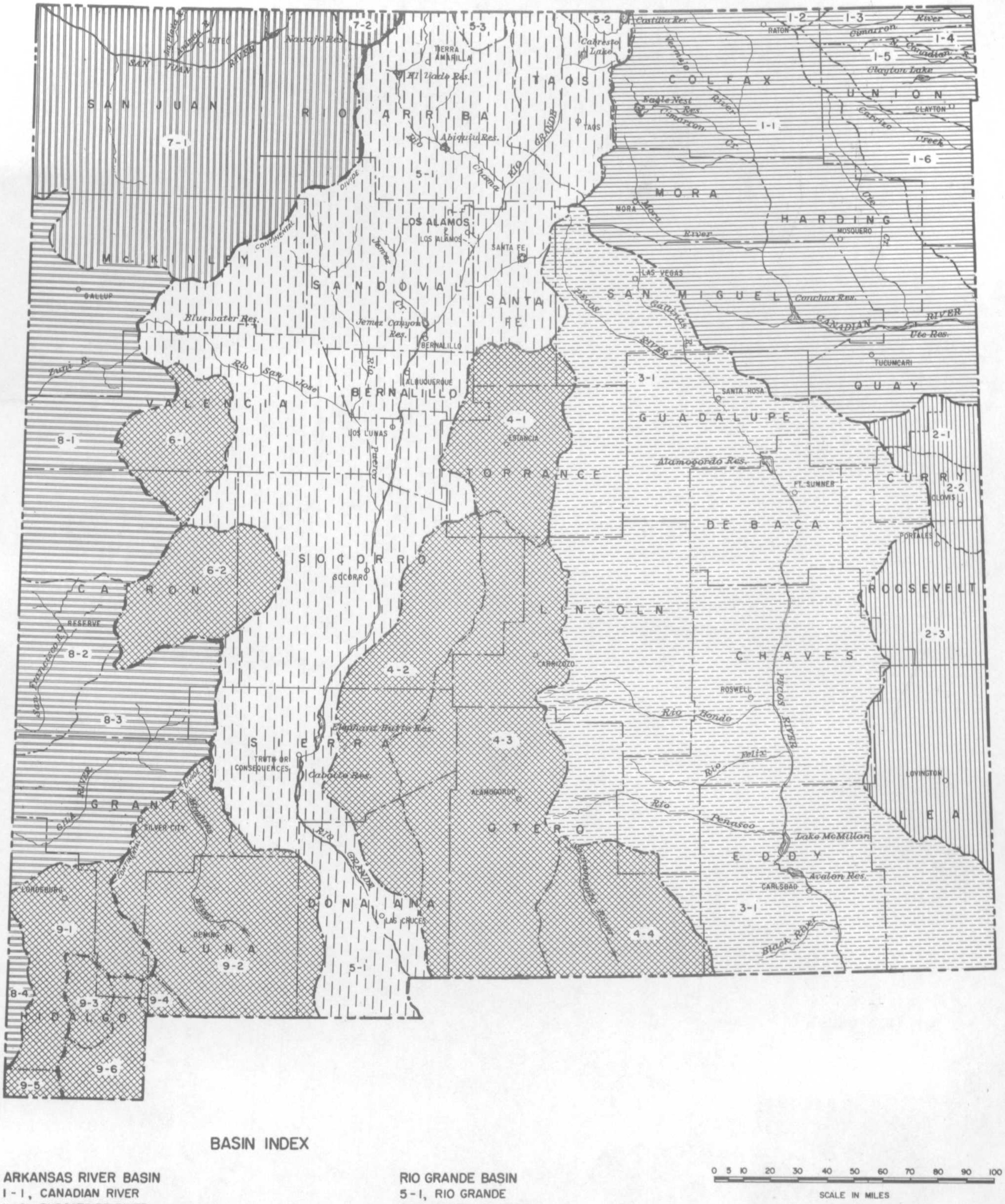


BASIN INDEX

ARKANSAS RIVER BASIN
1-1, CANADIAN RIVER
1-2, PURGATOIRE RIVER
1-3, CIMARRON RIVER
1-4, CARRIZOZO CREEK
1-5, NORTH CANADIAN RIVER
1-6, CARRIZO CREEK

SOUTHERN HIGH PLAINS
2-1, RED RIVER
2-2, BRAZOS RIVER
2-3, LEA PLATEAU

PECOS RIVER BASIN
3-1, PECOS RIVER

CENTRAL CLOSED BASINS
4-1, ESTANCIA BASIN
4-2, JORNADA DEL MUERTO BASIN
4-3, TULAROSA BASIN
4-4, SALT BASIN

RIO GRANDE BASIN
5-1, RIO GRANDE
5-2, COSTILLA CREEK
5-3, RIO SAN ANTONIO

WESTERN CLOSED BASINS
6-1, NORTH PLAINS
6-2, SAN AUGUSTIN PLAINS

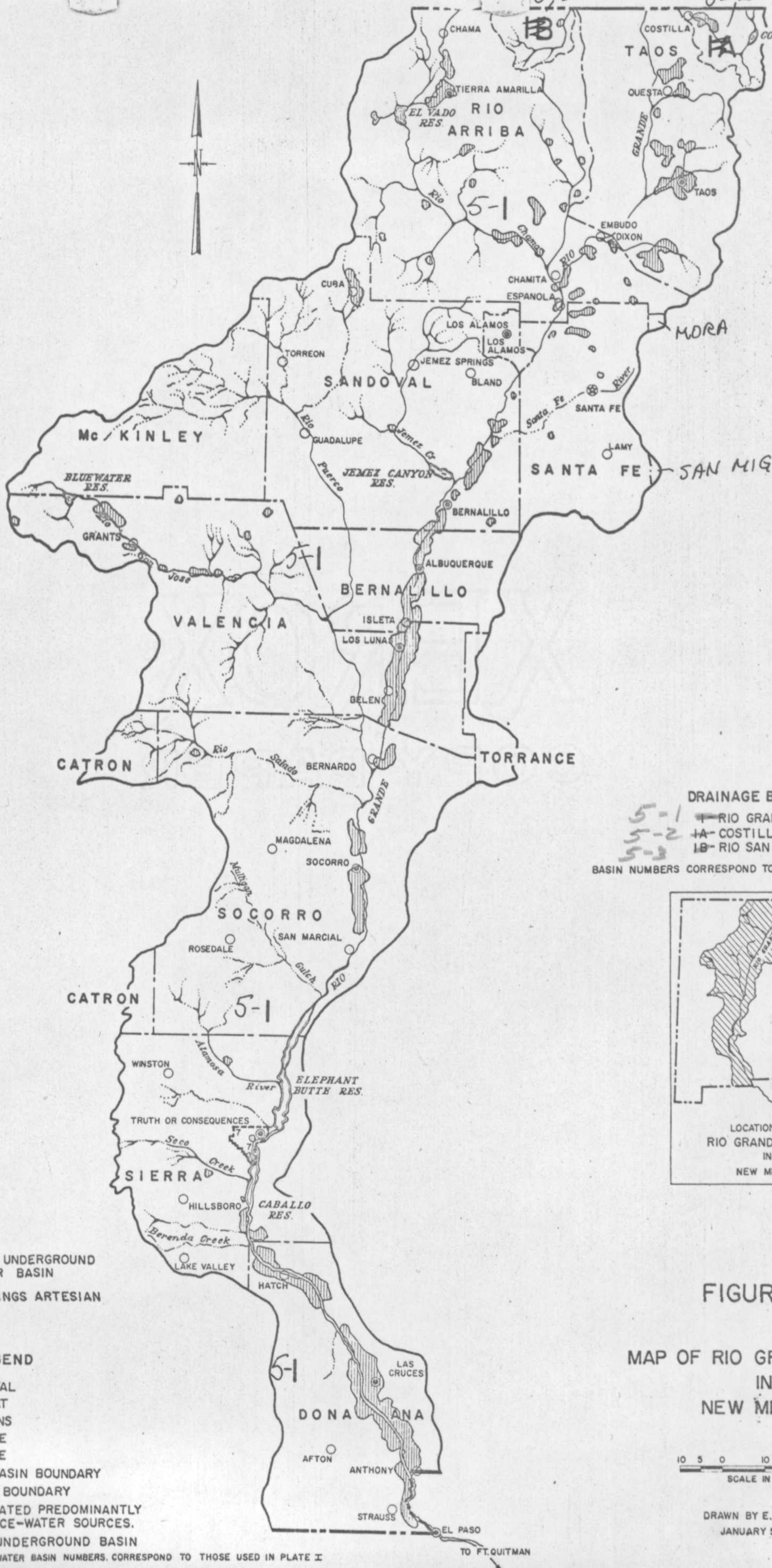
SAN JUAN RIVER BASIN
7-1, SAN JUAN RIVER
7-2, NAVAJO RIVER

LOWER COLORADO RIVER BASIN
8-1, LITTLE COLORADO RIVER
8-2, SAN FRANCISCO RIVER
8-3, GILA RIVER
8-4, SAN SIMON CREEK.

SOUTHWESTERN CLOSED BASINS
9-1, ANIMAS BASIN
9-2, MIMBRES BASIN
9-3, PLAYAS BASIN
9-4, WAMEL BASIN
9-5, SAN LUIS BASIN
9-6, HACHITA BASIN

FIGURE 1

DRAINAGE BASINS OF NEW MEXICO



DECLARED UNDERGROUND WATER BASIN

7-HOT SPRINGS ARTESIAN

LEGEND

- STATE CAPITAL
- COUNTY SEAT
- OTHER TOWNS
- STATE LINE
- COUNTY LINE
- DRAINAGE BASIN BOUNDARY
- SUB BASIN BOUNDARY
- LANDS IRRIGATED PREDOMINANTLY FROM SURFACE-WATER SOURCES.
- DECLARED UNDERGROUND BASIN

DECLARED UNDERGROUND WATER BASIN NUMBERS. CORRESPOND TO THOSE USED IN PLATE I

DRAINAGE BASIN INDEX

5-1 ~~1~~ RIO GRANDE
5-2 ~~1A~~ COSTILLA CREEK
5-3 ~~1B~~ RIO SAN ANTONIO

BASIN NUMBERS CORRESPOND TO THOSE USED IN FIGURE 16

FT. QUITMAN

LOCATION MAP
RIO GRANDE BASIN
IN
NEW MEXICO

FIGURE ~~25~~ 2

MAP OF RIO GRANDE BASIN
IN
NEW MEXICO

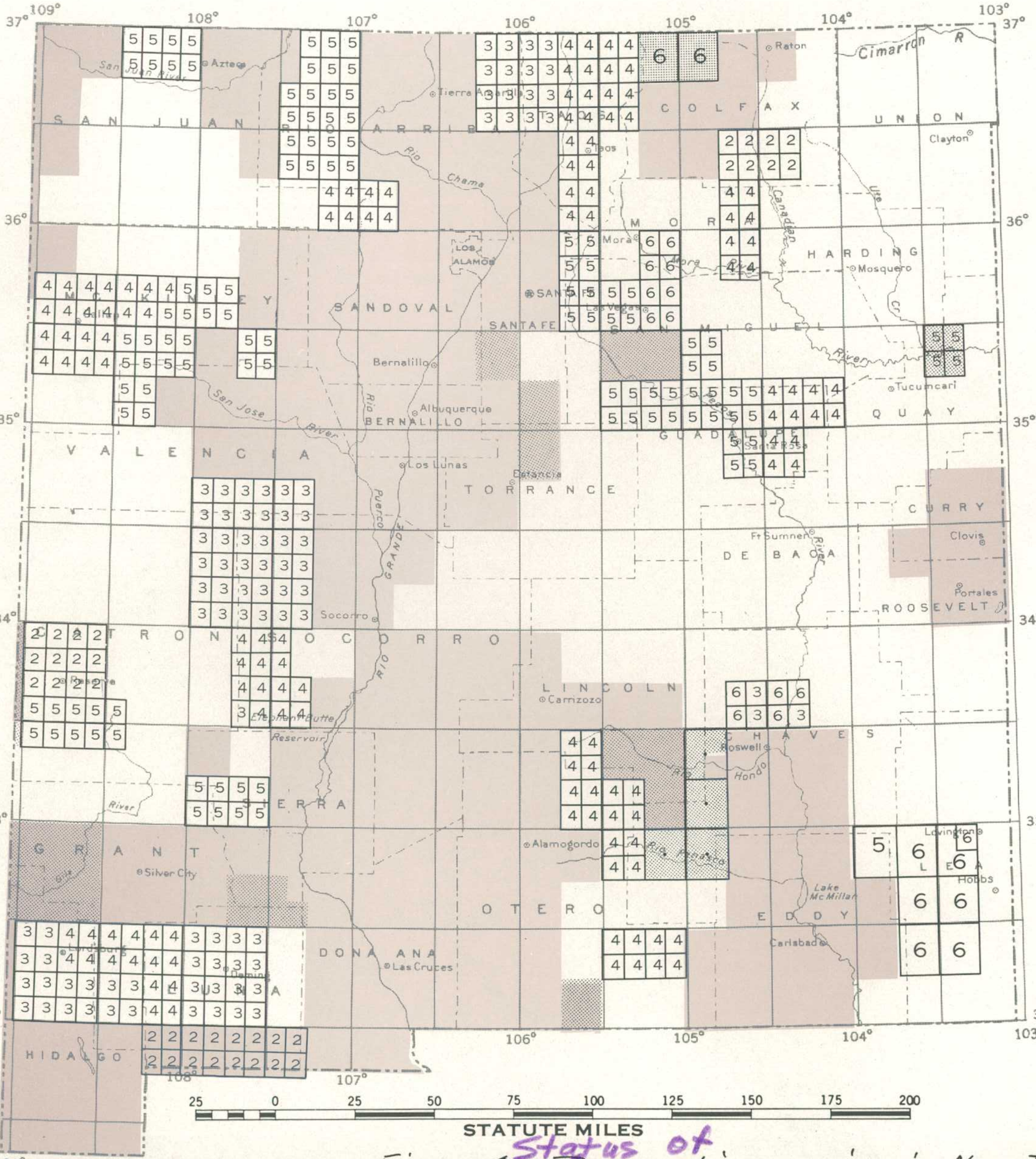
10 5 0 10 20 30
SCALE IN MILES

DRAWN BY E.H. HARRIS
JANUARY 5, 1955

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NEW MEXICO

TOPOGRAPHIC DIVISON
ROCKY MOUNTAIN AREA
DENVER, COLORADO
OCTOBER 1, 1964



ADVANCE MATERIAL AVAILABLE FROM CURRENT TOPOGRAPHIC MAPPING QUARTERLY EDITION

2 — Aerial photography completed. Information available from U.S. Geological Survey, Topographic Division, Federal Center, Bldg. 25, Denver, Colorado, 80225, or Map Information Office, U.S. Geological Survey, Washington, D.C., 20242.

3 — Basic horizontal and vertical control surveys completed. Descriptions and unadjusted coordinates and/or elevations are available. Price 50 cents for each 15-minute quadrangle horizontal or vertical control list. See notes.

P 4 — Prints of manuscripts compiled from aerial photographs are available at 50 cents each. Contours are shown in areas suitable for stereocontouring. Letter "P" indicates quadrangles on which contouring is not complete and which will require fieldwork to complete the contouring. (If shaded, see explanation below.)

5 — Field mapping and checking completed. One-color advance prints (without names) available for 50 cents each. (If shaded, see explanation below.)

6 — Final drafting completed. Partially-edited one-color advance prints (with names) available for 50 cents each. (If shaded, see explanation below.)

· — Maps published since latest edition of Index to Topographic Mapping— May, 1964. See statement below regarding published maps. (If shaded, see explanation below.)

EXPLANATION OF SHADING

Maps of areas shaded will be (or have been) published at 1:62,500 scale only. However, 1:24,000-scale advance prints in 7½-minute units (without names) are and will remain available, with accuracy and contour interval appropriate for that scale. Each 7½-minute print is 50 cents, or $2 for prints covering a complete 15-minute quadrangle.

NOTES

1. Send requests for control lists and advance prints to U.S. Geological Survey, Topographic Division, Federal Center, Bldg. 25, Denver, Colorado, 80225. Check, money order or draft in correct amount made payable to U.S. Geological Survey should accompany order. Please do not send stamps. No discount allowed.

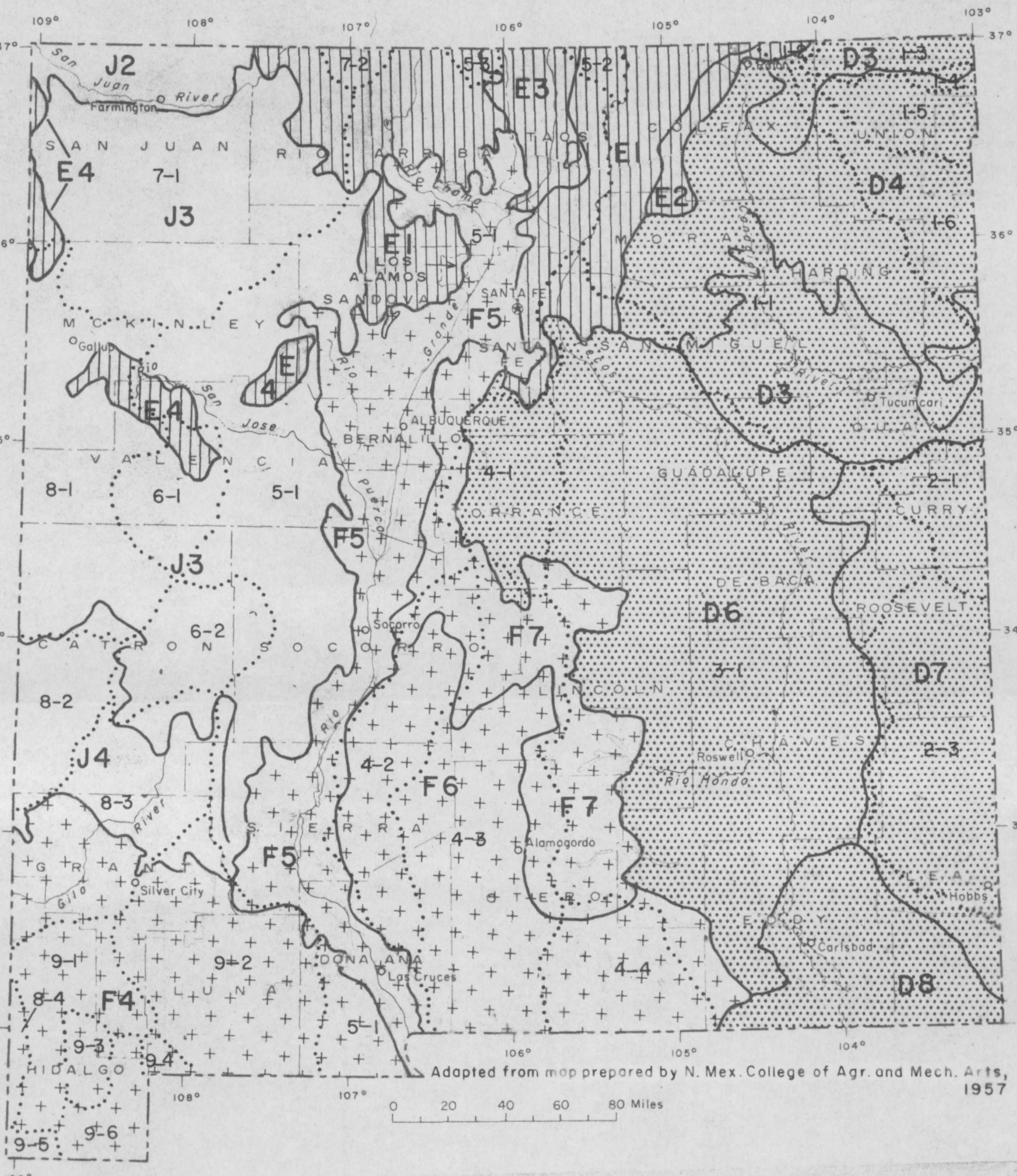
2. In ordering materials or requesting information, mark the area of interest on this index and forward it with your order. A new copy of the index will be returned to you for future use.

PUBLISHED MAPS

Published 7½′ or 15′ Quadrangles

State Index giving more detail available free. Published maps available at 30 cents each from U.S. Geological Survey, Denver Distribution Section, Federal Center, Bldg. 25, Denver, Colorado, 80225, or U.S. Geological Survey, Washington, D.C., 20242. On orders amounting to $10 or more a 20 percent discount is allowed; on orders amounting to $60 or more a 40 percent discount is allowed. Remittance may be made by check, money order or cash. Checks or money orders should be made payable to the U.S. Geological Survey.

Figure 3.--Status of ~~T~~ topographic mapping in New Mexico.



D_3 Generally shallow soils in steeply rolling and rough broken areas. Moderately deep and deep soils in valley bottoms and alluvial fans.

D_4 Largely moderately deep to deep, medium to heavy-textured soils interspersed with some areas of shallow soils; generally gently rolling topography.

D_6 Dominantly moderately deep to deep, medium-textured soils with rolling topography, interspersed with areas of shallow soils and deep sandy soils with dune-like topography.

D_7 Generally loose sandy soils with dune-like topography east of Pecos river, interspersed with areas of shallow to moderately deep, medium to heavy-textured soils west of Pecos river.

D_8 Similar to D-7, east of Pecos river, interspersed with areas of shallow to moderately deep, medium-textured soils west of Pecos river.

E_1, E_2, E_3, E_4 Largely shallow to moderately deep, light to medium-textured soils with rolling to mountainous topography. Generally shallow soils on escarpments and mountainous areas.

F_4 Generally light to medium-textured, deep and shallow soils with rolling topography, interspersed with low mountains. Dominantly shallow soils and rock outcrops in mountainous areas.

F_5 Large areas of light to medium-textured, shallow to moderately deep soils with gentle to moderate slopes.

F_6 Mesas, benchlands, and mountain slopes. Largely light to medium-textured, shallow to moderately deep soils on mesas and benchlands, and gravelly shallow soils on mountain slopes and foothills.

F_7 Largely mountain ranges and foothill slopes. Dominantly medium-textured soils on mountain slopes, and moderately deep to deep soils on foothill slopes.

J_2 Dominantly medium-textured, shallow soils on steep slopes. Medium-textured moderately deep soils on sloping plains, and dissected mesas; and medium to heavy-textured deep soils in valleys.

J_3 Largely medium-textured, moderately deep to shallow soils interspersed with areas of light-textured soils. Generally rolling topography with steep slopes in mountainous areas.

J_4 Generally mountainous shallow soils interspersed with rock outcrops and small areas of moderately deep soils. Generally mountainous topography.

2-1

Outline of river basins

Figure 4.--Soils resource map of New Mexico

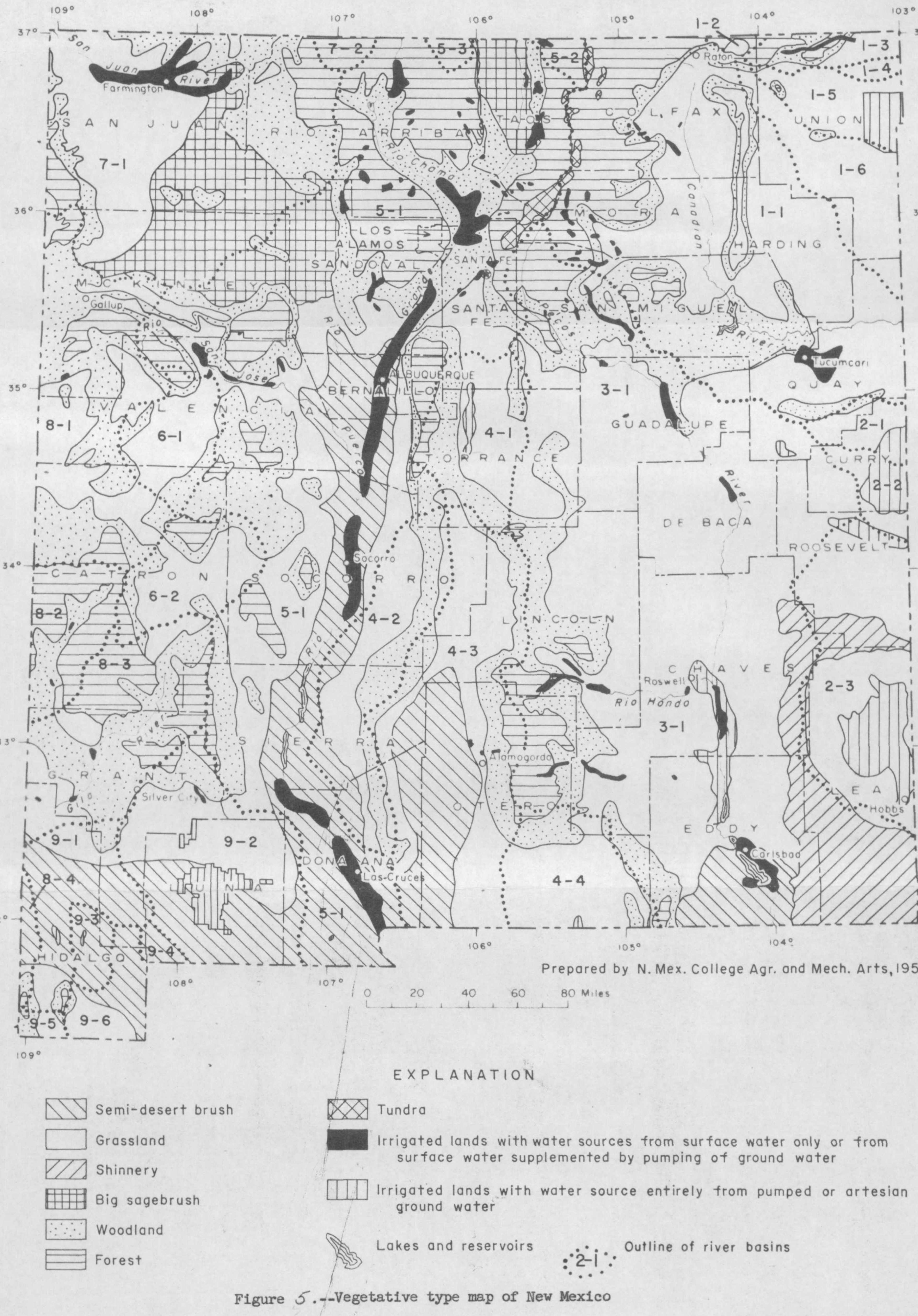
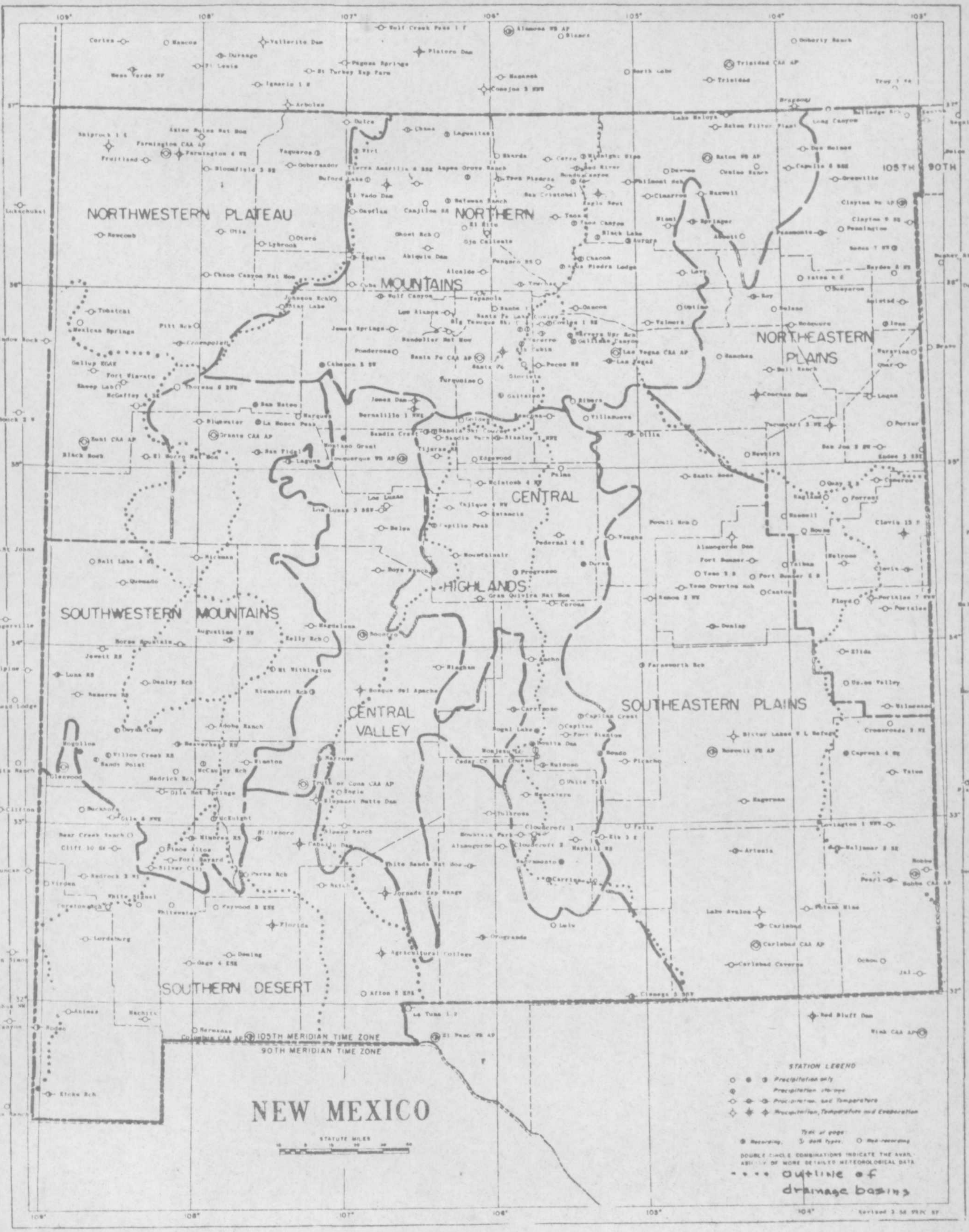


Figure 5.--Vegetative type map of New Mexico



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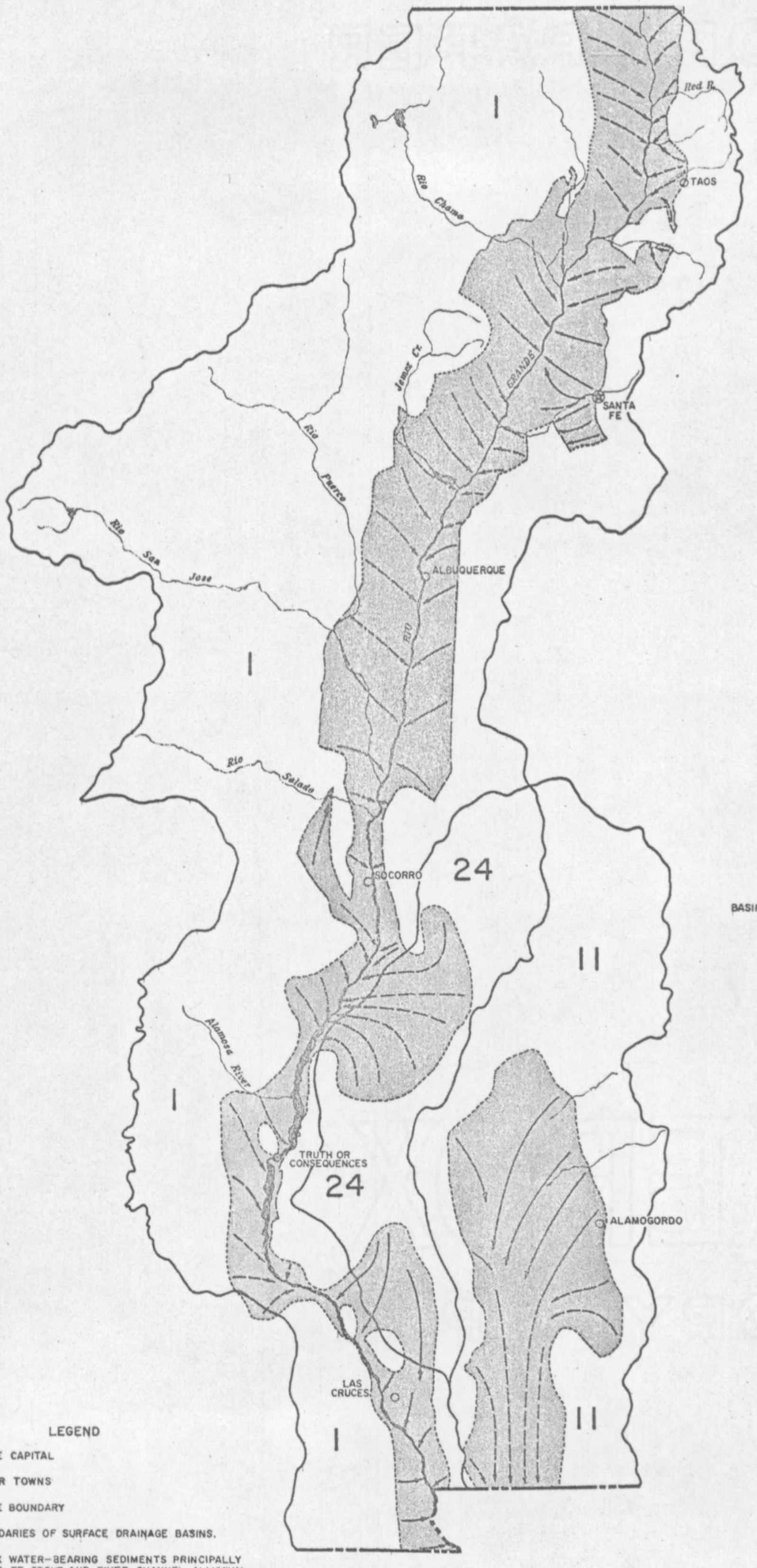
U.S. GOVERNMENT PRINTING OFFICE: 1959 O - 533379

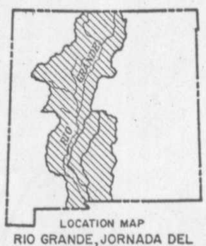
Figure 6.--Weather stations and climatologic divisions in New Mexico



DRAINAGE BASIN INDEX

I - RIO GRANDE
II - TULAROSA
24 - JORNADA DEL MUERTO

BASIN NUMBERS CORRESPOND TO THOSE USED IN FIGURE 16



LOCATION MAP
RIO GRANDE, JORNADA DEL MUERTO, & TULAROSA DRAINAGE BASINS IN NEW MEXICO

LEGEND

- STATE CAPITAL
- OTHER TOWNS
- STATE BOUNDARY
- BOUNDARIES OF SURFACE DRAINAGE BASINS.
- THICK WATER-BEARING SEDIMENTS PRINCIPALLY SANTA FE GROUP AND RIVER CHANNEL ALLUVIUM.
- FAULT BOUNDARY OF THICK WATER-BEARING SEDIMENTS (DOTTED WHERE UNCERTAIN).
- APPROXIMATE LIMITS OF THICK WATER-BEARING SEDIMENTS.
- GENERALIZED DIRECTION OF GROUND-WATER MOVEMENTS IN THICK WATER-BEARING SEDIMENTS (DASHED WHERE UNCERTAIN).

FIGURE ~~31~~ 7

MAP SHOWING

GROUND-WATER RESERVOIR IN THE RIO GRANDE DEPRESSION

IN NEW MEXICO

10 5 0 10 20 30
SCALE IN MILES

COMPILED BY Z. SPIEGEL
DRAWN BY M.B. HUEY

JANUARY 1955

Figure 8.--General availability of relatively fresh ground water in New Mexico

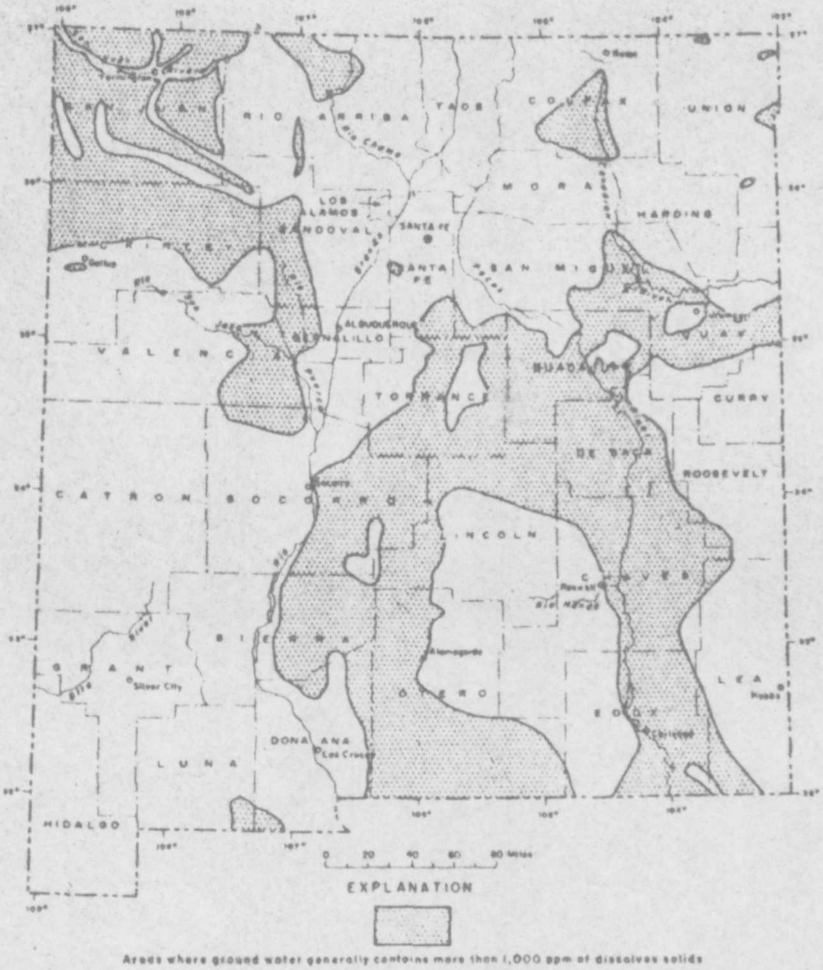


Figure 9.--General quality of shallow ground water in New Mexico

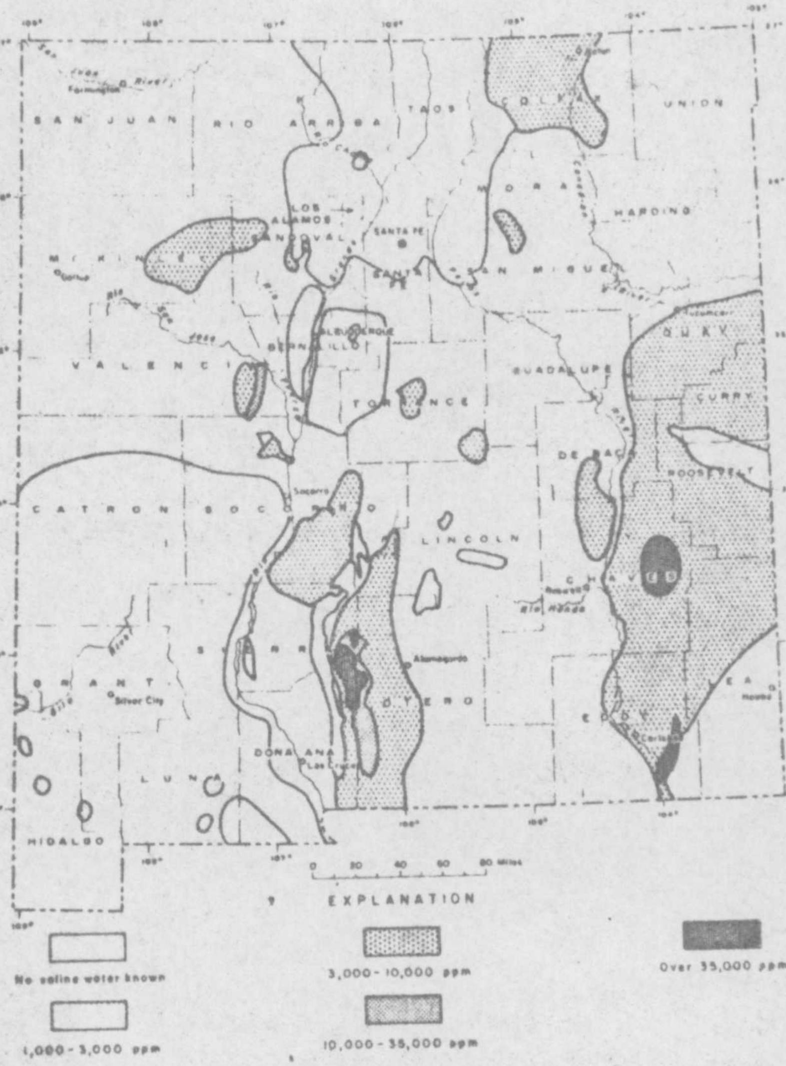


Figure 10.--General occurrence of saline ground water in New Mexico

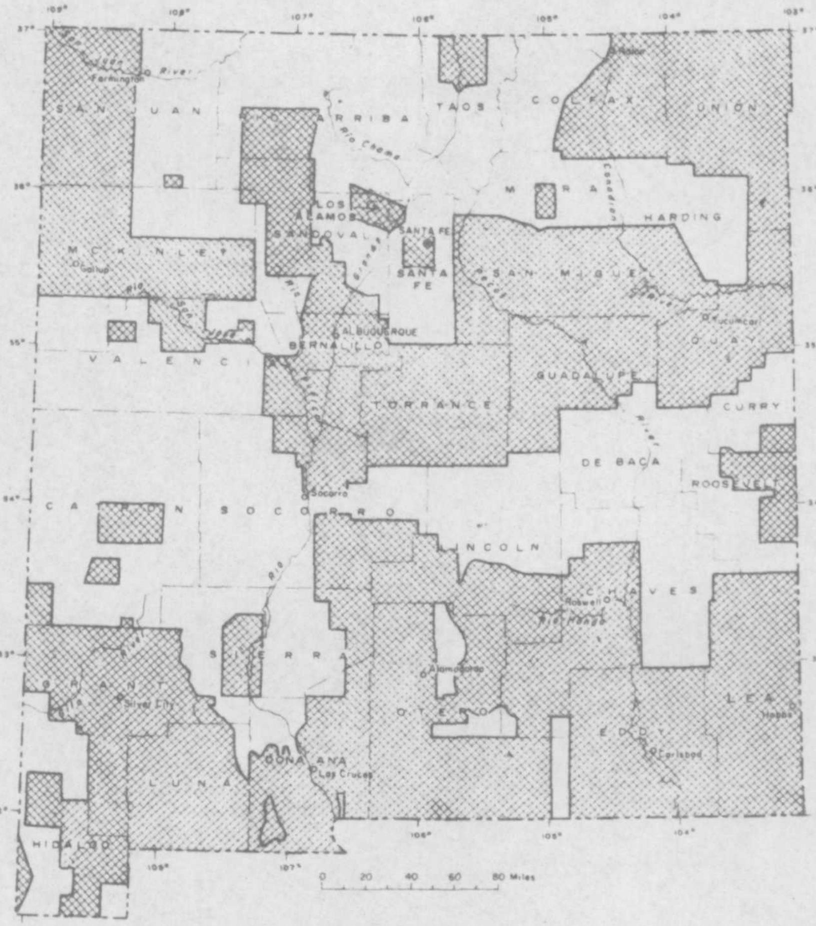


Figure 11.--Areas in New Mexico in which ground-water studies have been made.

Figure 12.--Areas of observation of water-level fluctuation in New Mexico