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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OFFICIAL BUSINESS

NM-123, Part 4

CENTRAL CLOSED BASINS

BY

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Part 4

Table 1.--Generalized stratigraphic section in the Central Closed Basins, New Mexico

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

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	Pediment, terrace, dune, playa, and other surficial deposits	Generally thin, but dunes may reach 40	Pediment and terrace deposits on bajadas. Dunes on valley flats and bajadas.	Gravel, sand, and silt; generally unconsolidated, but terrace deposits may be cemented by caliche.	Only playa deposits known to contain water -- this water highly saline.
	* Alluvium in present stream channels	Generally thin; probably less than 10	Pernnial and intermittent stream channels.	Unconsolidated sand and gravel.	Probably will yield small quantities of water to shallow wells where locally recharged by perennial streams; otherwise usually above zone of saturation. Water is generally fresh.
	Surficial volcanic rocks	0 to 300(?)	Large flows in northern parts of Jornada del Muerto and Tularosa Basin.	Massive to vesicular basalt with local breccia and scoria.	Not generally a water-yielding unit, but is recharge area for underlying aquifers.
	Lacustrine sediments	Probably 300 in Estancia and Salt Basins, unknown in Tularosa Basin	Central valley floors of Estancia, Tularosa, and Salt Basins.	Unconsolidated silt and clay, thin-bedded to minutely laminated; may contain few thin sand and gravel beds.	Yield small to large volumes of very highly saline water to wells.
Quaternary and Tertiary(?)	* Alluvial bolson sediments	0 to 300 in Estancia Basin; 0 to 1,000+ in Jornada del Muerto; 0 to 4,900 in Tularosa Basin; 0 to 500 in Salt Basin	Basin-filling sediments, interfingers with lacustrine sediments in centers of all but Jornada del Muerto.	Unconsolidated to compacted and moderately consolidated silt, clay, sand and gravel. Generally coarse near upland sources at basin sides, finer and better sorted toward basin centers.	Yield small to large volumes of potable to saline water to wells. Largest yields obtained from wells on bajadas penetrating thick sections of moderately well-sorted sand and gravel -- maximum yields: Estancia Basin, 2,380 gpm; Jornada del Muerto, 1,000+ gpm; Tularosa Basin, 1,000+ gpm; Salt Basin, 840 gpm. Fresh water mostly from wells on bajadas near sides of basin, grades to highly saline water toward basin centers and, commonly, at depth.
Quaternary(?) and Tertiary(?)	* Santa Fe Group	Maximum probably about 2,000 on west side of area	Southern and northwestern parts of Jornada del Muerto.	Poorly consolidated, thin-bedded silt, clay, sand, and gravel.	Yields large quantities of water to deep wells in Rio Grande trough and probably would also where thick in Jornada del Muerto. Water generally fresh to moderately saline.

Table 1.—Generalized stratigraphic section in the Central Closed Basins, New Mexico - Continued

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Tertiary	Rhyolitic to andesitic volcanic rocks (includes Datil Formation)	Maximum probably 2,000	Crops out locally on both sides of Jornada del Muerto and Tularosa Basin; presumed to underlie parts of both basins.	Massive, to thin-bedded flows, locally interbedded sandstone, conglomerate, tuff.	Usually will yield no water. Locally, small quantities might be developed from interbedded clastic rocks.
	*Clastic sedimentary units including Love Ranch,1/ Palm Park,2/ Baca, and Thurman3/ Formations	Maximum probably 2,000 to 3,000	do.	Interbedded sandstone, siltsone, shale, conglomerate, tuff.	Water-bearing characteristics mostly unknown. Probably will yield small quantities of water to wells in much of area of occurrence. Quality of water uncertain.
Tertiary(?) and Cretaceous(?)	* Cub Mountain Formation of Bodine (1956)	500 to 1,000	East side of Tularosa Basin in vicinity of Three Rivers and Carrizozo.	Sandstone, siltstone, and shale.	May yield small quantities of fresh water.
———?———	* McRae Formation4/	About 3,000	Central and northwestern Jornada del Muerto	Conglomerate, siltstone, and shale with locally interbedded andesitic tuff and breccia.	Do.
Cretaceous	* Mesaverde Group	500 to more tan 2,000	Northern parts of Estancia Basin, Jornada del Muerto, and Tularosa Basin.	Shale, siltstone, and sandstone with interbedded local coal.	Sandstone beds may yield small amounts of water, generally of saline to slightly saline quality.
	* Mancos Shale	Maximum thickness more than 1,000	do.	Dark-gray, marine shale, locally with thin interbedded sandstone and limestone.	Do.
	* Dakota Sandstone	50 to 300	do.	Fine-grained, quartzitic sandstone with interbedded carbonaceous shale.	Do.

1/ of Kottlowski, Flower, Thompson, and Foster (1956)

2/3/4/ of Kelley and Silver (1952)

Table 1.-- Generalized stratigraphic section in the Central Closed Basins, New Mexico - Continued

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Triassic	* Dockum Group	0 to about 1,000	Northern parts of Estancia Basin, Jornada del Muerto, and Tularosa Basin. Depositional wedge-out to south. Wedge edge crosses centers of Jornada and Tulrosa Basin.	Red, purple shale and siltstone with interbedded sandstone.	Sandstone will yield small to moderate quantities of water to wells. Water generally slightly to moderately saline.
Permian	* San Andres Limestone	250 to 700	Crops out on east and south and underlies center of Estancia Basin, crops out and underlies central and northern Jornada del Muerto and Tularosa Basin.	Limestone, dolomite, sandstone, gypsum.	Yields generally moderately/ saline water to some wells on southern Chupedera Mesa (north of Tularosa Basin). Not known to yield water in Estancia Basin.
	* Glorieta Sandstone	50 to 300	Crops out on east and south and underlies center of Estancia Basin, crops out around and underlies northern Jornada del Muerto and Tularosa Basin.	Sandstone, usually well cemented.	Yields up to 3,000 gpm to wells where intensely fractured as in north-central Estancia Basin; elsewhere where saturated, may yield small to moderate quantities. Generally yields fresh to moderately saline water.
	* Yeso Formation	Few hundred to about 4,000	Widespread; crops out in or underlies much of Central Closed Basins area.	Sandstone, shale, gypusm, limestone.	Commonly yields small to moderate quantities of water to wells; locally in Estancia Valley up to 3,000 gpm is probably derived from fractured and cavernous limestone of the Yeso. Generally yields slightly to moderately saline water.
	* Bone Spring Limestone	1,600 where cropping out in Guadalupe Mountains	Crops out around and underlies most of Salt Basin. Interfingers with Yeso and lower part of San Andres to north.	Cherty, cavernous limestone, and siliceous shale.	Yields up to 3,600 gpm (with 10 feet of drawdown) to irrigation wells in Crow Flats area of Salt Basin. Generally yields fresh to slightly saline water.
	* Abo Formation	300 to 1,400	Crops out around and underlies Estancia Basin, and most of Jornada del Muerto and Tularosa Basin. Interfingers with Hueco Limestone to south.	Shale with interbedded sandstone, and arkose.	Yields small quantities of water southwest of Estancia Basin; elsewhere not important as aquifer. Quality of water uncertain.
	* Bursum Formation	300 to 400	do.	Arkose, limestone, and shale.	Where saturated may yield small quantities of water to wells. Quality of water uncertain.

Table 1.--Generalized stratigraphic section in the Central Closed Basins, New Mexico - Continued

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Permian - Continued	Hueco Limestone	300 to 1,500	Crops out in Hueco Mountains between Salt Basin and Tularosa Basin, in Sacramento Mountains, and in San Andres Mountains. Thins northward.	Mostly limestone.	Not important as an aquifer.
Pennsylvanian ? (?)	*Magdalena Group	1,000 to 3,100	Crops out around all but Salt Basin; underlies all basins, usually at great depth.	Limestone with interbedded shale, sandstone, and arkose.	Yields small quantities of water in and near outcrop areas. Generally yields fresh water.
Mississippian	Sedimentary rocks	Variable but 1,400 maximum	Crops out around and underlies centers of all basins.	Sandstone, shale, and limestone.	Not important as aquifers.
Devonian	Sedimentary rocks	80 to 100	Crops out in Sacramento and San Andres Mountains and elsewhere around basins.	Thin units of shale, siltstone, and limestone.	Do.
Silurian	Fusselman Dolomite	0 to 1,000	Crops out in Sacramento Mountains and southern part of San Andres Mountains. Thins northward.	Massive, relatively pure dolomite.	Do.
Ordovician	Montoya Dolomite and	0 to 400	do.	Massive dolomite and limestone.	Do.
	El Paso Limestone	0 to 1,600	do.	Massive limestone and dolomite.	Do.

Table 1.--Generalized stratigraphic section in the Central Closed Basins, New Mexico - Concluded

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Ordovician and Cambrian	Bliss Sandstone	0 to 225	Crops out in Sacramento and San Andres Mountains. Thins northward.	Sandstone, quartzite, and shale.	Not important as aquifers.
Precambrian	*Metamorphic and igneous rocks	-	-	Igneous and metamorphic rocks.	Yield small quantities of water to a few springs in outcrop areas. Quality of water uncertain.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Albuquerque, New Mexico

Central Closed Basins

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(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

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Central Closed Basins

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Description

The Central Closed Basins consist of four basins of interior drainage extending from the central part of the State to the Texas border (fig. 1). The basins are Estancia Valley--mostly in Torrance

Figure 1 (caption on next page) belongs near here.

and Santa Fe Counties; the Jornada del Muerto--mostly in Socorro, Sierra, and Dona Ana Counties; the Tularosa Basin--astride the boundaries between Socorro, Lincoln, Sierra, Otero, and Dona Ana Counties; and the Salt Basin--the northern one-fourth of which is mostly in Otero County and the remainder in Texas. Contained within the Central Closed Basins are the towns of Estancia, Moriarty, and Mountainair in Estancia Valley, the villages of Engle and Organ in the Jornada del Muerto, and the towns of Carrizozo, Tularosa, and Alamogordo in the Tularosa Basin.

Figure 1.--Drainage basins of New Mexico.

Geography

The topographic divide surrounding Estancia Valley is formed in large part by the Sandia and Manzano Mountains on the west, Chupadera Mesa and Gallinas Peak on the south, and the Pedernal Hills on the east. The total drainage area is approximately 2,220 square miles. The basin has no perennial streams, and the centripital channels around the broad, flat floor of the basin carry runoff only following local rainfall. Numerous small to large playas with surfaces 20 feet or so below the general level of the valley floor lie in the central part of the valley floor. The usually dry stream courses around the sides of the valley broaden and disappear on the gentle slope as they near the valley floor. None of the channels reach the playas.

The Jornada del Muerto is separated on the east from the Tularosa Basin by the long line of the Sierra Oscura and San Andres Mountains. On the west the central part of the Jornada is bounded by the Fra Cristobal and Caballo Mountains. At the north and south ends of the Jornada del Muerto, however, the topographic divides between this basin and the adjacent Rio Grande Valley are low and indistinct. Much of the area might contribute runoff to the Rio Grande were it not for the very scant precipitation and low gradients which allow the water to soak in or to evaporate before flowing any great distance. The area of the Jornada is about 3,475 square miles. Runoff into the basin from the bounding highlands, similar to most of the other Central Closed Basins, occurs only following local rainfall.

The Tularosa Basin lies west of the mountain chain formed by Sierra Blanca and the Sacramento, and Hueco Mountains. On the west it is separated from the Jornada del Muerto by the Oscura and San Andres Mountains. On the southwest it is separated from the Rio Grande trough by the Organ and Franklin Mountains. A low topographic divide, about 10 miles north of the Texas-New Mexico border, separates the Tularosa Basin into a large area of interior drainage in New Mexico and a smaller area having a gradient toward the Rio Grande in Texas. The total area of the Tularosa Basin in New Mexico is about 6,540 square miles, making this the largest of the basins of interior drainage in New Mexico. A few streams, such as Three Rivers Canyon and Indian Creek in the high mountains bounding the basin on the east, have perennial flow in their upper reaches. The flow quickly sinks into the permeable sediment at the foot of the mountains.

The Salt Basin, southeast of the Tularosa Basin, is separated from Tularosa by the Hueco Mountains and Otero Mesa; its northern boundary is the Sacramento Mountains, and its eastern boundary the Guadalupe Mountains. The Salt Basin in New Mexico includes an area of 2,370 square miles; an extension of the basin into Texas is possibly three times as large as the New Mexico section. Like the Tularosa Basin, perennial streamflow is limited to the headward parts of streams in the high mountains on the east and north sides of this basin.

The Central Closed Basins are all in the Basin and Range physiographic province (Fenneman, 1931). In general there is considerable relief between the central part of each basin and the highest point on the mountainous rim. The Sierra Blanca, 12,003 feet altitude, is the highest point in southern New Mexico. The altitude of the low point in the Tularosa Basin is about 3,900 feet. The lowest point in any of the Central Closed Basins is 3,700 feet in the Salt Basin near the New Mexico-Texas State line.

Topographic maps, on a scale of 1:250,000 in the 2-minute series of the Army Map Service, are available for the entire area of the Central Closed Basins. Recent topographic maps on scales of 1:62,500 or larger are available for most of the area (fig. 2). Areas not

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

covered by these $7\frac{1}{2}$- and 15-minute maps of the U.S. Geological Survey include the southeastern part of Estancia Valley, the northern extremities of the Jornada del Muerto and Tularosa Basin, and parts of the Salt Basin. Maps in the $7\frac{1}{2}$-minute series are being prepared for part of the Salt Basin by the U.S. Geological Survey.

Figure 2.--Status of topographic mapping in New Mexico.

Geology

Sedimentary rocks

The rock units cropping out over all but a small fraction of the total area of the Central Closed Basins are sedimentary. A composite stratigraphic section for the area is given in table 1. The large central parts of three of the basins are underlain by unconsolidated bolson sediments of Quaternary age; these sediments consist 1) of material deposited in lakes in the centers of the basins, and 2) of alluvial sediments deposited around the lake sediments by the streams that fed the lakes. This pattern holds for all but the Jornada del Muerto which had no large lake. Bolson deposits in the Jornada are entirely alluvial. This basin apparently is atypical in that it has had exterior surface-water discharge throughout most of its history.

The lacustrine sediments in the other three basins consist mainly of allochthonous, minutely-bedded silt and clay with large amounts of autochthonous gypsum. Because of the gypsum, the ground water in the lake sediments is all high in dissolved solids.

The alluvium, in contrast to the lacustrine sediments, is very poorly sorted, and consists of sand, gravel, silt, and clay. It tends to be coarsest near the foot of the mountains surrounding the basins and becomes finer toward the basin centers. The alluvium in the central part of the Jornada del Muerto, even though this basin had no lake, is extremely fine and consists almost entirely of silt and clay. Where the alluvium has adequate thickness it is usually a reliable source of ground water. The quality of water in the alluvium ranges from good to poor, with saline water restricted generally to areas close to the zone where the alluvium interfingers with the lake sediments and to areas where recharge to the alluvium is from older rocks containing highly mineralized water.

Paleozoic, Mesozoic, and early Cenozoic (Tertiary) formations crop out in the mountainous areas surrounding the basins, and underlie the unconsolidated Quaternary bolson deposits that floor the basins. Here and there the older rocks stick up through the bolson deposits. Usually the older rocks are much less permeable than the bolson sediments, and yield much smaller quantities of water to wells. Locally, however, they may be highly permeable where fractured, or in the case of limestones, where honeycombed by solution channels. The quality of the ground water contained in bedrock aquifers is highly variable depending on the lithology of the containing rocks.

Igneous rocks

Intrusive rocks crop out locally, forming relatively small parts of the mountain masses around the basins. Among the larger intrusive masses in the area of the Central Closed Basins are those of Sierra Blanca and vicinity on the east side of the Tularosa Basin and the Organ Mountains on the southwest side of the Tularosa Basin; other examples are the Ortiz Mountains northwest of the Estancia Basin, the Jicarilla Mountains and Gallinas Peak on the northeast side of the Tularosa Basin, the Jarilla Mountains in the southern Tularosa Basin, and the Cornudas Mountains in the Salt Basin.

Extrusive igneous rocks comprise important parts of the Tertiary stratigraphic sequence in the Jornada del Muerto and the Tularosa Basin. The Quaternary basalt flows in the northern parts of the Jornada and the Tularosa Basin also have extrusive igneous origins.

Economic mineral deposits

Numerous mining districts are located in the mountainous areas bounding the basins. (See Northrop, 1959.) Mining activity has been nil in recent years. New Mexico mining districts within the Central Closed Basins that have produced more than 1 million dollars worth of copper, zinc, silver, gold, and lead include the Organ District at the south end of the Jornada del Muerto (4 million dollars, between 1869 and 1952), White Oaks District on the northeast side of the Tularosa Basin (3.1 million dollars, between 1879 and 1940), and the Orogrande District in the southern part of the Tularosa Basin (1.6 million dollars, between 1879 and 1929). Fluorite and barite have also been mined at many localities in the area. The playas in Estancia Basin, and also in the Tularosa Basin, have historic importance as sources of salt. Coal has been mined from the Carthage Field in the northern part of the Jornada del Muerto and from the Sierra Blanca Field in the northeastern part of the Tularosa Basin. These fields had measured original reserves of 19.7 and 3.3 million short tons of bituminous coal respectively.

Geologic mapping

A geologic map of the State of New Mexico has recently been published in four sections by the Geological Survey in the Miscellaneous Geologic Maps series (Dane and Bachman, 1957, 1958, 1961; Bachman and Dane, 1962). On each section are listed the more detailed maps from which the section was compiled. The Geologic Map Index of New Mexico compiled by Boardman and others (1956) is a comprehensive list and outline of areas of all geologic maps in the State published prior to 1956.

Soils and Vegetation

Major soil groups represented in the Central Closed Basins are shown on figure 3. In general soils near mountains are light and

Figure 3 (caption on next page) belongs near here.

soils in the broad valleys at some distance from the mountains (or near outcrops of clay or shale) are heavier. Caliche (secondary carbonate cement) is frequently found in soils in the area.

The life zones in the Central Closed Basins range from Lower Sonoran to Canadian, or possibly Hudsonian (fig. 4). The playas and salt flats

Figure 4 (caption on next page) belongs near here

have no vegetation. Except for the playas, the lower elevations are overgrown with grass and/or brush. At progressively higher elevations are piyon-juniper associations, a transition zone of ponderosa pine and juniper, a spruce-fir association, and finally, above an altitude of 11,000 feet, a possible subalpine association that includes arctic willow. Martin (1964) has summarized the life associations for the Sierra Blanca area, and his summary is generally applicable to the entire area of interest. The distribution of the plant life is illustrated in figure 5.

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

Figure 3.--Soils resource map of New Mexico.

Figure 4.--~~Map showing~~ Life zones of New Mexico.

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

Hydrology

The locations of weather stations in the Central Closed Basins are shown in figure 6. Mean temperatures and precipitation at selected

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places in the area are listed in table 2. The general distribution pattern of precipitation in New Mexico is shown in figure 7. More

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detailed climatological information is given in the monthly climatologic reports by the U.S. Weather Bureau, Department of Commerce.

Monthly pan evaporation rates for the Jornada Experiment Range are shown in figure 8.

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The interpolated evaporation rates from shallow reservoirs in New Mexico are shown on the map in figure 9.

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

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

Figure 7.--Mean annual precipitation in New Mexico, 1931-52.

Figure 8.--Mean monthly pan evaporation, in inches, at selected stations in New Mexico.

Figure 9.--Average annual evaporation, in inches, from shallow reservoirs in New Mexico.

Table 2.--Mean temperature and precipitation at places in the Central Closed Basins, New Mexico

(U.S. Weather Bureau, 1959)

Station	Division	January		February		March		April		May		June		July		August		September		October		November		December		Annual	
		Temp. (°F)	Prec. (inches)	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.	Temp.	Prec.
Carrizozo	Central Valley Division	37.1	0.75	41.0	0.77	46.8	0.73	55.2	0.70	63.6	0.95	72.5	1.14	75.3	2.19	73.8	2.27	67.9	2.08	57.3	0.92	44.4	0.55	38.4	0.83	56.1	13.88
Ancho	Central and Highlands Division	-	.99	-	.72	-	.91	-	.87	-	1.08	-	1.08	-	1.95	-	2.16	-	1.88	-	.99	-	.62	-	1.04	-	14.29
Cloudcroft 1		-	1.76	-	1.58	-	1.50	-	.90	-	1.20	-	1.99	-	5.77	-	4.57	-	2.60	-	1.47	-	.88	-	1.56	-	25.78
Corona		33.9	.88	37.4	.80	42.6	.81	50.6	1.03	58.5	1.47	67.3	1.15	70.0	2.58	68.7	2.74	63.4	2.12	54.2	.90	42.5	.57	35.8	.70	52.1	15.75
Gran Quivira NM		-	.71	-	.65	-	.68	-	.62	-	..92	-	1.17	-	2,43	-	2.97	-	1.80	-	.90	-	.51	-	.72	-	14.08
McIntosh 4 NW		29.7	.50	34.6	.46	40.6	.49	49.2	.72	57.4	1.17	66.4	.97	70.2	2.26	68.6	2.58	62.2	1.48	51.8	.83	39.2	.39	32.5	.48	50.2	12.33
Mescalero		-	.94	-	.99	-	.86	-	.70	-	.89	-	1.31	-	3.61	-	3.50	-	2.22	-	1.15	-	.87	-	1.13	-	18.17
Mountain Park		-	1.05	-	1.02	-	.87	-	.62	-	.74	-	1.33	-	3.15	-	3.08	-	2.03	-	1.30	-	.65	-	1.01	-	16.85
Mountainair		-	.84	-	.60	-	.65	-	.66	-	.93	-	.97	-	2.67	-	2.47	-	1.52	-	.97	-	.58	-	.91	-	13.77
Progresso		-	.59	-	.58	-	.56	-	.64	-	.99	-	1.16	-	2.75	-	2.50	-	1.72	-	.76	-	.44	-	.77	-	13.46
Tajique 4 NW		29.7	1.06	32.8	1.06	38.4	1.25	46.6	1.25	54.5	1.60	63.2	1.29	66.5	2.60	65.1	2.65	59.5	2.16	49.5	1.24	38.0	.91	32.1	1.12	48.0	18.19
Alamogordo	Southern Desert Division	-	.77	-	.54	-	.31	-	.37	-	.51	-	.75	-	1.68	-	1.42	-	1.60	-	.79	-	.42	-	.60	-	9.76
Jornada Exp. Range		39.2	.57	43.7	.45	49.7	.23	58.1	.26	66.0	.32	75.4	.59	79.5	1.63	77.8	1.45	71.7	1.57	60.4	.90	46.7	.40	40.4	.56	59.1	8.93
Orogrande		42.2	.50	46.9	.40	53.7	.25	62.2	.38	71.0	.47	80.7	.90	82.8	1.50	80.9	1,54	74.6	1.37	64.1	.92	49.7	.31	43.3	.47	62,7	9.01

Surface water

Nowhere in the Central Closed Basins is there a large supply of surface water. Most runoff occurs as floodflow following local rains. Neither the Estancia Valley nor the Jornada del Muerto have any significant perennial surface-water flow. The Tularosa Basin has perennial flow only from the flanks of Sierra Blanca in the vicinity of Three Rivers and Tularosa; the sketchy streamflow records from these areas constitute the only gage records in the entire area of the Central Closed Basins (see table 3). Sacramento River at the north end of the Salt Basin has perennial flow only in its upper reaches. The contours of mean annual runoff in New Mexico (fig. 10) show that the annual

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

runoff is less than half a foot in essentially all of the area of the Central Closed Basins.

The Rio Tularosa has an average runoff of 11,080 acre-feet of perennial flow per year near Tularosa (table 3). Alamo Creek, which is perennial at Wood Ranch near Alamogordo, has an annual runoff of 1,370 acre-feet. The New Mexico State Engineer Office has estimated that the total virgin streamflow from the east side of the basin is about 27,000 acre-feet annualy (written communication, 1964). With the exception of Rio La Luz, the streams near Three Rivers, and the two streams listed above, most of the estimated surface-water flow is from short-duration floods. The peak flood discharge that has been measured was 9,640 cfs (cubic feet per second) in Rio Tularosa near Tularosa in 1938.

Figure 10.--Mean discharge of principal streams in cubic feet per second, and mean annual runoff in inches in New Mexico.

Table 3

Surface water from Rio Tularosa, Rio La Luz, and Alamo Creek is diverted for municipal and irrigation use. Surface water from Three Rivers and Indian Creek is diverted for local irrigation.

In general neither the suspended-sediment load nor the chemical quality of water has in the past been monitored by the Geological Survey for the perennial streams in the Tularosa Basin. However, chemical analyses of water collected by the Geological Survey in 1963-64 from the Rio Tularosa near Bent show a maximum specific conductance of 1,760 micromhos and a maximum concentration of sulfate, the predominant anion, of 795 ppm (parts per million). In Three Rivers and Indian Creek, the average sulfate content of the water is probably about 100 ppm.

The only perennial flow of consequence in the Salt Basin is in the upper part of the Sacramento River at the north end of the basin. The New Mexico State Engineer Office has estimated (written communication, 1964) that the annual runoff for this river is somewhat less than 3,000 acre-feet.

Ground water

Aquifers in the Central Closed Basins, as elsewhere in the state, may be grouped into two broad catagories: bolson deposits and "bedrock." In general the bolson deposits are unconsolidated to poorly consolidated and are of Quaternary, sometimes Tertiary(?) and Quaternary age. "Bed-rock" is the generally consolidated and lithified older rock that crops out around the basins and forms the floors of the basins on which the bolson deposits rest. While it is recognized that the alluvium under present stream channels does not fit easily into this classification system, in the Central Closed Basins Recent alluvium apparently is not an important aquifer.

In this discussion alluvial sediments which form the bulk of the bolson deposits are distinguished from lacustrine sediments, which locally occupy the centers of all of the basins except the Jornada del Muerto. Figure 11 show the locations in New Mexico where

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

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alluvial deposits are important aquifers. The bolson alluvium is the most reliable aquifer in the area. The total volume of ground water produced from it probably exceeds the sum of water produced from all other aquifers combined. Pumping rates of 2,380 gpm (gallons per minute) in the Estancia Basin (Smith, 1957, p. 120) and 840 gpm in the Salt Basin (Bjorklund, 1957, p. 24) have been measured by Geological Survey personnel. At the southern end of the Jornada del Muerto and in the headquarters area White Sands Missile Range in the Tularosa Basin wells have been constructed that yield more than 1,000 gpm. Similar yields may be obtained elsewhere in these basins. In general the better wells are ~~located~~ in a relatively narrow zone around the sides of the basins, far enough basinward from the outcropping bedrock to penetrate a thick section of coarse-grained alluvium, but not so close to the basin center so as to tap the poor-quality ground water that is typical there.

Figure 11.--Principal sand and gravel aquifers in New Mexico.

Bedrock aquifers in the Central Closed Basins are usually sandstone or limestone (Figures 12 and 13). The known or probable

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

Figure 13 (caption on next page) belongs near here.

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aquifers tabulated in Table 1 are distinguished from stratigraphic units not known to be aquifers by asterisks. With the few notable exceptions described below, the bedrock aquifers yield only small to moderate quantities of water to widely spaced domestic or stock wells. The exceptions are the Bone Spring Limestone, the Yeso Formation, and the Glorieta Sandstone, all of Permian age. In the Salt Basin the Bone Spring Limestone is a prolific aquifer penetrated by many irrigation wells. This cherty, cavernous, and fractured limestone has yields measured at as much as 3,620 gpm with only 10 feet of drawdown (Bjorklund, 1957, p. 24). In the Estancia Basin a well that taps fractured limestone, probably of the Yeso Formation, reportedly was pumped at a rate of 3,000 gpm (Smith, 1957, p. 136). The water yielded by this aquifer, however, contained chlorides which ranged from ~~over~~ 900 to 6,000 ppm. Also in the Estancia Basin, the yield from an irrigation well producing from a fractured zone in the Glorieta Sandstone was measured at 3,040 gpm (Smith, 1957, p. 152). The production potential for generally potable ground water in New Mexico irrespective of aquifer is illustrated in Figure 14.

Figure 14 (caption on next page) belongs near here.

Figure 12.--Principal sandstone aquifers in New Mexico.

Figure 13.--Principal limestone aquifers in New Mexico.

Figure 14.--General availability of relatively fresh ground water in New Mexico.

Special mention is made of the Madera Limestone of Pennsylvanian age because of its importance as a source of domestic water in the Manzano Mountains bounding the Estancia Basin on the west. Yields from the formation are low--generally about 10 gpm. In some areas, particularly around the north end of the Manzanos, there are probably as many dry holes in the Madera as producing wells. The formation, which is on the order of 1,500 feet thick, is the only water-yielding unit over a large mountainous area that has had an increasing number of homes and summer cabins constructed in recent years.

The chemical quality of ground water in the Central Closed Basins is highly variable. The quality of water in bedrock aquifers generally reflects the presence and predominance of highly soluble minerals in the rocks. For example, water in many of the Cretaceous and Permian formations contains large amounts of sulfate, derived from gypsum in the rocks, whereas water in the Triassic formations commonly contains more chloride than sulfate. Other of the bedrock formations also frequently contain water that is high in dissolved solids. Under certain conditions, usually near the outcrop area where recharge occurs, most formations can contain ground water that is potable, owing 1) to the flushing of mineralized water from the aquifer, 2) to the short length of time that the water has been in contact with the soluble minerals, or 3) to the fact that the soluble minerals have been dissolved out by weathering. The general quality of shallow ground water in the state is shown on figure 15.

Figure 15 (caption on next page) belongs near here.

The salinity of the shallowest saline ground water is shown on figure 16.

Figure 16 (caption on next page) belongs near here.

Figure 15.--General quality of shallow ground water in New Mexico.

Figure 16.--General occurrence of saline ground water in New Mexico.

Water in the bolson sediments is also highly variable in chemical quality. (see Table 4.) In general the ground water from the central parts of the basins is highly saline, and thus is impotable; this includes all of the ground water in the lacustrine sediments. In the Jornada del Muerto, however, which has no lacustrine stratigraphic unit, ground water in fine-grained alluvium in the central part of the basin is of good to inferior quality, and does not generally contain as much mineral material in solution as ground water from the centers of the other basins. Sulfate and chloride are the most common contaminants; where neither sulfate nor chloride is present in excessive amounts, other chemicals are usually not present in such amounts as to be troublesome for drinking or irrigation. Sulfate commonly predominates over chloride, although in most saline water both are in excess of the limits required for potability. Ground water from parts of the Tularosa Basin contains more than 6,000 ppm of sulfate. In the shallow lacustrine sediments of Estancia Basin, however, chloride may be the dominant anion, occuring in concentrations greater than 6,000 ppm while chloride seldom goes over 3,000 ppm.

Table 4.--Chemical characteristics of water from selected wells which tap bolson deposits in the Central Closed Basins, New Mexico

Well location	Sulfate (ppm)	Chloride (ppm)	Hardness (as $CaCO_3$)	Specific conductance (micromhos at 25°C)
Estancia Basin				
Northern part	111	13	246	565
Central part	1,500	508	1,940	4,020
Southwestern part	32	14	160	370
Jornada del Muerto				
Northern part	2,150	42	-	3,430
Central part	905	49	-	1,500
Southeastern part	256	46	-	950
Tularosa Basin				
Northern part	2,050	94	-	3,350
Central part (White Sands)	2,970	2,540	-	-
Eastern part (Alamogordo)	489	96	-	1,380
Southwestern part (WSMR Hdq)	64	26	-	505
Salt Basin				
Northern part	435	17	680	1,150
Central part	2,230	82	2,470	3,530

Potable ground water in the alluvium of the Estancia Basin is generally more common and is available in larger quantities along the west side of the basin. In the Jornada del Muerto the west side and the south end of the basin generally contain water of better quality, although water of good to inferior quality may be obtained in all but the northern end of the basin. In the Tularosa Basin potable water is mostly restricted to the southeast side of the basin and to the east side in the vicinity of Alamogordo. Ground water of good to inferior quality may be obtained northward from Alamogordo along the east side of the basin. Small patches in which potable water may be found occur elsewhere in the basin such as in Mockingbird Gap. In the Salt Basin potable water in large quantities for irrigation is obtained west of the alkali flat that occupies the central part of the basin.

The total volume of potable water in storage in the alluvium can only be crudely estimated. To form such an estimate the saturated thickness of aquifers, their total area, and their porosity need to be known. In addition, the location and nature of the zones of contact between potable and impotable water need to be known. For each of the components listed above, the reliability of the available data is open to question. Therefore, except in the special case where all of the errors cancel each other out, the estimate resulting from their use will be wrong by a significant factor--perhaps by a factor of more than an order of magnitude. The following estimates thus should only be considered rude guesses. Furthermore, the volume of potable water estimated is not the volume of water that can be removed from the aquifers for use. In each of the basins the potable water is directly in contact with water that does not meet standards of potability. As potable water is removed from aquifers this impotable water will move in to contaminate well fields long before the potable water can all be removed.

The total volume of potable water stored in the Estancia Basin is estimated at roughly 2 million acre-feet. In the Jornada del Muerto an estimated 1.7 million acre-feet of potable water is stored, of which 1.5 million acre-feet is in the southern end of the basin (Herrick and others, 1961). In the Tularosa Basin an estimated 7.3 million acre-feet of potable water is stored, of which 6.5 million acre-feet is in the southwestern part of the basin south of the White Sands Missile Range Headquarters area (Knowles and Kennedy, 1956). In the Salt Basin the roughest sort of estimate suggests a storage of about half a million acre-feet. Thus the volume in storage may total 11.5 million acre-feet.

Ground-water studies have been made by the Geological Survey in most of the area of the Central Closed Basins. However, the Estancia Valley alone is covered in a published report (Smith, 1957). The work done on the Tularosa Basin and the part of the Jornada del Muerto that has been studied was done in cooperation with the White Sands Missile Range for the most part. Reports resulting from these studies are not published but exist only as open-file reports of the Geological Survey. The areas in the State that have been investigated are shown in figure 17.

Figure 17 (caption on next page) belongs near here.

The depth to water in the Central Closed Basins is highly variable as is shown in figure 18. In the vicinity of the playas lying in the

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Figure 18 (caption on next page) belongs near here.

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centers of most of the basins the water table is at or very near the surface. In contrast, along the sides of some of the basins, generally in the zones of thickest alluvium, the depth to water may be more than 500 feet.

Figure 17,--Areas in New Mexico in which ground-water studies have been made.

Figure 18.--Depth to ground water in New Mexico.

Periodic water-level measurements are made by the Geological Survey in a few parts of the Central Closed Basins where the demand for ground water is high (see fig. 19). The decline in water levels in

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Figure 19 (caption on next page) belongs near here.

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the Estancia Basin for the period 1948-60 is shown in figure 20. The

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Figure 20 (caption on next page) belongs near here.

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figure shows that in the area of most intensive pumping for irrigation the decline exceeds 25 feet. Other places in the Central Closed Basins in which periodic water-level measurements are made are White Sands Missile Range Headquarters and vicinity, the vicinity of Alamogordo-Tularosa, the vicinity of Carrizozo, and the central part of the Salt Basin. Water-level-change maps have not been prepared for these areas; however, in general water levels have declined in the areas of most intensive pumping.

Figure 19.--Areas of observation of water-level fluctuation in New Mexico.

Figure 20.--Decline of ground-water level in Estancia Valley, Santa Fe and Torrance Counties, New Mexico, for the period 1948-60.

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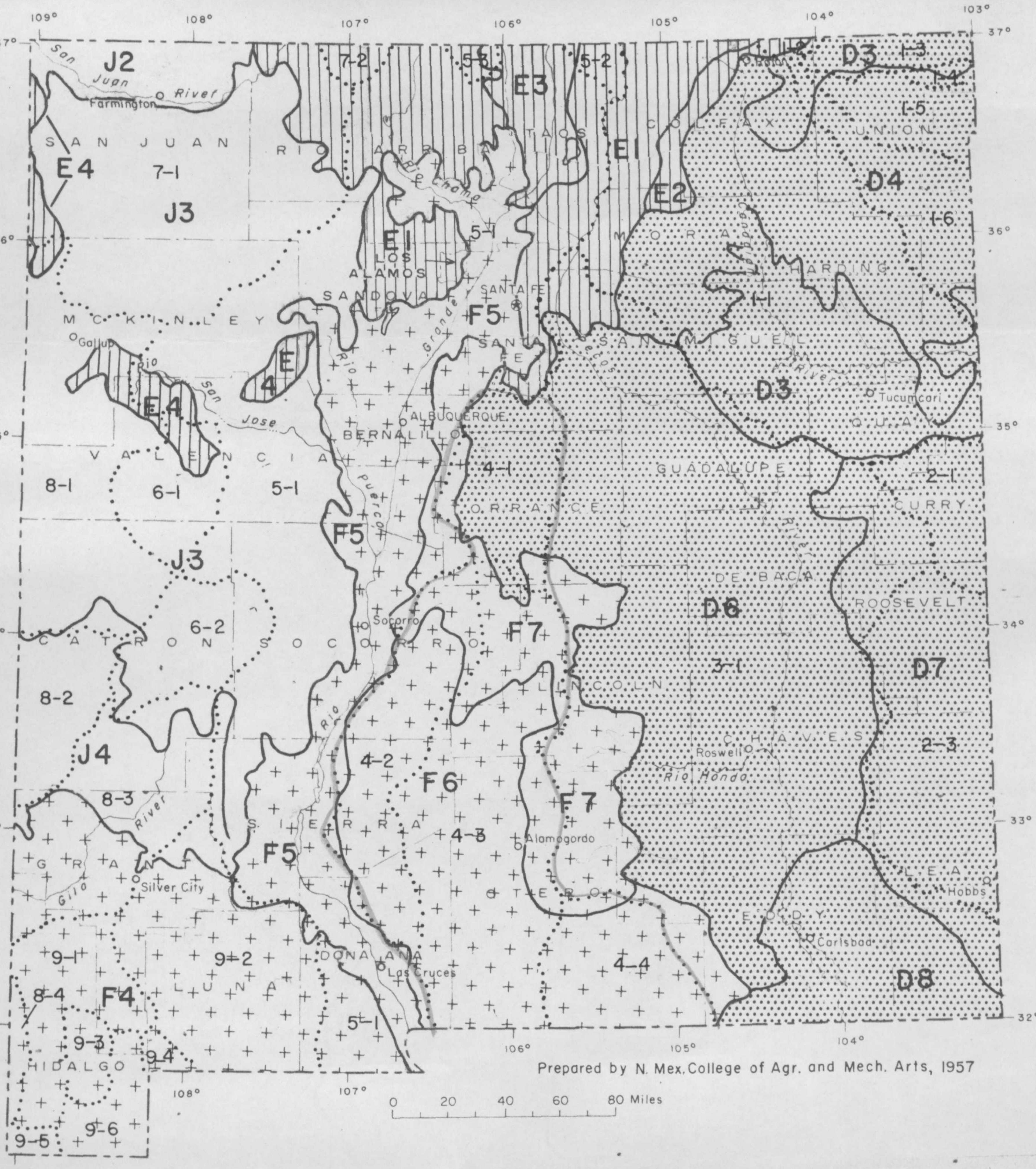


D_3 Generally shallow soils in steeply rolling and rough broken areas. Moderately deep and deep soils in valley bottoms and alluvial fans.

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.

2-1

Outline of river basins

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.

Fig. 3 - Soils resource map of New Mexico

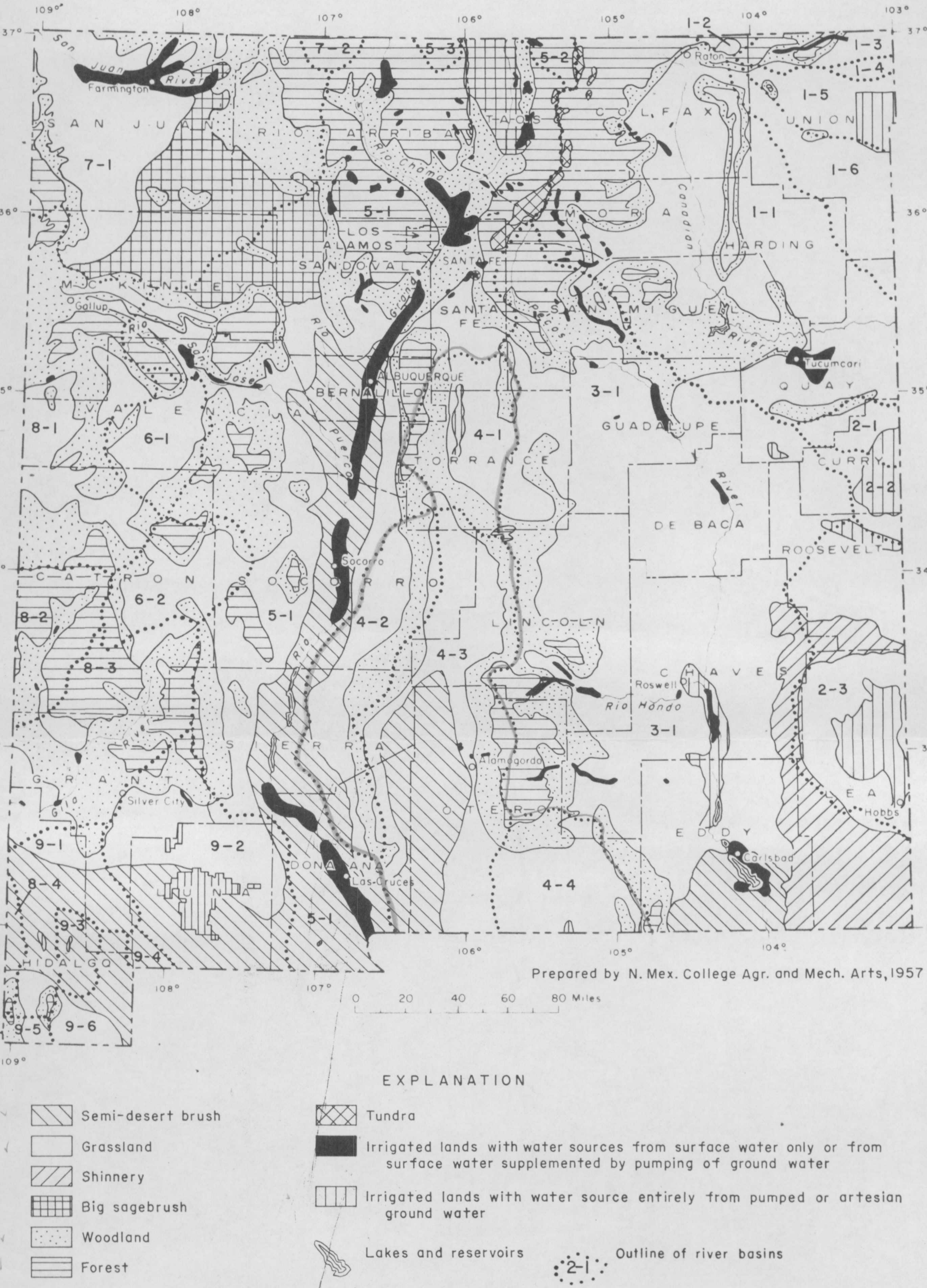
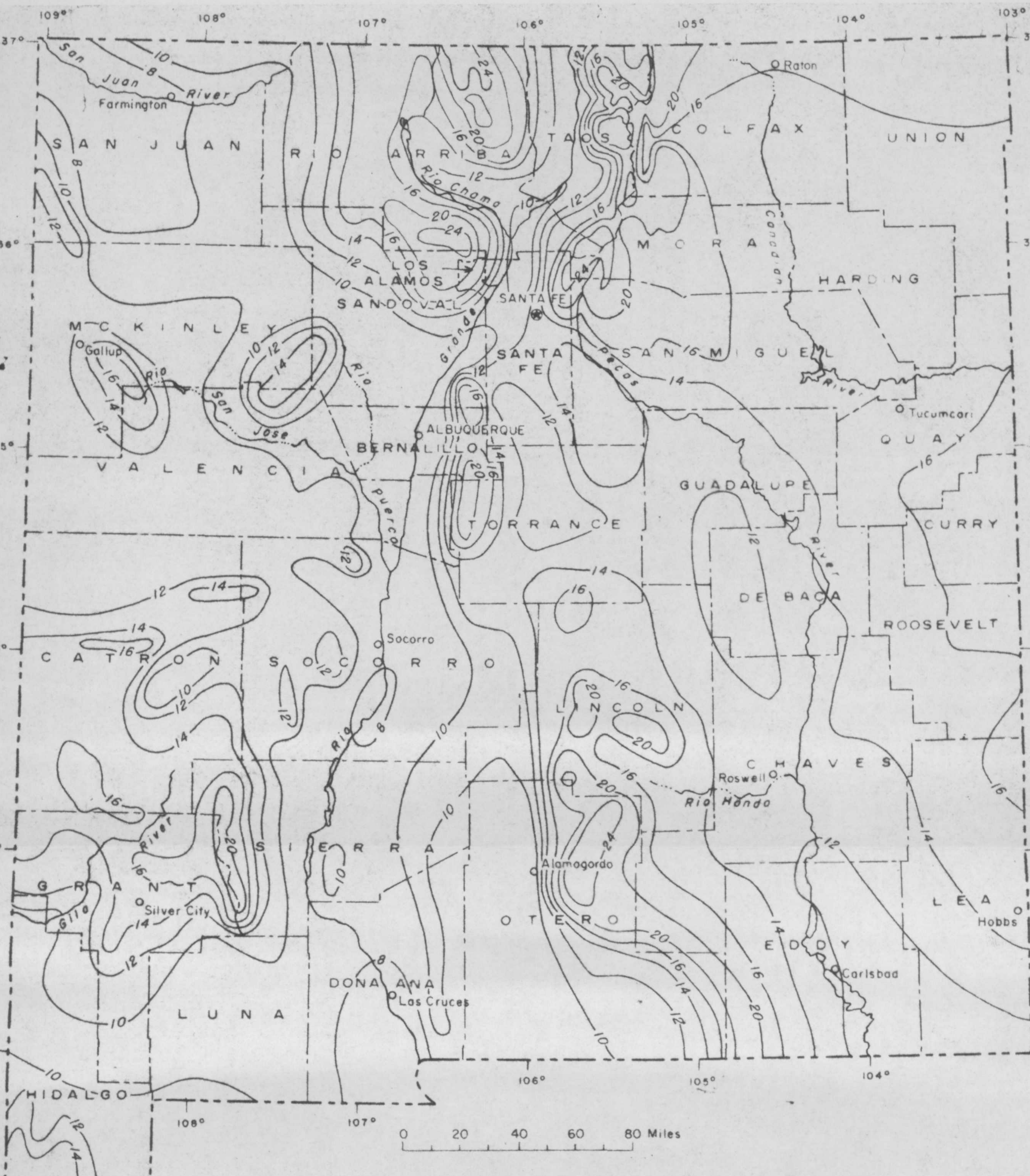


Fig. 5-- Vegetative-type map of New Mexico

Fig. 5



EXPLANATION

12

Contour showing equal annual precipitation, in inches, variable contour interval

FIGURE 7.--MEAN ANNUAL PRECIPITATION IN NEW MEXICO, 1931-52.

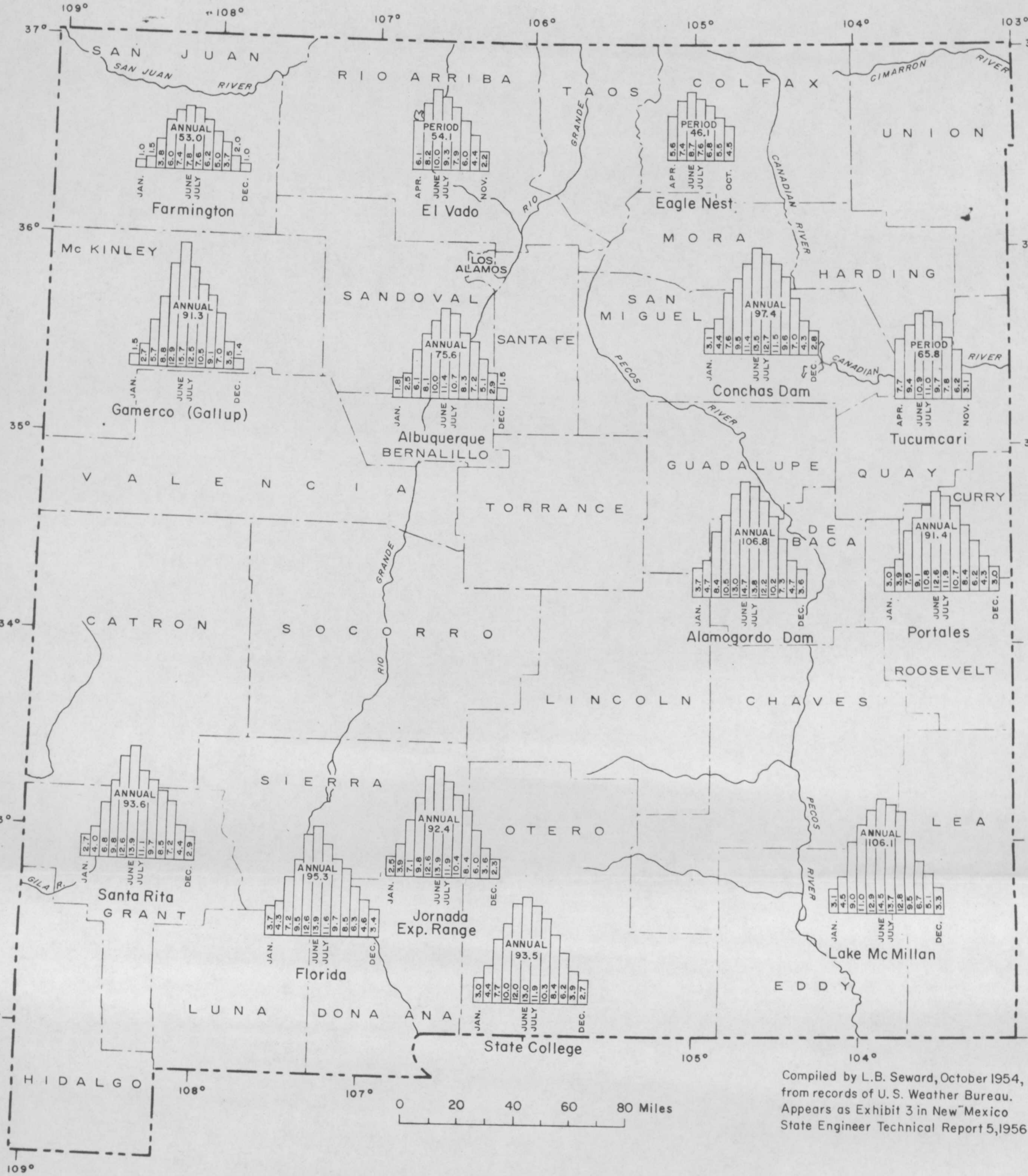
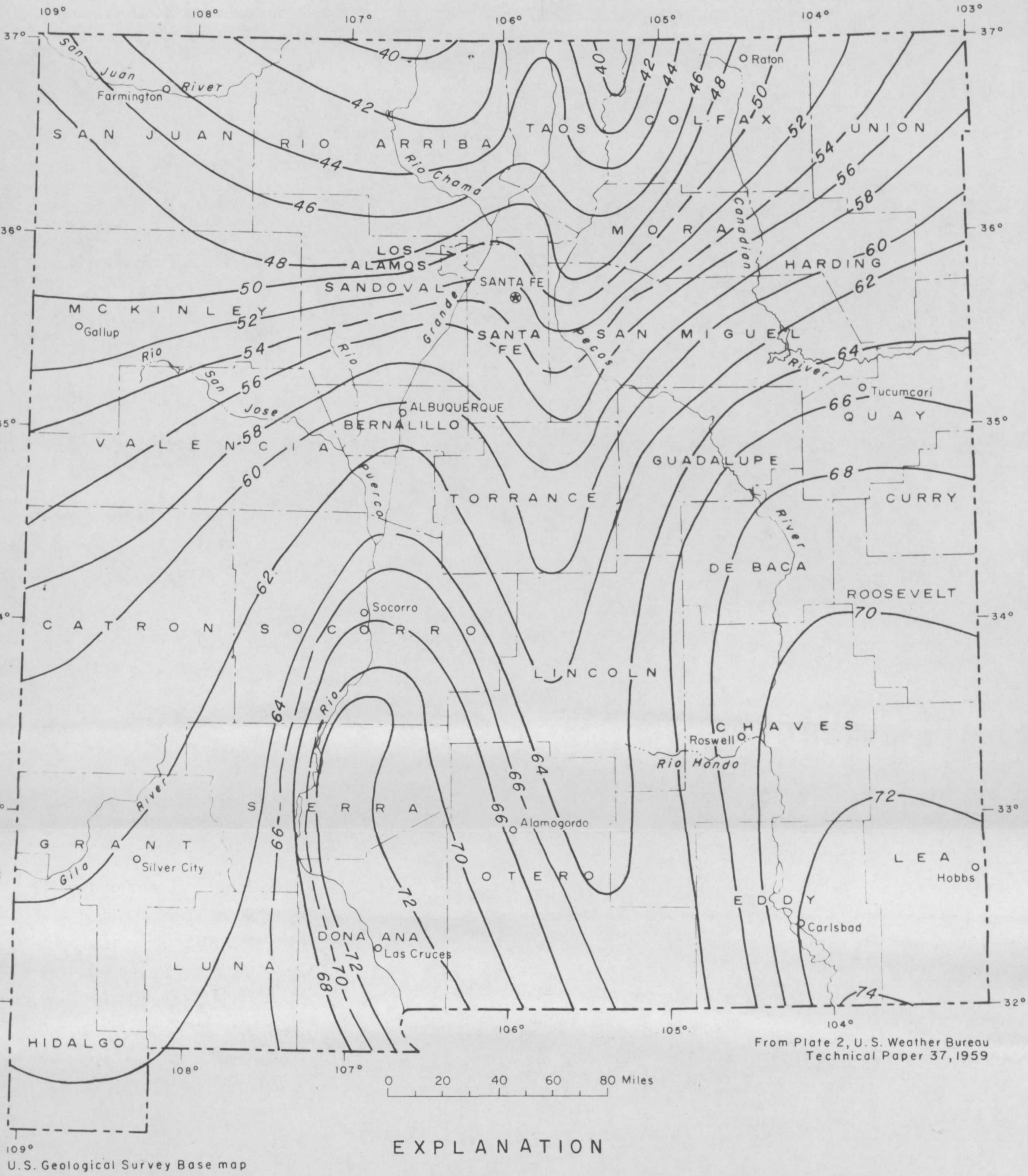


Figure 8--Mean monthly pan evaporation, in inches, at selected stations in New Mexico.



EXPLANATION

SEASONAL RESERVOIR EVAPORATION
(Applicable to shallow exposed reservoirs)

Month	Percent of annual	Month	Percent of annual
January	1	July	16
February	1	August	14
March	5	September	12
April	9	October	6
May	14	November	3
June	17	December	2

——66——

Lines of equal evaporation from shallow reservoirs, in inches

49

Figure 6.--Average annual evaporation, in inches, from shallow reservoirs in New Mexico (period 1946-55).

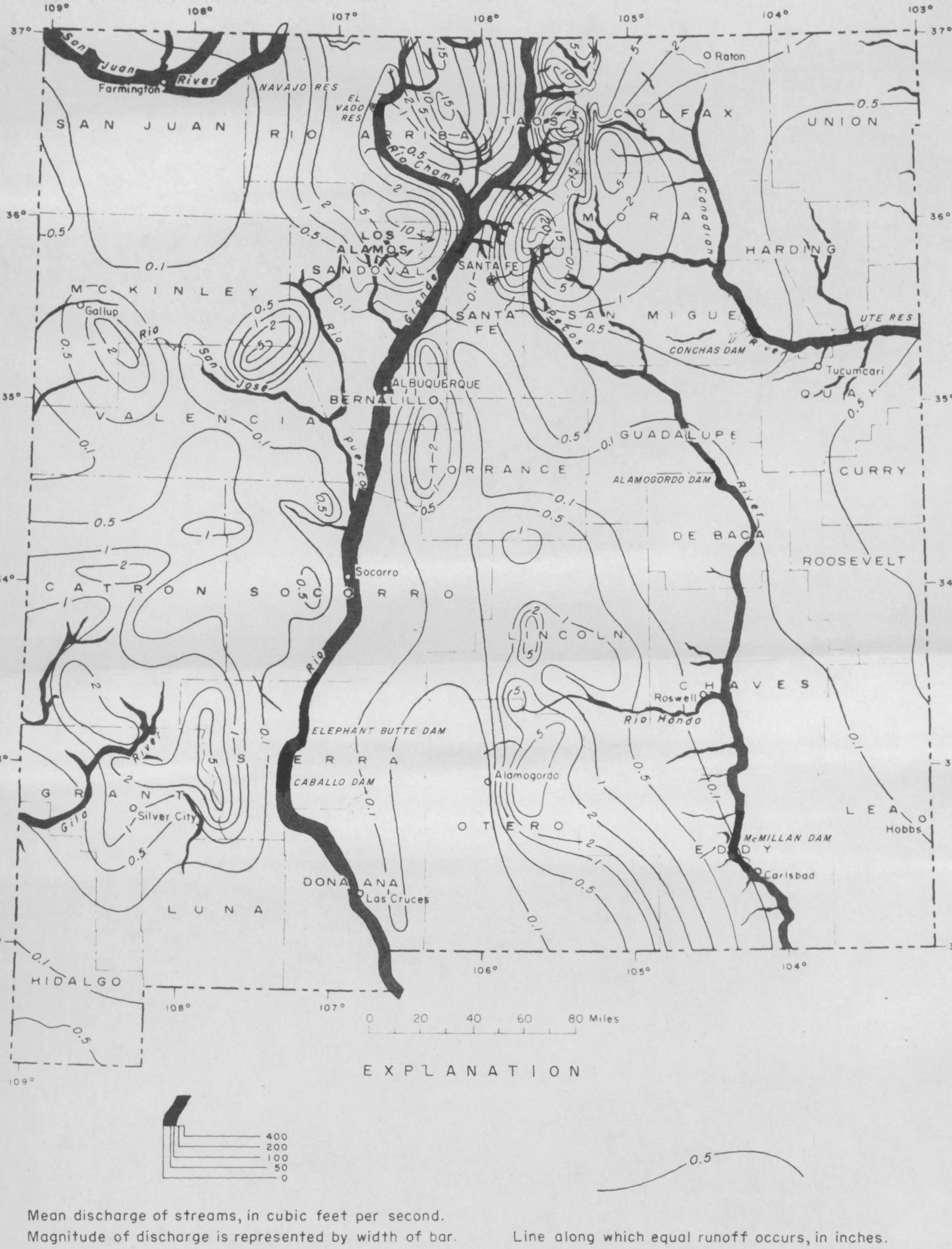


FIGURE 10.--MEAN DISCHARGE OF PRINCIPAL STREAMS IN CUBIC FEET PER SECOND, AND MEAN ANNUAL RUNOFF IN INCHES IN NEW MEXICO.

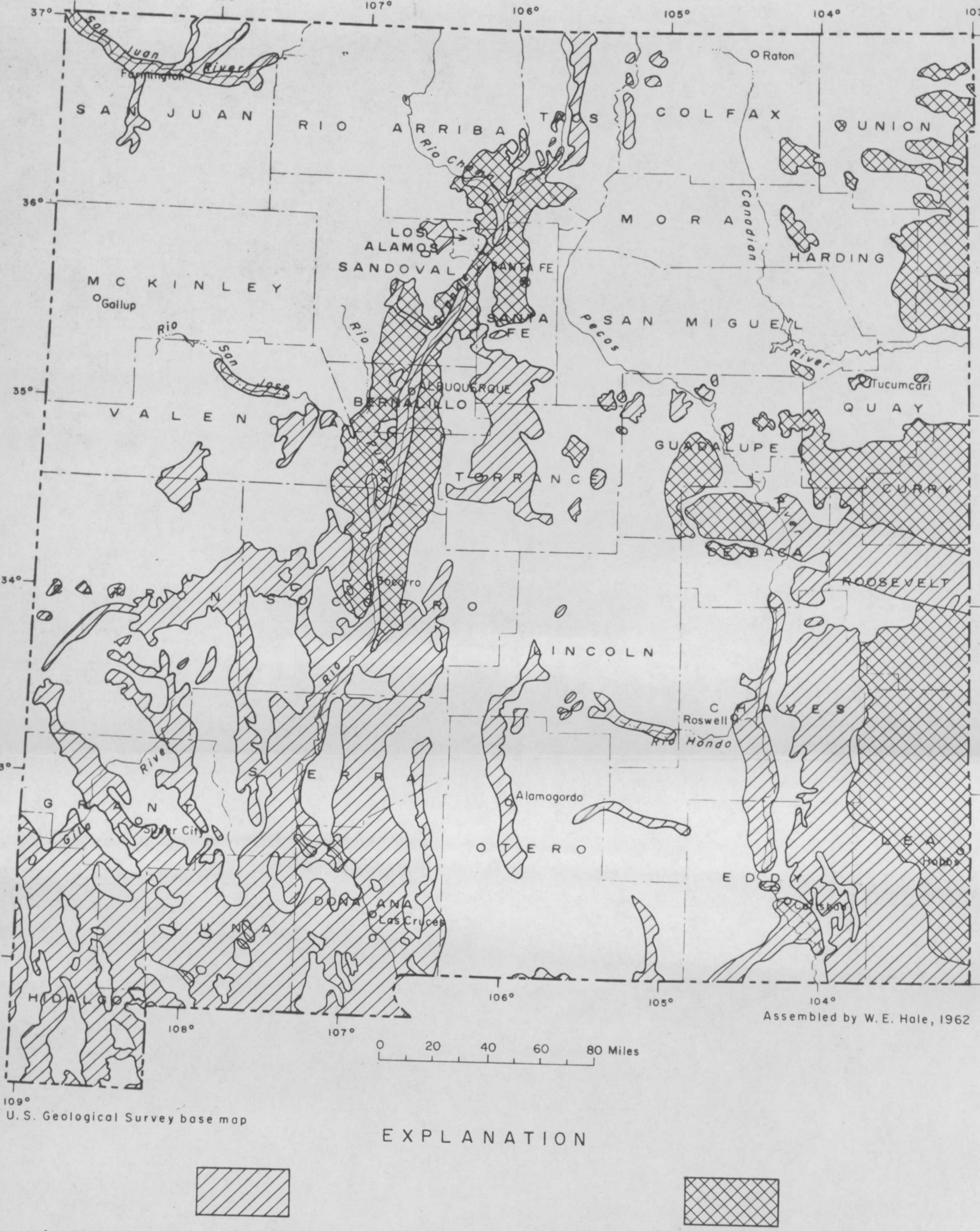


Figure .--Principal sand and gravel aquifers in New Mexico

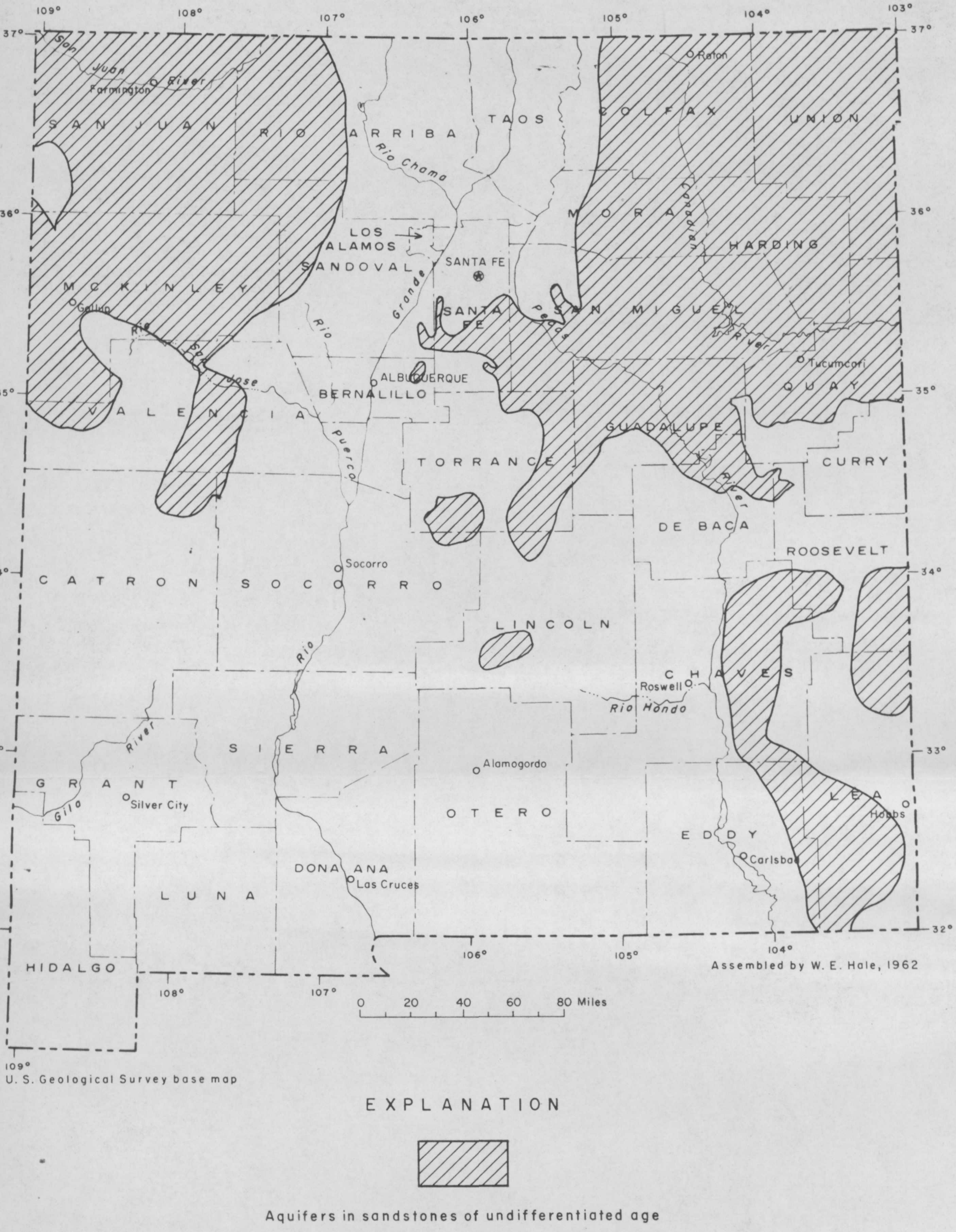


Figure 12.--Principal sandstone aquifers in New Mexico

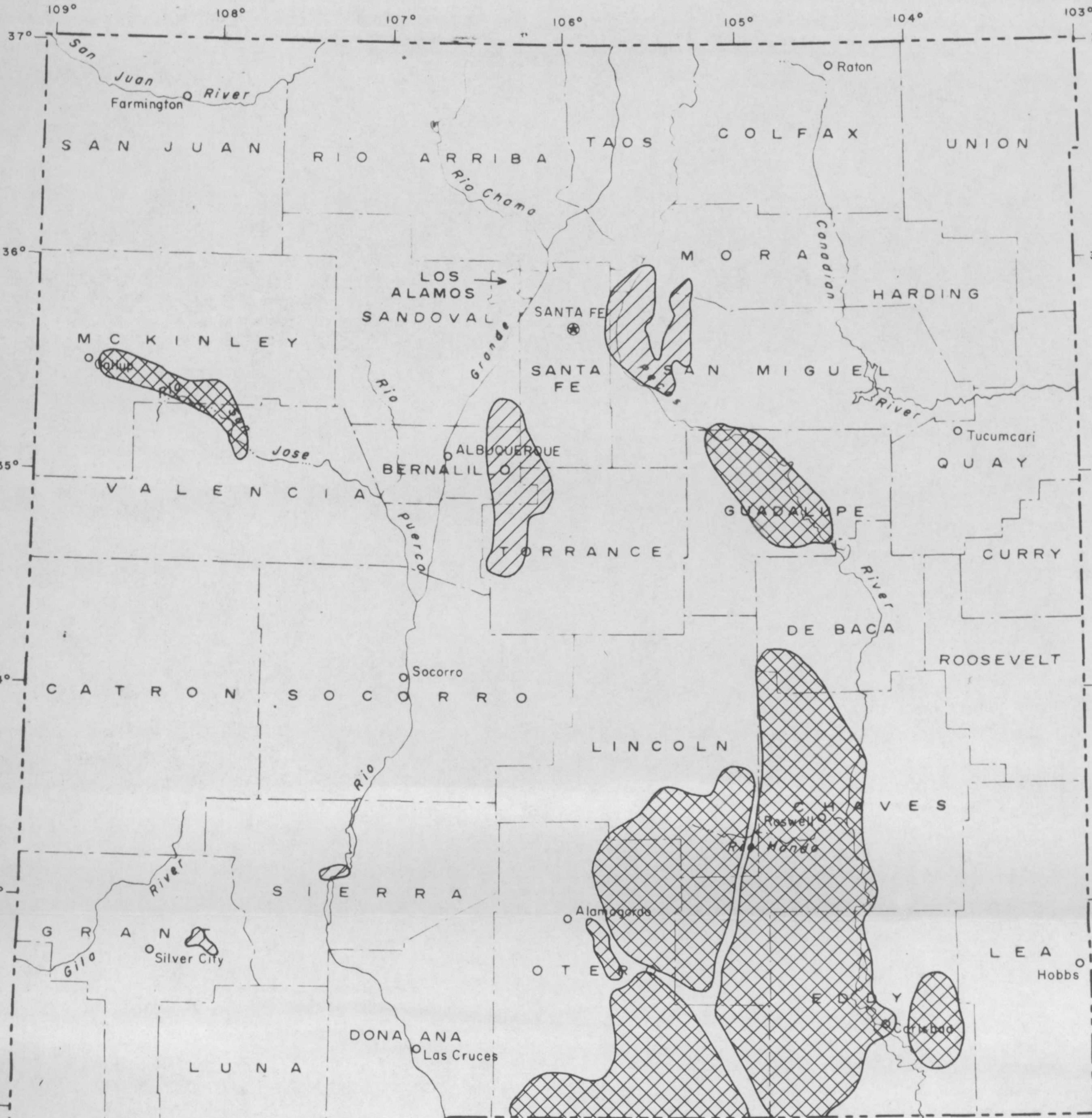


Figure 13.--Principal limestone aquifers in New Mexico

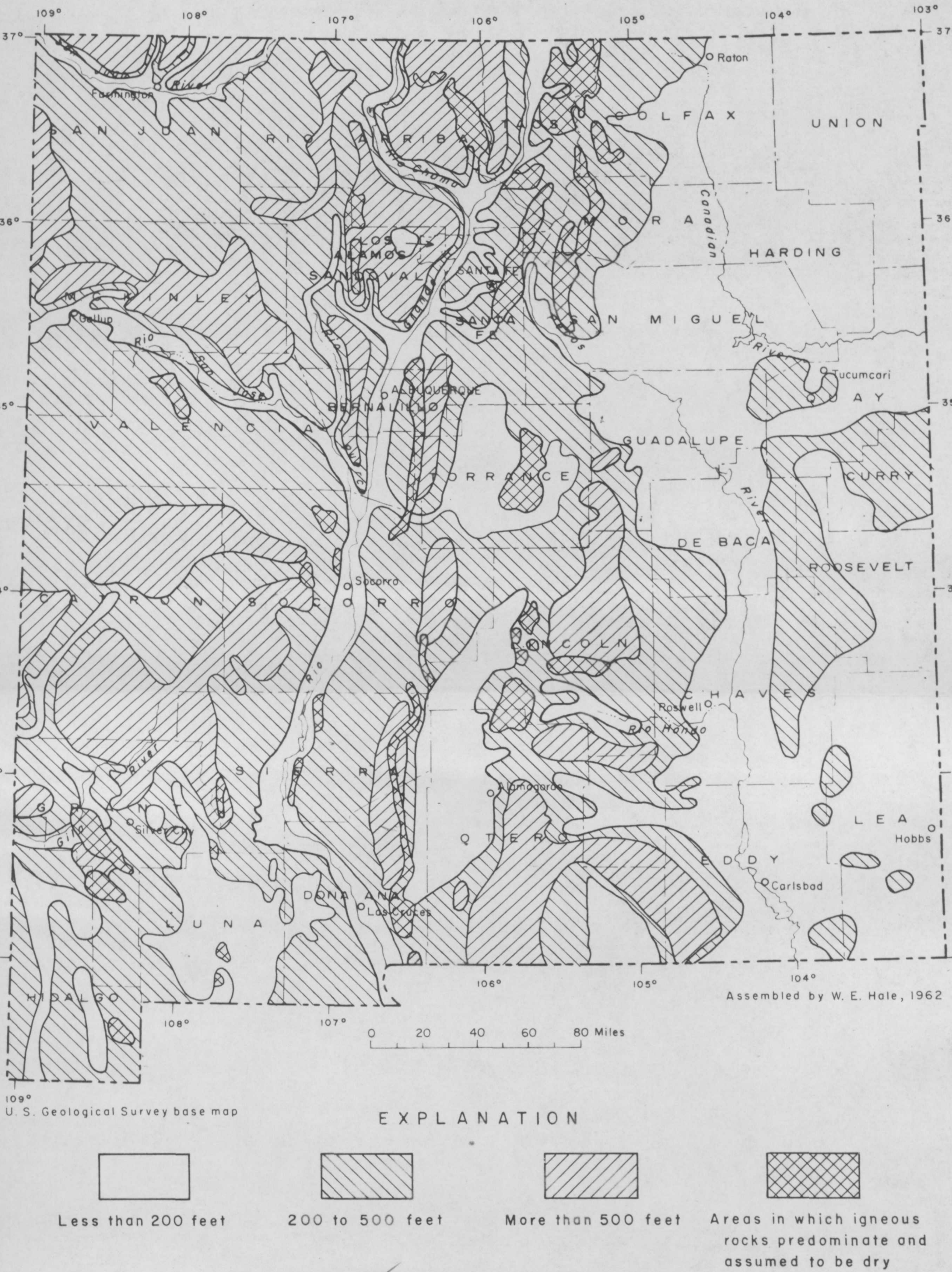
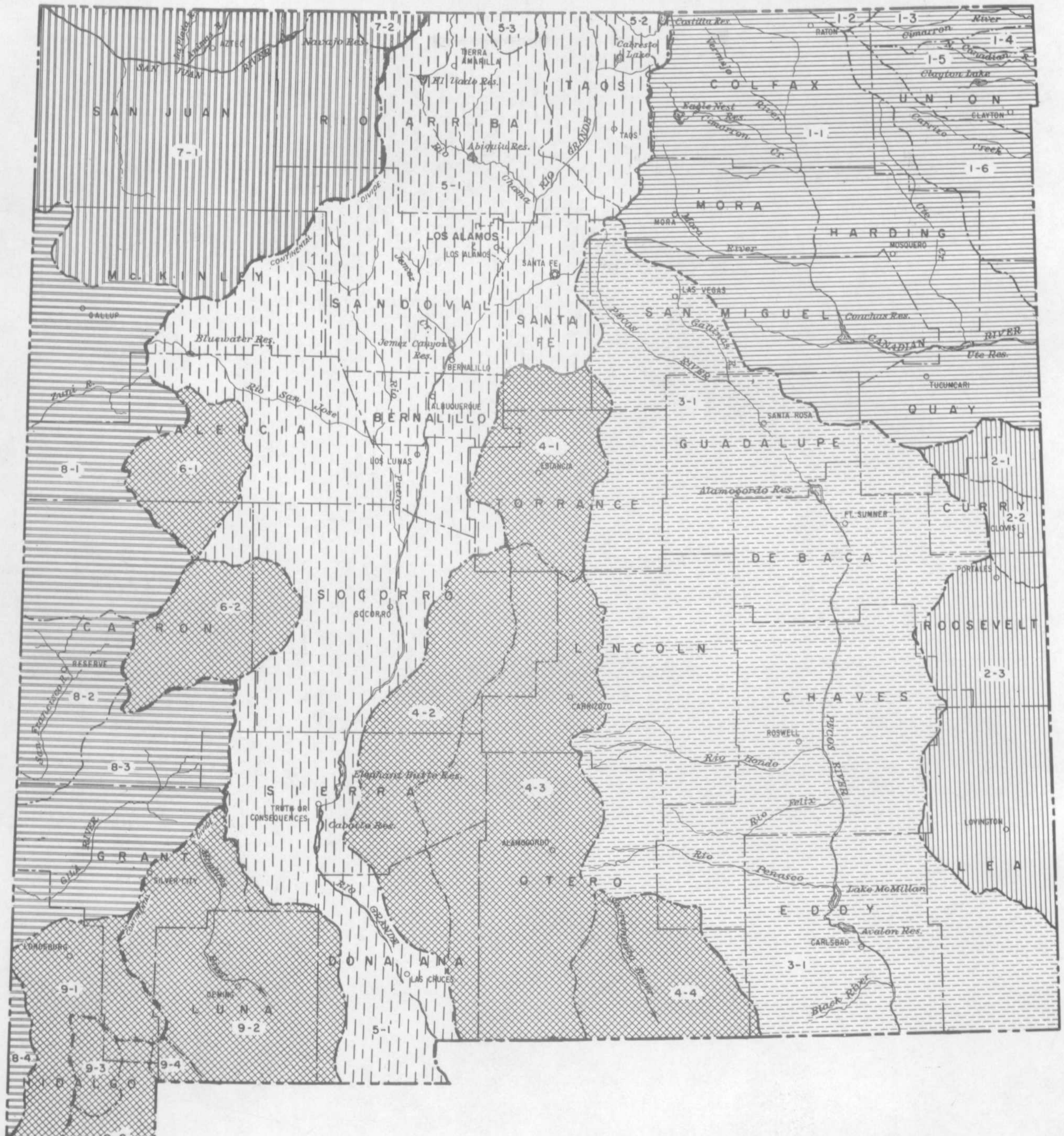


Figure 18.--Depth to ground water in New Mexico



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
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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

0 5 10 20 30 40 50 60 70 80 90 100
SCALE IN MILES

FIGURE 1
DRAINAGE BASINS
OF
NEW MEXICO

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NEW MEXICO

TOPOGRAPHIC DIVISON
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DENVER, COLORADO
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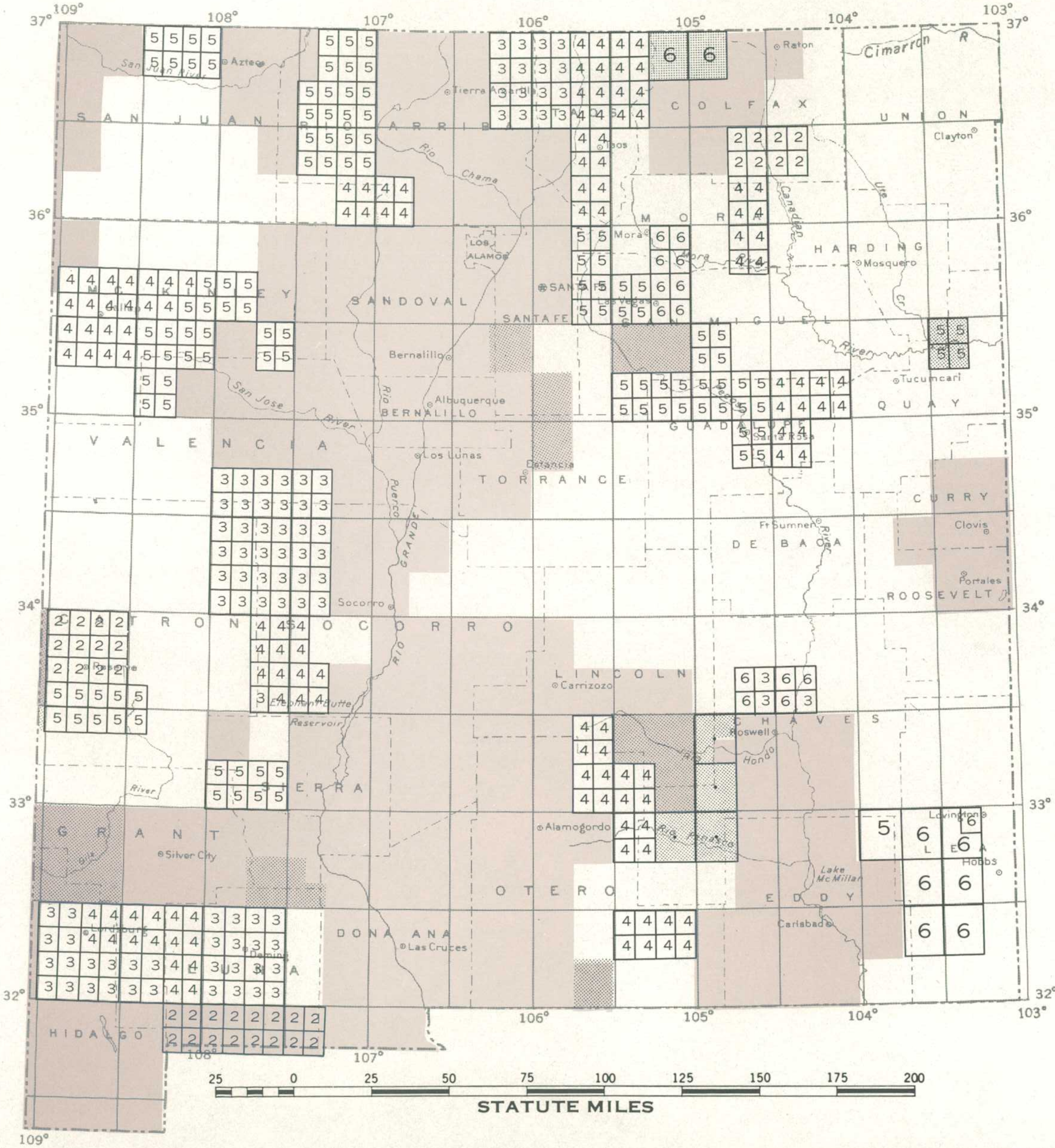

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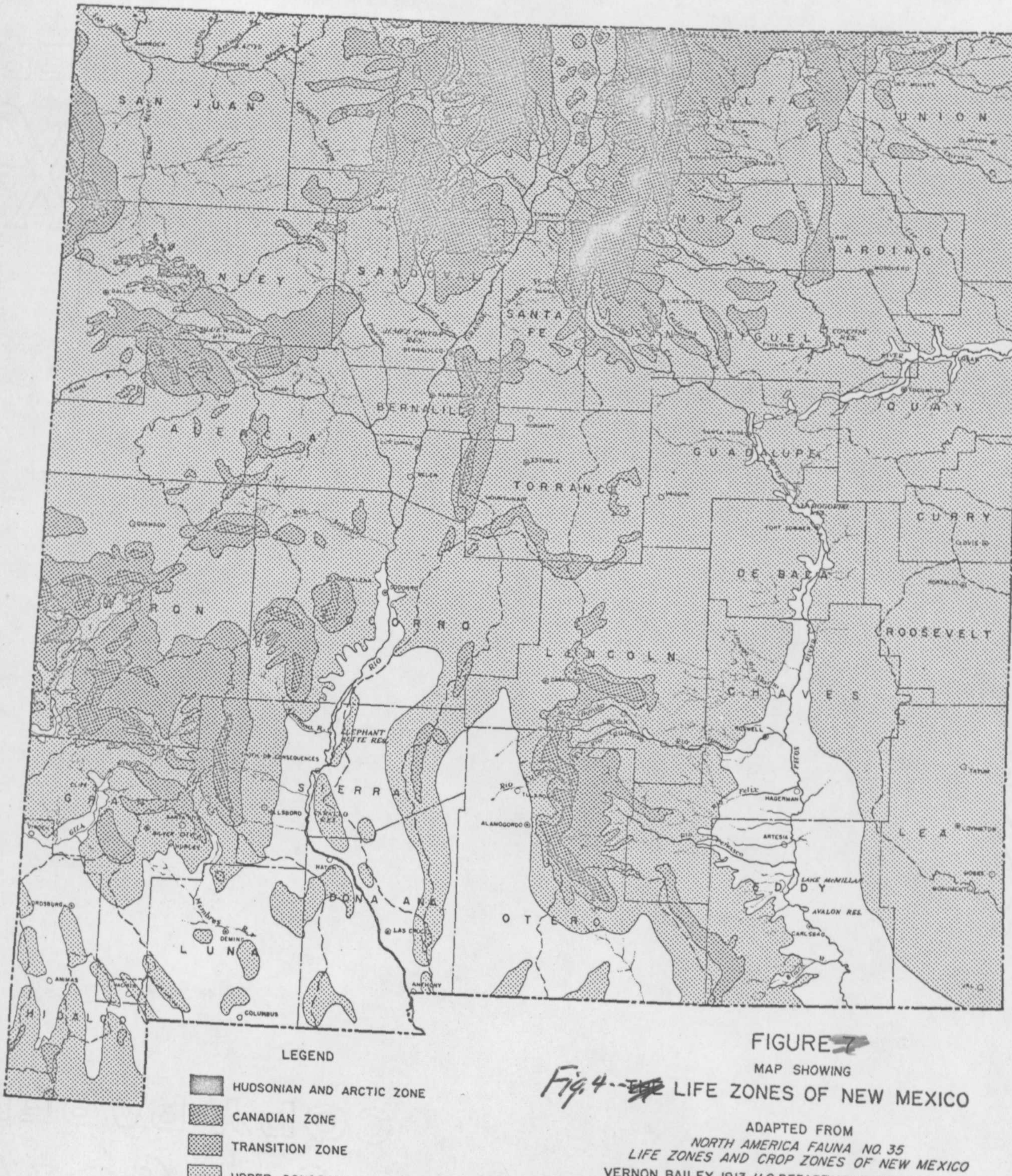
Fig. 2

Fig. 2.--Status of topographic mapping in New Mexico



LEGEND

- HUDSONIAN AND ARCTIC ZONE
- CANADIAN ZONE
- TRANSITION ZONE
- UPPER SONORAN
- LOWER SONORAN

FIGURE ~~7~~

MAP SHOWING

Fig. 4 ~~THE~~ LIFE ZONES OF NEW MEXICO

ADAPTED FROM

NORTH AMERICA FAUNA NO. 35

LIFE ZONES AND CROP ZONES OF NEW MEXICO

VERNON BAILEY, 1913, U.S. DEPARTMENT OF AGRICULTURE

DRAWN BY M.B. HUEY

JULY 1956

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SCALE IN MILES

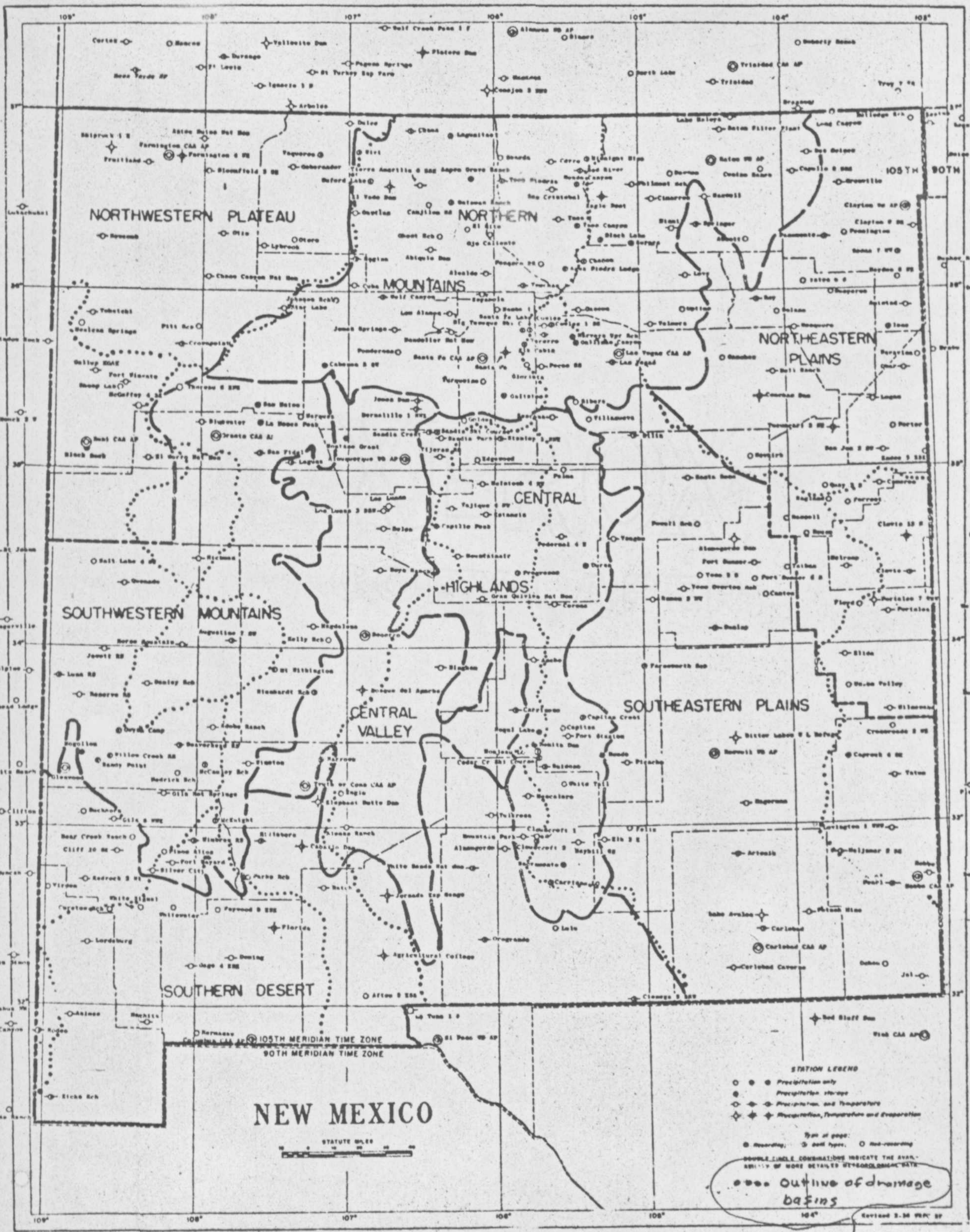

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Figure 6.--Weather stations ~~locations~~ and climatologic divisions in New Mexico

Note

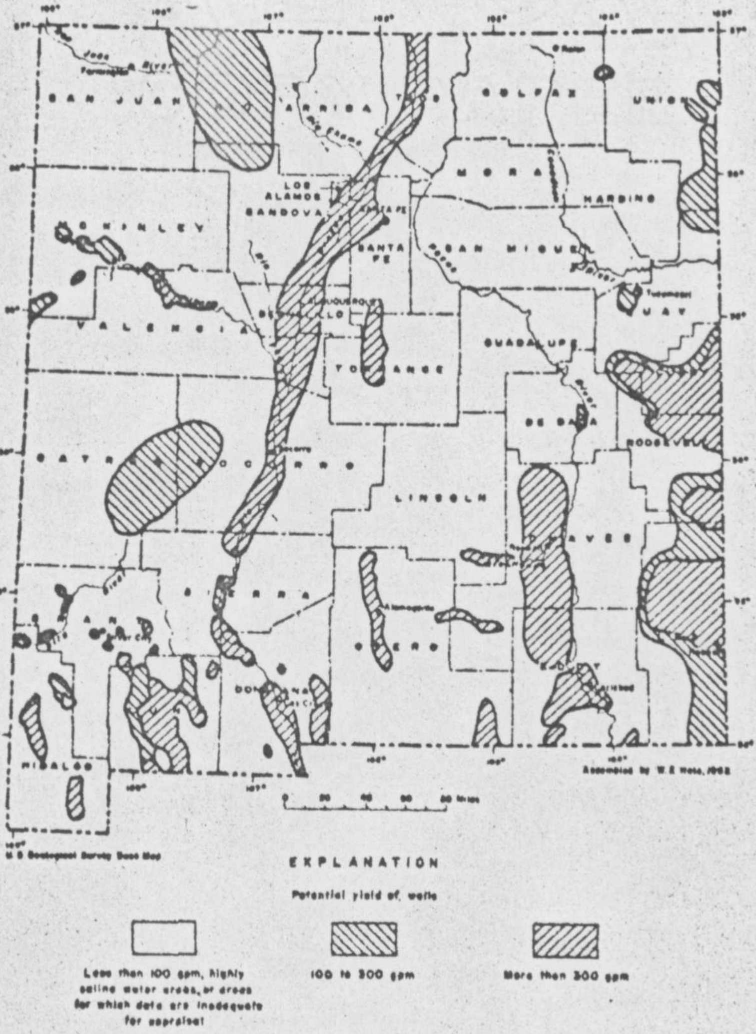

Figure 8 .--General availability of relatively fresh ground water in New Mexico

14

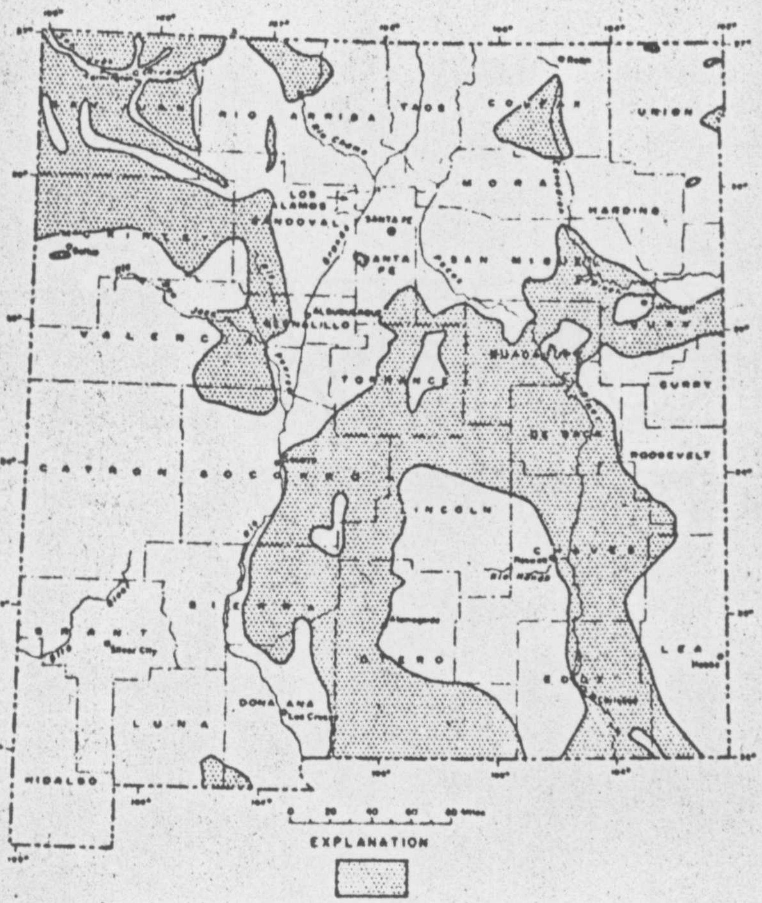

Figure 15 .--General quality of shallow ground water in New Mexico

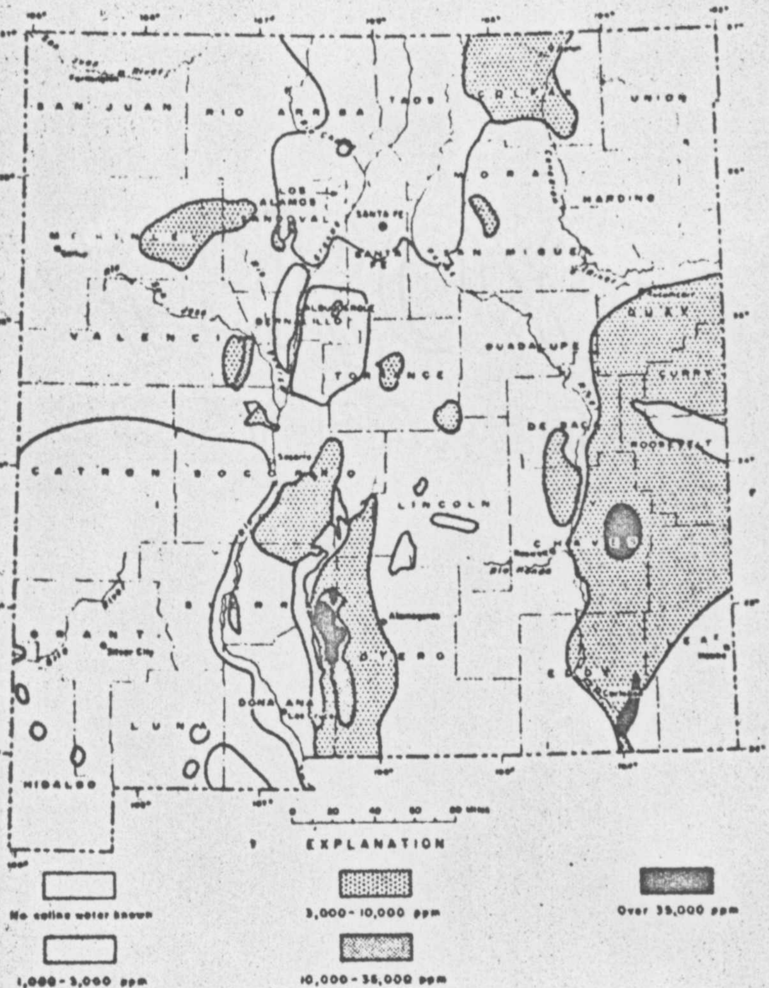

Figure 16.--General occurrence of saline ground water in New Mexico

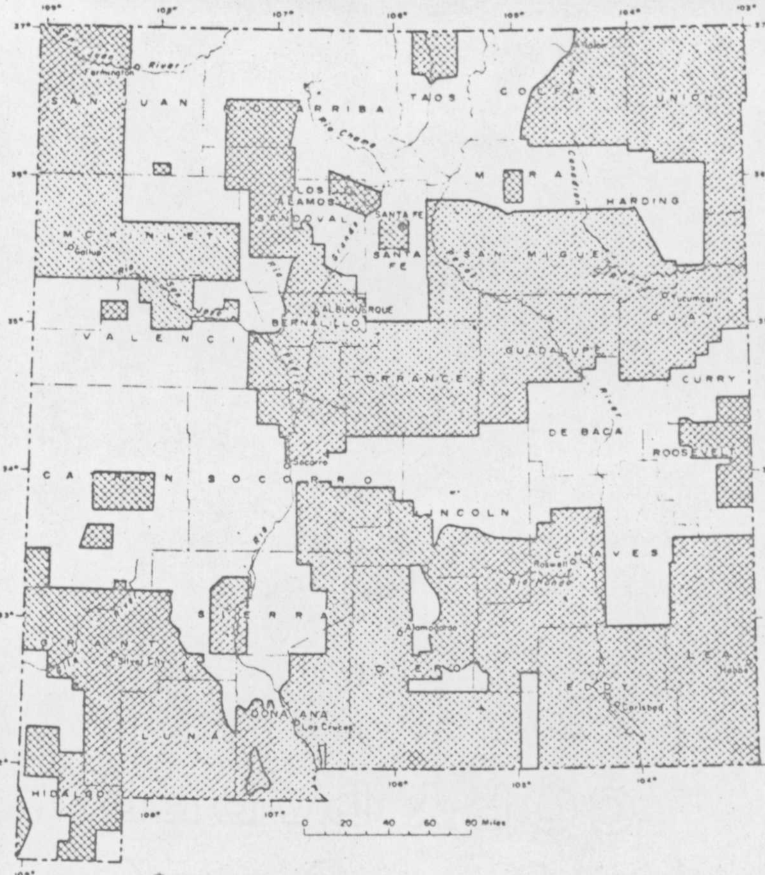

Figure 17.--Areas in New Mexico in which ground-
water studies have been made.

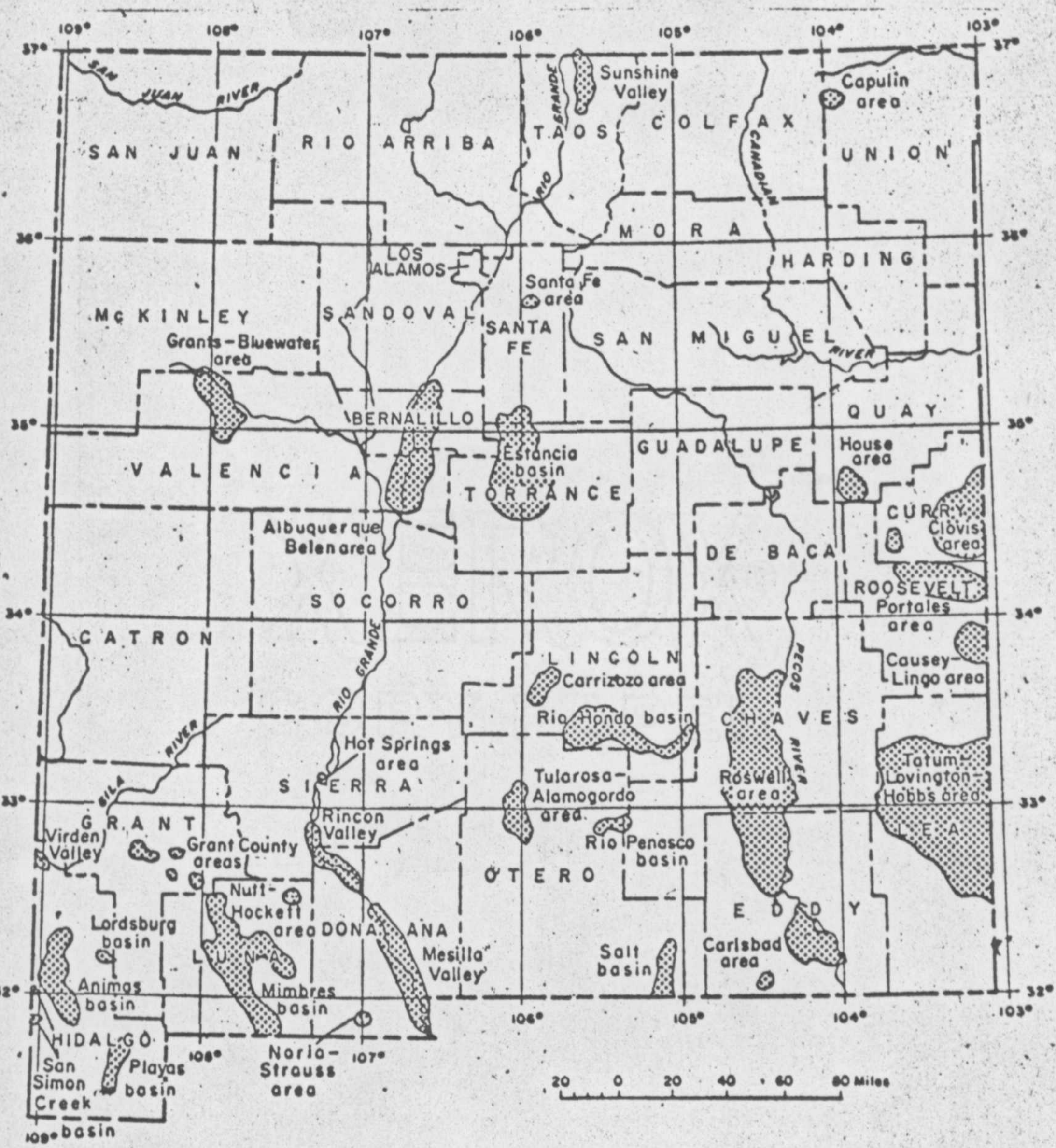

Figure 19.--Areas of observation of water-level fluctuation in New Mexico

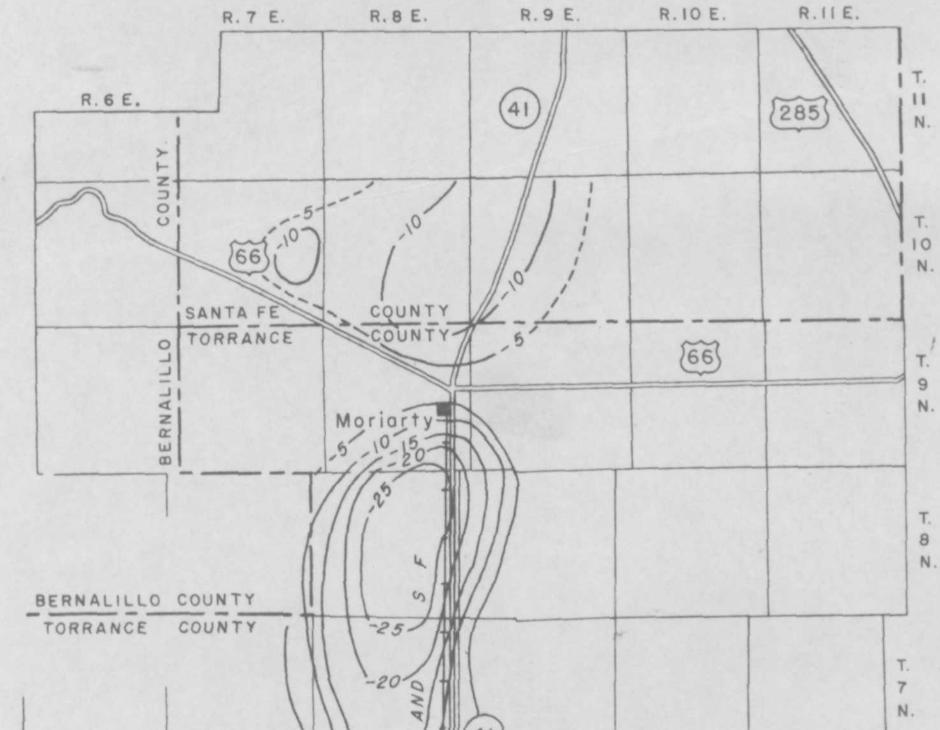

Figure ~~90~~ 20.--Decline of ground-water level in Estancia ~~Valley~~ basin, Santa Fe and Torrance Counties, New Mexico, for the period 1948-60.