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SAN JUAN RIVER BASIN

BY

JAMES B. COOPER AND FREDERICK D. TRAUGER

Table 1.-- Generalized stratigraphic section in the San Juan River basin, New Mexico

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Quaternary	*Alluvium	0-50	Stream deposits in all major valleys and local in most minor tributaries; wind-blown sand on inter-stream areas; terrace gravels.	Mostly unconsolidated clay, silt, sand, and gravel; generally poorly sorted; well-sorted dune sands.	Poor to excellent depending on the coarseness and degree of sorting; high yields uncommon because of generally thin deposits in the stream valleys; terrace gravels generally not water bearing. Generally yields fresh to slightly saline water.
Tertiary	Chuska Sandstone	1,000±	West side of the Chuska Mountains, Western San Juan County.	Gray to grayish-white, cross-bedded sand-stone with some interbedded shale and siltstone.	Unknown, but probably ranging from poor to good, depending on thickness of interbeds of shale and siltstone.
	*San Jose Formation	250± to 1,000±	Eastern part of San Juan Basin.	Gray to brown con-glomeratic sandstone interbedded with variegated shale; locally well-sorted sand beds.	Generally fair to excellent, depending on thickness of well-sorted beds of sand; potentially good to excellent aquifer; yields up to 200 gpm reported, yields up to 1,000 gpm predicted. Generally yields fresh to slightly saline water.
	*Nacimiento Formation	1,140 ±	Central and eastern part of San Juan Basin; underlies the San Jose Formation.	Lenticular yellow, to soft white, and con-glomeratic sandstone with interbedded variegated shale in northern part of basin; gray and red shale, soft sandstone and gray to black shale in southern part.	Poor, yields generally less than 10 gpm. Generally yields slightly to moderately saline water.
Cretaceous	*Ojo Alamo Sandstone	400±	Central and eastern part of San Juan Basin; underlies the Nacimiento Formation.	Gray to brown coarse sandstone, with lenses of pebbles and variegated shale.	Poor to locally fair -- a potential aquifer in the eastern half of the San Juan Basin to supply water to stock and domestic wells. Generally yields fresh water.

Table 1.-- Generalized stratigraphic section in the San Juan River basin, New Mexico - Continued

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Cretaceous-Continued	*Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, and Lewis Shale	1,000 ± to 4,500 ±	Underlies all the rocks of Tertiary age in the central and eastern part of the basin.	Mostly light-gray to blue-gray and brown shales; locally carbonaceous; and light-colored, soft, fine-grained sandstone, locally crossbedded.	Generally poor; sandstone units comprise important oil and gas reservoirs of the basin; most water saline except in immediate vicinity of outcrops where it may be fresh to slightly saline.
	Mesa Verde Group	600 ± to 3,500 ±	Underlies all the San Juan Basin in New Mexico except for a narrow strip along the NW side of San Juan County.	Yellow to reddish-brown and gray sandstone, massive to thin-bedded, some concretionary; sandy shale, and gray to dark gray carbonaceous shale.	Mostly poor everywhere, except for the Gallup Sandstone at the base, which, in the southwest part of the basin, yields fair to moderate amounts of fresh water. Sandstone units toward base of the group act as reservoir rock for oil and gas. Water in most rocks of the group is saline.
	*Mancos Shale and Dakota Sandstone	800±	Underlies all of the San Juan Basin in New Mexico except for a narrow strip along the NW side of San Juan County.	Dark gray to olive green, commonly fissile shale, and brown sandstone with thin shale and coal; cherty conglomerate locally at base.	Mostly poor everywhere in the shale beds; locally fair to good in the Dakota Sandstone near areas of outcrop; yields seldom more than 10-15 gpm from the Dakota. Generally yields fresh to moderately saline water.
Jurassic ? Triassic	*Morrison Formation, San Rafael Group, and Glen Canyon Group?	400± to 1,600±	Probably underlies all of the San Juan Basin.	Variegated shale and silty sandstone, orange-red to gray cross-bedded sandstone, red to gray shale, sandy shale, and red cross-bedded sandstone.	Generally poor everywhere; yields seldom more than 5-10 gpm of water. Generally yields slightly saline water near outcrop and very saline water away from outcrop.

Table 1.-- Generalized stratigraphic section in the San Juan River basin, New Mexico - Concluded

System	Stratigraphic Unit	Thickness (feet)	Distribution	Physical properties	Water-bearing characteristics
Triassic - Continued	*Chinle Formation	800 ± to 1,600	Probably underlies all of the San Juan Basin.	Red to variegated and white shale and sandstone; some thin beds of limestone.	Generally poor everywhere; yields generally less than 5 gpm, commonly less than 1 gpm. Generally yield slightly to moderately saline water.
Permian to Cambrian	*Sedimentary rocks	5,000±	Rocks of Paleozoic age are believed to underlie much of the northern and eastern part of the San Juan Basin. Oil test holes in the central part of the basin, in San Juan County, generally are bottomed at depths not greater than 7,000 ft. and at that depth commonly find the Morrison Formation of Jurassic age. Rocks of Pennsylvanian age yield oil and gas from depths of about 8,000 to 9,000 ft. in the Barker Creek area, north-central San Juan County.	Massive to thin-bedded limestone, local beds of evaporites, and widespread thick deposits of reddish and variegated shale, siltstone, sandstone, and conglomerate.	Generally yield moderately to very saline water.

DETAILED BASIN OUTLINE

Location

______________ basin is outlined on Figs. ___, ___. Sub-basins within this major drainage area are ______________, ______________, ______________. Counties and parts of counties included within the area are ______________, ______________. The larger cities and villages in the area are ____________, ______________.

Description

Geography

Drainage areas

Stream systems

______________ river and tributaries

Topography and physiographic provinces

Topographic mapping

Geology

Sedimentary rocks

Igneous rocks

Minerals

Geologic mapping

Soils and vegetation

Soils

Vegetation

Hydrology

General (weather stations, temperature, precipitation)

Surface water

Streamflow measuring network

Water yield, annual runoff

Description

Hydrology (cont'd)

Surface water (cont'd)

Supply

Virgin flow

Regulation (by reservoirs and projects)

Floods — areas subject to flooding

Sedimentation

Monitoring network

Origin and deposition

Chemical Quality

Monitoring network

Quality of water

Ground water

Known and probable reservoirs (alluvial or bedrock)

Stream-connected aquifers

Non-connected aquifers

Supply

Chemical quality

Monitoring network

Quality of water

Ground-water studies

Areas investigated

Water-level measurements

(The above part of report to be written by USGS)

Population and Economy of the Area

Population

Urban

Municipalities

Rural

Industries and commerce

Commercial enterprises

Agriculture

Irrigated

Non-irrigated

Timber

Minerals

Transportation facilities

Roads, railroads, airlines

Power availability

Fish, wildlife and recreation

Cultural resources

(This part of the report to be of a general and somewhat historical nature in order to provide a setting for the next section of the report)

Water Development and Use

Beneficial uses

Municipal, industrial, military, and rural domestic

Power production

Recreation, fish and wildlife

Water Development and Use (cont'd)

Beneficial uses (cont'd)

Agriculture

Non-irrigated

(Items as dry-land, rangeland, livestock, land treatment, erosion control, etc)

Irrigated

(Items as project lands, crops, water requirements, drainage problems, etc.)

Other consumptive uses

Reservoir evaporation

Native vegetation and phreatophytes

Channel losses

Summary Table of water uses Item	Unit of use	Units	Surface water Diver.	C.U.	Ground water Diver.	C.U.	SW and GW Diver.	C.U.
Agriculture								
Municipal and Industrial								
Rural domestic and livestock								
Power production								
Recreation, Fish & Wildlife								

(Note: Under each item discussed, uses of surface water, ground water, and combinations thereof to be discussed and developed as appropriate)

Problems of the Area

Surface water

Available supplies and shortages

Streamflow regulation (conservation storage, sediment, and flood control)

Problems of the Area (cont'd)

Surface water (cont'd)

Competitive demands for water uses

Quality of water

Pollution abatement

Consumptive waste from beneficial uses

M & I

Agriculture

Irrigation practices

Drainage problems

Other consumptive
Non-beneficial losses

Reservoir evaporation

Vegetative losses (native and phreatophytes)

Basic data collection program

Ground water

Availability

Stream-connected aquifers

Non-connected aquifers

Quality of water

Saline encroachment

Other

Basic data collection program

Water Resource Programs and Activities by Governmental Agencies

Local

State

Federal

(Note: The parts "Population and Economy" through above section to be written by personnel of SEO Technical Division)

Water Management and Legal Considerations (by the logical breakdown between surface and ground water, and as applicable in the basin area, the following items are to be discussed)

Water rights acquisition and administration*

Interstate compacts

Declared underground water basins

Court decress and adjudication

Transfer of place and method of use

* Breakdown of claimed rights for use of water will be furnished by Technical Div.

(Note: The above section to be written by legal staff of SEO. Much of the legal gulations, etc. set forth in the state-wide summary will be applicable to all areas of the State and need not be repeated for each basin area. This section is intended to cover only those items directly applicable to the area itself, Example: Rio Grande Compact in the Rio Grande Basin).

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

San Juan River basin

By

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

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Corrections made on carbon backs

Contents

Illustrations

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San Juan River basin

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Description

The San Juan River basin in northwestern New Mexico is outlined on figure 1. Counties and parts of counties included within the area

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

are San Juan, Rio Arriba, McKinley, and Sandoval. The principal cities and villages in the area are Farmington, Aztec, Bloomfield, and Shiprock in San Juan County; Dulce and Lindrith in Rio Arriba County; and Crownpoint in McKinley County.

Figure 1.--Drainage basins of New Mexico.

Geography

The San Juan River heads on the Continental Divide in the San Juan Mountains north of Pagosa Springs, Colorado. It flows southwestward into New Mexico, crosses the extreme northwest part of the State, and leaves the State near the northwest corner where it crosses a small part of Colorado and enters Utah. The river then takes a general westward course and joins the Colorado River in Utah, near Rainbow Bridge National Monument.

The basin in New Mexico has an area of 9,725 square miles and consists of two drainage areas -- the San Juan River drainage area, 7-1 on figure 1, and the Navajo River drainage area, 7-2 on figure 1.

The San Juan River drains an area of 9,480 square miles in New Mexico. Before entering the State from Colorado the river is made up of the Navajo, Little Navajo, East Fork of the San Juan, and West Fork of the San Juan. Below the State line major tributaries originating in Colorado and emptying into the San Juan River in New Mexico are Los Pinos, Animas, La Plata, and Mancos Rivers. The major tributaries arising in New Mexico are La Jara Creek, Canyon Largo, and Chaco River.

The Navajo River drains an area of 245 square miles in New Mexico. The Navajo also heads in the San Juan Mountains of Colorado, east of Pagosa Springs on the Continental Divide. The river flows southwestward into New Mexico. A few miles northwest of Dulce, New Mexico, where it is joined by the Amargo River, the channel of the Navajo swings sharply northwestward and re-enters Colorado, where it empties into the San Juan River near the village of Juanita. The total length of the Navajo River in New Mexico does not exceed 15 miles.

The San Juan River basin in New Mexico is in the Navajo section of the Colorado Plateaus province (Fenneman, 1931) which includes plateaus, buttes, mesas, and broad valleys. The San Juan River is at an altitude of about 6,600 feet at its inflow point into New Mexico near Rosa; in the central part of the basin near Farmington, the altitude is about 5,500 feet; and at the outflow point, the altitude is about 4,800 feet. Most of the area south of the San Juan River consists of a gently northward-sloping, desolate, and rather featureless plain, cut by numerous arroyos, and with only an occasional lone butte or mesa to provide contrast.

Topographic mapping

Army Map Service maps are available for the entire San Juan River basin. These maps are on a scale of 1:250,000 with a contour interval of 200 feet. More detailed topographic maps at scales of 1:62,500 and 1:24,000 are available for about a third of the area. Mapping for publication at these larger scales is in progress in the north-central and northeastern parts of the area. Figure 2 indicates the areas that

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

have been mapped at the larger scales, the areas in which mapping such is in progress, and the areas in which no such mapping has been done.

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

Geology

Sedimentary rocks exposed at the surface in the San Juan Basin in New Mexico range in age from Triassic to Recent (Dane and Bachman, 1957). Sedimentary rocks of Paleozoic age underlie much of the basin at known depths up to 9,000 feet. The Precambrian basement has been reached in oil test holes at depths of about 2,500 feet and 5,000 feet, respectively, on the flanks of the Chuska and Zuni Mountains. A few small basalt flows of Tertiary age lie along the crest of the Chuska Mountains. Intrusive igneous rocks of varied composition, also of Tertiary age, form plugs and dike swarms in the northeast and northwest parts of the basin.

The San Juan River basin is a structural as well as a topographic and hydrologic basin. The present San Juan structural basin was defined in Late Cretaceous to Early Tertiary time (Kelley, 1955, p. 85). Deposition of sediments of marine and continental origin has continued in the area since early Paleozoic time with only intermittent interruptions. The total thickness of sedimentary rocks in the central part of the basin probably is near 15,000 feet, but may be appreciably more. A summary description of the rocks, the general distribution, and the water-bearing characteristics are given in table 1.

Sedimentary rocks

Alluvium of Recent age consisting mostly of stream deposits and terrace gravel is found in and alongside the channels of the principal streams and main tributaries. These deposits in general are thin and poorly sorted because they are largely flood-wash residuals.

The San Juan River and other major streams are actively downcutting their channels. Floodflow and normal streamflow is sufficient to keep the channels relatively free of thick accumulations of sediments. Those left after each successive flood-runoff commonly are mixtures of coarse to fine materials. "Bed rock" (Consolidated older sediments) is exposed at many places in the channel of the San Juan River, and at other places on the flood plain of the river the deposits of sand and gravel form only a thin cover over the bedrock.

A veneer of wind-blown sand covers much of the older rock in the areas immediately south of the San Juan River, between Farmington and Shiprock. The sand locally may be several tens of feet thick.

The sandstones, shales, and associated rocks of Tertiary and Mesozoic age (table 1) are, for the most part, fine-grained and relatively dense. The sandstones commonly are shaley, the shales sandy, and conglomeratic sandstones are common locally. Many of the beds are carbonaceous, and some contain evaporites, mainly gypsum.

Marine and continental deposits of Paleozoic age consist largely of massive to thin-bedded limestone, local beds of evaporites, and widespread thick deposits of reddish and variegated shale, siltstone, sandstone, and conglomerate.

Igneous and metamorphic rocks

Basaltic flows, dikes, and volcanic cones and necks of varied composition are found on the perimeter of the San Juan structural basin. Their occurrence in the San Juan drainage basin is restricted to the northeast and northwestern parts. Shiprock, a well-known landmark, is a volcanic neck composed of tuff-breccia. (Callaghan, 1951, p. 120.)

Granite gneiss, metarhyolite, and metasedimentary rocks, of Precambrian age, are exposed in the Zuni Mountains. Precambrian granite comprises the core of the Nacimiento Mountains. The Precambrian basement rocks in the San Juan Basin are presumed to be of equally varied composition.

Economic minerals

The gold, silver, copper, and minerals that were so important in the settlement and development of the West in general, and much of New Mexico in particular, have virtually no place in the history of the San Juan River basin in New Mexico. The mineral wealth of the area was not to be realized until nearly 400 years after Coronado in about 1540 first explored the region.

Extensive deposits of coal were known in the area from the early explorations but were not much exploited. The first determined effort to utilize the coal was begun about 1960 when the Navajo Tribal Government entered into an agreement with private power interests to build a large electrical generating plant near Kirtland, San Juan County. Coal obtained by strip mining nearby will be used to power steam-driven generators.

Commercially workable uranium ores were first discovered in New Mexico near Grants about 1950. The only deposits of importance in the San Juan Basin, however, are in the extreme northwestern part of the State, west and southwest of Shiprock. Prospecting for uranium was intensive in the basin and it is unlikely than any large surficial deposits remain undiscovered.

Oil seeps near the San Juan River in Utah were reported as early as 1879, but the first oil well was not completed until 1908 (Kuhn, 1958, p. 1). It was not until 1911 that oil was found in the San Juan Basin in New Mexico. A well being drilled for water in the Seven Lakes area found shows of oil at shallow depth. No production was achieved, nor did subsequent exploratory drilling ever result in a producing well in that area. That was the beginning, however, of development that ultimately would produce wealth beyond the fondest dreams of the Conquistadores.

Exploratory drilling in the basin was intermittently intensive from 1911 on, but it was not until the period 1945 to 1955 that drilling and production hit full stride. The value of oil and gas produced in New Mexico in 1957 from fields in the San Juan Basin totaled $345,176,407 (Kuhn, 1958, p. 140).

Geologic mapping

The geology of the basin is shown on U.S. Geological Survey Miscellaneous Map Investigations I-224 (Dane and Bachman, 1957). This map was compiled mostly from larger-scale reconnaissance and detailed maps published at scales ranging from 1:125,000 to 1:48,000. An index and bibliography on the map shows the source of data used in the compilation.

Soils and vegetation

Most of the San Juan River basin south of the San Juan River is covered with a medium-textured, moderately deep to shallow soil that mantles gently-rolling topography. Along San Juan River and its northern tributary streams, a medium- to heavy-textured deep soil suitable for agriculture is present. In the northeast part of the basin in the more mountainous areas a shallow to moderately deep light- to medium-textured soil predominates. The distribution of the three soil types is shown on figure 3.

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

Most of the land surface in the San Juan River basin is covered with grasslands or with sagebrush. Woodlands of pinyon and juniper cover upland areas, and forests of pine and fir are present in the higher altitudes of the mountains in the northeast and southwest parts of the basin. Irrigated croplands occupy the valley of the San Juan River from Archuleta westward to Shiprock, and the valley of the Animas River northeast of Farmington. The distribution of the vegetation in the area is shown on figure 4.

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

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

Figure 4.--Vegetative-type map of New Mexico.

Hydrology

Climatology

Weather stations are located throughout the San Juan River basin (fig. 5). The San Juan River basin is in the Northwestern Plateau

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

climatologic division; mean temperatures and precipitation at selected places in the basin are listed in table 2. More detailed climatological information is given in the monthly climatologic reports of the U.S. Weather Bureau, Department of Commerce.

Precipitation over the San Juan River basin in New Mexico is low. About half the area averages 10 inches or less of rainfall annually. A small area adjacent to the Colorado State line in the extreme eastern portion of the basin in New Mexico averages about 20 inches.

Figure 5.--Weather stations and climatologic divisions in New Mexico.

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Table 2.--Mean temperature and precipitation at places in San Juan River basin, New Mexico

(U.S. Weather Bureau, 1959)

Station	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.
Aztec Ruins NM	28.3	0.67	34.1	0.80	41.1	0.80	50.2	0.58	58.3	0.69	66.4	0.47	73.6	0.96	71.6	1.34	64.5	1.21	53.5	0.93	39.3	0.48	30.9	0.87	51.0	9.80
Bloomfield 3 SE	-	.50	-	.74	-	.59	-	.51	-	.69	-	.35	-	.81	-	1.29	-	.98	-	.80	-	.44	-	.63	-	8.33
Crownpoint	-	.55	-	.59	-	.58	-	.51	-	.67	-	.66	-	1.78	-	2.06	-	1.24	-	.63	-	.51	-	.56	-	10.24

Surface water

Streamflow gaging stations are located at many points along the San Juan River and on its major tributaries in New Mexico, and at or near the point where the San Juan and its upper tributaries enter New Mexico from Colorado. The drainage areas, average annual runoff, peak discharges, and periods of record for these gaging stations in the San Juan River basin are listed in table 3.

The average annual runoff recorded at selected stream-gaging stations on the San Juan River and its major tributaries for the period 1920-49 is given in table 3. Virgin streamflow also is shown in the table inasmuch as the recorded flows for this period at the inflow points were considered to be virgin flows. At Shiprock the virgin flow was considered to be the sum of all recorded and estimated inflow above Shiprock plus the effective tributary inflow from the drainage in New Mexico. Based on these assumptions the virgin flows were estimated, as shown in the table, by the New Mexico State Engineer written communication (1964).

As shown by table 4, an average of over two million acre-feet of water annually flows through the San Juan River basin. Depletion of this flow, shown as 72,580 acre-feet (difference between recorded flow and virgin flow at Shiprock) is attributed by the New Mexico State Engineer (1964) to the following man-made depletions:

Use	Acre-feet
Irrigation	68,430
Municipal	1,000
Stock ponds	3,150
Total	72,580

Table 4.--Average annual recorded runoff at selected gaging stations, and virgin flow, in the San Juan River basin, New Mexico, for period 1920-49.

Gaging station	Average annual recorded runoff (acre-feet)
San Juan River at Rosa, N. Mex. (inflow point)	894,910
Los Pinos River at Ignacio, Colo. (inflow point)	230,680
Animas River near Cedar Hill, Colo. (inflow point)	781,590
La Plata River at State line (inflow point)	28,860
San Juan River at Shiprock, N. Mex.	2,036,420 1/
Gaged inflow above Shiprock, N. Mex.	1,936,040
Ungaged inflow above Shiprock, N. Mex.	20,900 2/
Inflow to New Mexico above Shiprock, N. Mex.	1,956,940
Estimated inflow from New Mexico drainage	152,060
Virgin flow at Shiprock, N. Mex.	2,109,000
Estimated inflow below Shiprock, N. Mex.	55,000 3/
Virgin flow at State line (outflow point)	2,164,000

1/ Partially estimated.

2/ Estimated by area-runoff relationship for ungaged areas in Colorado.

3/ Estimated by area-runoff relationship for ungaged area and relationship between recorded runoff of Mancos River with recorded runoff of La Plata River. (Between Shiprock, N. Mex., and the outflow point at the northwest corner of the State no gaging stations are in operation -- most of the runoff in this area comes from Mancos River drainage in Colorado.)

Aside from an estimated 1,659 stock tanks in the San Juan River basin the major regulation of base flow and runoff in the basin is provided by the Navajo Dam, part of the Upper Colorado River Storage Project. This earthfill structure is on the upper reaches of the San Juan River in New Mexico and creates storage for runoff from a 3,240-square-mile drainage area. The reservoir has an original capacity of 1,700,000 acre-feet with 672,000 acre-feet alloted for dead storage. The usual capacity is 1,028,000 acre-feet and the surface area of the reservoir is 15,650 acres. The water in the reservoir is used for irrigation, flood control, and recreation.

The San Juan River basin is rarely subject to floods. The annual high water due to melting of the heavy snow cover which is characteristic of the San Juan Mountains in Colorado normally keeps the river channels scoured out to the required capacity, and storms of sufficient intensity and extent to cause floods are rare (Follansbee and Sawyer, 1948). A few storms of sufficient intensity, however, have caused disastrous floods in the San Juan River basin in New Mexico.

The first recorded flood on the La Plata River occurred October 6, 1904. (Apparently previous flooding had occurred, as Murphy and others [1905] reported that the flood of 1904 caused the greatest destruction along the middle and lower part of this valley since 1882.) The greatest damage done by this flood was to reservoirs and irrigation ditches.

On September 5 and 6, 1909, severe floods were recorded on the San Juan River in New Mexico. Much of this flood was caused by extremely heavy rainfall on Animas River drainage.

The rainfall during the period October 4-6, 1911, caused the highest flood of actual record in the San Juan River basin. At Shiprock the peak of the flood on the San Juan River was recorded on October 6 when the estimated flow was 150,000 cfs (cubic feet per second) (Follansbee and Sayer, 1948, p. 134). The report of the New Mexico State Engineer (1912, p. 41) states that the crest of the flood was approximately 19 feet above the normal stage of the river.

Heavy rains during the period June 26-30, 1927, at a time when warmer weather was melting the mountain snow, caused the second highest flood of record in the San Juan River basin. On June 29, 1927, the gaging station on the San Juan River at Rosa, N. Mex., received a maximum discharge of about 25,000 cfs and the station on the San Juan River at Farmington, N. Mex., recorded a maximum discharge of about 68,000 cfs (U.S. Geological Survey, 1964a).

Flood flows on the San Juan River also occurred on August 11, 1929, when 25,000 cfs were recorded near Blanco, N. Mex., and 80,000 cfs were recorded at Shiprock. On June 19, 1949, 13,100 cfs were recorded on the Animas near Cedar Hill, and on July 27, 1957, on the San Juan River, 18,900 cfs were recorded near Archuleta, and 20,500 were recorded at Bloomfield, N. Mex. (U.S. Geological Survey, 1964).

Sedimentation in streams of the San Juan River basin is studied at observation and sampling points from near Pagosa Springs, Colorado, to Shiprock, New Mexico. Suspended-sediment concentration and suspended-sediment load are computed from samples collected at these sites. Sediment studies are vital to the determination of sediment deposition (quantity, method, and place) in channels and reservoirs. Table 5 lists the name and location of the sediment stations in the San Juan River 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.

Suspended sediment is that part of fluvial sediment (transported by, suspended in, or deposited by water) which remains in suspension in water owing to the upward components of turbulent currents or to colloidal suspension. Most fluvial sediment results from the continuing geologic process of erosion. Sediment is also contributed by agricultural practices, and industrial and construction activities.

The size of particles in stream sediments commonly ranges from colloidal clay (finer than 0.001 mm), to coarse sand, to gravel (coarser than 1.0 mm). The quantity in streams is affected by climatic conditions, precipitation, character of the soil, plant cover, topography, and land use. Conversely, the mode and rate of sediment erosion, transport, and deposition is determined largely by the size distribution of the particles. Sediment particles larger than 0.062 mm do not appear to be affected by flocculation or dispersion resulting from the mineral-constituent chemicals in solution in the transporting water. The diameter of clay and silt particles in suspension may vary considerably from point to point in a stream or reservoir, depending on the mineral matter in solution and suspension, and on the degree of turbulence.

The particle size of the sediment in transport at any point depends on the type of material in the drainage area, degree of flocculation, time in transport, and type of flow. The type of flow depends on the velocity of the water, turbulence, and the depth, width, and roughness of the channel. As a result of these variables, the size of particles transported, as well as the total sediment load, is in constant adjustment with the characteristics and physical features of the stream and drainage area (U.S. Geological Survey, 1964, p. 22-23).

Suspended sediments in waters in the San Juan River vary greatly in quantity during the year, and from year to year. The waters generally contain moderate amounts of suspended sediments, commonly 2,000 ppm (parts per million) or more, which give the waters a murky appearance. In the upper reaches of some of the tributary streams such as Rio Blanco and Navajo River (table 5) the suspended-sediment concentration is nearly always low and the waters are usually clear.

The chemical quality of the surface water in the San Juan River basin is determined by periodic sampling of water from streams within the basin at seven sampling points between Archuleta, New Mexico, and Shiprock, New Mexico. Table 6 lists the names and locations of chemical-quality sampling stations, 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.

All natural waters contain dissolved mineral matter. The quality of dissolved mineral matter depends primarily on the type of rocks or soils with which the water has been in contact and the length of time of contact. The dissolved-solids content in a stream is frequently increased by drainage from industrial or municipal wastes or from irrigated lands. The chemical quality of water in a stream is also related to variations in precipitation. Generally, lower concentrations of dissolved solids occur during periods of high streamflow.

Waters with less than 500 ppm of dissolved solids are usually satisfactory for domestic and some industrial uses. Water containing several thousand ppm of dissolved solids are sometimes used for irrigation, although water containing more than about 2,000 ppm generally is considered to be unsuitable for long-term irrigation. The surface water in the streams of the San Juan River basin is generally of good chemical quality. Waters excessively high in dissolved solids have, however, been reported on the La Plata River near Farmington, and on the San Juan River at Shiprock (table 6).

Ground water

Ground water is in short supply in the San Juan River basin. Few of the rock formations are capable of yielding large quantities of water, and the water from those that can yield large quantities is likely to be of poor quality. Little distinction can be made between shallow and deep-lying formations with respect to availability and quality of the water they might yield. An aquifer that yields good-quality water where it lies at shallow depth may or may not yield good-quality water where it lies deeper. If a generality can be made, it is that the deeper-lying formations yield more water but of poorer quality than do the shallow aquifers.

The basin-like structure of the rock formations in northwestern New Mexico results in successively older formations cropping out concentrically toward the margins of the basin. All the formations (table 1) will yield some water where they lie below the water table, but only a few should be considered as reservoirs. Many will yield usable water in the areas of outcrop, but water found in the same formation, where it lies deeply buried under younger rocks, may be unusable because of high mineral content.

The alluvium of the stream valleys constitutes a known and widespread reservoir of limited capacity. Because the alluvium in the stream valleys generally is thin, it does not yield large volumes of water to wells. It is possible that the alluvial reservoir locally may go dry during prolonged drought, but the fact that it is stream-connected results in rapid recharge when streamflow does occur. Only the alluvium in the valley of the main stem of the San Juan River and its perennial tributaries is assured of constant recharge.

The San Juan River crosses the outcrops of most of the formations. The formations may yield usable water in the areas of the crossing, and in these areas may be considered stream-connected reservoirs. Similarly, normally dry washes throughout the basin contribute some recharge to the outcrops of the various formations across which flood waters occasionally flow. The water in these locally stream-connected reservoirs may be potable, but potable water generally is not found to extend any great distance from the outcrop.

The San Jose and Nacimiento Formations which crop out over a large area in the eastern part of the basin yield up to 200 gpm (gallons per minute) and yields up to 1,200 gpm have been predicted (Baltz and West, p. 186). The San Jose and Nacimiento together in this area should be considered an important potential reservoir of large volume (fig. 6).

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

The Nacimiento Formation is a reservoir of sorts elsewhere in the basin and generally can furnish small amounts of water of poor to fair quality. The large percentage of shale in the formation in the central part of the basin is responsible for the low yield and poor quality of the water.

Figure 6.--General availability of relatively fresh ground water in New Mexico.

The Ojo Alamo Sandstone overall is a poor to fair reservoir, and is potentially better in the eastern part of the basin. Except in the areas of outcrop, the Ojo Alamo Sandstone and all older formations lie at depths generally impractical for development of water. The Ojo Alamo's greatest potential as a reservoir lies in the possibility it might contribute additional large volumes of water to deep wells tapping the overlying San Jose and Nacimiento Formations.

Formations older than the Ojo Alamo Sandstone constitute important oil and gas reservoirs in much of the basin. They also may contain much water, but the water in association with the oil and gas is invariably highly mineralized. The older and generally deeper-lying formations should be considered potential reservoirs of water generally not suitable for ordinary uses, but perhaps may be suitable for special purposes.

The San Juan River basin is large, and the amount of ground water in storage is great. However, as elsewhere in New Mexico, the distribution of the water is such as to make recovery in large quantities economically impractical at most places, and the supply available therefore is short. Little of the basin, and none of the deeper-lying formations, has been adequately prospected for ground water, thus data are lacking for quantitative determination of the over-all supply. As in other principal river basins in New Mexico, local, large undiscovered supplies of ground water probably are available but they must be sought out by test drilling in areas considered to be geologically favorable for finding water.

Systematic sampling of water for chemical analyses from rock formations in the basin has been done only for those parts of the basin that lie within the boundaries of the Navajo Indian Reservation (Cooley and others, 1964, p. 220-229) and the southern part of the Jicarilla Indian Reservation (Baltz and West, 1962, p. 137-152). Berry (1959) has included a discussion of ground water in his work on the hydrodynamics and geochemistry of some formations in the basin. No monitoring network has been established; remarks about the quality of water in the basin are based on the above reports, miscellaneous analyses from various places in the basin, and personal observations.

The general quality of shallow ground water in the western two-thirds of the San Juan River basin is poor. Only where the San Jose Formation crops out in the eastern part of the basin, in the outcrop area of the sandstone formations to the west, and in the valley of the San Juan River is it possible to drill a well with some assurance that the ground water will be reasonably good (fig. 7). Water found elsewhere

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

is apt to have more than 1,000 ppm of dissolved solids and to be unsuited for domestic use according to U.S. Public Health Service standards (1962).

Figure 7.--General quality of shallow ground water in New Mexico.

Cooley and others (1964), in describing the general character of the ground water on the Indian Reservations, state that the water is chiefly a bicarbonate type. They present a table showing the range of concentration of common constituents of ground water. Berry (1959, p. 141) cites an occurrence of ground water containing about 44,000 ppm of dissolved solids in a gas well penetrating a saline-water zone in the Pictured Cliff Sandstone, of Cretaceous age, about 6 miles south of Bloomfield. Berry (1959, p. 143) postulates that the Entrada Sandstone of Jurassic age (San Rafael Group) must contain water having concentrations of approximately 130,000 ppm or greater in the central part of the basin.

Baltz and West (1962, p. 137-152) describe the chemical quality of ground water in the southern part of the Jicarilla Indian Reservation and state that the water in formations of Cretaceous and Tertiary age varies widely in chemical quality. They report that, although much of the water in and near the southern part of the Jicarilla Reservation is undesirable for domestic use because of the high concentrations of dissolved solids, it is not so high as to classify it as impotable. Sulfate is the constituent most commonly present in concentrations large enough to make the water unsuitable for domestic use. It is probably that the conclusions of these investigators can be extended to cover adjacent areas where the geologic setting is similar.

Those parts of the basin in which ground-water investigations have been made in New Mexico are shown on figure 8. The principal

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

investigations are those made of the Navajo and Jicarilla Indian Reservations. Data and interpretation for these studies are available in open-file reports of the U.S. Geological Survey which will be published at some future time. A report on the availability of ground water at Chaco Canyon National Monument (West, 1957) also is in the open file.

Water-level measurements are not being made in the basin as part of a regular program. Miscellaneous measurements, made in connection with the investigations cited above, and in connection with other investigations made for administrative purposes, are available as basic data from the Geological Survey.

Figure 8.--Areas in New Mexico in which ground-water studies have been made.

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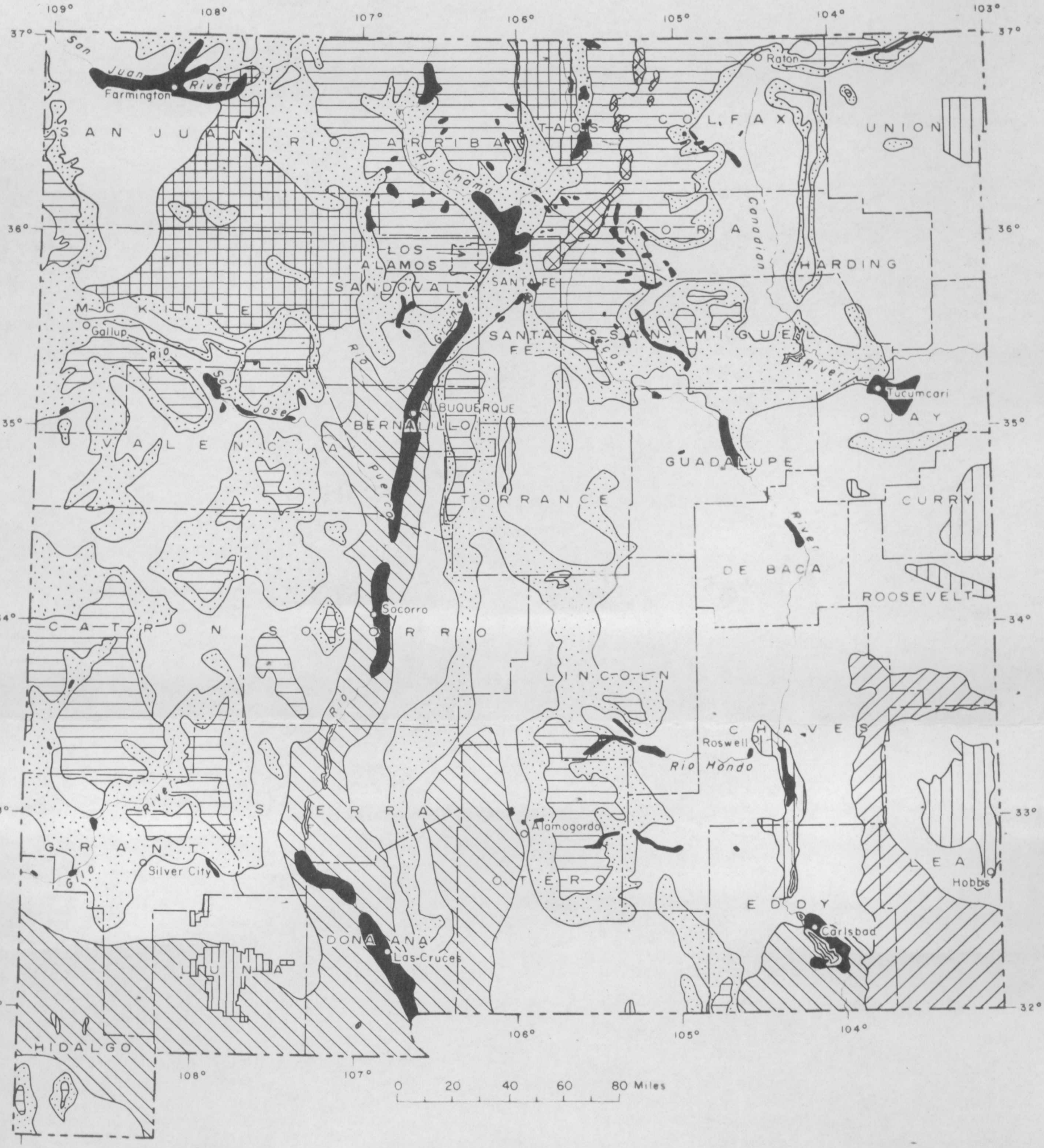
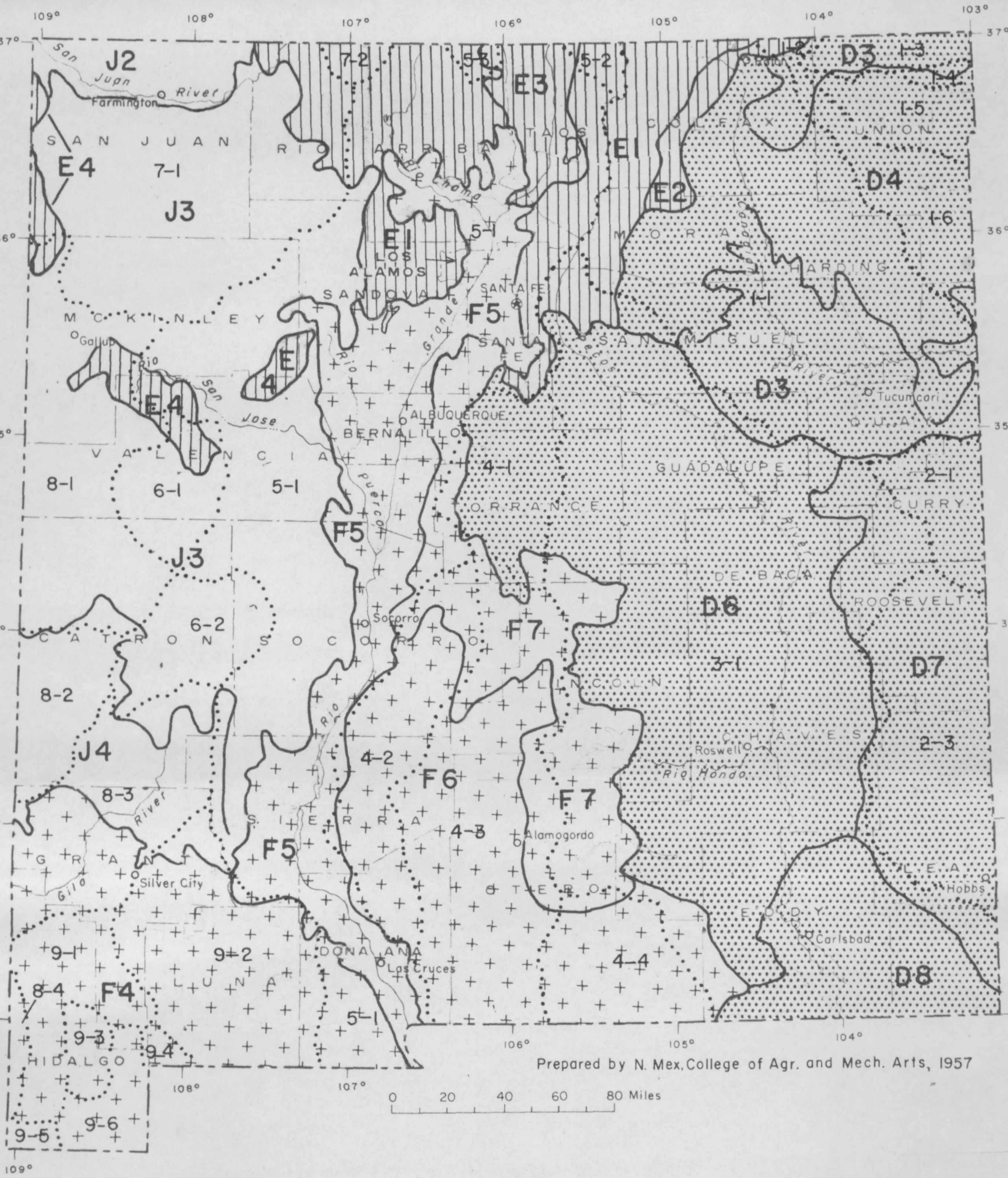


EXPLANATION

- Semi-desert brush
- Grassland
- Shinnery
- Big sagebrush
- Woodland
- Forest
- Tundra
- Irrigated lands with water sources from surface water only or from surface water supplemented by pumping of ground water
- Irrigated lands with water source entirely from pumped or artesian ground water
- Lakes and reservoirs

Figure 4. -- Vegetative-type map of New Mexico



D3 Generally shallow soils in steeply rolling and rough broken areas. Moderately deep and deep soils in valley bottoms and alluvial fans.

D4 Largely moderately deep to deep, medium to heavy-textured soils interspersed with some areas of shallow soils; generally gently rolling topography.

D6 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.

D7 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.

D8 Similar to D-7, east of Pecos river, interspersed with areas of shallow to moderately deep, medium-textured soils west of Pecos river.

E1, E2, E3, E4 — 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

F4 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.

F5 Large areas of light to medium-textured, shallow to moderately deep soils with gentle to moderate slopes.

F6 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.

F7 Largely mountain ranges and foothill slopes. Dominantly medium-textured soils on mountain slopes, and moderately deep to deep soils on foothill slopes.

J2 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.

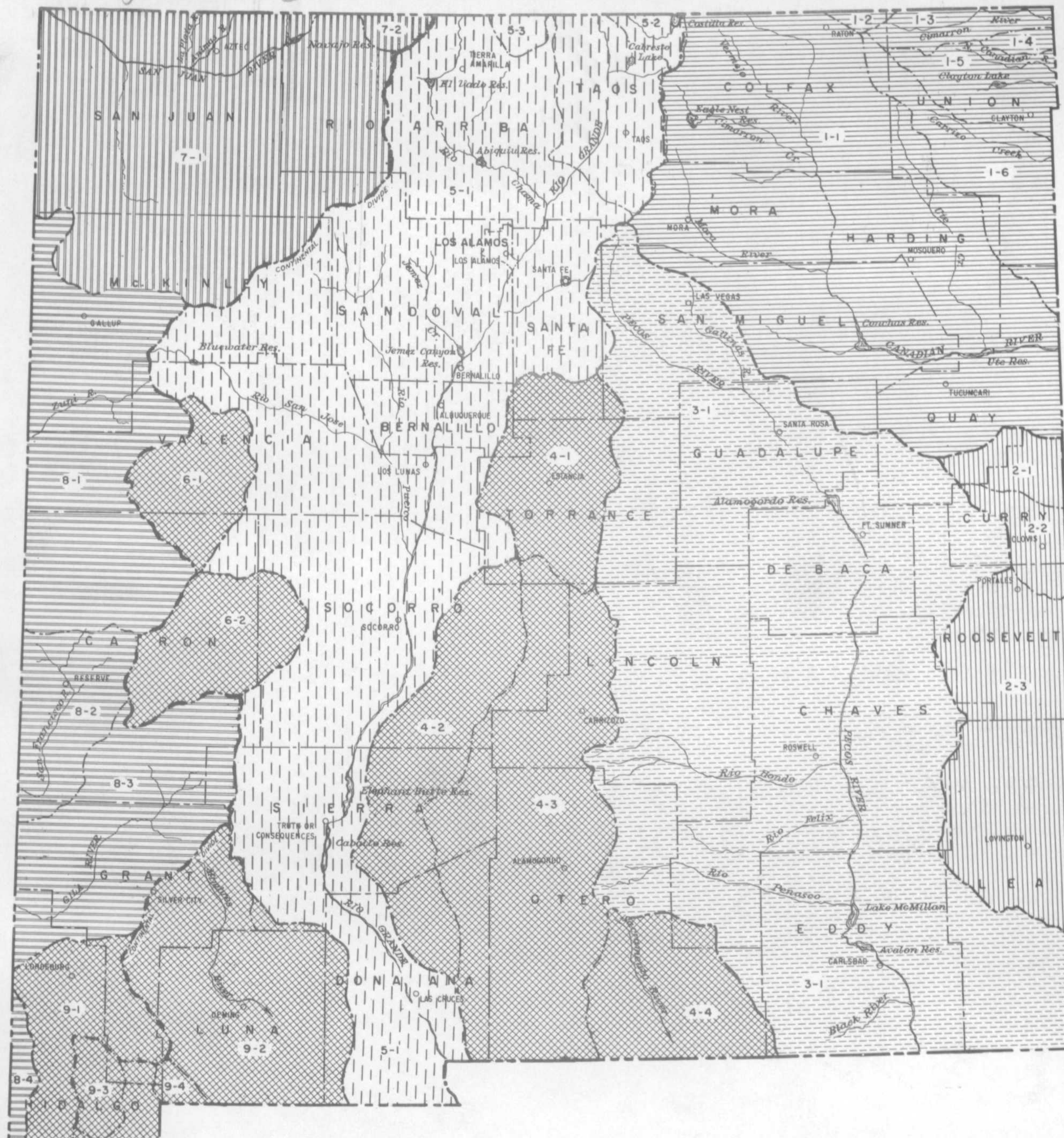
J3 Largely medium-textured, moderately deep to shallow soils interspersed with areas of light-textured soils. Generally rolling topography with steep slopes in mountainous areas.

J4 Generally mountainous shallow soils interspersed with rock outcrops and small areas of moderately deep soils. Generally mountainous topography.

Fig 3

Figure 3.-- Soils resource map of New Mexico

Cooper-Trough — San Juan



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

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

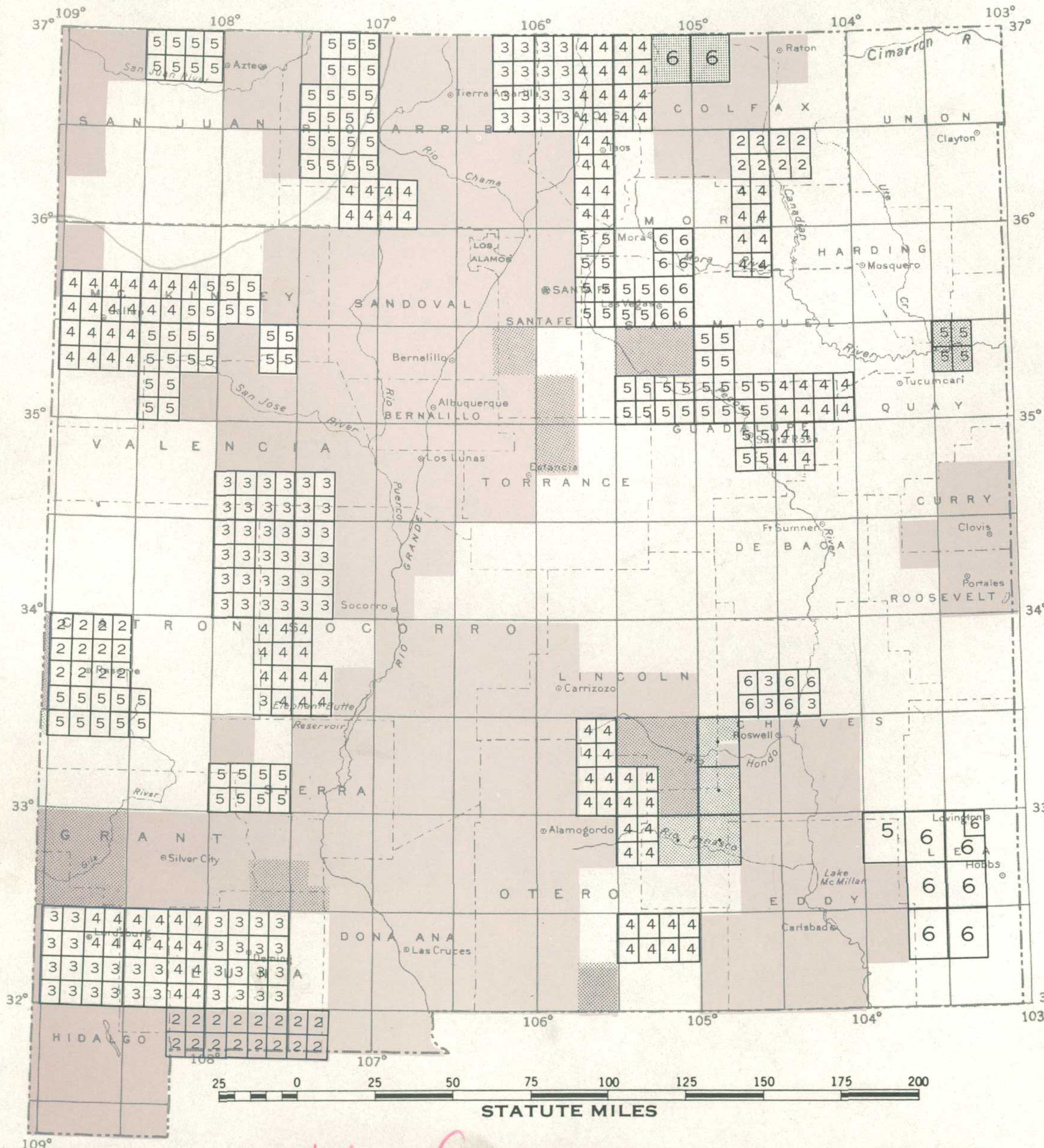
FIGURE I

DRAINAGE BASINS OF NEW MEXICO

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NEW MEXICO

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



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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.

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NOTES

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Figure 2.--~~Index to~~ Status of topographic mapping in New Mexico

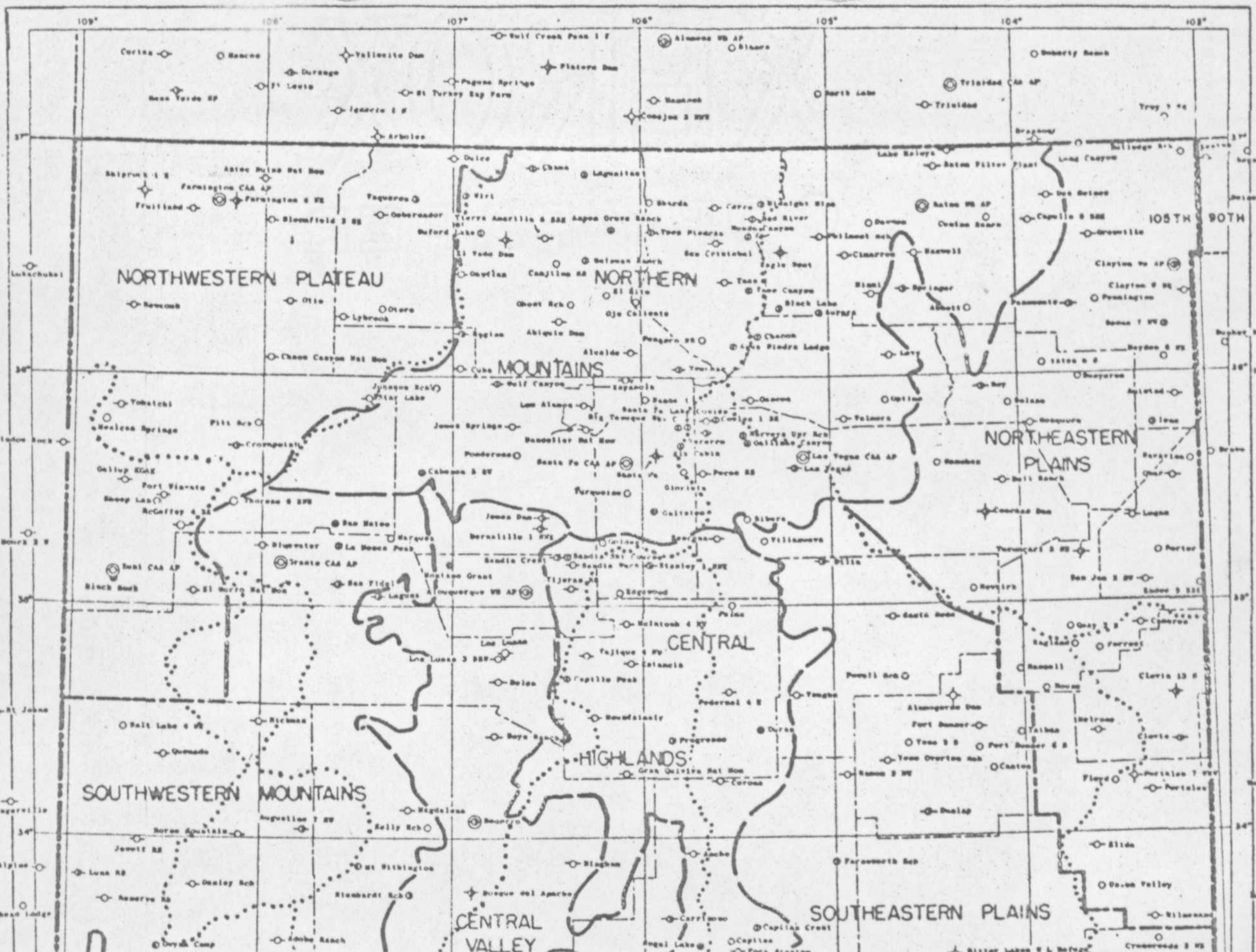

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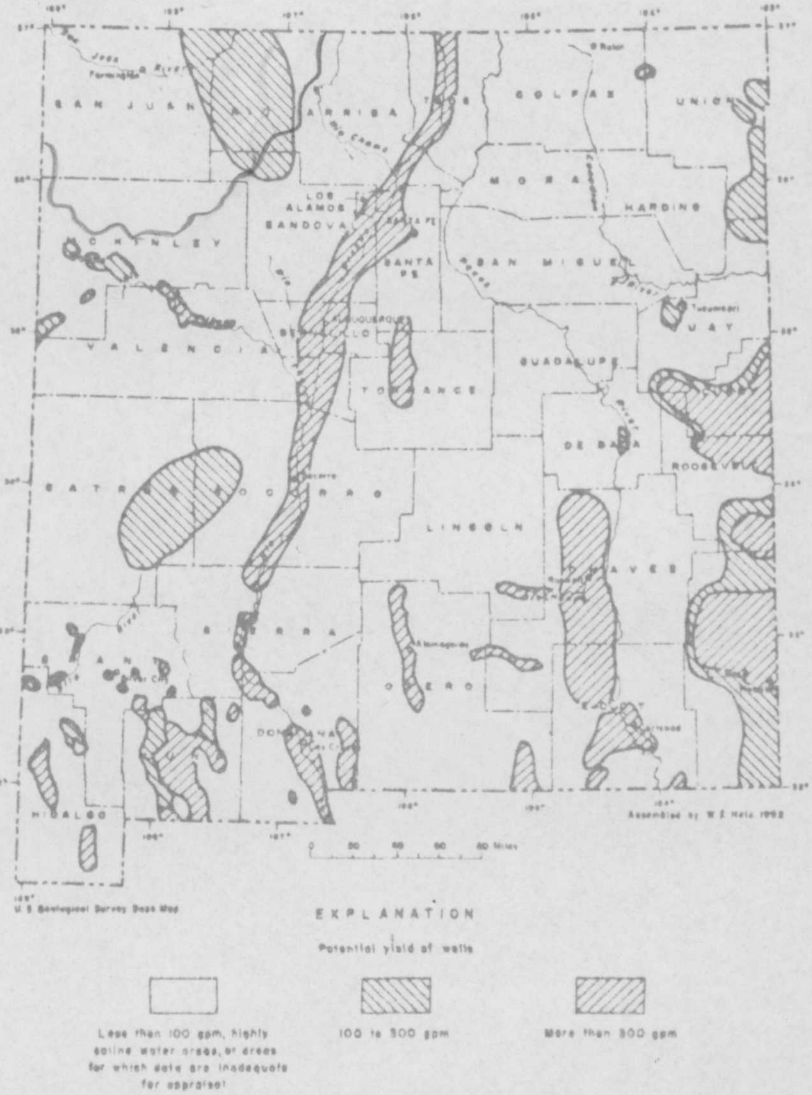
Figure 5.--Weather-stations ~~locations~~ and climatologic divisions in New Mexico

Note

San Juan Basin



Small Moderate Large

Figure 6.--General availability of relatively fresh ground water in New Mexico

San Juan

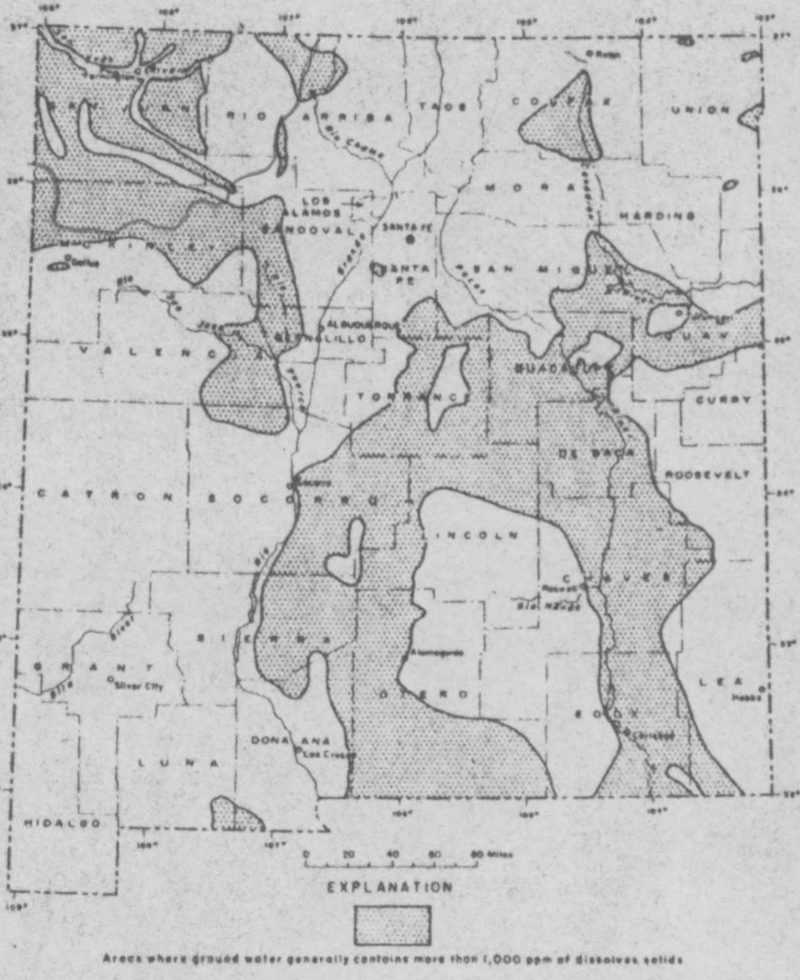


Figure V.--General quality of shallow ground water in New Mexico

San Juan

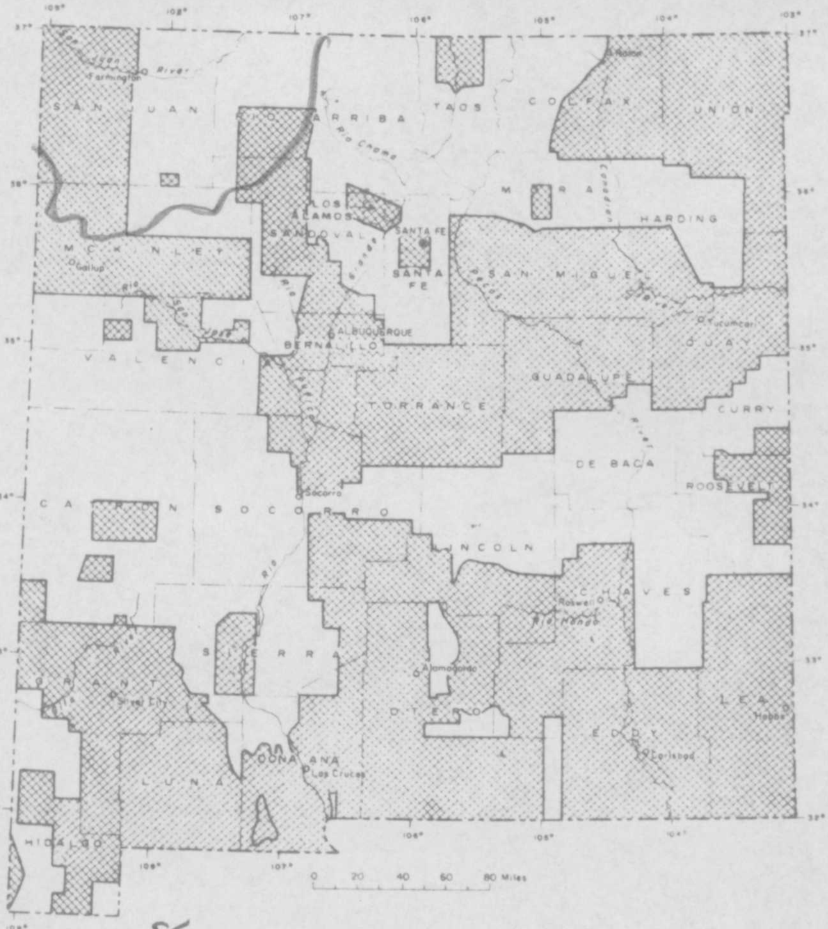


Figure 8.--Areas in New Mexico in which ground-water studies have been made.