GROUND WATER FOR ENERGY DEVELOPMENT, NORTHWESTERN NEW MEXICO

W. J. Stone
and
Tim Kelly

General Statement

Northwestern New Mexico holds a large share of three natural resources used in energy production: petroleum, coal, and uranium. Their development requires water. Virtually all of the surface water in northwestern New Mexico has been appropriated, the largest single claimant being the Navajo Tribe. Thus, water for future industrial or municipal use must either be negotiated surface water or ground water.

Surface water supplies and demands were a central issue at recent environmental-impact hearings in Window Rock and Farmington for the proposed coal-gasification plants in western San Juan county. In addition to the proposed gasification plants, surface water will also be utilized in the Navajo Indian Irrigation Project in northeastern San Juan County. With these heavy demands on the surface water sources--and some have even said there will not be enough for both projects -- the availability of ground water becomes very important.

William J. Stone is a hydrologist with the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico and Tim Kelly is a member of the United States Geological Survey, Water Resources Division, Albuquerque, New Mexico.

Stratigraphic nomenclature used herein is not necessarily that of the U.S. Geological Survey.

According to average annual water uses in the San Juan River Basin, published in 1967, ground water accounts for only 45/100ths of 1% of all water uses! Ground water has been previously ignored for several reasons: surface water is readily available, ground water is often deep and saline, and little is known of the occurrence and availability of suitable supplies.

In an effort to solve this problem, the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey Water Resources Division, are presently engaged in a cooperative study of the hydrogeology and ground water resources of northwestern New Mexico.

Purpose of Paper

The purpose of our paper today is three-fold:

a) to describe our project,

b) to summarize the regional setting of the study area and

c) to present our preliminary findings.

Location

The study area is located in the northwestern most corner of the state and includes all of San Juan County, northern McKinley County and the western parts of Rio Arriba and Sandoval Counties (Figure 1). The western part of the study area includes the New Mexico portion of the Navajo Nation.

Objectives/Approach

The objectives of our project are to collect and interpret basic hydrogeologic and ground water resource data.

Our approach includes both field and laboratory study. In the field, geologic information is being mapped and water wells are being inventoried. In the lab, rock and water samples are being analyzed and subsurface geologic data from the numberous oil and gas wells in the study area are being compiled in the form of geologic cross-sections.

Agencies Involved/Responsibilities

The principal agencies involved are the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey. The Bureau is responsible for working out the hydrogeologic setting and the Survey is responsible for collecting and analyzing the basic ground water data. We have, however, tried to contact all other local, state, federal and tribal agencies that may have input or that may ultimately benefit from such a study in order to explain our program, promote cooperation, and gain other perspectives on the problem.

Time Frame/Schedule

The project will take a total of about 5 years and has been divided into 3 parts or phases by area:

1st phase - San Juan County - duration 2 yrs.
2nd phase - Northern McKinley County - duration 1 1/2 yrs.
3rd phase - Wester Rio Arriba, Sandoval Counties - duration 1 yr.

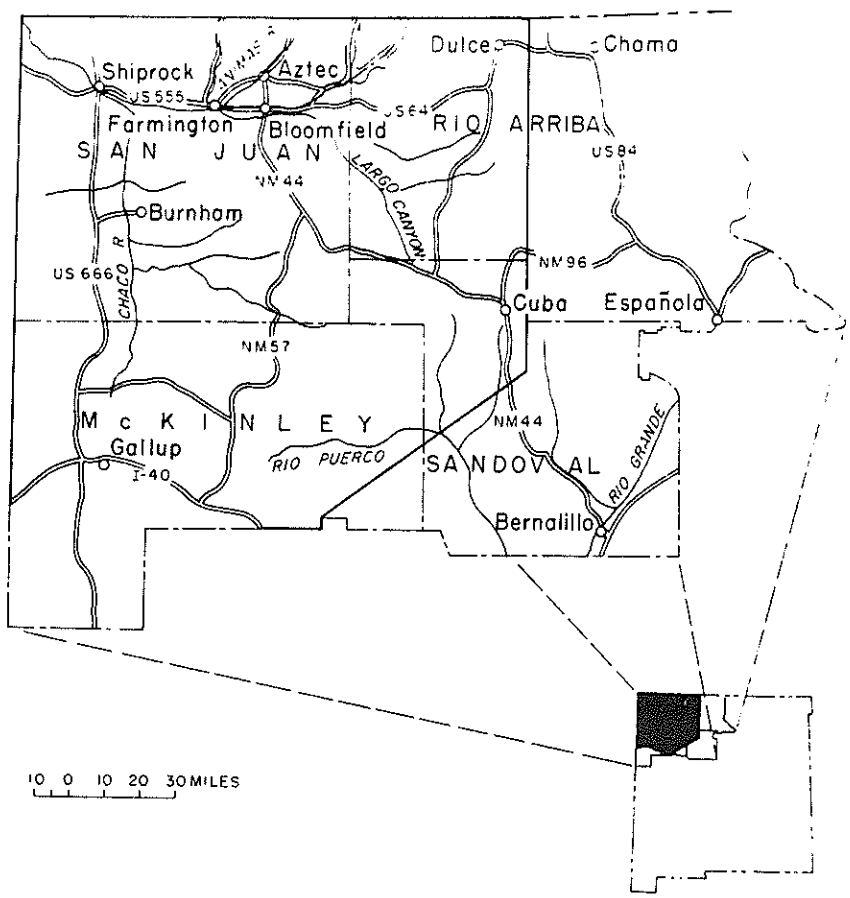

Figure 1. Location of study area.

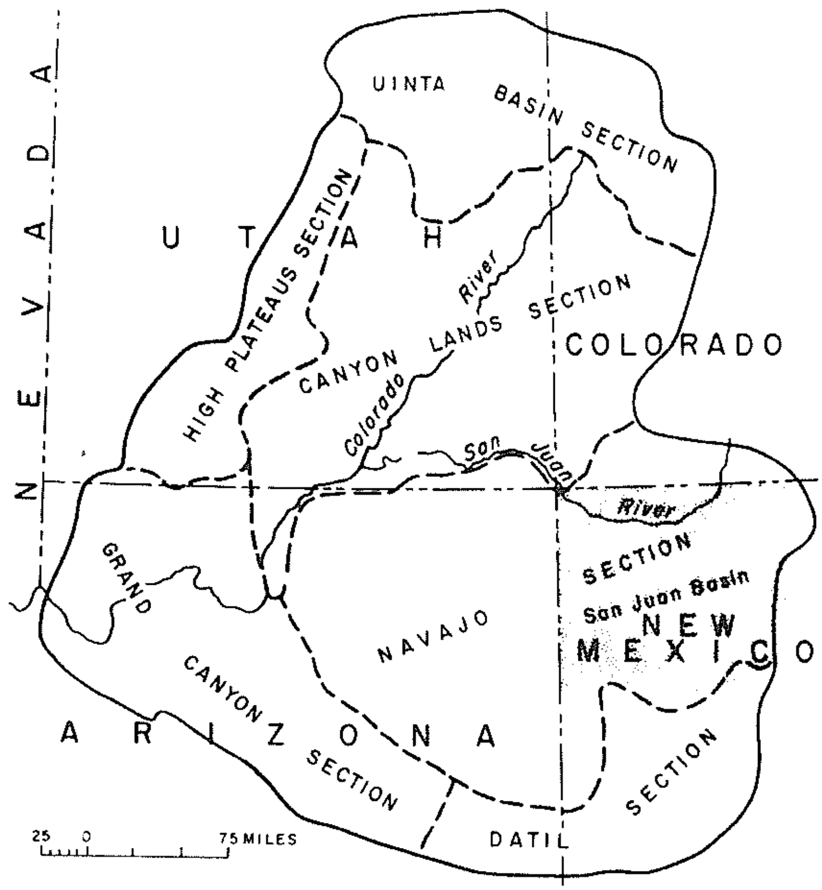

Figure 2. Physiography (Thornbury, 1965).

A separate report will be prepared for each of these 3 areas. We are now involved with Phase I - San Juan County. This area is being done first because of the urgent need for ground water data there in view of the anticipated energy development and growth.

The Study Area

Physiography/Climate

The study area is situated in the Navajo Section of the Colorado Plateau physiographic province, as seen in Figure 2. It has a semi-arid climate with an average annual precipitation of 8 - 10 inches and a pan evaporation rate of 67 inches (based on records for the period 1948 - 1962). The average January temperature is 28°F and the average July temperature is 73°F.

The physiography of the study area is characterized by broad open valleys, mesas, buttes, and hogbacks. Topographic relief is generally low away from the major valleys and canyons. Native vegetation is sparse and shrubby as seen in this slide.

The study area is drained by the San Juan River, which, as shown in Figure 3, is a part of the Colorado River system. The San Juan River is also the only permanent stream in the Navajo Section.

Major tributaries of the San Juan River include the Animas, Chaco, and La Plata Rivers. Examples of average annual discharge of the San Juan River system are shown in Figure 4. Between its inflow point, in Rio Arriba County, and its outflow point, in San Juan County, the San Juan River drops some 1800 ft. in elevation.

Structural Geology

The study area largely coincides with the geologic structure known as the San Juan Basin, which comprises about half of the Navajo Section of the Colorado Plateau. Kelley (1951) recognized several separate structural elements within the basin as shown in Figure 5. Monoclines are the most distinctive type of structure in the Colorado Plateau and several excellent examples occur in the San Juan Basin. This structural depression mainly occupies northwestern New Mexico but also extends into southern Colorado as well. It covers an area of about 10,000 sq. mi. and has about 6000 ft. of structural relief. The deepest well drilled in the Basin is near Gobernador, in northwestern Rio Arriba County, where 14,423 ft. of sedimentary rocks were penetrated without reaching basement.

Surface Geology

The geologic map of the study area (Figure 6) shows a typical basin, that is, distinct curving bands of outcrop with younger rocks in the center and older rocks around the outside. (Notice the stratigraphic succession of rock units in the legend for future reference.) The most prominent

Figure 3. Colorado River Basin (study area stippled).

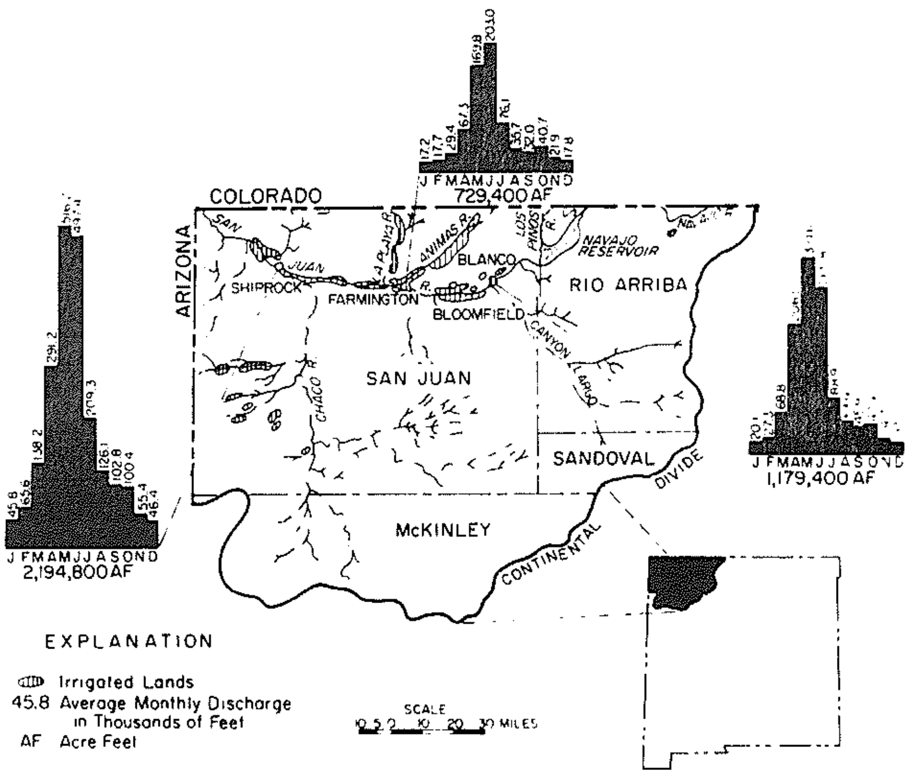

Figure 4. San Juan River Basin (Cooper and Trauger, 1967).

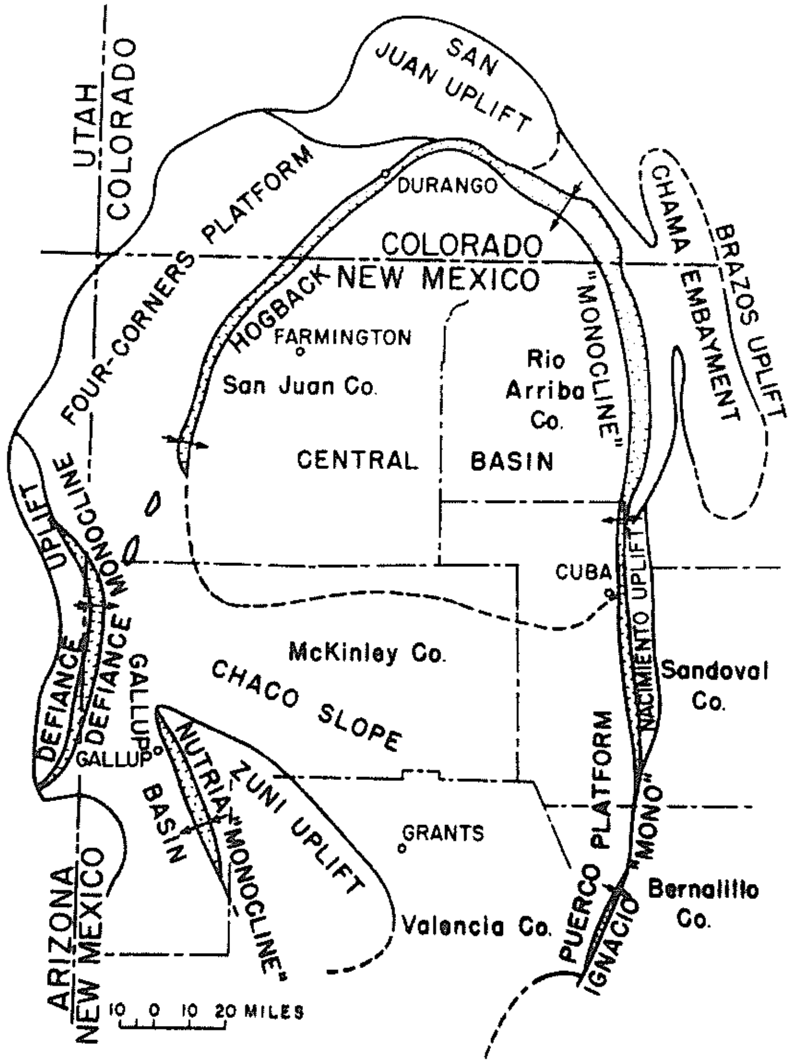

Figure 5. Structural geology (Kelley, 1951).

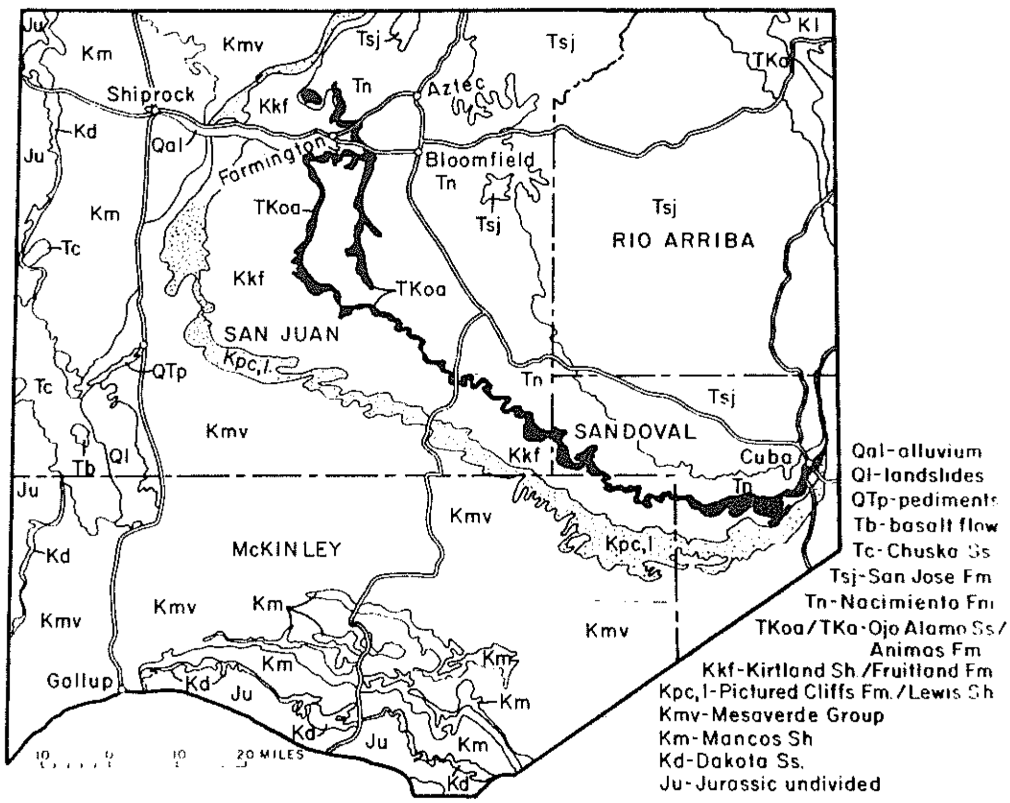

Figure 6. Surface geology (Dane and Bachman, 1965).

outcrops are those associated with the Cretaceous strata which cover much of the area as a broad band lying between the Jurassic and Tertiary aged strata. The North-South trending Hogback Mountain, along the west edge of the study area, consists of Cretaceous rocks dipping steeply eastward. The Ojo Alamo Fm., in part Cretaceous and in part Tertiary crops out in a distinct band as seen in this slide. Rocks of Tertiary age cover the large central portion of the basin. Quaternary deposits occur in stream valleys, along mountain fronts, and atop all other rock units throughout the Basin.

Subsurface Geology

In this study, only Jurassic and younger strata will be considered because older rocks are usually too deep to be economically feasible. The Jurassic rocks record nonmarine or continental deposition extending northward from and adjacent to highlands in the southern part of the region.

The Cretaceous strata represent deposition in and at the margins of the last great sea to invade the continent. In Cretaceous time (about 100 million years ago) the North American continent was divided by a seaway extending from the Arctic Ocean to the Gulf of Mexico. As this Cretaceous Sea lapped on and off the land, a unique rock record of alternating coastal plain carbonaceous shales and coals, shoreline sandstones, and off shore shales was produced (Figure 7).

Where present, continental Tertiary and Quaternary deposits overlie all of the other strata of the Basin and are nearly flat lying. The fact that the Basin is asymmetrical with its deepest part somewhat east of apparent center and has steeper dips on the east than on the west is clearly shown in a cross-section (Figure 8).

Preliminary Results

General Statement

The results are largely restricted to the area of Phase I of our project, San Juan County, and are based on our preliminary compilation of date. In compiling this date, 4 maps were prepared showing the following:

a) the location of outcrops of the aquifers (except in the case of the alluvium which is very widespread),

b) the location of wells penetrating the aquifers, and

c) the direction of deterioration of ground water quality for the wells involved.

In this mapping, the aquifers were grouped more or less geologically -- that is on the basis of age -- but the main consideration was clarity or readibility of the maps. It should be noted here, that the concentrations of wells on these maps are more an indication of local population densities than of ground water availability.

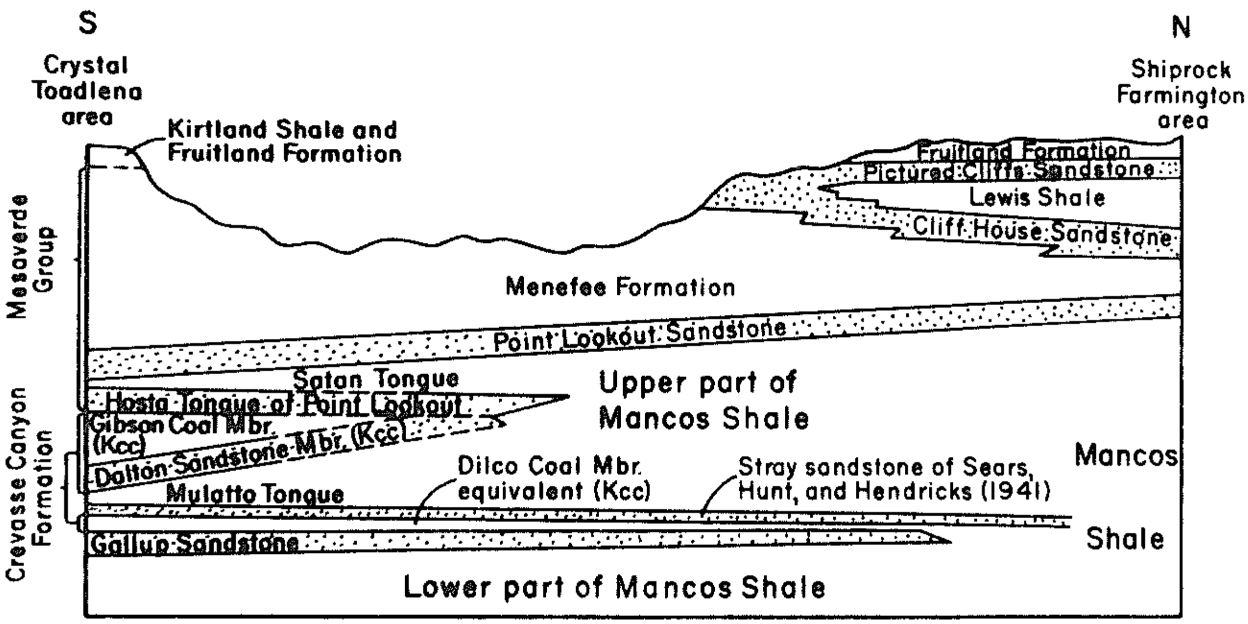

Figure 7. Cretaceous stratigraphy (O'Sullivan and Beikman, 1963).

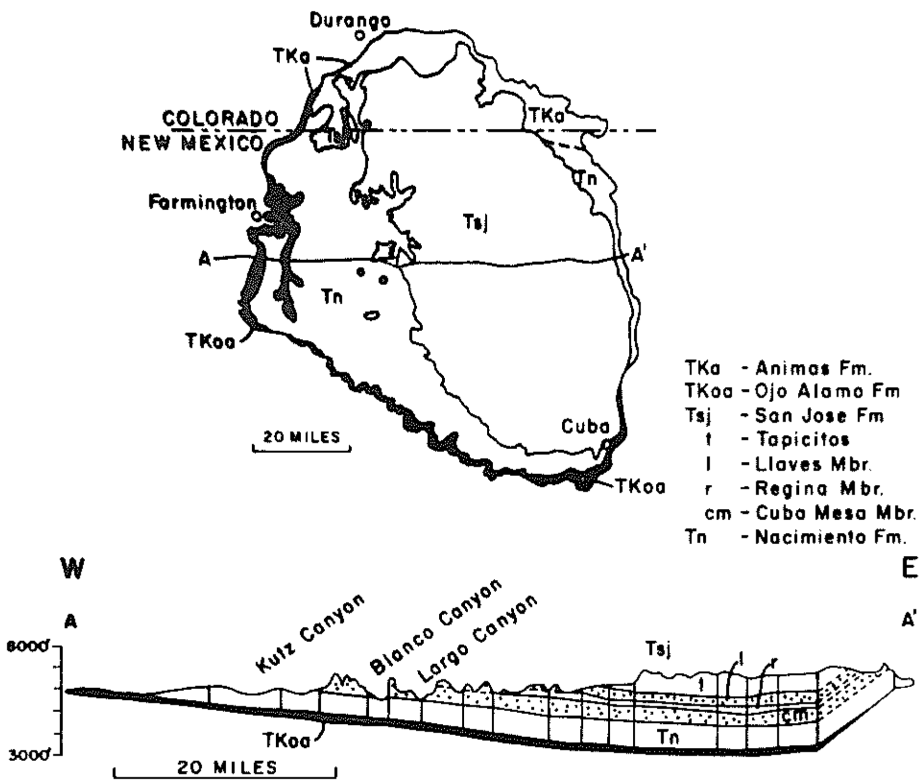

Figure 8. Tertiary stratigraphy (Brimhall, 1973).

Ground water quality will be given in terms of ppm (parts per million, total dissolved solids). For reference I might point out that the recommended drinking water limit is 500 ppm TDS, water with 500-35,000 ppm TDS is termed "saline", and that with greater than 35,000 ppm TDS is termed "brine". Obviously TDS content also effects suitability of ground water for agricultural and industrial uses as well. For example, water with TDS of more than 2000 ppm may be unsuited for long-term irrigation; as regards industrial use, TDS standards for boiler feed waters vary with pressures involved: for pressures ranging from 0 to greater than 400 psi, TDS standards range from 3,000-50 ppm.

The aquifers will be discussed in order of increasing depth (also, therefore, increasing geologic age).

Aquifers

Alluvium (Figure 9)

Distribution - at surface in stream valleys, along mountain fronts

Thickness - 0-50'

Lithology - unconsolidated clay, silt, sand, and gravel

Quality - fresh to slightly saline

Yield - poor to excellent, depending on coarseness and sorting

Remarks - Water from the alluvium generally is adequate and suitable for domestic purposes, however the quality usually reflects the water from nearby outcrops. In the badlands areas, water from alluvium generally is very highly mineralized.

Alluvium is a major source of water along the Chaco River but is only infrequently used along the San Juan and its tributaries.

Water in alluvium would be the first to be affected by strip-mining operations, particularly in the Chaco River alluvium near Burnham, Trading Post.

Chuska Ss. (Figure 10)

Distribution - west side of Chuska Mountains

Thickness - 1,000 ±

Lithology - sandstone with some interbedded shale and siltstone

Quality - fresh to slightly saline

Yield - poor to good, depending on the thickness of interbedded shale, siltstone

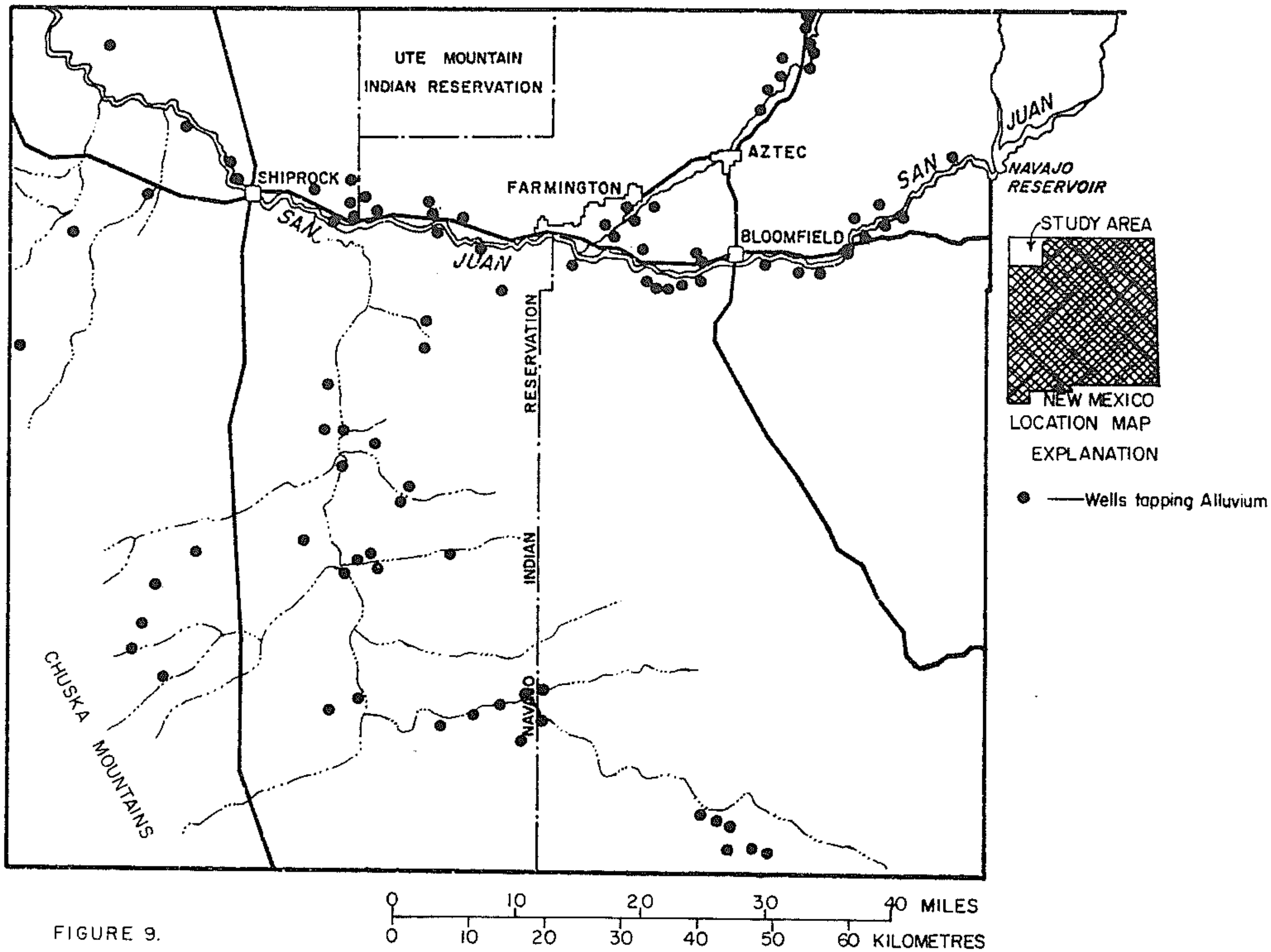

FIGURE 9.

Data collection points from wells and springs tapping alluvium in San Juan County, New Mexico.

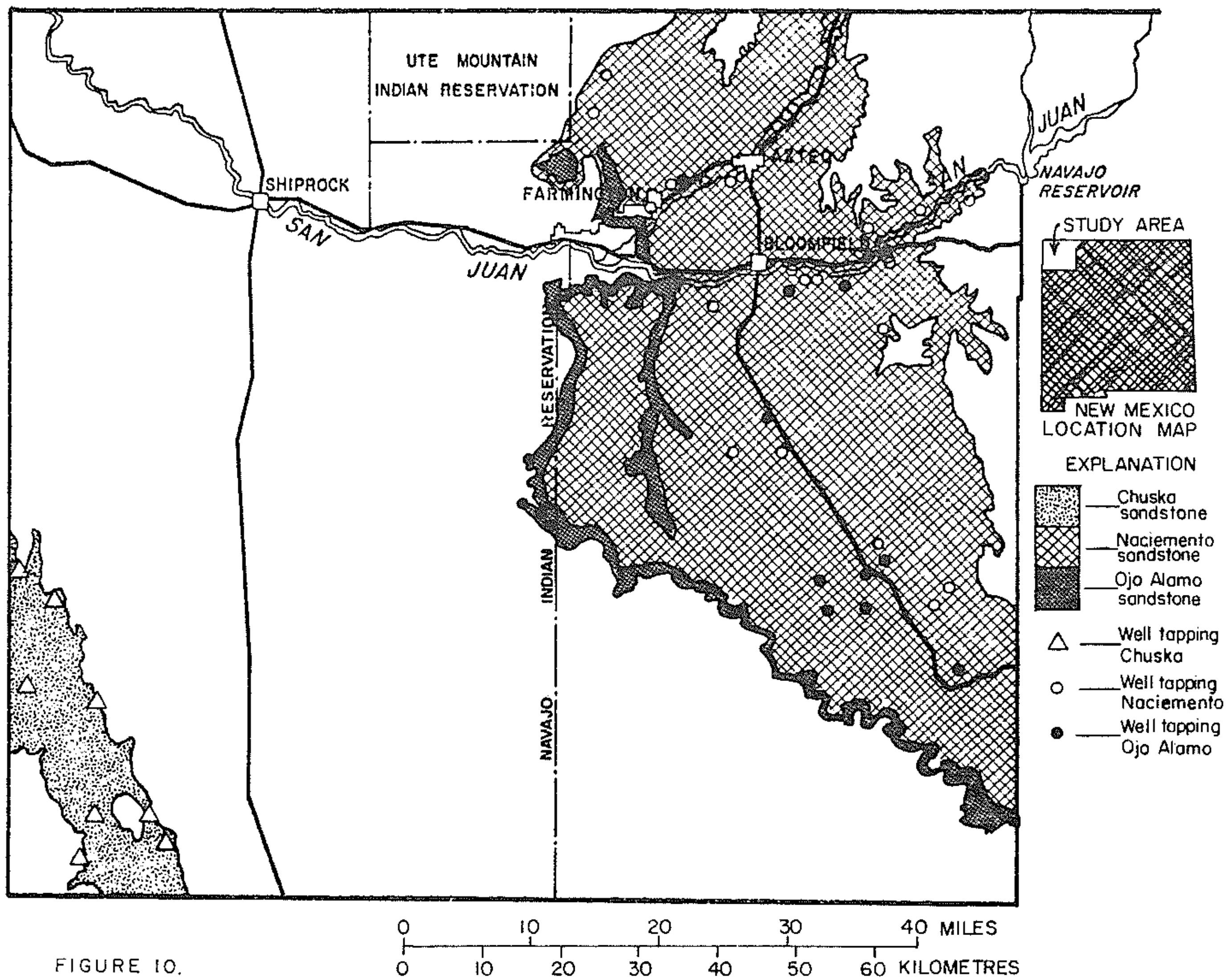

FIGURE 10.
Data collection points from various water-bearing units in San Juan County, New Mexico.

Remarks - Water from the Chuska is used locally for domestic purposes. The quality is excellent. Wells generally have small yields yields, but this may be due to well construction rather than aquifer capabilities. The Chuska is entirely within the Navajo Reservation and is generally untested.

<u>San Juan Fm.</u>

Distribution - not distinguished on the map because of little data for it in San Juan County; covers eastern edge of the area, east of the Nacimiento outcrop.

Thickness - 250 - 2000'

Lithology - sandstone, siltstone, and shale; Llaves and Cuba Mesa Mbrs. are sandstone and potential aquifers

Quality - Brimhall (1973) reported 1,824, ppm TDS - Cuba Mesa Mbr.; fresh to slightly saline generally.

Yield - 36-60 gpm (according to Brimhall, 1973)

Remarks - the sandstone members of the San Juan Fm. may be recharged by the Navajo Reservation and should be investigated further.

<u>Nacimiento Fm.</u>

Distribution - central and eastern half of area

Thickness - 1200 - 3000'

Lithology - shale and siltstone with local conglomeratic sandstone

Quality - 700-1400 ppm TDS (according to Brimhall, 1973); slightly to moderately saline

Yield - 35-200 + gpm

Remarks - The Nacimiento is primarily shale containing thin sandstone units. Shallow wells may provide adequate quantities of water for domestic use. Well yields are small. Water below about 150 feet is usually highly mineralized - in at least one instance exceeding 3,000 ppm.

<u>Ojo Alamo Fm.</u>

Distribution - central and eastern half of the area

Thickness - 50 - 400'

Lithology - coarse sandstone to conglomerate and shale

Quality - 1,000 ppm TDS has been reported near outcrop; generally fresh to slightly saline

Yield - large enough for domestic and stock use

Remarks - The Ojo Alamo is the principal shallow aquifer in eastern San Juan County. Water quality is gemerally good; well yields of up to 100 gallons per minute have been reported. Additional development of the Ojo Alamo should be anticipated. This aquifer possibly will be recharged by the Navajo Indian Irrigation Project.

Kirtland Fm. (Specifically, the Farmington Ss. mbr.) - Map (Figure 11) does not distinguish Kirtland from underlying Fruitland shale.

Distribution - central and eastern part of area; underlies all Tertiary strata

Thickness - 470' ±

Lithology - sandstone

Quality - potable near outcrop; 1,000 to 57,000 ppm TDS in basin

Yield - low

Remarks - The Farmington sandstone is the major water-bearing unit in the Kirtland-Fruitland Fms. Well yields are generally less than 100 gpm. Water quality depends on the proximity of shale to the producing horizon. At depths greater than 700 feet, water quality locally exceeds 8,000 ppm dissolved solids.

Pictured Cliffs Fm.

Distribution - occurs in most of area; underlies Kirtland Fm.

Thickness - 0 - 900'

Lithology - fine-grained sandstone

Quality - 30,200 - 37,800 ppm TDS; highly saline to brine

Yield - low

Cliff House Fm.

Distribution - occurs in most of area

Thickness - 0 - 800'

Lithology - sandstone

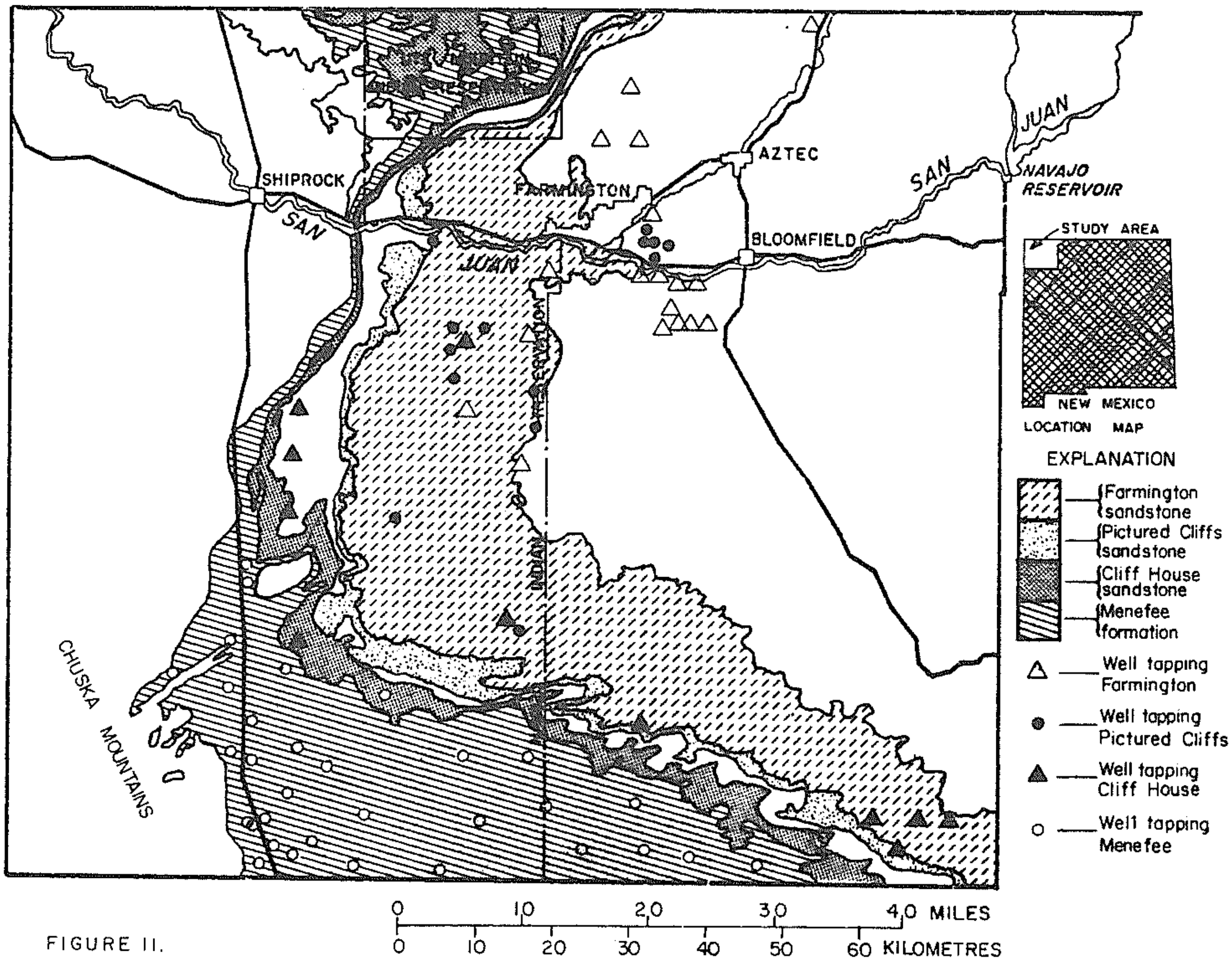

FIGURE II.

Data collection points from various water-bearing units in San Juan County, New Mexico.

Quality - mostly saline

Yield - low

Remarks - The Pictured Cliffs and Cliff House are hydrologically similar. Wells produce small quantities of good quality water near the outcrop belts; elsewhere the water quality deteriorates toward the northeast. These formations might yield sufficient water for industrial development.

Menefee Fm.

Distribution - present in most of the area

Thickness - 400 - 2200'

Lithology - carboaceous shale, sandstone

Quality - poor

Yield - locally sufficient for domestic, stock use

Remarks - The Menefee Fm. is one of the most widely-developed aquifers on the Navajo Reservation where it crops out over a broad area. Numerous stock and domestic wells tap this aquifer. The water quality is quite variable depending on depth and hydrologic conditions. Locally, Menefee wells flow. The The Menefee is generally not considered an aquifer in the sub-surface, that is, where it lies at some depth below the surface, farther out into the Basin.

Gallup Ss. (Figure 12)

Distribution - along the west edge of area

Thickness - 0 - 300'

Lithology - sandstone

Quality - fresh to slighty saline

Yield - fair to moderate

Remarks - The Gallup is a major aquifer in both San Juan and McKinley Counties. Yields of more than 1,000 gpm have been produced; water quality is good to excellent. Water from this unit is highly mineralized in the center of the basin.

Dakota Fm.

Distribution - underlies all of region except extreme western margin

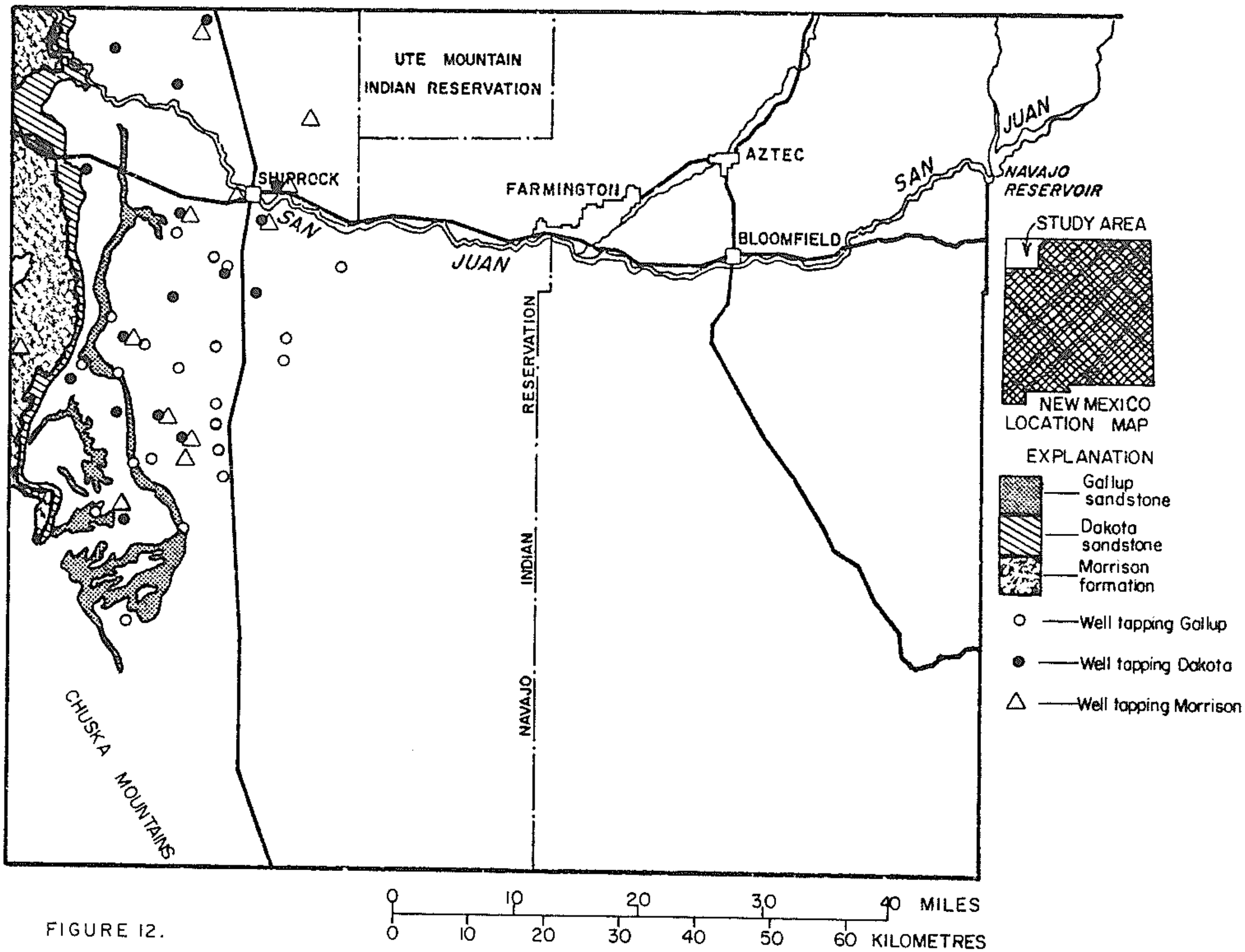

FIGURE 12.

Data collection points from various water-bearing units in San Juan County, New Mexico

Thickness	- 150 - 250'
Lithology	- sandstone, conglomerate, shale
Quality	- fresh to moderately saline
Yield	- 10 - 15 gpm
Remarks	- The Dakota sandstone generally yields small quantities of water but is a major producer of hydrocarbons. Water quality is good to excellent along the outcrop belts in San Juan and McKinley Counties, more mineralized in the eastern part of the basin.

<u>Morrison Fm.</u>

Distribution	- probably underlies most of the area
Thickness	- 300 - 600'
Lithology	- shale, sandy shale, silty sandstone, sandstone
Quality	- slightly saline near outcrops; very saline away from outcrops
Yields	- 5 - 800 gpm
Remarks	- The Morrison locally produces large quantities of water. Numerous oil tests have been plugged back to this formation and developed as water wells. One such well reportedly flows 800 gom of 95°F water. Numerous wells in McKinley County obtain water from the Westwater Canyon Member of the Morrison which also contains the major uranium mineralization in that area. The Morrison may provide sufficient water for industrialization and should be tested further.

Conclusions

1. Large quantities of ground water with excellent to poor quality are present in a dozen aquifers at depths of less than 2000 feet in much of the p project area.

2. Alluvium in the San Juan River and tributary valleys is generally less than 30 feet thick and probably will not yield adequate supplies for valley communities such as Aztec or Bloomfield.

3. The hydrologic impact of the Navajo Dam is difficult to assess but the reservoir may be an important source of ground water recharge for the San Juan Fm., a potential target for future water resources.

4. The Navajo Indian Irrigation Project may be a source of recharge for the Ojo Alamo sandstone and observation wells should be established to monitor

this system.

5. Adequate quantities of ground water probably exist in the coal-bearing areas, however, its poor quality usually renders it unsuitable for domestic use and undesirable for industrial use.

6. Likewise, adequate quantities of ground water also exist in the Grants uranium belt where the ore body - the Westwater Canyon Mbr. of the Morrison Fm. - is also the principal aquifer.

7. Ground water must be utilized in northwestern New Mexico to a greater extent in the future than at present in view of the already heavy dependence on the surface water supply and anticipated increases in surface water demands.

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