GEOHYDROLOGY OF THE AQUIFERS THAT MAY BE AFFECTED BY THE SURFACE MINING OF COAL IN THE FRUITLAND FORMATION IN THE SAN JUAN BASIN, NORTHWESTERN NEW MEXICO

By Robert G. Myers and Edward D. Villanueva

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

In this report, figures for measurements are given in inch-pound units only. The following table contains factors for converting to metric units.

Multiply inch-pound units	By	To obtain metric units
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	4,407	square meter
foot per day	0.3048	meter per day
foot squared per day	0.0929	meter squared per day
square mile	2.590	square kilometer
acre-foot	1,233	cubic meter
gallon per minute	0.0631	liter per second

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9(°F - 32).$$

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ABSTRACT

A monitoring network of 50 wells was installed from 1975 to 1979 in the surface-minable coal area of the Fruitland Formation in the San Juan Basin of northwestern New Mexico. The purpose of the network was to collect hydrologic data and to establish a data base. The hydrologic data consist of water-level measurements, water chemistry, and selected aquifer characteristics. The four aquifers considered in this study are: (1) The Pictured Cliffs Sandstone; (2) coal seams and interbedded lithologic units of the Fruitland Formation; (3) overburden of the Kirtland Shale and Fruitland Formation; and (4) the alluvium along the Chaco River and its eastern and northeastern tributaries. Five sites were selected for study. Four of these sites, Western Coal Company's lease near Fruitland, Bisti West, Kimbeto, and Ojo Encino, have surface-minable coal. The Chaco River alluvium was selected because it is downstream from anticipated mining activity. The specific conductances of the representative water samples from selected wells in the 4 aquifers in the 5 study areas ranged from 800 to 23,000 microsiemens per centimeter at 25° Celsius. The dominant cation in all samples was sodium. The dominant anion varied. The water is brackish in the Pictured Cliffs Sandstone and in the coal seams and interbedded lithologic units of the Fruitland Formation. It is fresh to saline in the overburden of the Kirtland Shale and Fruitland Formation, and fresh to brackish in the Chaco River alluvium.

INTRODUCTION

As a result of the increasing demand for energy, the surface-minable coal reserves of the Fruitland Formation in the San Juan Basin of northwestern New Mexico (fig. 1) are being considered for surface mining. These coal reserves generally are within 250 feet of the land surface. The mining activities probably will have an effect on the ground-water resources of the area.

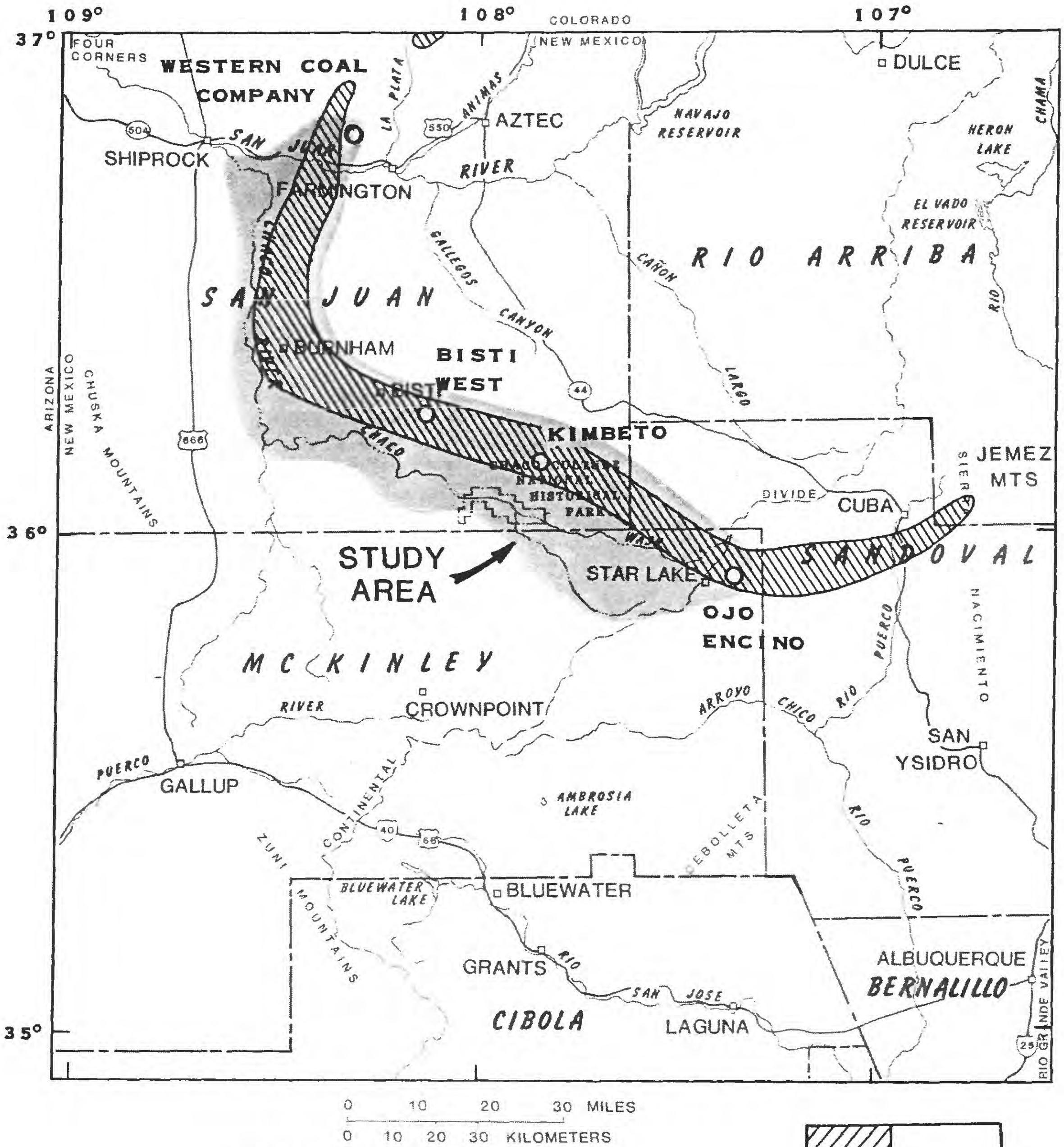
The purpose of this report is to summarize ground-water data collected from a U.S. Geological Survey monitoring-well network in the surface-minable coal area of the Fruitland Formation and to describe the geohydrology of the aquifers. The data includes water-level measurements, water chemistry, results of aquifer tests, and lithology. The monitoring network includes 50 observation wells. The network was started in 1975 and expanded each year through 1979. The surface-minable coal in the Fruitland Formation is located in the Central Basin of the San Juan Basin in parts of San Juan, McKinley, and Sandoval Counties in northwestern New Mexico. The aquifers considered in this study area are: (1) The Pictured Cliffs Sandstone; (2) coal seams and interbedded lithologic units of the Fruitland Formation; (3) overburden of the Kirtland Shale and Fruitland Formation; and (4) the alluvium along the Chaco River and its eastern and northeastern tributaries. Five sites were selected for study. Four of these sites, Western Coal Company's lease near Fruitland, Bisti West, Kimbeto, and Ojo Encino, are within the surface-minable coal area (fig. 1). The Chaco River alluvium was selected because it is downstream from anticipated mining activity.

This study is part of the technical investigations of the Federal coal-management program conducted in cooperation with the U.S. Bureau of Land Management. This program formerly was known as the Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) program.

The climate within the study area is semiarid to arid. Average annual precipitation ranges from 8 to 10 inches. Most of the precipitation occurs in the late summer and winter months. The temperature ranges from less than 0° to more than 100° Fahrenheit. Daily temperature variations usually exceed 30° Fahrenheit.

The topography of the study area is characterized by mesas, buttes, hogbacks, broad open valleys, and badlands with little or no vegetation. Altitudes range from about 5,300 feet above sea level in the northern part of the study area to about 10,000 feet above sea level on the eastern tip of the study area. Most of the area lies between 5,300 and 6,800 feet above sea level.

The streams in the area are ephemeral except for the San Juan River, which flows across the northern part of the study area. The perennial flow in the last 12.5 miles of the Chaco River and in the last 5 miles of Shumway Arroyo are caused by powerplant effluent.



EXPLANATION

SURFACE-MINABLE COAL RESERVES IN THE FRUITLAND FORMATION

O STUDY SITE

Figure 1.--Location of the surface-minable coal reserves in the Fruitland Formation.

Many previous investigations within the study area concentrated on the more productive aquifers that underlie the Pictured Cliffs Sandstone. Peabody Coal Company, Cherokee and Pittsburg Coal and Mining Company, and Genge Environmental Consultants, Inc. (1975) briefly mentioned the hydrology of the Fruitland Formation and Pictured Cliffs Sandstone in the Star Lake Coal Mine area of McKinley County. J. W. Shomaker prepared several unpublished consultant reports on the ground-water conditions of the Star Lake Coal Mine area between 1975 and 1979. Because these reports were not available, it is not known which reports include the aquifers considered in this report. Lyford (1979) mentioned the Chaco River alluvium and the Cretaceous aquifers underlying the Pictured Cliffs Sandstone in his report about ground water in the San Juan Basin. The U.S. Department of Interior, Bureau of Land Management (1976, 1981a, 1981b) presented some data for the Bisti West, Kimbeto, and Ojo Encino areas. Hejl (1982) described the hydrological studies within the San Juan Basin. Stone and others (1983) described the hydrogeology of the San Juan Basin.

Well Location and Numbering System

The system of numbering wells in this report is based on the latitude and longitude of the well. The first six numbers are the latitude north of the equator; the next seven numbers are the longitude west of the Prime Meridian; and the last two numbers are unique to the designated well to distinguish it from wells with the same latitude and longitude. The first two numbers of the well number are degrees of latitude; the third and fourth numbers are minutes of latitude; and the fifth and sixth numbers are seconds of latitude. The seventh to ninth numbers are degrees of longitude; the tenth and eleventh numbers are minutes of longitude; and the twelfth and thirteenth numbers are seconds of longitude. The fourteenth and fifteenth numbers are the unique identification number of the designated well. Minute, second, and unique numbers of one digit are preceeded by a zero. Thus, well number 360849107561801 is located at latitude 36°08'49" N. and longitude 107°56'18" W. The 01 is the unique identification number assigned to this well to distinguish it from other wells at this location.

The fifteen-digit well number used in this report is also the site-identification number of the well in the U.S. Geological Survey's Ground-Water Site Inventory (GWSI) File. This file is one of several files in the Water Data Storage and Retrieval System (WATSTORE). The system is used to manage hydrologic data. The GWSI File is cross-referenced with the Water Quality File and the Daily Value File. GWSI data include site location, site identification, geohydrologic characteristics, well-construction history, and one-time field measurements. Thus, the well number (WATSTORE site-identification number) in this report can be used to access data from the WATSTORE files.

Wells in the report are referred to by a 1- or 2-digit number in the figures, tables, and text. These numbers are cross-indexed with the fifteen-digit well numbers in the tables of records of observation wells.

GEOHYDROLOGY

Regional Setting and Geologic History

The San Juan Basin is on the eastern edge of the Colorado Plateau. The plateau uplift probably occurred during late Tertiary time. The plateau is characterized by widespread uplifts, structural basins, and monoclines. The San Juan Basin (fig. 2) is an asymmetrical, almost circular, northwest-trending structural basin formed during the Late Cretaceous and early Tertiary. The dip of the southwestern limb of the basin is gently sloping; the dip of the northeastern limb is very steep. The study area is located along the western and southern edge of the Central Basin and includes parts of the Hogback Monocline and Chaco Slope (fig. 2).

The San Juan Basin contains rocks ranging in age from Cambrian to Holocene (fig. 3), which have a combined thickness of as much as 15,000 feet. The Late Cretaceous intertonguing marine and nonmarine sedimentary rocks were deposited during the three major basin-wide cycles of transgression and regression of an epicontinental sea (Fassett and Hinds, 1977). In addition, there were many minor cycles of transgression and regression.

During the Late Cretaceous, the epicontinental sea, known as the Pictured Cliffs Sea, began its final withdrawal from the San Juan Basin. The last major regression of the Pictured Cliffs Sea was toward the northeast across the basin. Therefore, the Upper Cretaceous formations are younger from the southwest toward the northeast.

Four major depositional environments are associated with the Pictured Cliffs Sea regression (Beaumont, 1971). These environments produced marine and nonmarine sedimentary rocks that are gradational with adjacent units. The four environments are marine offshore, marine beach and nearshore, coastal swamps, and flood plains.

The offshore (sublittoral) deposition consisted of mud with streaks of fine-grained sand, silt, and limestone. These deposits are represented by the Lewis Shale. This formation underlies the Pictured Cliffs Sandstone, the oldest formation considered in this report.

The beach and nearshore (littoral) deposition in the study area consisted of moderately clean sand with streaks of mud and silt. This depositional environment also included the supralittoral beach sand and the mud in estuaries and lagoons. These deposits are represented by the Pictured Cliffs Sandstone.

The coastal-swamp deposition consisted of variable organic material, organic-enriched mud and silt, and the occasional accumulation of brackish-water pelecypod shells. Deltas, estuaries, and open lagoons in this environment interrupted local deposition, resulting in horizontally discontinuous coal deposits. These deposits are represented by the Fruitland Formation.

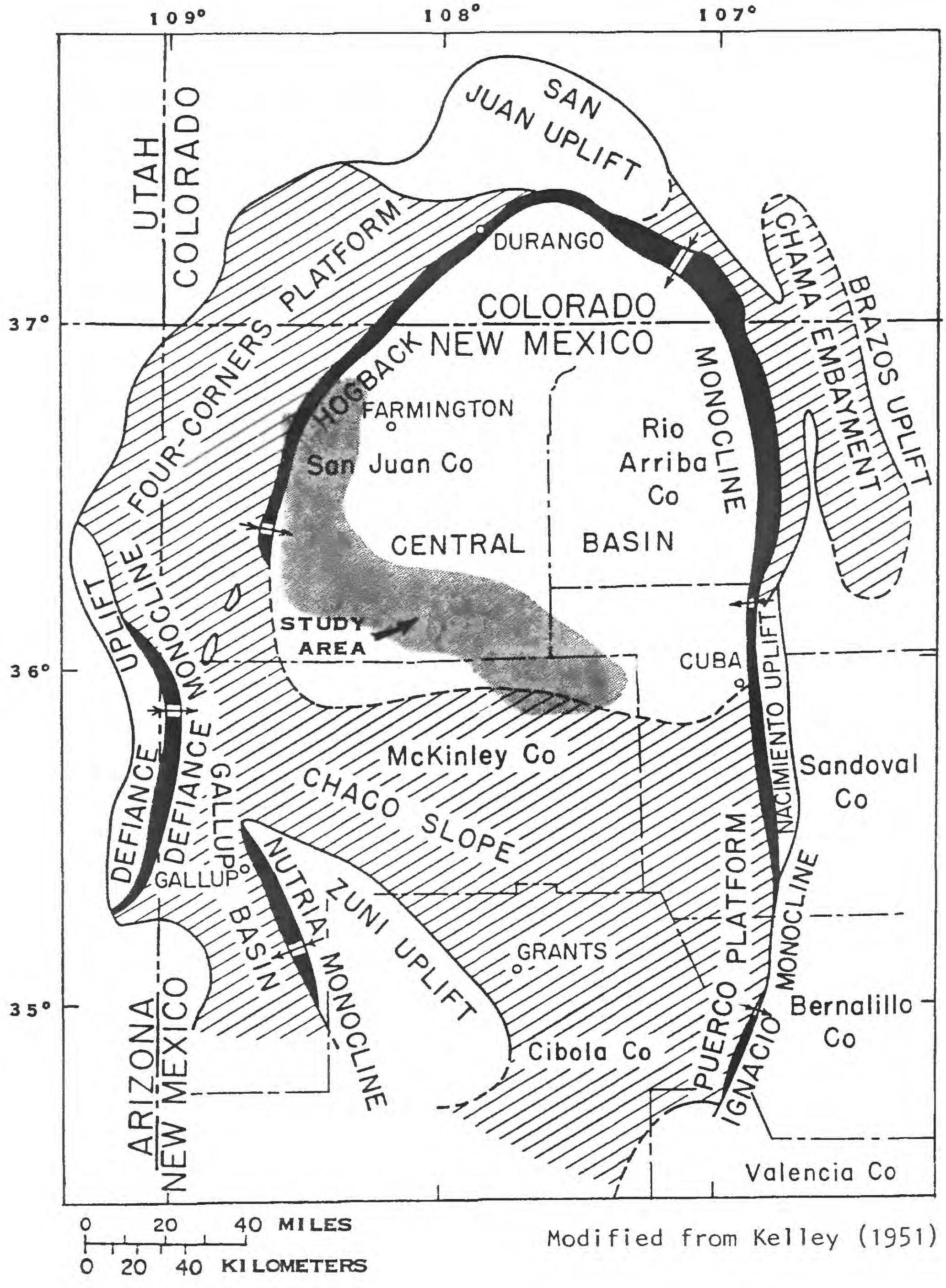
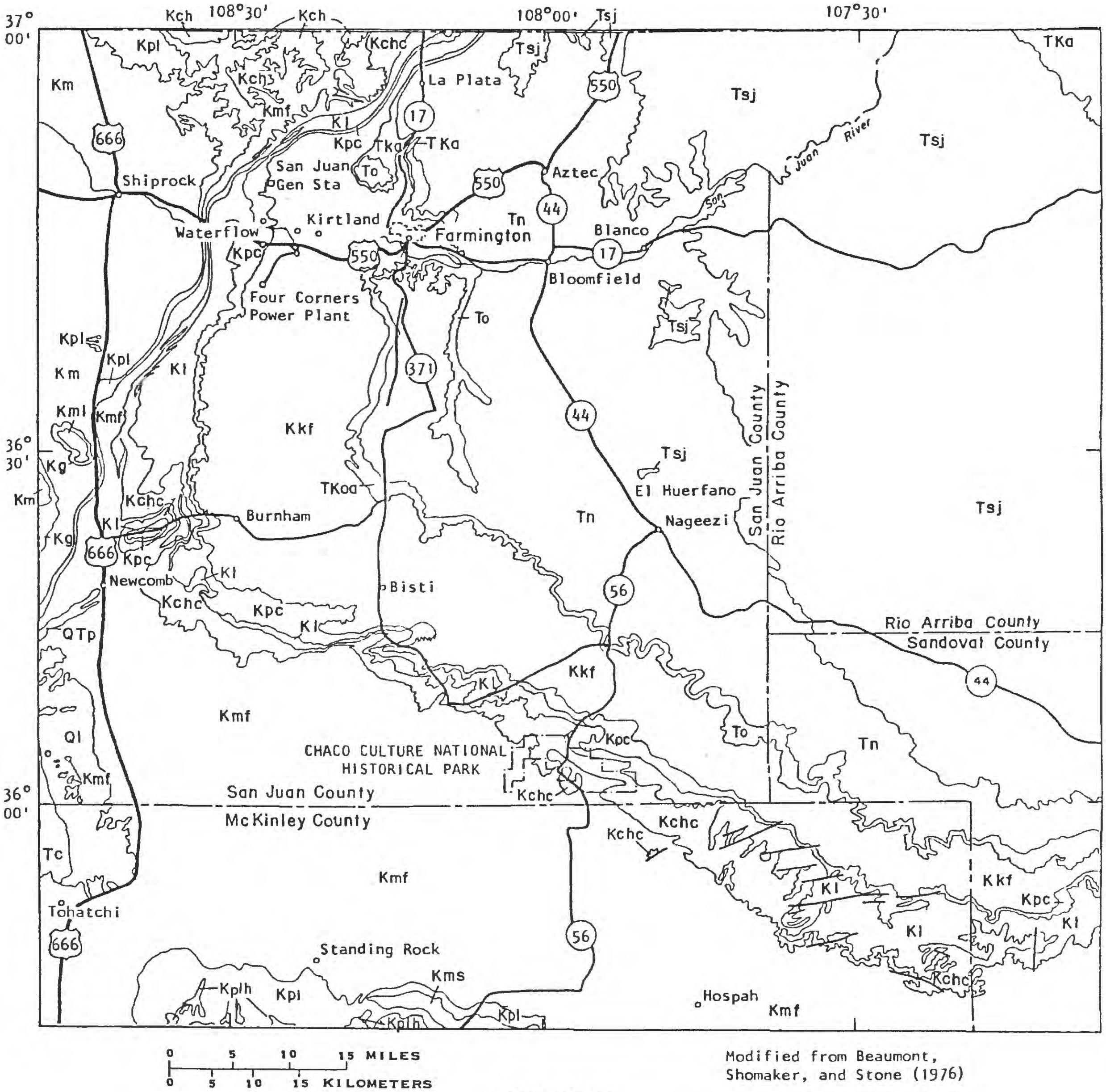


Figure 2.--Structural features of the San Juan Basin.



EXPLANATION

FAULT

QUATERNARY	Ql	LANDSLIDE DEPOSITS	
	QTp	PEDIMENT/TERRACE GRAVEL AND SAND	
TERTIARY	Tc	CHUSKA SANDSTONE	
	Tsj	SAN JOSE FORMATION	
	Tn	NACIMIENTO FORMATION	
	To	OJO ALAMO SANDSTONE	
	TKa	ANIMAS FORMATION	
CRETACEOUS	Kkf	KIRTLAND SHALE AND FRUITLAND FORMATION	
	Kpc	PICTURED CLIFFS SANDSTONE	
	Kl	LEWIS SHALE	
	Kch	CLIFF HOUSE SANDSTONE (Kchc, Chacra tongue)	MESAVERDE GROUP
	Kmf	MENEFEE FORMATION	MESAVERDE GROUP
	Kpl	POINT LOOKOUT SANDSTONE	MESAVERDE GROUP
	Kms	SATAN TONGUE OF MANCOS SHALE	
	Kplh	HOSTA TONGUE OF POINT LOOKOUT SANDSTONE	
	Kg	GALLUP SANDSTONE	
	Km	MANCOS SHALE (main part)	

Figure 3.--Surficial geology in and near the study area.

The flood-plain deposition consisted of fluvial and lacustrine sediments in the low areas adjacent to the coastal swamps and fluvial sediments predominantly composed of sand in the higher areas away from the coastal swamps. These deposits are represented by the Kirtland Shale.

The Chaco River basin (fig. 4) is thought to be the result of superposition and stream capture (DeAngelis, 1972). The basin consists of about 4,440 square miles. The river is ephemeral except for the last 12.5 miles, which has perennial flow caused by powerplant effluent.

The Quaternary deposits discussed in this report are the alluvium along the Chaco River and its tributaries to the east and northeast. The interbedded gravel, sand, silt, and clay were deposited in meandering arroyo and alluvial-fan environments (Ross, 1978).

The headwaters of the Chaco River basin are characterized by small shallow swales and discontinuous washes and arroyos. A wash is an ephemeral-stream channel with sloping banks, whereas an arroyo is a flat-floored ephemeral-stream channel with near-vertical to vertical banks. Chaco Canyon (fig. 4) is entrenched as much as 600 feet in the Cretaceous bedrock (Ross, 1978). The canyon is about 20 miles long. The relatively flat canyon floor varies in width from 1,600 to 3,300 feet. The width of the meandering Chaco Wash, also referred to as Chaco Arroyo, in the floor of the canyon averages about 200 feet, and the height of the walls varies from 10 feet to 36 feet (Love, 1977). Chaco Arroyo (Love, 1977) or Chaco Wash (Ross, 1978) coalesces with Escavada Wash at the western end of Chaco Canyon to form the Chaco River.

The Chaco River is a braided, sandy wash for the next 43 miles toward the west varying in width from 650 feet to 1,500 feet (Love, 1977). The river then turns north for about 43 miles, and the channel walls increase in height to as much as 16 feet. About 2.5 miles from the San Juan River, the Chaco River is diverted to the west by a gravel terrace. The river flows west for 11 miles, passing through the Hogback Monocline, and then joins the San Juan River.

Lithology and Ground-Water Hydrology

A monitoring network of 50 wells was installed in the surface-minable coal area of the Fruitland Formation from 1975 to 1979. The purpose of the network was to collect hydrologic data and to establish a data base. The hydrologic data collected consist of water-level measurements, water chemistry, and selected aquifer characteristics. The four aquifers considered in this study are: (1) The Pictured Cliffs Sandstone; (2) coal seams and interbedded lithologic units of the Fruitland Formation; (3) overburden of the Kirtland Shale and Fruitland Formation; and (4) the alluvium along the Chaco River and its eastern and northeastern tributaries. Five sites were selected for study (fig. 1). Four of these sites, Western Coal Company's lease near Fruitland, Bisti West, Kimbeto, and Ojo Encino, have surface-minable coal. The Chaco River alluvium was selected because it is downstream from anticipated mining activity.

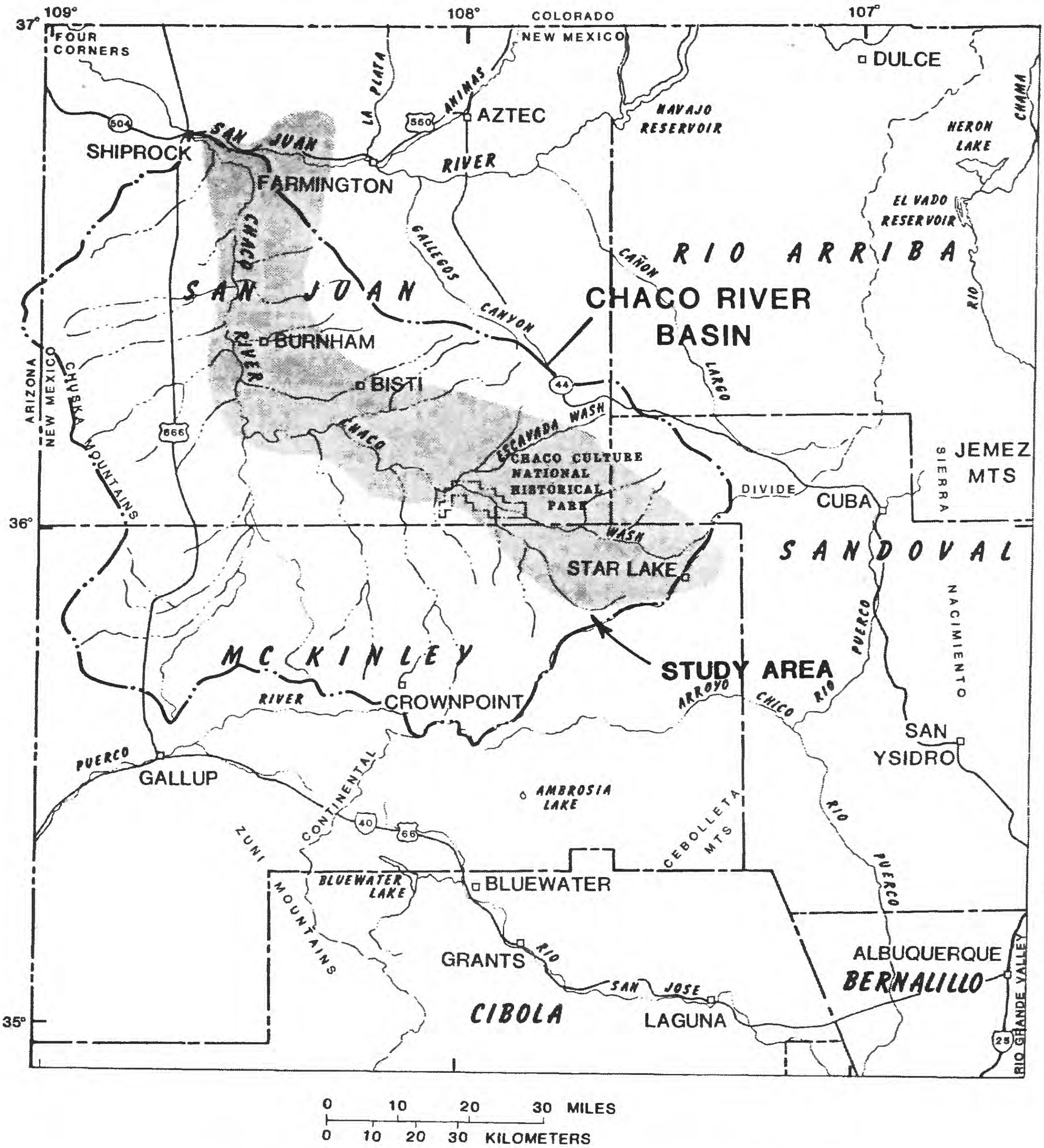


Figure 4.--Location of the Chaco River basin.

Water samples were collected from several wells for chemical analysis between 1975 and 1982. Analyses with similar chemical constituents and similar quantities of the chemical constituents were separated from any anomalous analyses for individual wells. A representative analysis (generally from the earliest sample collected) was selected from the group of similar analyses of each sampled well for use in this report. The other analyses of water samples may be obtained through the U.S. Geological Survey's WATSTORE Water-Quality File using the 15-digit location and site-identification number found in the tables of well records (tables 1, 3, 5, and 7).

Water is categorized in this report by the concentration of dissolved solids based on the classification of Freeze and Cherry (1979, p. 84). The classification is shown in the following table:

Category	Dissolved solids (milligrams per liter)
Freshwater	Less than 1,000
Brackish water	1,000 to 10,000
Saline water	10,000 to 100,000
Brine	Greater than 100,000

Pictured Cliffs Sandstone (Late Cretaceous)

The Pictured Cliffs Sandstone overlies and intertongues with the Lewis Shale and underlies and intertongues with the Fruitland Formation. The contact between the Lewis Shale and Pictured Cliffs Sandstone is gradational. The Pictured Cliffs Sandstone arbitrarily begins at the point where sandstone exceeds shale. The contact between the Pictured Cliffs Sandstone and Fruitland Formation is at the top of the massive sandstone underlying the lowermost coal bed. The Pictured Cliffs Sandstone can be divided into an upper part consisting of massive sandstone beds and a lower part consisting of thin layers of interbedded sandstone and shale. Burgener (1953) listed the average composition as a medium- to fine-grained sandstone containing quartz (86%), potassium-feldspar (7%), plagioclase feldspar (6%), and coal fragments (4%); the average cement was composed of calcite (60%), clay (30%), silica (10%), and iron oxide (less than 1%). The thickness of the Pictured Cliffs Sandstone generally is less than 200 feet where it is associated with the surface-minable coal deposits (Fassett and Hinds, 1971).

There are nine observation wells completed in the Pictured Cliffs Sandstone (fig. 5; table 1). Water-level measurements for the period of record are shown in figure 6.

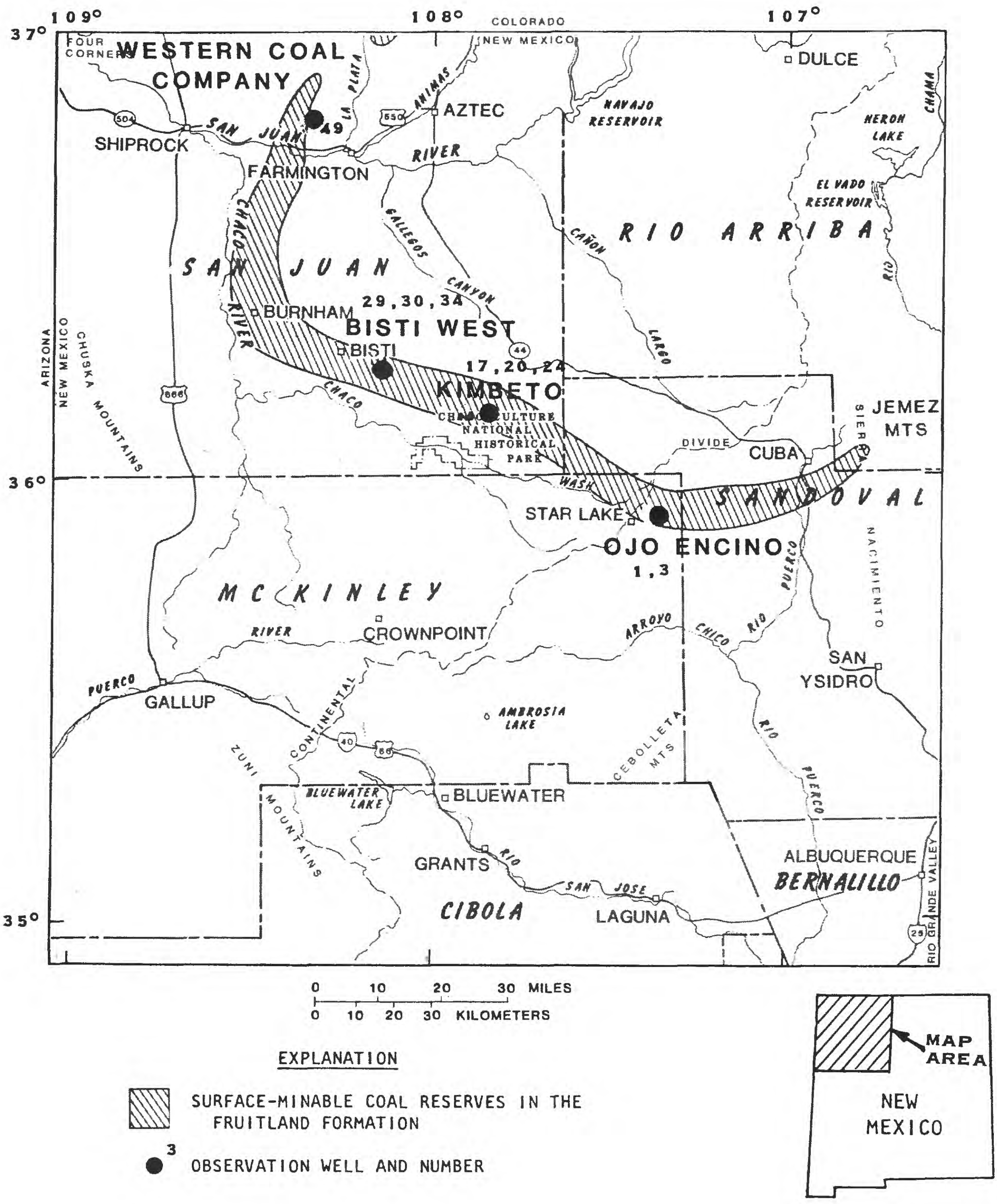


Figure 5.--Location of observation wells completed in the Pictured Cliffs Sandstone.

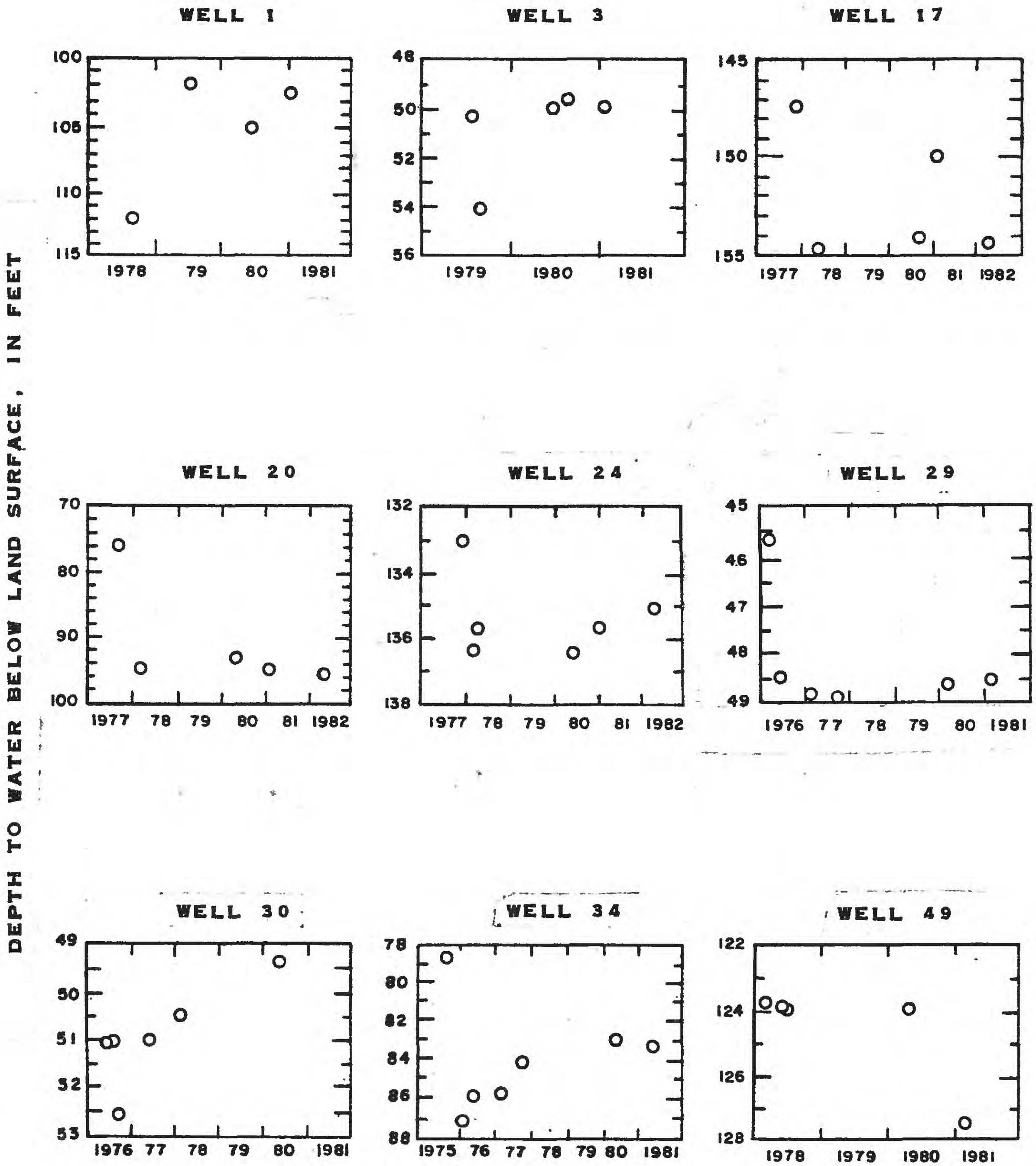


Figure 6.--Water-level measurements from observation wells completed in the Pictured Cliffs Sandstone.

The results of water-chemistry analyses are shown in table 2. The water is brackish. The specific conductance of the representative water samples ranges from 3,100 to 11,300 microsiemens per centimeter at 25° Celsius (microsiemens) (a calculated sum of approximately 2,200 to 6,800 milligrams per liter of dissolved solids). The dominant cation (fig. 7) in all samples is sodium. The dominant anion (fig. 7) is chloride except for samples from well 20, which is predominately bicarbonate, and well 29, which is predominately sulfate.

Transmissivities of the Pictured Cliffs Sandstone were determined from the results of slug tests and recovery tests after bailing from selected wells. These values ranged from 0.001 to 3 feet squared per day (Stone and others, 1983).

Coal Seams and Interbedded Lithologic Units of the Fruitland Formation (Late Cretaceous)

The Fruitland Formation overlies and intertongues with the Pictured Cliffs Sandstone and underlies the Kirtland Shale. The contact between the Pictured Cliffs Sandstone and Fruitland Formation is at the top of the massive sandstone underlying the lowermost coal bed. The contact between the Fruitland Formation and Kirtland Shale is at the top of the highest coal or carbonaceous-shale bed (Fassett and Hinds, 1971). The Fruitland Formation is composed of discontinuous, interbedded sandstone, siltstone, shale, coal, limestone, and carbonaceous sandstone, siltstone, and shale. The vertical lithology is somewhat consistent. The thin limestone beds composed of brackish-water pelecypod shells are in the lower part of the formation. The thicker coal beds are in the lower one-fifth to one-third of the formation. Sandstone generally is more abundant in the lower part of the formation. The upper part of the formation predominantly is siltstone and shale. The thickness of the Fruitland Formation generally is less than 300 feet within the study area (Fassett and Hinds, 1971).

Nine observation wells are completed in the coal seams and interbedded lithologic units of the Fruitland Formation (fig. 8; table 3). Water-level measurements for the period of record are shown in figure 9.

The results of water-chemistry analyses are shown in table 4. The water is brackish. The specific conductance of the representative water samples ranges from 1,900 to 13,000 microsiemens (a calculated sum of approximately 1,200 to 8,500 milligrams per liter of dissolved solids). The dominant cation in all samples is sodium (fig. 10). The dominant anion is bicarbonate for samples with specific conductances less than 5,000 microsiemens. The dominant anion for samples with specific conductances greater than 5,000 microsiemens is chloride, except for the sample from well 32, which is sulfate.

Transmissivities of the coal seams and interbedded lithologic units in the Fruitland Formation were determined from the results of slug tests and recovery tests after bailing from selected wells. These values range from 7 to 130 feet squared per day (Stone and others, 1983).

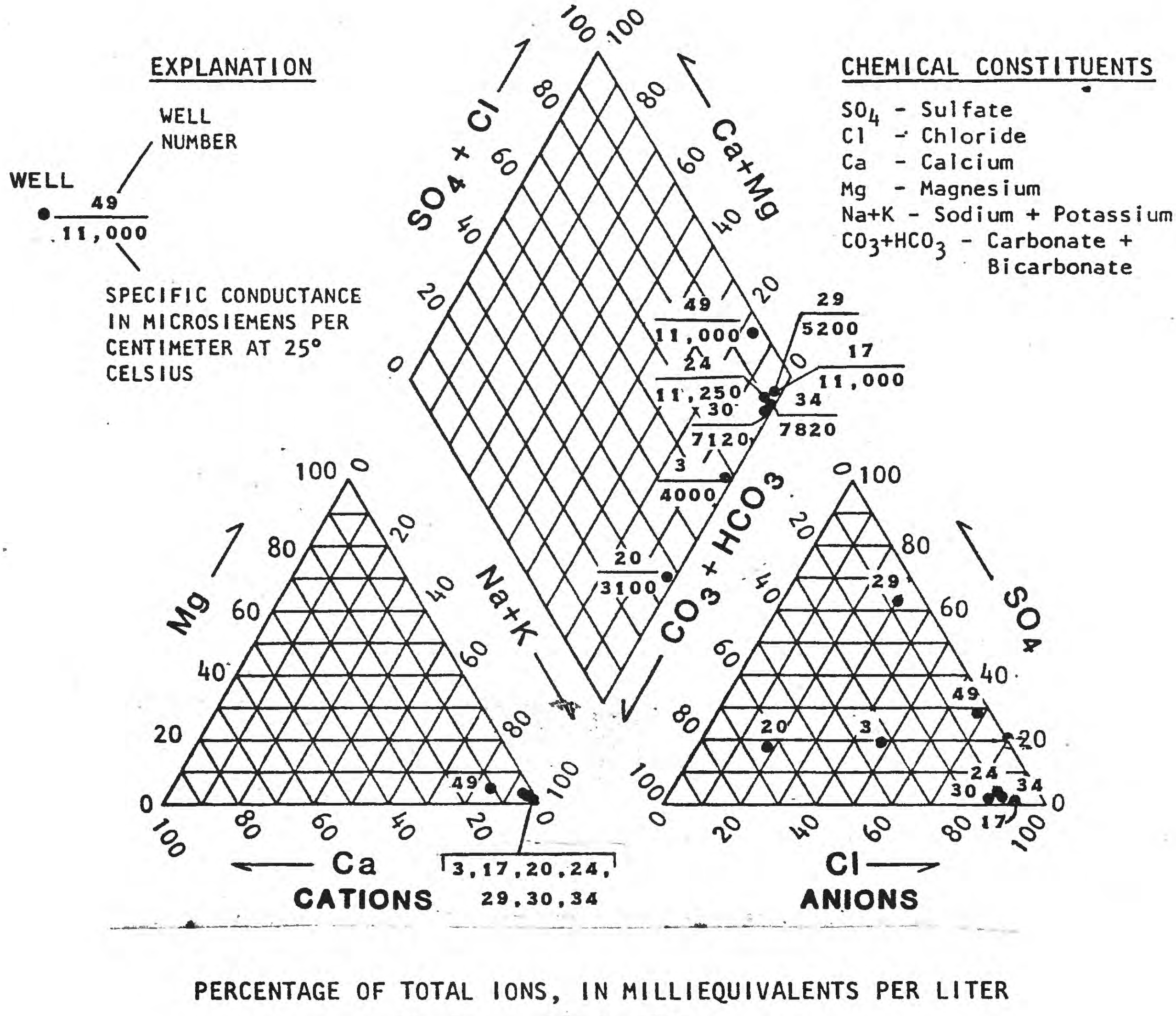


Figure 7.--Representative chemical analyses of water from selected wells completed in the Pictured Cliffs Sandstone.

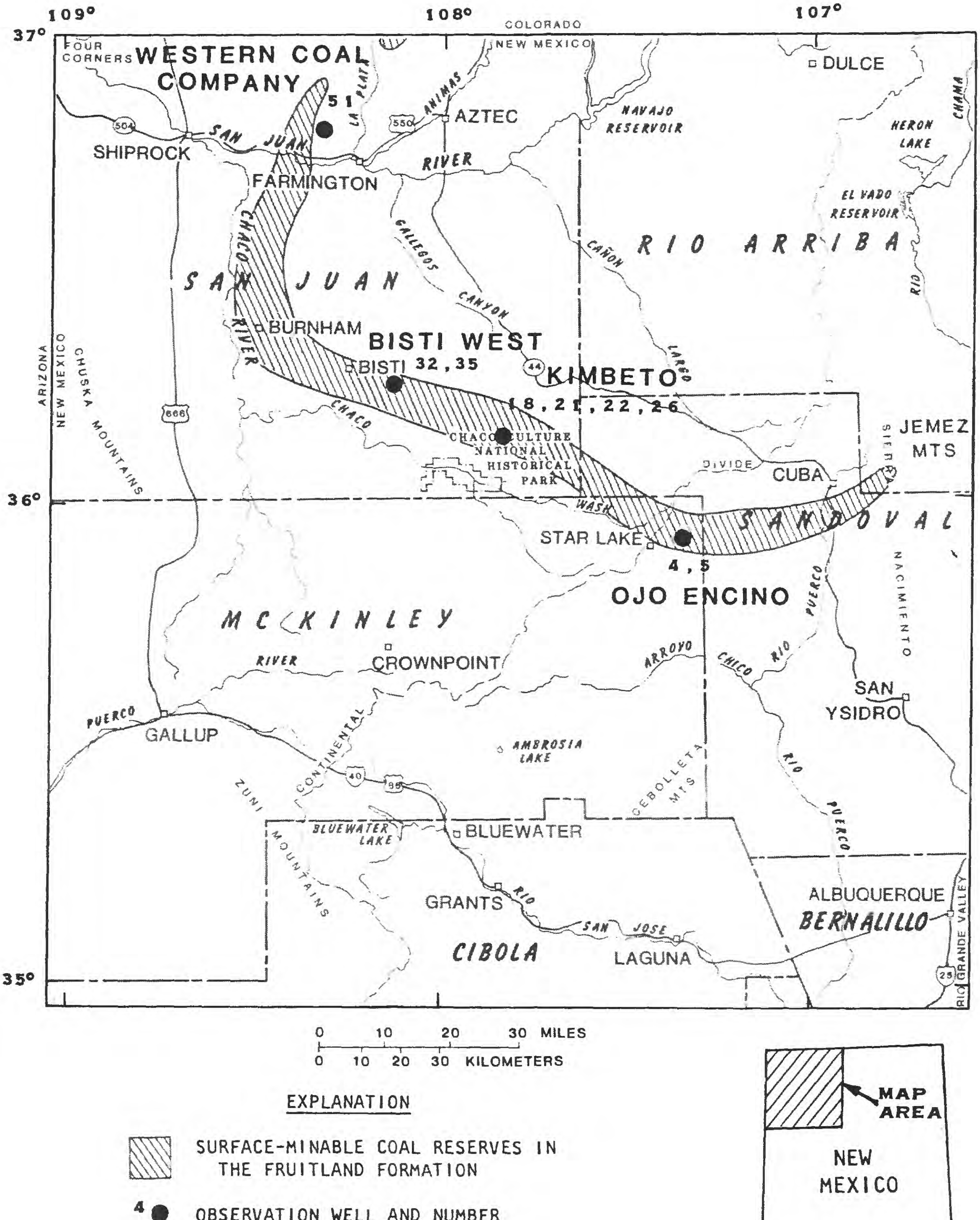


Figure 8.--Location of observation wells completed in coal seams and interbedded lithologic units of the Fruitland Formation.

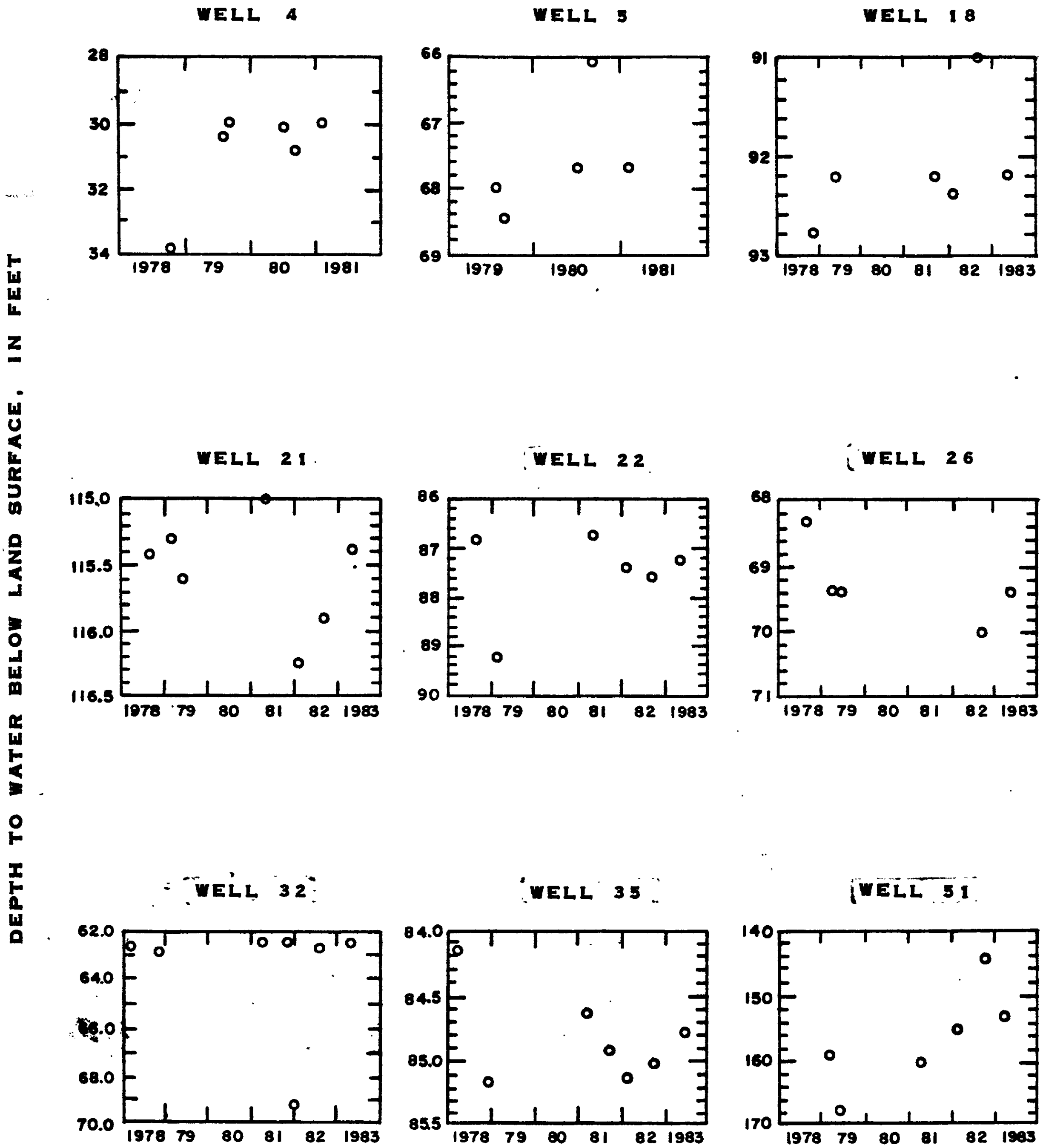


Figure 9.--Water-level measurements from observation wells completed in coal seams and interbedded lithologic units of the Fruitland Formation.

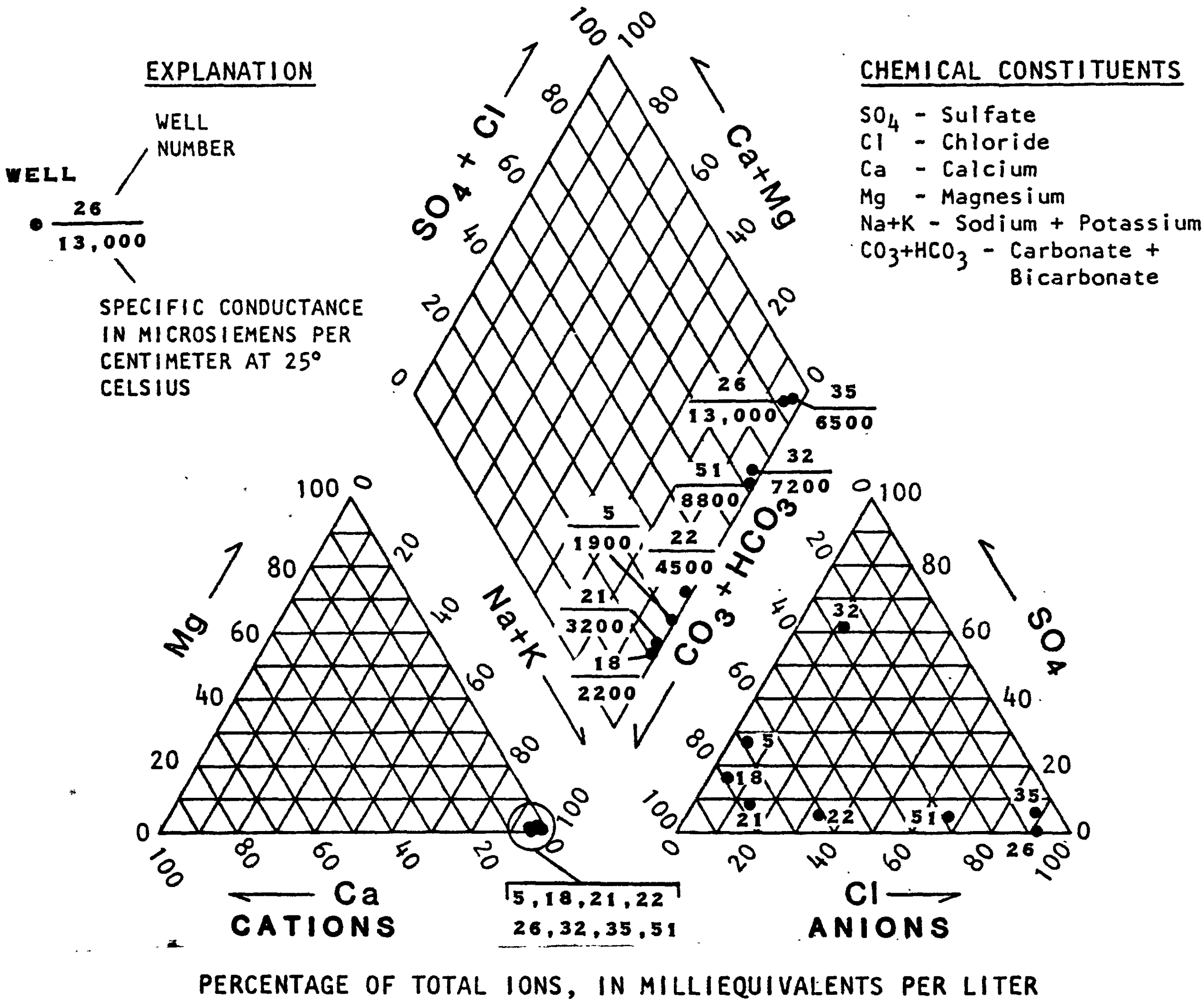


Figure 10.-- Representative chemical analyses of water from selected wells completed in coal seams and interbedded lithologic units of the Fruitland Formation.

Overburden of the Kirtland Shale and Fruitland Formation (Late Cretaceous)

The Kirtland Shale overlies the Fruitland Formation and underlies the Tertiary Ojo Alamo Sandstone. The contact between the Fruitland Formation and Kirtland Shale is at the top of the highest coal or carbonaceous-shale bed in the Fruitland Formation (Fassett and Hinds, 1971). The contact between the Kirtland Shale and Ojo Alamo Sandstone is gradational and arbitrary. Fassett and Hinds (1971) reported that a disconformity between the Kirtland Shale and Ojo Alamo Sandstone, which is based on subsurface evidence, is inconclusive in surface exposures. The Kirtland Shale is divided into a lower shale member, a Farmington Sandstone Member, and an upper shale member (Molenaar, 1977). The lower member predominantly is gray shale with some beds of siltstone and sandstone. It is sometimes difficult to distinguish the sandstone of the Farmington Sandstone Member from the upper shale member. Therefore, Fassett and Hinds (1971) included the Farmington Sandstone Member as part of the upper shale member. The Farmington Sandstone Member and upper shale member are composed of interbedded sandstone lenses and shale. The shale in the lower part of the Farmington Sandstone Member and upper shale member is lithologically similar to the shales of the lower member (Fassett and Hinds, 1971). The upper shale member is composed of white, gray, green, and purple shales. Locally, conglomerate is present in the purple shales in the western and southwestern parts of the San Juan Basin. There is a greater percentage of sandstone in the Farmington Sandstone Member and upper shale member in the northern part of the San Juan Basin. The thickness of the Kirtland Shale is less than 250 feet within the study area.

Eight observation wells are completed in the overburden of the Kirtland Shale and Fruitland Formation (fig. 11, table 5). Water-level measurements for the period of record are shown in figure 12.

The results of water-chemistry analyses are shown in table 6. The water is fresh to saline. The specific conductance of the representative water samples ranges from 1,180 to 23,000 microsiemens (a calculated sum of approximately 730 to 11,000 milligrams per liter of dissolved solids). The dominant cation in all samples is sodium (fig. 13). The dominant anion is bicarbonate for samples with specific conductances less than 5,000 microsiemens (fig. 13). The dominant anion for samples with specific conductances greater than 5,000 microsiemens is chloride or sulfate.

Alluvium along the Chaco River and the Tributaries to the East and Northeast (Quaternary)

The alluvium along the Chaco River and the tributaries to the east and northeast overlies Cretaceous sedimentary rocks of the San Juan Basin. The alluvial fill is composed of laterally discontinuous, vertically diverse beds of varying amounts of gravel, sand, silt, and clay derived from the bedrock outcrops within the drainage basin. The thickness of the alluvial fill generally is less than 50 feet (Lyford, 1979), although a thickness of 112 feet in Chaco Canyon was reported by Ross (1978).

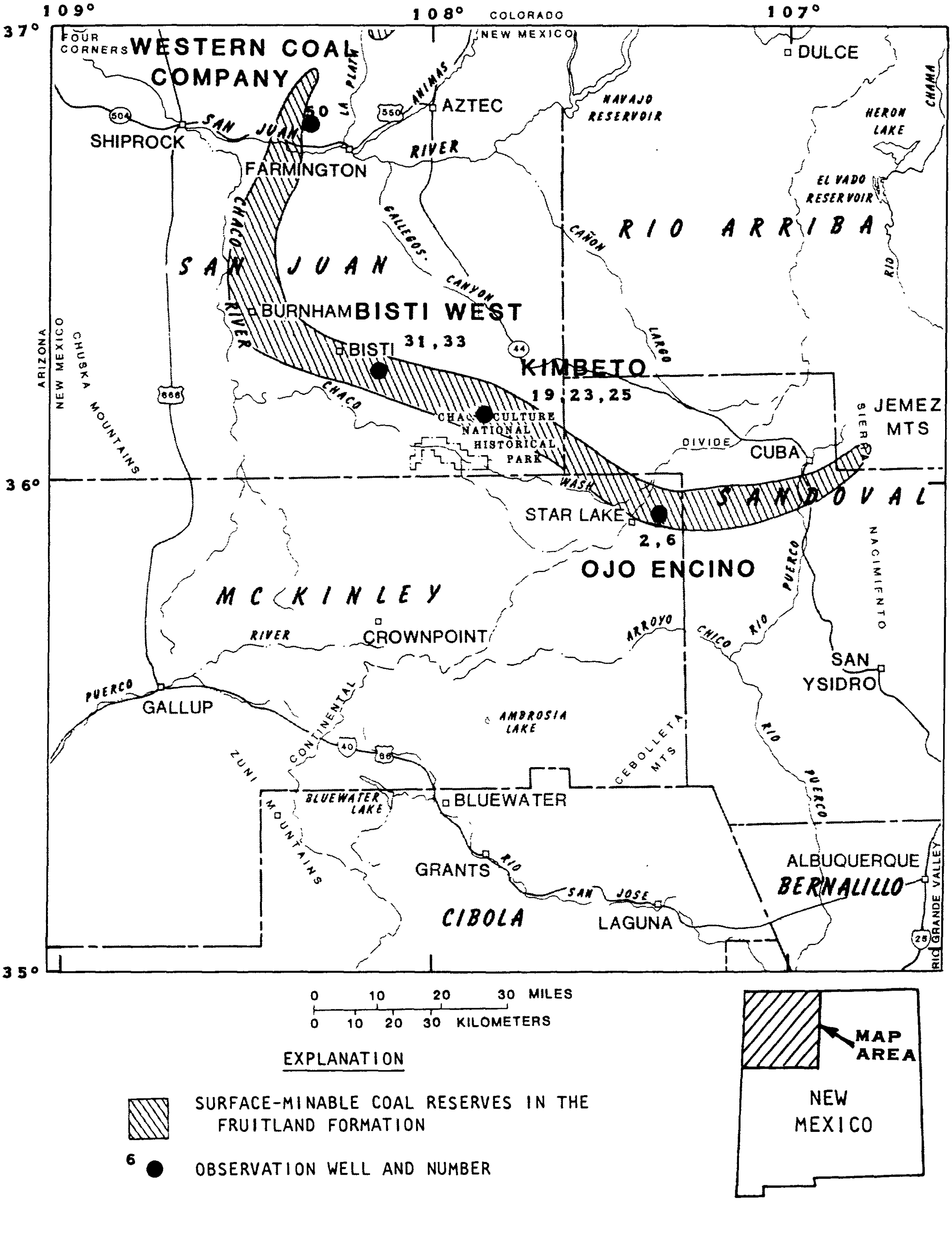


Figure 11.--Location of observation wells completed in the overburden of the Kirtland Shale and Fruitland Formation.

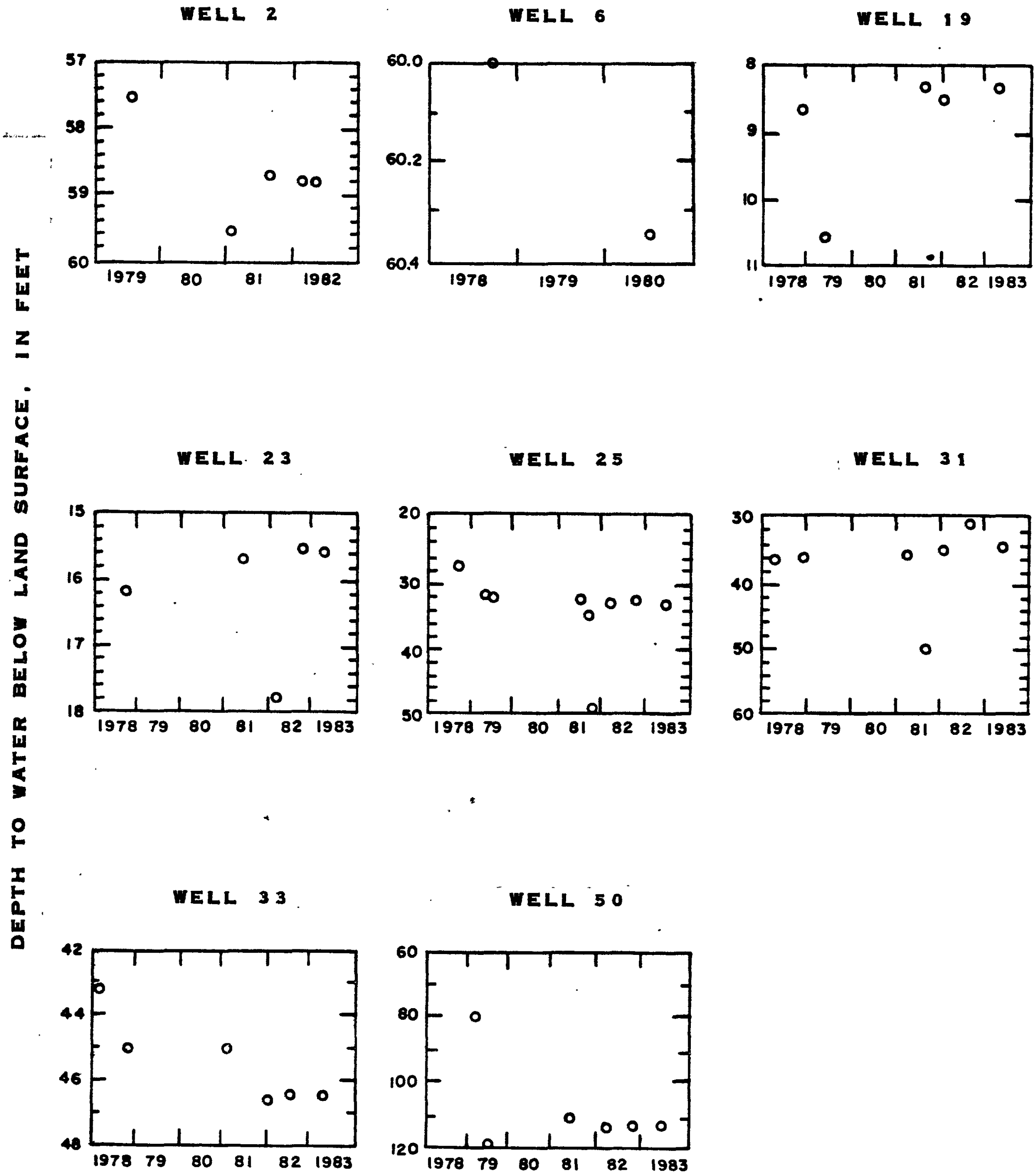


Figure 12.--Water-level measurements from observation wells completed in the overburden of the Kirtland Shale and Fruitland Formation.

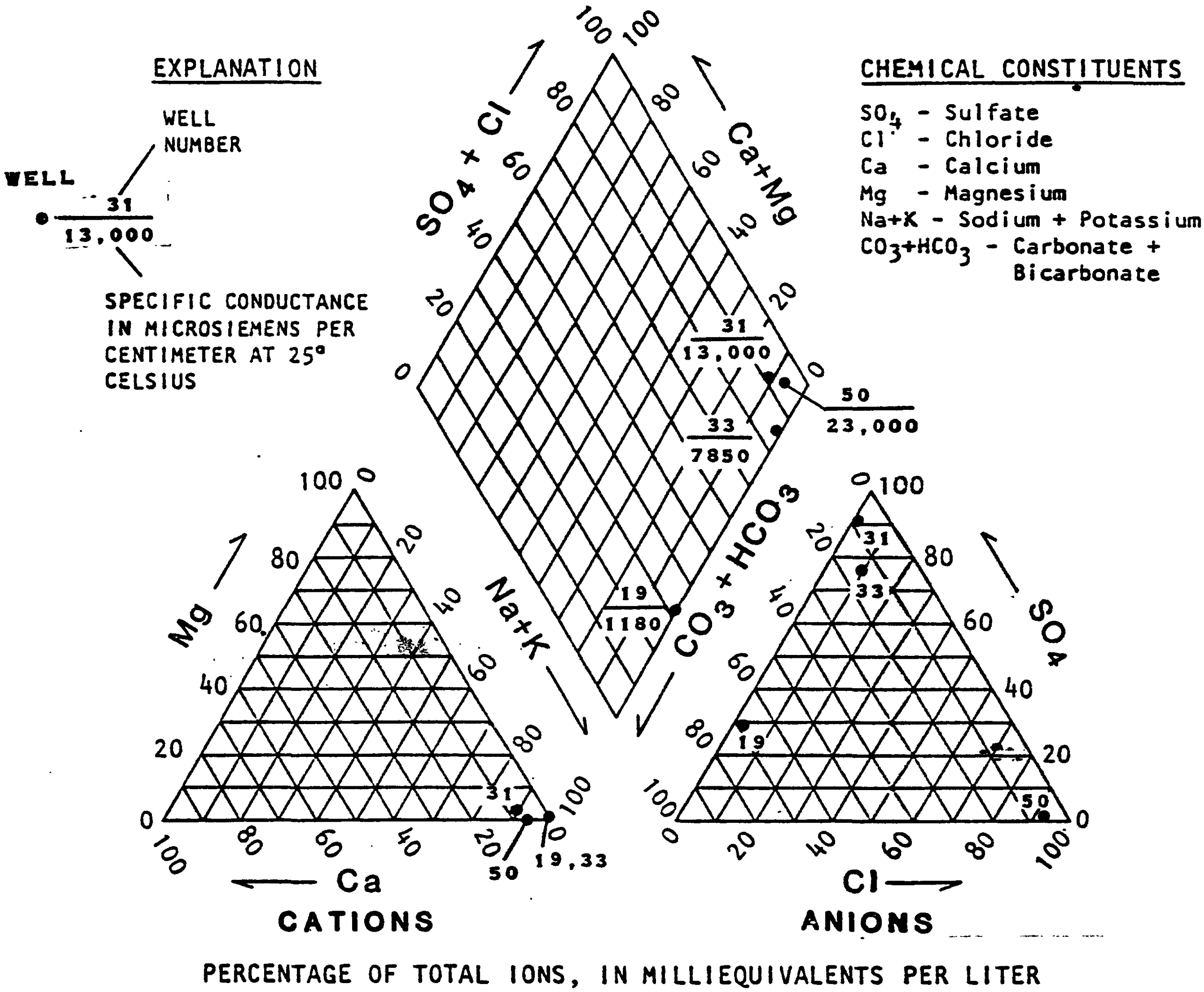


Figure 13.--Representative chemical analyses of water from selected wells completed in the overburden of the Kirtland Shale and Fruitland Formation.

Eighteen observation wells are completed in the alluvium along the Chaco River (table 7; fig. 14) and six observation wells were completed in the alluvium of tributary washes or arroyos east and northeast of Chaco Wash and Chaco River. Three of the wells (15, 43, and 48) in the alluvium were equipped with continuous water-level recorders for a time. Water-level measurements for the period of record are shown in figure 15. Water levels in the wells generally rise in the winter and spring during the period of low evapotranspiration and recharge from snowmelt runoff. The water levels in wells begin to decline with the increase of evapotranspiration during the summer. The lowest levels occur during the fall when there is little or no precipitation. Short-term increases of the water levels in the wells next to the wash or river channel occur during peak runoff caused by snowmelt or precipitation.

The results of water-chemistry analyses are shown in table 8. Well 48 is affected by recharge from the perennial river flow caused by powerplant effluent. The effluent water originally is diverted from the San Juan River, which causes the analyses of well 48 to be anomalous. The water in the Chaco River alluvium is fresh to brackish. The specific conductance of the representative water samples from wells in the Chaco River alluvium ranges from 800 to 3,580 microsiemens (a calculated sum of approximately 550 to 2,400 milligrams per liter of dissolved solids). The specific conductance of water samples from alluvium along tributaries ranges from 1,340 to 10,000 microsiemens (a calculated sum of approximately 890 to 8,800 milligrams per liter of dissolved solids). The dominant cation in all samples is sodium (figs. 16 and 17). The dominant anion in the samples from the Chaco River alluvium is bicarbonate or sulfate (fig. 16). Sulfate concentration increases downstream as the specific conductance increases. The dominant anion in the samples from the alluvium in the tributary washes and arroyos is sulfate, except for the sample from well 9, in which bicarbonate and sulfate are dominant (fig. 17). Sulfate increases with an increase in specific conductance. The water samples from wells in the alluvium in the tributary washes and arroyos are similar to those from the Kirtland Shale and Fruitland Formation overburden, except for well 48 near Fruitland (fig. 14), which has a slightly larger concentration of chloride.

All of the casing of the wells in the Chaco River alluvium is made of wrought iron. The dissolved-iron concentration in these wells fluctuates depending on the sampling technique.

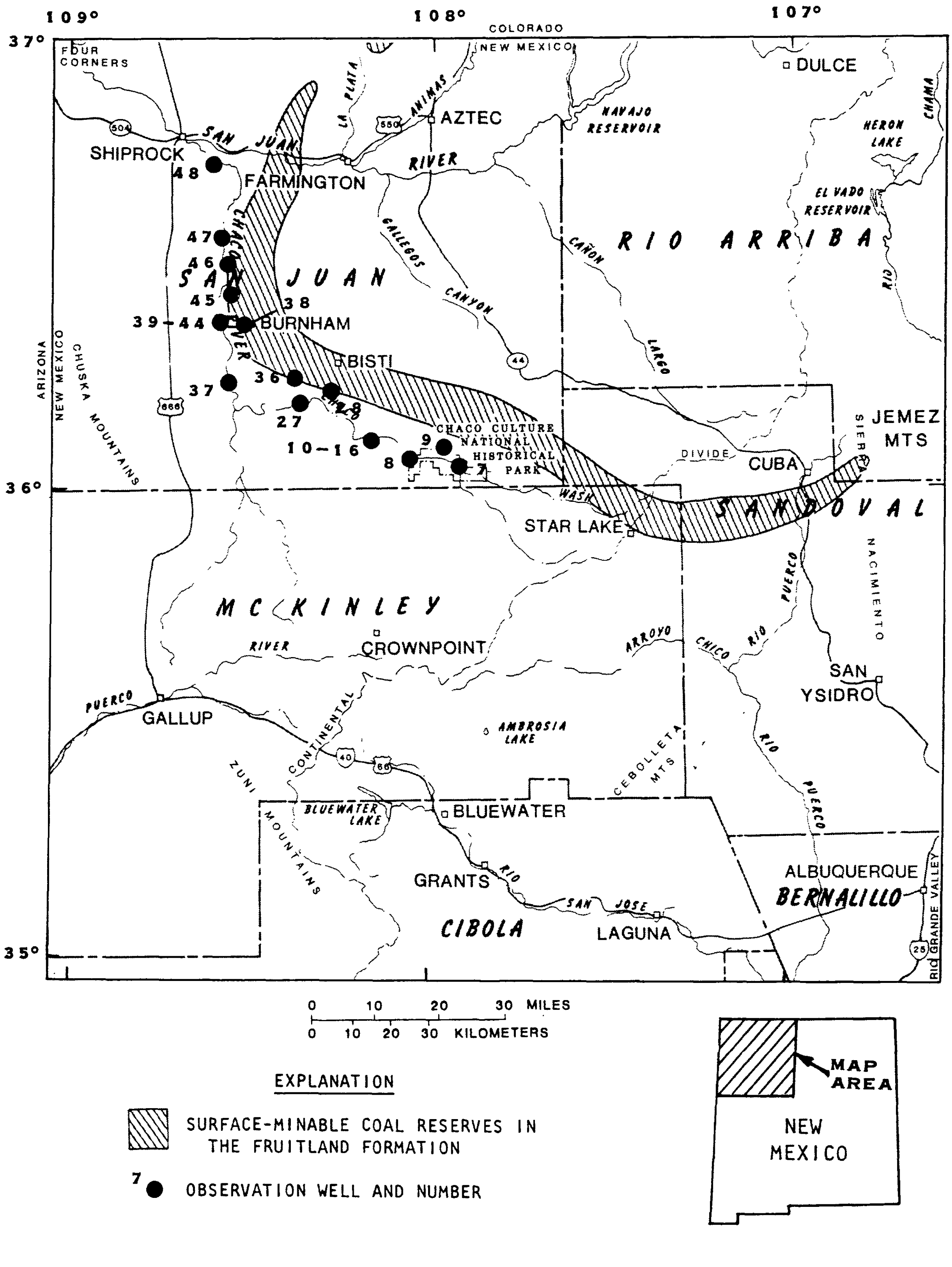


Figure 14.--Location of observation wells completed in the alluvium along the Chaco River and tributaries to the east and northeast.

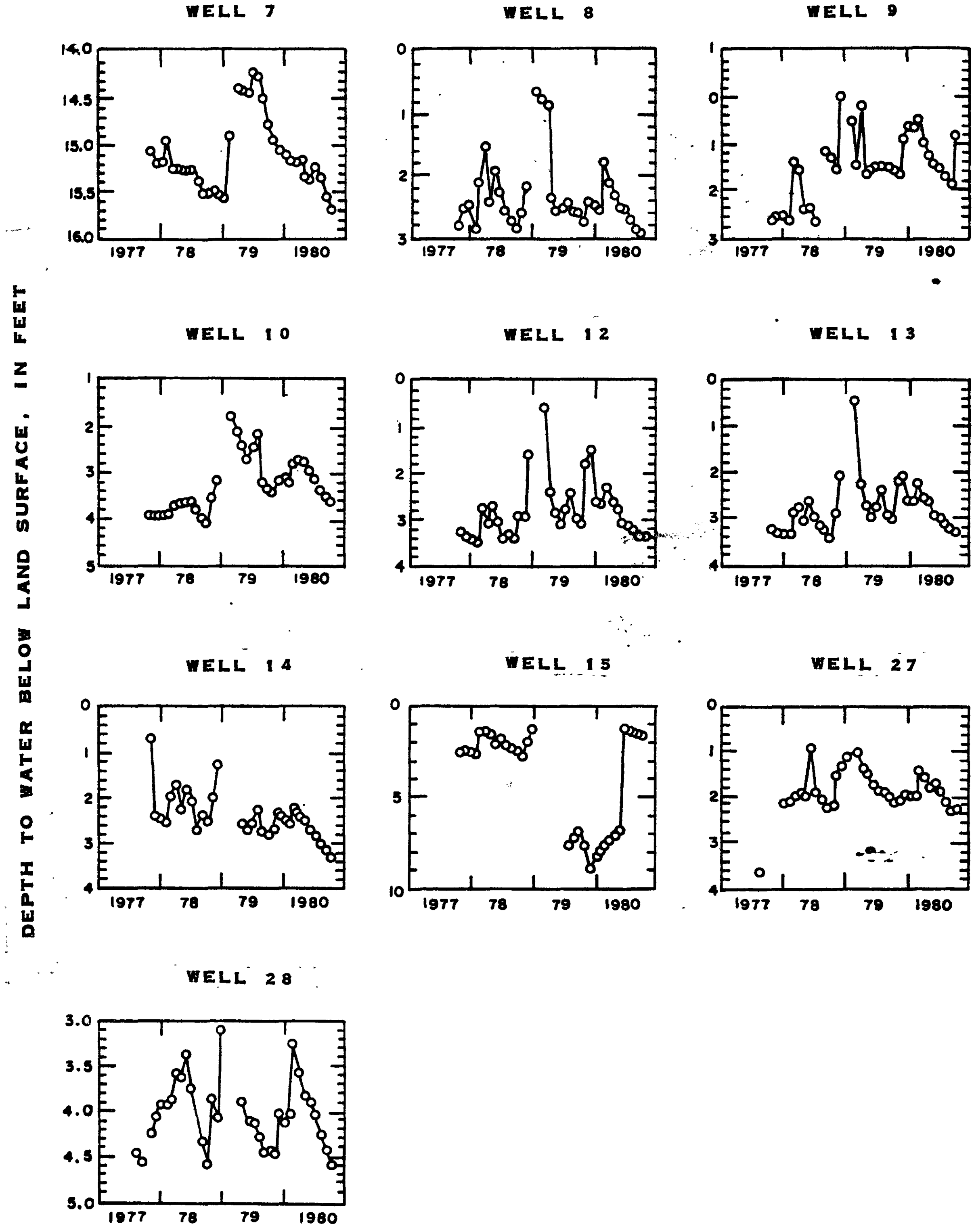


Figure 15.--Water-level measurements from observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast.

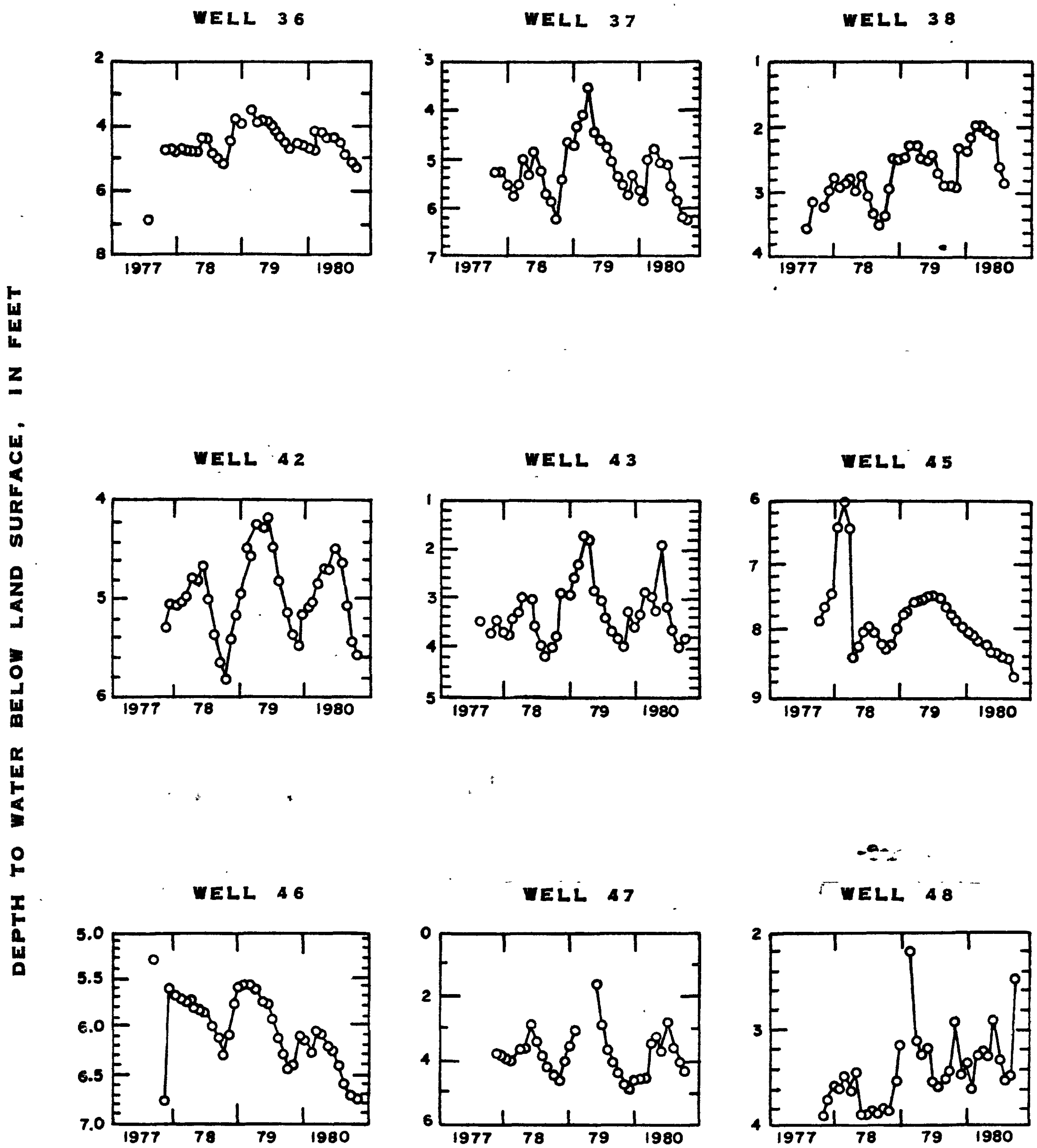


Figure 15.--Water-level measurements from observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast - Concluded.

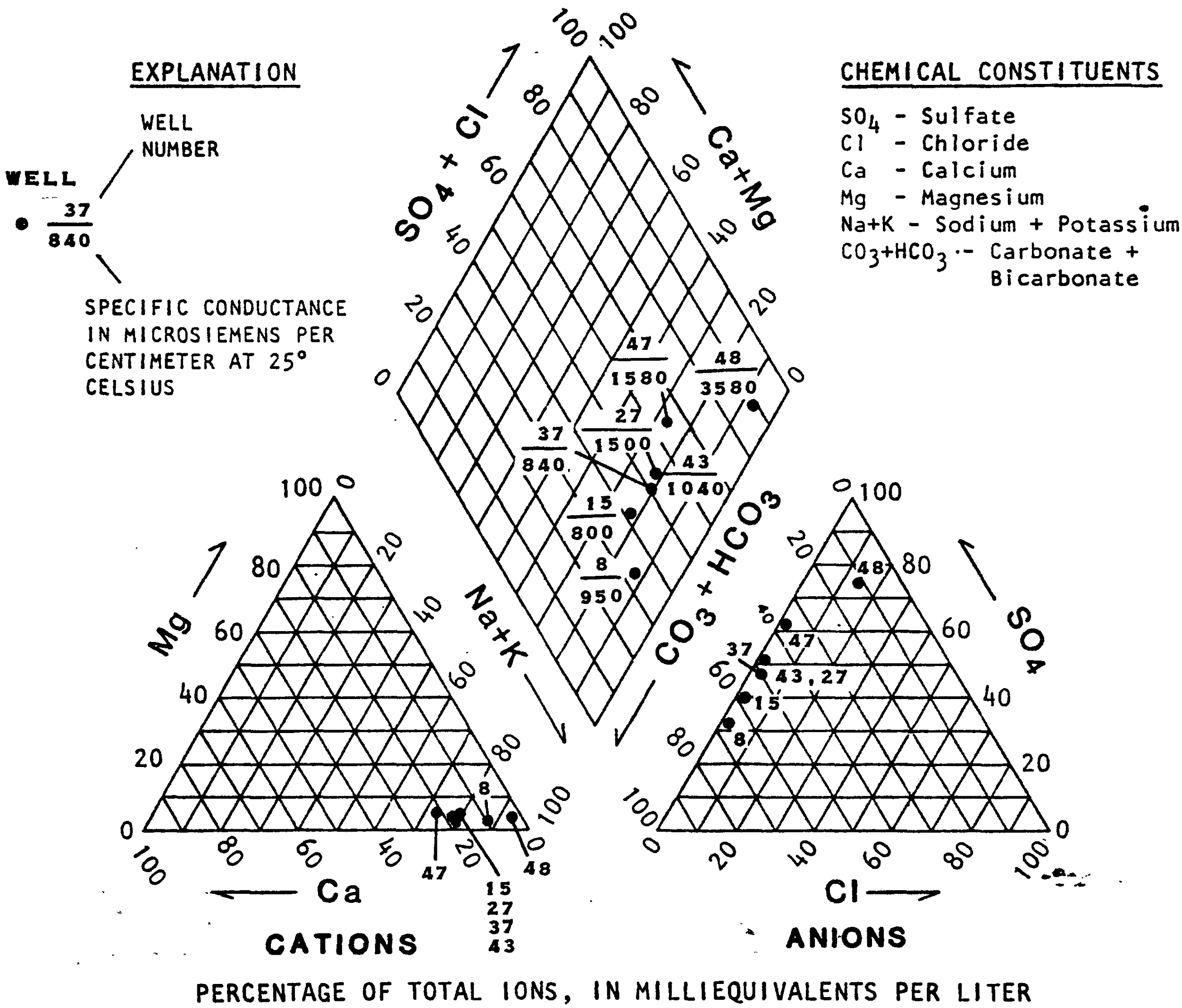


Figure 16.--Representative chemical anayses of water from selected wells completed in the alluvium along the main channel of the Chaco River.

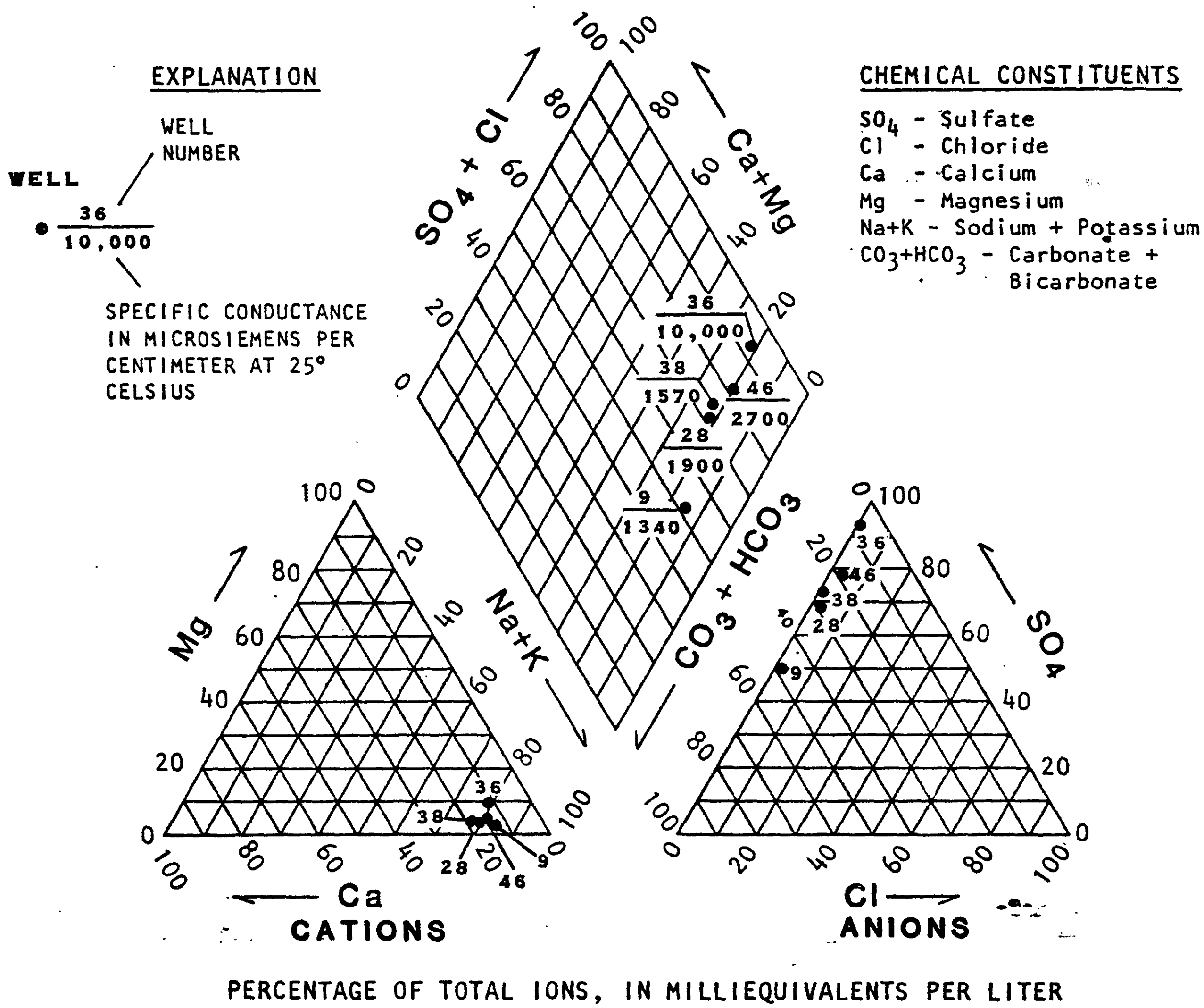


Figure 17.--Representative chemical analyses of water from selected wells completed in the alluvium in the tributary washes and arroyos east and northeast of the Chaco River.

SUMMARY

A monitoring network of 50 wells was installed in the surface-minable coal area of the Fruitland Formation from 1975 to 1979. The purpose of the network was to collect hydrologic data and to establish a data base. The hydrologic data consist of water-level measurements, water chemistry, and selected aquifer characteristics. The specific conductance of the representative water samples from selected wells in the 4 aquifers in the 5 study areas ranged from 800 to 23,000 microsiemens. The dominant cation in all samples was sodium. The dominant anion varied. The water is brackish in the Pictured Cliffs Sandstone and in the coal seams and interbedded lithologic units of the Fruitland Formation, fresh to saline in the overburden of the Kirtland Shale and Fruitland Formation, and fresh to brackish in the alluvium along the Chaco River and its tributaries to the east and northeast.

REFERENCES

Beaumont, E.C., 1971, Stratigraphic distribution of coal in San Juan Basin in Strippable low-sulphur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, p. 15-30.

Beaumont, E.C., Shomaker, J.W., and Stone, W.J., editors, 1976, Guidebook to coal geology of northwestern New Mexico: New Mexico Bureau of Mines and Mineral Resources Circular 154, 59 p.

Burgener, J.A., 1953, The stratigraphy and sedimentation of the Pictured Cliffs Sandstone and Fruitland Formation, Upper Cretaceous, of the San Juan Basin: Champaign, University of Illinois, unpublished M.S. thesis, 59 p.

Dane, C.H., and Bachman, G.O., 1965, Geologic map of New Mexico: U.S. Geological Survey, scale 1:500,000, 2 sheets.

DeAngelis, J.M., 1972, Physical geography of the Chaco Canyon country: Albuquerque, University of New Mexico, unpublished report to the National Park Service, Chaco Center, 113 p.

Fassett, J.E., and Hinds, J.S., 1971, Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey Professional Paper 676, 76 p.

_____1977, Geology and fuel resources of the Fruitland Formation and Kirtland Shale of the San Juan Basin, New Mexico and Colorado [abs.], in Guidebook of San Juan Basin III: New Mexico Geological Society, 28th Field Conference, p. 207.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N. J., Prentice-Hall, 604 p.

Hejl, H.R., Jr., 1982, Hydrologic investigations and data-collection network in strippable coal areas in northwestern New Mexico: U.S. Geological Survey Water-Resources Investigations 82-358, 32 p.

Kelley, V.C., 1951, Tectonics of the San Juan Basin, in Guidebook of the south and west sides of the San Juan Basin, New Mexico and Arizona: New Mexico Geological Society, 2d Field Conference, p. 124-131.

Love, D.W., 1977, Dynamics of sedimentation and geomorphic history of Chaco Canyon National Monument, New Mexico, in Guidebook of San Juan Basin III: New Mexico Geological Society, 28th Field Conference, p. 291-300.

Lyford, F.P., 1979, Ground water in the San Juan Basin, New Mexico and Colorado: U.S. Geological Survey Water-Resources Investigations 79-73, 22 p.

REFERENCES - Concluded

Molenaar, C.M., 1977, Stratigraphy and depositional history of Upper Cretaceous rocks of the San Juan Basin area, New Mexico and Colorado, with a note on economic resources, in Guidebook of San Juan Basin III: New Mexico Geological Society, 28th Field Conference, p. 159-166.

Peabody Coal Company, Cherokee and Pittsburg Coal and Mining Company, and Genge Environmental Consultants, Inc., 1975, Applicant's environmental assessment and continuing studies for the proposed Star Lake Coal Mine, McKinley County, New Mexico: 144 p.

Ross, J.R., 1978, A three-dimensional facies analysis of the canyon alluvial fill sequence, Chaco Canyon, New Mexico: Albuquerque, University of New Mexico, unpublished M.S. thesis, 87 p.

Stone, W.J., Lyford, F.P., Frenzel, P.F., Mizell, N.H., and Padgett, E.T., 1983, Hydrogeology and water resources of San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 6, 70 p.

U.S. Department of the Interior, Bureau of Land Management, 1976, Resource and potential reclamation evaluation, Bisti West study site — Bisti coal field: Albuquerque, N. Mex., EMRIA Report 5-1976, p. 69-80, F1-F16.

_____1981a, Resource and potential reclamation evaluation, Kimbeto study area: Albuquerque, N. Mex., EMRIA Report 17-1977, p. J1-J7, L13-L18, Q1-Q19.

_____1981b, Resource and potential reclamation evaluation Ojo Encino study area: Albuquerque, N. Mex., Technical Investigations Report 19-78, p. C17-C20, J1-J9, Q1-Q12.

Table 1. Records of observation wells completed in the Pictured Cliffs Sandstone

Number in figure 5	Station number	Date completed	Altitude of land surface (feet)	Well depth (feet)	Casing diameter (inches)	Water level (feet below land surface)	Date measured
1	355351107244401	08-27-78	6,690	127	2	112.00	08-27-78
3	355400107224201	11-20-78	6,640	233	2	50.32	07-25-79
17	360731107495701	09-24-77	6,420	483	1.5	147.41	11-15-77
20	360822107561601	06-09-77	6,240	285	1.5	75.77	08-18-77
24	360916107543901	10-14-77	6,340	474	1.5	133.01	11-14-77
29	361407108081901	08-21-75	5,925	235	2	45.58	03-31-76
30	361435108093001	08-05-75	5,905	350	2	50.93	06-15-76
34	361457108081901	08-12-75	5,940	394	2	78.58	10-22-75
49	364744108225001	11-04-77	5,290	730	2	123.75	02-21-78

Table 2. **Representative chemical analyses of water from selected observation wells completed in the Pictured Cliffs Sandstone**

[μS = microsiemens per centimeter at 25 degrees Celsius; deg. C = degrees Celsius; mg/L = milligrams per liter; fet-fld = fixed-pH endpoint titration - field; μg/L = micrograms per liter; -- indicates no data]

Number in figure 7	Station number	Date of sample	Specific conductance (μS)	pH (standard units)	Temperature (deg. C)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)
3	355400107224201	07-25-79	4,000	8.8	16.0	28	8.4	1.5	930	81	6.2	840
17	360731107494701	05-25-78	11,000	8.5	15.0	70	19	5.2	2,500	140	13	510
20	360822107561601	02-23-78	3,100	9.2	15.5	16	4.9	.80	800	92	13.6	990
24	360916107543901	11-14-77	11,300	8.0	15.5	140	37	12	2,600	98	12	700
29	361407108081901	03-31-76	5,200	9.2	18.0	36	11	2.0	1,200	91	5.4	210
30	361435108093001	10-21-75	7,120	9.6	16.0	23	4.1	3.2	1,500	140	9.9	300
34	361457108081901	08-20-75	7,820	9.2	17.0	27	4.8	3.6	1,700	150	11	320
49	364744108225001	02-21-78	11,000	8.1	15.0	820	230	58	2,100	33	20	250

Number in figure 7	Date of sample	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Iron dissolved (μg/L as Fe)	Carbon, organic dissolved (mg/L as C)	Carbon, organic suspended total (mg/L as C)
3	07-25-79	--	690	380	700	3.5	8.2	2,340	2,500	20	37	--
17	05-25-78	10	430	98	3,800	1.6	30	5,670	6,700	10	8.9	--
20	02-23-78	180	1,120	280	280	4.3	10	--	2,200	80	18	--
24	11-14-77	.00	570	250	3,400	1.4	9.6	--	6,700	40	8.8	--
29	03-31-76	8	184	1,600	590	4.0	4.5	--	3,500	110	40	--
30	10-21-75	130	462	85	2,000	1.5	7.0	--	4,000	80	--	--
34	08-20-75	62	365	120	2,300	1.1	6.6	--	4,400	140	80	--
49	02-21-78	.00	200	1,500	2,700	1.8	15	--	6,800	10	180	--

Table 3. Records of observation wells completed in the coal seams and interbedded lithologic units of the Fruitland Formation

Number in figure 8	Station number	Date completed	Altitude of land surface (feet)	Well depth (feet)	Casing diameter (inches)	Water level (feet below land surface)	Date measured
4	355446107204801	10-11-78	6,621	250	2	33.90	10-11-78
5	355447107224301	11-11-78	6,675	240	2	68.00	07-25-79
18	360734107523101	09-08-77	6,300	292	1.5	92.78	11-16-77
21	360823107544001	05-10-77	6,330	250	1.5	115.41	08-17-77
22	360849107561801	05-31-77	6,290	225	1.5	86.80	08-17-77
26	361008107543901	07-22-77	6,280	373	1.5	68.30	08-16-77
32	361446108090801	08-23-76	5,920	148	2	62.70	03-02-77
35	361513108090701	08-04-76	5,925	162	2	84.14	03-02-77
51	364845108214201	11-15-77	5,370	715	2	158.85	02-22-78

Table 4. Representative chemical analyses of water from selected observation wells completed in the coal seams and interbedded lithologic units of the Fruitland Formation

[μS = microsiemens per centimeter at 25 degrees Celsius; deg. C = degrees Celsius; mg/L = milligrams per liter; fet-fld = fixed-pH endpoint titration - field; μg/L = micrograms per liter; — indicates no data]

Number in figure 10	Station number	Date of sample	Specific conductance (μS)	pH (standard units)	Temperature (deg. C)	Hardness (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)
5	355447107224301	07-25-79	1,900	9.0	16.0	7	2.5	0.20	550	94	2.7	860
18	360734107523101	05-25-78	2,200	10.2	14.0	10	4.0	.10	490	67	4.9	250
21	360823107544001	02-23-78	3,200	10.2	14.0	15	5.6	.20	800	95	12	250
22	360849107561801	08-17-77	4,500	8.3	17.0	27	7.2	2.0	980	86	5.5	1,360
26	361008107543901	05-24-78	13,000	7.8	16.0	260	99	1.8	3,300	95	14	710
32	361446108090801	10-19-76	7,200	7.9	21.0	94	25	7.6	1,900	88	11	1,370
35	361513108090701	02-07-80	6,500	11.8	14.0	58	23	.00	1,400	85	9.1	0
51	364845108214201	02-22-78	8,800	8.1	18.0	46	12	3.6	2,000	130	7.4	1,480

Table 4. Representative chemical analyses of water from selected observation wells completed in the coal seams and interbedded lithologic units of the Fruitland Formation - Concluded

Number in figure 10	Date of sample	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)
5	07-25-79	39	770	290	31	2.7	7.5	1,200	1,400	--	--	--	--
18	05-25-78	370	820	160	30	4.9	37	1,250	1,200	--	--	--	--
21	02-23-78	710	1,390	140	200	1.7	38	--	2,800	--	--	--	--
22	08-17-77	98	1,280	120	500	2.3	8.6	--	2,500	--	--	--	--
26	05-24-78	.00	580	16	4,700	.80	10	6,590	8,500	--	--	--	--
32	10-19-76	.00	1,120	2,500	390	1.0	7.8	5,740	5,500	.0270	0.270	1.30	2.2
35	02-07-80	100	170	160	1,900	1.1	41	3,080	3,900	--	--	--	--
51	02-22-78	.00	1,210	160	2,000	2.4	11	--	4,900	--	--	--	--

Number in figure 10	Date of sample	Nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)	Iron dissolved (µg/L as Fe)	Carbon, organic dissolved (mg/L as C)	Carbon, organic suspended total (mg/L as C)
5	07-25-79	--	--	10	5.9	--
18	05-25-78	--	--	30	13	--
21	02-23-78	--	--	20	15	--
22	08-17-77	--	--	20	--	--
26	05-24-78	--	--	20	7.1	0.40
32	10-19-76	3.8	0.160	--	--	--
35	02-07-80	--	--	70	24	--
51	02-22-78	--	--	90	10	--

Table 5. Records of observation wells completed in the overburden of the Kirtland Shale and Fruitland Formation

Number in figure 11	Station number	Date completed	Altitude of land surface (feet)	Well depth (feet)	Casing diameter (inches)	Water level (feet below land surface)	Date measured
2	355353107244501	- -78	6,693	60	2	57.48	07-24-79
6	355448107212801	09-27-78	6,630	250	4	60.00	09-27-78
19	360754107505201	08-27-77	6,340	131	1.5	8.66	11-16-77
23	360857107531001	08-06-77	6,290	295	1.5	16.20	08-18-77
25	360941107561601	07-30-77	6,190	253	1.5	27.82	08-16-77
31	361446108083701	08-24-76	5,920	234	2	36.46	03-03-77
33	361447108090901	08-24-76	5,920	75	2	43.11	03-01-77
50	364750108214701	11-17-77	5,370	586	2	79.90	02-22-78

Table 6. **Representative chemical analyses of water from selected observation wells completed in the overburden of the Kirtland Shale and Fruitland Formation**

[μS = microsiemens per centimeter at 25 degrees Celsius; deg. C = degrees Celsius; mg/L = milligrams per liter; fet-fld = fixed-pH endpoint titration - field; μg/L = micrograms per liter; -- indicates no data]

Number in figure 13	Station number	Date of sample	Specific conductance (μS)	pH (standard units)	Temperature (deg. C)	Hardness (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)
19	360754107505201	05-25-78	1,180	8.5	13.0	7	1.4	0.80	280	48	2.2	490
31	361446108083701	10-19-76	13,000	7.5	14.5	930	320	31	3,500	52	17	800
33	361447108090901	02-08-80	7,850	10.0	--	20	3.0	3.1	1,900	190	14	360
50	364750108214701	03-05-80	23,000	12.0	15.0	550	210	3.3	3,600	71	31	0

Number in figure 13	Date of sample	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)
19	05-25-78	10	420	170	7.2	1.7	10	738	730	--	--	--	--
31	10-19-76	.00	657	7,100	63	.40	6.9	11,500	11,000	12.0	12.0	2.90	1.1
33	02-08-80	210	640	3,200	300	.90	54	1,430	6,100	--	--	--	--
50	03-05-80	380	636	120	6,000	1.0	4.5	9,940	11,000	--	--	--	--

Number in figure 13	Date of sample	Nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)	Iron dissolved (μg/L as Fe)	Carbon, organic dissolved (mg/L as C)	Carbon, organic suspended total (mg/L as C)
19	05-25-78	--	--	150	4.7	--
31	10-19-76	16	0.130	--	--	--
33	02-08-80	--	--	--	--	--
50	03-05-80	--	--	120	40	--

Table 7. Records of observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast

Number in figure 14	Station number	Date completed	Altitude of land surface (feet)	Well depth (feet)	Casing diameter (inches)	Water level (feet below land surface)	Date measured
7	360134107550401	10-17-77	6,141	18	1.25	15.06	10-17-77
8	360415108022201	07-15-77	6,005	8	1.25	2.82	10-17-77
9	360621107582301	10-17-77	6,104	18	1.25	2.67	10-17-77
10	360717108102301	09-27-76	5,874	13	1.25	3.93	10-17-77
12	360725108102701	09-27-76	5,868	16	1.25	3.29	10-17-77
13	360726108102801	09-27-76	5,865	8	1.25	3.19	10-17-77
14	360729108102901	09-27-76	5,864	8	1.25	0.69	10-17-77
15	360733108103201	07-15-77	5,865	10	4.00	2.66	10-17-77
16	360734108103201	07-15-77	5,876	8	1.25	3.00	07-23-77
27	361142108220401	07-23-77	5,646	8	1.25	3.00	07-23-77
28	361318108151401	07-23-77	5,770	8	1.25	4.53	07-23-77
36	361503108243801	07-23-77	5,545	8	1.25	6.89	07-23-77
37	361554108333201	07-22-77	5,402	13	1.25	7.90	07-22-77
38	362145108310901	07-22-77	5,382	8	1.25	3.46	07-22-77
39	362208108341201	08-20-79	5,323	38	2.50	12.88	08-20-79
40	362210108341001	08-18-79	5,317	70	2.50	7.55	08-21-79
41	362211108340601	08-18-79	5,315	47	2.50	5.15	08-18-79
42	362212108340701	06-22-77	5,317	8	1.25	7.50	06-22-77
43	362213108340501	06-22-77	5,314	13	4.00	9.59	06-22-77
44	362217108335701	08-17-79	5,220	47	2.50	18.00	08-21-79
45	362902108334801	06-21-77	5,220	8	1.25	7.82	10-13-77
46	363113108333501	06-21-77	5,196	11	1.25	5.29	08-01-77
47	363503108342101	06-21-77	5,129	8	1.25	7.50	06-21-77
48	364325108353001	07-15-77	5,100	13	4.00	3.87	10-16-77

Table 8. Representative chemical analyses of water from selected observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast

[μS = microsiemens per centimeter at 25 degrees Celsius; deg. C = degrees Celsius; mg/L = milligrams per liter; fet-fld = fixed-pH endpoint titration - field; $\mu g/L$ = micrograms per liter; -- indicates no data]

Number in figures 16 and 17	Station number	Date of sample	Specific conductance (μS)	pH (standard units)	Temperature (deg. C)	Hardness (mg/L as $CaCO_3$)	Calcium dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)
8	360415108022201	12-19-77	950	8.0	8.5	62	21	2.4	210	12	1.9	420
9	360621107582301	12-19-77	1,340	7.7	7.0	110	37	3.4	280	12	3.0	420
10	360717108102301	09-27-76	1,000	8.1	16.0	44	14	2.2	220	15	4.0	400
12	360725108102701	04-14-82	990	7.3	11.0	53	17	2.4	210	13	2.1	390
13	360726108102801	03-11-81	882	7.5	5.0	110	37	5.1	160	7	3.9	390
14	360729108102901	09-27-76	870	7.9	19.0	91	31	3.3	160	3	12	330
15	360733108103201	12-19-77	800	7.9	10.0	95	31	4.3	160	7	2.4	310
27	361142108220401	12-20-77	1,500	8.1	12.0	170	56	7.4	290	10	4.4	460
28	361318108151401	03-15-78	1,900	8.0	8.0	210	73	7.5	370	12	2.7	350
36	361503108243801	12-20-77	10,000	8.0	12.0	1,300	300	130	2,300	29	10	530
37	361554108333201	12-20-77	840	7.8	10.0	98	34	3.1	180	8	2.8	260
38	362145108310901	12-18-77	1,570	8.0	11.0	220	77	7.7	350	11	3.6	310
42	362212108340701	12-18-77	1,280	8.3	13.0	120	40	5.2	290	12	3.1	490
43	362213108340501	12-18-77	1,040	8.0	13.0	130	42	5.2	210	8	3.5	330
46	363113108333501	12-21-77	2,700	7.6	11.0	290	91	15	540	14	4.5	340
47	363503108342101	12-21-77	1,580	7.7	10.5	250	82	12	330	9	5.2	410
48	364325108353001	08-25-78	3,580	8.3	22.0	110	19	15	750	32	5.9	240

Table 8. Representative chemical analyses of water from selected observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast - Continued

Number in figures 16 and 17	Date of sample	Carbonate fet-fld (mg/L as CO_3)	Alkalinity field (mg/L as $CaCO_3$)	Sulfate dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate total (mg/L as N	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, organic total (mg/L as N)
8	12-19-77	.00	342	160	7.5	.90	11	636	620	--	.100	.080	.77
9	12-19-77	.00	344	340	9.3	.60	13	877	890	--	.100	.390	.00
10	09-27-76	.00	328	180	9.2	1.1	15	--	640	--	--	--	--
12	04-14-82	--	271	210	8.6	.90	14	654	630	--	--	--	--
13	03-11-81	.00	320	150	5.6	.40	13	575	570	.000	.000	.510	.69
14	09-27-76	.00	274	170	12	.80	13	--	570	--	--	--	--
15	12-19-77	.00	258	170	6.7	1.1	10	529	550	.010	.010	.010	.54
27	12-20-77	.00	376	400	9.5	.80	15	991	1,000	.010	.010	.730	.03
28	03-15-78	.00	283	640	22	.80	11	1280	1,300	2.90	2.90	.010	.73
36	12-20-77	.00	438	5,700	30	1.3	21	8,440	8,800	.180	.180	.040	.33
37	12-20-77	.00	214	210	8.7	1.0	13	557	590	.010	.010	.040	.11
38	12-18-77	.00	256	670	12	1.5	13	1,290	1,300	2.30	2.30	.010	.29
42	12-28-77	.00	404	350	11	1.5	15	931	960	--	.100	.290	1.0
43	12-18-77	.00	274	290	9.3	1.4	12	738	750	.030	.030	.460	.52
46	12-21-77	.00	275	1,100	36	1.6	12	1,950	2,000	1.90	1.90	.020	.21
47	12-21-77	.00	340	560	16	.90	14	1,150	1,200	.010	.010	.570	.00
48	08-25-78	.00	197	1,300	180	2.2	9.0	2,410	2,400	--	.100	1.50	.40

Table 8. Representative chemical analyses of water from selected observation wells completed in the alluvium along the Chaco River and the tributaries to the east and northeast - Concluded

Number in figures 16 and 17	Date of sample	Nitrogen, total (mg/L as N)	Phosphorus, total (mg/L as P)	Iron dissolved (μg/L as Fe)	Carbon, organic dissolved (mg/L as C)	Carbon, organic suspended total (mg/L as C)
8	12-19-77	0.85	0.170	90	2.1	1.9
9	12-19-77	.37	.020	140	4.2	.10
10	09-27-76	--	--	--	--	--
12	04-14-82	--	--	4,800	4.1	--
13	03-11-81	1.1	.050	10	13	1.3
14	09-27-76	--	--	1,600	--	--
15	12-19-77	.55	.110	70	2.7	1.8
27	12-20-77	.77	.060	30	5.0	.30
28	03-15-78	3.6	.060	30	1.9	.30
36	12-20-77	.55	.130	30	8.4	.50
37	12-20-77	.16	.050	40	4.2	.70
38	12-18-77	2.6	.120	270	--	--
42	12-18-77	1.3	.480	80	--	--
43	12-18-77	1.0	.080	1,800	--	--
46	12-21-77	2.1	.110	20	2.5	--
47	12-21-77	.56	.610	20	6.9	5.0
48	08-25-78	1.9	.130	20	4.1	1.3