PROGRESS REPORT ON THE GROUND-WATER, SURFACE-WATER, AND QUALITY-OF-WATER MONITORING PROGRAM, BLACK MESA AREA, NORTHEASTERN ARIZONA—1988-89

By Robert J. Hart and John P. Sottilare

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CONVERSION FACTORS

For readers who use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
mile (mi)	1.609	kilometer (km)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The Black Mesa monitoring program is designed to determine long-term effects on the water resources of the area resulting from withdrawals of ground water from the N aquifer by the strip-mining operation of Peabody Coal Company. Withdrawals by Peabody Coal Company increased from 95 acre-feet in 1968 to 4,090 acre-feet in 1988. The N aquifer is an important source of water in the 5,400-square-mile Black Mesa area on the Navajo and Hopi Indian Reservations.

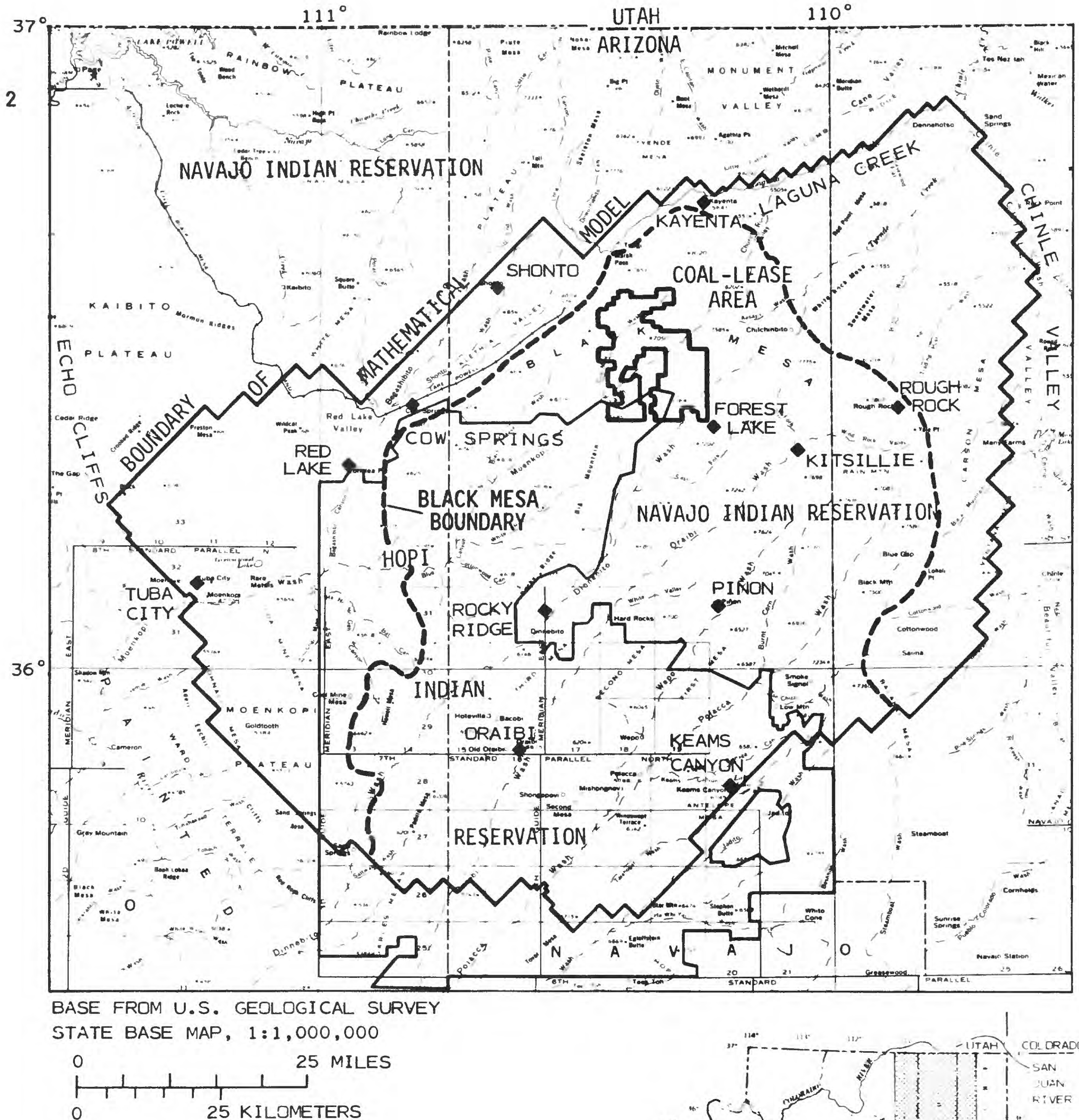
Water levels in the confined area of the aquifer declined as much as 19.7 feet near Low Mountain from 1988 to 1989. Part of the decline in the measured municipal wells may be due to local pumping. During 1965-88, water levels in wells that tap the unconfined area of the aquifer have not declined significantly and have risen in many areas. Chemical analyses indicate no significant changes in the quality of water from wells that tap the N aquifer or from springs that discharge from several stratigraphic units, including the N aquifer, since pumping began at the mine.

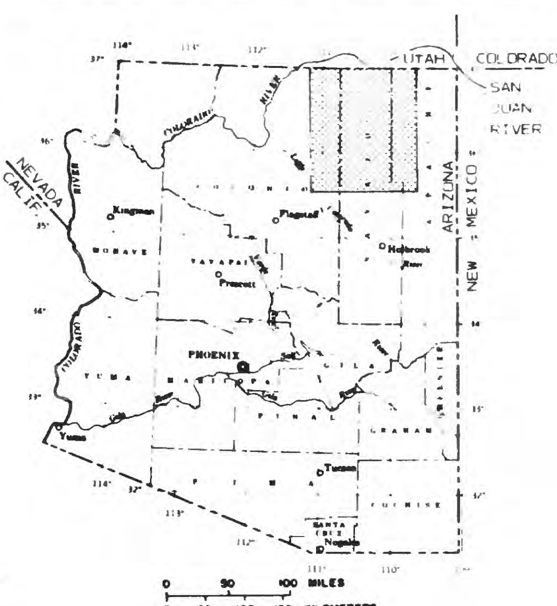
The ground-water flow model developed for the study area in 1988 was updated using pumpage data for 1985-88. The model simulated a steady decline in water levels in observation wells developed in areas of unconfined ground water. Measured water levels in these wells did not show this trend but indicated that water levels remained the same or increased. The model accurately simulated water levels in most observation wells developed in confined ground water.

INTRODUCTION

The N aquifer is an important source of water in the 5,400-square-mile Black Mesa area on the Navajo and Hopi Indian Reservations in northeastern Arizona (fig. 1). The aquifer consists of three rock formations that have been historically referred to as the N aquifer. The major water-bearing rock formations are the Navajo Sandstone of Jurassic and Triassic(?) age and the Lukachukai Member of the Wingate Sandstone of Triassic age. The Kayenta Formation underlies the Navajo Sandstone and locally yields small amounts of water (fig. 2).

On the northern part of the mesa, Peabody Coal Company operates a strip mine in a lease area of about 100 square miles. When operation of the mine began in 1968, the company pumped about 95 acre-feet of ground water from the N aquifer; in 1988, 4,090 acre-feet was pumped. Withdrawals





INDEX MAP SHOWING AREA OF REPORT (SHADED)

Figure 1.--Location of study area.

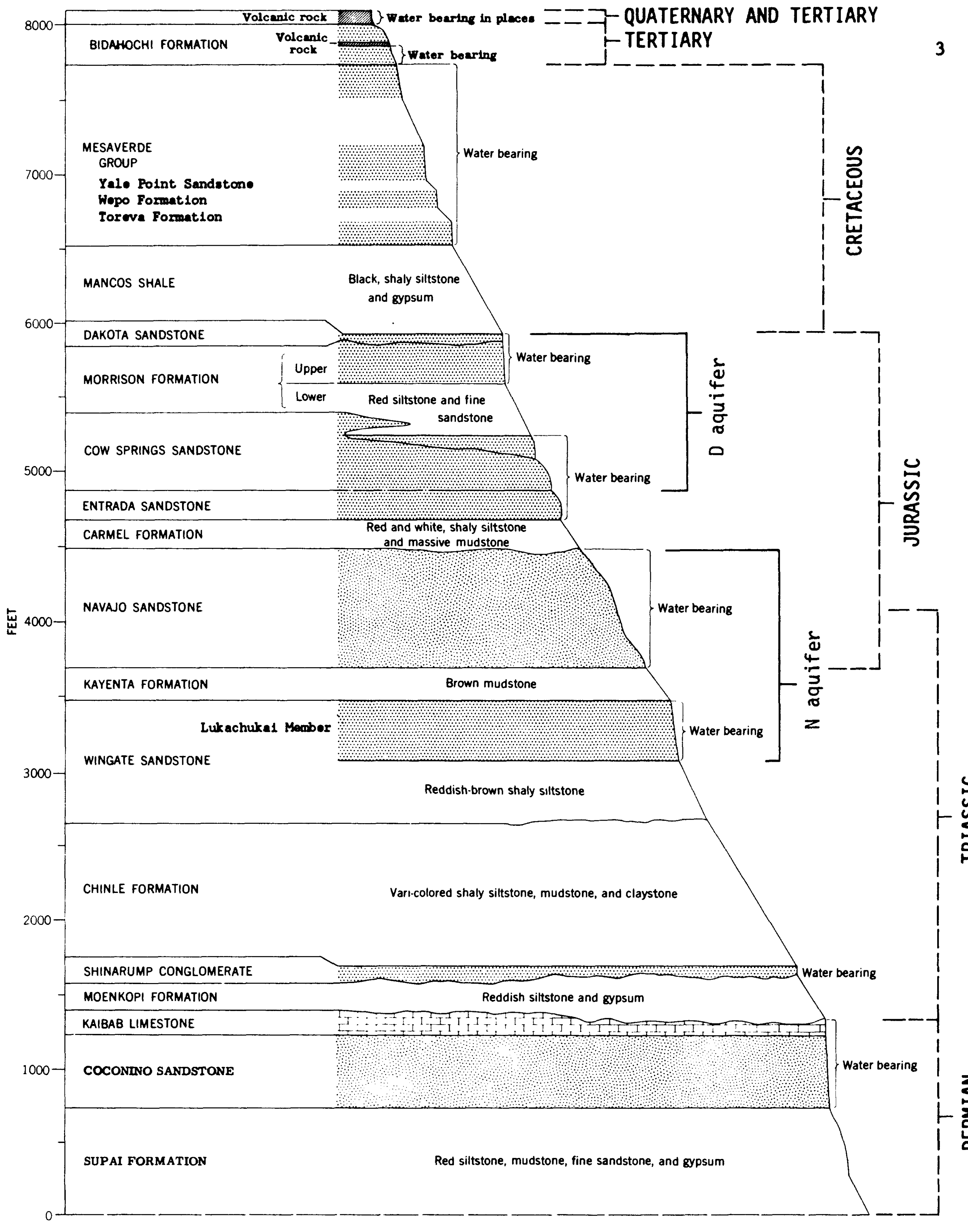


Figure 2.--Rock formations of the Black Mesa area (modified from Harshbarger and others, 1966).

from the N aquifer for municipal use increased from an estimated 70 acre-feet in 1965 to about 2,560 acre-feet in 1988. The Navajo and Hopi Tribes became concerned about the long-term effects of withdrawals from the N aquifer on supplies for domestic and municipal purposes. These and other concerns about the effects of strip mining led to the water-resources investigation of the Black Mesa area by the U.S. Geological Survey in cooperation with the Arizona Department of Water Resources in 1971. In 1983, the U.S. Bureau of Indian Affairs joined the cooperative effort.

The cooperation and assistance of the Navajo and Hopi Tribes and Peabody Coal Company are gratefully acknowledged. The Navajo Tribal Utility Authority; Peabody Coal Company; the Hopi Tribe; and the Western Navajo Agency, Chinle Agency, and Hopi Agency of the U.S. Bureau of Indian Affairs assisted in the collection of pumpage data. The Hopi Tribe, the Navajo Tribal Utility Authority, and the U.S. Bureau of Indian Affairs assisted in the collection of water-level data.

Purpose and Scope of the Report

This report covers the progress of the ground-water, surface-water, and quality-of-water monitoring program, Black Mesa area, northeastern Arizona, from July 1, 1988, to May 31, 1989. Except for some earlier data that are used for comparison, only new data will appear in this report. The scope of the work included water-level measurements, chemical analyses of ground water from wells and springs, compilation of pumpage data, and measurement of spring and surface-water discharge. These data were collected to determine the effects of industrial and nonindustrial pumpage from the N aquifer.

Previous Reports on the Program

Seven progress reports have been prepared by the U.S. Geological Survey on the monitoring phase of the program (U.S. Geological Survey, 1978; G.W. Hill, hydrologist, U.S. Geological Survey, written commun., 1982, 1983; Hill, 1985; Hill and Whetten, 1986; Hill and Sottilare, 1987; Hart and Sottilare, 1988). Most of the data obtained from the monitoring program are contained in these reports except for stream-discharge and sediment-discharge data from Moenkopi Wash collected prior to the 1986 water year, which were published in Water Resources Data for Arizona (U.S. Geological Survey, 1976-88). Eychaner (1983) showed the results of a mathematical model that was developed to simulate the flow of ground water in the N aquifer. The model was used to predict the effects of withdrawals through the year 2014. The model was converted to a new model program and recalibrated by using revised estimates of selected aquifer parameters and a finer spatial grid (Brown and Eychaner, 1988). The new model was used to predict effects of five pumping scenarios through the year 2051. The monitoring program is essential for checking the model simulations and determining water quality of the N aquifer as water levels decline.

HYDROLOGIC-DATA COLLECTION, 1988-89

Monitoring activities include continuous or periodic measurements of (1) ground-water levels in the confined and unconfined areas of the N aquifer; (2) major withdrawals from the confined and unconfined areas; (3) ground-water quality of the N aquifer; (4) discharge and chemical quality of selected springs that flow from the various formations, including the N aquifer; and (5) surface-water discharge. The surface-water and water-quality data-collection sites are shown in figure 3.

Ground-Water Levels

Ground-water levels in nonindustrial wells in the confined area of the N aquifer have continued to decline since 1968 when Peabody Coal Company began withdrawals from wells in the area. Water-level data collected from December 1988 to February 1989, however, showed that water levels in several nonindustrial wells in the confined area of the N aquifer had risen or had not changed since last measured during water year 1988. These wells are 8T-419, 8T-541, 10R-111, 10T-258, and 10R-119 (table 1). The water level in Low Mountain PM2 declined 19.7 feet from water years 1988 to 1989. Water levels in Keams Canyon 2 rose 18.9 feet from water years 1987 to 1988 but declined 17.2 feet from water year 1988 to 1989. Water levels in observation well BM6, about 15 miles south of the mine well field, declined 2.6 feet since previously measured in water year 1988. Most of the observation and nonindustrial wells in the northeastern part of the confined area of the N aquifer showed record declines.

Part of the decline in municipal wells probably is caused by local pumping. Pumping from the Kayenta municipal well field also may affect water levels in observation well 8T-500 (BM3). Withdrawals are not made from any observation wells.

Significant water-level changes have not occurred in most of the wells in the unconfined area of the N aquifer since pumping began at the mine. However, well 3T-546 at Tuba City has declined 30.5 feet since 1953, which probably is the result of local pumping (fig. 4).

Eychaner (1983) developed a mathematical model of the N-aquifer system on the basis of available information about the aquifer. Water-level changes were simulated for several nonindustrial wells and continuous-record observation wells that penetrate the N aquifer. During 1985, the model was rerun with measured withdrawals for 1980-84 to check the continued agreement of measured and simulated water levels. Results of these model runs are given in the 1987 progress report (Hill and Sottilare, 1987). Brown and Eychaner (1988) recalibrated the 1983 model using a new model program that provided a finer grid and more detailed hydrologic characteristics near Kayenta, Tuba City, Keams Canyon, Oraibi, and the coal-lease area. As part of the recalibration process, the model was used to simulate water-level changes from 1965 to 1984. Results of this simulation indicated general agreement between measured and simulated water-level changes observed in six continuous-record observation wells. A detailed description of these results is given in the report by Brown and Eychaner (1988).

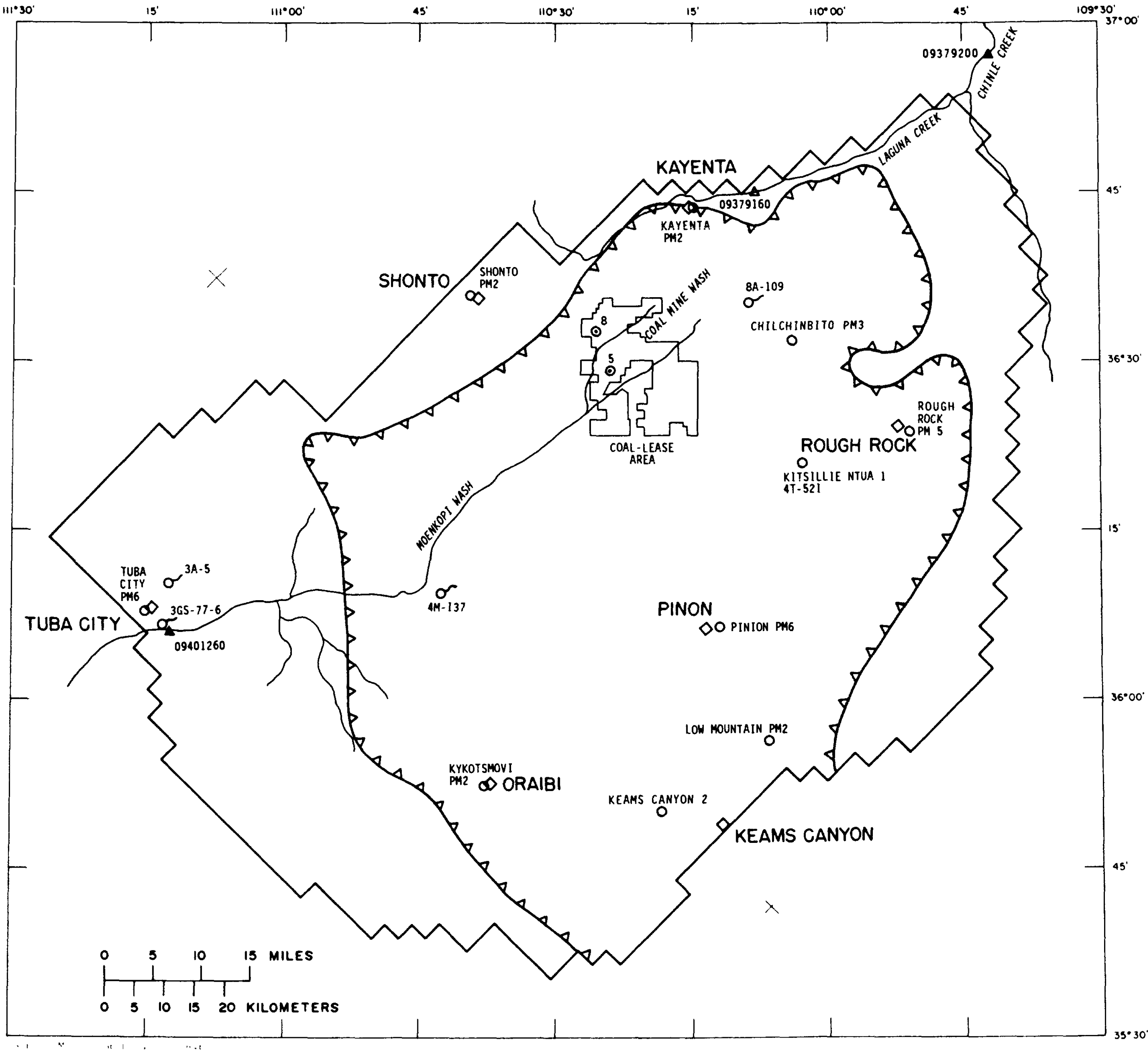


Figure 3.--Surface-water and water-quality data-collection sites, 1988-89.

EXPLANATION

PINON PM6

NONINDUSTRIAL WELL IN WHICH WATER-QUALITY SAMPLE WAS COLLECTED—Pinon PM6, is well name

5

WELL OWNED BY PEABODY COAL COMPANY IN WHICH WATER-QUALITY SAMPLE WAS COLLECTED—5, is well number

3A-5

SPRING AT WHICH DISCHARGE WAS MEASURED AND WATER-QUALITY SAMPLE WAS COLLECTED—3A-5, is spring identification number

09401260

STREAMFLOW-GAGING STATION OPERATED BY THE U.S. GEOLOGICAL SURVEY AT WHICH SURFACE-WATER DATA WERE COLLECTED—09401260, is station number

09379160

LOW-FLOW MEASUREMENT SITE—09379160, is site-identification number

CONFINED
UNCONFINED

APPROXIMATE BOUNDARY BETWEEN CONFINED AND UNCONFINED CONDITIONS—From Eychaner (1983)

BOUNDARY OF MATHEMATICAL MODEL—From Eychaner (1983)

Figure 3

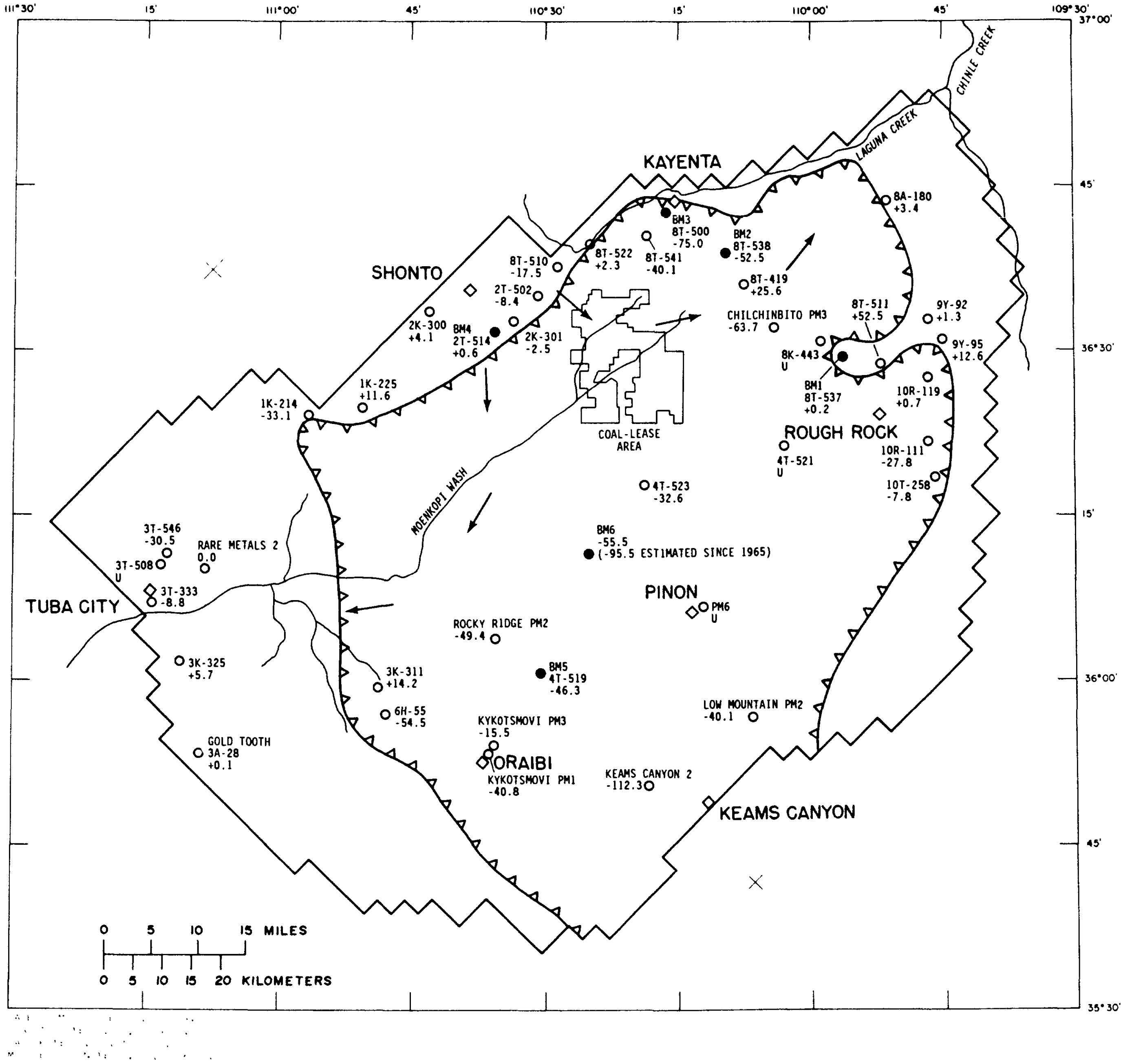


Figure 4.--Water-level changes in wells that tap the N aquifer, 1953-89 water years.

EXPLANATION

○ 4T-523 -32.6 — WELL IN WHICH DEPTH TO WATER WAS MEASURED ANNUALLY—First entry, 4T-523, is Bureau of Indian Affairs indentification number; second entry, -32.6, is change in water level, in feet, between measurements made during the prestress period and measurements made during 1987-88. U, unable to measure

● BM3 8T-500 -75.0 — CONTINUOUS WATER-LEVEL RECORDING SITE (OBSERVATION WELL) MAINTAINED BY THE U.S. GEOLOGICAL SURVEY—First entry, BM3, is U.S. Geological Survey identification number; second entry, 8T-500, is Bureau of Indian Affairs identification number; third entry, -75.0, is change in water level, in feet, from 1953 to 1988-89

CONFINED / UNCONFINED — APPROXIMATE BOUNDARY BETWEEN CONFINED AND UNCONFINED CONDITIONS—From Eychaner (1983)

→ GENERALIZED DIRECTION OF GROUND-WATER FLOW

— BOUNDARY OF MATHEMATICAL MODEL—From Eychaner (1983)

Figure 4

Table 1.--Water-level changes in wells that tap the N aquifer, 1983-89 water years

	U.S. Bureau of Indian Affairs field number	Change in water level from preceding water year, in feet							Altitude of water level NGVD, 1989 water year
		1983 water year	1984 water year	1985 water year	1986 water year	1987 water year	1988 water year	1989 water year	
Tuba City	3T-333	-0.1	-6.6	-2.0	+3.2	-1.3	+2.8	+0.2	4,908
Do.	3K-325	-0.4	+0.7	-0.4	+11.0	-10.5	+1.2	-0.2	5,058
Gold Tooth	3A-28	[3]-1.4	+1.4	-8.6	+17.8	-12.5	+3.4	0.0	5,151
Rocky Ridge	PM2	-4.0	-----	[3]-5.4	-1.3	-3.0	-2.1	-3.2	5,504
Kykotsmovi	PM1	[3]-31.0	-7.7	+8.5	-----	[3]-7.7	-1.5	-1.4	5,389
Do.	PM3	-----	-----	-----	[3]+0.3	([1])	([1])	[3]-3.6	5,404
Keams Canyon	2	-9.2	-----	-----	[3]+3.5	-32.6	+18.9	-17.2	5,404
Low Mountain	PM2	-1.4	-3.3	-2.7	-2.5	-2.0	-1.0	-19.7	5,544
Pinon	PM6	([1])	-----	-----	[2] [3]0.0	([1])	([1])	([1])	([1])
Forest Lake	4T-523	[3]+1.6	-----	-----	[3]-18.8	-2.4	-0.8	-12.2	5,515
Kitsillie	4T-521	-----	-----	-----	[3]-69.6	([1])	([1])	([1])	([1])
White Mesa Arch	1K-214	+0.4	+0.2	0.0	+11.4	-11.1	-0.9	+1.1	5,550
Cow Spring	1K-225	-0.1	+0.9	+0.8	+3.5	-2.6	+0.7	+0.3	5,674
Shonto	2K-300	-0.1	+0.5	+0.3	+0.8	-0.8	-0.5	+1.1	6,092
Chilchinbito	PM3	-11.4	-14.0	-8.9	+26.5	-8.7	+1.6	-9.9	5,481
Rough Rock	8T-511	([1])	[3]+3.3	-0.5	+3.4	+0.6	+0.7	-2.0	5,486
Do.	10R-111	-0.5	-12.7	+11.6	+11.1	-12.3	+3.1	+0.1	5,559
Do.	10T-258	-6.1	+3.7	-5.3	+16.6	-19.1	+6.7	+1.8	5,594
Do.	10R-119	-0.4	+1.7	-2.4	+1.5	+0.7	-0.9	+0.3	5,519
Do.	9Y-95	+4.7	+0.9	+0.7	+4.2	-8.1	+3.6	+2.4	5,526
Do.	9Y-92	-0.4	-2.5	+2.3	+8.6	-8.4	+1.6	-1.4	5,448
Northeast Rough Rock	8A-180	+0.1	+0.4	+0.3	+1.3	-1.2	+5.4	-5.1	5,156
BM5	4T-519	-5.6	-2.2	-3.1	-2.2	-3.7	-2.8	-4.0	5,488
BM6	BM6	-3.1	-7.0	-7.0	-3.8	-3.3	-2.7	-2.6	5,549
Shonto Southeast	2K-301	-0.5	-0.5	-----	[3]-0.5	+0.7	-0.5	-0.4	6,149
BM4	2T-514	-0.4	+0.1	+0.3	+0.1	0.0	-0.1	0.0	6,129
Sweetwater Mesa	8K-443	[3]+2.0	-0.5	-0.9	+0.1	-0.2	0.0	([1])	([1])
BM1	8T-537	([1])	[3]+1.3	+1.1	-1.1	+1.0	-0.1	+0.2	5,489
Long House Valley	8T-510	-0.8	+10.7	-13.5	+5.0	-0.1	-1.4	+0.8	6,146
Shonto Southeast	2T-502	+4.8	+0.2	-3.8	+4.1	+0.1	+1.8	-1.5	6,256
BM2	8T-538	-4.2	-4.5	-3.3	-4.5	-3.3	-2.0	-3.7	5,532
Owl Spring	8T-419	-0.2	-1.8	+9.5	-0.9	+2.4	0.0	+8.1	5,548
Marsh Pass	8T-522	-0.2	+0.8	+0.8	-1.0	-1.1	-0.3	+0.2	5,917
BM3	8T-500	-2.0	-2.6	-7.4	+9.0	-15.5	+4.6	-3.6	5,600
Kayenta West	8T-541	[3]-2.1	-2.1	-8.0	-0.6	-11.6	-12.6	+7.3	5,618
Howell Mesa	3K-311	[3]+11.1	-15.3	+14.8	+3.1	([1])	([1])	[3]+0.5	5,407
Do.	6H-55	+2.7	-0.9	+1.0	-0.4	-0.4	-0.2	-0.5	5,356
Tuba City	Rare Met. 2	+2.6	+0.1	+0.9	0.0	+0.4	+0.3	-0.2	5,051
Tuba NTUA 1	3T-508	+0.6	+3.1	-5.5	-6.9	-----	[3]+9.7	-----	-----
Tuba NTUA 4	3T-546	+1.0	-2.8	+1.9	+2.1	-4.9	------	[3]-9.3	5,156
Average annual change for wells measured in preceding year except the changes with footnote (3)		-1.2	-1.9	-0.9	+3.6	-5.1	+0.7	-2.0	

[1]Unable to measure.
[2]Figure reported by Bureau of Indian Affairs.
[3]Change in water level from last measurement of 2 years or more.

The recalibrated model was rerun in 1989 using measured withdrawals for 1985 through 1988. The contour map showing the simulated water levels for 1988 is shown in figure 5. Altitudes of water levels measured in 1988-89 also are plotted on this figure to illustrate the degree of agreement between the measured and simulated water levels. The measured and simulated water-level changes in BM1, BM2, BM3, and BM4 show some inconsistencies (fig. 6). Wells BM1 and BM4 are in an area of unconfined ground water. The model simulates small declines in these wells starting in about 1980. Measured water levels in wells BM1 and BM4 have not changed or have risen slightly since 1980. In well BM4, the rise in water levels probably is due to an increase in recharge. In wells BM2 and BM3, water-level declines started in 1970 and 1965, respectively. Well BM2 is in an area of confined ground water; however, the boundary between confined and unconfined conditions is only 5 miles northeast of the well. The model simulates less decline in water levels in BM2 after about 1985 than was measured. The difference between measured and simulated water levels in this well was about 12 feet in 1988. The simulated hydrograph for BM2 is insensitive to annual changes in pumping at the mine (Brown and Eychaner, 1988); pumpage ranged from 2,520 to 4,090 acre-feet per year between 1985 and 1988. The difference between measured and simulated water levels in well BM3 was about 28 feet in 1988. The simulated water levels for BM3 are sensitive to the location and to the rate of pumping within the Kayenta well fields (Brown and Eychaner, 1988). Wells BM5 and BM6 are in an area of confined ground water, and the measured and simulated water levels were within about 5 feet for both wells in 1988. Further refinement of the model may be necessary in order to reduce the inconsistencies in wells BM1-BM4.

Withdrawals from the N Aquifer

The three categories of ground-water withdrawal from the N aquifer are industrial (Peabody Coal Company) from the confined area, nonindustrial from the confined area, and nonindustrial from the unconfined area. The primary interest is in withdrawals related to the mining operation and nonindustrial withdrawals of significant amounts. Pumpage data have not been collected from wells equipped with windmills.

The U.S. Geological Survey has continued its efforts to improve and ensure accuracy of withdrawal data from industrial and nonindustrial wells that penetrate the N aquifer in the study area. The U.S. Bureau of Indian Affairs, Navajo Tribal Utility Authority, and Hopi Tribe operate nonindustrial well systems that consist of about 70 wells. These well systems serve the Navajo and Hopi Tribes in the Black Mesa area. The industrial system, which includes eight wells—the Peabody Coal Company mine well field—withdraws water from the N aquifer within the study area. During 1988, the Geological Survey made an inventory of the wells and tested the accuracy of the flowmeters (Hart and Sottilare, 1988). This quality-assurance program was initiated during 1985-86 and is conducted every third year on all wells that penetrate the N aquifer except those with windmills.

Annual pumpage for the three categories of withdrawals from the N aquifer for 1965-88 is given in table 2. Withdrawals during the 1988

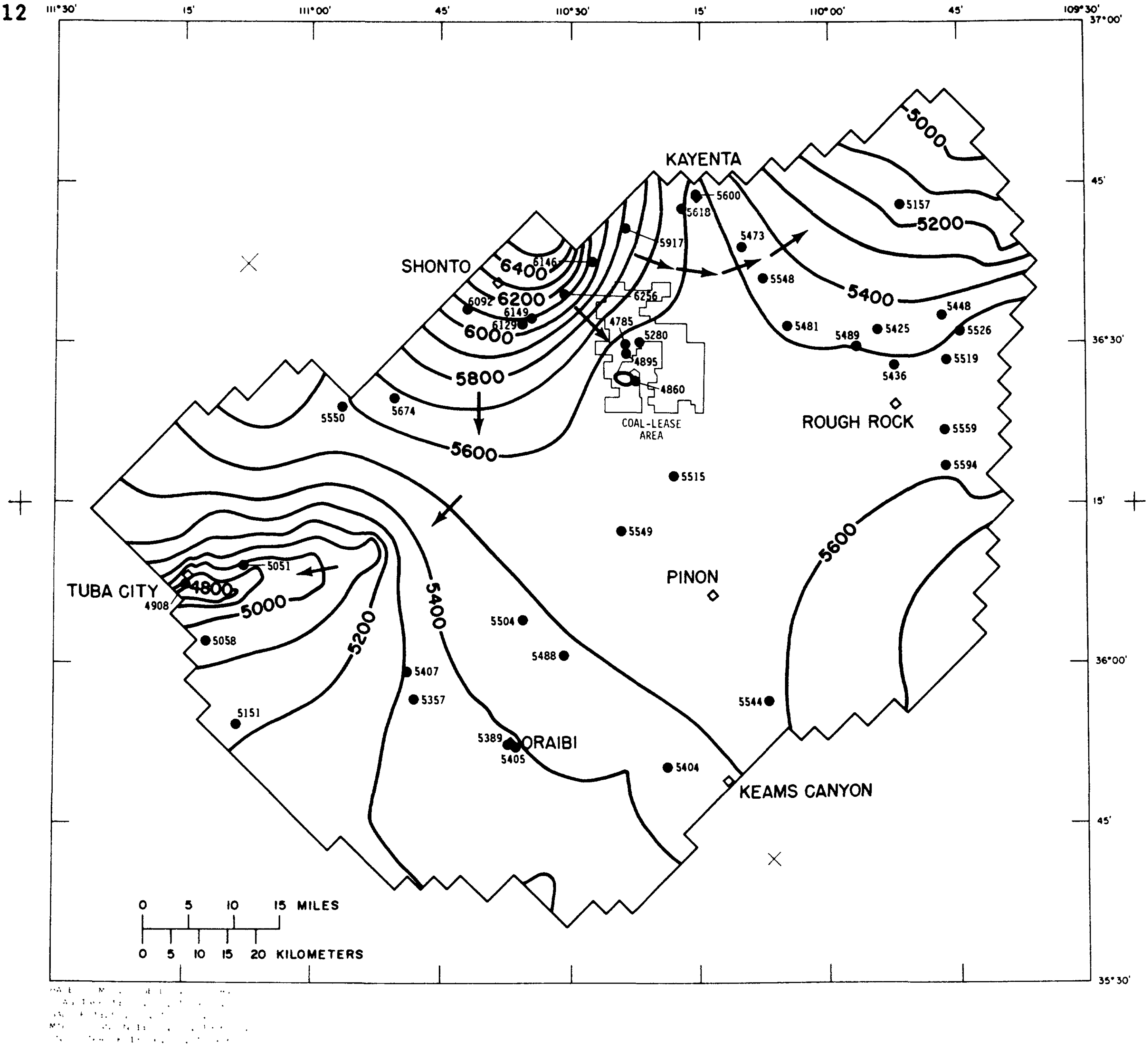


Figure 5.--Measured and simulated water-level altitudes in wells that tap the N aquifer, 1988-89.

EXPLANATION

5200 — LINE OF EQUAL SIMULATED WATER-LEVEL ALTITUDE—Interval 100 feet. Datum is sea level

5600 — WELL IN WHICH DEPTH TO WATER WAS MEASURED, 1988-89—Number, 5600, is altitude of the water level, in feet, above sea level

GENERALIZED DIRECTION OF GROUND-WATER FLOW

BOUNDARY OF MATHEMATICAL MODEL—From Eychaner (1983)

Figure 5

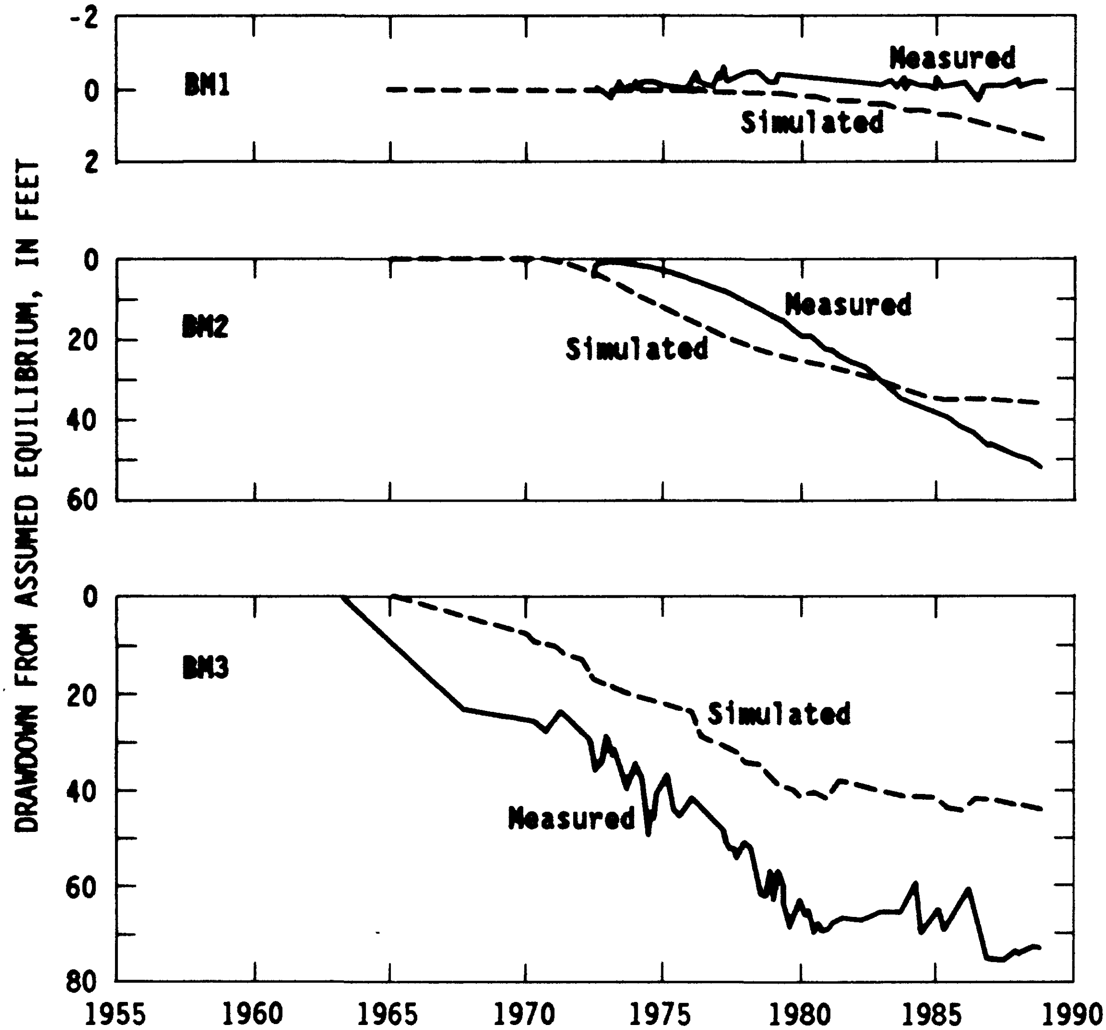


Figure 6.--Measured and simulated water-level changes for observation wells BM 1-6, 1955-88.

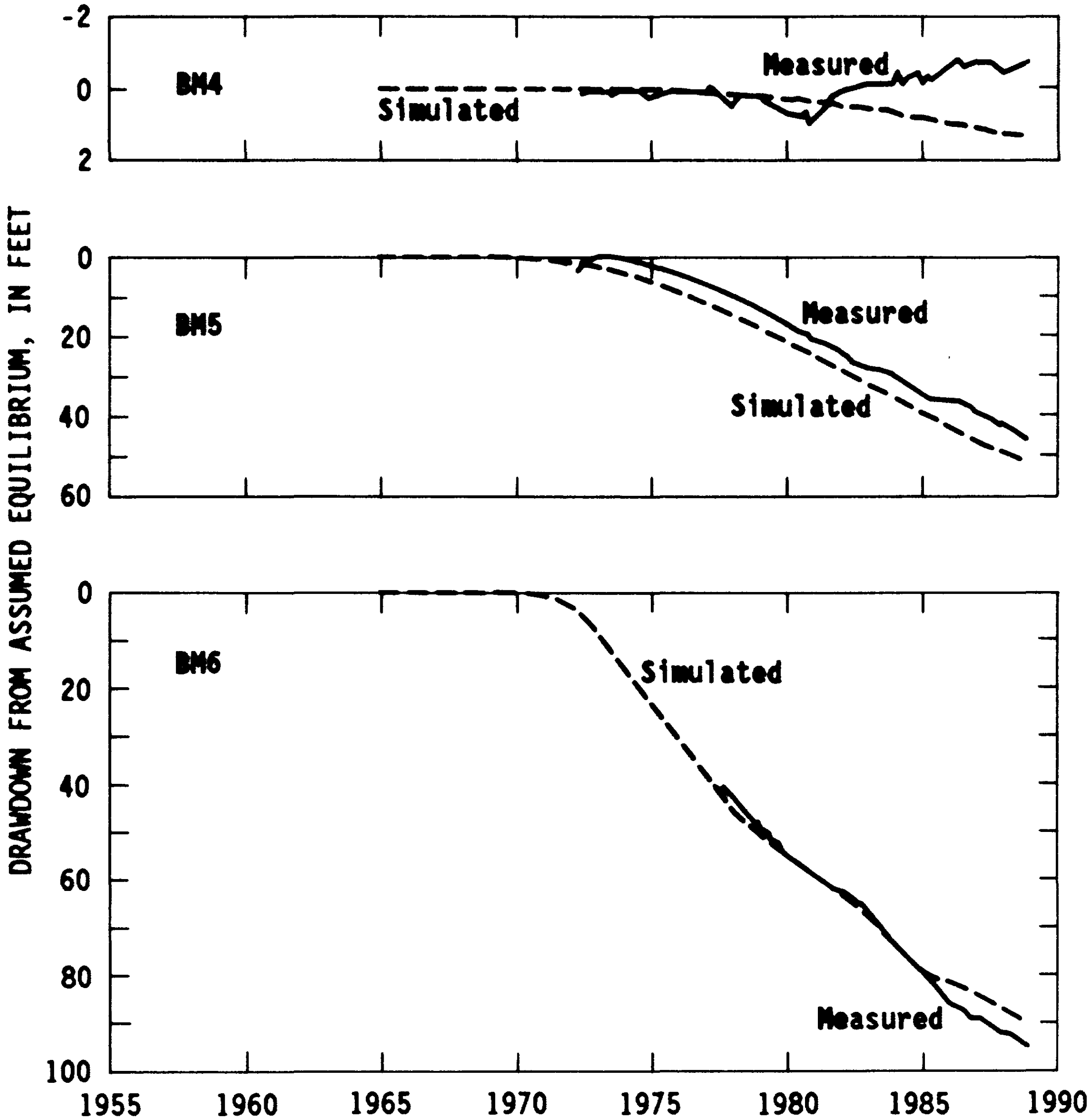


Figure 6.--Continued.

calendar year from nonindustrial and industrial well systems that pump from the N aquifer are given in table 3. Locations of these well systems are shown in figure 7.

Chemical Quality of Water from Wells that Tap the N Aquifer

The effect of withdrawals on the chemical quality of water in the N aquifer is monitored under the Black Mesa monitoring program. Eychaner (1983) stated that some water may enter the N aquifer from the upper confining beds. He also stated that the driving force for such flow is present because the head in the overlying D aquifer in 1964 averaged about 300 feet higher than that in the N aquifer. Differences in the chemical composition of the waters of the D aquifer and the N aquifer indicate that the amount of downward leakage must be small (Eychaner, 1983). On the average, the concentration of dissolved solids in water from the D aquifer is about 7 times greater than that from the N aquifer, the concentration of chloride ions is 11 times greater, and the concentration of sulfate ions is 30 times greater (Eychaner, 1983).

Any increase in the leakage rate as a result of pumping from the N aquifer should appear first as an increase in the dissolved-solids concentrations in the water from Peabody wells (Eychaner, 1983). Other indicators of leakage caused by stress on the N aquifer are increases in specific conductance, concentrations of dissolved chloride, and concentrations of dissolved sulfate.

During the fall of 1988, selected industrial and nonindustrial wells that penetrate the N aquifer were sampled for major ions and fluoride (fig. 3). On the basis of the analyses of water samples collected from 1967 to 1988 by the Geological Survey, no significant changes have occurred in the quality of water in the wells. Chemical analyses of the water from these wells are shown in tables 4 and 5.

Discharge and Chemical Quality of Springs

The effect of withdrawals from the N aquifer on the water quality of springs used for domestic purposes is a concern of some residents of the reservations. Many springs on Black Mesa discharge from several stratigraphic units including the Navajo Sandstone where these units crop out. The Geological Survey monitors selected springs as part of the monitoring program (fig. 3).

Four springs were selected for discharge measurements and water-quality analyses during 1988. The springs were Pasture Canyon Spring (3A-5, Navajo Sandstone), Moenkopi School Spring (3GS-77-6, Navajo Sandstone), Nasjo Toh Spring (8A-109, Dakota Sandstone), and Cottonwood Spring (near Hotevilla, 4M-137, alluvium). Pasture Canyon Spring was previously sampled in 1948, 1982, and 1986; Moenkopi School Spring in 1952

Table 2.--Withdrawals from the N aquifer, 1965-88

[Measurements are in acre-feet. Data for 1965-79 from Eychaner, 1983]

Year	Industrial[1]	Nonindustrial[2,3]	
		Confined	Unconfined
1965	0	50	20
1966	0	110	30
1967	0	120	50
1968	95	150	100
1969	43	200	100
1970	740	280	150
1971	1,900	340	150
1972	3,680	370	250
1973	3,520	530	300
1974	3,830	580	362
1975	3,550	600	508
1976	4,180	690	645
1977	4,090	750	726
1978	3,000	830	930
1979	3,500	860	930
1980	3,540	910	880
1981	4,010	960	1,000
1982	4,740	870	965
1983	4,460	1,360	1,280
1984	4,170	1,070	1,400
1985	2,520	1,040	1,160
1986	4,480	970	1,260
1987	3,830	1,130	1,280
1988	4,090	1,250	1,310

[1]Metered pumpage by Peabody Coal Company at their mine on Black Mesa.

[2]Does not include withdrawals from the wells equipped with windmills.

[3]Includes estimated pumpage, 1965-73, and metered pumpage, 1974-79, at Tuba City, metered pumpage at Kayenta and estimated pumpage at Chilchinbito, Rough Rock, Pinon, Keams Canyon, and Kykotsmovi prior to 1980; metered and estimated pumpage furnished by the Navajo Tribal Utility Authority and the U.S. Bureau of Indian Affairs and collected by the U.S. Geological Survey, 1980-85; and metered pumpage furnished by the Navajo Tribal Utility Authority, the U.S. Bureau of Indian Affairs, Kykotsmovi Village Administration, and the U.S. Geological Survey, 1986-88.

Table 3.--Withdrawals from the N aquifer by well systems, 1988

[Measurements, in acre-feet, are flowmeter data. BIA, U.S. Bureau of Indian Affairs; NTUA, Navajo Tribal Utility Authority; USGS, U.S. Geological Survey]

Location	Owner	Source of data	Confined aquifer well systems	Unconfined aquifer well systems
Tuba City	BIA	USGS		230
Shonto	BIA	USGS		170
Dennehotso	BIA	USGS		28.1
Red Lake	BIA	USGS		11.8
Kayenta	BIA	USGS	83.4	
Rocky Ridge	BIA	USGS	11.9	
Chilchinbito	BIA	BIA	7.9	
Pinon	BIA	USGS	31.2	
Rough Rock	BIA	BIA	69.8	
Hotevilla	BIA	USGS	21.7	
Second Mesa	BIA	USGS	9.2	
Hopi High School	BIA	USGS	17.5	
Keams Canyon	BIA	USGS	65.1	
Low Mountain	BIA	USGS	6.3	
Red Lake	NTUA	NTUA		39.0
Tuba City	NTUA	NTUA		773
Dennehotso	NTUA	NTUA		29.4
Shonto	NTUA	NTUA		6.5
Shonto Junction	NTUA	NTUA		26.5
Forest Lake	NTUA	NTUA	15.8	
Chilchinbito	NTUA	NTUA	30.0	
Kayenta	NTUA	NTUA	607	
Rough Rock	NTUA	NTUA	12.6	
Pinon	NTUA	NTUA	51.4	
Kitsillie	NTUA	NTUA	7.2	
Mine Well Field	Peabody	Peabody	4,090	
Polacca	Hopi	USGS	110	
Kykotsmovi	Hopi	USGS	61.3	
Shungopavi	Hopi	USGS	14.9	
Shipaulovi	Hopi	USGS	17.8	
Mishongnovi	Hopi	USGS	1.7	

Table 4.--Chemical analyses of selected industrial and nonindustrial wells that tap the N aquifer, 1988

Well number	Identification number	Date of sample	Temperature (°C)	Specific conductance (µS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
Peabody Well 5	362901110234101	11-17-88	32	263	9.2	110	0.96
Peabody Well 8	363130110254501	11-17-88	29.5	418	8.1	100	1.7
Keams Canyon 2	355023110182701	11-15-88	20	1,040	9.1	356	<.1
Rough Rock PM5 (BIA #2)	362418109514601	12-01-88	22	1,120	9.0	227	1.1
Kayenta PM2	364344110151201	11-17-88	16.5	358	8.0	105	.96
Low Mountain PM2	355638110064001	11-18-88	21	1,580	8.9	369	<.1
Kitsillie NTUA 1	362035110032201	12-01-88	27	418	9.9	211	1.3
Tuba City PM6	360802111144601	11-29-88	16	178	8.2	77	1.7

Well number	Identification number	Date of sample	Phosphorus, ortho, dissolved (mg/L as P)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Peabody Well 5	362901110234101	11-17-88	<0.01	3.6	0.08	57
Peabody Well 8	363130110254501	11-17-88	.25	24	3.6	70
Keams Canyon 2	355023110182701	11-15-88	<.01	.86	.24	230
Rough Rock PM5 (BIA #2)	362418109514601	12-01-88	<.01	2	.36	230
Kayenta PM2	364344110151201	11-17-88	<.01	42	7.3	27
Low Mountain PM2	355638110084001	11-16-88	.01	1.5	.47	320
Kitsillie NTUA 1	362035110032201	12-01-88	<.01	.8	.2	96
Tuba City PM6	360802111144601	11-29-88	<.01	21	4.2	12

Well number	Identification number	Date of sample	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
Peabody Well 5	362901110234101	11-17-88	0.8	4.1	26	0.2
Peabody Well 8	363130110254501	11-17-88	2.7	4.5	120	.1
Keams Canyon 2	355023110182701	11-15-88	.8	97	34	1.3
Rough Rock PM5 (BIA #2)	362418109514601	12-01-88	1.3	130	109	1.6
Kayenta PM2	364344110151201	11-17-88	1.3	3.8	74	.1
Low Mountain PM2	355638110064001	11-16-88	1.1	200	75	2.7
Kitsillie NTUA 1	362035110032201	12-01-88	.6	3.7	5.7	.2
Tuba City PM6	360802111144601	11-29-88	1.2	7.3	8.9	.2

Well number	Identification number	Date of sample	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)	Dissolved solids residue at 180°C (mg/L)
Peabody Well 5	362901110234101	11-17-88	20	40	5	174
Peabody Well 8	363130110254501	11-17-88	19	50	15	308
Keams Canyon 2	355023110182701	11-15-88	12	660	7	591
Rough Rock PM5 (BIA #2)	362418109514601	12-01-88	12	400	14	624
Kayenta PM2	364344110151201	11-17-88	16	20	3	235
Low Mountain PM2	355638110064001	11-16-88	11	1300	12	851
Kitsillie NTUA 1	362035110032201	12-01-88	24	40	8	241
Tuba City PM6	360802111144601	11-29-88	12	10	12	100

Table 4.--Chemical analyses of selected industrial and nonindustrial wells that tap the N aquifer, 1988--Continued

Well number	Identification number	Date of sample	Temperature (°C)	Specific conductance (μS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)
Shonto PM2 (BIA #1)	363558110392501	11-18-88	14	285	7.8	102	3.7
Kykotsmovi PM2	355215110375001	11-15-88	23	368	9.6	162	1.2
Pinon PM6	360614110130801	12-01-88	26.5	455	10.1	227	1.4
Chilchinbito PM3	363137110044702	11-17-88	20.5	414	9.5	190	1.2

Well number	Identification number	Date of sample	Phosphorus, ortho, dissolved (mg/L as P)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)
Shonto PM2 (BIA #1)	363558110392501	11-18-88	<0.01	45	6.2	5.9
Kykotsmovi PM2	355215110375001	11-15-88	.03	.51	.09	81
Pinon PM6	360614110130801	12-01-88	<.01	.53	.09	109
Chilchinbito PM3	363137110044702	11-17-88	<.01	4.4	.84	93

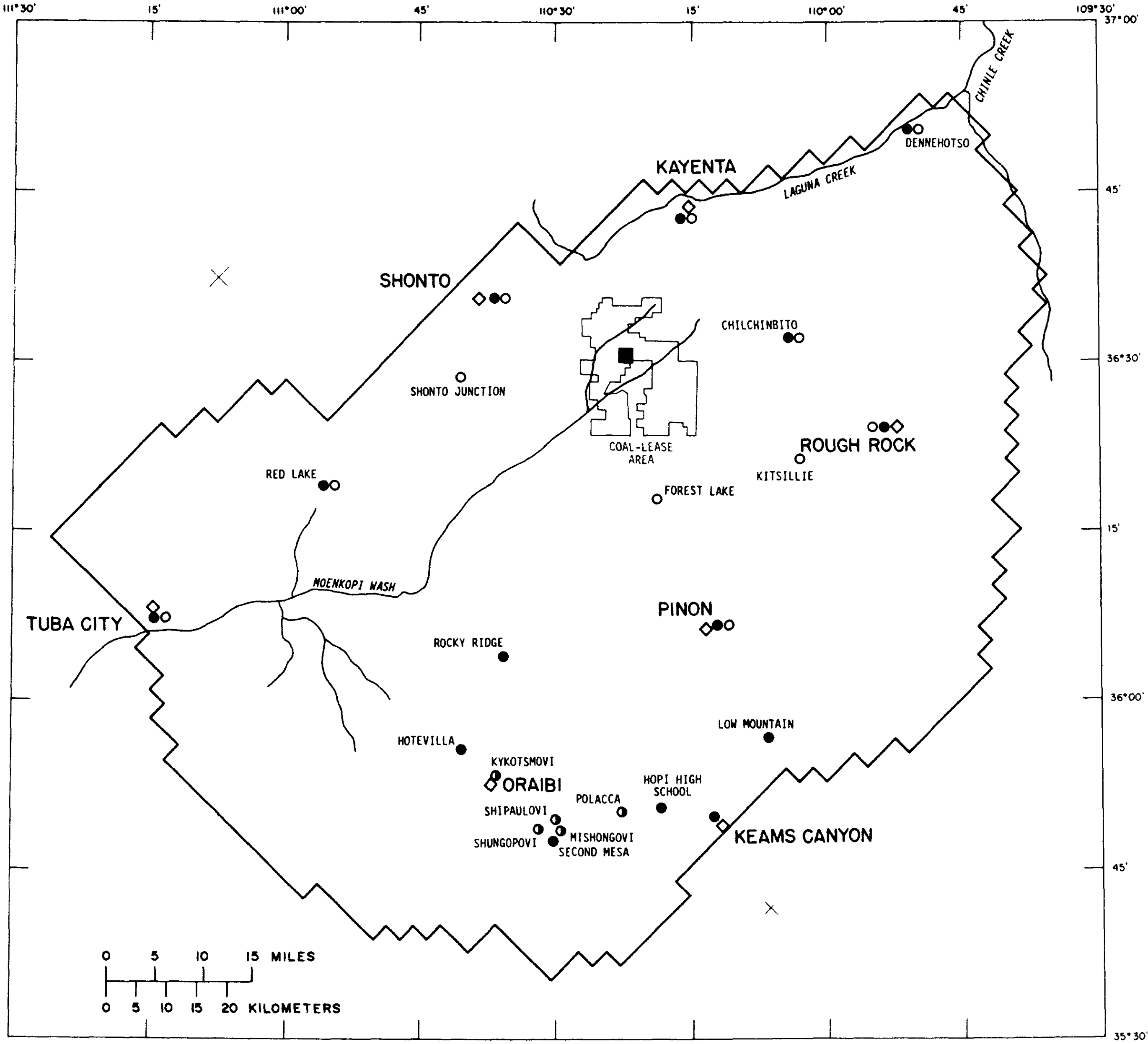
Well number	Identification number	Date of sample	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
Shonto PM2 (BIA #1)	363558110392501	11-18-88	1.7	13	14	0.10
Kykotsmovi PM2	355215110375001	11-15-88	.5	3.2	8.6	.2
Pinon PM6	360614110130801	12-01-88	.4	3.5	5.2	.2
Chilchinbito PM3	363137110044702	11-17-88	.9	2.7	31	.2

Well number	Identification number	Date of sample	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (μg/L as B)	Iron, dissolved (μg/L as Fe)	Dissolved solids residue at 180°C (mg/L)
Shonto PM2 (BIA #1)	363558110392501	11-18-88	14	10	6	171
Kykotsmovi PM2	355215110375001	11-15-88	23	30	8	212
Pinon PM6	360614110130801	12-01-88	27	50	5	278
Chilchinbito PM3	363137110044702	11-17-88	16	40	14	256

Table 5.--Selected parameters from chemical analyses of water from industrial and nonindustrial wells that tap the N aquifer, 1968 and 1980-88

Well number	Year	Specific conductance (µS/cm)	Dissolved-solids concentrations, residue at 180°C (mg/L)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)
Peabody Well 5	1968	224	[1]149	3.5	16
	1980	210	134	2.9	9.5
	1986	398	---	8.0	28
	[2]1986	602	338	12.0	62
	1987	270	168	4.6	21
	1988	270	184	5.1	22
	1988	263	174	4.1	26
Peabody Well 8	1980	420	283	4.8	100
	1983	440	278	4.8	100
	1984	436	264	4.7	100
	1986	445	---	4.9	110
	[3]1988	790	516	7.2	250
	[4]1988	438	300	4.8	120
	1988	418	308	4.5	120
Keams Canyon 2	1982	1,010	592	94	35
	1983	1,120	636	120	42
	1984	1,040	578	96	36
	1988	1,040	591	97	34
Rough Rock PM5	1983	1,090	628	130	110
(BIA #2)	1984	1,090	613	130	99
	1986	1,010	633	140	120
	1988	1,120	624	130	109
Kayenta PM2	1982	360	228	4.5	58
	1983	375	230	-----	60
	1984	365	209	4.2	51
	1986	300	181	8.2	30
	1988	358	235	3.8	74
Low Mountain PM2	1988	1,580	851	200	75
Kitsillie NTUA 1	1982	580	365	5.4	84
	1983	505	291	4.4	37
	1984	460	258	5.2	20
	1988	418	241	3.7	5.7
Tuba City PM6	1988	178	100	7.3	8.9
Shonto PM2	1986	290	---	10	14
(BIA #1)	1988	285	171	13	14
Kykotsmovi PM2	1988	368	212	3.2	8.6
Pinon PM6	1982	485	---	3.7	5.0
	1983	505	293	3.6	5.3
	1984	495	273	3.7	5.4
	1987	500	279	3.7	3.8
	1988	455	278	3.5	5.2
Chilchinbito PM3	1986	390	231	2.4	11
	1988	414	256	2.7	31

[1]Dissolved-solids concentrations from 1974.
[2]Volume of well bore not completely displaced prior to sampling.
[3]Well pumped for 16 hours at 470 gallons per minute.
[4]Well pumped for 20 hours at 600 gallons per minute.



BASE FROM U.S. GEOLOGICAL SURVEY
FLAGSTAFF 1:250,000, 1954-70,
GALLUP 1:250,000, 1950-70,
MARBLE CANYON 1:250,000, 1956-70,
AND SHIPROCK 1:250,000, 1954-69

Figure 7.--Location of well systems monitored for withdrawals from the N aquifer, 1988.

E X P L A N A T I O N

WELL-SYSTEM OWNER

● U.S. Bureau of Indian Affairs

○ Navajo Tribal Utility Authority

◑ Hopi Tribe

■ Peabody Mine Well Field

Figure 7

and 1987; Nasjo Toh Spring in 1984; and Cottonwood Spring in 1954 and 1983. Discharge measurements for these springs are as follows:

Spring	U.S. Bureau of Indian Affairs number	Year	Discharge, in gallons per minute
Pasture Canyon	3A-5	1948	174
		1982	135
		1986	160
		1988	211
Moenkopi School	3GS-77-6	1952	40
		1987	21.5
		1988	44
Nasjo Toh	8A-109	1984	1 (estimated)
		1988	collection box (unmeasurable)
Cottonwood	4M-137	1954	(unmeasurable)
		1983	<.5
		1988	collection box (unmeasurable)

On the basis of the analyses of water samples collected from the late 1940's to 1988 by the Geological Survey, no significant changes have occurred in the quality of water in these springs. Chemical analyses for the springs for all years sampled are shown in table 6. Discharges and chemical analyses of other springs have been reported previously (G.W. Hill, written commun., 1982, 1983; Hill, 1985; Hill and Whetten, 1986; Hill and Sottilare, 1987; Hart and Sottilare, 1988).

Surface-Water Data

Outflow from the N aquifer appears mainly as surface flow in Moenkopi Wash and Laguna Creek and as springs near the boundaries of the aquifer (Davis and others, 1963). Data were collected from the continuous-record streamflow stations on Moenkopi Wash at Moenkopi (09401260) and Chinle Creek near Mexican Water (09379200) and from the low-flow measurement site on Laguna Creek near Church Rock (09379160) (fig. 3). To estimate the winter base-flow discharge at these stations, low-flow measurements made during November through February were analyzed.

The average discharge of low-flow measurements made on Moenkopi Wash during November through February in the 1989 water year was 2.07 cubic feet per second, which is equivalent to about 1,500 acre-feet per year. The average of all low-flow measurements made during the same period from 1976 to 1989 was 3.34 cubic feet per second. Low flow in Moenkopi Wash during November through February has remained fairly constant since the streamflow station was established in 1976. Mean daily discharges during the 1987 and 1988 water years are shown in table 7. Mean daily discharges for previous water years have been published in Water Resources Data for Arizona (U.S. Geological Survey, 1977-89).

Table 6.--Chemical analyses of selected springs, 1948-88

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Temperature (°C)	Specific conductance (µS/cm)	pH (units)	Alkalinity (mg/L as $CaCO_3$)	Nitrogen NO_2+NO_3 dissolved (mg/L as N)
Pasture Canyon Spring	3A-5	361021111115901	Navajo Sandstone	02-27-48	15.5	199	---	77	----
				09-18-82	19	240	7.6	98	5.2
				05-19-86	17	257	8.0	76	4.7
				11-18-88	16	232	7.8	79	5.0
Moenkopi School Spring	3GS-77-6	360632111131101	Navajo Sandstone	05-16-52	----	222	---	92	----
				04-22-87	16	270	7.4	101	1.70
				11-29-88	18	270	7.2	98	1.90
Nasjo Toh Spring	8A-109	363504110093701	Dakota Sandstone	08-15-84	----	480	8.4	134	.68
				11-17-88	10	443	8.3	132	.74
Cottonwood Spring (near Hotevilla)	4M-137	360934110431401	Alluvium	10-28-54	15	560	---	---	----
				08-23-83	17	550	7.7	200	.10
				11-15-88	14	505	8.0	208	.21

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Phosphorus ortho, dissolved (mg/L as P)	Hardness (mg/L as $CaCO_3$)	Hardness noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)
Pasture Canyon Spring	3A-5	361021111115901	Navajo Sandstone	02-27-48	-----	85	8	26	4.9
				09-18-82	0.01	95	12	30	4.8
				05-19-86	.01	94	---	30	4.6
				11-18-88	.02	---	---	30	4.9
Moenkopi School Spring	3GS-77-6	360632111131101	Navajo Sandstone	05-16-52	-----	78	0	21	6.1
				04-22-87	.010	85	---	25	5.5
				11-29-88	<.010	---	---	27	5.9
Nasjo Toh Spring	8A-109	363504110093701	Dakota Sandstone	08-15-84	<.01	---	---	49	24
				11-17-88	<.01	---	---	47	26
Cottonwood Spring (near Hotevilla)	4M-137	360934110431401	Alluvium	10-28-54	-----	52	0	12	5.3
				08-23-83	.01	31	0	8.4	2.5
				11-15-88	.01	---	---	8.9	2.7

Table 6.--Chemical analyses of selected springs, 1948-88--Continued

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Sodium, dissolved (mg/L as Na)	Sodium absorption ratio	Percent sodium	Sodium+ Potassium, dissolved (mg/L as Na+K)
Pasture Canyon Spring	3A-5	361021111115901	Navajo Sandstone	02-27-48	---	0.6	23	12
				09-18-82	11	.5	20	---
				05-19-86	11	.5	---	---
				11-18-88	11	---	---	---
Moenkopi School Spring	3GS-77-6	360632111131101	Navajo Sandstone	05-16-52	---	.9	33	17
				04-22-87	22	1	---	---
				11-29-88	22	---	---	---
Nasjo Toh Spring	8A-109	363504110093701	Dakota Sandstone	08-15-84	13	---	---	---
				11-17-88	14	---	---	---
Cottonwood Spring (near Hotevilla)	4M-137	360934110431401	Alluvium	10-28-54	---	6.6	82	110
				08-23-83	110	9.2	88	---
				11-15-88	109	---	---	---

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)
Pasture Canyon Spring	3A-5	361021111115901	Navajo Sandstone	02-27-48	---	5.0	13	0.2
				09-18-82	1.2	5.1	18	.2
				05-19-86	1.3	5.4	19	.2
				11-18-88	1.4	5.3	18	.2
Moenkopi School Spring	3GS-77-6	360632111131101	Navajo Sandstone	05-16-52	---	6.0	---	---
				04-22-87	1.3	12	19	.2
				11-29-88	1.3	12	19	.1
Nasjo Toh Spring	8A-109	363504110093701	Dakota Sandstone	08-15-84	2.3	10	100	.6
				11-17-88	2.3	10	109	.5
Cottonwood Spring (near Hotevilla)	4M-137	360934110431401	Alluvium	10-28-54	---	10	62	.6
				08-23-83	2.2	7.1	60	.3
				11-15-88	2.2	6.8	58	.2

Table 6.--Chemical analyses of selected springs, 1948-88--Continued

Spring name	U.S. Bureau of Indian Affairs field number	U.S. Geological Survey identification number	Rock formation	Date of sample	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (μg/L as B)	Iron, dissolved (μg/L as Fe)	Dissolved solids: Residue at 180°C mg/L)	Dissolved solids: Sum of constituents (mg/L)
Pasture Canyon Spring	3A-5	361021111115901	Navajo Sandstone	02-27-48	----	---	---	123	---
				09-18-82	9.7	30	3	---	153
				05-19-86	9.8	30	5	---	---
				11-18-88	9.6	30	8	146	---
Moenkopi School Spring	3GS-77-6	360632111131101	Navajo Sandstone	05-16-52	----	---	---	---	---
				04-22-87	13	40	5	161	---
				11-29-88	14	30	6	155	---
Nasjo Toh Spring	8A-109	363504110093701	Dakota Sandstone	08-15-84	11	60	4	276	280
				11-17-88	10	40	18	321	---
Cottonwood Spring (near Hotevilla)	4M-137	360934110431401	Alluvium	10-28-54	14	---	---	341	---
				08-23-83	12	70	59	---	328
				11-15-88	12	70	42	327	---

Table 7.--Discharge data, Moenkopi Wash at Moenkopi, 1987 and 1988 water years

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2.8	10	•3.0	•3.0	•18	58	2.2	1.6	.10	.00	•1.2	.08
2	2.8	18	•3.0	•3.0	•8.4	•5.6	1.6	.80	.00	.00	•.60	.00
3	1.2	10	2.8	•3.0	•8.4	•4.4	1.2	1.0	.06	.00	•.20	.00
4	1.2	8.4	3.6	•3.0	•8.4	4.4	1.0	1.0	.06	.00	•.20	.00
5	1.2	5.6	2.8	•3.5	3.6	5.6	1.2	1.0	.05	.00	•.20	.00
6	1.6	5.6	3.6	•3.5	3.6	4.4	1.2	1.0	.02	.00	•.20	.60
7	2.8	6.8	8.4	•3.5	4.4	5.6	1.6	1.2	.00	.00	.20	.60
8	2.8	5.6	30	•3.0	2.8	6.8	2.2	1.2	.60	.00	124	.17
9	2.8	5.6	10	•3.0	2.2	8.4	2.2	.80	.12	.00	213	.20
10	3.6	8.4	11	•2.5	1.6	8.4	1.6	.80	.00	.00	36	.04
11	293	10	3.6	•2.5	1.6	6.8	1.6	.80	.00	.00	8.4	.00
12	285	10	2.8	•2.5	1.6	2.8	1.6	.80	.00	.00	30	.00
13	20	10	•3.0	•2.5	1.2	2.2	1.6	.80	.00	.00	49	.00
14	8.4	13	•3.0	•2.5	1.2	2.2	1.6	1.6	.00	.00	20	.00
15	3.6	13	•3.0	•3.0	1.2	1.6	1.6	26	.00	.00	4.4	.00
16	2.2	13	•5.5	•3.0	1.6	4.4	1.6	24	.00	.00	1.2	.00
17	2.2	13	6.8	•2.5	1.2	5.6	2.2	16	.00	.00	.47	.00
18	2.2	11	8.4	•2.0	1.0	2.8	1.2	14	.00	.00	.12	.00
19	2.2	127	•3.0	•2.0	1.0	2.2	1.0	1.6	.00	.00	.00	.00
20	2.2	•10	•3.0	•1.5	1.0	1.6	.80	1.0	.00	.00	.00	.00
21	1.6	•5.0	5.6	•1.5	1.0	1.6	.80	.36	.00	.00	.00	.00
22	1.6	•3.0	•5.5	•1.5	1.0	1.6	1.0	.36	.00	.00	.00	.00
23	1.6	•3.0	•5.0	•1.5	1.2	2.2	1.2	.47	.00	.00	411	.00
24	1.6	•3.0	•4.5	•2.5	5.6	3.6	1.2	.27	.00	.00	593	70
25	1.6	•3.0	•4.0	16	34	2.8	1.0	.20	.00	.00	144	1.2
26	1.6	•3.0	•3.5	10	24	2.8	1.0	.15	.00	.00	28	.80
27	1.6	•5.0	•3.0	8.4	20	2.2	1.2	.47	.00	7.4	13	.47
28	1.6	•3.0	•3.0	10	38	1.6	1.2	.15	.00	87	2.8	.36
29	1.6	•3.0	•3.0	4.4	---	1.6	1.0	.17	.00	•10	.80	.27
30	1.6	•3.0	•3.0	25	---	1.6	1.2	.04	.00	•5.6	.20	.17
31	2.2	---	•3.0	103	---	1.6	---	.10	---	•1.2	.10	---
TOTAL	662.0	348.0	163.4	238.8	198.8	167.0	41.60	99.74	1.01	111.20	1682.29	74.96
MEAN	21.4	11.6	5.27	7.70	7.10	5.39	1.39	3.22	.034	3.59	54.3	2.50
MAX	293	127	30	103	38	58	2.2	26	.60	87	593	70
MIN	1.2	3.0	2.8	1.5	1.0	1.6	.80	.04	.00	.00	.00	.00
AC-FT	1310	690	324	474	394	331	83	198	2.0	221	3340	149

CAL YR 1986 TOTAL 4956.55 MEAN 13.6 MAX 1070 MIN .00 AC-FT 9830
WTR YR 1987 TOTAL 3788.80 MEAN 10.4 MAX 593 MIN .00 AC-FT 7520
• Estimated

Table 7.--Discharge data, Moenkopi Wash at Moenkopi, 1987 and 1988 water years--Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.20	e1300	3.6	e7.0	30	e10	1.6	1.6	.12	8.4	e30	e130
2	.17	464	4.4	e8.5	20	e10	1.6	1.6	.12	1.6	e20	25
3	.17	e40	5.6	11	e40	e10	1.6	1.6	.12	1.0	e8.5	6.8
4	.12	16	5.6	16	e35	e5.0	1.6	1.6	.06	.80	e3.0	2.8
5	.12	11	3.6	14	50	2.8	1.6	1.2	.02	.80	e3.0	2.2
6	.36	162	3.6	18	35	2.2	1.6	1.0	.00	.36	e10.0	1.2
7	.27	47	2.8	14	25	1.6	1.6	1.0	.00	.12	e13	1.0
8	.27	10	2.8	14	20	2.2	1.6	1.2	.00	.00	e3.0	.60
9	.20	4.4	2.8	6.8	20	2.2	1.6	1.6	.00	.00	e.50	.60
10	.27	3.6	2.8	5.6	35	2.2	1.6	1.6	.00	.00	e.20	.60
11	.27	2.8	3.6	5.6	35	2.2	1.6	e1.6	.00	.00	.00	1.6
12	.36	2.2	5.6	5.6	e25	2.8	1.6	e1.2	.00	.00	.00	1.6
13	.80	2.2	2.2	5.6	e20	2.8	2.2	1.2	.00	.00	.00	8.4
14	2.2	2.2	2.8	5.6	e20	2.8	2.2	1.0	.00	.00	.00	10
15	1.2	2.2	2.8	3.6	e15	2.8	2.8	.60	.00	.00	.00	2.8
16	1.2	2.2	3.6	11	e10	2.8	5.6	.47	.00	.00	.00	2.2
17	1.2	2.2	3.6	16	e5.0	2.8	121	.47	.00	.00	.00	2.2
18	1.2	2.2	5.6	6.8	e20	2.8	30	.47	.00	.00	.00	1.6
19	1.2	2.2	5.6	10	20	2.8	8.4	.47	.00	.00	.00	1.6
20	1.6	2.8	6.8	e5.6	10	2.8	4.4	.47	.00	.00	.00	1.6
21	1.2	4.4	5.6	5.6	e25	2.2	5.6	.36	.00	.00	80	1.6
22	1.0	4.4	3.6	3.0	e15	2.2	6.8	.36	.00	.00	e55	1.6
23	.47	3.6	5.0	1.6	e8.0	2.2	11	.36	.00	.00	e20	1.6
24	.60	3.6	3.6	1.6	e15	2.2	11	.20	.03	.00	e75	1.6
25	1.6	2.8	2.2	1.6	e2.5	2.2	8.4	.20	7.7	.00	225	2.2
26	2.2	2.8	3.6	3.6	2.8	2.2	5.6	.20	e15	.00	130	2.2
27	2.2	3.6	e5.0	2.2	3.6	2.2	3.6	.08	e6.8	.64	1130	2.2
28	2.2	2.8	e5.0	3.8	11	1.6	2.8	.00	e35	.35	86	2.2
29	1.2	4.4	e5.0	1.6	e20	1.6	2.8	.00	e45	.00	49	1.6
30	e150	4.4	e5.0	e20	---	2.2	2.8	.00	209	e25	384	1.6
31	16	---	e6.0	e50	---	2.2	---	.06	---	26	120	---
TOTAL	192.05	2118.0	129.4	284.9	592.9	98.6	256.2	23.77	318.97	65.07	2445.20	222.80
MEAN	6.20	70.6	4.17	9.19	20.4	3.18	8.54	.77	10.6	2.10	78.9	7.43
MAX	150	1300	6.8	50	50	10	121	1.6	209	26	1130	130
MIN	.12	2.2	2.2	1.6	2.5	1.6	1.6	.00	.00	.00	.00	.60
AC-FT	381	4200	257	565	1180	196	508	47	633	129	4850	442

CAL YR 1987 TOTAL 5054.85 MEAN 13.8 MAX 1300 MIN .00 AC-FT 10030
WTR YR 1988 TOTAL 6747.86 MEAN 18.4 MAX 1300 MIN .00 AC-FT 13380
e Estimated

Table 8.--Discharge data, Chinle Creek near Mexican Water, 1987 and 1988 water years

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	11	7.6	11	●5.0	17	●12	.46	5.1	.14	.04	38	●.70
2	7.2	286	7.2	●5.0	17	●10	.69	13	.10	.00	36	●.70
3	3.7	188	●6.2	●5.0	11	●9.0	.50	39	.11	.00	2.2	●.70
4	1.8	84	●4.8	●7.0	18	8.0	1.4	12	.00	.00	.00	●.70
5	1.5	184	●3.7	●10	18	11	75	7.2	.11	.00	.00	●.70
6	1.5	77	3.1	●15	27	20	59	2.2	.15	.00	.00	●.70
7	1.5	99	6.2	●15	31	60	39	.84	.11	.00	270	●.80
8	1.8	233	152	●10	24	25	11	.61	.17	.00	657	●1.0
9	1.4	104	116	●7.0	14	23	5.3	.53	5.6	.00	169	●.80
10	1.8	59	106	●5.0	14	17	2.5	.53	19	.00	23	●.70
11	81	44	9.6	●4.0	11	11	1.5	.46	21	.00	11	●.60
12	138	28	●5.0	●4.0	23	11	1.2	.46	3.0	.00	6.5	●.60
13	160	25	●5.0	●4.0	22	30	10	.40	.09	.00	313	●.60
14	93	20	●6.0	●10	●15	12	11	.46	.00	.00	298	●.70
15	45	18	●10	●7.0	●10	7.6	5.3	5.5	.00	.00	69	●.90
16	34	18	●13	●5.0	●9.0	4.8	3.4	35	.14	.00	10	●.80
17	29	18	●14	●5.0	●8.0	3.7	59	22	.02	.00	4.5	●.70
18	21	117	●15	●1.0	●7.0	11	317	9.6	.00	.00	1.2	●.80
19	17	404	●14	●2.0	●6.0	10	413	6.9	.03	.00	.49	●.70
20	4.4	48	●5.0	●2.5	●5.0	8.0	433	2.4	.00	.00	.38	●.70
21	3.4	36	●6.0	●3.0	●5.0	7.2	351	.78	.00	.00	.84	●.60
22	2.5	21	●7.0	●4.0	●5.0	8.0	236	1.1	.00	.00	40	●.50
23	2.2	14	●10	●5.0	●5.0	8.4	147	.87	.00	.00	145	●.40
24	2.5	11	●10	●6.0	●7.0	8.0	55	.78	.00	.00	1160	.28
25	3.1	13	●9.0	●7.0	●10	5.7	103	.36	.00	.00	584	.30
26	3.4	11	●8.0	●8.0	●15	1.1	159	.38	.00	.00	45	.36
27	2.8	12	●.09	●7.0	●20	1.1	75	2.6	.00	.00	47	.72
28	1.2	16	●6.0	●10	●15	.61	11	2.2	.00	.00	12	.87
29	2.5	12	●5.0	14	---	.46	8.0	.38	18	.00	.88	.40
30	3.4	11	●5.0	13	---	.98	5.0	.36	2.6	.00	●.80	.53
31	4.8	---	●5.0	28	---	.53	---	.18	---	11	●.70	---
TOTAL	687.4	2218.6	590.8	235.5	389.00	346.18	2599.25	174.18	70.37	11.04	3945.49	19.56
MEAN	22.2	74.0	19.1	7.60	13.9	11.2	86.6	5.62	2.35	.36	127	.65
MAX	160	404	152	28	31	60	433	39	21	11	1160	1.0
MIN	1.2	7.6	3.1	1.0	5.0	.46	.46	.18	.00	.00	.00	.28
AC-FT	1360	4400	1170	467	772	687	5160	345	140	22	7830	39

CAL YR 1986 TOTAL 11,181.20 MEAN 30.6 MAX 771 MIN .00 AC-FT 22,180
WTR YR 1987 TOTAL 11,287.37 MEAN 30.9 MAX 1160 MIN .00 AC-FT 22,390
● Estimated

Table 8.--Discharge data, Chinle Creek near Mexican Water, 1987 and 1988 water years--Continued

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.60	177	•3.0	1.4	140	110	1.2	80	.24	26	32	461
2	.53	1260	•2.0	1.5	48	96	.98	79	.17	9.0	18	74
3	.38	155	•3.0	.98	1330	99	.98	82	.15	3.7	18	55
4	.32	38	3.8	1.2	1470	65	1.4	58	.12	16	16	19
5	.34	109	8.4	1.4	285	39	.98	40	.00	117	5.3	11
6	.30	1670	14	2.2	206	52	.78	34	.00	19	3.7	6.5
7	.23	645	11	2.5	146	61	.69	23	.00	7.6	.91	14
8	.32	88	8.0	19	131	70	.40	12	.00	2.2	14	7.2
9	.30	24	5.3	55	72	58	.40	4.1	.00	.34	4.4	2.8
10	.30	12	3.1	89	81	31	43	.87	.00	.17	1.5	1.1
11	.30	7.2	2.5	72	133	21	56	.46	.00	.04	.98	1.4
12	.32	4.8	2.4	98	89	16	32	.36	.00	3.1	3.5	73
13	.38	3.4	3.5	53	66	9.2	31	.33	.00	24	.24	653
14	51	13	3.4	55	75	3.7	14	.28	.00	13	.74	50
15	43	19	3.7	50	63	4.4	8.8	.30	.00	7.6	5.0	20
16	35	•10	2.5	22	48	4.4	124	.32	.00	1.3	5.9	11
17	14	•8.0	2.5	45	33	2.8	1800	.50	.00	.15	25	7.6
18	8.0	•7.0	2.5	53	25	2.2	1270	1.5	.00	.00	12	6.2
19	6.9	•7.0	3.7	134	17	1.8	462	.98	21	.00	2.5	4.4
20	6.2	•6.0	3.1	40	14	3.1	281	1.8	43	.00	1.2	3.7
21	5.3	•6.0	2.9	23	15	2.0	269	.36	37	.00	.36	3.1
22	5.7	•5.0	2.8	5.0	19	1.5	272	.28	14	.00	5.3	3.4
23	6.2	•5.0	3.1	5.7	21	.98	214	.26	4.6	.00	3.2	2.5
24	7.6	•4.5	3.4	7.9	23	.91	242	.28	2.0	.00	238	2.8
25	8.8	•4.5	2.0	5.7	20	.87	244	.28	56	.00	583	3.1
26	11	•4.0	2.8	4.4	22	.87	338	.24	183	.00	696	4.8
27	8.9	•15	2.8	4.6	28	.92	176	.13	200	.00	1050	4.1
28	4.8	•10	.98	5.5	144	.69	112	.01	472	.00	496	3.7
29	27	•7.0	2.9	8.4	146	.60	96	.00	756	.00	136	5.1
30	592	•5.0	2.8	35	---	.87	98	.26	128	.00	101	2.3
31	519	---	2.4	372	---	.98	---	.32	---	16	304	---
TOTAL	1365.02	4329.4	120.28	1273.38	4908	760.79	6188.61	422.02	1917.28	266.20	3783.73	1516.8
MEAN	44.0	144	3.88	41.1	169	24.5	206	13.6	63.9	8.59	122	50.6
MAX	592	1670	14	372	1470	110	1800	82	756	117	1050	653
MIN	.23	3.4	.98	.98	14	.60	.40	.00	.00	.00	.24	1.1
AC-FT	2710	8590	239	2530	9740	1510	12280	837	3800	528	7510	3010

CAL YR 1987 TOTAL 13,605.27 MEAN 37.3 MAX 1670 MIN .00 AC-FT 26,990
WTR YR 1988 TOTAL 26,851.51 MEAN 73.4 MAX 1800 MIN .00 AC-FT 53,260
• Estimated

Chinle Creek, which is along the northeast perimeter of the study area, receives water from the N aquifer principally from Laguna Creek. Laguna Creek flows along the north boundary of the study area and flows into the Chinle Creek about 5 miles above the gaging station (fig. 3). The average discharge of low-flow measurements made on Chinle Creek for November through February in the 1989 water year was 1.96 cubic feet per second or about 1,420 acre-feet per year. The average discharge of low-flow measurements for the same months during water years 1977-89 was 4.82 cubic feet per second or about 3,480 acre-feet per year. The mean daily discharges for the 1987 and 1988 water years are shown in table 8. All previous mean daily discharges have been published in Water Resources Data for Arizona (U.S. Geological Survey, 1964-89).

The average discharge of low-flow measurements made on Laguna Creek during November through February since the station was established in 1981 is 3.56 cubic feet per second or about 2,570 acre-feet per year. Only one low-flow measurement was made during the same months in the 1989 water year; the discharge for that measurement was 2.30 cubic feet per second. Continuous streamflow data are not collected at this station.

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