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A General Description of the Hydrogeology, Water Supply Wells, Groundwater Monitoring, and Potential Threats to Groundwater Resources of Chaco Culture National Historical Park, New Mexico

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Technical Report NPS/NRWRD/NRTR-2005/325

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January 2005

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Table of Contents

List of Tables

List of Figures

Appendices

Executive Summary

Chaco Culture National Historical Park lies near the center of the San Juan structural basin. The park is underlain by a series of sedimentary rocks which are mostly fine-grained siltstones and shales. Interbedded layers of sandstone contain groundwater under artesian pressure. Groundwater recharges the sandstone aquifers where they outcrop at the margins of the basin. Water quality deteriorates as groundwater flows toward the center of the basin.

Many shallow wells were constructed in the alluvium along Chaco Wash and its tributaries in the early years of the park in the search for a good supply of potable water. These efforts were only marginally successful because the quality of the alluvial groundwater is poor and the yield from the fine-grained sediments is low. In 1972 the park constructed a deep supply well into the Gallup Sandstone aquifer, which provides abundant water. The Gallup Sandstone is effectively isolated from adjacent aquifers by thick intervals of Mancos Shale.

This report includes recommendations for continued monitoring of alluvial groundwater within the park and monitoring of artesian pressure in the park's water supply well and a shallower monitoring well completed in the Point Lookout Sandstone. Monitoring at the Aggravation Well can be discontinued because it has been shown that the aquifer is hydraulically isolated from the aquifer supplying water for the park.

The water resources of the park are protected from impacts of mining activities in the basin by distance and geologic conditions. Uranium and coal mining areas near Crownpoint and Ambrosia Lake areas are tens of miles south of the park. Mining in these areas occurred in geologic formations that are buried thousands of feet below land surface at the park and are hydrologically isolated from the park by thousands of feet of low-permeability rocks. Coal mining near Farmington and other areas north of the park takes place in geologic formations that are stratigraphically higher than the formations that outcrop at Chaco Canyon. Intervening low-permeability rocks protect the park's water resources from impacts of mining in these younger geologic units. The park should remain vigilant, evaluating each new development proposal to determine whether it poses a threat to park resources.

A General Description of the Hydrogeology, Water Supply Wells, Groundwater Monitoring, and Potential Threats to Groundwater Resources of Chaco Culture National Historical Park

Introduction

The geologic formations of interest with respect to groundwater at Chaco Canyon are the Quaternary alluvium in the valleys and a thick sequence of Cretaceous age sedimentary rocks. The Cretaceous rocks are predominantly siltstones, but include layers of sandstone, coal, shale, and claystone. The sedimentary rocks underlying the park dip toward the north-northeast at a rate of about 100 feet/mile (West, 1957). Where the sandstone layers are continuous over large areas, they form regional aquifers that are often under artesian pressure and may result in flowing artesian water from wells that are completed in the sandstones. Confinement of the aquifers is not absolute and some leakage of groundwater between aquifers occurs. However, the rate of leakage is generally very low except in areas where the rock units making up the confining layers has been fractured (Stone and others, 1983).

The important regional sandstone aquifers underlying Chaco Canyon include the Point Lookout Sandstone, the Gallup Sandstone, the Dakota Sandstone, and the Westwater Canyon Member of the Morrison Formation. Relatively small, lenticular sandstone lenses occur throughout the stratigraphic sequence interbedded within formations that are otherwise primarily shale and siltstone. Where these sandstone lenses occur, they can be an important local source of groundwater to wells that penetrate them. However, these sandstone lenses are not important regional aquifers.

Scott and others (1984) provide a general description of the local geology of Chaco Canyon and the geologic formations underlying the area. A general hydrostratigraphic description of the geologic formations underlying Chaco Canyon is provided in Table 1. A southwest-northeast cross sectional diagram through the San Juan Basin is provided in Figure 1 to show the relationship of geologic formations in the vicinity of Chaco Canyon.

Until 1972, the water supply for the park was obtained from shallow dug wells in the alluvium of Chaco Wash. A deep (3095 feet) artesian well located in the maintenance yard provides the entire water supply for the park. The well is completed in the Gallup Sandstone. In addition to the park's water supply well, artesian pressures are occasionally monitored in the artesian aquifers above (Point Lookout Sandstone) and below (Westwater Canyon Member of the Morrison Formation) the Gallup Sandstone.

Development of natural resources; primarily uranium, coal, oil and gas, coal bed methane, and groundwater have the potential to affect the natural hydrologic regime of the park. Surface coal mining and development of coal bed methane within the surface drainage basins upstream of the park may affect natural streamflow characteristics of ephemeral and intermittent washes in the park.

Hydrogeology

Chaco Culture National Historical Park lies near the center of the San Juan structural basin. The basin contains a thick sequence of sedimentary rocks having a total accumulated thickness of nearly 15,000 feet. These sedimentary rocks dip toward the center of the trough-shaped basin. The basin is asymmetric, having a low angle from the southwest toward the center of the basin and steeper dip from the northeast margin of the basin toward the center. Older rocks outcrop near the margin of the basin and are overlain by progressively younger rocks toward the center of the basin (Kernodle, 1996)

In a simplified, general model of the groundwater flow system in the San Juan basin, groundwater enters the aquifers where the geologic formations outcrop at land surface, primarily at the margins of the basin. Groundwater then flows down the dip of the formations toward the center of the basin (Figure 1). In areas where the aquifer units are overlain by relatively impermeable sediments, artesian conditions develop and wells drilled into an aquifer may flow at land surface. Natural discharge from aquifers occurs as springs, seeps, upward leakage into alluvium underlying stream valleys, and direct discharge to streams. Discharge from an aquifer might also occur as slow leakage across a relatively impermeable confining unit to another aquifer. Artificial discharge occurs as groundwater pumping from aquifers. In the past, large volumes of groundwater were pumped from aquifers in the south-central part of the basin to facilitate underground mining of uranium. The mines have all closed and the groundwater levels are recovering (Kernodle, 1996).

Kernodle (1996) presents succinct summaries of the hydrostratigraphic units in the San Juan basin. The sedimentary sequence represents a long period of transgressive and regressive seas, with the shoreline generally being aligned in a northwest-southeast orientation and the shoreline continually shifting from the southwestern to the northeastern part of the basin. The sandstone formations were deposited in near-shore environments and the silt and shale formations were deposited in offshore, deepwater environments.

At Chaco Canyon, the geologic formations exposed at land surface are (from northeast to southwest and in descending order) the Lewis Shale, Cliff House Sandstone, and Menefee Formation. Other geologic formations underlying Chaco Canyon and their hydrogeologic function are summarized in the hydrostratigraphic column shown on Table 1. A more detailed description of the rocks in the San Juan Basin and at Chaco Canyon is provided by Craigg (2001) and Scott and others (1984).

In some cases, geologic units that are considered confining units on a regional scale will yield small quantities of water to wells from local sand lenses within the confining units. These wells are an important source of water for stock and domestic use. For example, the Menefee Formation is considered an aquifer on a local scale because it provides a source of groundwater for many shallow stock wells, however, regionally it acts as a confining unit above the Point Lookout Sandstone (Levings and others, 1996).

The Gallup Sandstone and Westwater Canyon Member of the Morrison Formation are classic examples of artesian aquifers. The aquifers are recharged by infiltration of precipitation in outcrop areas in the Zuni and Defiance Uplifts along the south and west margins of the basin. Groundwater flow is downdip in a northeasterly direction, toward the center of the basin where the aquifer becomes artesian. Wells completed in these aquifers in northern McKinley County and most of San Juan County flow at land surface.

Water Wells at Chaco Culture NHP

Alluvial Wells

There have been many shallow test holes and wells constructed at various places along Chaco Wash in the park. A summary of existing wells, prepared by the park superintendent in 1955, identifies 5 shallow dug wells. Four of the wells were in the immediate vicinity of Pueblo Bonito. The fifth well, called the Old CCC Well, was located on the west side of Chaco Wash a short distance downstream from the confluence of Fajada and Chaco Washes. This is probably the structure that is now called the Historic Masonry Well by park staff. The Old CCC Well supplied water for the then new headquarters area. This well is shown on the 1966 Pueblo Bonito topographic map in the NW¼ of the NE¼ of Section 29.

An anonymous, hand-written manuscript was found in the WRD files during this investigation. It describes the well construction and water supplies of Chaco Canyon going back to the first scientific expeditions by the National Geographic Society to the area in the 1890s. A typed copy of that manuscript is included in the appendices of this report.

Reports prepared by the regional geologist (Ross Maxwell) and the assistant chief of the Naturalist Division (H.E. Rothrock) in 1940 and 1942 identified the alluvium in the washes as the most likely source for development of a groundwater supply for the park. These gentlemen were aware of the potential for encountering artesian aquifers by drilling deep (more than 1000 feet) wells, but also were aware that the deep artesian aquifers would likely yield poor quality water.

In 1956, Sam West, with the USGS, evaluated the possibility of developing a groundwater supply at Chaco Canyon and recommended a test drilling program to locate and develop groundwater in the alluvium. Somewhere around 15-20 test holes were drilled in early 1957 to about 50 feet deep in the alluvium at locations suggested by Mr. West, but only damp sand was encountered.

In the winter of 1958-59, a new large diameter dug well and storage tank were constructed at the Pueblo Bonito area to provide a more sanitary water supply. This well had a 15-foot diameter steel casing installed to a depth of 33 feet. The well replaced several hand-dug wells in the area.

In early 1968 six more test wells were drilled into the alluvium in Gallo, Chaco, and Fajada Washes. These wells were constructed to depths of 100-200 feet. Although several of the wells encountered good amounts of water, the quality was very poor (high sulfate concentration and total dissolved solids of 4000 to 11,000 ppm). Most of the test holes were plugged and abandoned.

Kirk Vincent, with the USGS in Boulder, is conducting a research project which investigates the history of alluvial groundwater levels in Chaco Wash. A report is expected in 2005.

Menefee Well

In the summer of 1968, a deep well was constructed into the Menefee Formation. This well was drilled to a depth of 800 feet and produced a small quantity (less than 10 gpm) of poor quality water. It was decided to develop the well as a water supply for the park because it was from a deep aquifer that would be less vulnerable to surface contamination than the shallow dug wells in the alluvium. Initially it was thought that this well could provide an adequate supply for the park for the immediate future. However, shortly after the well was placed into service, it was announced that a research center would be constructed at the park. Due to the projected water needs of the research center coupled with an unexpected increase in park visitation, the search for additional water supplies continued.

This well was located in the back part of the maintenance yard, near the base of the cliff. The well was capped after the Gallup Sandstone well was completed in 1972. It could not be located and its fate is unknown.

NPS Water Supply Well – Gallup Sandstone

The deep, artesian, water supply well at Chaco Canyon was constructed in July-September, 1972. It is sometimes referred to as the "Fields" Well, after William Fields an NPS engineer from the Santa Fe regional office who was a proponent of constructing a deep well at Chaco for many years.

The well is 3095 feet deep and was cased and cement grouted for the entire depth of the well. The casing and grout were subsequently perforated by "shooting" the intervals from 3000-3020 and 3050-3090 feet below ground surface. The well originally had an artesian pressure of 175 psi and produced a sustained yield of about 110 gpm during a 24-hour test.

The static pressure in the well is shown on Figure 2. The pressure gradually declined from 175 to 120 psi during the first 15 years the well was used. It appears the pressure had then reached a new equilibrium corresponding to pumping water from the well for use at the park. Since 1987, the static pressure has remained near 120 psi. The well is equipped with a chart recorder to monitor the artesian pressure of the well. The chart is changed daily.

During a period of intensive monitoring from February 1988 to March 1989 the artesian pressure fluctuated between about 90-120 psi, depending on whether the well was flowing or shut in (Figure 3). During this same time, the artesian pressure in the point Lookout Sandstone well was nearly constant at 42-46 psi. These data show that there is not a good hydrologic connection between the two aquifers. The thick sequence of shale bedrock between the aquifers is a very effective confining unit, making it unlikely that pumping from one of the aquifers would affect artesian pressure in the other aquifer.

The geologic log for the water supply well at Chaco shows the following geologic formations were encountered;

Depth, ft	Formation	Lithology
0-20	Overburden	Sand
20-1763	Menefee Formation	Interbedded sandstone and claystone
1763-1948	Point Lookout Sandstone	Medium to fine-grained sandstone
1948-2905	Mancos Shale	Mudstone and Claystone
2905-3095	Gallup Sandstone	Sandstone

USGS Monitoring Well – Point Lookout Sandstone

The USGS constructed a monitoring well into the Point Lookout Sandstone in September 1987. The well has casing cemented in place to 1767 feet below ground surface to seal off any groundwater from shallower geologic units. The well was completed as an open borehole in the Point Lookout Sandstone from 1767-1872 feet.

Artesian pressure in the aquifer was monitored at 15 minute intervals from February 1988 to March 1989. Artesian pressures in the aquifer during that period were very stable at around 42-46 psi. There was a slight increasing trend in the artesian pressure, but because the period of intensive monitoring lasted only one year, it is impossible to make any general statements regarding the long-term trend of artesian pressure in the Point Lookout Sandstone in the vicinity of Chaco Canyon. The artesian pressure in this well has not been monitored since 1989. Park staff should install a pressure gauge and monitor the pressure in this well monthly for a year, and then analyze the data to determine whether the monitoring frequency should be changed.

Comparison of the artesian pressure in the Point Lookout Sandstone with the artesian pressure in the underlying Gallup Sandstone (Figure 3) shows that there was no change in the artesian pressure in the Point Lookout Sandstone due to pumping of water from the park's water supply well completed in the underlying Gallup Sandstone. These data show that the confining units in the Mancos Shale between the two aquifers act as a barrier to groundwater flow between the aquifers.

Aggravation Well – Westwater Canyon Member of Morrison Formation

The Aggravation Well was drilled as a uranium exploration well in 1978. The well did not encounter uranium ore and was subsequently converted to a monitoring well in a cooperative project by NPS and the Department of Energy. The purpose of the monitoring well was to monitor changes in the artesian pressure in the Morrison Formation related to groundwater pumping associated with uranium mining in the Grants and Crownpoint areas. NPS paid $50,000 and the Department of Energy paid the remainder of the cost for casing, cementing, perforating the well, and equipping the wellhead to withstand the maximum anticipated artesian pressure of the well; approximately 85 psi.

The test well was drilled to 4436 feet below ground surface. The well was cased over the entire depth with 5½" casing which was cemented in place to seal off the annular space outside the casing and prevent any flow of water between aquifers. The casing and cement grout were subsequently shot-perforated from 3957-3987 feet below ground surface with 60 holes to allow communication with the Westwater Canyon Member of the Morrison Formation.

Artesian pressure in this well declined in the early 1980s in response to pumping of large quantities of water from the Morrison Formation for uranium mining in the Grants and Crownpoint areas. Artesian pressure showed some recovery following the cessation of uranium mining operations in the late 1980s, but the artesian pressures have not fully recovered to the original pressure observed when the well was first constructed (Figure 4). Artesian pressure at the well has been measured only three times since 1991 with the pressure remaining nearly constant at 57-58 psi.

Summary of Water Well Construction at Chaco Canyon

At least 15 wells have been constructed at Chaco Canyon; twelve in the alluvium, one in the Menefee Formation (800 feet), one in the Gallup Sandstone (3100 feet), and one in the Point Lookout Sandstone (1870 feet). Additional exploratory drilling, such as the 1957 drilling is not included in this summary because there is no clear record of the test hole locations and all of the test holes were immediately backfilled and abandoned. Table 2 summarizes the data available for the water wells and test holes that have been constructed at Chaco Canyon. Well locations are shown on Figure 5.

Water Use

The entire water supply for NPS facilities at Chaco Canyon is obtained from an artesian well located in the maintenance yard. The well is completed in the Gallup Sandstone and has been the sole source of water for the park since its construction in 1972. The well provides water for two separate water systems at the park. Potable water is sent through a reverse osmosis unit, chlorinated, and then pumped to a storage tank on the mesa. The treated water flows by gravity from the storage tank through the distribution system in the housing area and to the visitor center and park offices. A separate raw water tank is also on the mesa. Raw water is distributed by a separate system to provide water for the campground, toilet flushing and outside watering.

Raw water usage is generally less than 5000 gallons per day (Figure 6), except for occasional periods of higher use. Treated water usage is generally averages 4000 to 8000 gallons per day (Figure 7). Water usage for both the treated and raw water systems is highest in summer and lowest in winter.

The park has a water right for municipal use of 100 acre-feet per year (32 million gallons). Average water use in recent years has been 2½-3 million gallons.

Groundwater Monitoring Plan

Alluvium

There are three transects of monitor wells perpendicular to Chaco Wash with three shallow wells in each transect. The transects are located (from upstream to downstream) near the eastern boundary of the park at Shabikaschee, about 300 meters downstream from the bridge near the visitor center, and near Casa Chiquita. Water levels in the wells at Shabikashchee and Casa Chiquita are measured quarterly. One of the wells at the middle transect (the historic masonry well) is equipped with a datalogger that records water levels every 15 minutes. The other two wells in that transect are measured bimonthly. Additionally, there is a datalogger at one of the exploratory water wells that was constructed in 1967. This well is called the Fajada View Well South by park staff and is located on the valley floor north of Chaco Wash, south of the paved road, and about midway between the maintenance area and the visitor center.

Deep Artesian Aquifers

The water supply well for the park, completed in the Gallup Sandstone, is equipped with a chart recorder that continuously monitors the artesian pressure in the well. The chart paper is circular, completing one rotation each day. On days when the chart is not changed, the pen traces overlap, making it impossible to determine which part of the line corresponds to each day. It might be advisable to replace the 24-hour clock mechanism with a 7-day clock so the chart only needs to be changed once a week.

Monthly measurements of the artesian pressure should be made at the "USGS monitoring well" that is completed in the Point Lookout Sandstone aquifer. This monitoring can be accomplished by attaching a regular pressure gauge to the well head and opening the valve to the well. After taking the reading, the valve should be closed and the water should be drained to prevent freezing. The artesian pressure probably will remain in the 40-50 psi range.

The Aggravation Well, located 4 miles south of Fajada Butte, is completed in the Westwater Canyon Member of the Morrison Formation. The Westwater Canyon Member aquifer is separated from the Gallup Sandstone by a thick sequence of Mancos Shale. Previous monitoring has shown that the Mancos Shale is an effective confining unit and severely restricts movement of groundwater between the aquifers. Park staff have not monitored the artesian pressure for many years, but the park continues to pay an annual "lease" fee to the New Mexico State Land Office. The only recent data that could be found for the artesian pressure at this well are from the measurements made by the USGS, once every five years, as part of a cooperative monitoring program with the Office of the State Engineer. Since the Morrison Formation is not hydrologically connected with the park's source of water, the Gallup Sandstone, it isn't necessary to continue monitoring this well. The lease can be terminated. Perhaps the New Mexico Office of the State Engineer will continue to include this well in their monitoring network.

Potential Impacts from Surface Coal Mining

In the late 1970s and early 1980s, the USGS established a network of 50 groundwater monitoring wells to assess the geohydrology of aquifers that might be affected by surface mining of coal in the Fruitland Formation in the San Juan Basin (Myers and Villanueva, 1986). The area where coal deposits are close enough to the surface to allow surface mining extends from Farmington south through Burnham, then southeasterly through Bisti, Kimbeto, and Star Lake, and then east-northeasterly toward the Jemez Mountains as shown on Figure 8. In the vicinity of Chaco Canyon, the strippable coal deposits occur along a northwest-southeast band approximately 10 miles wide beginning about 10 miles northeast of the park.

Stratigraphically, the strippable coal deposits are separated from the Gallup Sandstone, the source of the park's water supply, by about 3000 feet of sedimentary rocks which include the confining units in the Lewis Shale, Menefee Formation, and the upper part fo the Mancos Shale. Furthermore, the area of the strippable coal deposits roughly coincides with the northeastern extent of the Gallup Sandstone, i.e., the Gallup Sandstone pinches out a short distance northeast of the park so that there is no Gallup Sandstone in the area underlying the potential coal mining area (Figure 9).

Myers and Villanueva (1986) did not consider potential impacts to aquifers below the Pictured Cliff Sandstone because the low-permeability sediments in the underlying Lewis Shale Formation provide an effective barrier to groundwater communication between deeper aquifers and the shallow formations that would be affected by surface coal mining.

Surface coal mining in this area would not affect the park's water supply. However, if a deep artesian well was constructed into the Gallup Sandstone to provide water for mine facilities, it might have the potential to affect the artesian pressure at the park's water supply well. There is a possibility that surface coal mining could affect the natural runoff patterns of surface water through the park if the strip mining included areas within drainage basins that flow into the park.

The most probable impacts to park resources from surface coal mining would be to air quality, noise, and night sky. Groundwater resources will only be affected if deep artesian wells are constructed into aquifers that underlie the park.

Production of coal-bed methane from coal beds in the Fruitland Formation could locally result in production of significant quantities of water. If this produced water is released into surface drainages that are tributary to Chaco Wash upstream of the park, the surface flow characteristics in the park may be affected.

The Lee Ranch Coal Mine is about 35 miles south of Chaco Canyon. It is a surface coal mine which mines coal from several seams near the base of the Mesaverde Group. Potential impacts to the park's water supply from coal mining in this area are extremely unlikely because of the distance from the mine to the park and the vertical separation of the geologic formation containing the coal and the Gallup Sandstone (Figure 9). There is a thick sequence of low permeability Mancos Shale separating the coal seams and the Gallup Sandstone.

Existing and known planned coal mining operations in the San Juan Basin are unlikely to affect water resources at the park. However, future development may pose a greater threat. Each proposal will need to be evaluated to ass the potential to affect park resources.

Potential Impacts from Uranium Mining

Uranium mining in the San Juan Basin occurred primarily south of the park in the Crownpoint and Ambrosia Lake areas. Currently there are no active mining operations. It is possible that mining operations could resume in the future, depending on the demand and market price for uranium ore. Uranium ore is found in the Morrison Formation, primarily in the Westwater Canyon Member, along the south and southwest margins of the basin. Mining operations require pumping large volumes of groundwater to dewater the underground workings.

USGS (Hejl, 1978) evaluated the potential for mine dewatering to affect the availability of water at the park's water supply well in Chaco Canyon. At that time (1978) projected uranium mining in the area was expected to increase to 33-100 mines by the year 2000, pumping an aggregate of 7000 gpm to dewater the mines. Hejl (1978) concluded that pumping from the Morrison Formation would have almost no effect on water levels in the Gallup Sandstone. The low permeability sediments in the Mancos Shale between the two aquifers form an effective barrier to groundwater flow between the aquifers in the vicinity of Chaco Canyon. Hejl (1978) concluded that the most significant effects on artesian pressure in the Gallup Sandstone would be from pumping of the park's water supply well.

The "Aggravation Well", located about 5 miles south of park headquarters, was completed by NPS as a monitoring well to monitor changes in artesian pressure in the Morrison Formation due to groundwater pumping at the uranium mines further to the south. Artesian pressure in the Aggravation Well decreased in the early 1980s, probably due to groundwater pumping at the uranium mines. Pressures began to recover in the mid 1980s as uranium mining, and groundwater pumping, declined (Dam and others, 1990) (Figure 4).

One of the primary uses of groundwater in the Morrison Formation was dewatering to facilitate uranium mining in the Crownpoint and Ambrosia Lake areas about 35 miles south of Chaco Canyon. The primary uranium ore body is found in the Westwater Canyon Member of the Morrison Formation. Uranium mining in the area became well established in the 1950s, peaking in the late 1970s and essentially finished by the mid-1980s. Water levels in wells completed in the Westwater Canyon Member show the drawdown and recovery associated with pumping of groundwater to dewater mines (Dam and others, 1990). The drawdown of the potentiometric surface in the Westwater Canyon Member may extend to the area underlying Chaco Canyon as evidenced by the drawdown and recovery of the artesian pressure in the "Aggravation Well" located 5 miles south of park headquarters. The top of the Westwater Canyon Member is about 4200 feet below ground surface at park headquarters, more than 1000 feet below the bottom of the park's water supply well. The location of potential uranium mining areas relative to the park's water supply well is shown in Figure 9.

Summary

The main water-bearing formations at Chaco Canyon are the alluvium covering the floor of the canyon and several deep artesian aquifers. The alluvium yields only small amounts of poor-quality water to shallow wells. The major artesian aquifers are the Point Lookout Sandstone, Gallup Sandstone, and the Westwater Canyon Member of the Morrison Formation. They are effectively isolated from one another by thick intervals of low permeability rock. Artesian aquifers under the park generally have poor water quality due to poor circulation and long residence time.

Water for park facilities is obtained from an artesian well completed in the Gallup Sandstone at a depth of 3100 feet below ground surface. The Gallup Sandstone is protected from most external impacts by virtue of being sandwiched between thick intervals of Mancos Shale.

There is no need to continue leasing the Aggravation Well (W-580) from the New Mexico State Land Office. Data from past monitoring has shown that the Morrison Formation aquifers and the Gallup Sandstone do not have a significant hydrologic interconnection. There is no threat to park resources from distant groundwater pumping from the Morrison Formation. The New Mexico Office of the State Engineer might continue to include the Aggravation Well in their monitoring network.

Park staff should continue monitoring groundwater levels in alluvial wells throughout the park, at least until there are enough data to conduct an analysis of trends. Artesian pressure in the park's water supply well should continue to be monitored. A pressure gauge should be installed on the USGS Point Lookout Sandstone well to facilitate monthly monitoring of artesian pressure in the well.

Chaco Culture National Historical Park is extremely fortunate that hydrogeologic conditions, including the geologic structure of the basin, provide protection to park resources from external activities. The primary hydrologic concerns should be with respect to activities within the surface watershed of the park that might cause changes to streamflow availability or runoff patterns.

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Formation Name		Hydrologic Function	Occurrence at Chaco	Description
Lewis Shale		Confining Unit	Present at the surface in some areas of the north and northeast part of the park	Marine shale contains several bentonite layers
Mesaverde Group	Cliff House Sandstone	Not an aquifer in the park because it isn't saturated	Outcrops at land surface in much of the park. Forms erosion resistant cliffs	Very fine to fine-grained sandstone
	Menefee Formation	Confining Unit	Outcrops in the southern part of the park and at land surface for about 20 miles south of the park	Alternating layers of various thickness; sandstone, siltstone, shale, claystone, and shale
	Point Lookout Sandstone	Aquifer	Occurs at about 1750-1950 feet below ground surface in the park. Poor quality water in the area underlying the park	Fine to medium-grained sandstone
Upper part of Mancos Shale		Confining Unit	Nearly 1000 feet thick in the area underlying the park	Mudstone and claystone
*Gallup Sandstone		Aquifer	Occurs at 2905-3195 feet below ground surface at the park	Fine to medium-grained sandstone
Lower part of Mancos Shale		Confining Unit	Estimated thickness 800 feet	Mudstone and claystone
Dakota Sandstone and Westwater Canyon Member Morrison Fm.		Aquifer	Estimated depth to top is 4000 feet (Stone and others, 1983)	Fine to coarse-grained sandstone

* Source of park's water supply

Table 1. General hydrostratigraphic description of geologic formations underlying Chaco Culture National Historical Park.

Well Name	Location	Year Constructed	Depth Feet	Diameter Inches	Water Level Feet bgs	Water Level Date	Yield Rate, gpm	Yield Date
Old CCC Well	21:10:29:211	1940	16	144	11.96	9/14/56	6	6/56
Chaco Well No. 1	21:11:12:333	1937	15	180	18.94	9/14/56	--	----
University Well No. 1	21:11:13:121a	1940	20	180	---	---	--	----
New Concrete Pipe Well	21:11:13:121b	1952	16	48	16.76	9/14/56	2-3	6/27/56
Fajada View Test Well	21:10:28:123a	1967	56	4	---	8/4/72	---	---
Fajada View Test Well	21:10:28:123b	1967	58	4	42	8/4/72	---	---
Gallo Wash Test Well	21:10:28:111	1968	96	24	55	1968	---	---
Gallo Wash Test Well	21:10:29:222	1968	92	24	45	1968	50	1968
Fajada Wash Test Well	21:10:29:344	1968	100	10	---	1968	---	1968
Fajada Wash Test Well	21:10:29:433	1968	200	10	---	1968	---	---
Chaco Wash Test Well	21:10:27:114	1968	100	10	---	1968	---	1968
Chaco Wash Test Well	21:10:27:214	1968	100	10	---	1968	---	1968
Menefee Well	21:10:21:344a	1968	800	10	69	1968	9	1968
NPS Supply Well	21:10:21:344b	1972	3100	6	+400	1972	170	1972
USGS Monitor Well	21:10:21:344c	1987	1870	6	+92	1987	---	---

Location numbers are derived from the Township:Range:Section:Qtr:Qtr:Qtr
Where the Qtr numbers are listed from largest to smallest: 1=NW, 2=NE, 3=SW, 4=SE

Table 2. Records for Water Wells at Chaco Culture National Historical Park. Well locations are shown on Figure 5.

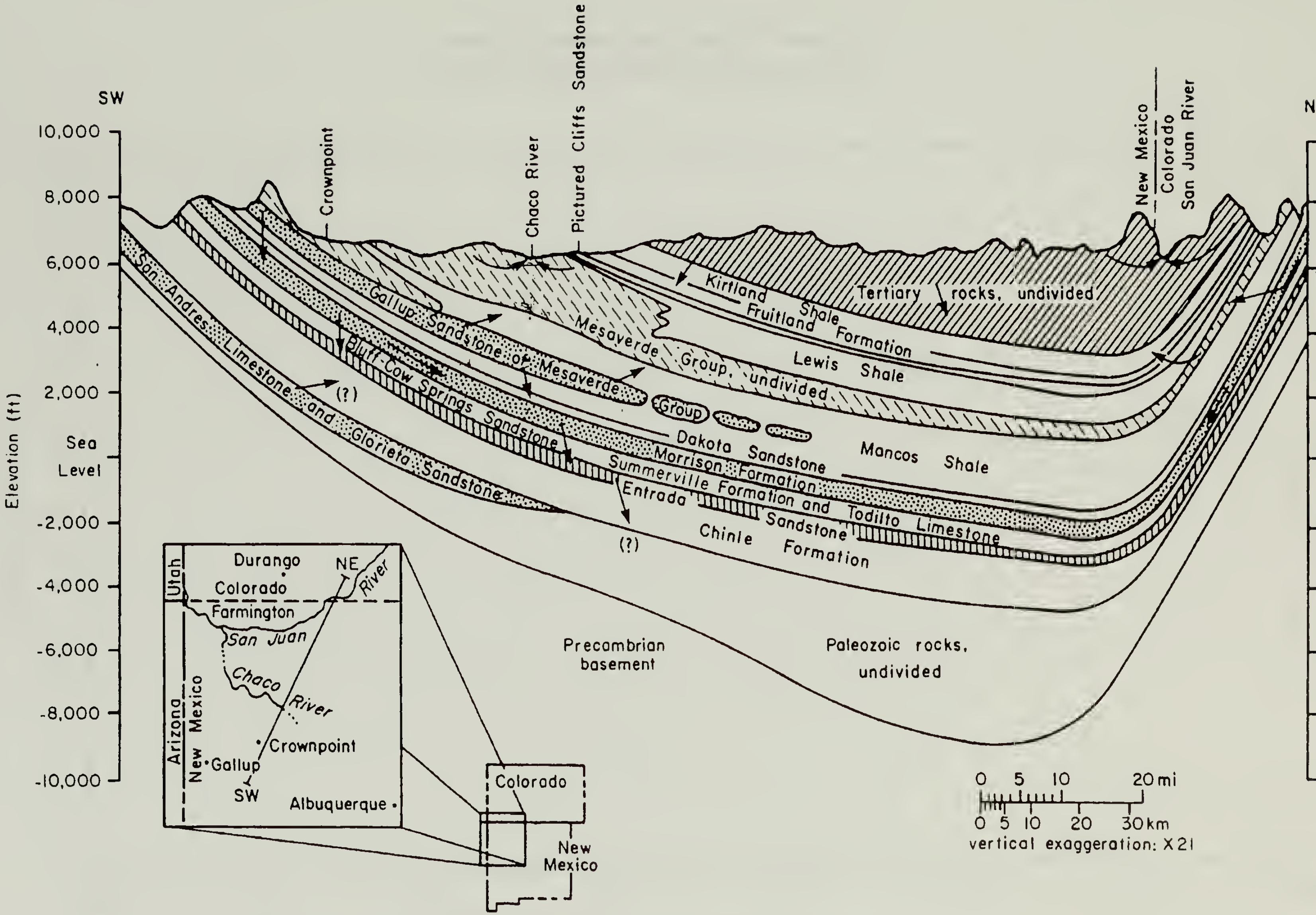


Figure 1. Generalized hydrogeologic cross section of the San Juan Basin showing aquifers (patterns) and confining units (blank). Arrows show general direction of groundwater flow. (Stone and others, 1983)

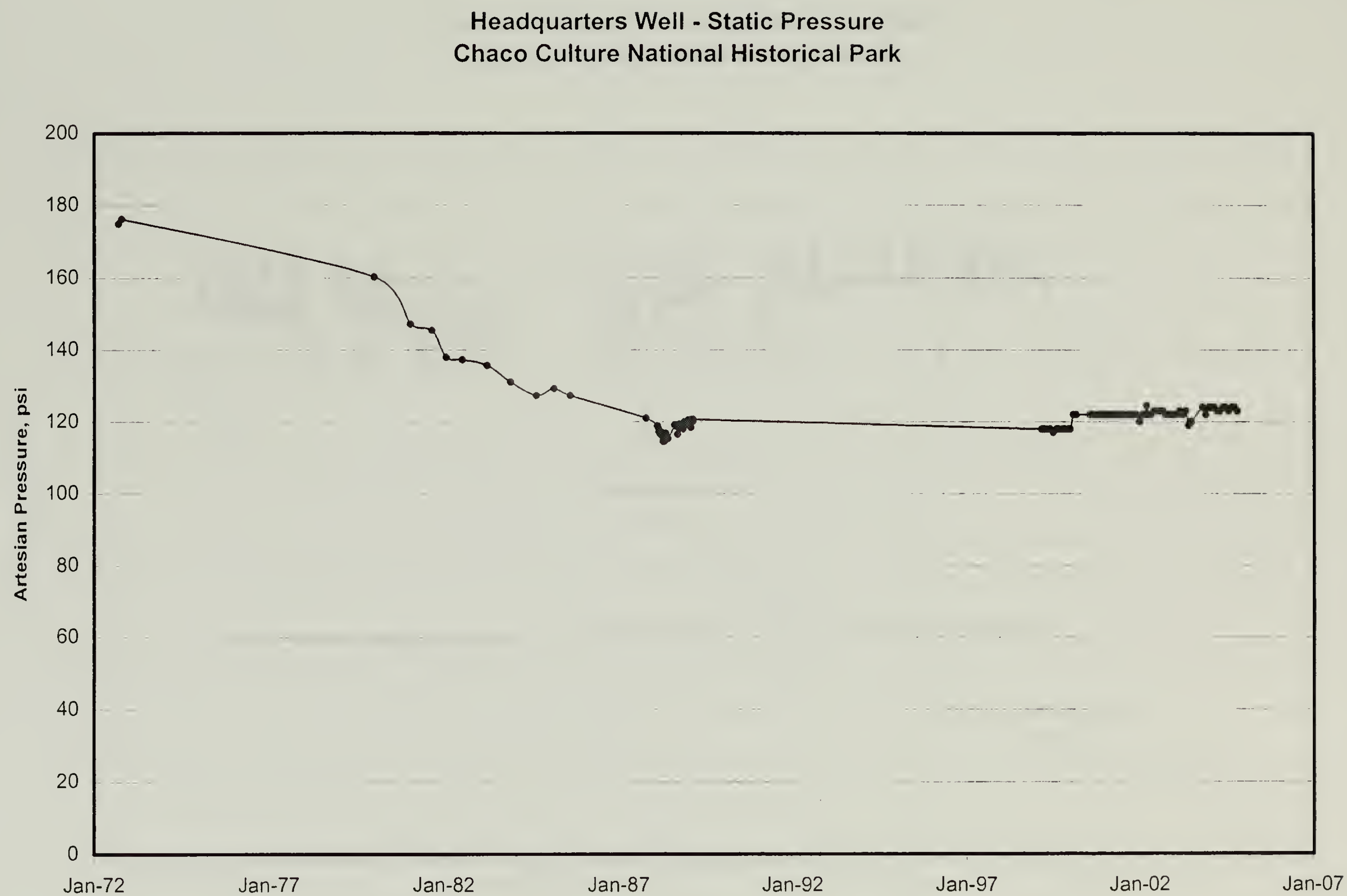


Figure 2. Static pressure in the water supply well completed in the Gallup Sandstone.

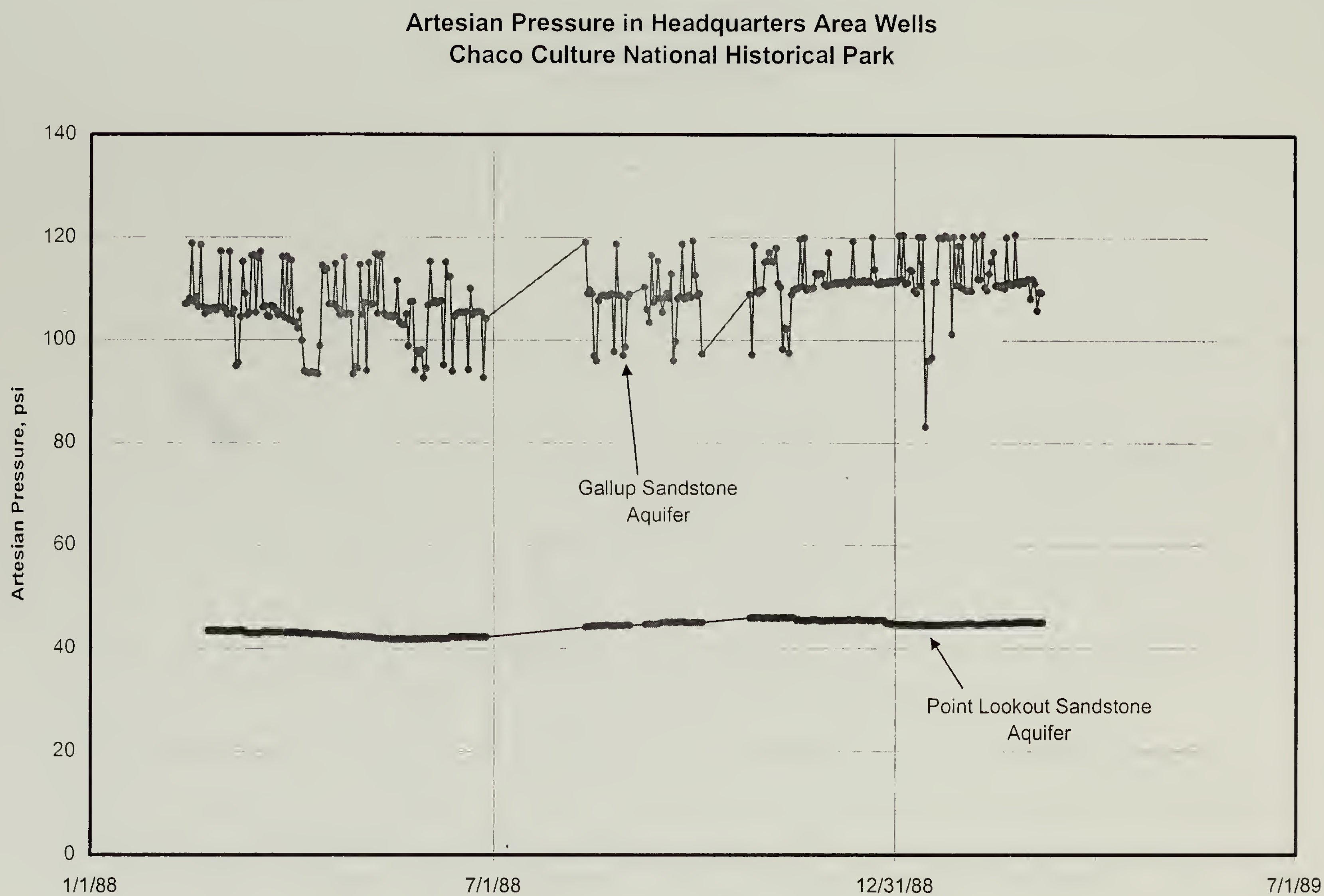


Figure 3. Artesian pressure in the water supply well and a monitoring well in the Headquarters area.

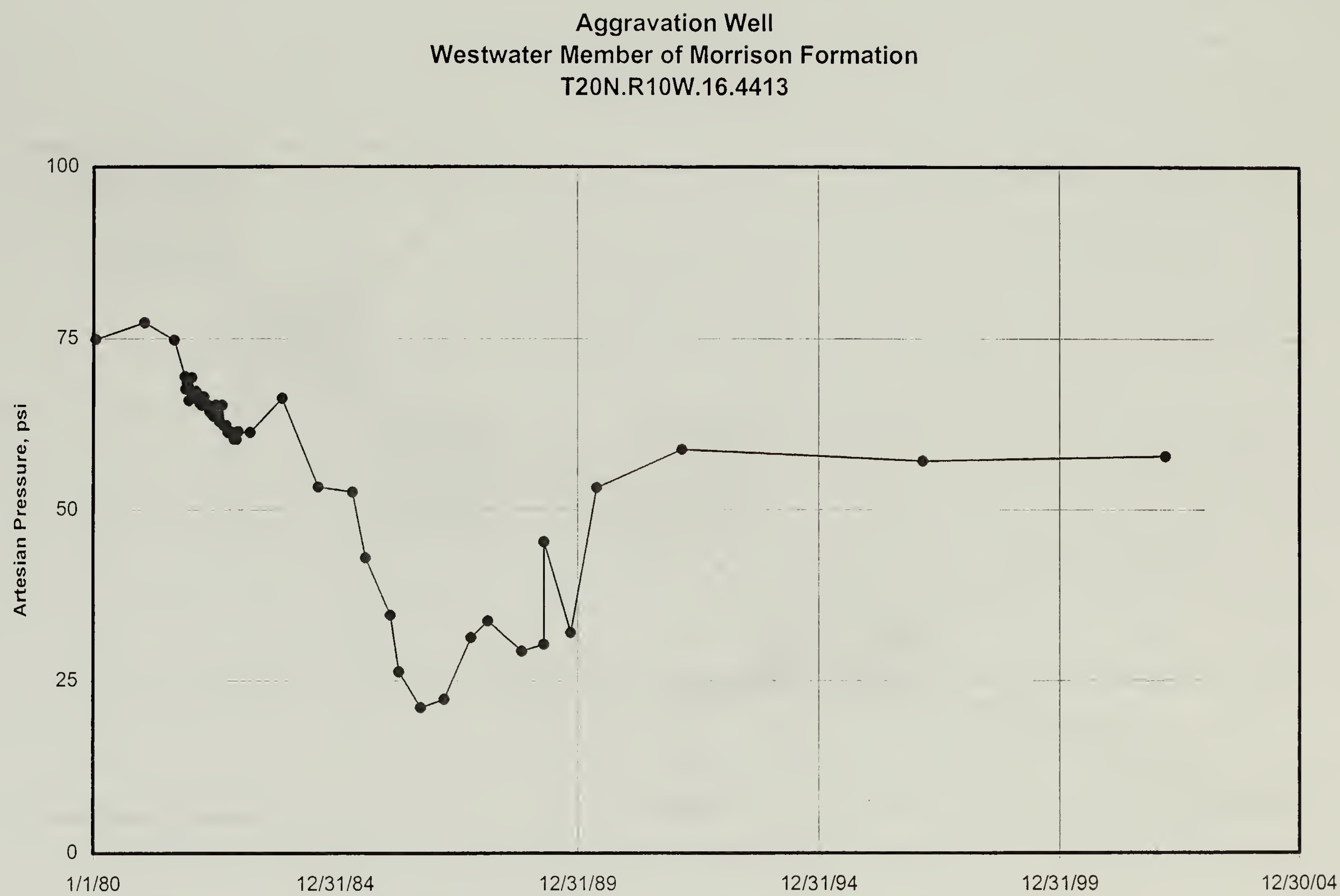


Figure 4. Artesian pressure in the Aggravation Well south of Chaco Culture National Historical Park.

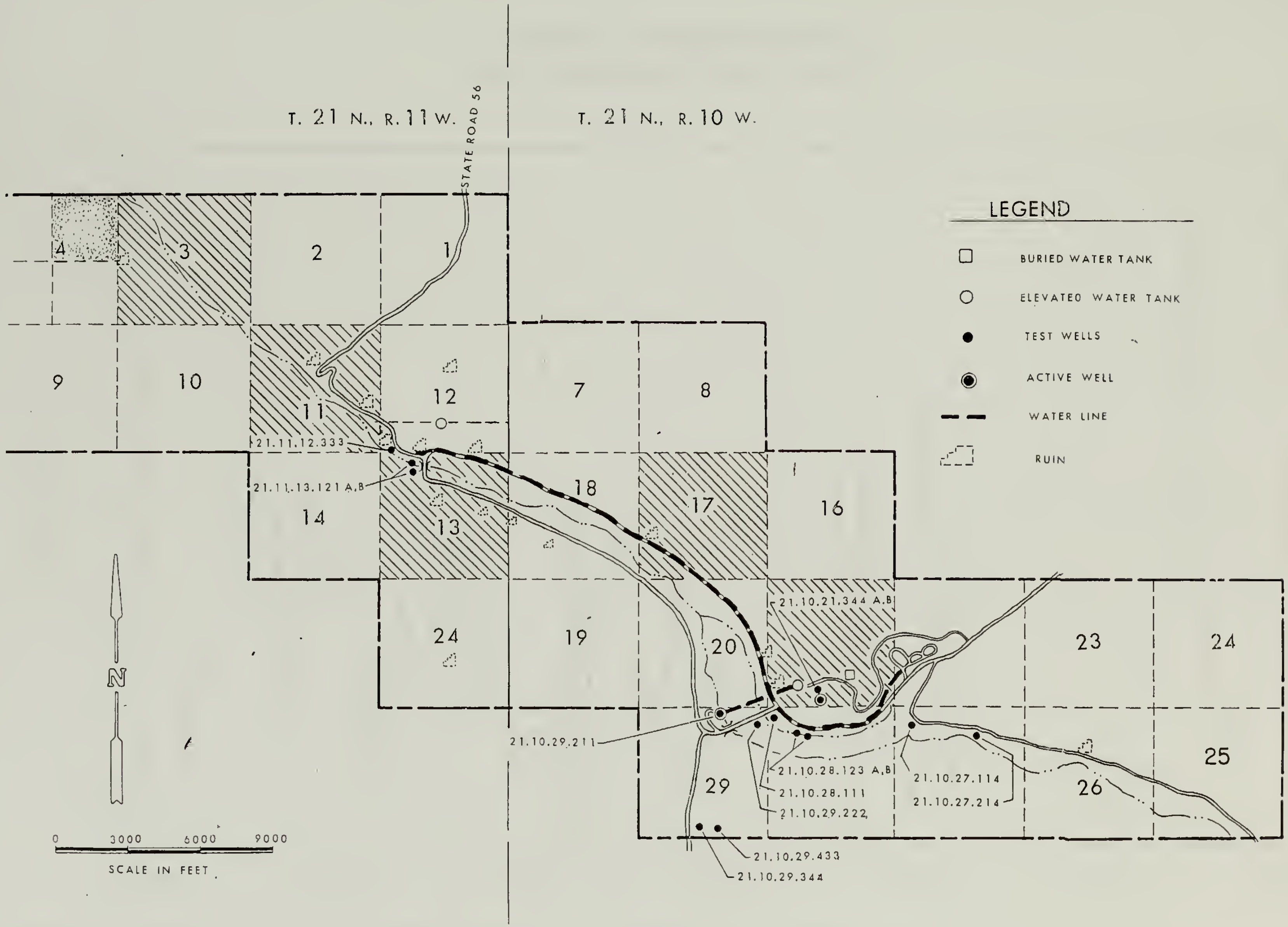


Figure 5. Location of wells at Chaco Culture National Historical Park (boundary has changed since this map was prepared in 1978).

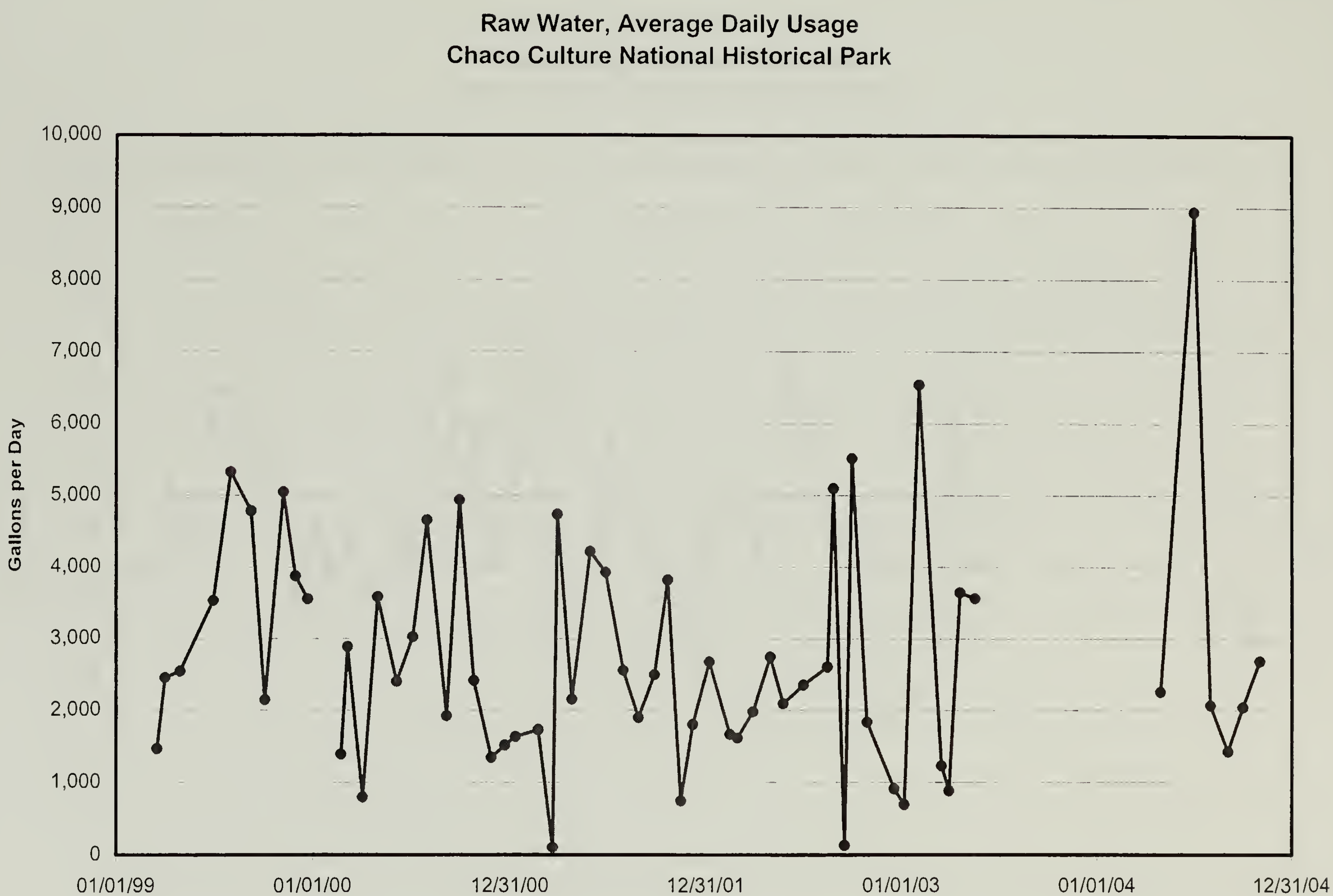


Figure 6. Average daily use of raw water at Chaco Culture National Historical Park.

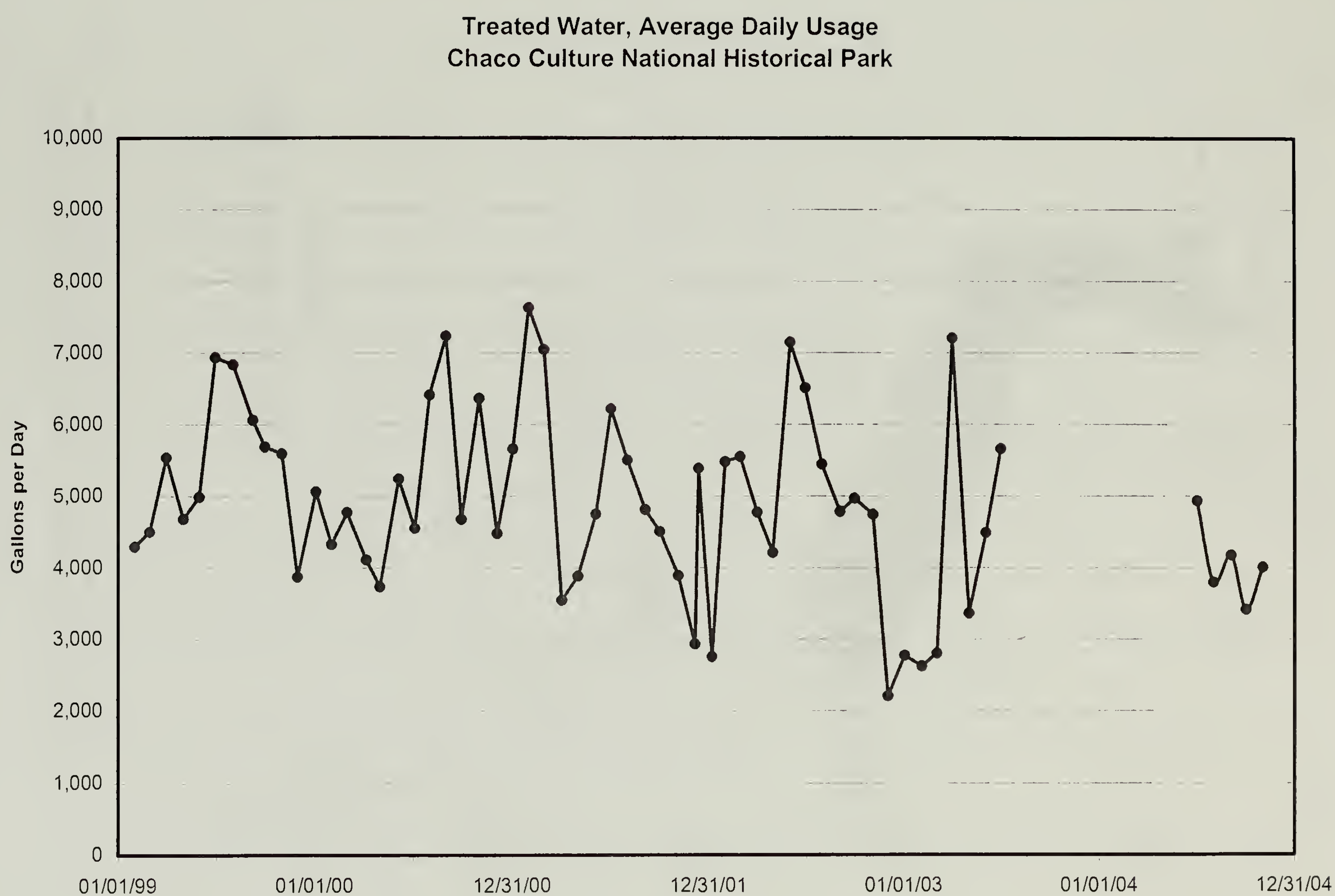


Figure 7. Average daily use of treated water at Chaco Culture National Historical Park.

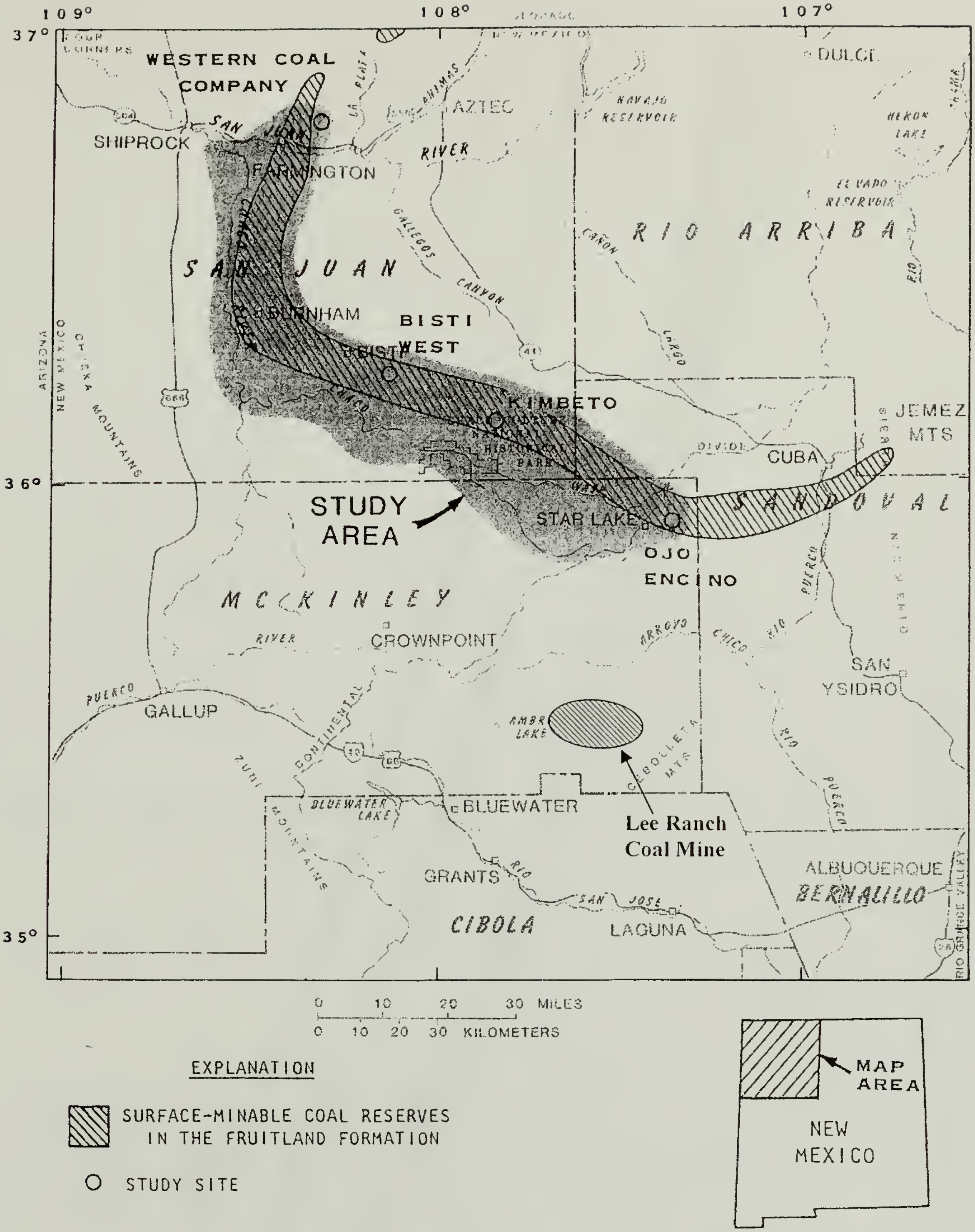


Figure 8. Location of existing and potential coal mines near Chaco Culture National Historical Park (modified from Myers and Villanueva, 1986).

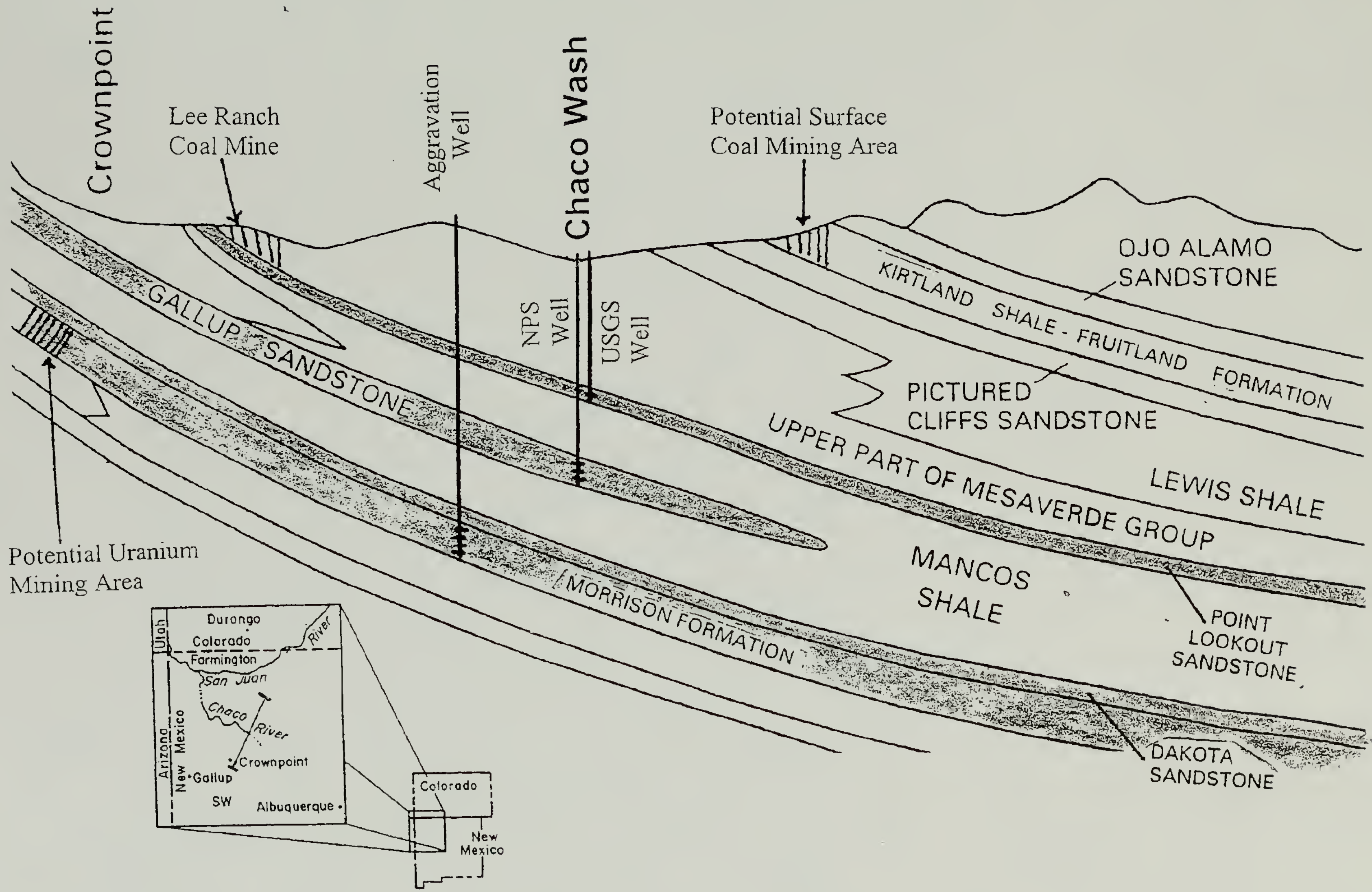
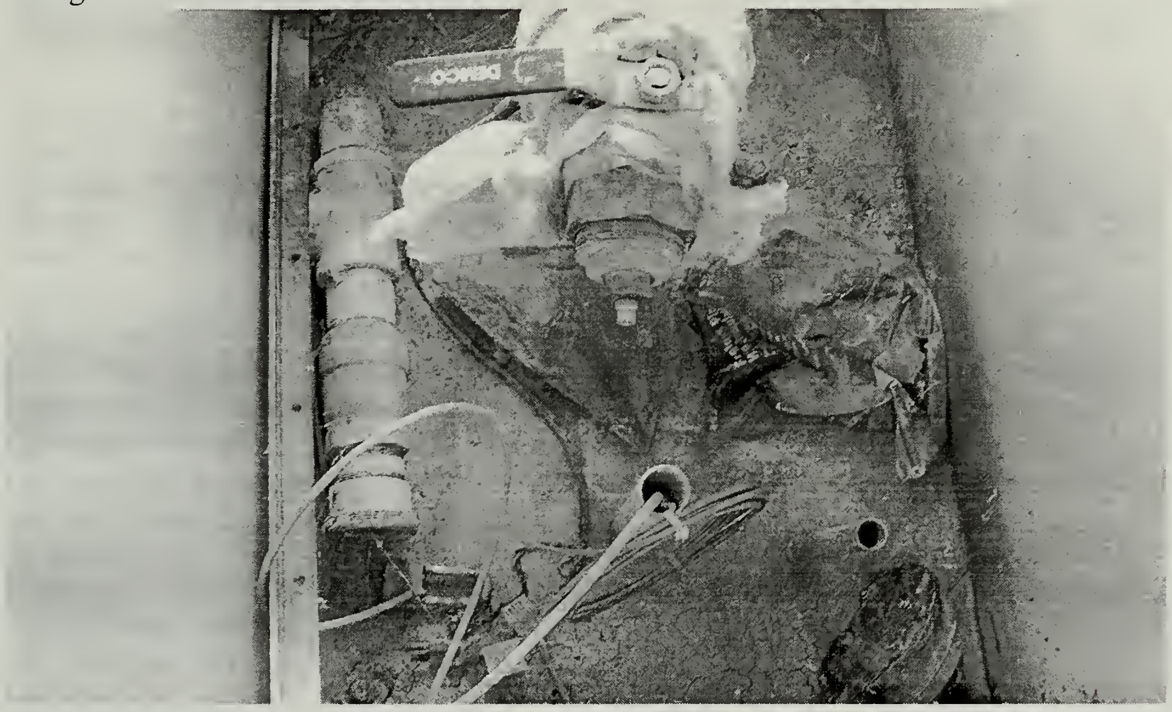


Figure 9. Schematic hydrogeologic cross section showing relative locations of major aquifers, wells, and potential mine areas. Major aquifers are shown with a stippled pattern.

APPENDICES

Monitoring Protocol for Point Lookout Sandstone Well at Chaco Culuture NHP (former USGS monitoring well)

The wellhead of the Point Lookout Sandstone Well is located inside a steel box on the terrace about 50 feet east of the maintenance offices. The well has a valve and a number of pipe fittings and reducers at the wellhead.



The artesian pressure in the well can easily be monitored by installing a pressure gage at the wellhead. This will require a little basic plumbing. Acquire a pressure gage with a range of 0-60 psi. Pressure gages are available that will read directly in feet; in that case get a gage that has a range up to 120 feet. A digital gage will be easier to read and more accurate. A variety of pressure gauges can be found and compared at www.coleparmer.com. Attach the pressure gage to a tee fitting. Remove the existing plug and screw one end of the tee to the wellhead. Start a plug into the open end of the tee, then open the valve a little bit, allow the water from the well to force the air from the new fittings. Tighten the plug and open the valve part way. The reading should stabilize almost instantly and remain constant regardless of whether the valve is open partially or completely. The well can be left with the valve partially open, so that the pressure reading can be accomplished in a few seconds. In very cold weather it might be prudent to close the valve and drain the tee fitting to reduce the chance of damage from freezing.

The pressure should be monitored monthly for at least a year. Then analyze the data to see how much (if any) variation there is and determine whether the frequency should be increased, decreased, or remain the same.

Larry Martin
NPS Water Resources Division
January 2005

This document is a typed version of a handwritten document found in NPS Water Resources Division files in Ft. Collins. The date and author are not identified.

Pueblo Bonito

Several wells have been drilled or dug in the Pueblo Bonito area. Since this is the major ruin in Chaco Canyon, it has been a focus of study for exploring expeditions, university research groups, etc. In addition it served as a trading post and park headquarters was located there for several years.

The earliest well reported was drilled by the Hyde Exploring Expedition which worked here from 1896 to 1899. The hole was reportedly drilled at the southwest corner of Pueblo Bonito to a depth of 350 feet with a diameter of 6 inches (Pierson, 1956, p. 76). The National Park Service is also reported to have drilled a well to a depth of 275 feet at the southeast corner of Pueblo Bonito (Pierson, 1956, p. 76). Neither of these two holes resulted in suitable quality water, and several wells were dug in the Chaco Wash to satisfy the demand for water. Lloyd Pierson reported that the Hyde Expedition (1896-1899), the National Geographic Expedition (1921-1927), and the University of New Mexico (sometime in the 1930s) each a constructed or improved a well in the area (Pierson, 1956, p. 77). Sam West (1957) mentions a "Chaco #1" which was constructed in 1937 as well as "University #1" and "University #2". University #1 was reportedly dug in 1940, but late abandoned. University #2 was "still in use" at the time of West's report in 1957.

Undoubtedly there is some overlap in reporting and nomenclature. Many of these wells were merely redeveloped, and most have now been destroyed. Furthermore, location descriptions are often vague or inaccurate. In short, the situation is quite confused.

At present, the remains of 5 wells can be found in the area. University #1 and University #2 sit close together about 100 feet west of the bridge which crosses the Chaco Wash. Chaco #1 (which Pierson says was first dug by the Hyde Expedition) has been backfilled, but it was located about 150 feet east of Pueblo Del Arroyo. Another well (unmentioned by West) is located about ¼ mile east from the University Wells. Pierson believes that the well was dug by the National Geographic Expedition. Presumably this well was redeveloped by the Park Service, and this well along with University #2 were used to supply the Bonita area until the mid 1950s.

Finally, the remains of a well can be seen at the southwest corner of Pueblo Bonito. Presumably, this is the well which was drilled by the Hyde Expedition to a depth of 350 feet.

References

Pierson, Lloyd M., 1956, A History of Chaco Canyon National Monument

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USGS RASA Study

In 1978 the USGS began a systematic study of the major ground-water systems of the United States through its Regional Aquifer System Analysis (RASA) Program. The broad objectives of the RASA Program were to: 1) assemble data from numerous local studies and long-term monitoring programs into regional databases; 2) provide descriptions of the geologic, hydrologic, and geochemical characteristics of the regional aquifer systems; and 3) provide an understanding of the groundwater flow systems under natural (predevelopment) and current (developed) conditions.

The San Juan Basin RASA study began in 1984 and was officially completed in 2001 with publication of Professional Paper 1420 (Craigg, 2001), although the project was essentially completed in 1995. The stated objectives of the San Juan Basin RASA were to: 1) define and evaluate the ground-water system; 2) assess the effects of past, present, and potential ground-water use on aquifers and streams; and 3) determine the availability and quality of ground water (Welder, 1986).

A large number of publications were produced from the San Juan Basin RASA study. These publications included a series of 10 hydrologic atlases, each describing a major hydrogeologic unit in the basin. The atlases are:

HA-720-A	San Jose, Macimiento, and Animas Formations
HA-720-B	Ojo Alamo Sandstone
HA-720-C	Kirtland Shale and Fruitland Formation
HA-720-D	Pictured Cliffs Sandstone
HA-720-E	Cliffhouse Sandstone
HA-720-F	Menefee Formation
HA-720-G	Point Lookout Sandstone
HA-720-H	Gallup Sandstone
HA-720-I	Dakota Sandstone
HA-720-J	Morrison Formation

Other reports describing the geologic framework, groundwater flow system, and geochemistry of groundwater in the basin are included in the list of references for RASA studies in the San Juan Basin.

San Juan Basin RASA References

Craigg, S.D., 2001

Geologic framework of the San Juan basin of New Mexico, Colorado, Arizona, and Utah, with emphasis on Triassic through Tertiary rocks: U.S. Geological Survey Professional Paper 1420.

Craigg, S.D., Dam, W.L., Kernodle, J.M., and Levings, G.W., 1989

Hydrogeology of the Dakota Sandstone in the San Juan structural basin, New Mexico, Colorado, Arizona, and Utah: U.S. Geological Survey Hydrologic Investigations Atlas HA-720-I, scale 1:1,000,000 and 1:2,000,000, 2 sheets.

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Hydrogeology of the Ojo Alamo Sandstone in the San Juan structural basin, New Mexico, Colorado, Arizona, and Utah: U.S. Geological Survey Hydrologic Investigations Atlas HA-720-B, scale 1:1,000,000 and 1:2,000,000, 2 sheets.

Thorn, C.R., Levings, G.W., Craigg, S.D., Dam, W.L., and Kernodle, J.M., 1990b
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As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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