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# A Review of Hydrogeologic Investigations And Groundwater Development At Petrified Forest National Park Arizona

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# A Review of Hydrogeologic Investigations and Groundwater Development at Petrified Forest National Park


## Summary

This report was written to summarize the work of previous hydrogeologic investigations and groundwater exploration at Petrified Forest National Park. The report will help park staff and the general public understand the geologic and hydrologic conditions controlling the availability and quality of groundwater underlying the park and surrounding area. It will also help park management to assess options for groundwater development , should it become necessary for the park to operate its own public water supply system at some time in the future.

The only reliable sources of groundwater in, or near, the park are from shallow, alluvial wells constructed along the Puerco River or deep wells (approximately 1000 feet deep) completed in the Coconino Aquifer. Water quality from either of these sources is poor. Treatment would be required to meet drinking water standards. Water quality in the Coconino Aquifer gets progressively worse from south to north in the park.

The current groundwater monitoring program at the park is limited to monthly water level measurements at the Puerco Well No. 2 and Agate Bridge wells and quarterly water quality sampling from the Puerco Well No. 2. Annual water quality sampling and analysis from the Puerco River Well No. 2 would be sufficient to identify any long-term trends or water quality changes in the alluvial aquifer.

The park should purchase a 500-foot water level meter so that water levels in the Rainbow Forest Well No. 2 can be monitored. Water level monitoring by the USGS from 1998-2003 showed that water levels in the wells at Petrified Forest were declining, most likely in response to groundwater pumping for municipal, industrial, and agricultural uses south and east of the park . The USGS monitoring program has been discontinued at the park and there is no way to know if the groundwater level decline is continuing. Cost of a new 500-foot meter would be approximately $400. Water levels should be measured monthly.

## Introduction

Obtaining a reliable source of good-quality drinking water has been a problem at Petrified Forest National Park since it was first set aside as a national monument in 1906. The park is in the arid, high desert of eastern Arizona near the southern edge of the Colorado Plateau. Average annual precipitation at the park is less than 10 inches. The Puerco River flows through the park, but it is ephemeral and is not a reliable source of water. In addition, water quality in the river is poor and would require treatment to meet drinking water standards.

Over the years, a lot of time, effort, and money have been expended in searching for a reliable source of good-quality groundwater to supply potable water for park staff and visitors. These previous investigations have proven that there is no source of good-quality groundwater available in, or near, the park. The purpose of this report is to summarize the work of previous investigations and therefore prevent wasting time and money in the future repeating the work that has already been done. This report will also help park staff and the general public understand the geologic and hydrologic conditions controlling the availability and quality of groundwater underlying the park and surrounding area.

In 1997, the park began purchasing potable water from the Navajo Tribal Utility Authority (NTUA). This eliminated the need for the park to operate water supply wells, although the park is still responsible for operation and maintenance of the pipelines and distribution system that transports water to park facilities in the Painted Desert and Rainbow Forest areas.

The only reliable sources of groundwater in, or near, the park are from shallow, alluvial wells constructed along the Puerco River or deep wells (approximately 1000 feet deep) completed in the Coconino Aquifer. Water quality from either of these sources is poor. Treatment would be required to meet drinking water standards.

Figure 1 is a map of the park to provide general orientation for report readers. Figures 2-5 show the locations of wells in the park that are discussed in this report.

## Scope of Report

Whealan and others (2003) completed a water resources scoping report for the park. Their report contains information describing general geography and hydrologic environment of the park including a description of the climate. That material is not repeated here.

This report is focused solely on the hydrogeology of the park, describing past efforts to develop groundwater resources, and providing recommendations for future development of groundwater resources.

## Previous Investigations & Reports

Vandiver (1936) described the geology of Petrified Forest National Park. The report includes a general description of groundwater resources and information regarding the construction and testing of the original well (Rainbow Forest Well No. 1) in the Coconino Aquifer in the Rainbow Forest area.

Walker (1937) reported on the results of drilling shallow wells in the Lithodendron Wash area in the northern part of the park to provide water for park facilities in the Painted Desert area. Walker also apparently wrote a report describing the construction of the well into the Coconino Aquifer (in 1932) and other efforts to secure a water source for the Rainbow Forest area, which at that time was the headquarters for the park. A copy of the 1932 report could not be located.

Gould (1938) wrote a report that included a discussion of some of the geological aspects of the park and also summarized the water supply situation. At that time, water for the Painted Desert was obtained from several shallow wells constructed in Lithodendron Wash about two miles west of the park facilities at Painted Desert. Water was pumped via a pipeline from the wells to park facilities. Water for facilities at the south end of the park was obtained from a shallow well constructed in the alluvium of the Puerco River and hauled 16 miles to the headquarters and CCC camp in the Rainbow Forest area.

Palmer (1957) summarized the geology and hydrogeology of the park and provided a description of existing water supply systems at the time. Those systems included the Puerco Well No. 1 which supplied the southern part of the park and the wells in Lithodendron Wash (which he called the Zuni Wells) which supplied the development in the Painted Desert area of the park. The report also discussed options for alternative water supply sources in the future. These options included; purchasing the Santa Fe Railroad water system at Adamana, constructing large water storage tanks, drilling wells along the Puerco River, drilling more wells in the Painted Desert, and developing a deep well in the southwestern part of the monument.

In 1960, several test holes were constructed in the alluvium on the north side of the Puerco River. One of these holes was converted to a production well (Puerco Well No. 2) which produced 100 gpm. A pipeline was constructed from this well to distribute water to park facilities in the Painted Desert area. The well was also connected to the existing pipeline from the Puerco Well No. 1 to the Rainbow Forest area. Poor-quality water from the alluvial well caused excessive wear on pumps, creating a large maintenance expense for the park.

Akers (1964) described the geology and groundwater resources of the central part of Apache County. The park is in the northwest corner of the study area.

Gray (1968) provided a brief description of geology, hydrology, and the history of water development at the park. He also presented options for development of additional water supplies for the park. These options included; 1) drilling wells into the Coconino Aquifer at both Rainbow Forest and Painted Desert and constructing separate treatment plants at each location, 2) constructing additional wells in the alluvium of Lithodendron Wash west of the Painted Desert loop road, and 3) purchasing additional land south of the park and constructing a well into the Coconino Aquifer in that area where the groundwater would likely have better quality.

In 1969-70, the USGS was asked to investigate alternative water sources for the park. Test wells were constructed in Lithodendron Wash and although there was water present in all of the test holes, none of the holes produced enough water to warrant development as production wells. In a memo report to the Park Service, USGS concluded that the alluvium along the Puerco River and the Coconino Aquifer were the only viable sources of water for the park and that treatment options should be investigated for groundwater from either of those sources (Babcock, 1970).

Aughenbaugh (1970a and 1970b) wrote two reports describing the condition of the park's water systems. At that time, the park was relying on the Puerco Well No. 2 (on the north bank of the Puerco River) as the sole source of water supply for the park, with a pipeline extending 7 miles north from the Puerco River to the Painted Desert area and 12 miles south from the Puerco River to the Rainbow Forest area. The reports also summarized past efforts to obtain good-quality water for the park and presented cost estimates for various water treatment alternatives and future demand based on increased park visitation. The water treatment alternatives were for construction of either one reverse osmosis treatment system to service the entire park versus installation of two separate systems to service the Painted Desert and Rainbow Forest areas.

Witucki (1972) reported on a trip to the park to meet with USGS staff to discuss results of a study to identify potential groundwater sources and test well locations to supply water for the Rainbow Forest area. At that time, the plan was to construct a well into the Coconino Aquifer and treat the water by reverse osmosis to make it potable. It would be another 12 years before these wells were constructed.

Mann (1977) prepared a series of maps showing groundwater conditions in the Puerco-Zuni area, including a description of geology and groundwater quality for the Coconino, Moenkopi, Chinle, and Bidahochi Formations. The park is in the west-central part of the study area.

Mann and Nemecek (1983) described the hydrogeology and water use in southern Apache County. Petrified Forest National Park is included in the northwest part of their study area. They also identified areas that might be suitable for development of groundwater in the future. The primary screening factors in identifying potential groundwater sources were the water chemistry and depth to water. The areas identified as being suitable for potential development of groundwater resources are more than 10 miles east or south of the park.

White (1984) reported on the results of drilling and testing of two wells constructed into the Coconino Aquifer at Rainbow Forest and Agate Bridge in the park. Rainbow Forest Well No. 2, located near the south entrance to the park, produced 185 gpm, but the water quality was very poor (9,900 mg/l total dissolved solids). The Agate Bridge Well produced 30 gpm of very poor quality water (19,900 mg/l total dissolved solids). There is no record that either well was ever used for water supply. Treatment facilities were not constructed.

Webb, Rink, and Favor (1987) and Webb, Rink, and Radtke (1987) conducted investigations to determine whether discharges of mine and mill waste from uranium mining operations upstream in New Mexico had impacted water quality and related resources along the Puerco River. They concluded that water quality in the alluvial aquifer is naturally poor and that contamination in the alluvial aquifer does not change in the downstream direction.

Dixon (1990) described the hydrogeology and groundwater quality of an area immediately upstream from the park. He concluded that most of the observed radioactivity in the alluvial aquifer was produced by natural sources and not from effluent from mining and milling operations upstream in New Mexico.

Hart, et.al. (2002) provide a general description of the hydrogeology of the Coconino Aquifer in northeastern Arizona and an estimate of the water budget for the aquifer.

The remainder of this report is a compilation, interpretation, and analysis of information from the previous investigations cited above.

## Hydrogeology

Petrified Forest National Park is underlain by several thousand feet of nearly flat-lying sedimentary rocks. The Chinle Formation is at the surface through most of the park, except for a few small areas where younger deposits of alluvium or lava are at the surface. The lower part of the Chinle is referred to as the Shinarump Conglomerate. Underlying this, in order, are the Moenkopi Formation, the Kaibab Limestone, the Coconino Sandstone and the Supai Formation. The

Kaibab limestone pinches out to the north. It is 40 feet thick at Rainbow Forest and is totally absent at Painted Desert.

A well drilled at Rainbow Forest in 1932 encountered the following sequence of geologic formations:

| Depth, Feet below ground surface | Formation |
|---|---|
| 0-300 | Chinle Formation |
| 300-355 | Shinarump Conglomerate |
| 355-755 | Moenkopi Formation |
| 755-795 | Kaibab Limestone |
| 795-1023 | Coconino Sandstone |

The full thickness of the Coconino Sandstone was not penetrated by this well.

Table 1 shows the stratigraphic sequence of rocks underlying the park and identifies those units that might be considered aquifers. While small amounts of poor-quality water might be obtained locally from wells completed in the Chinle, Shinarump, and Moenkopi Formations, they are generally not considered to be aquifers.

The primary aquifers underlying the park are alluvium associated with the Puerco River and Lithodendron Wash, and the Coconino Aquifer. The Coconino Aquifer is composed of the Coconino Sandstone, the uppermost beds of the underlying Supai Formation and the overlying Kaibab Limestone. Water quality from either of these sources (alluvium and Coconino Aquifer) is generally poor and would require treatment to meet drinking water standards.

Alluvium is derived from the weathering and transport of local bedrock materials, in this area the local bedrock is the Chinle Formation. The alluvium associated with the Puerco River is composed of interbedded gravel, sand, silt, and clay that may be as much as 200 feet thick. Groundwater in the alluvium is recharged by infiltration of precipitation and intermittent surface flow in the Puerco River. Dissolution of naturally-occurring minerals in the alluvium results in poor groundwater quality. The water is characterized as having high concentrations of dissolved solids, particularly sodium, sulfate, iron, and manganese. Water quality data for the alluvial aquifers associated with the Puerco River and Lithodendron Wash are provided in Table 2.

The Coconino Aquifer is generally 500 -1000 feet below ground surface in the park. Recharge occurs where the formation outcrops along the Mogollon Rim south of the park. Groundwater flow is generally to the north with considerable discharge occurring at springs along the Little Colorado River (Akers, 1964). North of the Little Colorado River, groundwater flow gradually turns toward the northwest and flows slowly toward the major regional discharge area at Blue Springs. Beneath the park, groundwater in the Coconino Aquifer is salty, possibly because of upward seepage of poor quality water from underlying Supai Formation in the deeper part of the structural basin. The Coconino Aquifer is

under confined, or artesian, conditions throughout the park. Salt concentration in the Coconino Aquifer under the park increases from south to north.

Groundwater quality is fairly good in the Coconino Aquifer south of the Little Colorado River, more than 5-6 miles south of the park. It is thought that groundwater in this area is better because it is near the recharge area on the Mogollon Rim and that there is good circulation of groundwater between the recharge area and discharge points at springs along the Little Colorado River (Figure 6).

North of the Little Colorado River, groundwater quality in the Coconino Aquifer deteriorates rapidly, becoming increasingly salty toward the north. The area underlying the park is near the axis of a large synclinal basin or trough. Geologic formations are fairly flat-lying and the area is a long distance from recharge or discharge areas for the Coconino Aquifer. Groundwater moves very slowly through the aquifer in this area. Artesian pressure in the underlying Supai Formation forces poor quality groundwater from the Supai to slowly flow upward and commingle with groundwater in the Coconino Aquifer, causing the groundwater in the Coconino Aquifer to become increasingly salty.

An example of the increased saltiness of groundwater in the Coconino Aquifer in and near the park is provided in Figures 7 and 8. These figures show that the concentration of total dissolved solids or conductivity (as a surrogate for total dissolved solids) increases rapidly north of the Little Colorado River. These data further substantiate the hypothesis that there is an active groundwater flow system in the area south of the Little Colorado River, with recharge along the Mogollon Rim and discharge at springs along the Little Colorado River. Groundwater movement in this area is apparently fast enough to maintain good-quality groundwater. North of the Little Colorado River, groundwater flow is relatively stagnant and water quality is poor due to dissolution of minerals in the bedrock and seepage of poor quality groundwater from adjacent formations.

General water chemistry for wells completed in the Coconino Aquifer in Petrified Forest National Park is provided in Table 2.

## Potential Potable Water Supplies

Potential potable water supplies at Petrified Forest National Park can be summarized as:

1. Groundwater from the deep Coconino Aquifer is plentiful, but very poor quality.
2. The few springs that exist in the park are in remote areas and produce only small quantities of water.

3. Alluvium along the Puerco River produces sufficient water, but would require treatment to meet drinking water standards. (It is better quality than water from the Coconino Aquifer.)
4. Test drilling in the Moenkopi Formation and alluvium of Lithodendron Wash in the northern part of the park showed that some wells in this area could produce up to 5 gpm of water with quality comparable to the alluvium along the Puerco River.

## History of Public Water Supply Developments

The first record of a water supply well in the park was a deep well (1023 feet) constructed in 1932 into the Coconino Aquifer near park headquarters at the south end of the park. Water from the well was too salty to drink and the well was plugged back to 950 feet in an attempt to eliminate the poor quality water. The water remained too salty to drink and efforts to develop a well near headquarters were abandoned. It is believed that this well was capped below ground surface. No evidence of the well's location remains. The approximate location of this well (Rainbow Forest Well No. 1) is shown on Figure 5.

The Puerco Well No. 1 was completed in the alluvium on the south bank of the Puerco River in 1934. The well was 48 feet deep and produced a sufficient quantity of water with acceptable quality water to meet park demand. Water from this well was hauled 16 miles to provide water for park headquarters and the CCC camp at the south end of the park (Gould, 1938). In 1940, a pipeline was constructed from the well to the headquarters area.

Around 1937, the development of park facilities at Painted Desert was authorized. Several shallow wells were constructed in Lithodendron Wash about 2 miles west of park facilities in the Painted Desert area to supply the development. These wells were completed in either the alluvium of the wash or a sandstone lens in the Chinle Formation (Walker, 1937). These wells were collectively referred to as the Zuni Wells, probably after the old Zuni oil well. The original Zuni oil well, drilled to a depth of 3000 feet, was located in Lithodendron Wash about a mile southwest of the Zuni water wells. The Zuni wells were the water supply for the Painted Desert area (Palmer, 1957) into the early 1960's, until after construction of the Puerco Well No. 2. Gray (1968) reported that only one of the Zuni wells remained connected to the distribution system and that it was used only as a backup source.

Palmer (1957) reported that a small amount of water was being collected from a spring in the Agate Bridge area. He did not specify how much water was being collected or what it was used for.

In 1960, the Park Service constructed a series of test holes on the north bank of the Puerco River and developed one of the test holes as the Puerco Well No. 2.

The impetus for the drilling project was the decreasing yields from both the Puerco Well No. 1 and the Zuni Wells caused by silt moving into the gravel pack surrounding the wells. By 1970, The Puerco Well No. 2 had become the sole source of water for the park, with a pipeline running from the well at the Puerco River to the Painted Desert facilities about 7 miles north of the river and to the Rainbow Forest area about 12 miles south of the river (Aughenbaugh, 1970a and 1970b).

By 1972, the park was again looking for a local source of water for the Rainbow Forest area (Witucki, 1972). The USGS was contracted to conduct a reconnaissance study including an inventory of existing nearby wells and interpretation of all applicable data. At the same time, the Park Service was investigating alternatives and costs for treatment (including reverse osmosis) for water from the Puerco Well No. 2 and from wells completed in the Coconino Aquifer. The analysis included comparison of the cost of operating local water systems with separate treatment systems for deep wells located at Painted Desert and Rainbow Forest vs. the cost of treating water from the Puerco Well No. 2 and operating an extensive distribution system throughout the park.

In 1984, test wells were constructed to determine the yield and chemical quality of the Coconino Aquifer in the Rainbow Forest and Agate Bridge areas of the park (White, 1984). The well at Rainbow Forest was pumped at 185 gpm for 24 hours. The water had 9,900 mg/l dissolved solids. The well at Agate Bridge was pumped at 30 gpm for 24 hours. The water had 19,800 mg/l dissolved solids. Neither of these wells was ever used as a water supply for the park. Treatment systems were not constructed.

In 1997, the park began purchasing water from the Navajo Tribal Utility Authority (NTUA). The development of the Navajo New Lands and the increasing number of residents dependent upon the NTUA system for drinking water pose the greatest risk to the continued future purchase of NTUA water by the park. The NTUA is under no obligation to continue supplying water to the park. Should it become disadvantageous for the NTUA to sell water to the park, the park would be compelled to develop and treat its own water sources or find another provider willing to sell water to the park.

Table 3 provides a summary of well information and Arizona well registration numbers for wells at Petrified Forest National Park. For those wells which have them, copies of well completion forms are attached to this report.

## Current Groundwater Monitoring Program

NPS Resource Management staff at the park make monthly water level measurements at the Puerco Well No. 2 and Agate Bridge wells. Water samples from the Puerco Well No. 2 are collected quarterly for chemical analyses. The

water samples are shipped to the University of Virginia where the samples are analyzed for pH, conductivity, alkalinity, and major cations and anions. These data are kept in the files of the resource management staff at the park.

Park staff indicated that they can not monitor water levels in Rainbow Forest Well No. 2 because the cable on the water level meter is not long enough. In recent years, the depth to water in this well has ranged from 310-320 feet (Figure 9). This problem could easily be solved by purchasing a new water level meter with a 500-foot cable. Cost of a new meter would be approximately $400.

The USGS conducted quarterly monitoring of groundwater levels in two wells completed in the Coconino Aquifer at the park. These wells are at Rainbow Forest and Agate Bridge. The monitoring program was established in 1998 in response to a NPS request for the USGS to develop additional groundwater information for the Coconino Aquifer in the Little Colorado River Basin that could be used in the ongoing adjudication of water rights in the basin (Don Bills, USGS Flagstaff, written communication). The monitoring program ended in Fall 2003 due to lack of funding. Water level data is available from the USGS NWIS database on the internet. Hydrographs showing the water level in these two wells are shown in Figures 9 and 10. Water levels in the wells at Petrified Forest are declining, most likely in response to groundwater pumping for municipal, industrial, and agricultural uses south and east of the park (Don Bills, USGS written communication).

Dr. David Cooper, from Colorado State University, is conducting a research project to characterize the riparian community potential of the streams in the park based upon their physical environment. The project includes intensive monitoring of the water table in the alluvium along the Puerco River. Presumably, these data will be summarized and published in Dr. Cooper's final report. It is anticipated that this research project will lead to the development of a Riparian Area Resource Management Plan, including a Tamarisk Integrated Pest Management Plan and Environmental Assessment. These documents should be available from the park in the near future.

## Hydrogeologic Issues of Concern to the Park

Whealan and others (2003) completed a water resources scoping report for Petrified Forest National Park. In this report they identified significant water-related issues of concern to the park. Several of these issues are directly related to groundwater resources of the park and are discussed briefly in the following paragraphs.

1. Alluvial water quality.
Radionuclides in the Puerco River and the alluvial groundwater are a product of both the natural erosion of uranium-bearing rock and past mining-related

activities upstream of the park. Groundwater in the alluvium, the source of water for the Puerco Well No. 2, has not been affected by anthropogenic releases of radionuclides upstream of the park. However, the USGS has recommended continuing intermittent sampling of the alluvial groundwater to determine whether significant water quality changes have taken place. Annual sampling and analysis is sufficient to identify any long-term trends or water quality changes.

2. Ferrellgas Petroleum Storage at Adamana
Ferrellgas, Inc. operates a liquefied petroleum gas (LPG) storage terminal near the old railroad town of Adamana. Adamana is located at the Puerco River approximately 0.8 miles west of the park boundary. The facility stores LPG in underground caverns in the Supai formation. Ferrellgas has obtained an ADEQ Aquifer Protection Permit for the operation of four surface brine impoundments, twelve injection wells and sub-surface storage caverns. Werrell (1994) investigated the potential for hydrological impacts to park resources from operation of the LPG gas storage operations and brine ponds at the Adamana Ferrellgas facility. Both the depth of the Supai Formation (1000 feet below land surface) and the presence of a large thickness of relatively impermeable rocks (Moenkopi and Chinle Formations) overlying the LPG storage area effectively isolate the storage area from the surface. Werrell (1994) concluded that the LPG storage project presented no threat to park resources unless water flowed uphill in this area.

3. Inventory groundwater resources.
Groundwater resources and hydrogeologic conditions in the park have been thoroughly documented. No additional studies or inventory are needed. If the park boundary is expanded, as has been proposed, an inventory of wells and springs in the new areas should be completed. The basic principles of hydrogeology and groundwater occurrence discussed in this report will not change because of expansion of the park. The description of groundwater resources and water quality can be extended into the new areas of the park. Unless the park boundary is extended several miles south of the current boundary, there will still be no good-quality groundwater resources underlying the park.

4. Coordinate monitoring program.
Park staff and hydrologists from Water Resources Division should review the various hydrologic monitoring programs to insure that there is no unnecessary overlap of programs and that there are no gaps between programs. These programs include; monitoring conducted by park staff, USGS monitoring, any monitoring that might be proposed or conducted by the Southern Colorado Plateau Network, Vital Signs, Natural Resources Challenge, or the I&M program. The entire monitoring program should be reviewed and revised as necessary.

5. Dependence on NTUA for potable water.
In 1997, the park began to purchase water from the Navajo Tribal Utility Authority (NTUA). Currently, the park is entirely dependent on NTUA as the only source of potable water for the park. NTUA water supplies are adequate to meet the park's current and future demands. However, the Navajo Nation has expressed interest in using some of that water to encourage future development in the New Lands area of the reservation. The long-term ability and willingness of the NTUA to continue supplying water to the park should be a concern for park management. If NTUA is not able to meet the water supply demands of the park, the park would need to find another source of water. That would most likely be wells in the alluvium of the Puerco River or in the Coconino aquifer. Groundwater from either of these sources would need to be treated to meet public health standards. Construction and operation of a water treatment system would be very expensive and would also require that park staff include several licensed water treatment plant operators.

## References


Akers, J.P., 1964, Geology and Ground Water in the Central Part of Apache County, Arizona, USGS Water Supply Paper 1771, 107 pp.

Aughenbaugh, Dustin M.,1970a, Additional Water Sources for Petrified Forest National Park, internal NPS memo to Chief of Water Resources Section Office of Land Acquisition and Water Resources, November 13, 1970, 13 pp.

Aughenbaugh, Dustin M., 1970b, Water Supply at Petrified Forest National Park, unpublished NPS administrative report, 24 pp.

Babcock, H.M., 1970, memo to Gerard Witucki, National Park Service, Results of test drilling along Lithodendron Wash in the Petrified Forest National Park, 8 pp.

Dixon, Earle Campbell, 1990, Hydrogeology and Ground-Water Quality in the Sanders Area, Western Puerco River Basin, Arizona, M.S. thesis, Department of Geoscience, University of Nevada, Las Vegas, 156 pp.

Gray, A.W., 1968, Water Resources at Petrified Forest, internal NPS memo to Chief of Branch of Water Resources, November15, 1968, 5 pp.

Hart, Robert J., John J. Ward, Donald J. Bills, and Marilyn E. Flynn, 2002, Generalized Hydrogeology and Ground-Water Budget for the C Aquifer, Little Colorado River Basin and Parts of the Verde and Salt River Basins, Arizona and New Mexico, USGS Water-Resources Investigations Report 02-4026, 47 pp.

Mann, Larry J., 1977, Maps Showing Ground-Water Conditions in the Puerco-Zuni Area, Apache and Navajo Counties, Arizona-1975, USGS Water-Resources Investigations 77-5 Open-File Report, 3 sheets

Mann, Larry J., and E.A. Nemecek, 1983, Geohydrology and Water Use in Southern Apache County, Arizona, Arizona Department of Water Resources Bulletin 1, 86 pp.

Palmer, John J., 1957, Water Resources of Petrified Forest National Monument, unpublished NPS report, 16 pp. plus addenda

Vandiver, Vincent W., 1936, Geology of the Petrified National Forest National Monument, internal NPS report by the regional geologist, 52 pp.

Walker, M.V., 1937, Report on Drilling Operations for the Painted Desert Water Development, unpublished NPS report, 11 pp.

Webb, Robert H., Glen R. Rink, and Barbara O. Favor, 1987, Distribution of Radionuclide and Trace-Elements in Ground Water, Grasses, and Surficial Sediments Associated With the Alluvial Aquifer Along the Puerco River, Northeastern Arizona – A Reconnaissance Sampling Program, USGS Open-File Report 87-206, 108 pp.

Webb, Robert H., Glen R. Rink, and Dean B. Radtke, 1987, Preliminary Assessment of Water quality in the Alluvial Aquifer of the Puerco River Basin, Northeastern Arizona, USGS Water-Resources Investigation Report 87-4126, 70 pp.

Whealan, Ann, John Reber, Mark D. Flora, and Karen Beppler-Dorn, 2003, Petrified Forest National Park Arizona Water Resources Scoping Report, National Park Service Technical Report NPS/NRWRD/NRTR-2003/313, 34 pp.

White, W. Lowell, 1984, Summary of Well Tests Conducted at Petrified Forest National Park, internal NPS memo to the Superintendent of Petrified Forest National Park, June 29, 1984, 4 pp.

Witucki, Gerard S., 1972, Trip Report to Petrified Forest Regarding a Test-Well for Rainbow Forest Area, internal NPS memo to Chief of Water

**Table 1. Hydrostratigraphy of Petrified Forest National Park**

| Formation | Thickness | Description | Aquifer |
|---|---|---|---|
| Alluvium | 0-200 | Interbedded gravel, sand, and silt. | Puerco River Alluvial Aquifer |
| Chinle Formation | 300 | Multi-colored claystone, mudstone, siltstone, sandstone. Some sandstone units contain water, usually of poor quality. | Not an aquifer |
| Shinarump Conglomerate | 50 | Conglomerate, sandstone, siltstone. Minor local units may contain water, usually of poor quality. | Not an Aquifer |
| Moenkopi Formation | 400 | Mostly shale, siltstone, and sandstone. Contains water of very poor quality in some areas. | Not an aquifer |
| Kaibab Limestone | 0-50 | Limestone with lenticular beds of sandstone. Contains water where fractured. | Mostly absent |
| Coconino Sandstone | 200-400 | Fine-to-medium grained well-sorted quartz sandstone. Contains water. Major regional aquifer. Contains salty water in the vicinity of the park. | Coconino Regional Aquifer, or C Aquifer |
| Supai Formation | 1000-2000 | Interbedded sandstone, siltstone, mudstone and evaporate deposits. May contain local pockets of salty water | Not an aquifer |

After Akers (1964)

**Table 2. General water chemistry for wells at Petrified Forest National Park**

| | Zuni Well No. 1* | Puerco River Well No. 2 | Rainbow Forest Well No. 1 | Rainbow Forest Well No. 2 | Agate Bridge Well |
|---|---|---|---|---|---|
| Date | 5/7/64 | 4/26/67 | ca. 1934 | 1/11/84 | 2/3/84 |
| pH | 8.4 | 8.0 | ----- | 7.1 | 6.8 |
| TDS | 1640 | 954 | 3480 | 9920 | 19,800 |
| Sp. Cond. | 2650 | 1510 | ----- | 16,300 | 29,800 |
| Ca | 8.7 | 26 | 56 | 150 | 390 |
| Mg | 1.8 | 5.6 | 9.0 | 34 | 100 |
| Na | 578 | 329 | 1380 | 3500 | 6900 |
| $HCO_3$ | 363 | 546 | 112 | 366 | 642 |
| $SO_4$ | 266 | 202 | 96 | 440 | 900 |
| Cl | 506 | 96 | 2100 | 5400 | 11,000 |
| Total depth, feet | 45 | 109 | 1023 | 980 | 780 |
| Average depth to water, feet | 15 | 13 | 121 | 315 | 270 |

*Zuni Well No. 1 is one of the shallow wells located in Lithodendron Wash in the north part of the park

**Table 3. Wells at Petrified Forest National Park**

| ADWR Registration Number | Date Constructed | Well Name | Depth |
|---|---|---|---|
| 55-629112 | 1932 | Rainbow Forest Well No. 1 | 1023' |
| 55-629113 | 1934 | Puerco Well No. 1 | 48' |
| 55-629091 | 1960 | Puerco Well No. 2 | 109' |
| 55-506605 | 1983-84 | Rainbow Forest Well No. 2 | 980' |
| 55-506603 | 1983-84 | Agate Bridge Well | 780' |
| 55-525728<br>55-525729<br>55-525730<br>55-532551<br>55-532552<br>55-532553<br>55-571339<br>55-571462<br>55-571463<br>55-571464<br>55-571766<br>55-586893 | 1989-2001 | Shallow wells drilled in the Painted Desert development area by the concessionaire to document and remediate impacts of a leaking underground storage tank | Less than 50' |
| The Zuni oil well and shallow water-supply wells in Lithodendron Wash were abandoned prior to requirements for registration with the state. | | | |

# Arizona Department Of Water Resources

# Well Completion Reports

# For Wells At

# Petrified Forest National Park

Rainbow Forest No. 1

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004

Declaration: The United States gives this notification to the State in the interest of comity, and does not concede that the State has power to regulate the rights of the United States to the use of water.

# REGISTRATION OF EXISTING WELLS

*READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING*
*PRINT OR TYPE — FILE IN DUPLICATE*

RECEIVED
JUN 9 1982
DEPT. OF
WATER RESOURCES

03.

| REGISTRATION FEE (CHECK ONE) | |
|---|---|
| EXEMPT WELL (NO CHARGE) | ☒ |
| NON-EXEMPT WELL – $10.00 | ☐ |

FOR OFFICE USE ONLY
REGISTRATION NO. 55- 629117
FILE NO. A(16-23)1bdc
FILED 6-9-82 (DATE) AT 1:30 (TIME)
INA —
AMA —

1. Name of Registrant:
National Park Service, Western Region, Division of Water Resources
450 Golden Gate Avenue, Box 36063 (Address) San Francisco, (City) CA (State) 94102 (Zip)

2. File and/or Control Number under previous groundwater law:
(File Number) 35- (Control Number)

3. a. The well is located within the SW ¼ SE ¼ NW ¼, Section 1, of Township 16 N N/S, Range 23 E E/W, G & SRB & M, in the County of Navajo.

b. If in a subdivision: Name of subdivision ____, Lot No. ____, Address ____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
Unused.

5. If for irrigation use, number of acres irrigated from well ____.

6. Owner of land on which well is located. If same as Item 1, check this box ☒
(Address) (City) (State) (Zip)

7. Well data (If data not available, write N/A)
a. Depth of Well 950 -- plugged back from 1023 feet
b. Diameter of casing 8 inches
c. Depth of casing 745 feet
d. Type of casing steel.
e. Maximum pump capacity N/A gallons per minute.
f. Depth to water 121 feet below land surface.
g. Date well completed (Month) (Day) 1932 (Year).

8. The place(s) of use of water. If same as Item 3, check this box ☐.
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
Petrified Forest -- Rainbow Forest Well
Attach additional sheet if necessary.

9. DATE JUN 3 1982 SIGNATURE OF REGISTRANT Gerard S. Witucki
GERARD S. WITUCKI
CHIEF, DIVISION OF WATER RESOURCES

Puerco Well No. 1

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004

Declaration: The United States gives this notification to the State in the interest of comity, and does not concede that the State has power to regulate the rights of the United States to the use of water.

# REGISTRATION OF EXISTING WELLS

*READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING*
*PRINT OR TYPE — FILE IN DUPLICATE*

RECEIVED JUN 9 1982 DEPT. OF WATER RESOURCES

03

| REGISTRATION FEE (CHECK ONE) | |
|---|---|
| EXEMPT WELL (NO CHARGE) | [X] |
| NON-EXEMPT WELL – $10.00 | [ ] |

FOR OFFICE USE ONLY
REGISTRATION NO. 55- 629113
FILE NO. A(18-24)9aca
FILED 6-9-82 (DATE) AT 1:30 (TIME)
INA —
AMA —

1. Name of Registrant:
National Park Service, Western Region, Division of Water Resources
450 Golden Gate Avenue, Box 36063 (Address) San Francisco, (City) CA (State) 94102 (Zip)

2. File and/or Control Number under previous groundwater law:
(File Number) 35- (Control Number)

3. a. The well is located within the NE ¼ SW ¼ NE ¼, Section 9, of Township 18 N N/S, Range 24 E E/W, G & SRB & M, in the County of Apache.

b. If in a subdivision: Name of subdivision _____, Lot No. _____, Address _____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
Unused.

5. If for irrigation use, number of acres irrigated from well _____.

6. Owner of land on which well is located. If same as Item 1, check this box [XX]
(Address) (City) (State) (Zip)

7. Well data (If data not available, write N/A)
a. Depth of Well 48 feet
b. Diameter of casing 5 inches
c. Depth of casing N/A feet
d. Type of casing steel .
e. Maximum pump capacity N/A gallons per minute.
f. Depth to water 10.7 feet below land surface.
g. Date well completed (Month) (Day) 1934 (Year).

8. The place(s) of use of water. If same as Item 3, check this box [ ].
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
____¼ ____¼ ____¼, Section ____ Township ____ Range ____
Petrified Forest -- Puerco Well #1
Attach additional sheet if necessary.

9. DATE JUN 3 1982 SIGNATURE OF REGISTRANT Gerard S. Vituchi
GERARD S. VITUCHI
CHIEF, DIVISION OF WATER RESOURCES

Puerco
Well No. 2

DEPARTMENT OF WATER RESOURCES
99 EAST VIRGINIA AVENUE
PHOENIX, ARIZONA 85004

Declaration: The United States gives this notification to the State in the interest of comity, and does not concede that the State has power to regulate the rights of the United States to the use of water.

# REGISTRATION OF EXISTING WELLS

*READ INSTRUCTIONS ON BACK OF THIS FORM BEFORE COMPLETING*
*PRINT OR TYPE — FILE IN DUPLICATE*

RECEIVED JUN 9 1982 DEPT. OF WATER RESOURCES

03

| REGISTRATION FEE (CHECK ONE) | |
|---|---|
| EXEMPT WELL (NO CHARGE) | ☐ |
| NON-EXEMPT WELL – $10.00 | ☒ |

FOR OFFICE USE ONLY
REGISTRATION NO. 55- 62909/
FILE NO. A(18-24)9 abb
FILED 6-9-82 (DATE) AT 1:30 (TIME)
INA
AMA

1. Name of Registrant:
National Park Service, Western Region, Division of Water Resources
450 Golden Gate Avenue, Box 36063 (Address) San Francisco, (City) CA (State) 94102 (Zip)

2. File and/or Control Number under previous groundwater law:
01-704 (File Number) 35- (Control Number)

3. a. The well is located within the NW ¼ NW ¼ NE ¼, Section 9, of Township 18 N N/S, Range 24 E E/W, G & SRB & M, in the County of Apache.

b. If in a subdivision: Name of subdivision _____, Lot No. _____, Address _____.

4. The principal use(s) of water (Examples: irrigation - stockwater - domestic - municipal - industrial)
Public supply, fire protection, domestic.

5. If for irrigation use, number of acres irrigated from well _____.

6. Owner of land on which well is located. If same as Item 1, check this box ☒
(Address) (City) (State) (Zip)

7. Well data (If data not available, write N/A)
a. Depth of Well 99 feet
b. Diameter of casing 13 inches
c. Depth of casing 103 feet
d. Type of casing concrete, perforated from 79 - 99 feet below land surface datum
e. Maximum pump capacity 100 gallons per minute.
f. Depth to water 13 feet below land surface.
g. Date well completed _____ (Month) _____ (Day) 1958 (Year).

8. The place(s) of use of water. If same as Item 3, check this box ☐.
NW ¼ SE ¼ NW ¼, Section 1 Township 16 N Range 23 E
SW ¼ NW ¼ NE ¼, Section 10 Township 19 N Range 24 E
Petrified Forest - Puerco Well #2
Attach additional sheet if necessary.

9. DATE JUN 3 1982 SIGNATURE OF REGISTRANT Gerard S. Fitzsche
GERARD S. FITZSCHE
CHIEF, DIVISION OF WATER RESOURCES

STATE OF ARIZONA

DEPARTMENT OF
WATER RESOURCES

Agate Bridge Well

# WELL DRILLER REPORT

(2)

This report should be prepared by the driller in all detail and filed with the Department within 30 days following completion of the well.

1. Owner National Park Service, Petrified Forest National Park
Name
Holbrook Arizona 86025
Address

2. Lessee or Operator PERRY & PERRY
Name
2033 N Navajo Dr - Flagstaff, Az 86001
Address

3. Driller Lloyd C PERRY
Name
2033 N Navajo Dr Flagstaff, Az 86001
Address

4. Location of well: 17N 24E Section 9 (SW¼ NW¼ NE¼)
TWN Range

5. Permit No. 55-506603
(if issued)

## DESCRIPTION OF WELL

6. Total depth of hole 780 ft.
7. Type of Casing Steel - standard Wall thickness
8. Diameter and length of casing 10 3/4 in. from +3 ft to 690 ft in from
216 SKS of
to .
9. Method of sealing at reduction points Cement pumped from bottom of casing to surface
10. Perforated from None to , from to , from to
11. Size of cuts — Number of cuts per foot —
12. If screen was installed: Length None Diam in. Type
13. Method of construction drilled
drilled, dug, driven, bored, jetted, etc.
14. Date started 12-7-83
Month day year
15. Date completed 2 4 1984
Month day year
16. Depth to water 276 ft. (If flowing well, so state.)
17. Describe point from which depth measurements were made, and give sea-level elevation if available.
ground level
18. If flowing well, state method of flow regulation
19. REMARKS: 30 gpm. dd 276 To 340 ft -
10" open hole 690 - 780 ft -
Salty Water

DO NOT WRITE IN THIS SPACE
OFFICE RECORD
Registration No. 55-506603
Received By
Entered 2-23-84 By
File No. A(17-24)9abc

(Well log to appear on Reverse side)

RECEIVED
FEB 16 1984
DEPT. OF
WATER RESOURCES

DWR-6 5-83

VERIFIED

VERIFIED

# LOG OF WELL

Indicate depth at which water was first encountered, and the depth and thickness of water bearing beds. If water is artesian, indicate depth at which encountered, and depth to which it rose in well.

| FROM (FEET) | TO (FEET) | DESCRIPTION OF FORMATION MATERIAL |
|---|---|---|
| 0 | 10 | Sandstone - Gray |
| 10 | 240 | Sandy Shale - Gray |
| 240 | 260 | Sandstone - Red |
| 260 | 390 | Sandy Shale - Blue-Gray |
| 390 | 685 | Shale - Red |
| 685 | 780 | Coconino Sandstone - Gray |

I hereby certify that this well was drilled by me (or under my supervision), and that each and all of the statements herein contained are true to the best of my knowledge and belief.

Driller Lloyd E. C. Perry
Name Lloyd C Perry
2033 N. Navajo Dr.
Flagstaff, Ariz. 86001

Date 2-10-54

STATE OF ARIZONA

DEPARTMENT OF WATER RESOURCES

Rainbow Forest Well No. 2

FEB 1984 DEPARTMENT OF WATER RESOURCES

# WELL DRILLER'S REPORT

This report should be prepared by the driller in duplicate and filed with the Department within 30 days following completion of the well.

1. Owner National Park Service - Petrified Forest National Park
   Name
   Holbrook, Arizona 86025
   Address

2. Lessee or Operator PERRY & PERRY
   Name
   2033 N Navajo Dr. Flagstaff Az 86001
   Address

3. Driller Lloyd C. PERRY
   Name
   (Same as above)
   Address
   Rainbow Forest District 4

4. Location of well: 17N (Twp.) 23E (Range) 35 (Section) - NE¼ SE¼ SE¼

5. Permit No. 55-5-06605 (if issued)

## DESCRIPTION OF WELL

6. Total depth of hole 980 ft.
7. Type of Casing Steel .5 wall thickness
8. Diameter and length of casing 10 3/4 in. from +3' to 851', 14 in from 0 to 57'. 300 SKs-
9. Method of sealing at reduction points Cement pumped from bottom of casings To surface
10. Perforated from None to —, from — to —, from — to —
11. Size of cuts 0 Number of cuts per foot 0
12. If screen was installed: Length None ft. Diam — in. Type —
13. Method of construction Drilled
    drilled, dug, driven, bored, jetted, etc.
14. Date started Oct (Month) 26 (day) 1983 (year) — 6 IC. VA-10-25-83 mw
15. Date completed Feb (Month) 4 (day) 1984 (year)
16. Depth to water 329 ft. (If flowing well, so state.)
17. Describe point from which depth measurements were made, and give sea-level elevation if available. ground level
18. If flowing well, state method of flow regulation —
19. REMARKS: 182 gpm with drawdown from 329 to 340
    10" open hole from 851 - 980 ft
    Salty Water

DO NOT WRITE IN THIS SPACE
OFFICE RECORD
Registration No. 55-506605
Received — By —
Entered 2-20-84 By —
File No. A(17-23)35dda

(Well log to appear on Reverse side)

RECEIVED

DWR-6 5-83

# LOG OF WELL

Indicate depth at which water was first encountered, and the depth and thickness of water bearing beds. If water is artesian, indicate depth at which encountered, and depth to which it rose in well.

| FROM (FEET) | TO (FEET) | DESCRIPTION OF FORMATION MATERIAL |
|---|---|---|
| 0 | 6 | Shale |
| 6 | 20 | Sandstone |
| 20 | 540 | Blue Shale |
| 540 | 740 | Red Shale |
| 740 | 980 | Gray Coconino |

I hereby certify that this well was drilled by me (or under my supervision), and that each and all of the statements herein contained are true to the best of my knowledge and belief.

Driller. Lloyd C Lenny
Name

2023 N. Navajo Dr. Flagstaff, Ariz 86001
Address

Date 2-10-84

# Figures

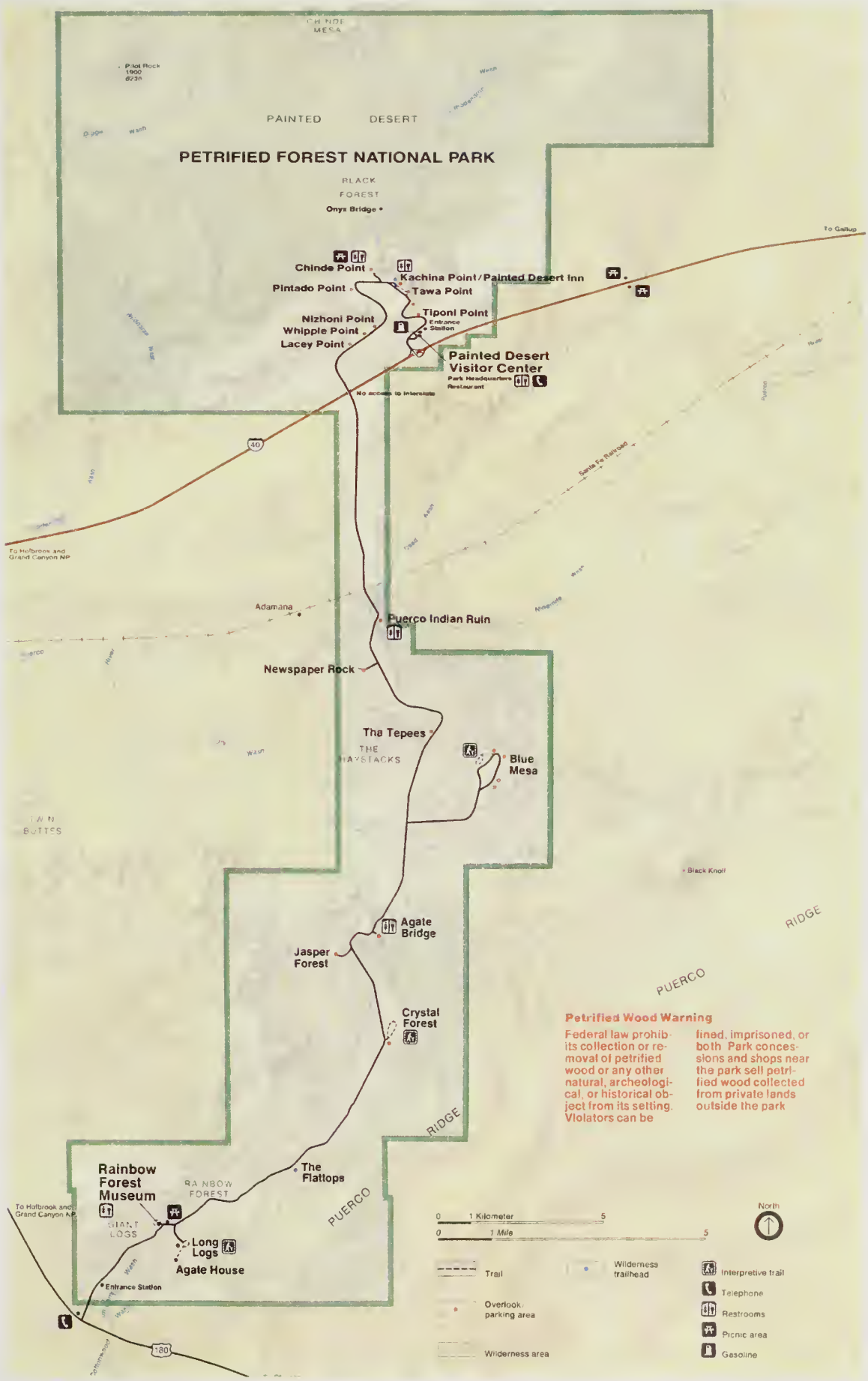



Figure 1. Map of Petrified Forest National Park

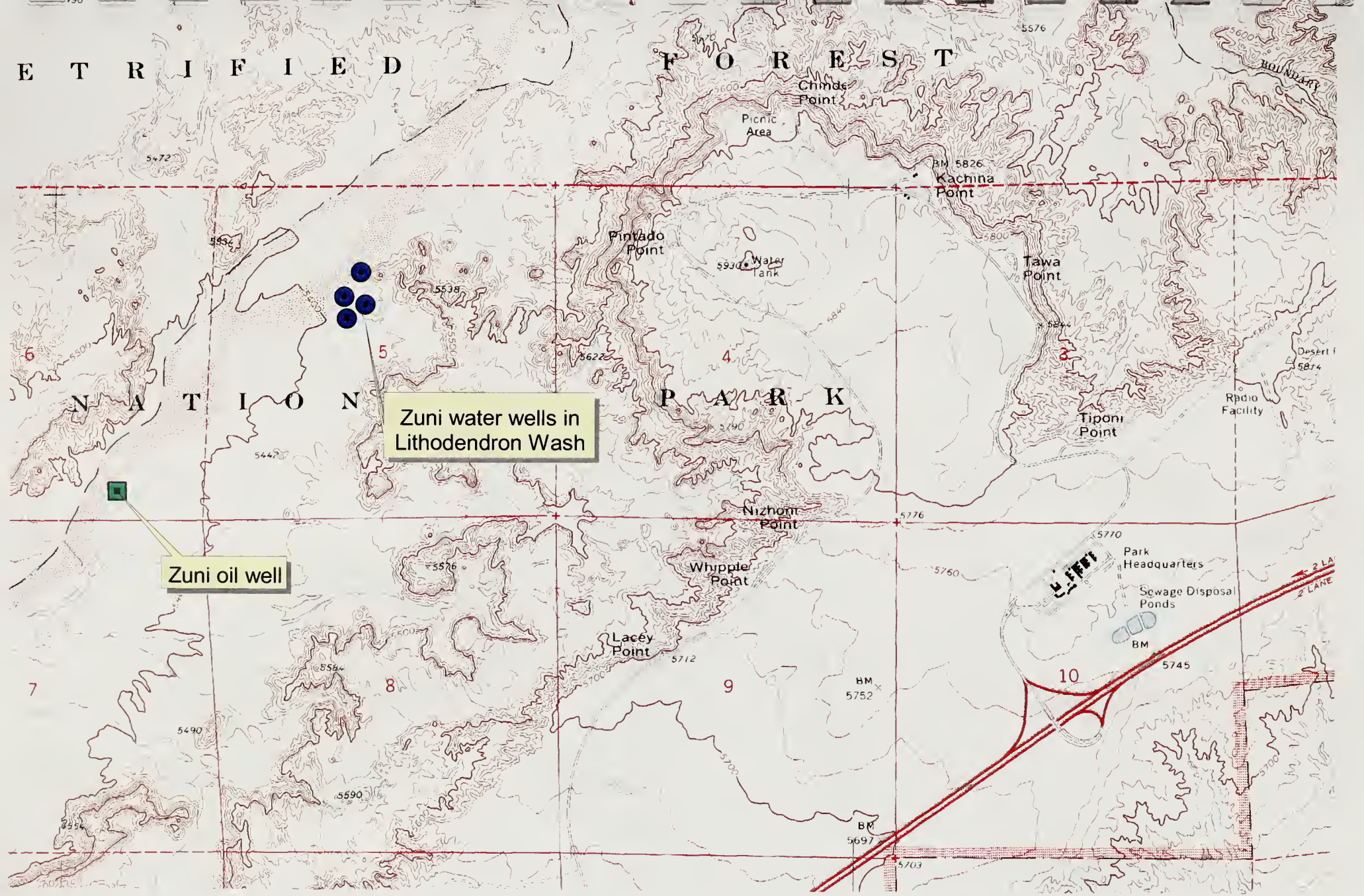



**Figure 2. Wells in the Painted Desert Area, Petrified Forest National Park**


**Figure 3. Wells at the Puerco River, Petrified Forest National Park**


**Figure 4. Location of Agate Bridge Well, Petrified Forest National Park**

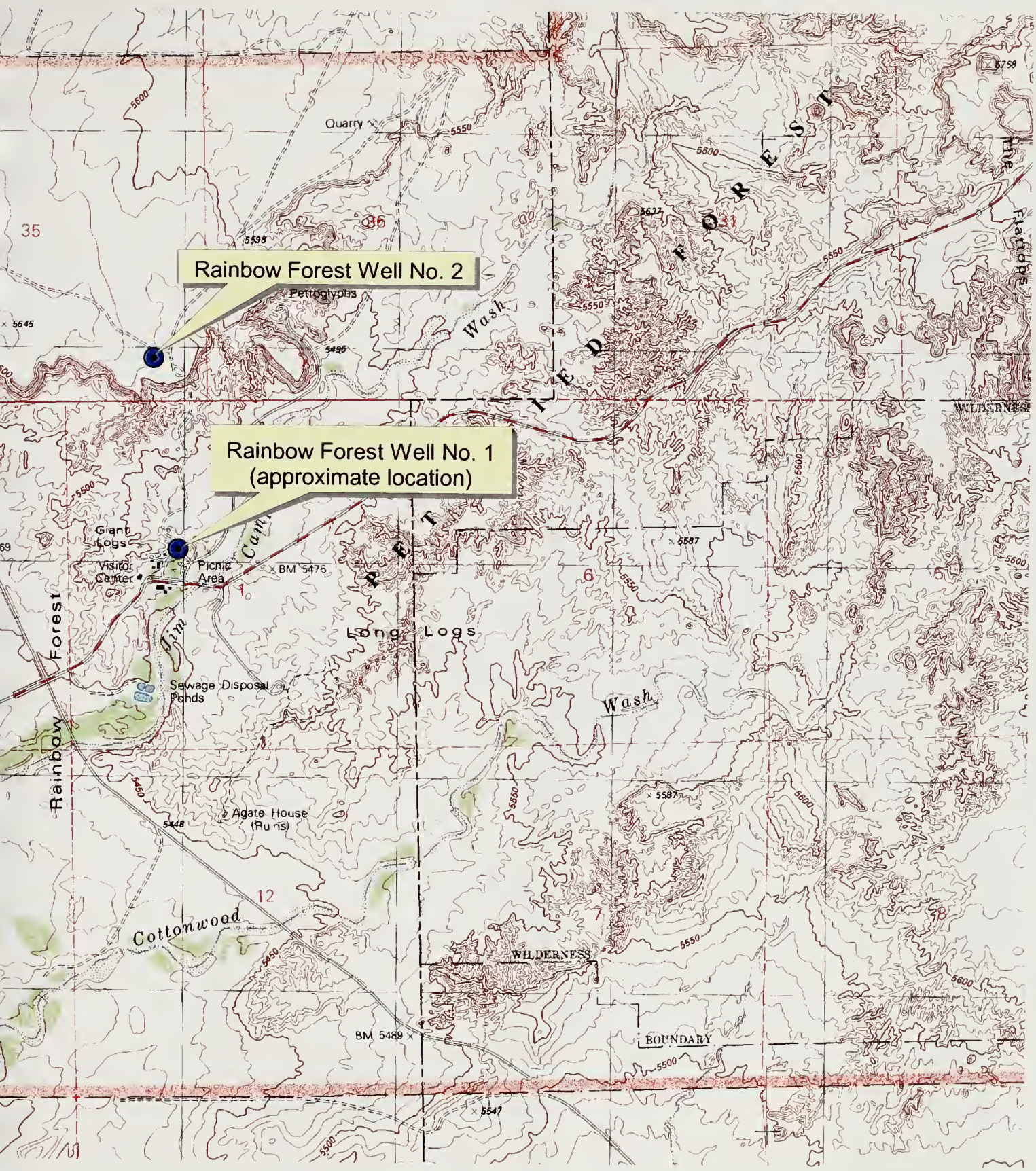
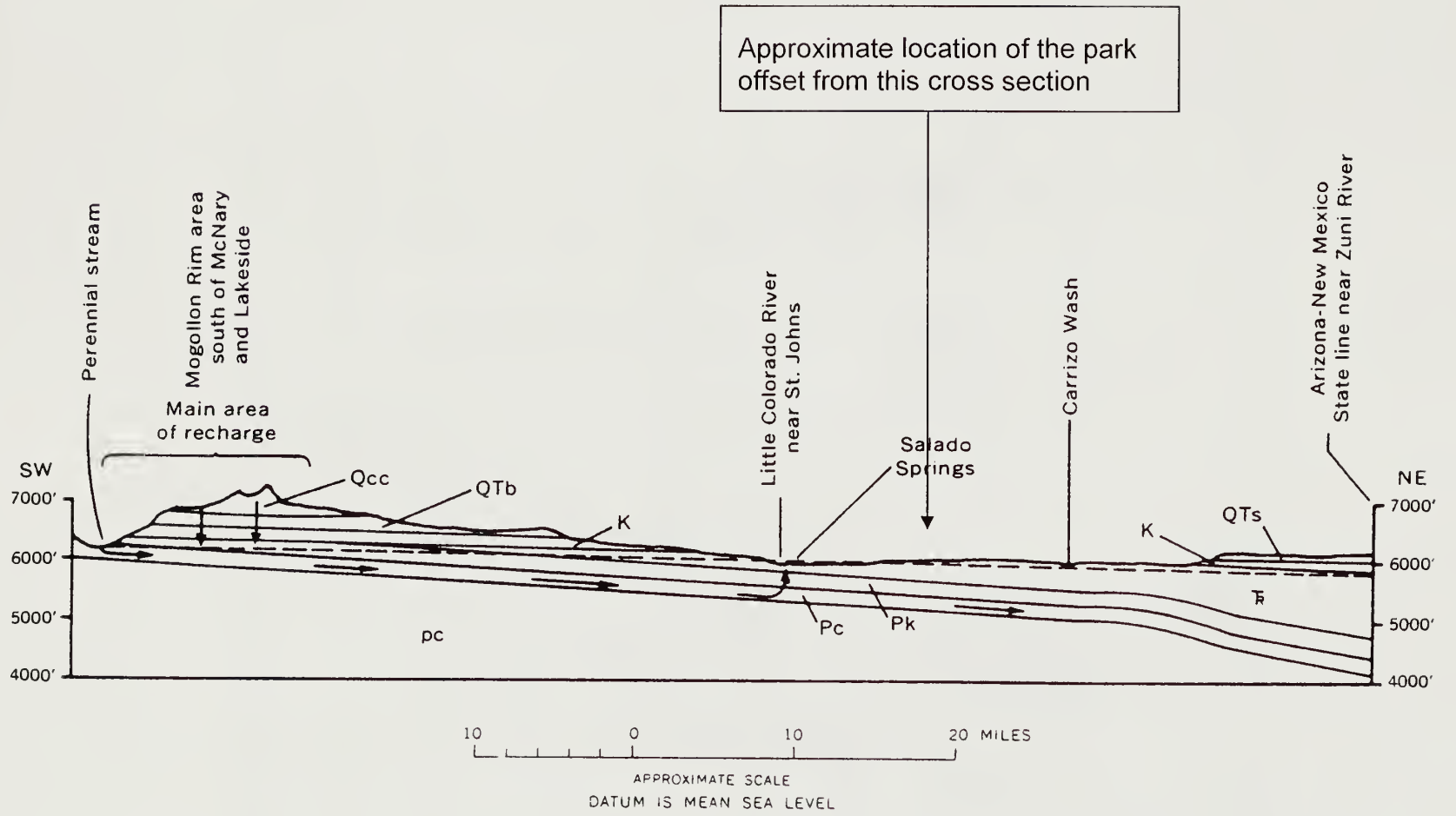



**Figure 5. Location of Wells in the Rainbow Forest Area, Petrified Forest National Park**




From Akers (1964)

Figure 6. Cross section showing general groundwater flow patterns in the Coconino Sandstone in the vicinity of Petrified Forest National Park (from Akers, 1964). Direction of groundwater flow is shown by arrows. The dashed line is the piezometric surface of the Coconino Aquifer. Geologic formations shown on this cross section are; Kaibab Limestone (Pk), Coconino Sandstone (Pc), Quaternary cinder-cone deposits (Qcc), basalt of Quaternary and Tertiary (QTb), Quaternary and Tertiary sediments (QTs), Cretaceous rocks (K), Triassic rocks (TR), and rocks older than Coconino Sandstone (pc).

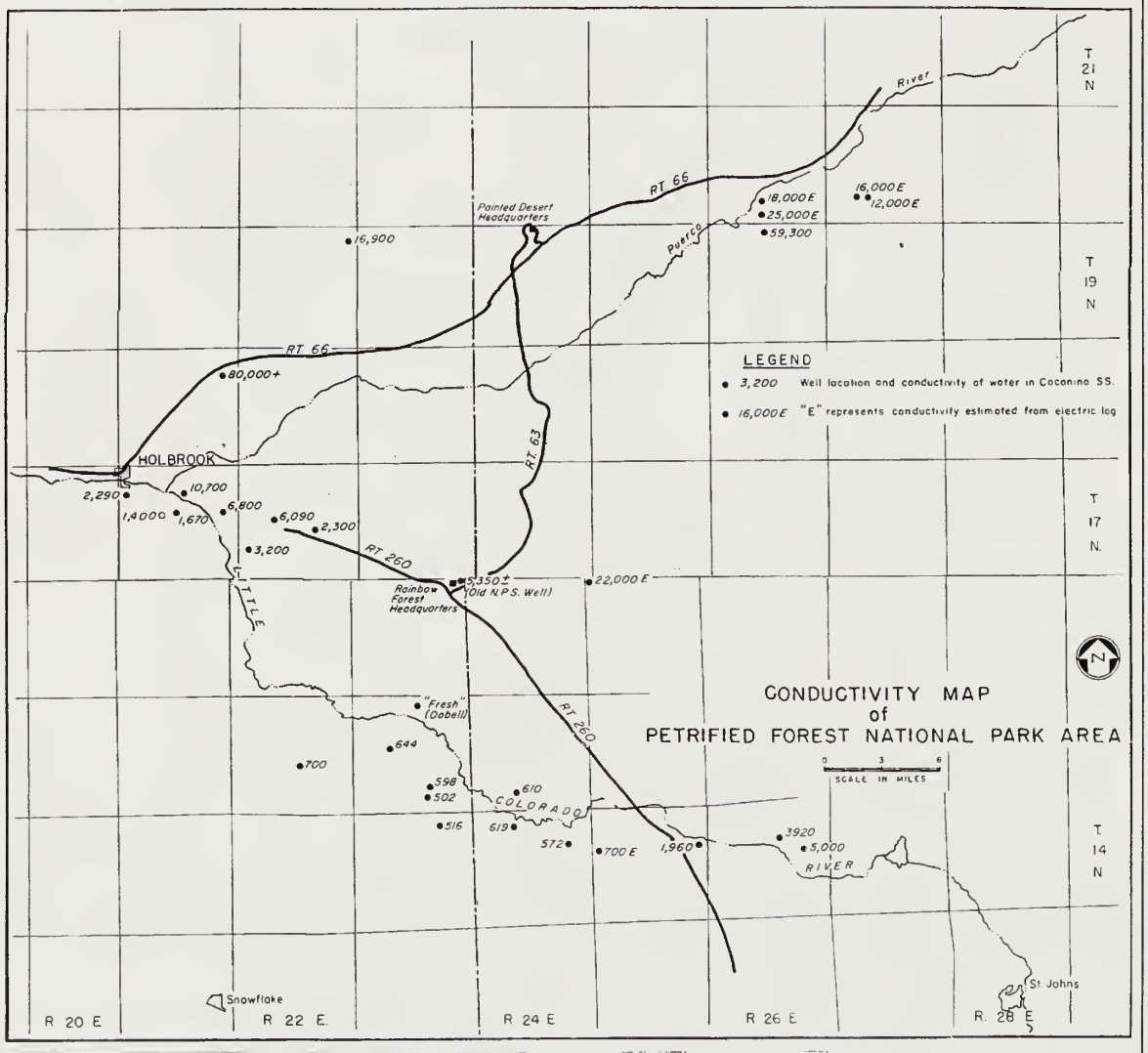



Figure 7. Map showing conductivity of groundwater in the Coconino Sandstone in the vicinity of Petrified Forest National Park (from Gray, 1968).

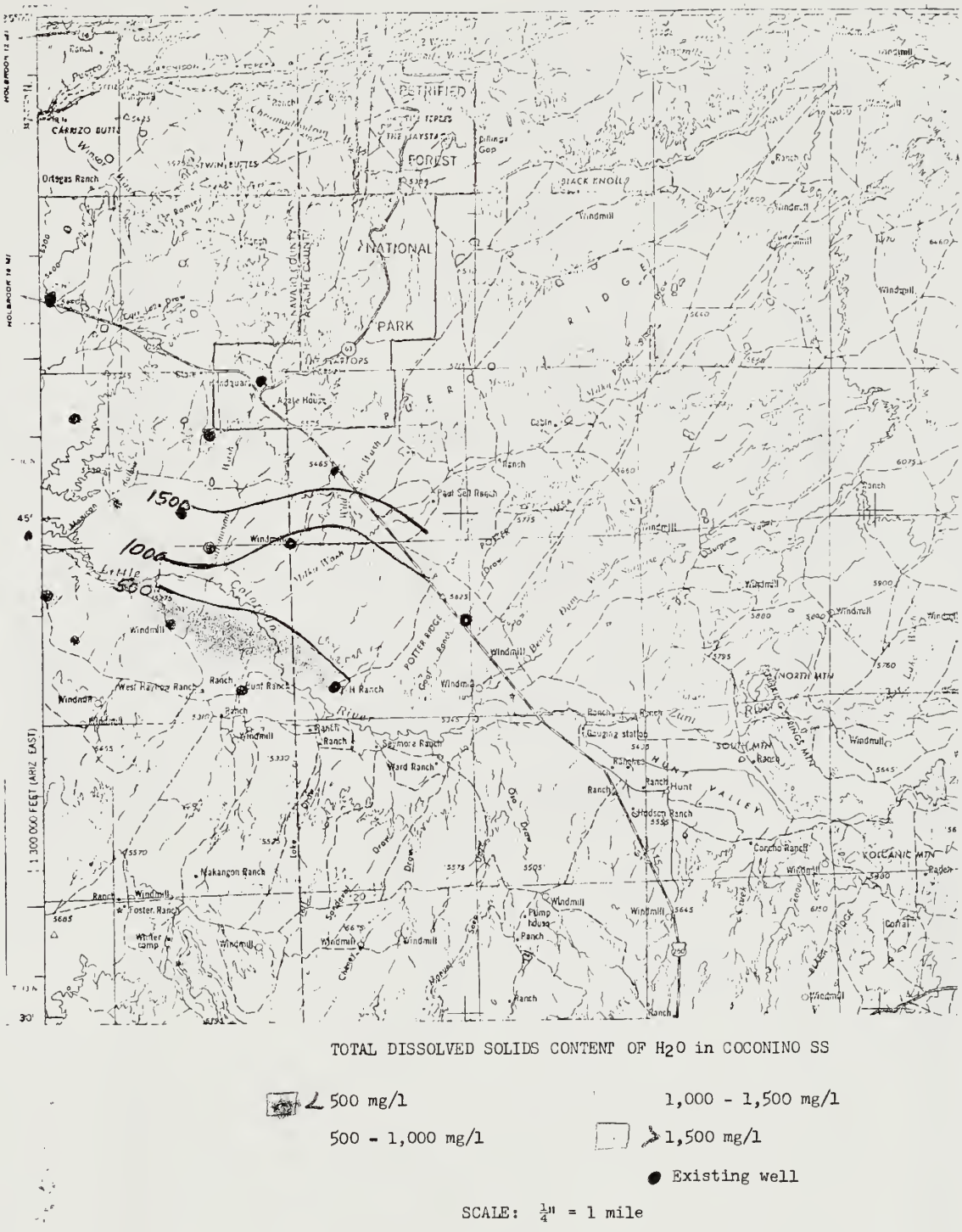



Figure 8. Map showing increasing conductivity of groundwater in the Coconino Aquifer northward from the Little Colorado River (from Witucki, 1972).

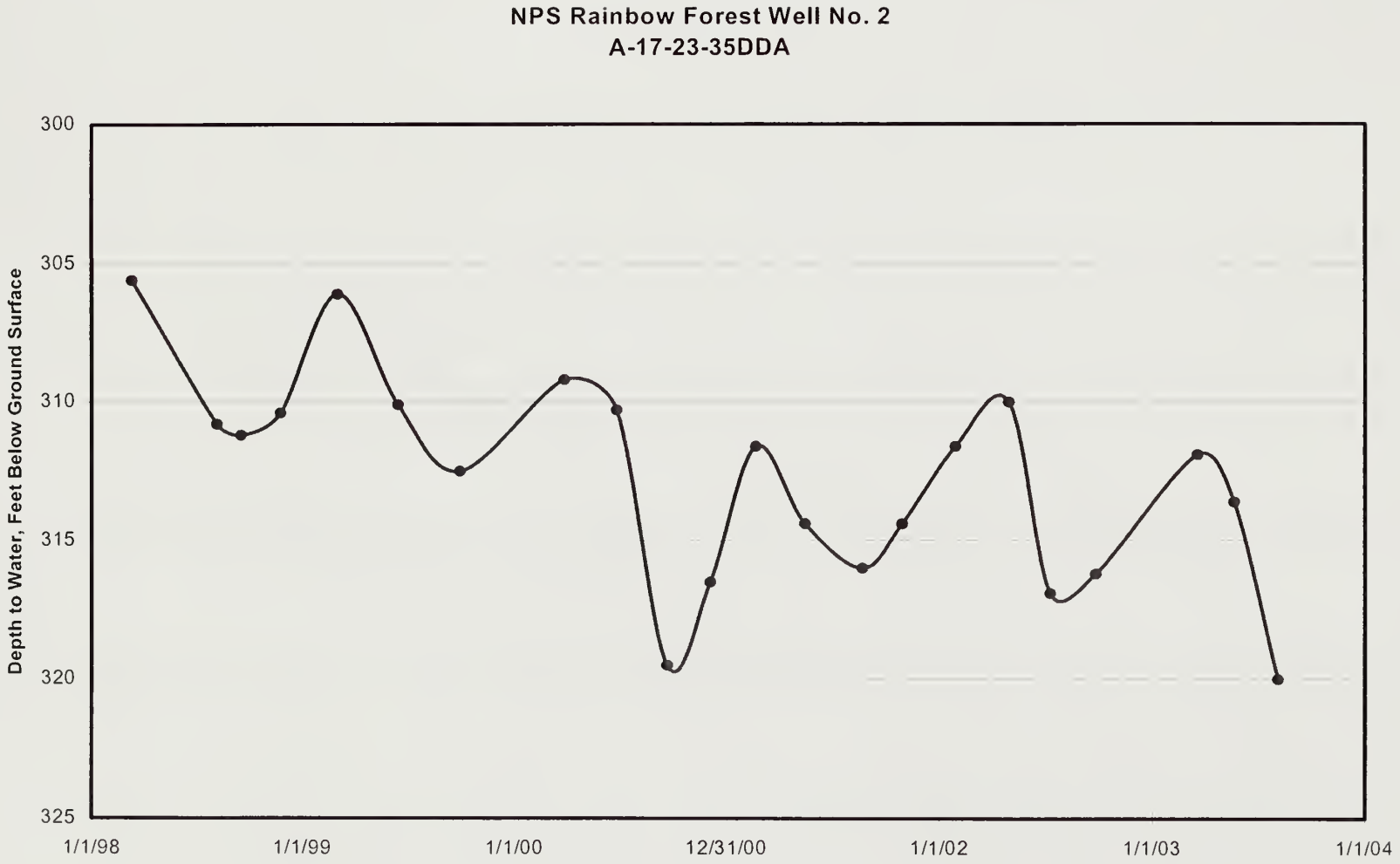



Figure 9. Hydrograph for Rainbow Forest Well No. 2

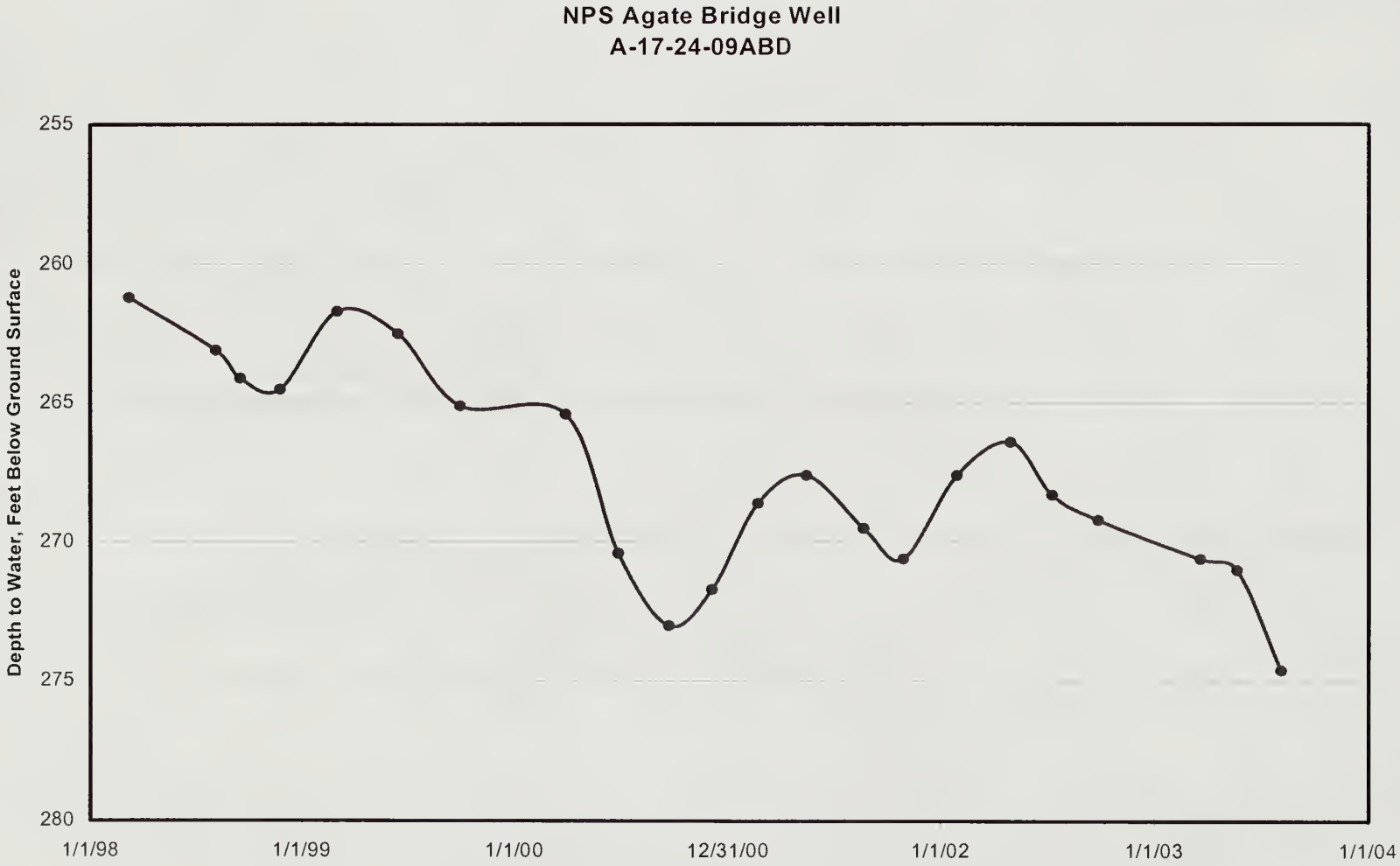



Figure 10. Hydrograph for Agate Bridge Well