WATER SUPPLIES
FOR
COULEE DAM
NATIONAL RECREATION AREA
WASHINGTON

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
1969

OPEN-FILE REPORT

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By

Henry W. Anderson, Jr.

Prepared in cooperation with the
National Park Service

OPEN-FILE REPORT

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WATER SUPPLIES FOR COULEE DAM NATIONAL RECREATION AREA, WASHINGTON

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ABSTRACT

Because of a planned expansion of campground facilities at Coulee Dam National Recreation Area the National Park Service requested the U.S. Geological Survey to aid in investigating the availability of additional water supplies and assist in their development. A general evaluation was made of the overall water resources of the recreation area, and potential water supplies were located and described in detail at several campgrounds where expansion of facilities is anticipated.

Although surface water is available from streams at several campgrounds and from Franklin D. Roosevelt Lake at all sites, the treatment required of surface-water supplies makes ground water a preferred source. For this reason this report emphasizes the occurrence and availability of ground water.

Most ground water in Coulee Dam National Recreation Area is available from unconsolidated deposits that formed glacial-lake deltas and glacial outwash in Pleistocene time. Ground water may possibly be available from the bedrock which includes basalt of the Columbia River Group of Miocene-Pliocene age in the southern part of the area, and the Northport Limestone of Cambrian age in the northern part of the area.

The project included an evaluation of the water-supply potential at 35 campgrounds and picnic areas. Ground-water supplies were obtained by production wells drilled at four sites. The investigation further indicated that ground water

could be obtained at each of eight other campgrounds where a detailed study was made, and that supplies could be obtained at most of the other 23 campgrounds in the project area.

The chemical quality of ground water in most of the area is good, except for being hard and, in some places, having a high iron content. Water from one well contained twice the recommended limit of dissolved solids as well as excessively high sulfate.

INTRODUCTION

Purpose and Scope

The planned expansion of campgrounds and picnic areas at Coulee Dam National Recreation Area resulted in a request by the National Park Service that the U.S. Geological Survey aid in investigating the availability of additional water supplies and assist in their development. To assist the Park Service in its objective to keep pace with the public demand for more and more recreation facilities, a general evaluation was made of the overall water resources of the recreation area. Also, at several campgrounds where expansion of facilities is anticipated, potential water supplies were located and described in detail.

Both surface- and ground-water sources were investigated. The surface-water examination included measurements of low flows of 17 streams and estimates of 32 others. However, because the U.S. Public Health Service requires that the Park Service filter all surface-water supplies, thus increasing the cost of using surface water, emphasis in this study was placed on ground-water supplies. The ground-water investigation consisted of a general geologic and hydrologic reconnaissance of the area as a whole, with emphasis on the 35 campgrounds or areas of public use. Test holes were augered at seven campgrounds, and production wells were drilled at four.

Location

Coulee Dam National Recreation Area, in northeastern Washington, includes Franklin D. Roosevelt Lake (the reservoir behind Grand Coulee Dam) and lands immediately adjacent to the lake. The lake extends from the dam eastward about 40 miles to the mouth of the Spokane River, then northward about 90 miles almost to the Canadian border (fig. 1). The entire shoreline of the lake, including drowned valleys of tributaries, is about 660 miles long. Sanpoil Bay, the drowned valley of the Sanpoil River, is about 8 miles long, the Spokane River arm is about 30 miles long, and the Kettle River arm is about 8 miles long. The property under administration of the National Park Service extends, in most places, to an altitude 20 feet above high lake level, which is 1,290 feet.

Because Franklin D. Roosevelt Lake is a multipurpose reservoir, its stage must fluctuate in response to demands for power and for flood control. Normally, the level fluctuates about 40 feet, between altitudes of 1,250 and 1,290 feet. From June to September, when the recreation area has the most visitors and the greatest water demand from wells, the lake level is usually at about an altitude of 1,290 feet. Therefore, when a reference in this report is made to lake level, an altitude of 1,290 feet is implied.

Previous Investigations

The geology of various parts of the Coulee Dam National Recreation Area has been described in earlier publications. Figure 2 indicates the areas mapped geologically by various authors and the publications in which their reports appear. In addition to the geologic mapping indicated in figure 2, earlier reports describe local glacial features (Flint, 1936; Bretz and others, 1956, 1959; and Richmond and others, 1965), and landslides along the Columbia River valley and some related geology (Jones and others, 1961). Previous hydrologic work near the area was limited to the evaluation of water supplies for Inchelium in an administrative report by Grolier of the U.S. Geological Survey (unpub. data). Ground-water conditions for Laurier and Ferry border stations also were reported (Walters, 1960).

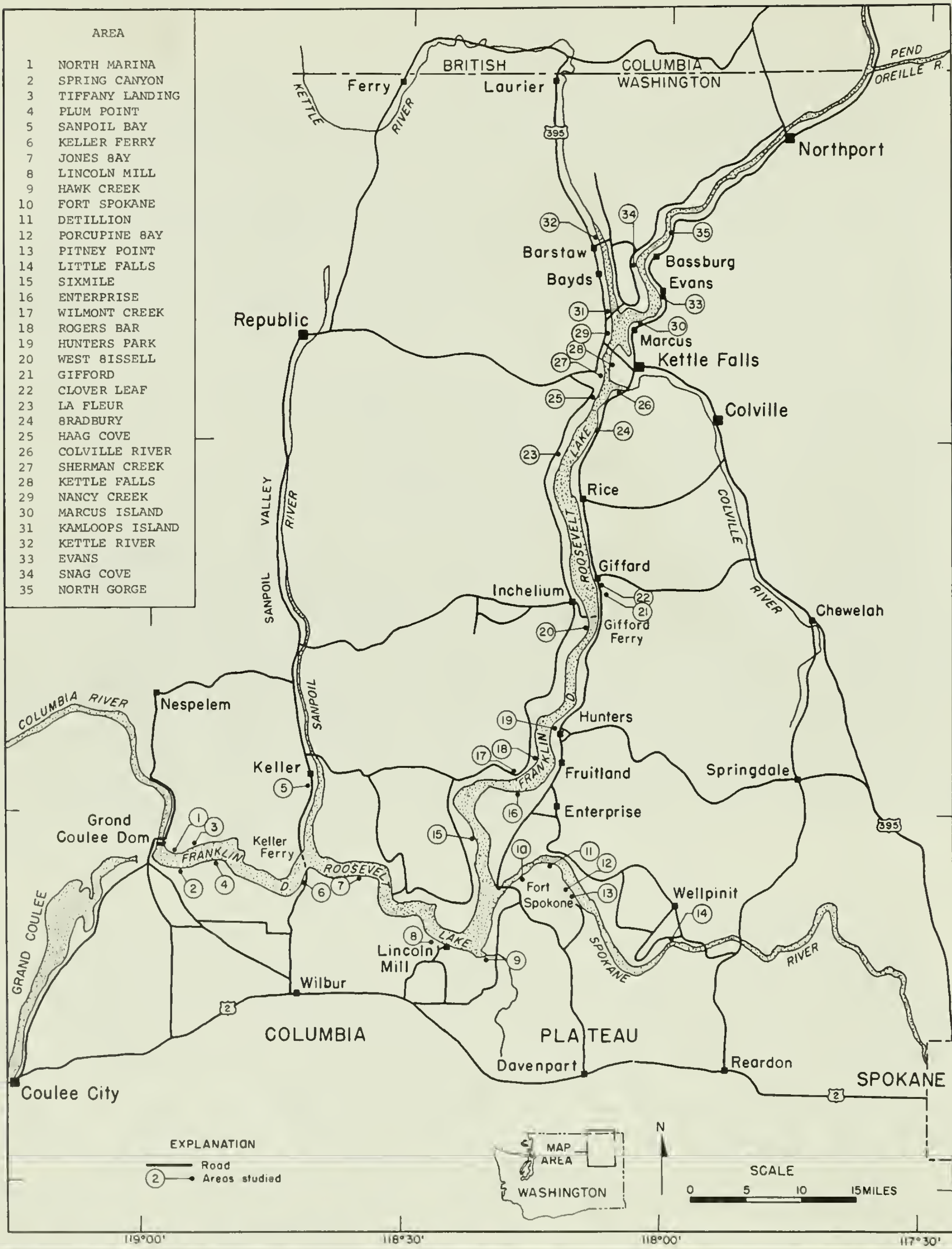

FIGURE 1.--Locations of campgrounds and picnic areas, Coulee Dam National Recreation Area, Washington.

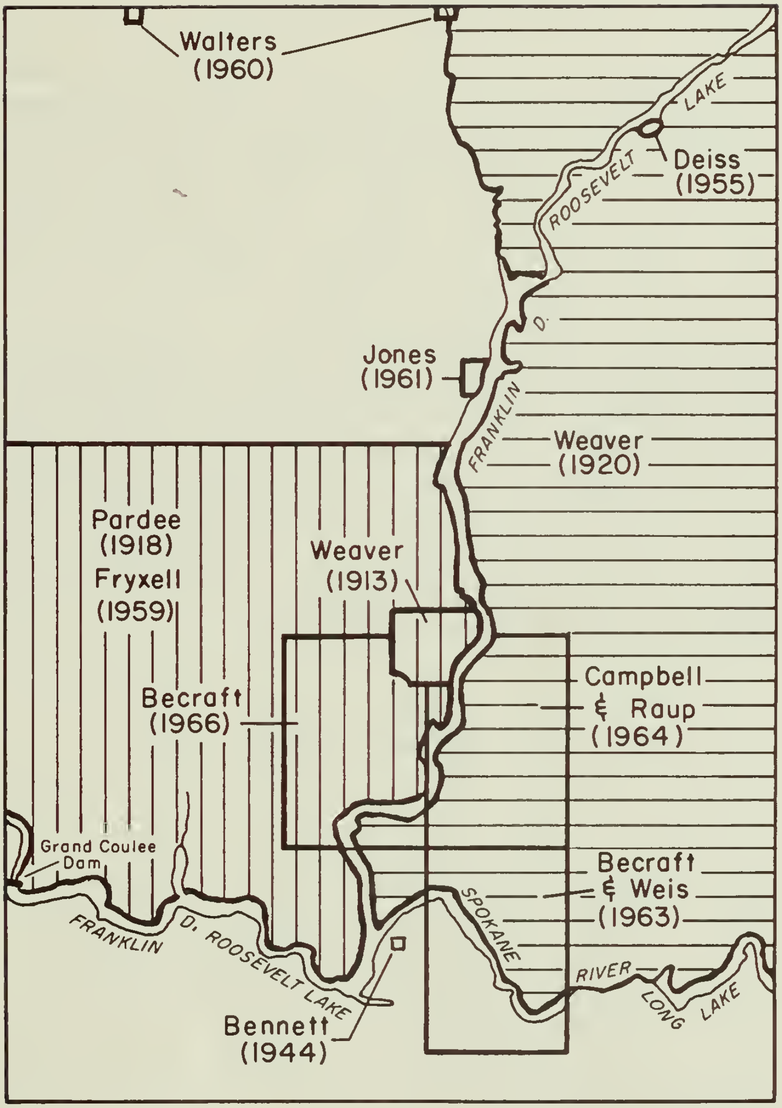

FIGURE 2.--Index to previous geologic investigations in various parts of Coulee Dam National Recreation Area.

Acknowledgments

This investigation was made and the report prepared under the general supervision of L. B. Laird, district chief, Water Resources Division, U.S. Geological Survey, and under the immediate supervision of A. A. Garrett. H. W. Robinson, Superintendent of Coulee Dam National Recreation Area, and H. H. Chapman who succeeded Mr. Robinson upon his retirement, and employees of the National Park Service at Coulee Dam National Recreation Area rendered valuable assistance in all phases of the investigation. Roald Fryxell, geologist, Department of Anthropology, Washington State University at Pullman, and A. E. Caswell, geologist, U.S. Bureau of Reclamation, Ephrata, Wash., were very helpful in discussing the geology of northeastern Washington with the writer. Technical review of the manuscript by Allen Sinnott and K. L. Walters of the Geological Survey provided suggestions that were of benefit to the final report.

Topography and Drainage

The project area lies on the boundary of two strikingly different physiographic subdivisions--the mountainous highlands to the north and the nearly flat Columbia Plateau to the south. The boundary between these subdivisions, with minor exceptions, follows the general westward trend of the Spokane and Columbia Rivers (fig. 1). The plateau on the south is a part of the vast lava plain that spreads over a large part of the Pacific Northwest. The highlands that lie north of the boundary are made up of south-trending valleys between low, subparallel mountain ranges. The principal south-trending valley is occupied by the Columbia and Kettle Rivers.

The major drainage in the northern part of the project area is southward. This drainage continues to the edge of the Columbia basalt plateau where it is diverted to the west.

Precipitation

The project area experiences the low rainfall that is characteristic of much of the State of Washington east of the Cascade Mountains. Precipitation in the area of study increases from the southwest toward the northeast. At Coulee Dam the average precipitation is about 10 inches per year, at Inchelium about 16½ inches, and at Northport about 19½ inches.

SURFACE WATER

In Coulee Dam National Recreation Area surface water is available both from streams tributary to Franklin D. Roosevelt Lake and from the lake itself. Low flow was measured or estimated in 49 tributary streams, and 25 dry stream channels also were noted (table 1). Only five of the existing campgrounds are adjacent to streams whose low flows are adequate for campground use. Water samples collected from 22 streams were tested by the Washington State Department of Health for coliform organisms. Analyses of all five of the 10-milliliter portions from each sample showed the presence of the coliform group (U.S. Public Health Service, 1962, p. 5), and each water sample was indicated by the State Department of Health as bacteriologically unsatisfactory without treatment.

Lake water is accessible at all campground areas, inasmuch as the recreation area was established to include all land adjacent to Roosevelt Lake. R. T. Gale, Park Ranger, reported that on several occasions he sent lake-water samples to the Washington State Department of Health for bacteriological examination. In each instance the report indicated the water was uncontaminated. In spite of this favorable report, lake water is not considered a preferred water supply because of possible future contamination. In reference to a study at Pend Oreille Lake, Dr. C. H. Drake, professor of bacteriology, Washington State University (oral commun., 1967) commented on the potential hazard of using untreated lake water. Although bacteria counts on water samples from Pend Oreille Lake indicated negligible numbers of coliform bacteria, there was an observable increase in numbers of coliform organisms at the opening of fishing season. This increase was apparently related to the increase in the number of boats being used on the lake, and indicates the susceptibility of lake water to contamination.

TABLE 1.--Data on selected streams discharging into Franklin D. Roosevelt Lake[a]

Stream	Location				Discharge (cfs) estimate (e)	Date	Coliform organisms present
	Township	Range	Section	Side of lake [b]			
Columbia River main stem (Roosevelt Lake)							
Onion Cr	39	39	23	(L)	3e	9-15-65	
Rattlesnake Cr	39	39	19	(R)	.04e	9-15-65	
Crown Cr	39	38	25	(R)	4e	9-15-65	Positive
Ryan Cr	38	39	7	(L)	dry	9-15-65	
Flat Cr	38	38	4	(R)	1e	9-15-65	Positive
Fifteenmile Cr	38	38	4	(R)	2e	9-15-65	Positive
Unnamed cr	38	38	8	(R)	.04e	9-15-65	Positive
Unnamed cr	38	38	19	(R)	.004e	9-15-65	
Unnamed cr	38	37	25	(R)	dry	9-15-65	
China Cr [d]	37	38	18	(L)	dry	9-15-65	
Kettle River arm							
Hodgson Cr	38	37	29	(R)	.04e	9-15-65	
Doyle Cr	38	37	32	(R)	1e	9-15-65	
Mattson Cr	37	37	5	(R)	.22e	9-15-65	
Unnamed cr	37	37	9	(L)	dry	9-15-65	
Unnamed cr	37	37	17	(L)	dry	9-15-65	
Deadman Cr	37	37	17	(R)	3-5e	9-15-65	

Columbia River main stem (Roosevelt Lake)

Nancy Cr	37	37	33	(R)	1e	9-15-65	
Pingston Cr	36	38	6	(L)	dry	9-15-65	
Sherman Cr d/	36	37	27	(R)	10e	9-16-65	Positive
Roper Cr	35	37	9	(R)	.01e	9-13-65	
Mink Cr	35	37	9	(R)	.04e	9-13-65	
La Fleur Cr d/	35	37	31	(R)	.06e	9-13-65	
Quillisascut Cr	34	37	18	(L)	.7e	9-13-65	Positive
Cobbs Cr	33	37	31	(R)	.2e	9-13-65	
Hall Cr	32	36	1	(R)	12e	9-13-65	Positive
Stranger Cr d/	32	37	3	(L)	1e	9-13-65	
Stranger Cr	32	37	7	(R)	10e	9-13-65	
Deer Cr	32	37	15	(L)	dry	9-14-65	
Unnamed cr	32	37	31	(R)	dry	9-14-65	
Unnamed cr	31	36	12	(R)	.7e	9-14-65	
Unnamed cr	31	36	13	(R)	.06e	9-14-65	
Harvey Cr	31	37	29	(L)	.07e	9-14-65	
Nez Perce Cr	31	36	26	(R)	.2e	9-14-65	Positive
Falls Cr	31	36	34	(R)	.06e	9-14-65	
Coyote Cr	30	36	3	(R)	.03e	9-14-65	
Monaghan Cr	30	36	22	(R)	.15	9- 9-65	Positive
Alder Cr	30	36	24	(L)	1.62	9- 9-65	Positive
O-Ra-Pak-En Cr d/	29	36	2	(L)	2.37	9-10-65	
Wilmont Cr d/	30	36	31	(R)	1.39	9- 9-65	Positive
Glasgow Canyon cr	29	36	4	(L)	dry	9-10-65	
Unnamed springs	29	36	5	(L)	.01	9-10-65	
Corkscrew Canyon cr	29	35	1	(L)	dry	9-10-65	
Little Ninemile Cr	29	35	16	(R)	2.45	9- 9-65	Positive
Unnamed cr	29	35	23	(L)	.06e	9-10-65	
Unnamed cr	29	35	25	(L)	.12	9-10-65	
Unnamed cr	29	35	25	(L)	dry	9-10-65	
Unnamed cr	29	35	25	(L)	(trickle) dry	9-10-65	

TABLE 1.--Data on selected streams discharging into Franklin D. Roosevelt Lake[a]--Con.

Stream	Location				Discharge (cfs) estimate (e)	Date	Coliform organisms present
	Township	Range	Section	Side of lake b/			
Columbia River main stem (Roosevelt Lake)--Con.							
Sixmile Cr d/	29	35	34	(R)	0.08	9- 9-65	Positive
Castle Rock Cr	29	36	31	(L)	.05	9-10-65	
Cottonwood Cr	28	35	2	(R)	dry	9- 9-65	
Unnamed cr	28	35	1	(L)	(trickle)	9-10-65	
Unnamed cr	28	35	12	(L)	dry	9-10-65	
Threemile Cr	28	35	11	(R)	dry	9- 9-65	
Spokane River arm							
Mill Canyon cr	27	38	31	(L)	.2e	9- 8-65	
Harker Canyon cr	27	37	36	(L)	(bed wet) dry	9- 8-65	
Unnamed cr	27	37	23	(L)	.1e	9- 8-65	
Unnamed cr	27	37	24	(R)	dry	9- 8-65	
Unnamed cr	27	37	23	(L)	.1e	9- 8-65	
Unnamed cr	27	37	11	(R)	dry	9- 8-65	
Unnamed cr	27	37	11	(R)	dry	9- 8-65	
Green Canyon cr	28	37	33	(L)	.41	9- 8-65	Positive
Pitney Cr d/	28	37	33	(L)	.11	9- 8-65	Positive
Blue Cr	28	37	27	(R)	.03	9- 8-65	Positive
Unnamed cr near Porcupine Bay	28	37	29	(L)	.08	9- 8-65	Positive
Sand Cr	28	37	20	(R)	dry	9- 8-65	
Hollies Cr	28	37	19	(L)	dry	9- 8-65	
Orazada Cr	28	37	7	(R)	.51	9- 8-65	Positive

Columbia River main stem (Roosevelt Lake)							
Hawk Cr d/	27	36	30	(L)	c/1,010	1-24-59	
Sanpoil River arm							
Sanpoil River	30	33	20	(R)	--	9- 7-65	Positive
Copper Cr	30	33	28	(L)	.2e	9- 7-65	
Silver Cr	30	33	33	(L)	.14	9- 7-65	Positive
John Tom Cr	29	33	9	(L)	.08	9- 7-65	Positive
Dick Cr	29	33	16	(L)	dry	9- 7-65	
Manila Cr	29	33	18	(R)	.47	9- 7-65	Positive
Unnamed cr	29	33	32	(L)	dry	9- 7-65	
Columbia River main stem (Roosevelt Lake)							
Neal Canyon cr	28	32	19	(L)	dry	9- 7-65	

a/ Listed in downstream order from head of lake and tributary arms.

b/ Letter in parentheses denotes side of river (Franklin D. Roosevelt Lake), looking downstream: L, left shore; R, right shore.

c/ Peak flow (Hawk Cr).

d/ Named stream shown on small campground-area maps; other streams not shown on maps within report.

GROUND WATER

Geologic Setting

The occurrence of ground water in the project area is partly controlled by the character, distribution, and structure of the rocks of the region. The geologic setting is presented here as a background for discussion of ground-water occurrence. The discussion of glacial history is based largely on a study by Richmond and others (1965).

The oldest rocks in the area are represented largely by the metasedimentary argillite or phyllite, dolomitic limestone, and quartzite of Precambrian and Paleozoic age. During Cretaceous time, extensive igneous activity resulted in the emplacement of the Loon Lake Granite (Weaver, 1920) and related intrusive rocks. This was followed by volcanism in the Tertiary Period. In Oligocene time, according to Becraft and Weis (1963), flows, pyroclastics, and intrusive rocks formed the Gerome Andesite. During Miocene and Pliocene time basalt of the Columbia River Group flowed into the area from the south, partly filling the southward trending valleys. This blocked the drainage of the ancestral Columbia River, forcing it to take a route to the west around the edge of the basalt field. The present course of the Columbia River in this reach was established mainly at that time.

Deposits of Pleistocene age exposed in the recreation area indicate three separate advances of the Cordilleran Ice Sheet. The maximum advance recognized in this area occurred during the Bull Lake Glaciation (Richmond and others, 1965, p. 235). Also found along Roosevelt Lake are deposits representing two advances of glacial ice during the Pinedale Glaciation.

During each of these glacial advances, three lobes of the ice sheet moved into the project area, following the main river valleys--the Okanogan, the Sanpoil, and the Columbia (fig. 3). The Okanogan Lobe, the largest in the project area formed an ice dam at the present location of Grand Coulee Dam on at least three occasions. First, during the Bull Lake Glaciation, it dammed waters of the ancestral Columbia River to an altitude of 2,350 feet to form Glacial

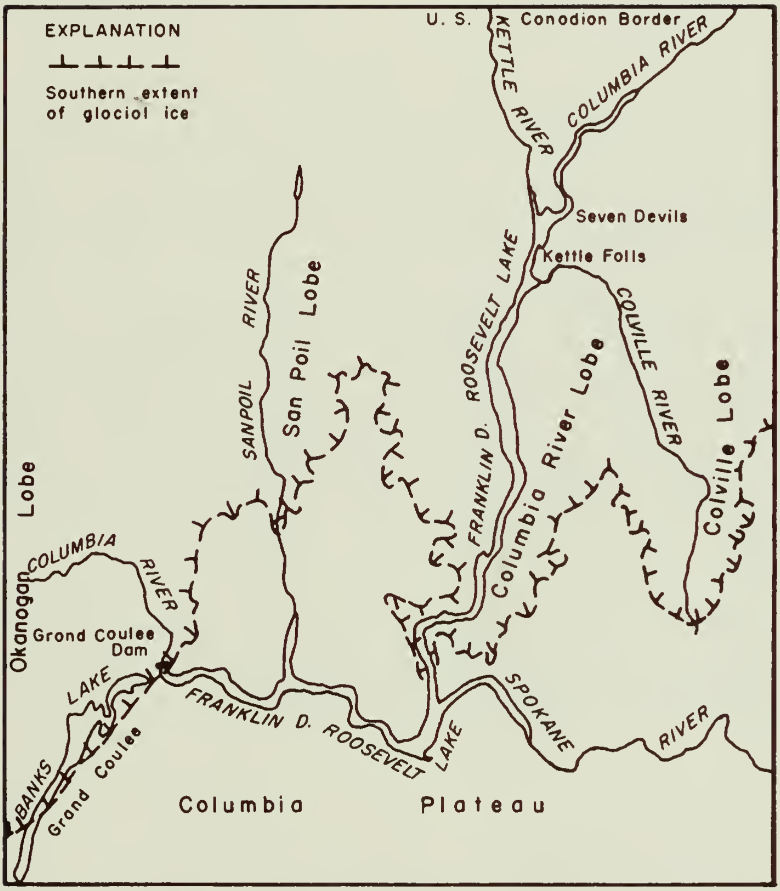

FIGURE 3.--Maximum southern extent of glacial ice during Pinedale Glaciation. After Richmond and others (1965, p. 232).

Lake Columbia. Second, during the early stage of the Pinedale Glaciation, Glacial Lake Columbia was filled to an altitude of 1,950 feet. Third, during middle Pinedale time the glacial lake was filled to an altitude of about 1,800-1,950 feet.

The main drainage from the glacial lake formed waterfalls which eroded headward toward the lake, forming the present Grand Coulee and lowering the lake level from an altitude of about 2,350 feet to 1,800 or 1,900 feet, and then to about 1,700 feet. The various lake levels are recorded by terraces on the valley wall above Roosevelt Lake. As the Okanogan Lobe of each glaciation receded, water began to find its way down the preglacial Columbia River channel around the ice front. During this retreat, stillstands of ice stabilized the level of the glacial lake, resulting in the formation of terraces. The last time the glacial lake was filled (middle Pinedale time), extensive terraces formed at altitudes of about 1,300, 1,400, 1,700, and 1,800 feet.

The presence of the San Poil Lobe during either the Bull Lake or Pinedale Glaciations, a short distance north of what is now the recreation area, is recorded by coarse, poorly sorted outwash deposits along the shore of Sanpoil Bay.

The Columbia River Lobe, during Bull Lake time, crossed the Spokane River and abutted the margin of the Columbia Plateau. During both early and middle Pinedale time, it left moraines just north of the Spokane River. The end moraine of the early stage is overlain by flood deposits at the 2,480-foot altitude.

The Columbia River Lobe, during middle Pinedale time, removed most of the earlier glacial deposits in the northern part of the area. Glacial-lake terraces at the 1,800-foot altitude as far north as the Canadian border indicate that the Columbia River Lobe had retreated north of the border before the glacial lake was lowered below this level.

Glacial Lake Columbia became nearly filled with silt each time it formed and deposits from tributary valleys formed deltas contemporaneously with the silting in of the lake. The deltas are indicated by coarser materials commonly found interbedded with glacial-lake silt and clay. As the outlet of Glacial Lake Columbia dropped to progressively lower altitudes, streams cut channels deeply and quickly into the soft lacustrine sediments. As base level stabilized temporarily, coarser fluvial deposits were laid down in the channels, only to be partly or totally removed by erosion following subsequent lowering of base level.

Probably even before Glacial Lake Columbia was finally drained by the retreat of the Okanogan Lobe, rapid erosion of the Columbia River channel caused extensive large-scale landslides in the lacustrine deposits. Remnants of these landslides, some as much as 2 miles long, are seen along the Columbia River valley north of the mouth of the Spokane River.

The presence of 1,800-foot and 1,400-foot middle Pinedale terraces at the Canadian border indicates that the Columbia River Lobe did not extend that far south during late Pinedale time. Thus it is clear that the Columbia River and its tributaries have continued downcutting action since the end of middle Pinedale time.

Geologic Units and Their Water-Bearing Characteristics

Most of the ground water available in Coulee Dam National Recreation Area is from the unconsolidated Pleistocene deposits, although at a few campgrounds the igneous or metamorphic bedrock may contain water. The Pleistocene deposits were laid down similarly during and subsequent to each glaciation: glacial-lake deltas, outwash, flood gravel, glacial-lake silt and clay, till, and landslide debris.

The bedrock and these unconsolidated deposits and their water-yielding characteristics are discussed here by rock type.

Bedrock

Bedrock with water-yielding potential is discussed under two headings, basaltic rocks and limestone. The bedrock with little water-yielding potential is discussed under a third heading, granite and miscellaneous metamorphic rocks.

Basaltic rocks.--Two basaltic units occur in the area, the Gerome Andesite, and basalt of the Columbia River Group. The Gerome Andesite crops out in numerous isolated localities along Roosevelt Lake, particularly between the Spokane River and the Colville River. The impermeable andesite is not a potential aquifer in the project area.

In the Columbia Plateau province south of the project area basalt of the Columbia River Group is the main aquifer but the decreased thickness of the basalt beneath the recreation area reduces its importance as an aquifer. However, interflow zones in the basalt which yield water in the Davenport area south of Roosevelt Lake may be present in the Hawk Creek area.

Limestone.--The area north of Kettle Falls is possibly the only one in the project area underlain by a limestone aquifer. A dolomitic limestone described as the Northport Limestone by Weaver (1920, p. 76) is tapped by the well serving the town of Marcus. This formation crops out near several campgrounds, such as Marcus Island, Evans, and North Gorge, and water possibly may be obtained from it at any of these campgrounds. The limestone may also occur at Nancy Creek, Snag Cove, and Kamloops Island campgrounds but its existence at these places has not been established. Although few wells near the recreation area obtain water from limestone, there are indications that the town well at Marcus does yield water from this aquifer.

Granite and miscellaneous metamorphic rocks.--Granite, argillite, and quartzite are widespread throughout the Coulee Dam National Recreation Area, but none of these rocks offer much promise as aquifers. However, where the granite surface has been weathered to a depth of several feet this weathered interval may provide small supplies locally. The weathered granite zone is tapped by numerous shallow wells near Wellpinit, which is just outside the recreation area north of the Spokane River (fig. 1).

Unconsolidated Deposits

Most aquifers developed in the recreation area are in unconsolidated deposits, in glacial-lake deltas and glacial outwash. The most widespread deposit within the recreation area is composed of glacial-lake silt and clay. The deposit has been distorted in many places by landslides, especially in the area north of the Spokane River. The aquifers in the unconsolidated deposits in the area probably receive some recharge from local precipitation and underflow from adjacent uplands, but water levels in those aquifers appear to be controlled primarily by Roosevelt Lake; ground-water levels in the project area fluctuate in response to changes in lake level.

Glacial-lake deltas.--Deltas occur where tributary streams reworked the glacial till and colluvium and carried sand and gravel into Glacial Lake Columbia. Some of the coarse deltaic materials are interbedded with fine silt and clay which settled out in Glacial Lake Columbia. As silt deposition continued, some of the deltas were buried, and coarse material was deposited farther upstream in the tributary channels. Spring Canyon, Sanpoil Bay, and Gifford are typical of campgrounds underlain by delta deposits.

Glacial outwash.--Where glacial-outwash deposits are below lake level and are free of silt and clay, they will yield large volumes of water.

Outwash deposits, both silty and silt-free, are present in the area north of Kettle Falls. Much of the outwash in that area is very silty, and has low permeability as seen at Marcus Island, Evans, and North Gorge campgrounds. Although silt-free outwash gravel is exposed at Nancy Creek and at Snag Cove, the thickness of these deposits is not known.

In the Columbia River valley between Kettle Falls and the mouth of the Spokane River arm of the lake, numerous outwash-channel deposits and remnants are exposed. The clean, coarse, channel deposits that occur below present lake level are excellent aquifers. Where such channel remnants are exposed at the surface they may indicate the positions of deeper, buried, outwash-filled channels. Remnants of channel deposits are present in several areas, such as at Keller Ferry, Jones Bay, Fort Spokane, Little Falls, West Bissell, and Rogers Bar campgrounds.

Most of the outwash deposits along Sanpoil Bay are silty and have low permeability. In campground areas near the west end of Roosevelt Lake, glacial-outwash deposits are generally thin and overlie granitic bedrock.

Bars of very coarse flood gravel, generally formed downstream from bedrock knobs, are exposed at several sites along the shore of the Spokane River arm of Roosevelt Lake and downstream along the main Columbia River channel, at such places as Plum Point, Detillion, and Porcupine Bay. Those coarse gravel deposits may extend well below lake level and probably would yield large supplies of ground water. Coarse gravel along the Spokane River provides water to the Fort Spokane well.

<u>Glacial-lake silt and clay</u>.--The fine-grained glacial-lake deposits are widespread, and are generally thick (as much as 600 feet or more). They are too fine grained to yield water to a well. Many of the campgrounds are on terraces of middle Pinedale age, formed on silt and clay at about 1,300 feet and again just above 1,400 feet. The wide distribution and great thickness of silt and clay conceals any underlying coarse water-bearing deposits, thereby causing problems in locating water supplies.

Glacial till.--Glacial till is exposed in various localities within Coulee Dam National Recreation Area, but especially along the northern part of the Columbia River valley. The till is generally of low permeability and extremely varied in thickness. At the Seven Devils area just north of Kettle Falls (fig. 3), it is at least 200 feet thick. Exposures of till are more commonly 10 to 20 feet in thickness. Till does not occur commonly near any of the developed campground sites and thus has little significance relevant to water supplies.

Landslide debris.--Landslides of gigantic proportions, as much as 2 miles long, occurred commonly during erosion of the glacial-lake silt and clay from the Columbia River valley, especially in the northern part of the Roosevelt Lake area. Several campground sites are located on debris of ancient landslides, such as at Nancy Creek, Haag Cove, West Bissell, Rogers Bar, Wilmont Creek, and Enterprise campgrounds along the north arm of the lake, and at Tiffany Landing near the west end of the lake. The landslides are mostly of the slump, earth-flow type described by Jones and others (1961, p. 6). Tilted, distorted bedding and terraces tilted downward away from the lake indicate rotated slump blocks. Hummocky surfaces in several areas may indicate earth flow. Because the ancient landslides disturbed the subsurface units, test drilling would be required to locate aquifers.

Water Supplies for the Recreation Area

As of 1968, 35 campgrounds and picnic areas in the Coulee Dam National Recreation Area had been developed to various degrees. Figure 1 indicates the approximate location of each area of development. Of these campgrounds 22 presently have water supplies; however, some supplies are considered inadequate for present or future park needs. New water supplies were obtained during the study at the following four campgrounds: Spring Canyon, Sanpoil Bay, Hunters Park, and Gifford.

TABLE 2.--Chemical analyses of water samples from wells and auger holes.

Well	Altitude of land surface (ft)	Well depth (ft)	Water level below land surface (ft)	Sample collection date	Water temperature (°C)	Water temperature (°F)	Milligrams per liter													Dissolved solids			Specific conductance (micromhos per cm at 25°C)	pH
							Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Orthophosphate (PO_4)	Residue at 180°C	Calculated	Hardness (as $CaCO_3$)		
Spring Canyon well	1,319	173	30.04	10-24-67	14	57	30	0.14	123	70	38	13	222	0	486	2.1	1.2	6.7	--	1,000	879	596	1,190	8.2
Sanpoil Bay well	1,304	205	13.90	10-17-67	11	51	21	.57	38	8.6	8.4	1.3	156	0	17	.4	.3	.3	--	183	172	131	286	7.8
Keller Ferry auger hole 4	1,305	55.5	14.24	9-27-67	13	55	13	.02	20	7.0	2.9	2.0	94	0	12	.5	.2	1.4	--	106	105	79	178	8.1
Hawk Creek auger hole 3	1,293	43.8	1.56	9-27-67	11	52	32	.12	42	14	13	4.3	205	0	18	3.0	.3	3.9	0.20	224	232	163	362	7.9
Fort Spokane well	1,337	202	47.59	10-13-67	11	52	23	.19	20	17	13	4.5	150	3	16	.9	.5	3.9	--	180	176	120	289	8.3
Porcupine Bay well	1,297	189	8.16	10-16-67	11	52	25	.04	31	5.1	5.5	1.4	118	0	10	.7	.9	.6	--	133	138	99	219	7.9
Rogers Bar auger hole 1	1,295	79.8	6.05	9-22-67	11	52	20	.66	62	16	6.7	2.3	169	0	99	.5	.3	1.1	.02	301	291	221	450	7.9
Rogers Bar auger hole 2	1,297	55.9	7.69	9-23-67	12	54	16	1.6	33	6.6	2.4	1.1	122	0	13	.5	.2	.6	.17	131	134	110	221	7.9
Hunters Park test well 1	1,298	146	7.75	8-18-67	--	--	19	1.9	69	23	25	3.8	288	0	84	1.0	.2	.1	--	355	367	267	580	8.0
West Bissell auger hole 1	1,295	73.9	5.66	9-24-67	12	53	21	.85	56	12	4.8	1.9	187	0	42	.5	.2	.9	.09	239	231	189	374	8.1
West Bissell auger hole 2	1,296	43.8	7.25	9-25-67	11	51	17	.09	54	10	3.0	1.1	207	0	13	.5	.1	3.6	.01	201	204	176	349	7.9
Gifford well	1,302	146	--	10-25-67	11	51	3.6	.99	33	26	8.1	2.6	204	0	36	.5	.1	.0	--	223	209	190	386	8.0
Haag Cove auger hole 1	1,296	44.1	7.62	9-26-67	9	48	29	.04	16	5.9	5.0	1.5	84	0	12	.8	.2	1.9	--	122	113	65	165	7.0
Kettle Falls auger hole 1	1,307	67.3	19.08	9-26-67	10	50	25	.06	42	9.6	5.3	2.3	173	0	15	.8	.2	2.0	.35	191	188	145	298	8.1
Kettle Falls auger hole 4	1,300	64.4	10.27	9-20-67	8	47	20	.05	46	12	5.4	2.8	194	0	15	.8	.3	1.3	.13	198	199	165	327	8.1
Marcus Island auger hole 3	1,295	15.4	5.42	9-21-67	14	57	18	2.2	30	5.8	1.9	1.5	107	0	14	.2	.2	.1	.38	111	125	99	200	7.6

The National Park Service selected eight sites for special attention in evaluating future water supplies. Five of those areas (Keller Ferry, Fort Spokane, Haag Cove, Kettle Falls, and Marcus) now have water, but need more. The other three (Hawk Creek, Rogers Bar, and West Bissell) do not have water supplies at present (1968). A detailed evaluation of water-supply potential was made at each of the eight areas, and test wells were augered and tested at seven of the sites. At Fort Spokane, the eighth site, logs are available from three diamond-drill holes, and a pumping test was conducted on the existing well. Evaluation of water supply was of a reconnaissance nature for the remaining 23 campgrounds.

Ground-water levels in most areas adjacent to Roosevelt Lake are within a few feet of lake level and fluctuate in response to changes in lake level. Because annual variations in lake level average about 40 feet and water-level fluctuations in wells are similar, an attempt was made to locate ground water at sufficient depth so that wells would not go dry at times of low lake level.

Generally, springs are not an important source of water for park use. An exception to this is the spring at Fort Spokane which provides a major part of the water for the area. At Haag Cove the spring at the north end of the campground could supply water for park use; however, a well is a more desirable source because it would be less subject to contamination.

The chemical quality of ground water in most of the recreation area is good, except for being hard and having high iron content in some places. Water samples were collected for analysis by the Geological Survey from six drilled wells in the area and from the ten cased auger test holes. The analyses are reported in table 2. Water from one well at Spring Canyon contained twice the concentration of dissolved solids recommended by the Public Health Service (1962, p. 7) for drinking water. Moreover, the water was excessively high in sulfate.

TABLE 3.--Public Health Service drinking water standards, 1962

Recommended limits		Limitations which justify rejection of a water supply	
Constituent	mg/l	Constituent	mg/l
Alkyl benzene sulfonate (detergent)	0.5	Arsenic (As)	0.05
Arsenic (As)	.01	Barium (Ba)	1.0
Chloride (Cl)	250	Cadmium (Cd)	.01
Copper (Cu)	1	Chromium (hexavalent) (Cr^{+6})	.05
Cyanide (CN)	.01	Cyanide (CN)	.2
Fluoride (F)	>0.9 <1.7	Fluoride (F)	2.4
Iron (Fe)	.3	Lead (Pb)	.05
Manganese (Mn)	.05	Selenium (Se)	.01
Nitrate (NO_3)	45	Silver (Ag)	.05
Phenols	.001		
Sulfate (SO_4)	250		
Total dissolved solids	500		
Zinc (Zn)	5		
Turbidity	5 units		
Color	15 units		
Odor	3 units		

A summary of the 1962 Public Health Service standards is presented in table 3. This summary includes certain trace constituents not usually included in a chemical analysis. The only sample that contained a constituent which exceeded the recommended concentration level for trace constituents was from the Hunters Park well: the manganese was greater than 0.05 mg/l (milligrams per liter) but less than 0.1 mg/l. This manganese concentration, along with the 1.9 mg/l of iron, may cause stains if the water is used for laundering but is not likely to cause problems when used for human consumption.

For convenience in the following section of this report, each of the campgrounds developed in Coulee Dam National Recreation Area is discussed in upstream order, from Grand Coulee Dam to the north end of Roosevelt Lake.

North Marina

North Marina campground is on the north shore of the lake, about a mile upstream from Grand Coulee Dam (fig. 1). As the campground is served by municipal water from the town of Coulee Dam, no additional supply is needed. The area is developed on a narrow terrace cut into outwash sand and gravel which overlies granitic bedrock exposed on the hillside just above the campground.

If a water supply were sought locally a well in the outwash sand and gravel probably would produce adequate water for the campground. The depth to bedrock in this area probably is not great, and would limit the thickness of the outwash sand tapped by a well. If such a well is constructed, adequate precautions should be taken against the possibility of surface contamination.

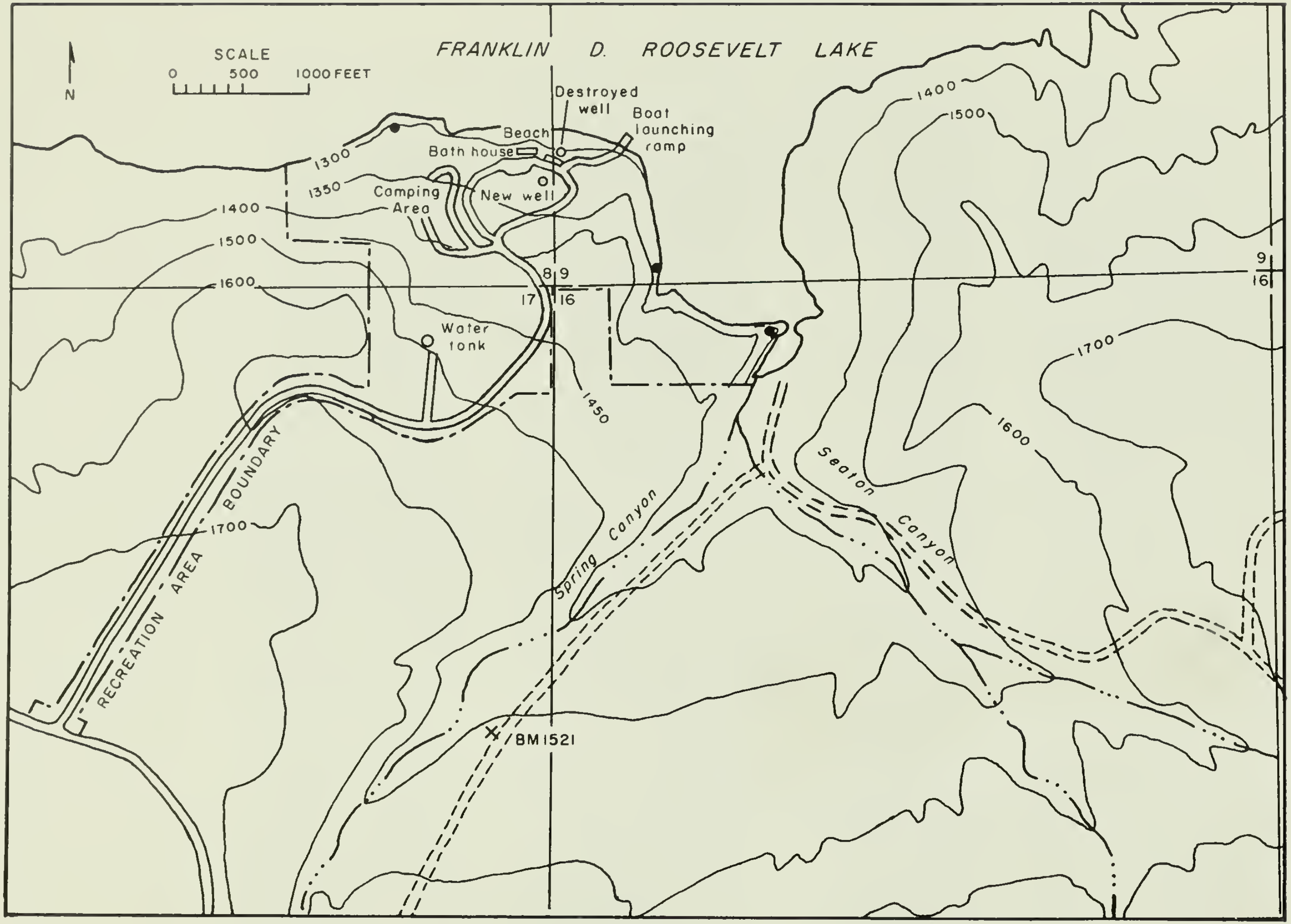

FIGURE 4.--Spring Canyon campground (No. 2 on fig. 1). General areas where channel gravel is exposed are marked by • . Base from NPS developed area plan, and from USGS quadrangle.

Spring Canyon

Spring Canyon campground is on the south shore of the lake, about 3 miles upstream from Grand Coulee Dam (fig. 1). The campground is on the west side of a small bay formed at the mouth of Spring Canyon (fig. 4).

For several years water was supplied to the campground from an 8-inch well drilled in 1954 to a depth of 111 feet. The well was reported originally to have yielded 200 to 350 gpm (gallons per minute), but because the well decreased in yield, and also was pumping sand, it was deepened in 1959. The log of this well is in table 4. The well still was not entirely satisfactory and attempts to improve its yield were made again in 1963. It then yielded 35 gpm, and the water still contained fine sand. The U.S. Geological Survey located a potential well site and supervised the drilling of a new well which was completed December 1965.

The campground at Spring Canyon is underlain by deltaic deposits formed in Glacial Lake Columbia. The gravel of the delta is interstratified with silty clay. Channel deposits within the delta appear to be the most likely source of ground water.

Coarse gravel is exposed at three sites in the area of Spring Canyon (fig. 4). These exposures delineate a channel that is offset slightly from Seaton Canyon, but which is alined in a similar northwesterly direction. If earlier channels (now buried) were similarly located and were gravel filled, more coarse material should be penetrated than by wells drilled to either side of it. The well that was drilled in 1954 is northeast of this exposed channel. This well was deepened, then abandoned because of sand problems and inadequate yield. The site selected for the new well is 200 feet southwest of the earlier well and in line with the channel whose course is indicated by the three exposures of channel deposits.

The new well penetrated clean sand and gravel from 155 to 179 feet (table 4). A step-drawdown pumping test and a constant-rate pumping test were performed. During the constant-rate test, the well was pumped at 370 gpm for 5½ hours. The drawdown was about 38 feet. The water

TABLE 4.--Logs of two wells at Spring Canyon campground

Destroyed Spring Canyon well: Drilled to 111 ft by Curley Beard, 1954; deepened by Clyde Woolery, 1959, altitude 1,300 ft; 8-inch casing to 111 ft, 6-inch casing to 155 ft; various intervals screened at various times; water level 25 ft below land surface, 6-10-59; yield 35 gpm. Casing removed, Oct. 1965.	Thickness (feet)	Depth (feet)
Sand	21	21
Sand and gravel	14	35
Clay, sandy	10	45
Clay	15	60
Sand, some water	19	79
Clay, sandy	26	105
Gravel, fine	6	111
Gravel	2	113
Shale, hard [clay]	2	115
Sand and gravel	9	124
Clay	2	126
Gravel, fine "pea"	9	135
Clay	2	137
Gravel, water-bearing	6	143
Sand and gravel	10	153
Gravel, fine "pea"	3	156

TABLE 4.--Logs of two wells at Spring Canyon campground--Con.

New Spring Canyon well: Drilled by Bach Drilling Co., 1965; altitude 1,319 ft; 8-inch casing to 158 ft; screen 158-173 ft; water level 30.04 ft below land surface, 10-24-67; yield 370 gpm for 5½ hrs, drawdown 38 ft.	Thickness (feet)	Depth (feet)
Sand	15	15
Sand and silt	15	30
Sand, fine, and clay	30	60
Sand, coarse, and clay	5	65
Sand, fine, and clay	15	80
Sand, fine to coarse, and clay	14	94
Clay, blue, and sand	11	105
Clay, very little sand	14	119
Clay, some coarse gravel; water level at 55 ft	11	130
Clay and fine sand; water level at 35 ft; bailed 50 gpm	10	140
Sand, coarse, some clay	10	150
Sand, fine, some clay; water level at 44 ft; bailed 50 gpm for 15 minutes, drawdown 50 ft	5	155
Sand and gravel	5	160
Sand, coarse, and gravel; bailed 50 gpm, drawdown 5 ft	5	165
Gravel and some sand	8	173
Sand, fine, and gravel	6	179
Sand, gravel, and clay; bailed 50 gpm, drawdown 50 ft	4	183

level recovered to within 1 foot of the static level in less than 1 minute after the pump was shut off. A summary of the measurements recorded during the step-drawdown test of the new well is presented below:

Step	Time since pumping began (min.)	Rate (gpm)	Cumulative drawdown (ft)	Specific capacity (gpm/ft)
1	105	142	9	15.8
2	145	195	14	13.9
3	230	263	20	13.1
4	285	339	27	12.5
5	305	390	34	11.5

The specific capacity decreased with increase in pumping rate during the step-drawdown test which indicates that some well loss occurred.

The results of an analysis of water from the new Spring Canyon well are in table 2 and indicate a total dissolved-solids content of 1,000 mg/l. This is twice the amount recommended as the limit by the Public Health Service (1962, p. 7). Sulfate is the only constituent in the sample from the new Spring Canyon well that exceeds the recommended limits of the Public Health Service.

The water level in the new well at Spring Canyon responds to changes in lake stage. The tests described above were made when Roosevelt Lake was about 12 feet below maximum operating stage. During the summer, when the well will be subjected to peak demand, the lake is expected to be full and the available drawdown will be greater as a result.

Tiffany Landing

Tiffany Landing campground is on the north shore of the lake about 3 miles east of Grand Coulee Dam (fig. 1). The campground is on a broad peninsula between two bays (fig. 5). A water supply has not been developed for the area.

A thin layer of loose sand covers the surface on much of the peninsula. The sand is underlain by glacial-lake silt and clay which is exposed along the south shore of the peninsula at water level. Gravel is exposed on the east side of the peninsula near the north end of the larger bay, about 20 feet above lake level. A landslide trace cuts the sediments in the same area. It was not possible to determine the extent to which the landslide disturbed the sediments at depth below the peninsula. Granitic bedrock is exposed on the hillside north of the campground and also at the extreme north end of the bay east of the campground.

The most promising location for a test well at Tiffany Landing is the southeast corner of the peninsula. That area appears to be the farthest from any bedrock exposure, and a well there would most likely penetrate the greatest thickness of surficial material from which water might be obtained.

Plum Point

Plum Point is on the south shore of the lake a little more than 6 miles east of Grand Coulee Dam (fig. 1). The campground is on a point of land with a bay on the west side of the point (fig. 6).

The present well at Plum Point is a sandpoint driven to a depth of 20 feet near the north end of the campground. The well penetrated sand and gravel to its full depth, and the water level stands 3 feet below land surface when the lake is full. A hand pump on the well serves the present needs of the campground (1968).

Plum Point is a sand and gravel bar formed in the lee of a bedrock knoll half a mile upstream from the campground. The gravel contains numerous deeply weathered granite and schist boulders, some of which disintegrate when struck with

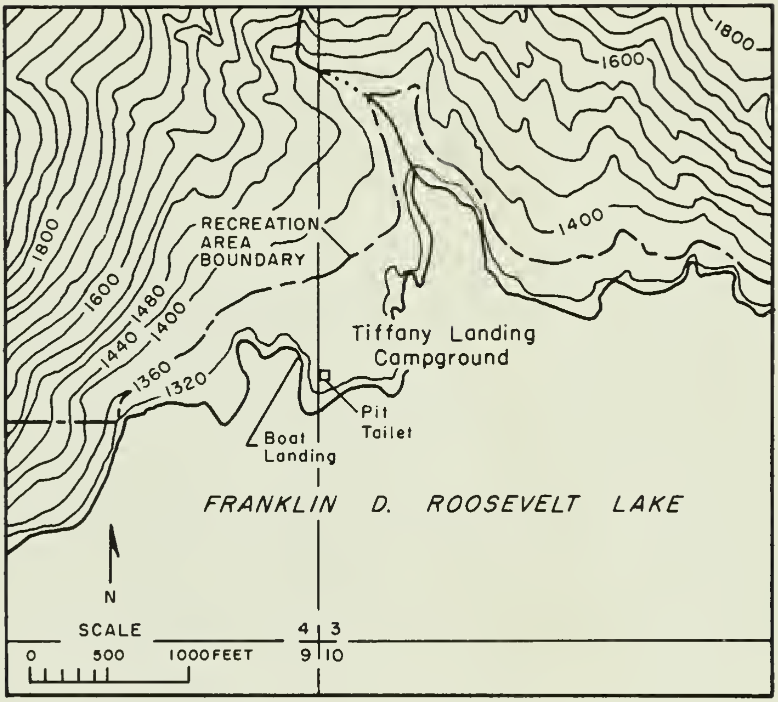

FIGURE 5.--Tiffany Landing campground (No. 3 on fig. 1). Base from USGS quadrangle.

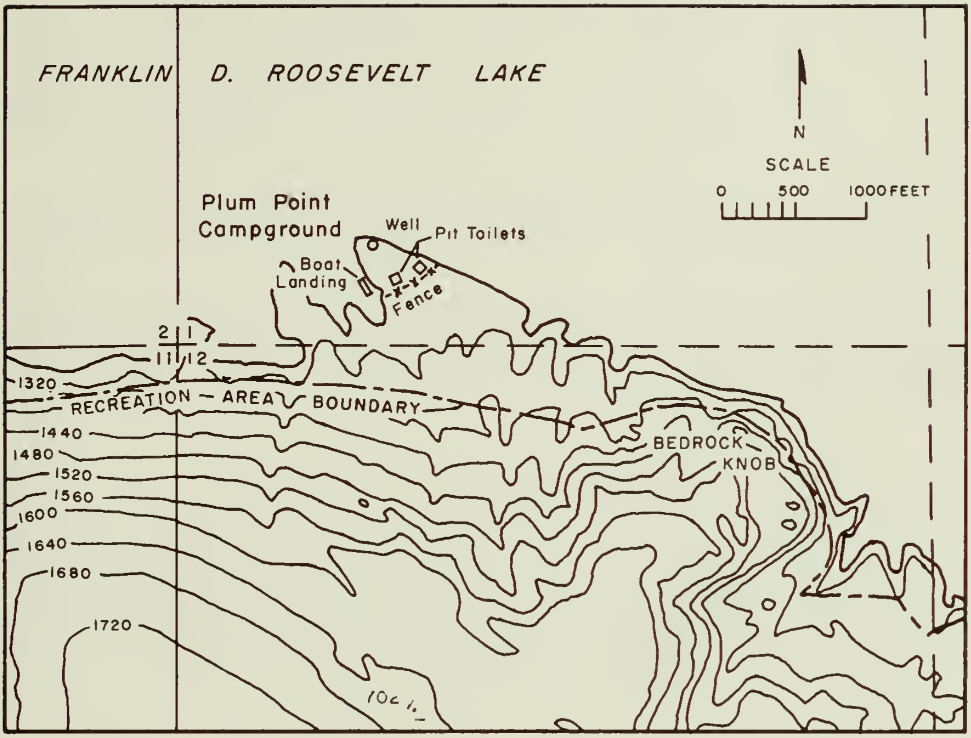

FIGURE 6.--Plum Point campground (No. 4 on fig. 1).
Base from USGS quadrangle.

a hammer. That degree of weathering suggests that the deposit is quite old. If this is a flood-deposited gravel, it is probably quite thick and extends well below the 20 feet penetrated by the present well. The deposits become increasingly coarse and silt free toward the northwest, which indicates that the chance of penetrating coarse water-bearing material in a well may also increase toward the northwest.

If an additional water supply is sought for this area, the best site for a new well is between the present well and the northwest tip of the point.

Sanpoil Bay

Sanpoil Bay campground is on the west shore of Sanpoil Bay, about 6½ miles north of the mouth of the bay (fig. 1). The campground is on a delta formed in Glacial Lake Columbia, at the mouth of a small tributary valley (fig. 7).

When the campground was being developed the National Park Service jetted a small-diameter test hole to a depth of 110 feet at a site near the center of the campground just west of the driveway. The well penetrated 10 feet of sand and gravel at the surface, then clay with seams of sand which increased in number toward the bottom of the hole. The hole was dry, and was plugged and abandoned. A spring about 0.3 mile north of the campground was developed and used for several years. The spring, which issues a short distance below a terrace that is being farmed and used for grazing, became contaminated and was abandoned. The National Park Service requested that the U.S. Geological Survey aid in the selection of a site for drilling a well at Sanpoil Bay.

The selection of a drilling site was based on two criteria. First, the site should be as far from bedrock outcrops as possible, and second, it should be toward the center of the tributary valley where the likelihood of penetrating coarse material is greatest. The north end of the campground near the beach is farthest from bedrock outcrops, and is nearest the center of the tributary valley. For these reasons that location was considered the most favorable for the well site.

An 8-inch well was completed at a depth of 205 feet (driller's log in table 5). At the recommendation of the driller, and in consideration of the coarseness of the gravel at the bottom of the well, it was finished with the bottom of the casing open at 205 feet.

The well was developed by pumping at rates from 30 to 80 gpm for 9 hours. A small amount of sand was withdrawn throughout the pumping. During the tests, the specific capacity of the well increased from 13 gpm per foot of drawdown to 18 gpm per foot, indicating that the intermittent pumping of the well improved its production considerably.

After the well had been in operation for two seasons (pumped intermittently at about 65 gpm), a constant-rate pumping test was run. The drawdown was 3 feet after the well was pumped at 66 gpm for 6 hours. The water level recovered almost completely less than a minute after the pump was shut off. The specific capacity of the well at the end of the test--22 gpm per foot of drawdown--showed an increase over that at the time the well was completed.

During the later pumping test coarse sand, 87 percent of which was between 0.020 and 0.040-inch diameter, was withdrawn at the rate of about 1 teaspoonful in 20 gallons of water, enough to cause wear on the pump. This sand problem could be eliminated by installation of a 5-foot section of 0.080-inch slot screen from 200 to 205 feet, then developing the well by surging. Reducing the production rate of the well (perhaps to 30 gpm) may also eliminate the sand problem.

The water from the Sanpoil Bay well is of good quality, and in all respects meets the chemical qualifications for drinking water established by the Public Health Service (1962, p. 7-8). The analysis of a water sample collected at the time of the pumping test in October 1967 is reported in table 2.

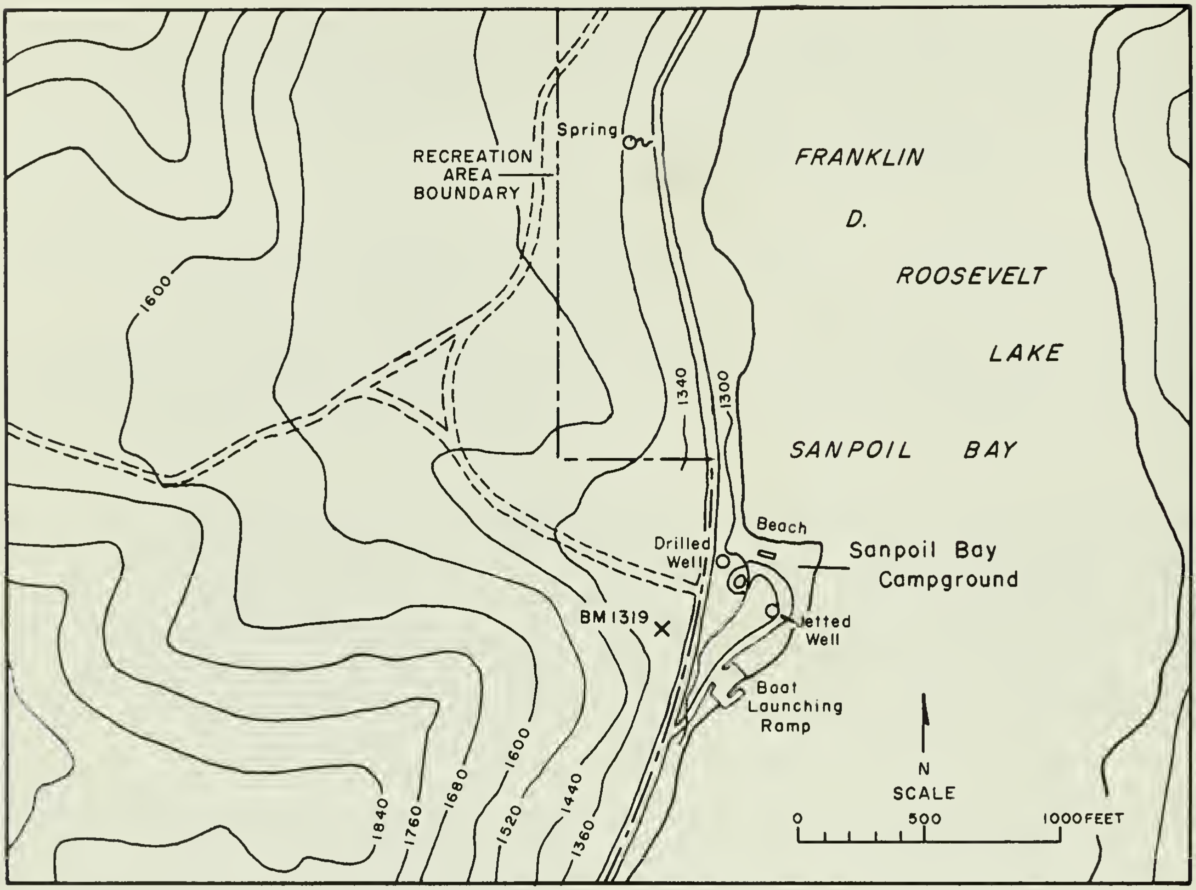

FIGURE 7.--Sanpoil Bay campground (No. 5 on fig. 1). Base from USGS quadrangles and NPS master plan.

TABLE 5.--Log of well at Sanpoil Bay campground

Drilled by Bach Drilling Co., 1966; altitude 1,304 ft; 8-inch casing to 205 ft, open end; water level 13.90 ft below land surface, 10-17-67; yield 66 gpm for 6 hrs, drawdown 2.98 ft.	Thickness (feet)	Depth (feet)
Soil, cobbles, and boulders	10	10
Gravel, cobbles	8	18
Clay	14	32
Clay and fine sand, some water at 35 ft and from 85 to 96 ft	68	100
Sand, fine, less clay than from 32 to 100 ft	25	125
Clay and fine sand, some fine gravel	35	160
Sand, fine, some clay	10	170
Gravel, coarse	5	175
Sand, fine, some gravel	10	185
Sand, coarse, heaving	5	190
Gravel, coarse, and heaving sand	5	195
Gravel, coarse	10	205

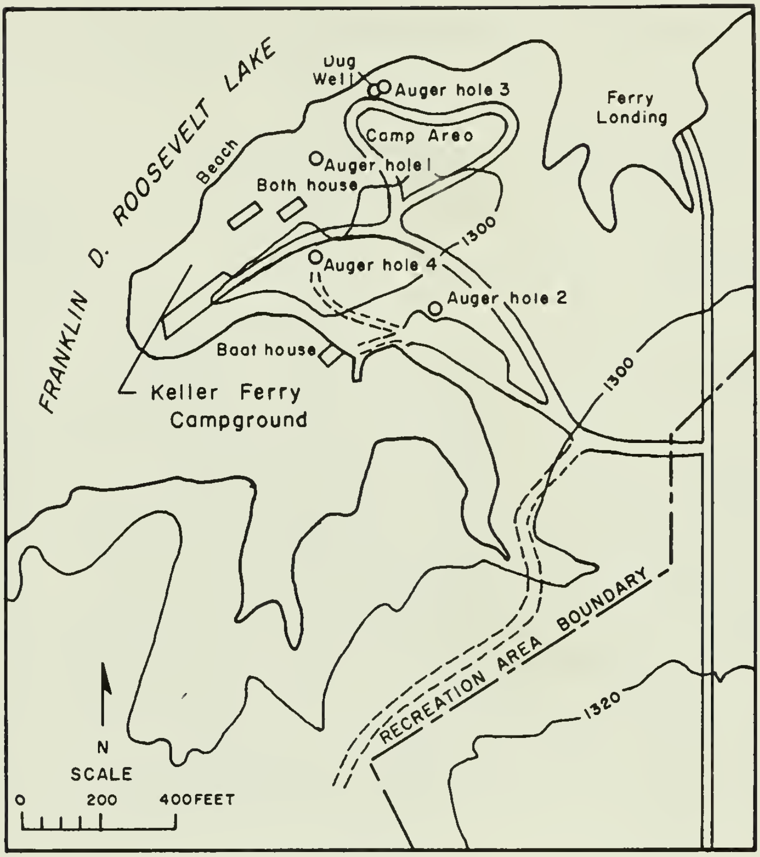

FIGURE 8.--Keller Ferry campground (No. 6 on fig. 1). Base from NPS master plan.

Keller Ferry

Keller Ferry campground is on the south shore of the lake, directly opposite the mouth of Sanpoil Bay (fig. 1). The campground was developed on a point of a large terrace just above 1,300-foot altitude immediately west of the ferry landing (fig. 8).

A 43-foot well, dug for the National Park Service in 1959, penetrated only sand and gravel. It is a reliable water supply when Roosevelt Lake is full or nearly so, but it goes dry when the water level in the lake drops 25 feet. The water level in the lake is expected to drop more than 100 feet during the winters of 1968 and several following years because of work being done on the third powerhouse for Grand Coulee Dam.

The campground is on a terrace which is underlain by a sand and gravel channel deposit. The deposit becomes coarser toward the center of the lake. The depth of the sand and gravel was explored by four auger holes drilled in August 1967. The location of these holes is indicated in figure 9. At 25 feet or less, each of the first three holes encountered cobble gravel which the auger could not penetrate. The fourth auger hole encountered cobble gravel at 26 feet, but with difficulty was able to penetrate to 63 feet. Logs for the auger holes are in table 6.

A gamma-ray log of auger hole 4 was made through the hollow-stem auger. A zone of high gamma radiation from about 35 to 48 feet probably indicates finer material (silt and clay) present in the sand and gravel. The hole was cased to a depth of 56 feet with 4-inch pipe that had perforations from 48 to 52¼ feet. After development, the well was pumped at 20 gpm for half an hour and had a drawdown of 0.05 foot.

The chemical quality of the water from auger hole 4 at Keller Ferry is good. All constituents were below the limits recommended by the U.S. Public Health Service (1962, p. 7-8). A chemical analysis of a water sample from this auger hole is presented in table 2.

TABLE 6.--Logs of four auger holes at Keller Ferry campground. Bored by U.S. Geological Survey, 1967

	Thickness (feet)	Depth (feet)
Auger hole 1: Altitude 1,293 ft.		
Sand, medium to very coarse, silty	20	20
Gravel, coarse to cobble	7	27
Auger hole 2: Altitude 1,295 ft.		
Sand, medium to coarse, and very coarse gravel	3	3
Gravel, very coarse, and coarse to very coarse sand	14	17
Sand, very coarse, with some gravel	7	24
Gravel, cobble	--	24+
Auger hole 3: Altitude 1,295 ft.		
Sand, medium to very coarse, silty	19	19
Gravel, cobble	.5	19.5
Auger hole 4: Altitude 1,305 ft; 4-inch casing to 55.5 ft, perforations 48 to 52½ ft; water level 14.24 ft below land surface, 9-27-67; yield 20 gpm for ½ hr, drawdown 0.05 ft.		
Silt, sandy	8	8
Gravel, medium	5	13
Sand, medium to very coarse, silty	13	26
Gravel, medium to cobble, sandy, silty with layers of silty sand; most silty zone indicated by high gamma radiation 35-48 ft	22	48
Gravel, medium to cobble, sandy; low gamma radiation	15	63

Information on ground-water potential in this area was obtained from the well (not shown on map) serving the ferry landing just east of the campground. The well penetrated sand and gravel all the way to bedrock which is 154 feet below high-water level in Roosevelt Lake. The bedrock surface is probably even deeper below the campground area, and a successful well probably could be developed anywhere within the campground.

Jones Bay

Jones Bay campground is on the south shore of the lake, about 5 miles upstream from the mouth of Sanpoil Bay (fig. 1). The campground is on a point near the head of the bay formed at the mouth of Penix Canyon (fig. 9). There is no water supply at Jones Bay at present (1968).

Jones Bay is west about 2 miles from a bedrock knob from which a sand and gravel bar extends and continues beyond the campground. The sand and gravel deposit probably extends at least to a depth of 100 feet, and probably would yield water to a well located almost anywhere in the campground area.

Lincoln Mill

The Lincoln Mill picnic area is on the south shore of the lake, just east of a small bay, 2½ miles west of the mouth of the drowned Hawk Creek valley (fig. 1). This area is served by the same water supply as the community of Lincoln. No additional water supply is needed at present (1968).

A delta remnant of clean sand and gravel is exposed at the surface in the picnic area. Although the thickness of the sand and gravel in the picnic area is unknown, exposures of granite overlain by Columbia River Basalt a short distance east of the area suggests that the deposits should be thickest toward the west. The most promising well site is near the west end of the terrace on which Lincoln Mill picnic area is developed.

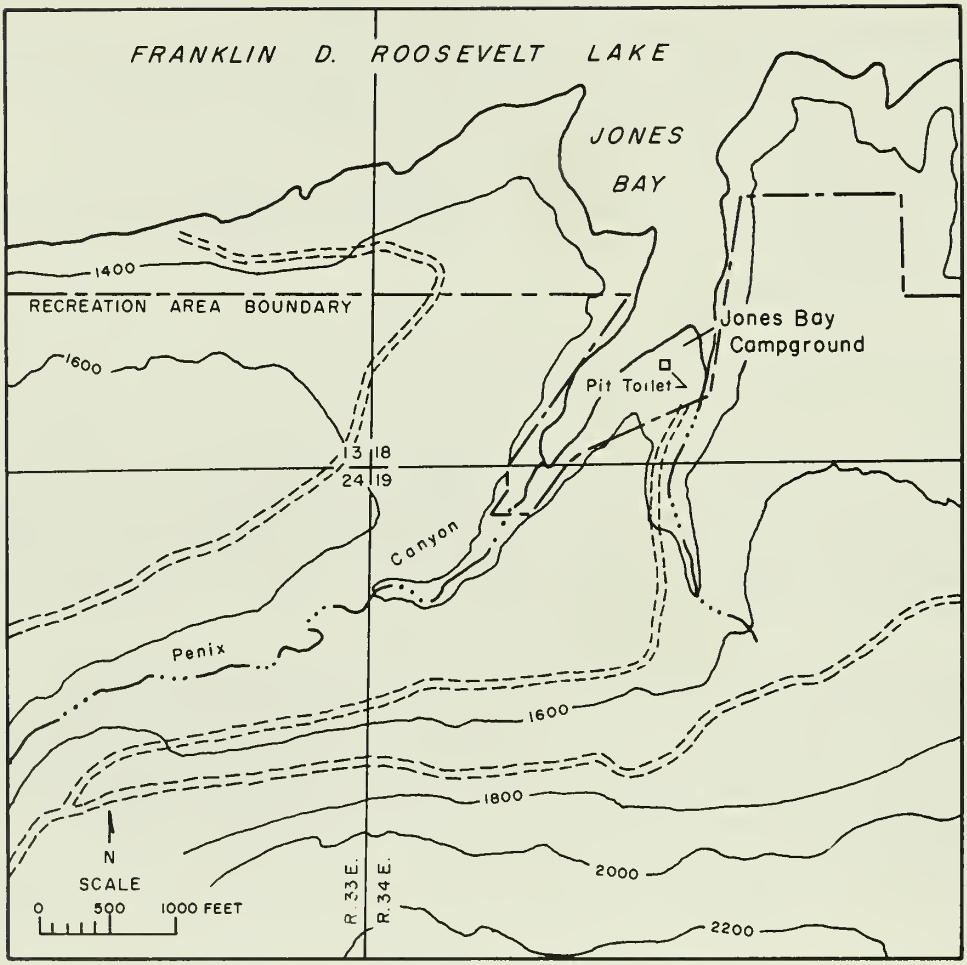

FIGURE 9.--Jones Bay campground (No. 7 on fig. 1). Base from USGS quadrangle.

Hawk Creek

Hawk Creek campground is at the head of the bay formed in the drowned part of Hawk Creek valley at the southeast side of the sharp bend in Roosevelt Lake (fig. 1). The campground is on the valley flat just below the waterfall where Hawk Creek drops to lake level (fig. 10).

No water is available at the campground at present (1968). A well (not shown on map) was jetted to a depth of 15 or 20 feet by the National Park Service in 1956, and was abandoned in 1967 because it became contaminated by coliform bacteria.

The campground is in a deep narrow valley cut into basalt. Coarse basalt rubble overlain by very fine sand and silt form the valley floor at the campground. The sand and silt deposit is too fine to yield water, but the basalt rubble exposed along the valley wall is open and appears very permeable. This rubble probably extends to the middle of the valley and, if the interstices have not been filled by the overlying silt, it should form an excellent aquifer.

Neither of the first two auger holes bored in the campground (fig. 11, AH1 and AH2) in August 1967 penetrated a suitable aquifer. (Logs for the Hawk Creek auger holes are in table 7.) The gamma-ray log for auger hole 3 indicated a zone of low radiation between 38 and 44 feet and another such zone from about 52 to 60 feet. Those zones of lower radiation were interpreted as indicating less fine material and correspondingly greater permeability. However, this interpretation may be complicated by radiation from the basalt rubble.

The hole was cased and perforated between 39 and 43 feet below land surface. The casing filled with silt to the top of the perforations as it was being installed indicating that the zone between 38 and 44 feet contained some silt. The well was developed with compressed air for 3 hours, at which time the water level had risen from 26.94 to 1.56 feet below land surface, indicating improvement in the well capacity. When the well was test pumped at 4 gpm, the drawdown was 21 feet. The small specific capacity of this well indicates that the interstices of the rubble are at least partly filled with silt to the depth of the perforations.

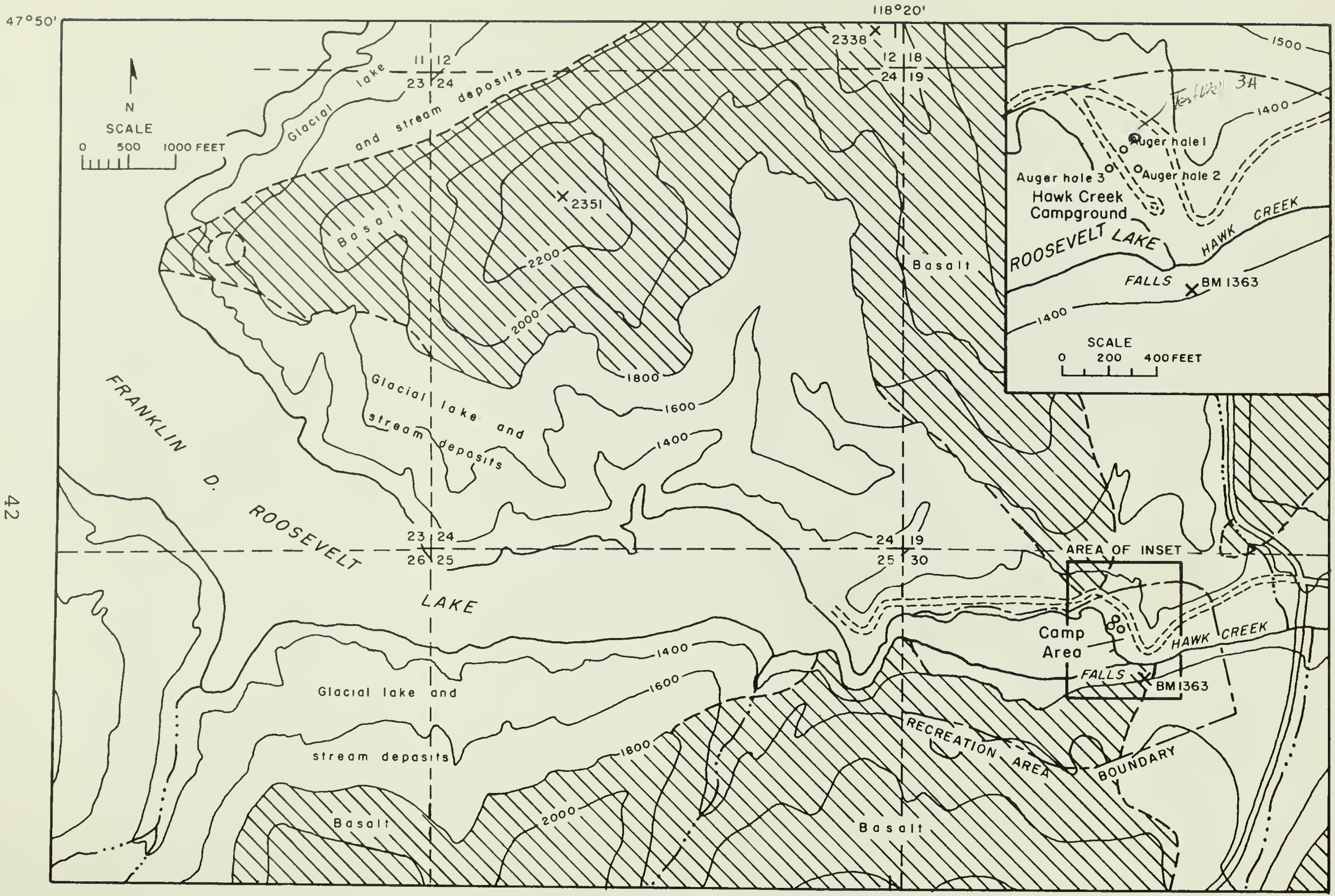

FIGURE 10.--Hawk Creek campground, and vicinity (No. 9 on fig. 1). Base from USGS quadrangle.

TABLE 7.--Logs of three auger holes at Hawk Creek campground. Bored by U.S. Geological Survey, 1967

	Thickness (feet)	Depth (feet)
Auger hole 1: Altitude 1,301 ft.		
Silt, brown, dry	11	11
Sand, fine to medium, silty, wet	8	19
Basalt, broken, or cobble gravel	--	19+
Auger hole 2: Altitude 1,301 ft.		
Silt, brown, dry	8	8
Sand, medium, silty, wet	6	14
Gravel, very coarse, wet	15	29
Basalt, broken, or cobble gravel	--	29+
Auger hole 3: Altitude 1,293 ft; 4-inch casing to 43.8 ft, perforations 39.3-43.3 ft; water level 1.56 ft below land surface, 9-27-67; yield 4 gpm for 1¾ hrs, drawdown 21.03 ft.		
Sand and silt, wet	8	8
Gravel, very coarse, wet	14	22
Silt, sandy, wet	6	28
Sand and gravel, silty, wet	5	33
Basalt rubble, or very coarse gravel with thin silty layers; low gamma radiation 38-44 ft, and 52-60 ft	30	63

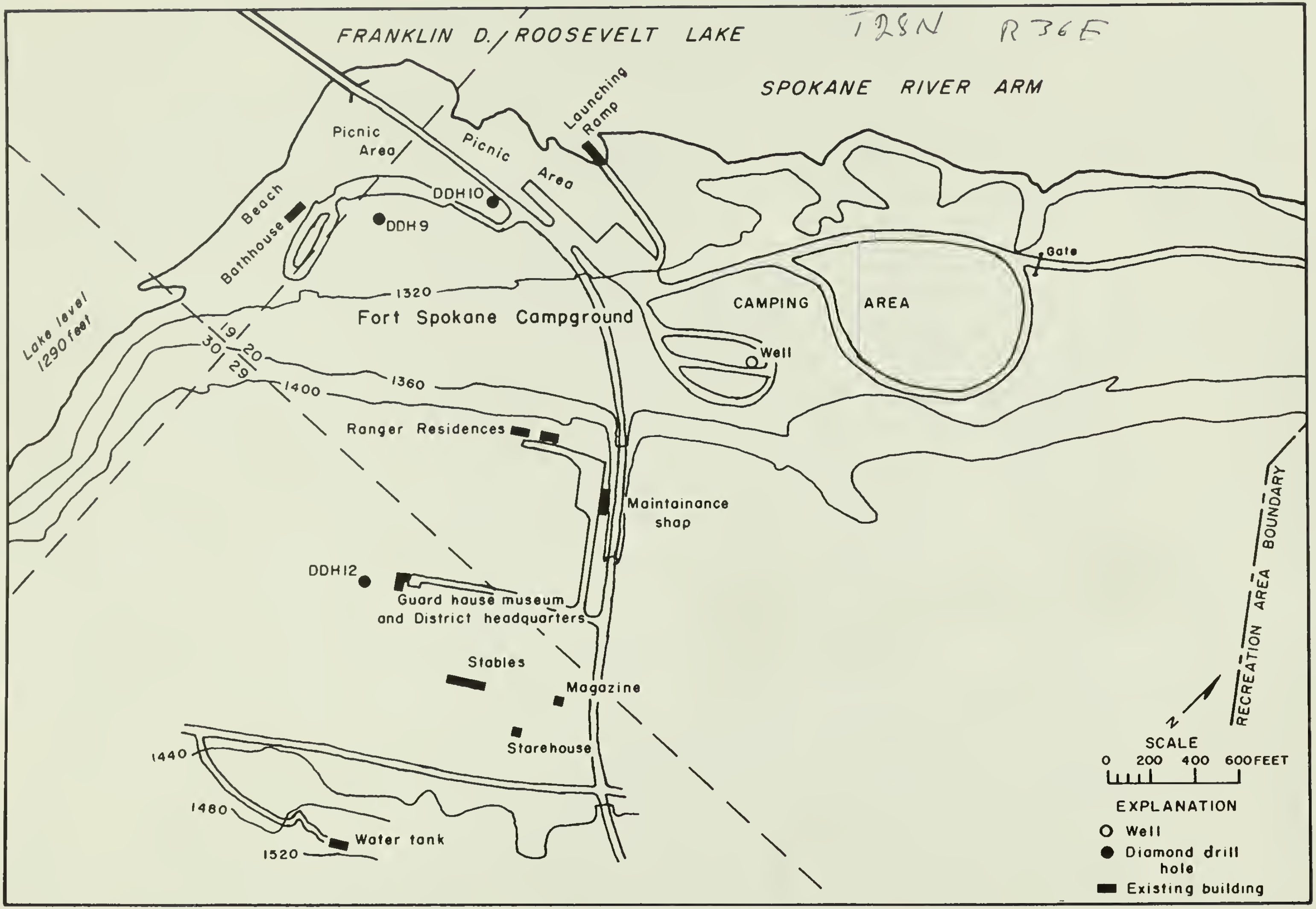

FIGURE 11.--Fort Spokane campground and district headquarters (No. 10 on fig. 1). Includes parts of secs. 19, 20, 29, and 30. Base from NPS master plan.

The chemical quality of the water from Hawk Creek auger hole 3 is good (table 2), except that it is hard. The nitrates content is slightly higher than that in most well waters in the Coulee Dam National Recreation Area, but is well below the limit of 45 mg/l set by the Public Health Service (1962, p. 7).

Two possible sources for a ground-water supply exist at Hawk Creek campground. Material near the middle of the valley may yield some water at a depth of about 50 feet. Material with greater permeability may be below that explored by the auger holes; in any case, a well tapping the silty rubble penetrated by auger hole 3 will probably yield less than 10 gpm. Interflow zones within the basalt bedrock are a second possible source for a ground-water supply at the campground.

Fort Spokane

The Fort Spokane area is on the southeast shore of the Spokane River arm of Roosevelt Lake, from 1½ to 2½ miles upstream from the mouth of the river (fig. 1). The campground is developed on a terrace just above 1,300-foot altitude, and the old fort is on a terrace just above 1,400-foot altitude (fig. 11). The old fort has been partly restored and developed as the Fort Spokane District Headquarters of Coulee Dam National Recreation Area.

The present water supply comes from a well and is augmented by water from a spring (not shown on map) that issues just above the 1,400-foot terrace. The well is pumped at 25 gpm at present (1968).

The 1,400-foot terrace, on which old Fort Spokane was built, is underlain by coarse flood gravel. The lower (1,300 foot) terrace is underlain by silty sand and gravel which in turn, below depths of 35 to 40 feet, is underlain by glacial-lake sand, silt, and clay.

The subsurface of the Fort Spokane area has been explored by the U.S. Bureau of Reclamation by means of three diamond-drill holes. Later a water well was drilled by cable tool for the Park Service. Drillers' logs for all four of these wells are presented in table 8.

Diamond-drill holes 9 and 10, and the Fort Spokane well, all drilled on the lower terrace (1,300-ft altitude), pass from the base of silty lakebeds into permeable gravel and boulder materials at depths ranging from 120 to 147 feet (1,163- to 1,190-ft altitude). Diamond-drill hole 12 (drilled from the 1,400-foot terrace) did not encounter gravel and boulders immediately below the silty lakebeds but penetrated 137 feet of hard-packed sand just below them, and gravelly material below the hard-packed sand. The three holes drilled on the lower terrace probably are alined with a gravel-filled channel cut into the hard-packed sand encountered in diamond-drill hole 12. The floor of the bedrock channel at Fort Spokane is quite flat. The three diamond-drill holes indicate only 13 feet of relief in the bedrock surface over a distance of about a third of a mile. All three holes entered granite between 985- and 998-foot altitude.

When the Fort Spokane well was drilled, it was bailed at 40 gpm. When test pumped in October 1967, at 25 gpm (the production-pump rate) the water level declined 3½ feet. The well apparently could produce a significantly larger volume of water than at present. A step-drawdown test, at rates greater than that desired, is needed to determine the yield that could be efficiently obtained from this well without pumping sand.

The chemical quality of the water from the Fort Spokane well is good, except that it is hard (table 2). The nitrate content is slightly higher than that in most wells in Coulee Dam National Recreation Area, but is well below the 45 mg/l recommended limit.

An additional water supply could be obtained easily from the aquifer tapped by the present well anywhere along the lower 1,300-foot terrace, between the Fort Spokane well and diamond-drill holes 9 and 10 (fig. 11). A well drilled on the upper terrace may tap a shallow perched water body but, to tap an aquifer below the Pinedale lakebeds, such a well would have to be at least 100 feet deeper than one drilled on the lower terrace. The permeability of the hard-packed sand (137 ft thick) below the Pinedale lakebeds in diamond-drill hole 12 is not known. A well on the upper terrace may require drilling below the sand to reach permeable material. If so, such a well would be more than 200 feet deeper than one drilled from the lower terrace.

TABLE 8.--Logs of water well, and three diamond-drill holes at Fort Spokane campground

Fort Spokane well: Drilled by Jasper Jones, 1955; altitude 1,337 ft; 8-inch casing to 198 ft, 6-inch casing from 194.5 to 202 ft, perforations 169-184 ft and 196-202 ft; water level 47.59 ft below land surface, 10-12-67; yield 25 gpm for 4 1/3 hrs, drawdown 3.49 ft.	Thickness (feet)	Depth (feet)
Sand, gravel, and boulders	35	35
Sand	20	55
Clay and sand, some gravel below 60 ft; hole caving with some water and some gravel from 65-77 ft	25	80
Clay, brown, sandy below 87 ft	10	90
Sand and blue clay	5	95
Sand, fine, blue	11	106
Clay, blue	4	110
Clay, sandy, blue, gray, and brown	37	147
Sand, coarse, and gravel; heaving into casing from 152 to 192 ft	55	202
Diamond-drill hole 9: Drilled by U.S. Bureau of Reclamation, 1940; altitude 1,310 ft.		
Topsoil	3	3
Gravel and boulders	6	9
Hardpan and gravel	3	12
Gravel and boulders	9	21
Hardpan and gravel	6	27
Gravel and boulders	12	39
Clay	21	60
Sand and clay	40	100
Sand	12	112
Gravel	3	115
Sand	4	119
Clay	3	122
Sand, very hard; clay layer from 135-137 ft	16	138
Sand, gravel, and boulders, permeable; several sand layers from 1 to 10 ft thick; clayey between 168 and 174 ft and from 232 to 234 ft	179	317

(continued)

TABLE 8.--Logs of water well, and three diamond-drill holes at Fort Spokane campground--Continued

Diamond-drill hole 9--Continued	Thickness (feet)	Depth (feet)
Sand, hard packed	4	321
Hardpan, gravelly	2	323
Sand, hard packed	2	325
Granite, hard, medium-grained	30	355

Diamond-drill hole 10: Drilled by U.S. Bureau of Reclamation, 1940; altitude 1,308 ft.

	Thickness (feet)	Depth (feet)
Topsoil	3	3
Sand and gravel	9	12
Clay	10	22
Sand, 2 ft gravel at base	15	37
Sand and clay	83	120
Sand, permeable	4	124
Gravel, a little clay at base	6	130
Sand, gravel, and boulders, with sand layers up to 6 ft thick	49	179
Sand, packed	21	200
Gravel and boulders, with sand layers from 1 to 5 ft thick	115	315
Granite, medium-grained with numerous sealed joints	30	345

TABLE 8.--Logs of water well, and three diamond-drill holes at Fort Spokane campground--Continued

Diamond-drill hole 12: Drilled by U.S. Bureau of Reclamation, 1941; altitude 1,414 ft.	Thickness (feet)	Depth (feet)
Topsoil	4	4
Gravel, coarse	16	20
Sand, coarse at top, fine toward bottom	22	42
Clay	5	47
Sand, with traces of clay	67	114
Sand	20	134
Sand and gravel, cemented	33	167
Clay	3	170
Clay and sand	3	173
Sand, hard packed	60	233
Clay	1	234
Clay and sand	6	240
Sand, hard packed	137	377
Sand and gravel, hard packed	19	396
Sand, gravel, and boulders	3	399
Gravel, cemented	4	403
Sand, gravel, and boulders	13	416
Granite, medium-grained, slight alteration along joints	24	440

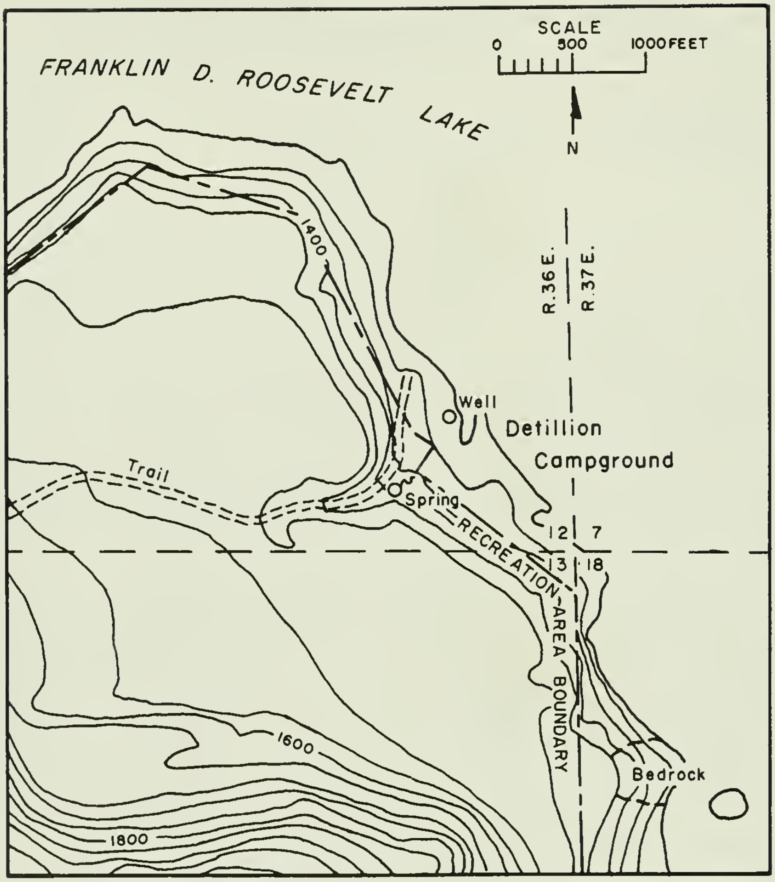

FIGURE 12.--Detillion campground (No. 11 on fig. 1). Base from USGS quadrangle.

Detillion

Detillion campground is on the southwest shore of the Spokane River arm about 7½ miles upstream from the mouth of the Spokane River (fig. 1). The campground is near lake level on a small terrace formed on a locally silty sand and gravel bar (fig. 12). The campground is accessible only by boat.

The water supply at Detillion is from a 17-foot well jetted by the National Park Service in 1956. A hand pump on this well provides an adequate supply for present (1968) needs.

Quartzite bedrock is exposed half a mile southeast of the campground. A large sand and gravel bar extends to the northwest from this bedrock exposure and underlies the campground area.

The sand and gravel at the surface become increasingly silty northwestward along the shore from the campground. About 1,000 feet northwest of the campground, glacial-lake silt is overlain by silty sand and gravel at 1,290-foot altitude. Farther northwest, a 20-foot cliff has exposures of glacial-lake silt overlain by a thin cap of sand and gravel at 1,310-foot altitude. The depth to the silt and its thickness in the area of the campground itself is unknown.

The sand and gravel tapped by the existing small-diameter shallow well may yield more water to a larger well. A deeper permeable gravel probably exists below the glacial-lake silt which underlies the surface gravel to unknown depths. A spring yielding an estimated 5 gpm in the draw just south of the campground, a little below 1,400-foot altitude, also is a potential water source. It appears to discharge at a point where sand overlies the glacial-lake silt.

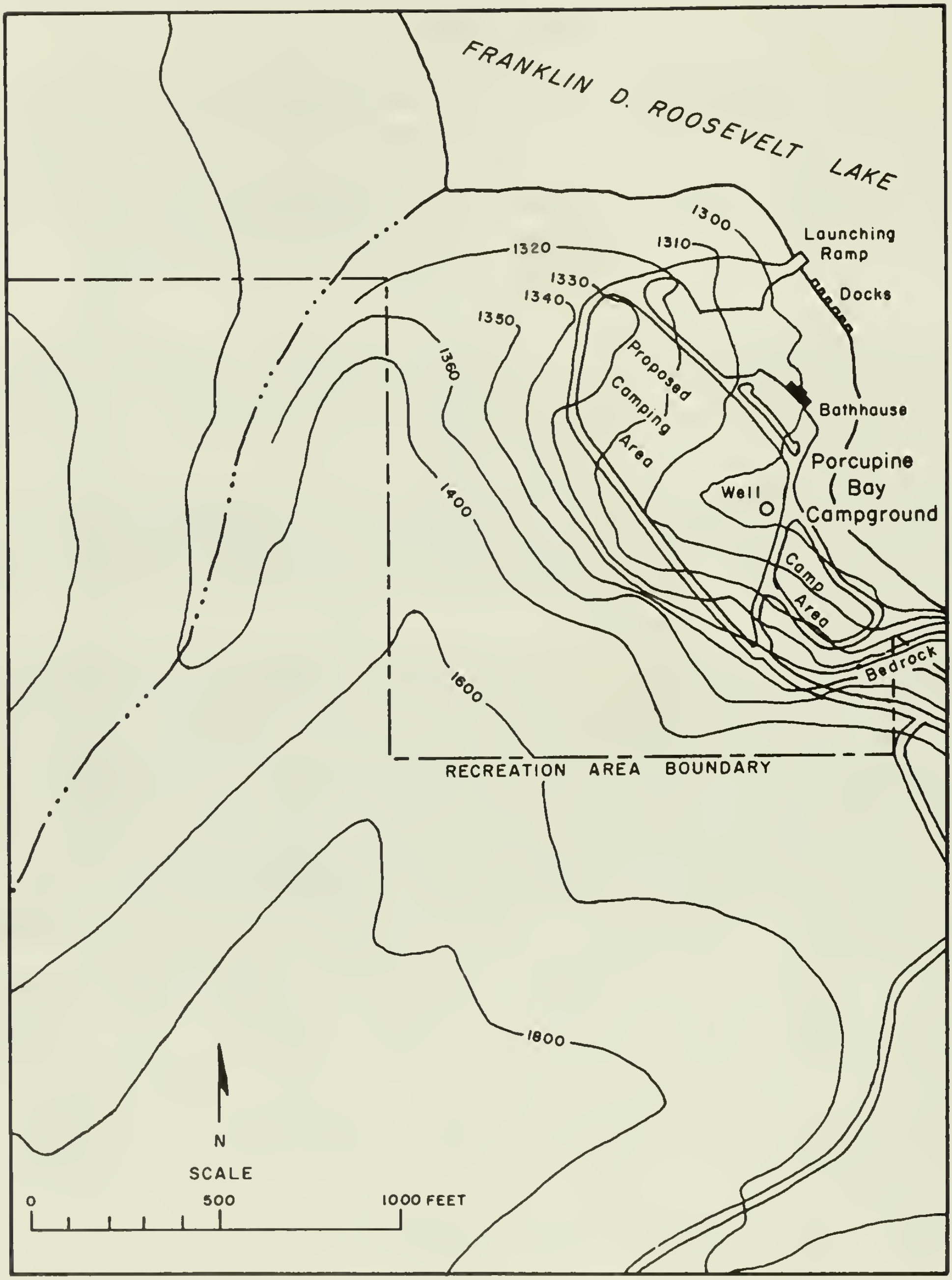

FIGURE 13.--Porcupine Bay campground (No. 12 on fig. 1). Base from USGS quadrangle and NPS developed area plan.

Porcupine Bay

Porcupine Bay campground is on the southwest shore of the Spokane River arm, about 10½ miles upstream from the mouth of the Spokane River (fig. 1). The campground is on a terrace remnant which is protected by granitic bedrock to the southeast (fig. 13).

The development of a water supply at Porcupine Bay began about 1956 when a well (not shown on map) was jetted by the National Park Service to a depth of about 25 or 30 feet. Production from this well was considered very good for the hand pump that served the campground area until 1960. At that time the campground was improved and an 8-inch well was drilled to a depth of 190 feet. The log for this well (table 9) indicates that a gravel aquifer underlies 185 feet of generally fine-grained sediments that represent glacial-lake deposition. The well was finished with open-end casing at 189 feet below land surface. It yields 28 gpm, which is adequate for the present needs of the area (1968). At the time the well was drilled, it was test pumped and yielded 60 gpm and had 12 feet of drawdown. Doubtless the aquifer is adequate to meet the future needs of the campground.

A water sample collected in October 1967 (table 2), indicated that the chemical quality of the water was good and the water was only moderately hard.

Pitney Point

Pitney Point picnic area is on the southwest shore of the Spokane River arm of the lake (fig. 14). The area is about 12 miles upstream from the mouth of the Spokane River (fig. 1) and is accessible only by boat.

No water supply exists at Pitney Point at present (1968). The likelihood of a well being productive is about the same anywhere in the campground. Very silty, sandy gravel is exposed at the surface and is probably underlain by silty glacial-lake deposits similar to those at Porcupine Bay and at Fort Spokane. The lake deposits at both Fort Spokane and at Porcupine Bay are underlain by water-bearing gravel. The gravel may also underlie Pitney Point, but present information is inadequate to determine its extent if present.

TABLE 9.--Log of water well at Porcupine Bay campground

Altitude 1,297 ft; 8-inch casing to 189 ft, open end; water level 8.16 ft below land surface, 10-16-67; yield 28 gpm for 5 1/3 hrs, drawdown 1.06 ft.	Thickness (feet)	Depth (feet)
Sand, fine to coarse, poorly sorted, gray to brown	55	55
Silt and clay, gray	15	70
Clay, banded, gray	30	100
Silt and clay, gray	35	135
Sand, fine to medium, light gray	35	170
Clay, moderately plastic, light gray	10	180
Sand, fine to very coarse	5	185
Gravel, medium, and silty sand, poorly sorted, permeable	5	190

Little Falls

Little Falls campground is on the north shore of the Spokane River arm of the lake (figs. 1 and 15). This campground is on a narrow terrace just above 1,300-foot altitude and is underlain by sand and gravel which is locally silty. A 30-foot well, jetted by the National Park Service in 1956, was abandoned in 1967 because of contamination by coliform bacteria. The sand and gravel underlying Little Falls campground extends to an unknown depth, and may extend deep enough to avoid the possible influence of surface contamination. The sand and gravel may be underlain by glacial-lake clay and also by water-bearing gravel, as at Fort Spokane and Porcupine Bay.

Sixmile

Sixmile campground is on the west shore of Roosevelt Lake, at the north side of the mouth of Sixmile Creek (figs. 1 and 16). Water is supplied to this campground by a 20-foot well jetted by the National Park Service in 1956. This hand-pumped well provides an adequate supply for the present needs (1968) of the campground.

Silty sand and gravel are exposed in the campground area near the well. The bottom of the 20-foot jetted well is below lake level and is in this same silty sand and gravel. The deposit probably came from the Sixmile Creek drainage basin, and may continue to greater depths below the campground area than the bottom of the well. However, a short distance both north and south from Sixmile Creek valley, glacial-lake silt is exposed at lake level.

The area north of the present well near the projected axis of the bedrock valley is the most promising location for test drilling. Deltaic deposits would probably be thickest in line with the valley axis.

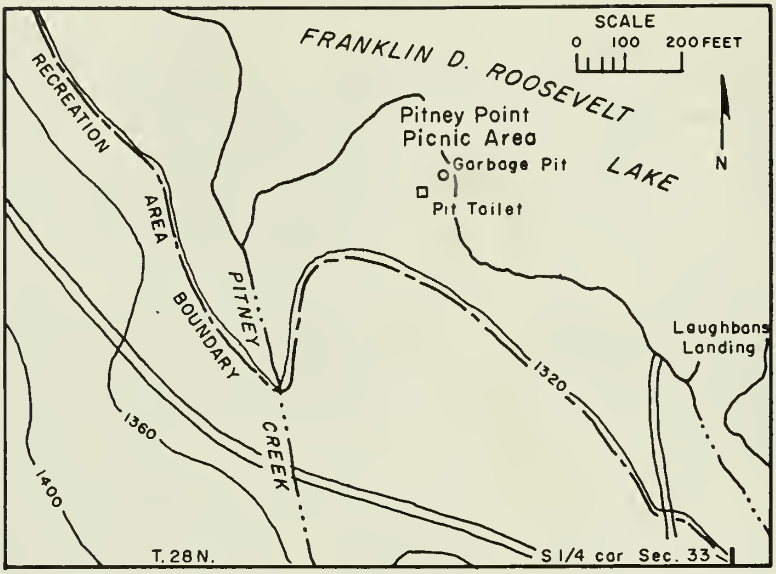

FIGURE 14.--Pitney Point picnic area (No. 13 on fig. 1). Base from USGS quadrangle.

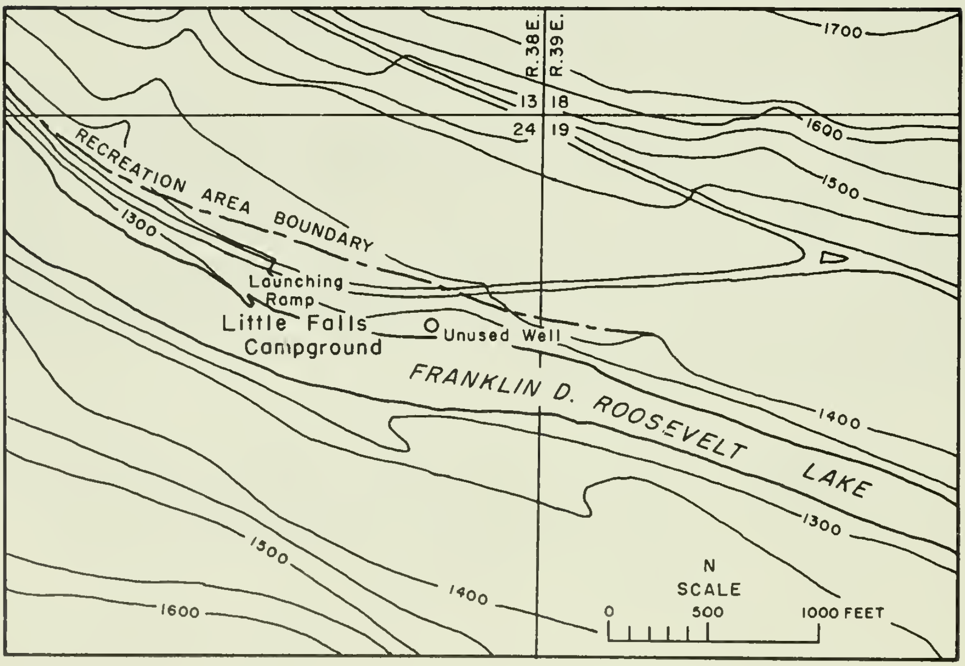

FIGURE 15.--Little Falls campground (No. 14 on fig. 1). Base from USGS quadrangle.

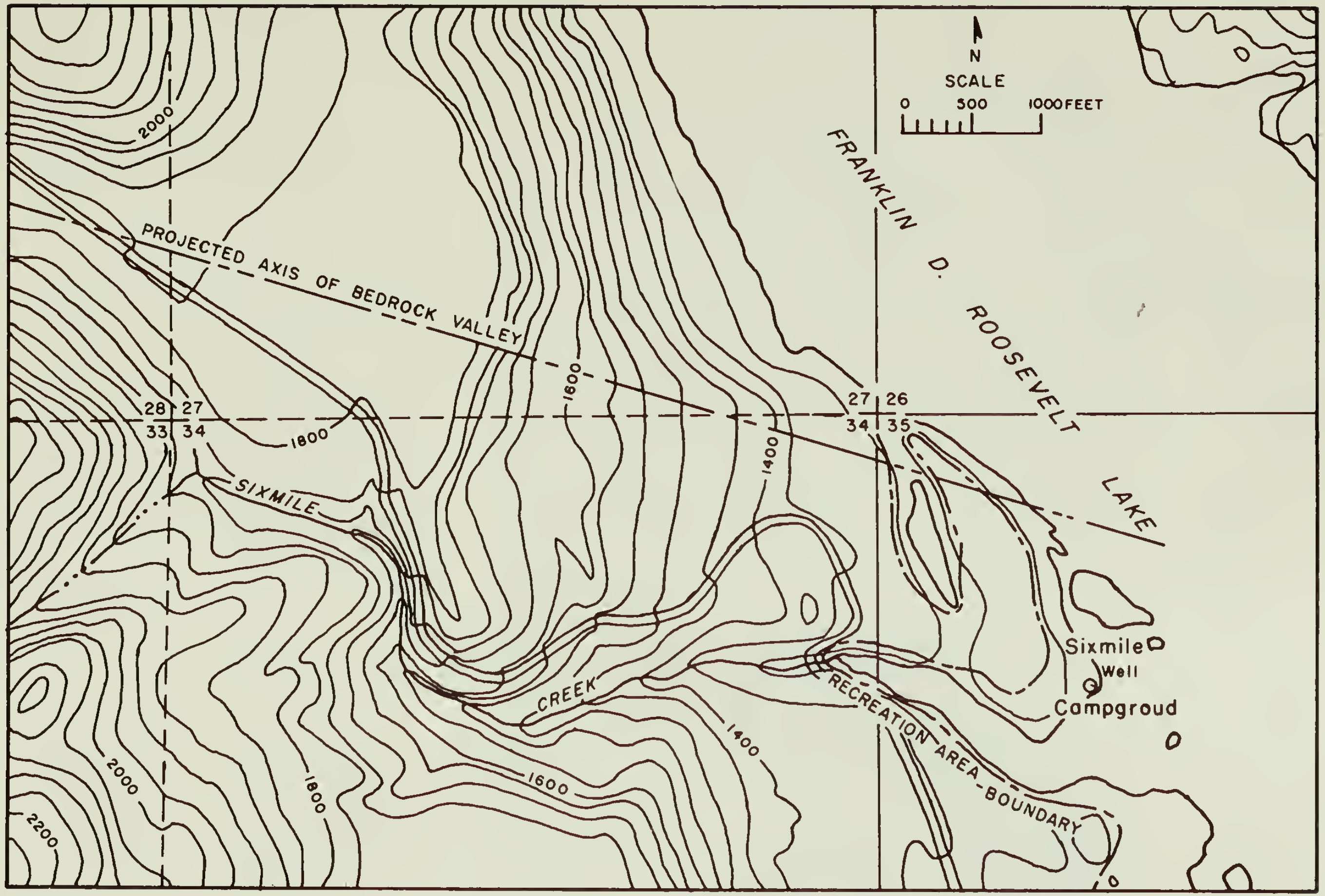

FIGURE 16.--Sixmile campground (No. 15 on fig. 1). Base from USGS quadrangle.

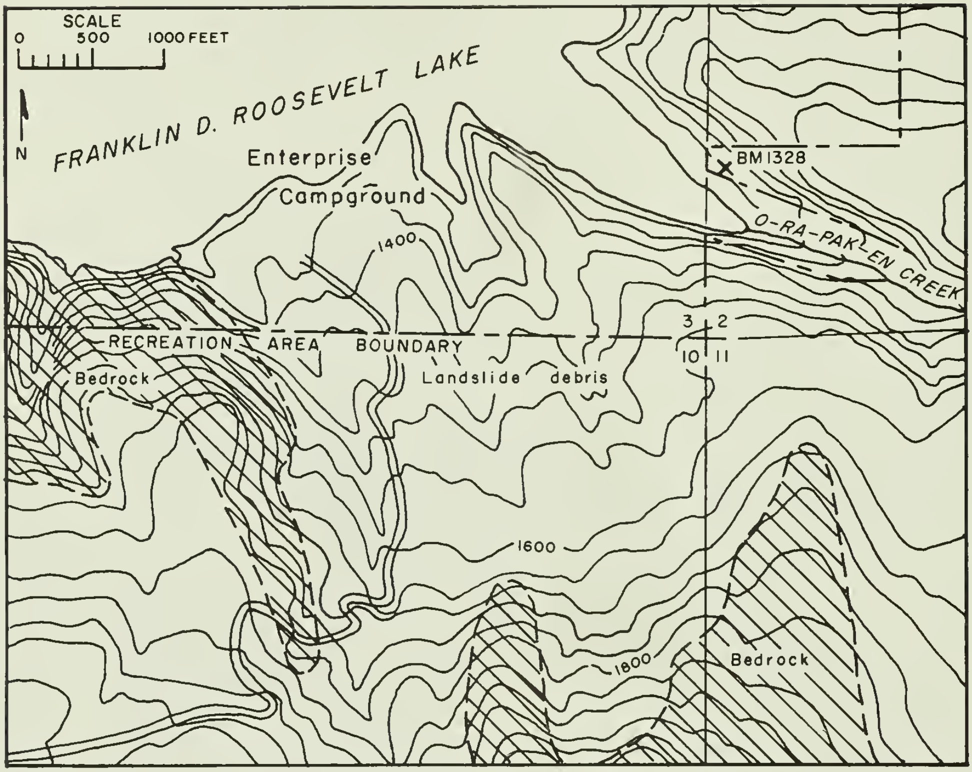

FIGURE 17.--Enterprise campground at O-Ra-Pak-En Creek (No. 16 on fig. 1). Base from USGS quadrangle.

Enterprise

Enterprise campground is on the southeast shore of the lake just west of the mouth of O-Ra-Pak-En Creek (figs. 1 and 17). This campground is accessible by boat, and by a private road through a farmyard. The campground has no water supply at present (1968).

The entire campground appears to be on landslide debris, as indicated by a hummocky surface just above the campground area between 1,360- and 1,400-foot altitudes. Landslide activity is indicated also at the northeast end of the campground by a 15-degree dip toward the south valley wall in silt and clay. At that point, medium sand overlies the tilted silt and clay. Southwestward along the shore, the medium sand grades into fine sand and then to silt toward the southwest. Bedrock is exposed southwest and southeast of the campground and probably continues under the campground area at fairly shallow depth. The ancient landslide mass probably slid on the bedrock surface.

Auger holes would probably be the most economical method of exploring the water-bearing potential of the surficial material in the campground area. However, the possibility of developing a water supply from either the landslide debris or from the bedrock is not great.

Wilmont Creek

Wilmont Creek campground is at the head of Wilmont Cove, the bay formed in the drowned part of the Wilmont Creek valley (figs. 1 and 18). Wilmont Creek campground has no water supply at present (1968).

Glacial-lake silt extends from a 1,900-foot altitude terrace to the shores of Wilmont Cove, where the campground is located. Permeable channel deposits from the Wilmont Creek drainage may occur within the glacial-lake beds, but are more likely to be found immediately overlying bedrock at the base of the lakebeds. If such coarse deposits exist, they would be the most likely source of water for the campground. A test well west of the present campground, near the

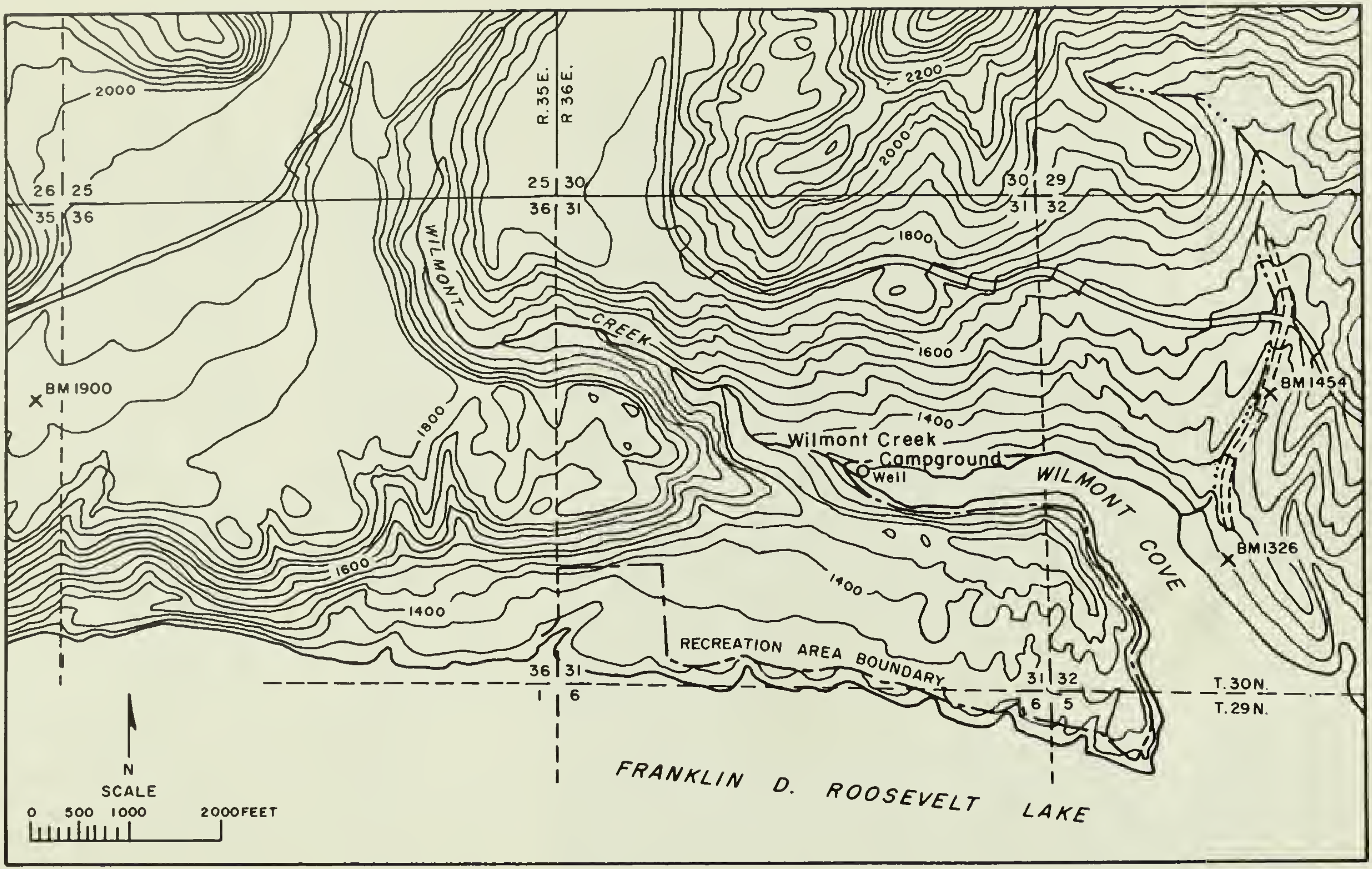

FIGURE 18.--Wilmont Creek campground (No. 17 on fig. 1). Base from USGS quadrangle.

axis of the bedrock valley would be more likely to penetrate coarse deltaic beds than would a test well in the present campground area. The bedrock valley is alined approximately north-south with the township line.

Rogers Bar

Rogers Bar campground is on a terrace at about 1,300-foot altitude on the west shore of Roosevelt Lake (fig. 1), and extends between about 2 miles and 3 miles northeast of Wilmont Cove. The present Rogers Bar camping area is at the north end of terrace (fig. 19).

Although no water supply exists at Rogers Bar at present (1968), future campground development on the terrace to the south, near the two bays, is planned to include 193 acres. Several good swimming beaches and a large area for waterfront campsites could be developed in the area.

A very thin layer of sand overlies glacial-lake silt in the area of the present campground development. The sand layer becomes thicker and the grain size grades from medium to coarse within 600 yards south of the developed campsite. At the mouth of the northern bay, the sand layer contains some gravel and extends from about 1,300-foot altitude to at least 1,255-foot altitude. Near the west end (head) of this bay, clay is found at an altitude of about 1,280 feet (10 ft below high lake level). The sand-clay contact dips fairly steeply along the bottom of the bay toward the center of the lake and is below 1,255-foot altitude at a point even with the main shoreline. A gravel-filled channel trending south-southwest cuts across the southeast corner of the point of land between the two large bays in the campground. If a similar gravel-filled channel could be found at sufficient depth it would be an excellent aquifer. Coarse permeable deposits may exist between bedrock and the base of the glacial-lake clay; however, depth to bedrock may be more than 600 feet.

The near-surface deposits at Rogers Bar were explored by two holes augered by the Geological Survey in August 1967. As shown in figure 19, the first auger hole is near the

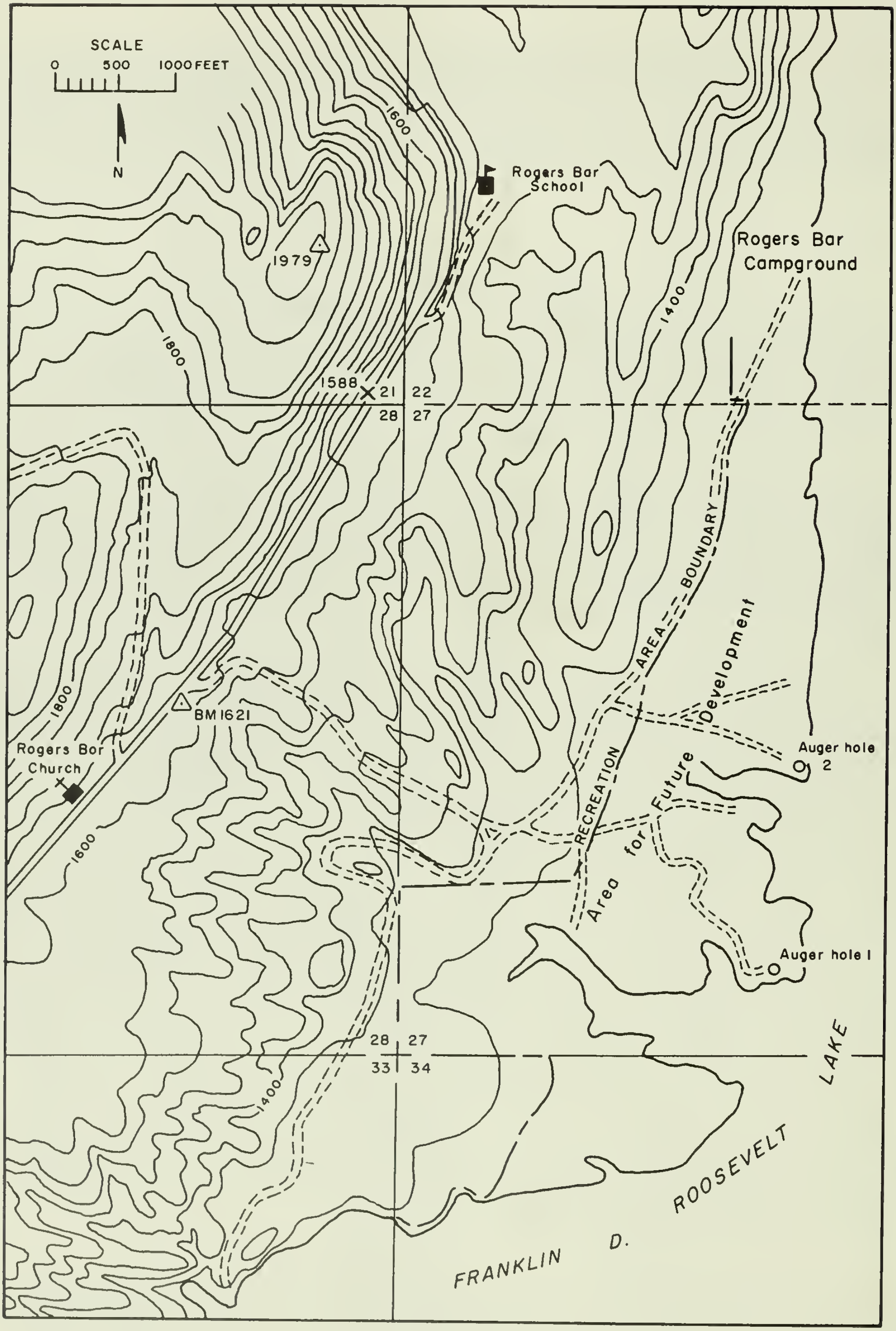

FIGURE 19.--Rogers Bar campground (No. 18 on fig. 1). Base from USGS quadrangle

southeast tip of the point between the two large bays, and the second is on the north side of the mouth of the northern bay. Logs of these holes are in table 10. The first hole penetrated layers of sand, gravel, and silt and entered clay at 80 feet below land surface (1,215-ft altitude). The second hole also penetrated layers of sand, gravel, and silt and entered clay at 73 feet below land surface (1,224-ft altitude). The first hole was completed in fine to coarse sand, the second in silty sand.

A gamma-ray log of auger hole 1 indicated that the most permeable zone is probably between 64 and 79 feet below land surface. A 4-inch steel casing was installed to a depth of 79.8 feet and had perforations between 73.3 and 79.3 feet below land surface, at a level with fine to coarse sand.

The hole was developed with compressed air, and a large amount of sand was removed. The hole was test pumped at 25 gpm, and the water level was drawn down 12 feet.

The gamma-ray log of auger hole 2 indicates that the most permeable zone is about 53 to 60 feet below land surface. Casing was installed to a depth of 55.9 feet below land surface so that perforations between 49.4 and 55.4 feet were opposite silty sand.

Auger hole 2 also was developed with air and a large amount of sand was removed. The well was test pumped for half an hour at 7.5 gpm, and the water level was drawn down 23.09 feet.

A chemical analysis was made of a water sample from each of the auger holes at Rogers Bar (table 2). Both samples met the required limits set by the Public Health Service (1962), but both exceeded the Public Health Service recommended limit for iron content. The water from auger hole 1 was very hard, while the water from auger hole 2 was moderately hard.

The most likely source for a ground-water supply at the Rogers Bar campground is from the sand and gravel overlying brown clay that was entered by auger holes 1 and 2 at depth of 80 feet and 73 feet, respectively. The fineness of the

TABLE 10.--Logs of two auger holes at Rogers Bar campground. Bored by U.S. Geological Survey, 1967

Auger hole 1: Altitude 1,295 ft; 4-inch casing to 79.8 ft, perforations 73.3-79.3 ft; water level 6.05 ft below land surface, 9-22-67; yield 25 gpm for 1¼ hrs, drawdown 12 ft.	Thickness (feet)	Depth (feet)
Sand, very fine to medium at top, medium to coarse at base	20	20
Silt	4	24
Gravel, medium	9	33
Silt and clay	7	40
Gravel	3	43
Sand, silty, clayey	17	60
Sand, fine to coarse, clean, most permeable zone indicated by low gamma radiation 64-79 ft (0.010-inch slot screen retained 47 percent of sand entrained in water during test pumping)	20	80
Clay, brown	8	88
Auger hole 2: Altitude 1,297 ft; 4-inch casing to 55.9 ft, perforations 49.4 to 55.4 ft; water level 7.69 ft below land surface, 9-22-67; yield 7½ gpm for half an hour, drawdown 23.09 ft.		
Sand, coarse, and silt	8	8
Sand, coarse to very coarse; with gravel 14-15 ft	10	18
Clay	2	20
Sand, very coarse, to very fine gravel; mixed	10	30
Gravel	12	42
Silt	3	45
Sand	1	46
Sand, silty (0.010-inch slot screen retained 17 percent of sand entrained in water during test pumping)	7	53
Sand, most permeable zone indicated by low gamma radiation 53-60 ft	7	60
Sand, increasingly silty and clayey with depth	13	73
Clay, brown	10	83

sand in both of these holes indicates that a fine screen would be necessary, and a gravel pack may also be required, to eliminate the sand problem in a production well. The clay surface dips toward the southeast, hence the thickness of potentially productive overlying material increases in that direction. A production well probably could be developed near either of the auger holes; in any case, a well should be located as far to the southeast as is practical.

Permeable material also may occur below the glacial-lake clay that underlies Rogers Bar. However, the clay may be as much as 600 feet thick, and exploratory drilling would be needed to determine the existence of water-yielding coarser materials.

Hunters Park

Hunters Park campground is on the east shore of the lake, about 1 mile north of the mouth of Hunters Creek (figs. 1 and 20). The campground is on a terrace at about 1,300-foot altitude between two bedrock knobs just east of the campground, in line with an abandoned and buried channel of Hunters Creek.

At the outset of this water-supply evaluation, the National Park Service had begun expansion and improvement of facilities at Hunters Park. A well had been dug to 40 feet, but the yield was only 1½ gpm of turbid water, unsuitable for use. The reconnaissance of surface features in the area was followed by the drilling of two test wells, neither of which was entirely satisfactory because of small yields.

The two surface features that influenced the selection of the test-well sites were (1) the location of the abandoned and buried channel of Hunters Creek, which is between the two bedrock knobs northeast and southeast of the campground, and (2) the distribution of coarse gravel exposed along the shoreline of Roosevelt Lake at low water. The gravel is concentrated in line with the buried channel, and indicates the most promising site for a well.

The first of the two test wells was drilled near the south side of the buried channel, 250 feet southeast of the boat-launching ramp. The driller reported water-bearing

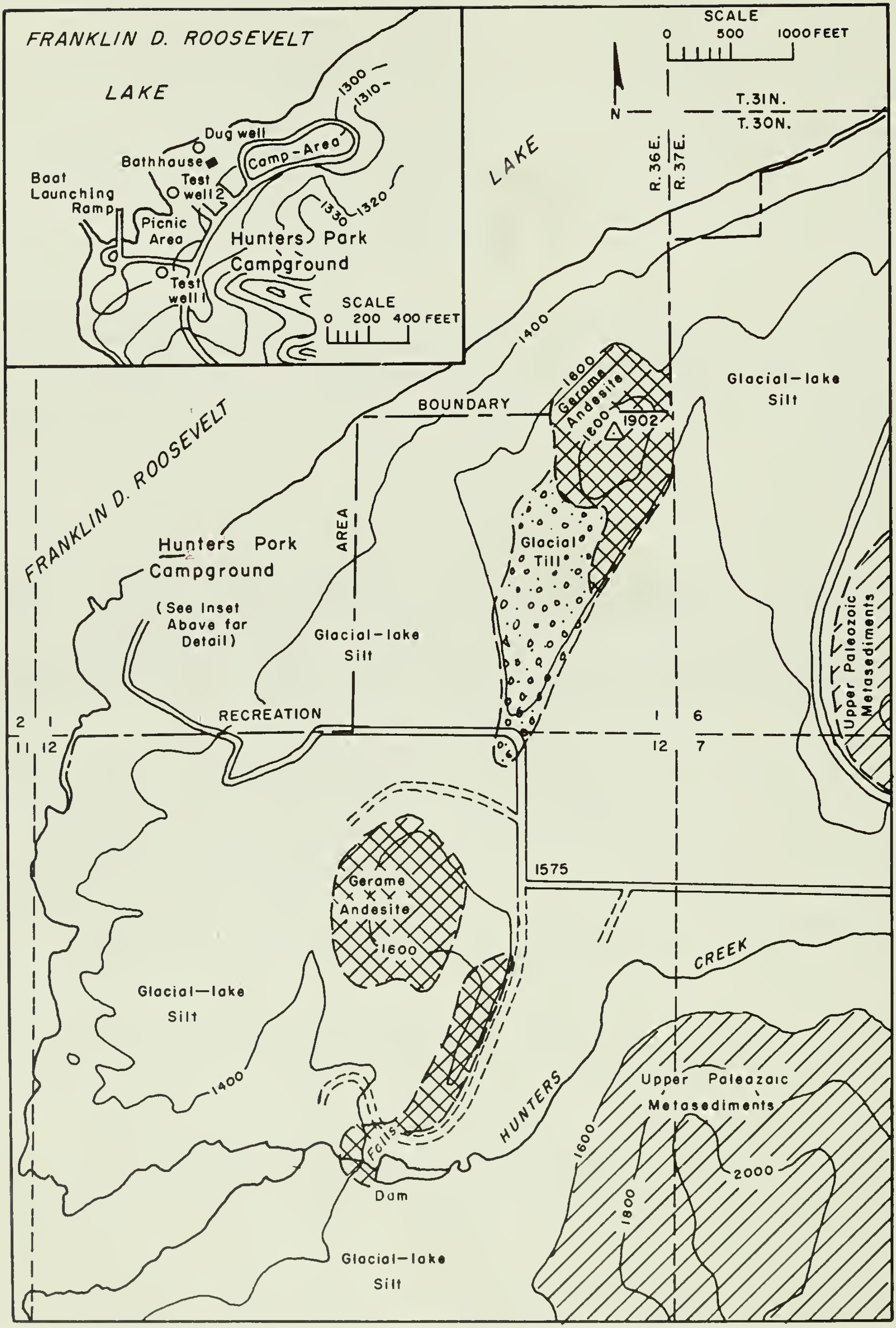

FIGURE 20.--Hunters Park campground (No. 19 on fig. 1). Base from USGS quadrangle. Insert area from NPS developed area plan.

gravel from 135 to 146 feet and basalt bedrock at 157 feet below land surface (table 11). Problems in getting sediment-free water from the first test well led to drilling the second test well which was located near the center of the buried channel, about 400 feet north of the first test well. The second well was drilled at nearly the same altitude and penetrated sand and gravel between 128 and 146 feet below land surface, about the same depth as in the first well. The sand and gravel in the second well was silty and yielded only 2 gpm. The second well continued either to bedrock or to a large boulder at 241 feet below land surface without penetrating an aquifer. Although these depths substantiate the existence of the buried Hunters Creek channel, the channel gravel failed to yield water to the second test well at a rate adequate for the needs of the campground.

Attempts to develop a water supply from the first test well were then renewed. A 0.008-inch slot stainless steel screen 4 inches in diameter was centered in the 8-inch casing opposite perforations from 135 to 145 feet, and grade-16 silica sand was used to form an envelope around the screen. The well was developed with compressed air for about 24 hours to remove any accumulation of silt and clay from the formation just outside the perforated 8-inch casing, and it was pumped for 10 hours at varying rates up to 25 gpm. The maximum drawdown was 64.50 feet. During test pumping, the well produced no sand and by the end of the pumping period the water showed only very slight turbidity. The screen appears to have improved the well so that it is able to produce as much as 25 gpm of sand-free water.

A sample of water for chemical analysis was collected from the well near the end of the pumping period (table 2). The water appears to be of good quality, but the iron content is higher than desirable.

An additional ground-water supply probably could be obtained in the future from a well drilled a short distance northwest of the first test well. An 8-inch well with an 8-inch screen of proper slot size probably would yield at least 25 gpm. Greater assurance of success could be obtained by drilling a larger diameter well and gravel packing around a 6- or 8-inch screen.

TABLE 11.--Logs of two test wells at Hunters Park campground. Drilled by Bach Drilling Co., 1966

	Thickness (feet)	Depth (feet)
Test well 1: Altitude 1,298 ft; 8-inch casing to 158 ft; perforations 136-146 ft, 4-inch casing 123-135 ft and 145-154 ft; 4-inch diameter 0.008-inch slot screen 135-145 ft; water level 7.75 ft below land surface, 8-19-67; yield 25 gpm, drawdown 64.50 ft.		
Clay, yellow	60	60
Clay with sand; yield 5 gpm	40	100
Clay, gray	35	135
Gravel, fine, "pea"-sized; yield 50 gpm	11	146
Silt, sandy, clayey, heaving ("quicksand")	11	157
"Basalt"	8	165
Test well 2: Altitude 1,297 ft; 8-inch casing to 240 ft, 6-inch casing to 241 ft; dry hole.		
Clay, silty, sandy, some water at 35 ft	65	65
Sand, fine, silty, clayey, enough water for drilling	35	100
Clay, some sand	5	105
Clay, dark blue	23	128
Sand and gravel, clayey; water 2 gpm	18	146
Clay with sand and gravel	29	175
Clay, sandy	66	241
Graywacke bedrock (or boulders)		241+

West Bissell

West bissell campground is on the west shore of the lake about 2½ miles southeast of the town of Inchelium (fig. 1). The campground is on a terrace at about 1,300 feet. An island in the lake, half a mile long, is separated from the northern part of the campground by a shallow channel.

No water supply exists at West Bissell campground at present (1968). Because the Park Service plans to improve the facilities at this area, evaluation of surface features was augmented by two auger test holes.

Sand and gravel at the surface of the terrace on which the campground is developed is underlain by glacial-lake clay. Large-scale landslide activity, extending more than a mile along the lakeshore is suggested by distorted bedding in the clay about half a mile north of the campground and immediately south of the area, and a hummocky slope between 1,400- and 1,700-foot altitudes just west of the campground. The landslide occurred during channel cutting in the glacial-lake clay, probably near the end of middle Pinedale time. The landslide debris (mostly silt and clay) was subsequently channeled parallel with the Columbia River, and subsequently some of the channels were partly filled with sand and gravel. The gravel-clay contact is at 1,279-foot altitude on the southeast side of the island. Just south of the island, at the bottom of a deep east-trending channel, gravel occurs below 1,258-foot altitude, indicating a sand- and gravel-filled channel west of the island. This gravel-filled channel continues across the peninsula south of the island. At the south end of the mainland terrace both sand and gravel deposits extend from the surface to below 1,258-foot altitude. This probably represents filling in the same channel observed half a mile north.

During August 1967, two auger holes (fig. 22) explored this sand- and gravel-filled channel which parallels the Columbia River. Logs of the West Bissell auger holes are in table 12. Auger hole 1, near the south end of the area, penetrated 76 feet of medium to very coarse sand with 25 feet of gravel near the top, and entered fine sand and silt that probably represent glacial-lake deposits at 1,219-foot altitude. Auger hole 2, at the north end of the area,

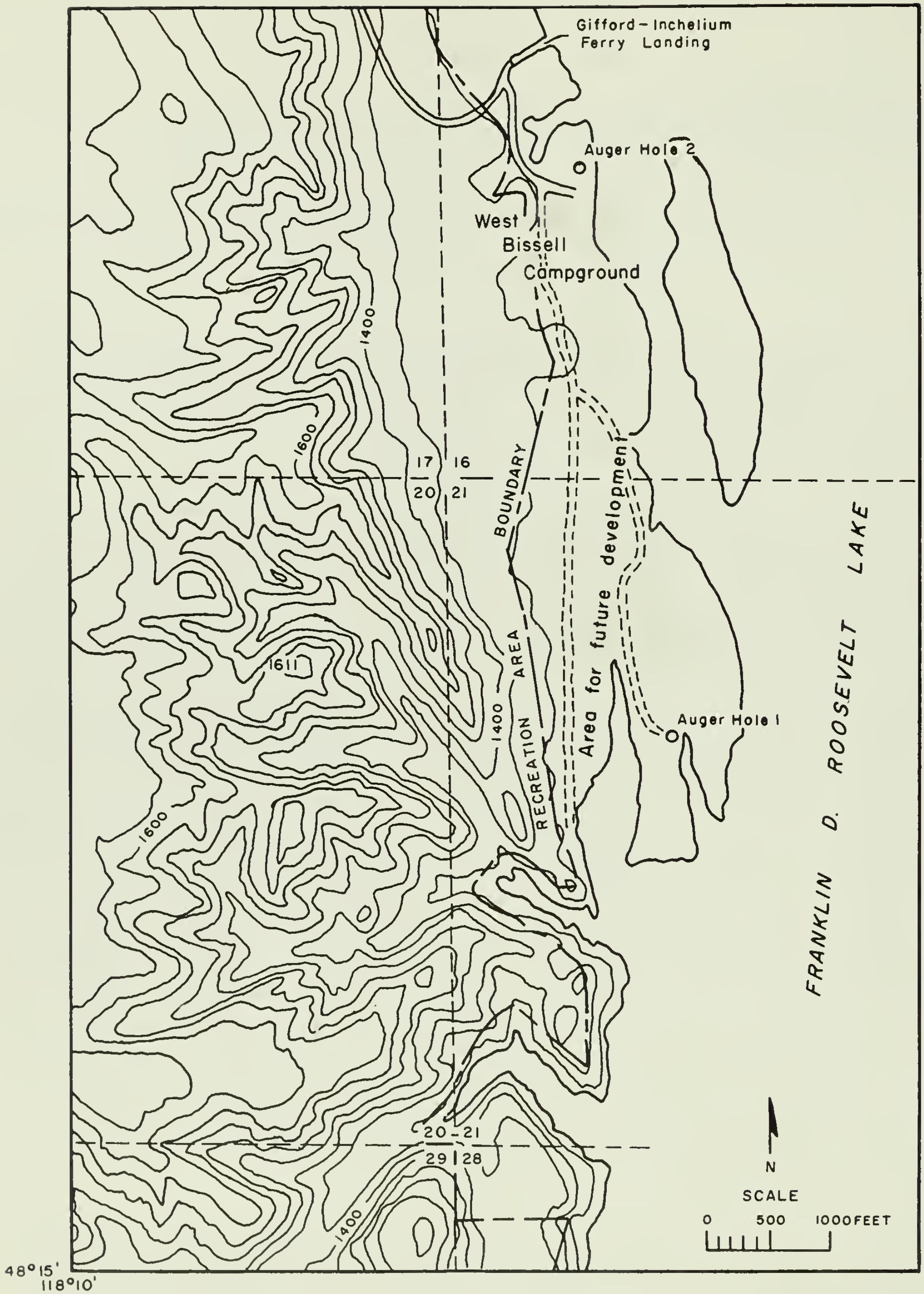

FIGURE 21.--West Bissell campground (No. 20 on fig. 1). Base from USGS quadrangle.

penetrated 11 feet of gravel then 67 feet of mostly medium to very coarse sand with some very fine sand and silt interbedded in the lower 34 feet. Glacial-lake clay was entered at 1,218-foot altitude. The logs of the two holes suggest that the buried sand- and gravel-filled channel extends the length of the campground area.

These auger holes were developed and test pumped with compressed air. Auger hole 1 was test pumped at 30 gpm and had a drawdown of 3.29 feet. Auger hole 2 was test pumped at 14 gpm and had a drawdown of 9.81 feet. The two auger holes indicate that water is available at shallow depth at both ends of the West Bissell area and probably at points between.

The water from auger hole 1 is very hard and contains more iron than the Public Health Service recommended limit (1962). The water from auger hole 2 is of better quality but is hard (table 2).

A water supply for the campground could be obtained near either of the auger holes; however, a well near auger hole 1 may have a larger specific capacity than one near auger hole 2.

Additional test holes east and west from auger hole 1 probably would locate coarser sand or gravel. Coarse water-bearing deposits may also exist below the glacial-lake sediments, but the fine lake sediments may extend to the 650-foot altitude, the approximate altitude of bedrock in the Columbia River channel about 20 miles upstream at Haag Cove. The disturbance of the sediments by landslides makes it difficult to predict with any certainty the possibility of obtaining a water supply below or from coarse deposits interbedded with the glacial-lake beds.

TABLE 12.--Logs of two auger holes at West Bissell campground. Bored by the U.S. Geological Survey, 1967

	Thick-ness (feet)	Depth (feet)
Auger hole 1: Altitude 1,295 ft; 4-inch casing to 73.9 ft, perforations 67.4-73.4 ft; water level 5.66 ft below land surface, 9-24-67; yield 30 gpm for 1 hr, drawdown 3.29 ft.		
Topsoil, silty clay	3	3
Sand, and medium gravel, silty	25	28
Sand, very coarse, clean	7	35
Sand, very coarse, silty	5	40
Sand, coarse to very coarse, clean	10	50
Sand, coarse, silty	6	56
Sand, medium to very coarse, clean	5	61
Sand, medium to coarse, clean, most permeable zone indicated by low gamma radiation (0.012-inch slot screen retained 56 percent of sand entrained in water during test pumping)	15	76
Sand, fine, silty	17	93
Auger hole 2: altitude 1,296 ft; 4-inch casing to 43.8 ft; perforations 38.8-43.3 ft; water level 6.10 ft below land surface, 9-24-67; yield 14 gpm for 2 1/3 hrs, drawdown 9.81 ft.		
Gravel, medium, and silt	11	11
Sand, medium to very coarse	9	20
Silt	1	21
Sand, medium to very coarse, silty	7	28
Sand, medium to very coarse, most permeable zone indicated by low gamma radiation (0.012-inch slot screen retained 48 percent of sand entrained in water during test pumping)	16	44
Sand, very fine to very coarse, silty	29	73
Sand, silt, and clay	5	78
Clay	5	83

Gifford

Gifford campground is on the east shore of the lake, and extends from 1 to 1¾ miles south of the town of Gifford (figs. 1 and 22). The presently (1968) developed campground is at the south end of the Gifford area. In 1964, a well was jetted to 21 feet in silt near the center of the campground. During the summer of 1965, water from this well became turbid and contained silt. In response to a request from the National Park Service in the spring of 1966, a well site was selected, and Geological Survey supervision was provided for drilling an 8-inch diameter well. The well was finished at a depth of 152 feet, and water is temporarily being supplied to the campground by a hand pump.

A large amount of gravel is exposed along the shore at low water near the launching ramp. That gravel is concentrated in an area in line with Buck Canyon, and is interpreted as being a deltaic deposit from the tributary drainage of Buck Canyon. The gravel is interbedded with glacial-lake clay and silt.

The new well penetrated 15 feet of water-yielding sand and gravel between 137 and 152 feet (table 13). A screen with 0.080-inch slots was installed between 140 and 146½ feet. The well was surged and developed for 25 hours. A step-drawdown pumping test was performed on April 22, 1966, at rates ranging from 75 to 317 gpm. The pumping rates and other information derived from the test are summarized below:

Step	Time since pumping began (min.)	Rate (gpm)	Cumulative drawdown (ft)	Specific capacity (gpm/ft)
1	35	75	2.95	25.4
2	102	160	6.85	23.4
3	169	210	7.97	26.3
4	222	266	10.15	26.2
5	227	317	12.32	25.7

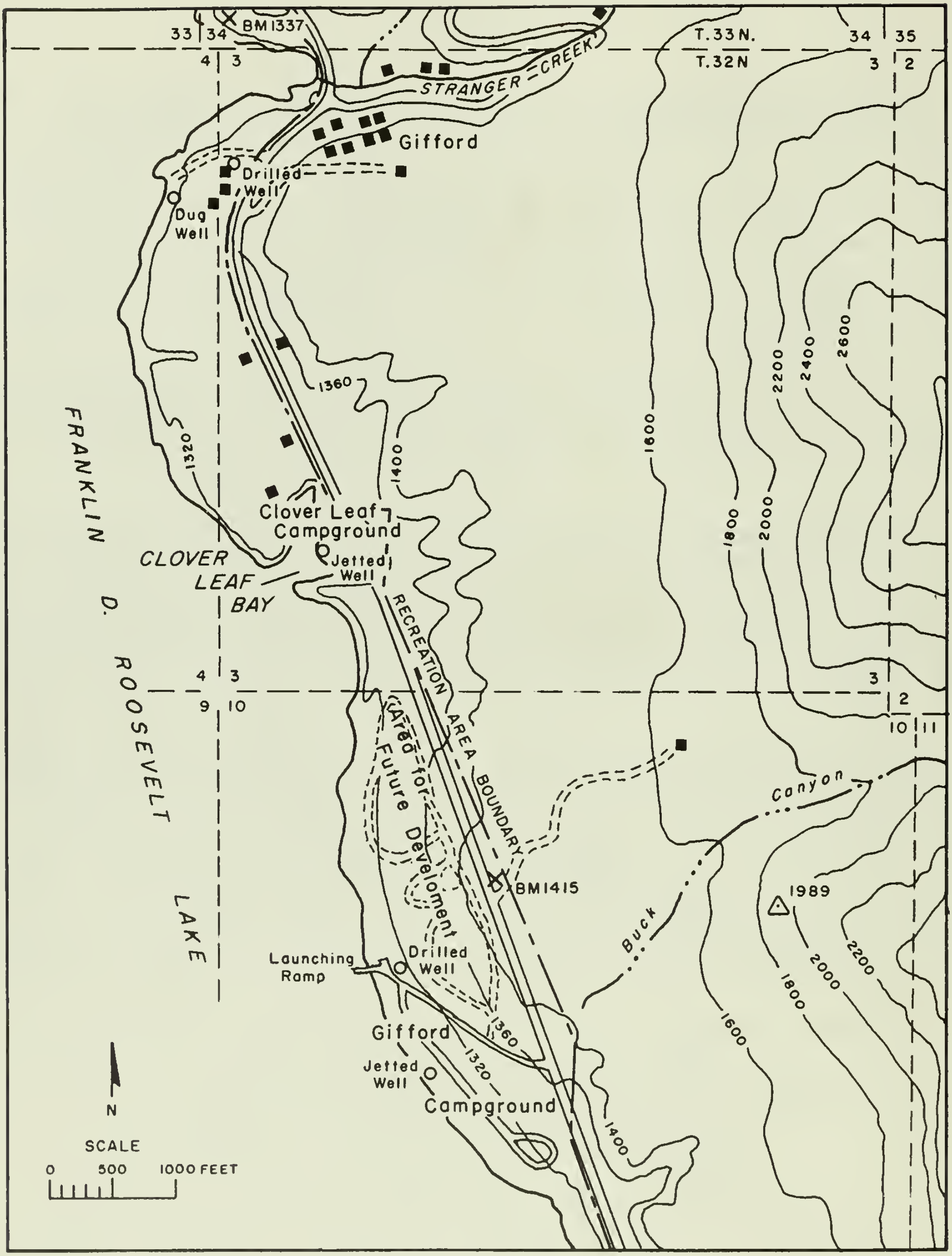

FIGURE 22.--Gifford campground and Clover Leaf campground (Nos. 21 and 22 on fig. 1). Base from USGS quadrangle and NPS master plan.

TABLE 13.--Log of the well at Gifford campground

Drilled by Bach Drilling Co., 1966; altitude 1,302 ft; 8-inch casing to 140 ft; 10-ft screen, 0.080-inch slot, exposed 140-146.5 ft; water level 51.98 ft below land surface, 4-22-66; 75 gpm for 35 min, drawdown 2.95 ft.	Thickness (feet)	Depth (feet)
Topsoil and gravel, mixed	4	4
Gravel and boulders	12	16
Gravel and clay, mixed	48	64
Sand and gravel, mixed with clay	10	74
Sand and some fine gravel	10	84
Sand, fine, and silt	51	135
Sand and gravel	1	136
Sand, medium, clean	1	137
Sand, coarse, and some gravel, water-bearing	1	138
Gravel, thin layer of cobbles (3 to 6 inch diameter) at base, water-bearing	6	144
Sand and gravel, water-bearing	5	149
Sand, coarse, and some gravel, heaving	1	150
Sand, medium to coarse, and fine gravel; heaved 6 ft into well	2	152

A water sample collected from a hand pump withdrawing between 3 and 4 gpm for 15 minutes was very hard and contained much iron (table 3). Later, at the time the well was test pumped, another sample was collected. As analyzed by the Washington State Department of Health, that sample had an even higher hardness (320 mg/l), and a much lower iron content (0.21 mg/l).

The results of the pumping test indicate that the well could be pumped at rates up to 1,000 gpm. This yield is sufficient to meet all the needs of the Gifford campground area, and it could also supply the Clover Leaf campground which is less than three-quarters of a mile north of the well.

Clover Leaf

Clover Leaf campground is on the east shore of Roosevelt Lake, halfway between Gifford campground and the town of Gifford. The campground is on the east side of a small bay (figs. 1 and 22). Water is supplied to the area from a small-diameter 30-foot well jetted into silt and fine sand by the National Park Service in 1956.

A hummocky surface just east of the bay suggests that landsliding may have occurred. A small valley extending northeastward from the north end of the bay appears to be an abandoned channel of Stranger Creek which now flows into Roosevelt Lake at the town of Gifford, half a mile north of the bay. This indicates that the Stranger Creek drainage flowed through the Clover Leaf area and may have left deltaic deposits interbedded with the glacial-lake clay and silt. Just north of the bay, silty sand overlies sand and gravel crossbedded toward the south-southwest at altitudes ranging from 1,295 to 1,310 feet. The crossbedded sand and gravel in turn overlie silt at 1,293-foot altitude. Immediately south of the bay, silt and clay overlie sand and very fine gravel at altitudes ranging from 1,295 to 1,310 feet. At the bay this sand and very fine gravel extend from the surface to an unknown depth below lake level.

If a larger water supply is sought for this area in the future, several possibilities can be considered, as follows: (1) a well drilled in the area would probably penetrate sand and gravel layers that would provide an adequate water supply, (2) the Gifford well is less than three-quarters of a mile south of Clover Leaf and yields more than enough water to meet the needs of both areas, and (3) if the Clover Leaf area should be expanded to the north, water might be obtained from an existing domestic well, drilled to a depth of 170 feet, just south of the mouth of Stranger Creek, on property now owned by the Park Service (fig. 22).

La Fleur

La Fleur campground is on the west shore of the lake at the mouth of La Fleur Creek (figs. 1 and 23), which is about 8 miles downstream from the mouth of the Colville River. The campground is on a very small terrace at about 1,300-foot altitude. La Fleur campground has no water supply at present (1968).

The small terrace on which the campground is located is part of a gravel delta at the mouth of La Fleur Creek. Argillite bedrock is exposed on the west side of the highway that parallels the lake shoreline. Silt is exposed along the shore a short distance both north and south of the campground area and indicates that the gravel delta is small. Although its thickness is not known, the gravel is the most likely source of water in this area. Neither the silt to the north and south nor the bedrock is likely to yield sufficient water for the campground.

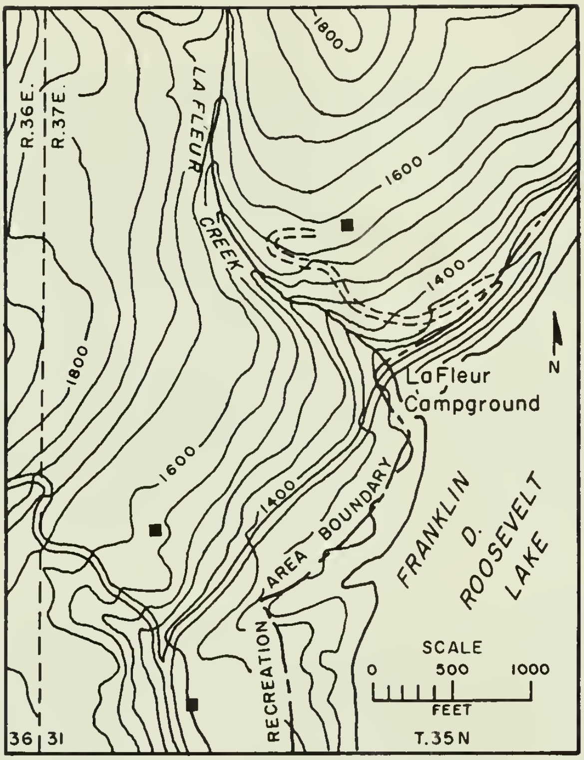

FIGURE 23.--LaFleur campground (No. 23 on fig. 1). Base from USGS quadrangle.

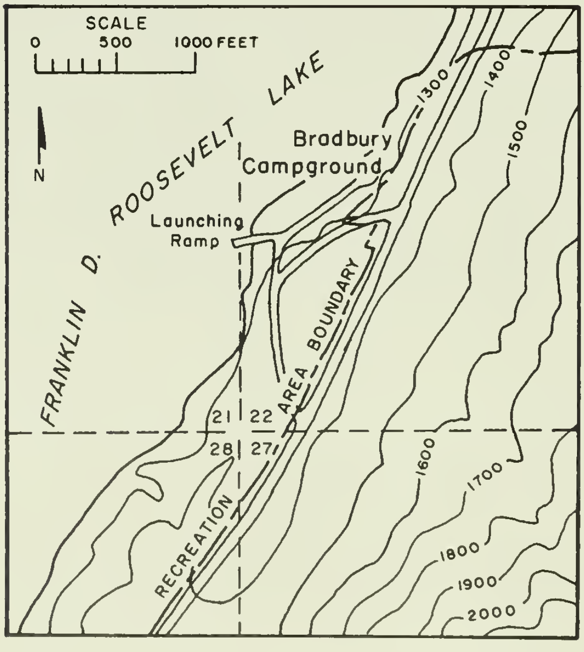

FIGURE 24.--Bradbury campground (No. 24 on fig. 1). Base from USGS quadrangle.

Bradbury

Bradbury campground is on the east shore of the lake, about 4 miles south of the mouth of the Colville River (fig. 1). The campground is on a narrow terrace at about 1,300-foot altitude (fig. 24). Bradbury has no water supply at present (1968).

The deposits along the shore at Bradbury are mostly silty sand and gravel. Both north and south of the campground this deposit overlies clean, fine sand at about 1,295-foot altitude. The silty sand and gravel is of unknown thickness and probably is a remnant of outwash-channel deposits. A shallow well drilled near the shore would probably obtain at least a small water supply.

Haag Cove

Haag Cove campground is on the west shore of the lake less than 2 miles south of the mouth of the Colville River (fig. 1). The campground area extends from a small group of sand-bar islands southwestward to the western end of Haag Cove (fig. 25). Water is supplied to Haag Cove campground from a 25-foot well that was jetted by the National Park Service in 1956.

Haag Cove itself is a landslide reentrant in an area of ancient landslides. Clay beds at the head of the cove dip to the northwest. Recent landslide activity was observed when a large multiple-alcove landslide occurred in the spring of 1952 in the Reed terrace area immediately north of Haag Cove. Haag Cove is quite shallow, and is filled with landslide debris. The debris appears to have stabilized the toe of the landslide material in the hillside above the campground. Clay is present throughout much of the area at relatively shallow depth and is covered by a surface layer of sand and gravel. In the cove, 500 to 1,000 feet from shore, the sand and gravel overlies clay at about 1,285-foot altitude, only 5 feet below high lake level.

The depth of the sand and gravel in the campground area was explored by two auger holes. One of the auger holes was placed north of the present developed area, and the other one south (fig. 25). Logs of these holes are in

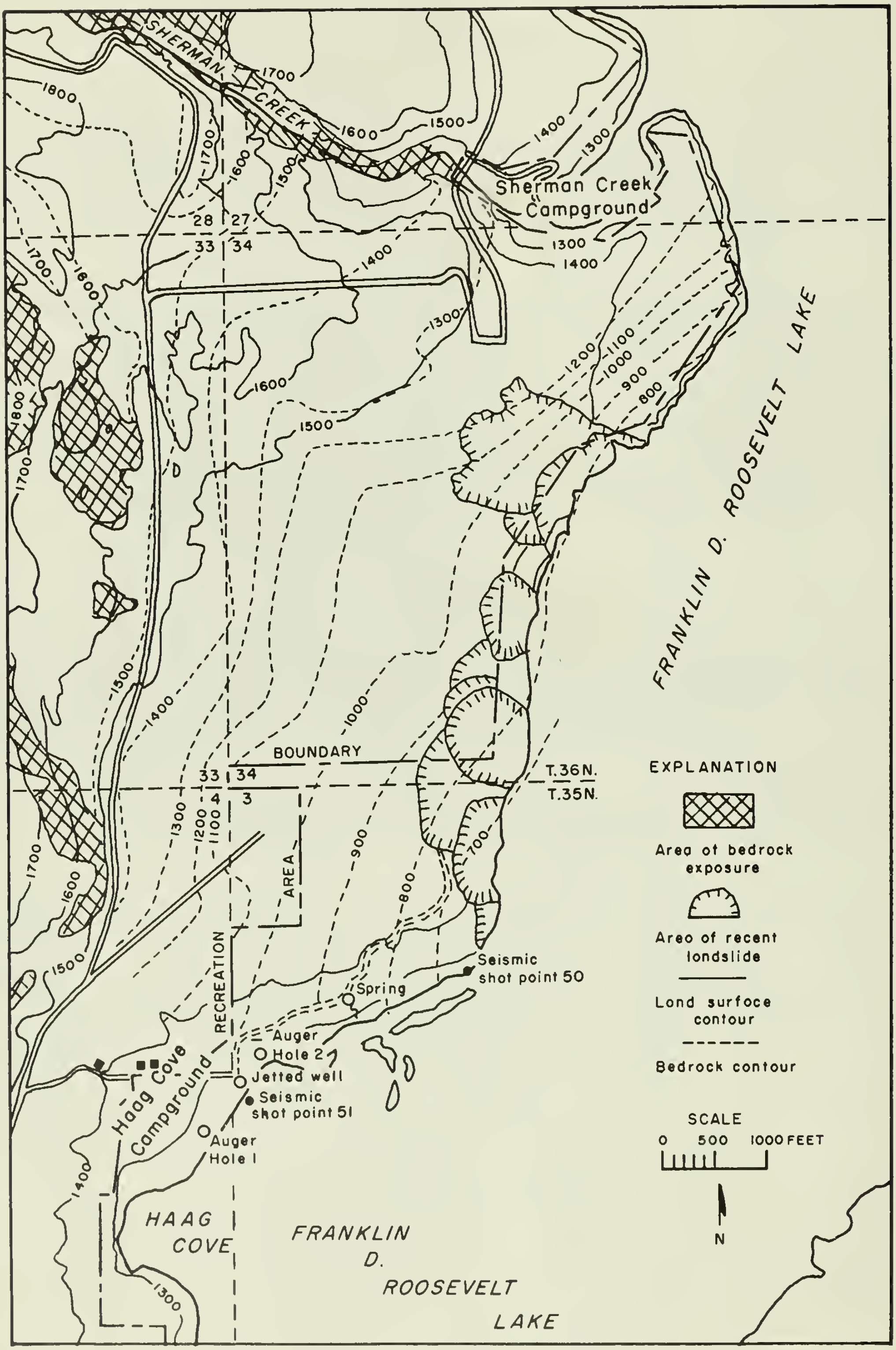

FIGURE 25.--Haag Cove campground and Sherman Creek campground (Nos. 25 and 27 on fig. 1). Land-surface and bedrock-surface contours are shown. Bedrock exposure and landslide areas are indicated. Map from "Geologic map of Reed Terrace area, Washington" (Jones, 1961, pl. 1).

table 14. Auger hole 1 penetrated mostly sand and gravel, and entered glacial-lake clay at 62-foot depth. A gamma-ray log, to a depth of 56 feet, indicated two zones in the sand and gravel with higher permeability than the rest. The first zone is from 36 to 47 feet below land surface and the other is from 50 to 56 feet. The deeper is possibly the more permeable of the two. Below 56 feet the driller reported a gravel which was hard to penetrate perhaps because it was very coarse or because it contained some clay.

The sandy gravel between 30 and 47 feet was tested for yield. A 4-inch casing, with perforations between 38 and 44 feet, was installed to a depth of 44 feet. A little sand and much silt was removed from the well during development with compressed air. The well was test pumped at 25 gpm for 1½ hours and the drawdown was only 0.32 foot.

The chemical quality of the water from auger hole 1 is excellent (table 2). The hardness is close to the boundary between soft and moderately hard water.

Auger hole 2 was drilled near the north end of the area. The lowest gamma radiation was recorded between 30 and 38 feet, indicating that this zone might be the most favorable for development. The sand and gravel there probably continue to a depth similar to that in auger hole 1 and are probably underlain by the same clay.

A satisfactory water supply probably can be obtained from the lower part of the sand and gravel at the site of either auger hole. The gravel layer presumably continues between the two auger hole sites. Gravel deposits may overlie bedrock at the base of the clay; however, seismic tests reported by Jones (1961, p. 72-74) indicate bedrock is at considerable depth in this area. Two of 75 shot points, numbered 50 and 51, and located in figure 25, indicate a bedrock altitude of 667 feet and 985 feet.

Another possible source of water for Haag Cove campground is a spring at the northwestern end of Haag Cove campground (fig. 25). Local residents, most of whom obtain water supplies from springs in the area, report that this spring is never dry.

TABLE 14.--Logs of two auger holes at Haag Cove campground. Bored by U.S. Geological Survey, 1967

Auger hole 1: Altitude 1,296 ft; 4-inch casing to 44.1 ft; perforations 37.8 to 43.8 ft; water level 7.62 ft below land surface, 9-26-67; yield 25 gpm for 1½ hrs, drawdown 0.32 ft.	Thickness (feet)	Depth (feet)
Sand and gravel layers	30	30
Gravel, sandy; permeable zone indicated by low gamma radiation 36-47 ft	17	47
Sand, silty	3	50
Sand, most permeable zone indicated by low gamma radiation	7	57
Gravel, probably very permeable (no gamma log)	5	62
Clay	1	63
Auger hole 2: Altitude 1,295 ft.		
Sand, coarse, clayey	13	13
Silt and clay	6	19
Gravel, coarse, silty and clayey	6	25
Gravel, coarse, most permeable zone indicated by low gamma radiation	13	38
Gravel, coarse, silty	10	48

Sherman Creek

Sherman Creek campground is on the west shore of Roosevelt Lake, directly opposite the mouth of the Colville River (fig. 1). The campground is at the head of the bay formed when the lower part of Sherman Creek valley was flooded by the lake (fig. 25).

A campground has no water supply. Some campers have used water from Sherman Creek; however, such use is hazardous: a water sample collected for bacterial analysis from Sherman Creek in the fall of 1965 was indicated as unsatisfactory by the Washington State Department of Health.

Phyllite and slate are exposed along the walls of Sherman Creek valley, and the valley appears to contain very little alluvium. About the only sand and gravel there underlies the point that extends northward across the mouth of Sherman Creek. The point probably is a remnant of a delta deposited by Sherman Creek in Glacial Lake Columbia.

A well drilled near the middle of Sherman Creek valley, in the campground near the mouth of the creek, would tap the area's maximum thickness of valley alluvium and probably could supply an adequate volume of water for the campground. Such a well would probably be shallow. Moreover, the deltaic deposits on the point extending north across the mouth of Sherman Creek also might supply an adequate volume of water for the campground.

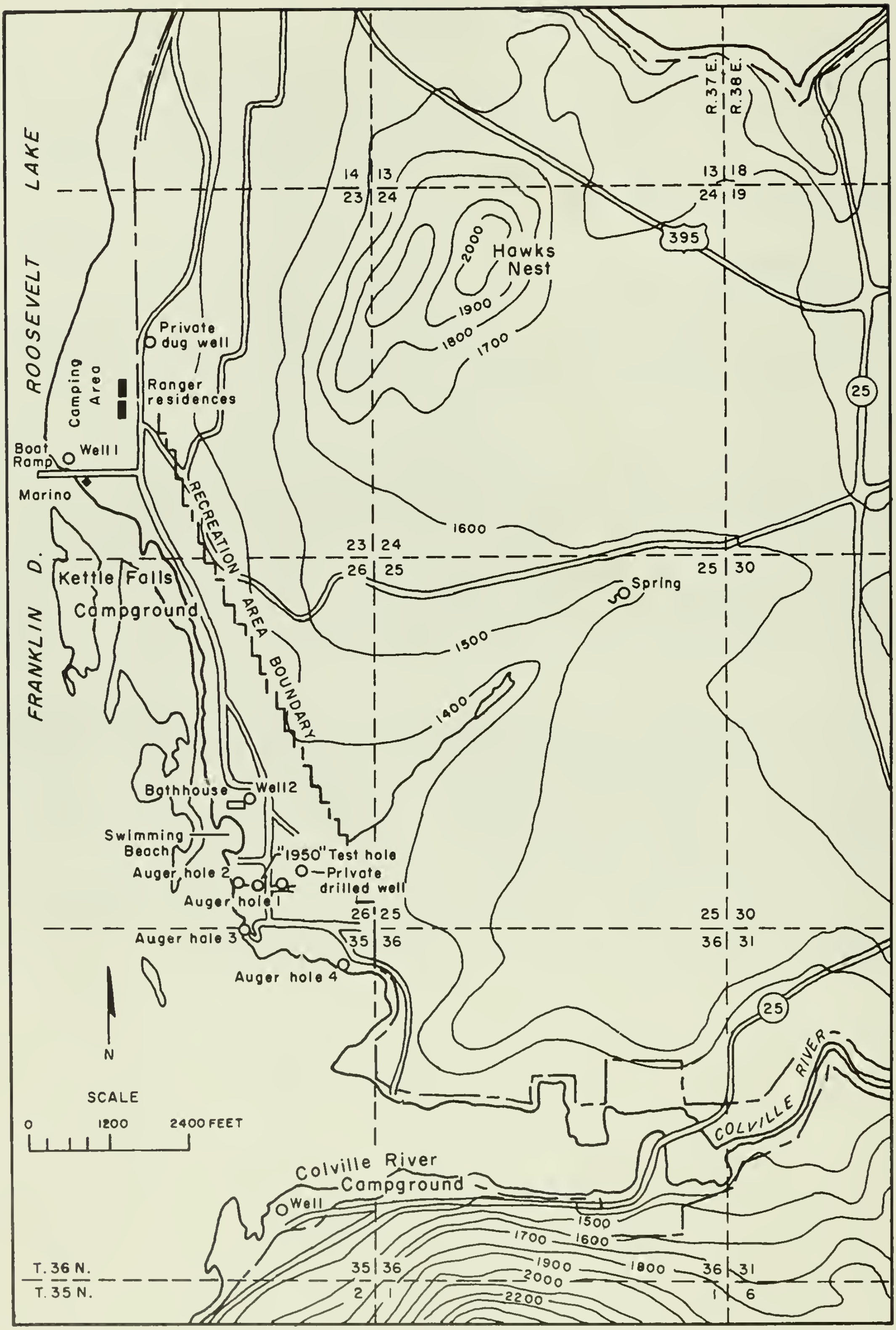

FIGURE 26.--Kettle Falls campground and Colville River campground (Nos. 26 and 28 on fig. 1). Base from USC&GS chart.

Colville River

Colville River campground is on the east side of the lake, south of the mouth of the Colville River (figs. 1 and 26). The campground is on a terrace at about 1,300-foot altitude. Water is supplied to the campground from a 20-foot well jetted by the National Park Service in 1964.

Gravel and some clay are exposed along the shore in the campground area. These materials are deltaic deposits of the Colville River, and are interbedded with glacial-lake clay of middle Pinedale age. The thickness of the gravel sequence is not known. The gravel tapped by the present shallow well may yield all the water that will be needed for the future. However, unless the gravel extends to depths below the lowest seasonal level of Roosevelt Lake, it probably will be dry during periods of low lake level. Under these circumstances, a deeper aquifer would have to be sought.

Kettle Falls

Kettle Falls campground is on the east shore of the lake, and extends about 2 miles north from the mouth of the Colville River (figs. 1 and 26).

The present (1968) water supply is obtained from Roosevelt Lake. Several test holes were drilled about 1950. One of them ("1950" test hole, fig. 26) remains in the area south of the campground's swimming beach (log in table 15). In the past, two production wells have served the area. Kettle Falls well 1, drilled in 1952 near the present boat-launching ramp, penetrated water-bearing gravel from 25 to 39 feet. At the 39-foot depth, it entered clay which extended to a depth of 95 feet (log in table 15). A few years ago well 1 silted in and was abandoned. Kettle Falls well 2, near the swimming beach (fig. 26), was drilled in 1955 to a depth of 50 feet, 45 feet below lake level (no log available). It reportedly also had silt problems and is not used.

TABLE 15.--Logs of test hole, two wells, and four auger holes at Kettle Falls campground

"1950" test hole: Drilled 1950, driller unknown; altitude 1,300 ft; 6-inch casing to unknown depth.	Thickness (feet)	Depth (feet)
Sand	20	20
Gravel	4	24
Clay	16	40
Kettle Falls well 1: Drilled 1952, driller unknown; altitude 1,296 ft; 12-inch casing to 85 ft; perforations 25-39 ft; yield 23 gpm.		
Soil	2	2
Mud and gravel	6	8
Gravel, water-bearing	2	10
Unknown	3	13
Sand	12	25
Gravel, "pea-size," water-bearing	14	39
Clay, blue, soft	56	95
Kettle Falls well 2: Drilled 1955, driller unknown; altitude 1,295 ft; depth 50 ft; yield 50 gpm. No log data available.		

TABLE 15.--Logs of test hole, two wells, and four auger holes at Kettle Falls campground--Continued

Auger hole 1: Bored by U.S. Geological Survey, 1967; altitude 1,307 ft; 4-inch casing to 67.3 ft, perforations 60.3-66.8 ft; water level 19.08 ft below land surface, 9-26-67; yield 20 gpm for 1 hr, drawdown 0.37 ft. All material water bearing below 21 ft.	Thickness (feet)	Depth (feet)
Sand, silty, brown	11	11
Gravel, sandy, gray	10	21
Sand, medium to coarse	3	24
Gravel, cobble	16	40
Gravel, medium, sandy	10	50
Sand	1	51
Gravel, medium, sandy	9	60
Sand, some gravel	11	71
Gravel, most permeable zone indicated by low gamma radiation 77-80 ft	9	80
Sand	3	83
Auger hole 2: Bored by U.S. Geological Survey, 1967, altitude 1,295 ft.		
Sand, silty	13	13
Sand, medium to coarse with gravel layers	17	30
Gravel, coarse, sandy, fine material indicated by high gamma radiation	5	35
Silt and very fine sand, high gamma radiation	16	51
Clay, very high gamma radiation	7	58

TABLE 15.--Logs of test hole, two wells, and four auger holes at Kettle Falls campground--Continued

Auger hole 3: Bored by U.S. Geological Survey, 1967; altitude 1,293 ft.	Thickness (feet)	Depth (feet)
Sand	16	16
Sand and gravel	2	18
Gravel, coarse	13	31
Clay	7	38

Auger hole 4: Bored by U.S. Geological Survey, 1967; altitude 1,300 ft; 4-inch casing to 64.4 ft, perforations 59.0-64.0 ft; water level 10.27 ft below land surface, 9-20-67; yield 15 gpm for 2 hrs, drawdown 13.31 ft. All material below 10 ft is water bearing.	Thickness (feet)	Depth (feet)
Silt, brown	8	8
Sand, medium, brown	16	24
Gravel, coarse, most permeable zone indicated by low gamma radiation 36-45 ft	17	41
Sand, fine	3	44
Gravel, medium, coarse near bottom; sandy (0.020-inch slot screen retained 49 percent of sand entrained in water during test pumped)	19	63
Gravel, cobble; fine material indicated by high gamma radiation, 70-76 ft	11	74
Sand	9	83

The area at the north end of Kettle Falls campground is underlain by bedrock at shallow depth, and a bedrock knob called Hawks Nest is just north of the campground. A privately owned dug well just north of the Kettle Falls campground (fig. 26) penetrated 15 feet of fine sand and then encountered bedrock. The well reportedly yields 5 gpm, and is typical of other wells along the flanks of Hawks Nest.

A major feature of the Kettle Falls area is a buried bedrock channel of the Columbia River east of Hawks Nest. A well about 300 feet east of the road intersection in the SW$\frac{1}{4}$ of sec. 19, T. 36 N., R. 38 E., is reported to have penetrated more than 400 feet of sediment without reaching bedrock. The channel filling exposed along the shoreline is mostly glacial-lake clay and silt of middle Pinedale age. This clay and silt probably is underlain by silty, sandy outwash deposited in the glacial lake in front of the retreating middle Pinedale glacier. The recessional outwash probably rests on bedrock scoured by the glacier. The depth to bedrock at Haag Cove (about 3 miles southwest) is 632 feet (667-ft altitude).

Kettle Falls well 1, the 1950 test hole, and auger holes 2 and 3 (fig. 26) all penetrated sand and gravel and entered lacustrine silt or clay less than 40 feet below land surface (about 30 feet below high lake level). Logs of the wells are in table 15. These logs and clay exposures along the lakeshore, also about 30 feet below high lake level, indicate that most of the Kettle Falls campground is underlain by nonproductive silt and clay.

Auger holes 1 and 4 on Park Service land, and the privately owned, drilled well several hundred feet northeast of auger hole 1, each penetrated about 70 or 80 feet of sand and gravel without reaching the lacustrine silt or clay. The three wells appear to tap an aquifer in gravel that was deposited in a channel cut into the surface of the lakebeds.

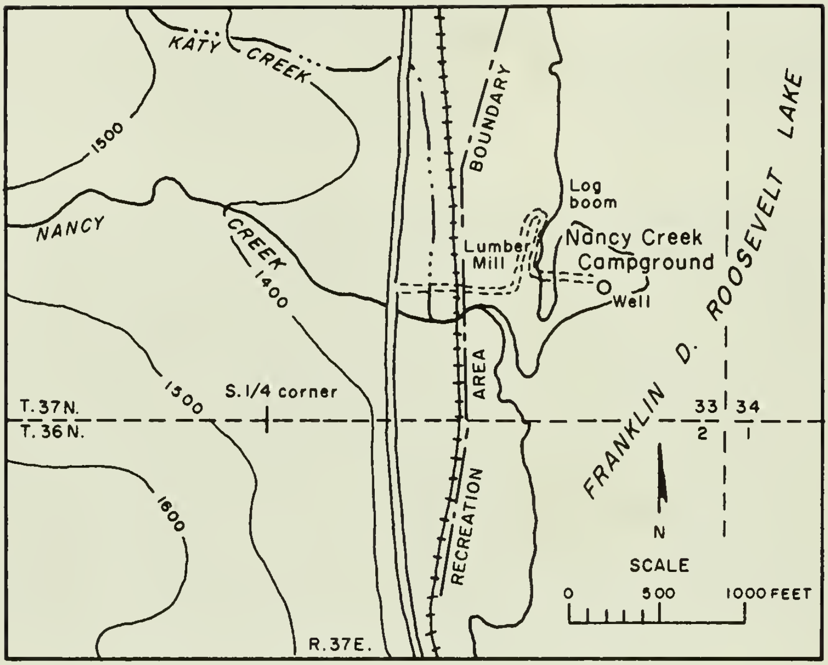

FIGURE 27.--Nancy Creek campground (No. 29 on fig. 1). Base from USC&GS chart.

The gravel aquifer was tested by auger holes 1 and 4. Casing was installed to depths of 67 and 64 feet, respectively, and both were developed and test pumped with compressed air. Auger hole 1 was test pumped at 20 gpm and had less than 1 foot of drawdown, whereas auger hole 4 was test pumped at 15 gpm and had about 13 feet of drawdown. During development and pumping, auger hole 4 yielded sand. The water from both auger holes 1 and 4 is good except for being hard (table 2). Because ground-water levels fluctuate as much as 40 feet in response to changes in lake level, it is desirable to obtain a water supply at a depth greater than 40 feet below high lake level. A production well at Kettle Falls should be near auger hole 1 or 4, or possibly in the channel that is indicated as existing between them. The channel probably extends northward from auger hole 1, but its exact location is not defined.

Nancy Creek

Nancy Creek campground is on the west shore of the lake, about a mile south of the mouth of the Kettle River arm of the lake. The campground is on a triangular peninsula joined to the main shoreline by a narrow isthmus at the south end and by a causeway for a road in the middle (fig. 27). The campground is supplied with water from a 20-foot well jetted by the National Park Service in about 1956.

The point on which the campground is located is the top of what appears to be a remnant of a landslide block. Schist bedrock is exposed at the south end of the point near the isthmus. That exposure indicates that the landslide block probably slid on a bedrock surface. Along the main shoreline of the lake, west and north of the point, a 5- to 15-foot cap of very fine sand overlies a 35-foot-thick coarse gravel which in turn overlies the glacial-lake clay. The contact between the gravel and the clay is about at 1,335-foot altitude, or 45 feet above lake level. The contact between the gravel and the overlying cap is at about 1,370-foot altitude along the main shoreline and between 1,289- and 1,295-foot altitude, or near lake level, in the campground area.

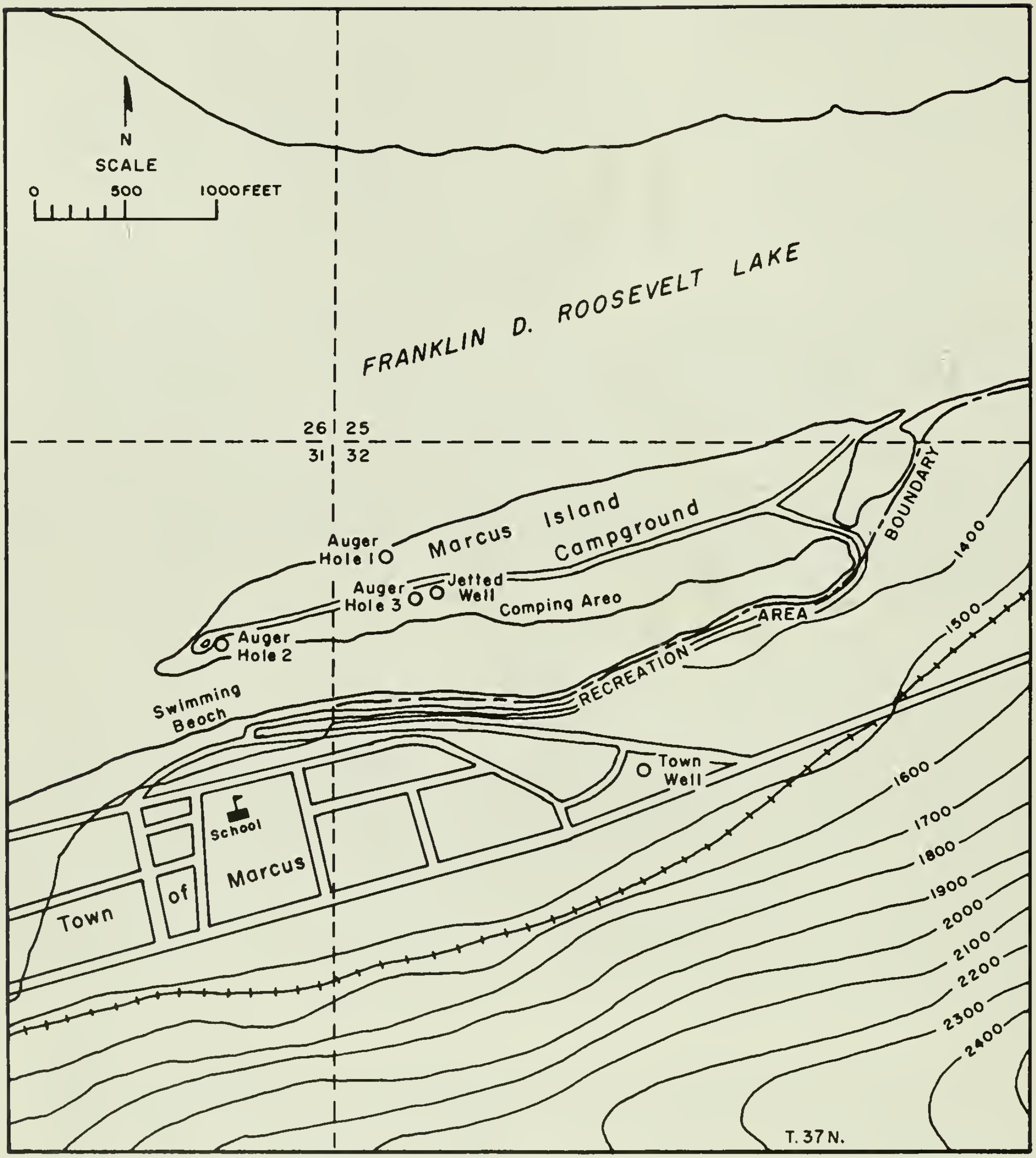

FIGURE 28.--Marcus Island campground (No. 30 on fig. 1). Base from USC&GS chart.

The most likely source of water in this area is the gravel underlying the campground area. If the gravel is 30 to 35 feet thick in the landslide block, as it is on the main shoreline, it may be adequate to serve the campground when the lake is full, but when the lake level drops during the winter a well tapping the gravel would probably be dry. Bedrock is not likely to yield water in this area.

Marcus Island

Marcus Island is about three-quarters of a mile long and lies opposite the mouth of Kettle River (fig. 1). The island is separated from the main lake shoreline by a narrow, shallow channel (fig. 28). A causeway at the east end of the island connects it to the mainland. Water is supplied to the campground at present (1968) by a 15-foot well jetted by the National Park Service in 1956.

Auger holes were drilled at three sites on Marcus Island, but none penetrated more than 22 feet below land surface. They all encountered cobble gravel that stopped the auger. Logs of those holes are recorded in table 16. The first two holes did not reach water. Auger hole 3 penetrated 10 feet of saturated, silty, very coarse to cobble gravel to a total depth of 18 feet. A 4-inch casing, with perforations between 9.7 and 14.9 feet, was installed in auger hole 3 to a depth of 15.4 feet. The well was developed by surging with compressed air for several hours, and when test pumped at 4 gpm, it had a drawdown of about 3 feet.

A drilled well might provide a small water supply from the gravel which is as much as 15 feet below high lake level. Two other sources for a ground-water supply on the island are outwash-gravel layers interbedded with the clay at greater depths, and limestone bedrock underlying the glacial deposits. The latter possibility is shown by the well that serves the town of Marcus, about two-tenths of a mile southeast of the island. The town well was drilled from a land surface altitude of

TABLE 16.--Logs of three auger holes at Marcus Island campground. Bored by U.S. Geological Survey, 1967

Auger hole 1: Altitude 1,308 ft.	Thickness (feet)	Depth (feet)
Sand, fine, brown------------------------------	15	15
Gravel, cobble (dry)--------------------------	7	22
(3 holes were drilled within 25 ft of each other at this site, all entered cobbles at 15 ft. The first two stopped at 16 ft, and the third stopped at 22 ft. All three holes were dry.)		
Auger hole 2: Altitude 1,300 ft.		
Sand, fine to very fine----------------------	13	13
Gravel, cobble (dry)--------------------------	5	18
Auger hole 3: Altitude 1,295 ft; 4-inch casing to 15.4 ft, perforations 9.7-14.9 ft; water level 5.42 ft below land surface, 9-21-67; yield 4 gpm for 4 hrs, drawdown 2.93 ft.		
Sand, fine, brown------------------------------	8	8
Gravel, very coarse to cobble, and silty, medium, brown sand; water-bearing----------	10	18

1,445 feet and reportedly entered limestone at about 1,245-foot altitude. It penetrated about 27 feet of limestone from which it obtained a water supply sufficient for the town.

The water from auger hole 3 is high in iron and moderately hard, but is acceptable otherwise (table 2).

Kamloops Island

Kamloops Island campground is at the mouth of the Kettle River arm of Roosevelt Lake (fig. 1). A causeway crosses from the east side of the lake to the island and bridges take the highway and a railroad from the island to the west side of the lake (fig. 29). The campground is on the island northwest of the highway. No water supplies are on the island at present (1968).

Bedrock is exposed along the west and southwest shore of Kamloops Island. It is overlain by sand and gravel outwash deposits interbedded with glacial-lake clay.

A well drilled near the east or northeast side of the island would most likely reach a layer of outwash sand and gravel at sufficient depth to serve as an aquifer. Two holes were attempted with an auger in August 1967, but penetration was stopped at 7 feet and 12 feet by boulders, or possibly by bedrock.

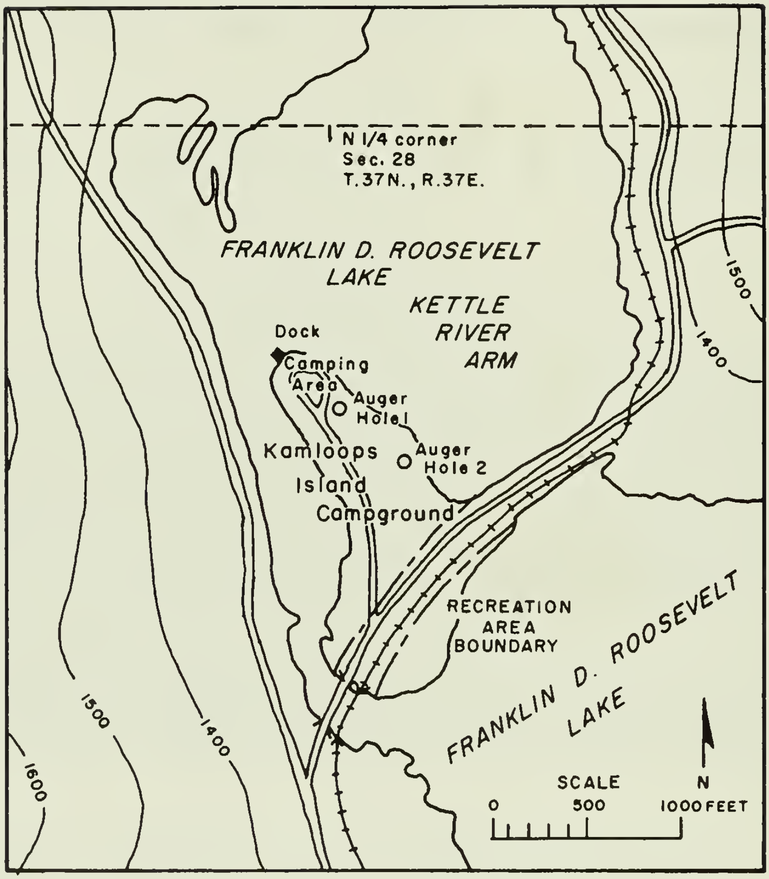

FIGURE 29.--Kamloops Island campground (No. 31 on fig. 1). Base from USC&GS chart.

Kettle River

Kettle River camground is on the west shore of the Kettle River arm of Roosevelt Lake, about 6 miles north of the confluence of the valleys of the Kettle and Columbia Rivers (fig. 1). The campground is on the flood plain of the Kettle River, inside a meander of the channel (fig. 30).

Water is supplied to the campground from a 20-foot well jetted by the National Park Service in 1964. This well is near the bank of the river and a hand pump is installed in the well.

Much of the flood plain in the area of the campground is covered by about 4 feet of fine sand which overlies a layer of cobble gravel 4 feet above, to an unknown depth below, lake level. The cobble gravel appears too coarse to be a recent deposit of the Kettle River and may be a remnant of outwash gravel from glacial drainage. The same material seems to underlie all parts of the campground. The selection of a site for test drilling or a production well therefore should be on the basis of avoiding contamination from such sources as the pit toilets (fig. 30).

Evans

Evans campground is on the east shore of Roosevelt Lake, about 5 miles upstream from the Kettle River arm (fig. 1). The campground is on a terrace at about 1,200-foot altitude (fig. 31).

In seeking a ground-water supply in 1961, an 8-inch test well was drilled to bedrock at a depth of 173 feet, but the well yielded only 15 gpm of "muddy" water. The plan for a ground-water supply was abandoned, and today the water supply for the campground is taken directly from Roosevelt Lake. The present system is adequate for the present needs of the campground (1968).

Although the gravel penetrated by the test well drilled in 1961 was too silty to yield usable water, the gravel north of Evans campground appears much more permeable. This is shown by two domestic-supply wells that have been dug in

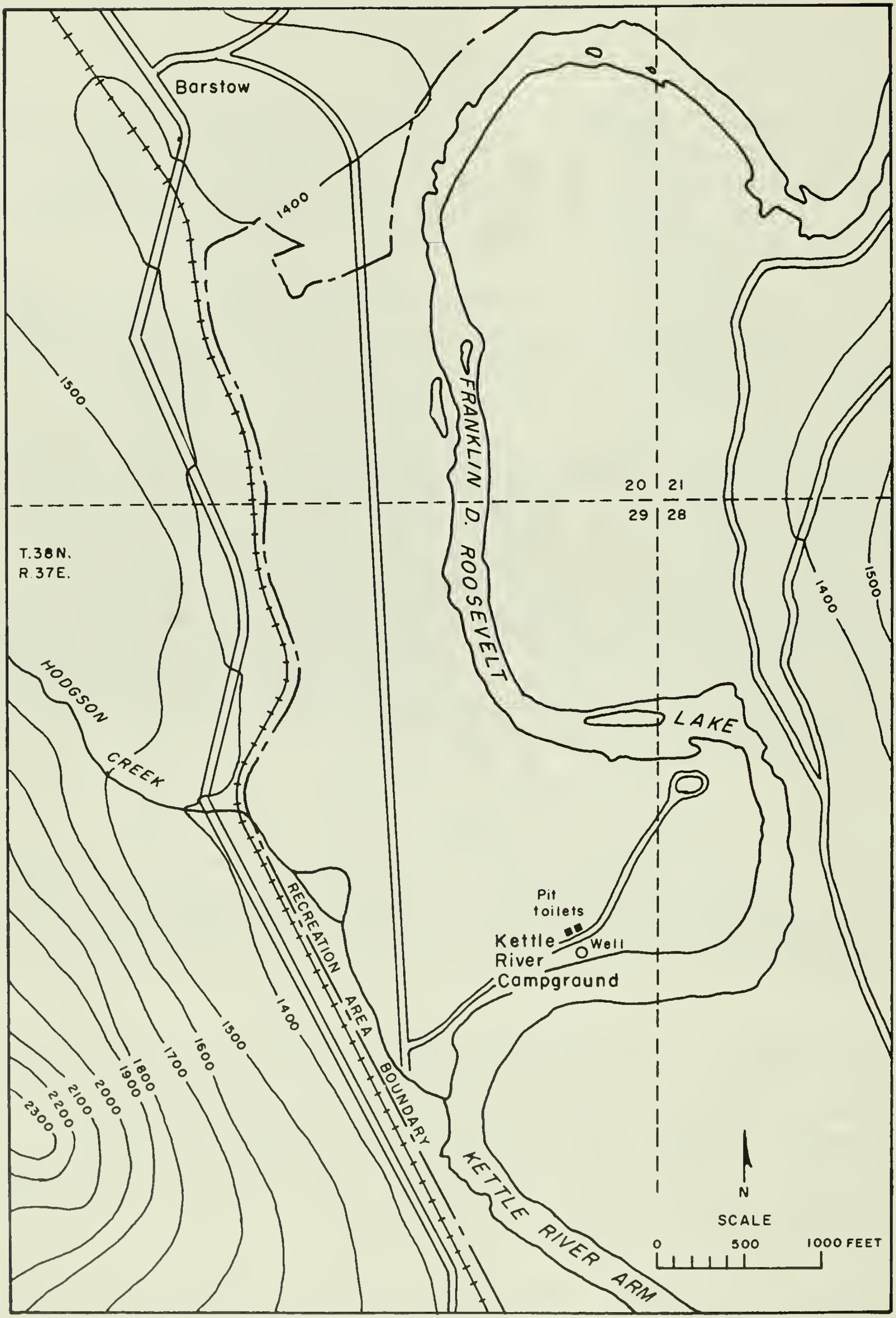

FIGURE 30.--Kettle River campground (No. 32 on fig. 1). Base from USC&GS chart.

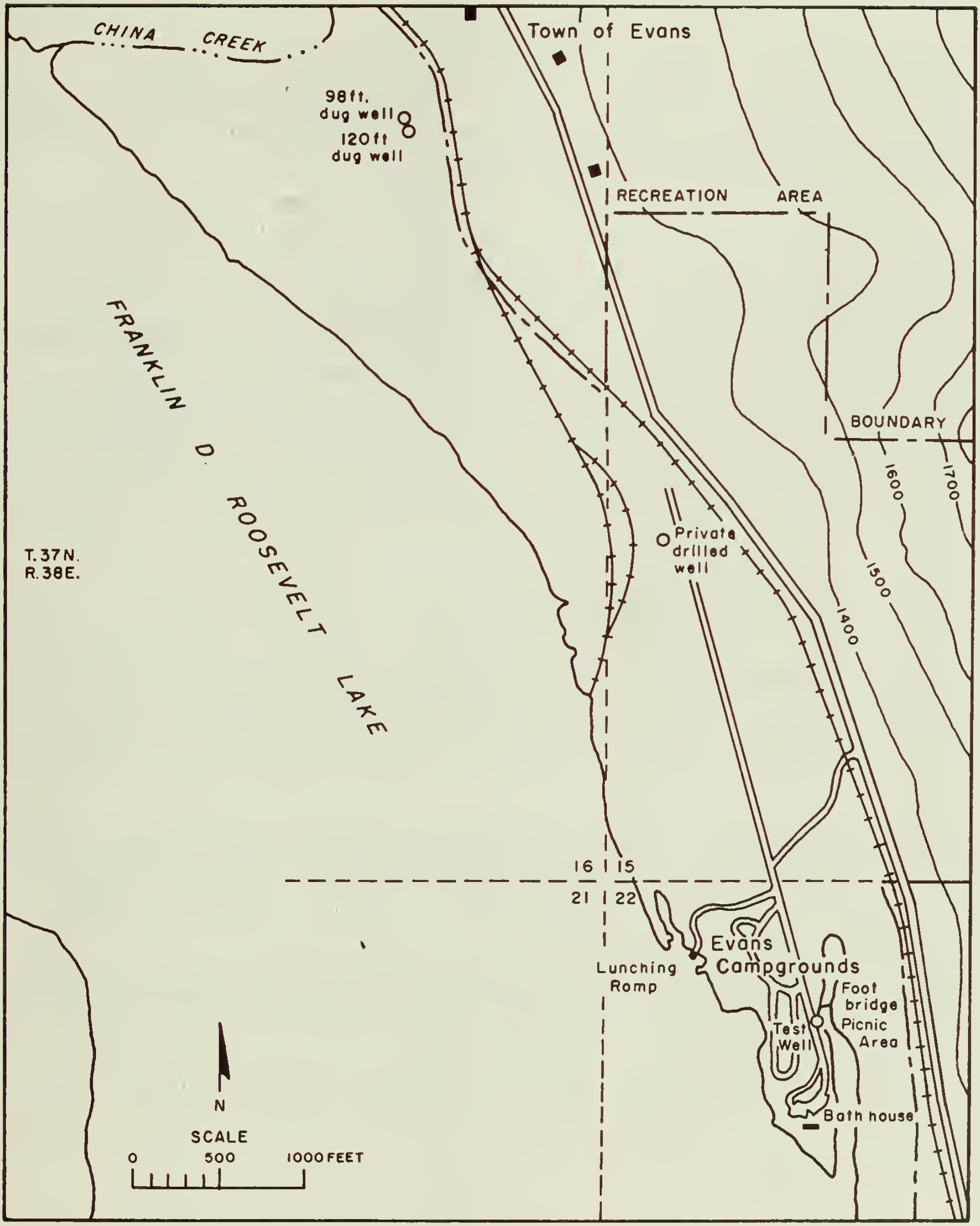

FIGURE 31.--Evans campground (No. 33 on fig. 1). Base from USC&GS chart, and NPS developed area plan.

the gravel about a mile north of the campground to depths of 98 and 120 feet. Both of these wells started at an altitude of about 1,320 feet (30 ft above lake level). The 120-foot well is not being used, but the 98-foot well yields enough water to supply 10 families.

If a ground-water supply is sought for Evans campground, two possible sources could be explored. First, a test well might be drilled into the gravel farther north than the one drilled in 1961. Second, a water supply might be developed from the limestone underlying the surficial deposits. Limestone is exposed in several areas near this campground. The town of Evans, about a mile north of the campground, was developed around a limestone-quarrying operation, and the campground area probably is underlain by limestone bedrock.

Snag Cove

Snag Cove campground is on the west shore of the lake about 8 miles upstream from the Kettle River arm (fig. 1). This small campground is on a gravel bar jutting into the lake.

Water is supplied to the campground from a 12-foot well jetted by the National Park Service in 1964. A hand pump in this well meets the present needs of this area (1968).

Cobble- to boulder-size gravel is exposed in the campground area and bedrock crops out along the highway above the lakeshore less than a quarter of a mile south of the campground. The thickness of the gravel is not known, but it is the most likely source for a ground-water supply for this area.

North Gorge

North Gorge campground is on the east shore of the lake, about 13 miles upstream from the Kettle River arm (fig. 1). The present campground area is on a limestone point. North of the point a large pine-covered terrace at about 1,300 feet is planned as a site for future development (fig. 32).

The present (1968) campground is served by a hand pump in a 20-foot well jetted by the National Park Service in about 1965. If the planned facilities are developed, a larger water supply will be required. Exploration with the auger was impractical, owing to the presence of a layer of large cobbles at high lake level along the terrace, and the absence of an access road.

Near the north end of the proposed development site the cobble gravel underlying the terrace extends only about 5 feet below high lake level, and sand with some fine to medium gravel extends down another 5 feet. Below this sand and gravel, at an altitude of 1,280 feet, the deposits appear to be mostly very fine sand and silt. On the point near the south end of the terrace, gravel extends down to 1,265- or 1,270-foot altitudes. A well tapping this gravel would probably go dry whenever the lake level dropped 20 to 25 feet. Two other possibilities for a water supply are (1) water-bearing gravel may occur between the silt and the bedrock and (2) if the bedrock is limestone, as it appears to be, fractures and solution cavities in the limestone may yield a water supply adequate for the needs of the campground.

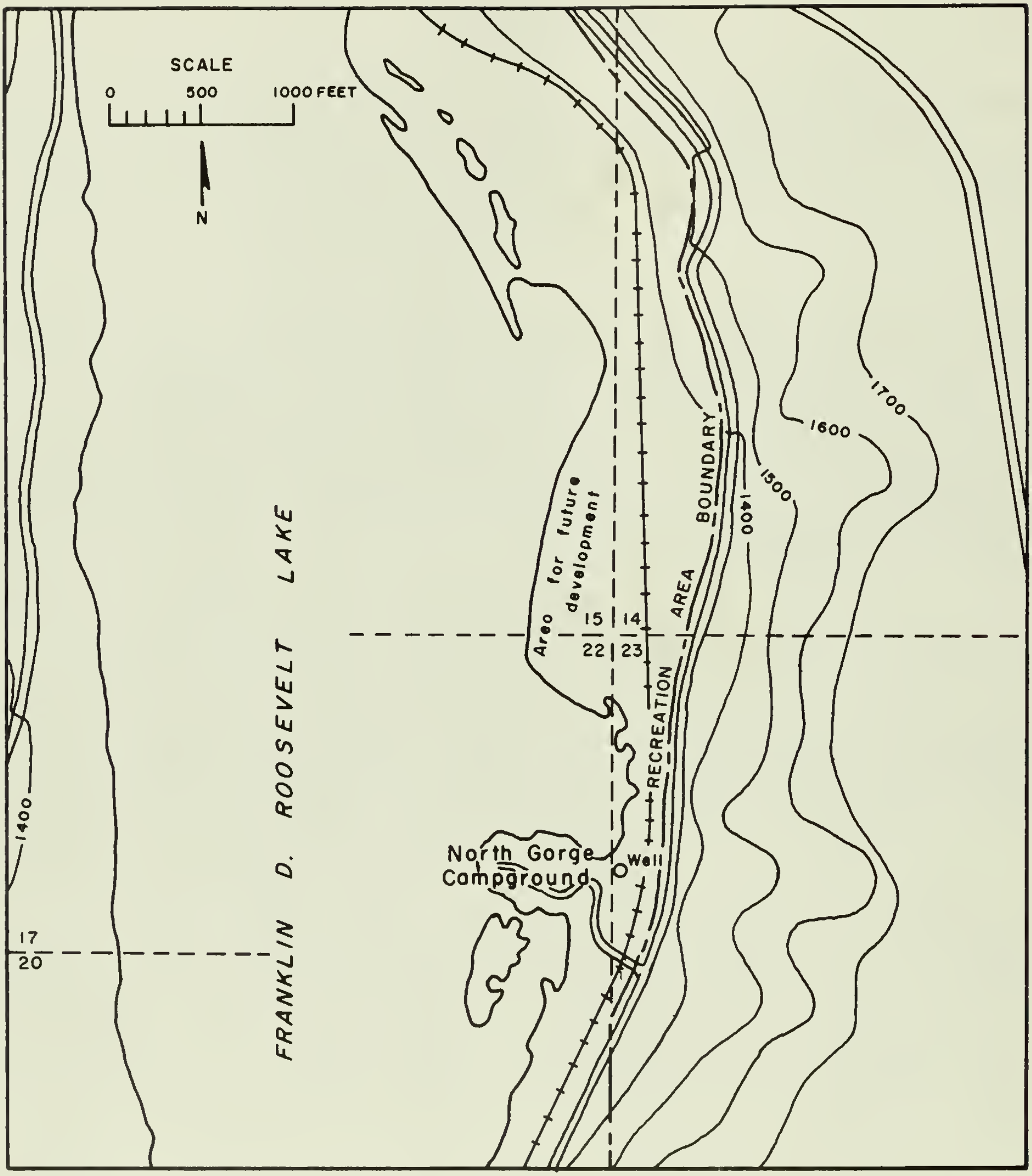

FIGURE 32.--North Gorge campground (No. 35 on fig. 1).
Base from USC&GS chart.

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