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SURFACE WATER WITHIN GLEN CANYON NATIONAL RECREATION AREA

by

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Abstract

The results of a study of the surface water drainages within Glen Canyon Recreation and Resource Area are reported. The drainages which contribute significant amounts of surface water to Lake Powell have been identified, and their surface areas measured from topographical maps. Forty-three drainages were visited and surveyed for flowing water, local geology, plant and animal life, and the presence of tar sands and uranium. Each site was photographed, flow measurements were recorded where possible, and water samples were collected for chemical analysis. The drainages included in this study are: Alcove Canyon, Bowns Canyon, Bullfrog Creek, Castle Creek, Cha Canyon, Chaol Canyon, Clearwater Canyon, Copper Canyon, Cow Canyon, Coyote Gulch, Crystal Spring Canyon, Dark Canyon, Desha Canyon, Forbidding Canyon, Forgotton Canyon, Four Mile Canyon, Grand Gulch, Hansen Creek, Iceberg Canyon, Johns Canyon Lake Canyon, Long Canyon, Moki Canyon, Mtn. Sheep Canyon, Nasja Creek, Navajo Creek, Nokai Wash, Oak Canyon, Oljeto Wash, Padre Canyon, Piute Creek Waterfall, Piute Creek, Red Canyon, Reflection Canyon (right fork), Rockhouse Gulch, Slickhorn Canyon, Slickrock Canyon, Smith Fork, Ticaboo Creek, Trachyte Creek, White Canyon and Wilson Canyon.

Introduction

Congress established Glen Canyon National Recreation Area in 1972, declaring that the National Park Service would administer the area and "provide for public outdoor recreation use and enjoyment of Lake Powell and lands adjacent thereto . . . and to preserve scenic, scientific, and historical features contributing to public enjoyment of the area" (P.L. 92-593).

The Park Service has formulated a general management plan using this directive as a guideline and proposed a series of objectives to be met in administering the recreation area. Any proposals concerning water rights reservations must be justifiable according to these management plan objectives. The objectives which are most applicable are listed as Level III objectives in the General Management Plan (NPS, 1979). One objective is "to encourage the maintenance of high water quality in all bodies and sources of water and to perpetuate the natural flow of free water." Another is "to accommodate many varieties of use, but to favor water-oriented recreation."

Water in the Lake Powell area is derived from two sources: groundwater and surface runoff. The drainages which sustain intermittent flow do so largely from runoff. They tend to sustain a regular flow in the spring during snowmelt and to flash flood in the monsoon season. These drainages would be highly susceptible to ecological distsurbance if a diversion of water were to occur.

Those drainages which flow perennially usually maintain flourishing riparian vegetation, markedly increasing the scenic and aesthetic value of these stream valleys. These perennial streams rely mostly on groundwater as their source, except in the area of Navajo Mountain. Besides sustaining large amounts of vegetation, these perennial streams support insect, fish and wildlife communities. Also, many of these stream valleys were sites of American Indian cultivation and often boast historic ruins.

Description of Study Area. Glen Canyon Recreation Area is a water-based recreational use area in northern Arizona and southern Utah. The region includes tributaries to Lake Powell and the Escalante, San Juan, Dirty Devil and Colorado rivers. Figure 1 is a vicinity map showing the study area.

Previous Investigations. Several previous investigators have surveyed different areas of the Lake Powell region. Cooley's (1965) work was an extensive air survey in which springs and seeps were located and their discharge estimated, and no sampling was attempted. Most of these springs are now inundated by Lake Powell. Hand (1979) and Williamson (1985) surveyed springs in the Orange Cliffs, Waterpocket Fold, and Wilson Mesa areas. Samples were taken by both investigators and chemical analyses were performed. Laity and Malin (1985) inventoried seeps and springs in Bowns and Longs canyons as part of a larger study, but no chemical analyses were reported. Blanchard (1986), in an analysis of groundwater conditions for the Lake Powell area, did a partial inventory of springs in the area north of the Utah border, east of Halls Creek and west of the San Juan River. Some chemical analysis was included in Blanchard's work.

Purpose of this Study. A reconnaissance-level survey of streams draining into Lake Powell in Glen Canyon National Recreation Area (GCNRA), is needed for several reasons. The Glen Canyon National Recreation Area contains limited water resources (other than Lake Powell), and it is important that they be identified and characterized. In addition, GCNRA contains several areas which could be targeted for future development of energy resources. The development of these resources would require large volumes of water to be removed from local aquifers. The National Park Service wishes to protect and maintain its water resources to provide for the Recreation Area. The purpose of this survey was to pinpoint perennial sources of water and establish their baseline chemical composition.

The Recreation Area is protected by Federally Reserved Water Rights, but these water rights may be subject to adjudication in state water courts. For proceedings such as these, quantification of claims may be necessary to fully protect park water resources. Therefore, the Park Service is investigating methods of quantifying instream flows needed to maintain its resources.

Methodology

The Survey Area. The part of Glen Canyon Recreation Area surveyed for this study extends north of Glen Canyon Dam in Arizona to just above Hite, Utah on the Colorado River, and includes the San Juan and Escalante river drainages. It does not include the Dirty Devil River. This area is included on the USGS map titled *Glen Canyon Recreation Area, Utah-Arizona, 1969.*

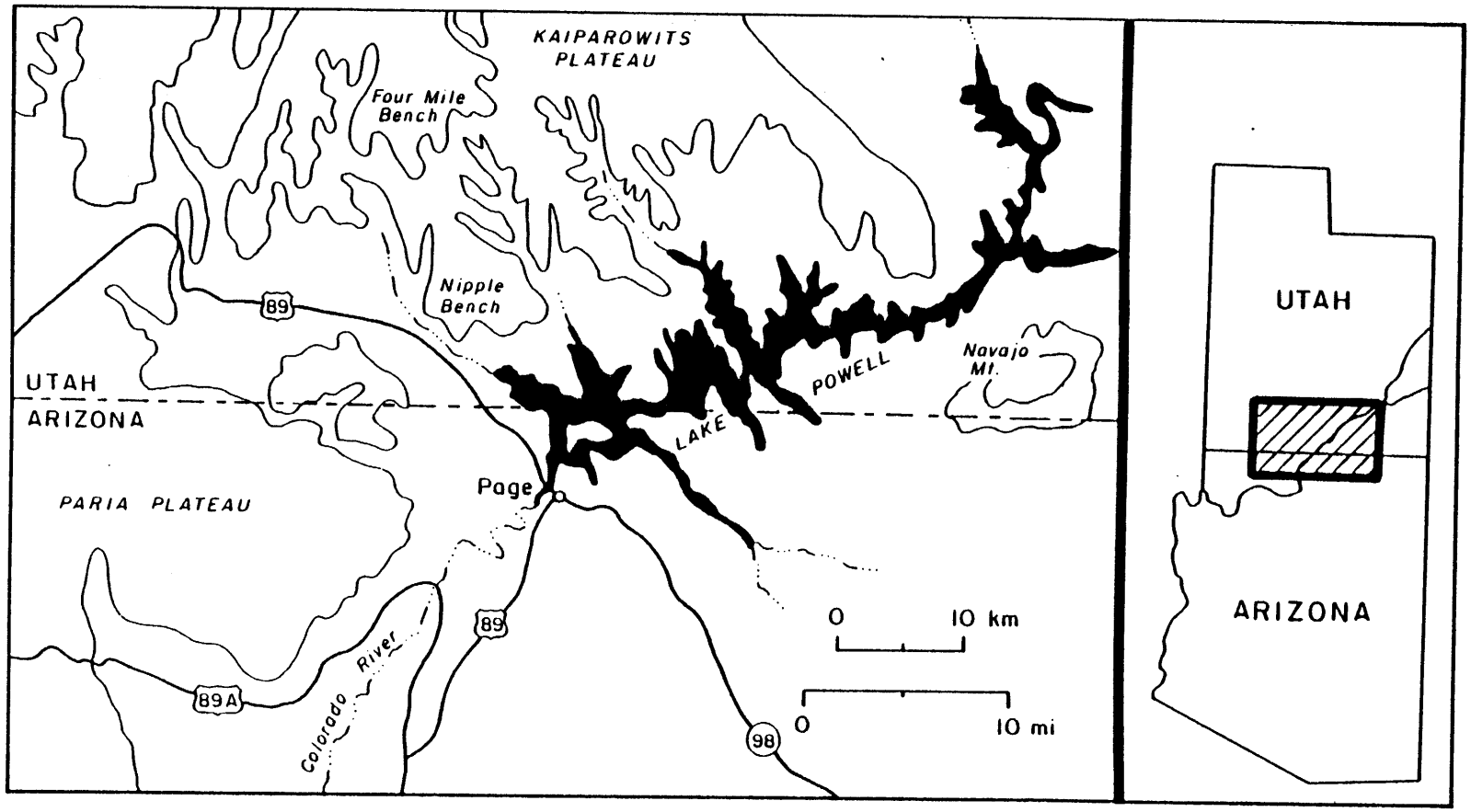


Figure 1. Vicinity Map Showing Lake Powell and the Glen Canyon Recreation and Resource Area.

The geologic strata of the area range from Pennsylvanian to Cretaceous in age and are mostly sedimentary eolian and marine deposits (see Fig. 2). The Lake Powell area is part of the Colorado Plateau and consists of mostly horizontal sediments cut by steep vertical canyons. The trend of the strata is generally west at about 5° of dip. Major structural features are the Waterpocket Fold, the Henry Mountains, Navajo Mountain, and the Echo Monocline. The Henry Mountains and Navajo Mountain are all igneous structures. Principal aquifers for the region reside in the Navajo, Wingate, and Entrada sandstones.

Drainage Selection. A topographic map of Glen Canyon National Recreation Area (1:250,000 scale, USGS, 1969) was used to delineate 86 drainages. Delineation was accomplished by outlining drainage divides (high points which control which way water will flow) and application of the rule that water flows perpendicular to contours (Manning, 1987). These drainages empty into Lake Powell, or into major tributaries (the San Juan and Escalante rivers) which feed Lake Powell. Drainages emptying into the Dirty Devil River were not included in this study due to time and accessibility limitations.

A survey of the geologic formations present in each drainage was done using the USGS map *Geology, Structure and Uranium Deposits of the Escalante Quadrangle, Utah and Arizona* (Hackman et al. 1973). Drainage areas were measured with a planimeter, the reported value being an average of three trials.

Time limitations prevented every drainage from being visited by the survey crew. Therefore, a list of about 30 drainages were chosen to represent a cross section of streams feeding into Lake Powell. Criteria for selection were: 1) geologic type; 2) drainage size; 3) location along the lake (lower, middle and upper), and; 4) the presence of tar sands or uranium (both of which can have significant effects on surrounding water resources if they are removed mechanically). These 30 drainages formed the core of the survey. Other drainages in the vicinity were visited as time permitted.

Survey Process. Access is probably the single greatest problem faced by any researcher in the Lake Powell area and it played an important part in the final results (which drainages were actually surveyed) of this project. All drainages surveyed were accessed from the lake by powerboat because this is the most expedient way to reach the survey areas. Notes were made on accessibility and are included in the presentation of results.

At the site, the drainage was described geomorphologically and photographs were taken to help with site documentation. Water discharge measurements were taken with a Price AA pygmy meter when water depth permitted; however, this was possible on less than a third of the discharging streams. Other methods employed to measure discharge rates were: 1) bucket and stopwatch, and; 2) visual estimation. Water samples were collected in 500 mL, acid-washed, CPE polyethylene bottles at each site where water volume permitted, and returned to the Ralph M. Bilby Research Center of Northern Arizona University for chemical analysis.

Vegetation type and plant density were estimated at each drainage in the study and the presence of tamarisk was noted qualitatively. A search for endangered plant and animal species was not done due to lack of qualified personnel.

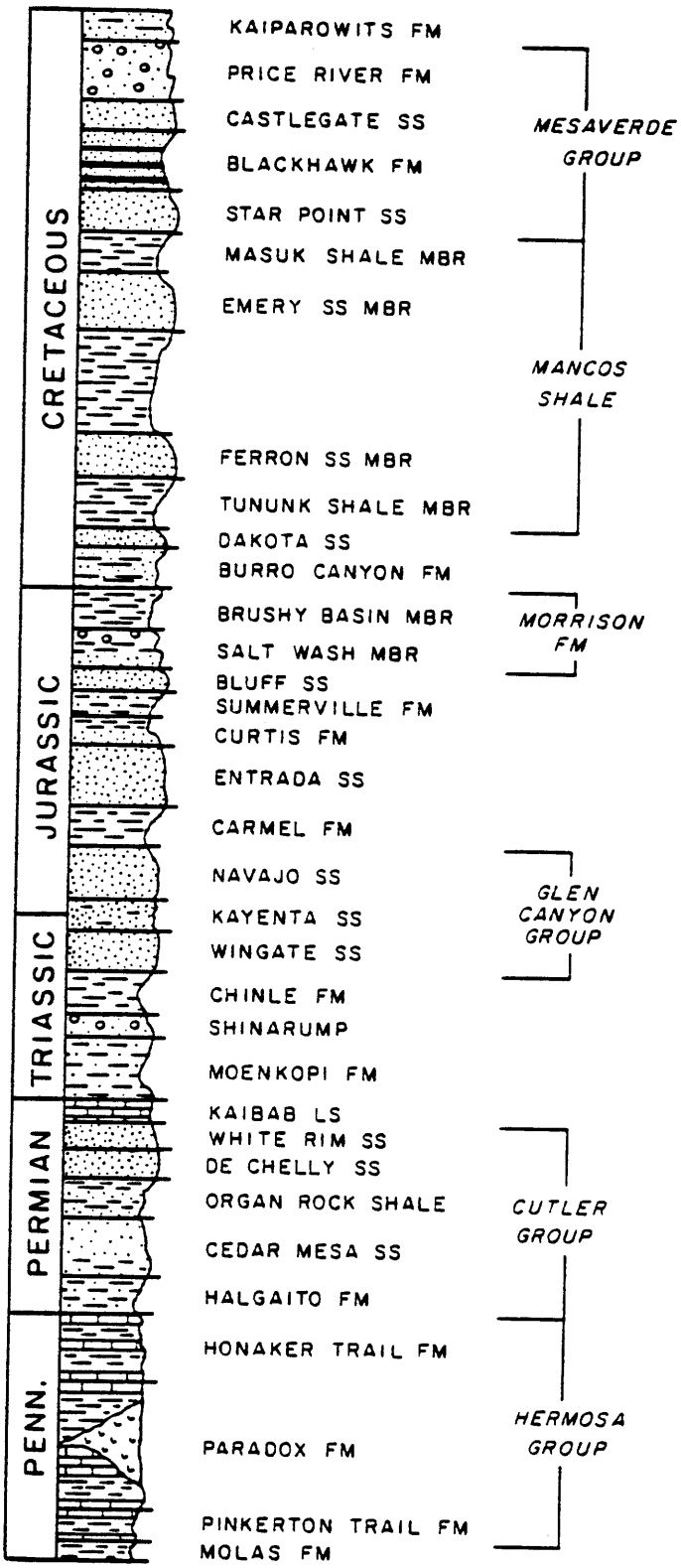


Figure 2. Geologic Strata of the Glen Canyon Recreation Area

Special attention was made to identify areas which could have a bearing on reserving instream flows or which could be classified as "critical reaches." A critical reach is any section of a drainage which would be influenced more drastically than other sections by a reduction of water. Critical reaches were identified by applying the following criteria: 1) Is there a threat to the instream flow which supports the site or area? 2) Does the site or area have any unique characteristics of scenic, historic or scientific interest? 3) Would a reduction of instream flow reduce access to the site, or to an area for recreational purposes? 4) Would a reduction of instream flow be detrimental to the site or area? 5) Is this site readily accessible to a reasonable amount of users of GCNRA?

Chemical Analysis. The measurements that were recorded include: pH, alkalinity, chloride, nitrate, sulfate, calcium, magnesium, sodium, potassium, iron, manganese, zinc, selenium and arsenic. The pH was measured with an Orion Model 701A Digital Ionalyzer select ion meter equipped with Beckman combination pH electrodes, Model 39502. The pH meter was standardized at values of pH = 7.0 and pH = 4.0 with commercially prepared buffers (J.T. Baker Chemical Company) and corrected for any temperature differences between the buffers and the water sample. The pH values recorded in this manner are considered accurate to within ±0.1 pH unit.

Alkalinity titrations were performed in duplicate by titrating 50.00 mL of water samples with 0.1000 M hydrochloric acid. The acid was added to the water sample from a 10.00 mL micro-buret (Corning No. 2128) and the titration was monitored using the pH meter described above. The alkalinity titration was considered complete at a pH of 4.3.

Cation and anion determinations were made in the laboratory on samples that were collected, transported and stored in CPE polyethylene bottles. Two water samples were collected at each site. The first was not treated before transporting to the laboratory but the second was treated with one mL of redistilled nitric acid to prevent the formation of metal precipitates.

Iron, calcium and magnesium levels were determined by flame atomic absorption spectrophotometry with a Perkin-Elmer Model 560 A.A. spectrophotometer (Perkin-Elmer, 1980; Christian and Feldman, 1970). Lanthanum (1000 PPM final concentration) and cesium (1000 PPM final concentration) were added to the water samples to control chemical and ionization interferences for the calcium and magnesium analyses. Sodium and potassium levels were determined by flame emission spectrophotometry with the same instrument. Cesium solution (1000 PPM final concentration) was added to water samples to control ionization interferences before preforming the sodium and potassium analyses. The values reported for cation levels determined by these procedures are accurate to ±0.1 PPM. Electrothermal atomization atomic absorption spectrophotometry was used to measure the manganese, zinc, selenium and arsenic concentrations. A Perkin-Elmer Model 5000 atomic absorption spectrophotometer equipped with a Perkin Elmer Model 400 graphite furnace was used for this purpose. The Mn, Zn, Se and As levels are considered accurate to ± 10 percent of the reported value.

Bicarbonate levels were determined titrametrically from the alkalinity titration described above. Sulfate and nitrate levels were determined by the technique of ion chromatography using a Spectra-Physics SP8700 pump equipped with a Wescan ion conductivity detector and Vydac anion colums. The bicarbon-

ate values are considered accurate to within 1 percent of the reported value while the sulfate and nitrate levels are considered accurate to within 5 percent of the reported value. Chloride levels were determined potentiometrically in the laboratory with an Orion Model 701A Digital Ionalyzer equipped with an Orion chloride electrode. All samples were diluted 1:1 with a commercial total ionic strength adjusting buffer before pCl values were recorded, and the reported values are considered accurate to within ±0.01 ppm.

Results

A total of 43 drainages were visited, with only 18 containing sufficient amounts of water to permit sampling for chemical analysis. Tables I and II contain alphabetical listings of each drainage visited.

Table I is titled "Drainage Characteristics" and summarizes the name of the drainage and the name of the area drained, the geologic units represented at each site, and gives the total area drained. Table II is titled "Drainage Observations" and lists the vegetation identified at each site, the dischagre rate for flowing water and comments about: 1) access, 2) whether or not samples were taken for chemical analysis, 3) a qualitative description of the vegetation, and 4) observations about critical reaches, the presence of uranium or tar sands, and miscellaneous field observations. Table III contains additional field observations that could not be incorporated into Tables I and II. The chemical results are listed separately in Tables IV and V.

Discussion

Charge balance calculations were performed on all water samples to insure that no chemical constituents were missed in the analysis. The results of these calculations are shown in Table VI.

All water samples are alkaline with pH's ranging from 7.24 (Bowns Canyon) to 8.44 (Johns Canyon). The measured alkalinities (due almost exclusively to bicarbonate ion, HCO_3^-) ranged from 134 mg $CaCO_3$/L (Bowns Canyon) to 882 mg $CaCO_3$/L (Slickrock Canyon No. 2). The calcium levels are high in all samples ranging from 15.3 PPM Ca (Bowns Canyon) to 114 PPM (Dark Canyon) and the magnesium levels range from 6.60 PPM (Bowns Canyon) to 63.6 PPM. These data represent typical values expected for waters which have been exposed to limestone and dolomite minerals in arid environments; these waters would be classified as "hard" to "very hard."

Two water sources (Dark Canyon, 410 PPM, and Hanson Creek, 302 PPM) have sulfate levels that exceed the 250 PPM standard for domestic water quality criteria (see Table VII). There is no established sulfate standard for freshwater aquatic, marine or wildlife use (see Table VIII). The high sulfate levels in these water sources indicates exposure to gypsum, a mineral common to the area.

The chloride concentration was less then 10 PPM in all cases except for two water samples (Grand Gulch, 38.7 PPM and Slickhorn Canyon, 24.7 PPM). The sodium level in Grand Gulch was 58.4 PPM and, 47.6 PPM in Slickhorn Canyon, suggesting the source of chloride in these waters to be sodium chloride.

Table 1. Drainage Characteristics

Name of Drainage[1]	Date Surveyed	Geologic Units Present (Oldest to Youngest)	Area of Drainage (square miles)	Name of Area Drained
Alcove Canyon: SJR	8/87	Kayenta, Navajo	1.17	Gray Mesa
Bowns Canyon	8/87	Navajo	5.76	Waterpocket Fold/Straight Cliffs
Bullfrog Creek	8/87	Navajo, Summerville, Entrada, Morrison, Cedar Mtn/Brushy Basin, Dakota, Mancos Shale, Igneous Diorites	253.76	Tarantula Mesa, Mt. Pennell, Mt. Ellsworth
Castle Creek: SJR	8/87	Moenkopi, Chinle, Wingate, Kayenta, Navajo	79.7	Clay Hills
Cha Canyon: SJR	8/87	Chinle, Wingate, Kayenta, Navajo, Morrison	16.5	Navajo Mountain
Chaol Creek	6/87	Wingate, Navajo	77.0	Navajo Mountain
Clearwater Canyon	9/87	Hermosa, Rico, Cedar Mesa	20.6	Orange Cliffs, The Block
Copper Canyon: SJR	8/87	De Chelly, Organ Rock, Cedar Mesa, Moenkopi, Petrified Forest, Shinarump, Wingate, Navajo	115.7	Monitor Mesa, Monument Valley, Hoskinni Mesa
Cow Canyon: ER	8/87	Navajo	18.1	West Waterpocket Fold
Coyote Gulch: ER	8/87	Navajo, Carmel, Entrada, Summerville, Dakota, Tropic Shale	132.6	Straight Cliffs
Crystal Spring Canyon	8/87	Navajo, Carmel	4.6	Between Moki and Cedar Mesa
Dark Canyon	9/87	Hermosa, Rico, Cedar Mesa, White Rim, Moenkopi	269.3	Dark Mesa Plateau
Desha Canyon: SJR	8/87	Chinle, Wingate, Kayenta, Navajo, Morrison	25.3	Navajo Mountain
Forbidding Canyon	8/87	Navajo	12.1	Navajo Mountain
Forgotton Canyon	8/87	Navajo, Carmel	12.2	Between Moki and Cedar Canyon
Four Mile Canyon	9/87	Chinle, Wingate, Kayenta, Navajo, Carmel, Igneous Diorites	13.6	Mt. Holmes
Grand Gulch: SJR	6/87	Cedar Mesa, Halgaito Tongue	192.2	Grand Gulch Plateau

Table I (continued)

Name of Drainage[1]	Date Surveyed	Geologic Units Present (Oldest to Youngest)	Area of Drainage (square miles)	Name of Area Drained
Hansen Creek	8/87	Carmel, Entrada, Morrison, Dakota, Mancos, Tununk	129.0	Mt. Ellsworth, Mt. Hillers, Coalbed Mesa
Iceberg Canyon	8/87	Kayenta, Navajo, Carmel	4.5	Between San Juan River & Moki Canyon
Johns Canyon: SJR	6/87	Hermosa, Rico, Cedar Mesa, Halgaito Tongue	33.4	Grand Gulch Plateau
Lake Canyon	8/87	Navajo, Carmel	40.3	Between San Juan River & Moki Canyon
Long Canyon	8/87	Navajo	17.8	Southwest Waterpocket Fold
Moki Canyon	8/87	Chinle, Wingate, Kayenta, Navajo, Carmel, Entrada	81.1	Clay Hills, Mancos Mesa
Mtn. Sheep Canyon	8/87	Navajo, Carmel, Entrada, Morrison	16.2	Cummings Mesa
Nasja Creek: SJR	8/87	Navajo, Carmel	9.4	Navajo Mountain
Navajo Creek	8/87	Navajo	210.4	Gray Mesa, Navajo Mountain
Nokai Wash: SJR	8/87	White Rim, Organ Rock, Moenkopi, Shinarump, Petrified Forest, Wingate, Kayenta	181.0	No Man's Mesa
North Wash	9/87	Chinle, Wingate, Kayenta, Navajo, Carmel	145.3	East Henry Mountains
Oak Canyon	8/87	Navajo	30	Navajo Mountain
Oljeto Wash: SJR	6/87	Organ Rock, Cedar Mesa, Moenkopi, Shinarump	476.8	Monument Valley, Oljeto Mesa
Padre Canyon	8/87	Navajo, Entrada, Summerville, Morrison, Dakota, Tropic	4.5	Middle Kaiparowits Plateau
Piute Crk Waterfall:SJR	8/87	Wingate/Chinle contact	<1	N/A
Piute Creek: SJR	8/87	Petrified Forest, Kayenta, Navajo	244.5	Navajo Mountain, Piute Mesa
Red Canyon	9/87	Organ Rock, Moenkopi, Chinle, Wingate, Kayenta	171.4	Red House Cliffs, Clay Hills, West Grand Gulch Plateau

Table I (concluded)

Name of Drainage[1]	Date Surveyed	Geologic Units Present (Oldest to Youngest)	Area of Drainage (square miles)	Name of Area Drained
Reflection Canyon, Right Fork	8/87	Navajo	--	Southeast Kaiparowits Plateau
Rockhouse Gulch: SJR	8/87	Cedar Mesa, Shinarump	39.5	Monument Valley
Slickhorn Canyon: SJR	6/87	Rico, Halgaito Tongue, Cedar Mesa	45.8	Grand Gulch Plateau
Slickrock Canyon	8/87	Kayenta, Navajo	2.7	Between San Juan River & Moki Canyon
Smith Fork	8/87	Kayenta, Wingate, Navajo, Carmel, Entrada, Mancos Shale, Igneous Diorites	23.0	Mt. Ellsworth
Ticaboo Creek	9/87	Chinle, Wingate, Kayenta, Navajo, Igneous Diorites	26.2	Ticaboo Mesa, Mt. Ellsworth, Mt. Holmes
Trachyte Creek, SW Fork	9/87	Moenkopi, Chinle, Wingate, Kayenta, Navajo, Carmel, Entrada, Cedar Mtn., Dakota, Tununk	182.6	Henry Mountains
White Canyon	9/87	Cedar Mesa, Organ Rock, White Rim, Moenkopi, Wingate, Kayenta	293.1	Grand Gulch Plateau
Wilson Canyon: SJR	8/87	Wingate, Kayenta, Navajo	3.7	Wilson Mesa

[1]SJR = San Juan River; ER = Escalante River.

Table II. Drainage Observations

Name of Drainage[1]	Vegetation[2]	Discharge[3]	Access	Chemical Data Available	Comments[4]
Alcove Canyon: SJR	Medium, C,T,HG	seep, UMD	good	x	two branches; both seep over slickrock
Bowns Canyon	well developed, C,H,G	stream, D=1.9 cfs	good	x	critical reach
Bullfrog Creek	sparse, T	ND	poor		
Castle Creek: SJR	sparse, T	ND	good		
Cha Canyon: SJR	sparse, C	ND	fair		uranium
Chaol Creek	medium, C	stream, D=2.94 cfs	good		waterfall, critical reach
Clearwater Canyon	medium, C	ND	poor		tar sands, uranium
Copper Canyon	sparse, T	ND	fair		uranium
Cow Canyon: ER	well developed, C	seep, UMD	good		
Coyote Gulch: ER	well developed, C,H,G	stream, D=2.78 cfs	good, road and boat	x	critical reach
Crystal Spring Canyon	unknown	unknown	none, blocked by rockfall		
Dark Canyon	well developed, C	stream, D=1.73 cfs	good	x	tar sands, critical reach
Desha Canyon: SJR	well developed, C,T,HG	rocky stream, UMD	good	x	uranium, critical reach
Forbidding Canyon	well developed, HG,C	stream, D=0.4 cfs	good	x	Rainbow Bridge, critical reach
Forgotten Canyon	medium, C	ND	good		
Four Mile Canyon	sparse, T	ND	good		uranium
Grand Gulch: SJR	medium, HG,C	pool, UMD	raft only	x	
Hansen Creek	medium, C,T	seep, UMD ~ 0.5 cfs	good	x	uranium
Iceberg Canyon	well developed, C,T,O	stream, D=1.59 cfs	good		critical reach

Table II (continued)

Name of Drainage[1]	Vegetation[2]	Discharge[3]	Access	Chemical Data Available	Comments[4]
Johns Canyon: SJR	sparse	pool, UMD	raft only	x	
Lake Canyon	well developed, C,W	wide, shallow stream, UMD ~3-4 cfs	good	x	critical reach
Long Canyon	well developed, HG,W	seeps, UMD ~3 gpm	good	x	critical reach
Moki Canyon	well developed, C,O	ND	good		uranium
Mtn Sheep Canyon	unknown	unknown	poor		
Nasja Creek: SJR	sparse	ND	poor, high pour-offs		
Navajo Creek	medium, T,C	wide shallow stream, UMD ~2 cfs	good	x	
Nokai Wash: SJR	sparse, T	ND	fair		tar sands, uranium
North Wash	sparse	ND	good		uranium
Oak Canyon	well developed, O,C,T	seep, UMD	good		
Oljeto Wash: SJR	sparse, C	ND	raft only		uranium
Padre Canyon	sparse, T	ND	good		
Piute Creek Waterfall: SJR	well developed, HG, C	spring, D=4.6 gpm	good	x	uranium, critical reach
Piute Creek: SJR	medium, T,C	seep, UMD	fair (none at lower lake levels)		uranium
Red Canyon	sparse, T	ND	good		uranium
Reflection Canyon, Right Fork	well developed, C	stream, D= <1 cfs	good	x	
Rockhouse Gulch: SJR	sparse, T	ND	good		uranium

Table II (concluded)

Name of Drainage[1]	Vegetation[2]	Discharge[3]	Access	Chemical Data Available	Comments[4,5]
Slickhorn Canyon: SJR	well developed, HG	stream, UMD	raft only	x	
Slickrock Canyon	well developed, W	seep, D ~4 gpm	good	x	
Smith Fork	sparse, C,T	ND	good		
Ticaboo Creek	well developed, HG,C,T	seep, D ~2-3 gpm	good	x	uranium
Trachyte Creek, Right Fork	medium, C,T	wide shallow stream, UMD 3cfs	good	x	
Wilson Canyon: SJR	well developed, C,W,O	stream, D=0.2 cfs	good	x	critical reach
White Canyon	sparse, T	ND	good		tar sands, uranium

1 SJR = San Juan River; ER = Escalante River

2 HG = Hanging Garden; C = Cottonwood; T = Tamarisk; O = Oak; W = Willow

3 ND = No Discharge; UMD = Unmeasurable Discharge

4 "Geology, Structure, and Uranium Deposits of the Escalante Quadrangle, Utah and Arizona." U.S. Geological Survey Miscellaneous Investigations Map I-744, sheet 2.

5 Monitoring Recommendations to Evaluate Tar Sand Development Influences on Water Resources: Glen Canyon National Recreation Area. Water Resources Field Support Laboratory Report No. 85-GLCA-01.

Table III. Additional Comments on Surveyed Drainages.

Chaol Canyon: Lovely waterfall and probable perennial flow coupled with closeness to main Wahweap marinas make this canyon a good target to justify instream flow requirements. Access by either boat or trail would aid in further study.

Dark Canyon: This canyon drains such a large area, much further study would be needed to ascertain where the perennial flow originates. One of the few drainages in the upper lake which sustains perennial flow. Lower canyon contains perfect site for stream flow monitoring.

Desha Canyon, Left Fork: Ease of access by boat at low lake levels would make this the ideal representative location for the San Juan arm of the lake.

Long Canyon: Availability of good-sized seeps makes this site a good one for a hanging garden study. At low lake level, watch for large submerged rocks.

Oak Canyon: Very well developed riparian growth; a high recreational use area with easy access by boat at low lake levels.

Slickrock Canyon: Main drainage never inundated due to drop-off at lake/stream contact.

Wilson Canyon: Good candidate for riparian vegetation study. Easy access from Dangling Rope. Drainage never has contact with lake due to dropoff at lake/stream contact. Lightly impacted with only a single trail. Source of flow accessible. Flourishing vegetation/insect/wildlife community.

Table IV. Chemical Data for Glen Canyon National Recreation Area Surface Waters - Cations[1]

Water Source	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Fe	Mn	Zn^{2}
Bowns Canyon	15.3	6.60	1.90	3.04	0.681	0.056	4.5
Coyote Gulch	46.7	12.4	2.66	2.14	0.428	0.061	2.7
Dark Canyon	114.	63.6	19.6	4.21	<0.012	<0.004	<0.5
Desha Canyon	42.1	24.4	12.3	2.50	0.142	0.078	0.9
Forbidding Canyon	18.8	7.20	4.40	3.35	0.338	0.116	<0.5
Grand Gulch	55.5	34.0	58.4	4.69	0.027	0.016	<0.5
Hanson Creek	44.1	28.0	104.	6.06	0.076	0.018	0.5
Johns Canyon	65.2	13.0	15.3	4.15	0.072	0.080	<0.5
Long Canyon	48.3	30.4	22.8	2.00	0.670	1.044	<0.5
Navajo Creek	50.5	16.9	21.5	5.44	1.289	0.196	7.2
Piute Creek	28.5	12.5	11.8	0.85	0.023	0.017	<0.5
Reflection Canyon	53.7	11.6	2.88	1.91	0.613	0.124	<0.5
Slickhorn Canyon	68.5	32.0	47.6	4.24	0.066	0.028	2.2
Slickrock Canyon (No. 1)	44.9	18.2	6.20	2.03	0.737	0.146	15.7
Slickrock Canyon (No. 2)	80.1	38.0	20.4	0.94	0.864	0.684	1.0
Ticaboo Creek	36.6	24.0	12.9	2.86	0.041	0.017	<0.5
Trachyte Creek	43.7	28.0	40.0	5.40	0.078	0.046	<0.5
Wilson Creek	24.5	10.8	7.50	1.19	0.050	0.035	<0.5

1. All concentrations reported as milligrams per liter (PPM) except where noted.
2. Reported as micrograms per liter (PPB).

Table V. Chemical Data for Glen Canyon National Recreation Area Surface Waters - pH and Anions.[1]

Water Source	pH	Alkalinity[2]	SO_4^{2-}	Cl^-	NO_3^-	Se[3]	As[3]
Bowns Canyon	7.24	134.	7.78	2.28	1.39	4.0	1.4
Coyote Gulch	7.78	274.	11.2	1.85	<0.02	3.5	2.8
Dark Canyon	7.88	289.	410.	9.01	<0.02	0.5	<1.0
Desha Canyon	8.13	460.	13.3	12.4	0.29	0.9	14.1
Forbidding Canyon	7.56	167.	11.7	4.72	2.44	<0.5	4.5
Grand Gulch	7.78	472	139.	38.7	<0.02	<0.5	1.0
Hanson Creek	8.04	307.	302.	9.70	0.14	2.1	2.6
Johns Canyon	7.88	448.	43.8	7.23	<0.02	0.5	2.1
Long Canyon	8.44	602.	13.7	8.21	2.27	0.8	7.0
Navajo Creek	8.18	420	19.5	12.4	1.85	3.1	6.2
Piute Creek	7.96	190.	9.10	5.27	2.95	<0.5	3.9
Reflection Canyon	7.78	428.	7.00	1.58	<0.02	0.9	2.6
Slickhorn Canyon	7.84	399.	186.	24.7	<0.02	<0.5	<1.0
Slickrock Canyon (No. 1)	7.95	419.	13.4	3.87	<0.02	1.5	3.4
Slickrock Canyon (No. 2)	8.05	882.	1.23	4.08	4.56	<0.5	<1.0
Ticaboo Creek	8.27	435.	23.0	4.79	1.77	0.6	1.4
Trachyte Creek	8.10	452.	105.	5.83	2.88	<0.5	6.0
Wilson Creek	7.86	264.	4.13	2.81	1.91	1.3	1.5

1. All concentrations reported as milligrams per liter (PPM) except where noted.
2. Reported as milligrams of $CaCO_3$ per liter.
3. Reported as micrograms per liter (PPB).

Table VI. Charge-Balance Relationships for Glen Canyon Recreation Area Water Sources.

Water Source	Cation Meq	Anion Meq	% Agreement
Bowns Canyon	1.48	1.58	3.3
Coyote Gulch	3.53	3.02	<7.8
Dark Canyon	11.88	11.68	0.8
Desha Canyon	4.71	5.23	5.2
Forbidding Canyon	1.82	2.08	6.7
Grand Gulch	8.23	8.71	6.1
Hanson Creek	9.17	9.63	2.4
Johns Canyon	5.59	5.10	4.68
Long Canyon	6.57	6.01	4.5
Navajo Creek	4.99	5.04	0.5
Piute Creek	2.29	2.98	13.1
Reflection Canyon	4.47	3.83	7.7
Slickhorn Canyon	8.57	8.23	2.0
Slickrock Canyon (No. 1)	4.58	4.10	5.5
Slickrock Canyon (No 2)	9.03	8.12	5.3
Ticaboo Creek	5.00	4.44	5.9
Trachyte Creek	6.92	6.36	4.2
Wilson Creek	2.84	2.47	7.0

$$\text{Percent Agreement} = \frac{|[\text{Cation Meq}] - [\text{Anion Meq}]|}{[\text{Cation Meq}] + [\text{Anion Meq}]} \times 100$$

Table VII. Water Quality Criteria for Domestic Water Supplies[1,2,3]

Constituent	Permissible Criteria	Desirable Criteria
Arsenic, As	50	Absent
Baruum, Ba	1,000	-
Boron, B	1,000	-
Cadmium, Cd	10	-
Chlorides, Cl	250,000	<25
Chromium, Cr (Hexavalent)	50	Absent
Copper, Cu	1,000	Virtually absent
Iron, Fe (Filtrable)	<300	Virtually absent
Lead, Pb	<50	Absent
Manganese, Mn (Filtrable)	<50	Absent
Mercury, Hg	2	-
Selenium	10	Absent
Silver	50	-
Sulfates	250,000	<50
Zinc	5,000	Virtually absent

[1]All concentrations reported as micrograms of solute per liter, part-per-billion (PPB).

[2]"Quality Criteria for Water," U.S.EPA Report-440/9-76-023 (1976).

[3]"Report of the Committee on Water Quality Criteria." Federal Water Pollution Control Administration, U.S. Dept. of the Interior, U.S. Government Printing Office, Washington D.C., 1968

Table VIII. Water Quality Criteria for Freshwater Aquatic, Marine and Wildlife Uses.[1]

Element	Concentration, Micrograms of Solute per Liter, PPB		
	Freshwater Aquatic	Marine	Wildlife
Cadmium, Cd	1.2[2]	5.0[2]	-
Chromium, Cr	100	-	-
Copper, Cu	89[3]	89[3]	-
Iron, Fe	1,000	-	-
Lead, Pb	13.8[4]	-	-
Mercury, Hg	0.05	0.10	0.05
Nickel, Ni	392[5]	392[5]	-
Selenium, Se	25	25	-
Silver, Ag	100[6]	100[6]	-
Zinc, Zn	72[7]	72[7]	-

[1] "Quality Criteria for Water," U.S. EPA Report-440/9-76-023 (1976).

[2] Hardness in excess of 150 PPM.

[3] For Rainbow trout, *Salmo gairdner*, hardness of 290 PPM.

[4] For Rainbow trout, *Salmo gairdner*, hardness of 300 PPM.

[5] Species of fish unspecified, 'hard' water specified.

[6] For Stickleback, *Gasterosteus aculeatus*.

[7] For Rainbow trout, hardness of 333 PPM.

Potassium levels ranged from 0.85 PPM to 6.06 PPM, well within the range expected for natural waters of this type (Hem, 1970).

Iron, manganese and zinc concentrations are important because they can be used as indicators of environmental pollution. Although there are many natural sources for these elements in surface waters, mineral extraction and mining operations will result in elevated iron, manganese and zinc levels. The iron and manganese concentrations listed in Table V are significantly higher than for similar water samples in the Grand Canyon. Iron concentrations exceed the permissible criteria for domestic water supplies, 0.300 PPM, at eight sites (Bowns Canyon, Coyote Gulch, Forbidding Canyon, Long Canyon, Navajo Creek, Reflection Canyon and Slickrock Canyon, Nos. 1 & 2). The iron concentration for freshwater aquatic, marine and wildlife use, 1.000 PPM, is only exceeded in one water source (Navajo Creek, 1.289 PPM). There are no established standards for freshwater aquatic, marine, and wildlife use for manganese in water, but the permissible standard for domestic drinking water is 0.050 PPM. This manganese standard is exceeded in ten water sources (Bowns Canyon, Coyote Gulch, Desha Canyon, Forbidding Canyon, Hanson Creek, Johns Canyon, Long Canyon, Navajo Creek, Reflection Canyon and Slickrock Canyon Nos. 1 & 2). The zinc levels for both domestic water supplies and freshwater aquatic standards were within acceptable levels at all sites. Although these measured iron and manganese concentrations were higher than expected, they do not indicate external pollution. The concentrations reported for these elements are within the ranges expected for uncontamainated, natural waters.

Selenuim and arsenic concentrations were measured in the water samples because they represent a serious health threat if present, and they have been reported at elevated levels in many Grand Canyon waters (Foust and Hoppe, 1985). All of the selenium and arsenic levels recorded were within both the limits established for domestic drinking water and for freshwater aquatic, marine and wildlife use.

The focus of this survey was primarily on establishing the location of perennial streams. But, the availability of water can influence a particular area in many different ways. First of all, since the ratio of dry drainages to running drainages is quite high in GCNRA, the scarcity of running tributaries to Lake Powell (excluding major tributaries such as the San Juan and Escalante rivers) is itself a basis for protection (i.e., "preserving the natural flow of free water," NPS, 1972). Many of these streams maintain a delicate balance which could be easily disrupted by withdrawal of water from the watershed.

For this study, a cross section of drainages was selected with the initial idea that perhaps some "average" of instream flow could be calculated for the Lake Powell area. In reality, the influencing factors of instream flow requirements are so variable that each individual area or specific drainage would have its own set of minimum flow requirements; these requirements could not be transferred to another area. The only real commonality might be the minimum requirement to maintain riparian vegetation.

A reduction in flow due to groundwater diversion could easily upset the ecological balance of the drainages in GCNRA. Certain points in life cycles of fish and vegetation could be disrupted by lack of water. If the instream flows were decreased or stopped, sites with unique characteristics such as

waterfalls or natural bridges, would not only have their aesthetic appeal reduced but also the processes causing their formation. Water-sensitive vegetation in hanging gardens, for example, would be severely impacted by reductions in flow due to groundwater diversion. In the dry climate of GCNRA, the occurrence of verdant pockets of vegetation contrasted against the stark red walls of the canyons is of major aesthetic importance to the recreation area. Since most of these gardens are dependent on groundwater seepage, diversion from the supporting aquifer through wells would be the greatest danger.

Surface water diversion would also disrupt the cleansing cycle of flash floods, increasing the influence of vegetation enroachment on stream channels. This could be a hazard since only a proportionally larger flood could use the channel, perhaps after building up a dangerous head of pressure behind damming obstacles. Vegetation encroachment is also undesirable if it obstructs recreational use of the area. Tamarisk thickets pose the greatest threat of vegetation enroachment to the drainages of GCNRA.

Reduction of instream flow may have an adverse affect on the control of *Tamarix pentandra*, commonly known as tamarisk, a non-native type of riparian vegetation. Seedlings of tamarisk, unless washed away by periodic fluctuations in river level, will grow in thickets which obstruct access to banks of tributaries. This restricts available campsites which are accessible from the lake and restricts recreational use by fishermen and hikers (Irvine et al., 1976). Tamarisk, unless controlled, has a competitive advantage over the two native tree species of the area, *Salix exigua* and *Populus fremontii*. Besides the physical problems caused by thick encroachment along shorelines, it can be argued that since tamarisks are not a native tree and the nature of their growth pattern is so different from that of native species, they are destructive to scenic and aesthetic features of the recreation area.

If diversion of surface runoff causes a significant and consistent decrease in flood characteristics, tamarisk encroachment becomes a serious threat at the lake/tributary mouth interface. This area is where many of the available campsites are found at Lake Powell.

In a water-sensitive area, any diversion could have a negative impact far downstream. Glen Canyon Recreation Area contains few of the sources for drainages which end up in the park. Only by protecting the resources which maintain areas within GCNRA can the recreation area fulfill its obligation to its users.

Reasons for Hydrologic Diversion. Diversion of instream flow could arise from several sources. Many areas of the recreation area already are impacted by cattle grazing. To provide for these cattle, ranchers want to be allowed to divert surface runoff into tanks. These tanks are often formed by blocking off a source of runoff. One use of water appropriated by the state would be to allocate runoff for cattle.

Another use for instream flow is for mineral/energy fuels extraction. Besides the potential environmental damage from tar sands or uranium development due to erosion and pollution, there is also the amount of hydrologic impact to consider. The damage resulting from lowering the water table by intensive water extraction has yet to be assessed, but vegetation which is dependent upon groundwater seepage would be strongly impacted. In many places

in GCNRA, there are no other consistent sources of water. If the groundwater resources are lost, hanging gardens and riparian vegetation will be lost also.

Reserving Instream Flows. There are several justifications the Park Service can use to reserve rights to instream flows. One is to justify the water demand under a need for recreation. This can be water-oriented recreation, such as fishing, boating, and other water sports, or land-based recreation such as camping and hiking.

Another way for GCNRA to justify water reservaton claims is to argue that the water is needed for the preservation of species, be they endangered or simply sensitive to fluctuation of water supply. Such species would include wildlife, fish or vegetation. This sort of preservation would fall under protection of scientific and scenic features. Tables IX, X and XI contain lists of plant, animal and bird species known to be in the Glen Canyon National Recreation Area (Foust, 1981). Unfortunately, little is known about indigenous native fish species in smaller tributaries of Lake Powell.

Any historic site in the recreation area which needed flowing water to maintain its historic interest or authenticity could also be used as a sufficient reason to reserve instream flows.

Finally, the broadest justification for GCNRA to reserve in stream flows would be the protection of scenic or aesthetic features contained in the Lake Powell area. This would include of the above justifications, in addition to any site which had intrinsic appeal due to flowing water.

Identification of Critical Reaches. Only those drainages sustaining perennial discharge were considered when identifying critical reaches, thereby reducing the selection field from 43 to 23, including Alcove Canyon, Bowns Canyon, Chaol Creek, Cow Canyon, Coyote Gulch, Dark Canyon, Desha Canyon, Forbidding Canyon, Grand Gulch, Hansen Creek, Iceberg Canyon, Lake Canyon, Long Canyon, Navajo Creek, Oak Canyon, Piute Creek Waterfall, Piute Creek, Reflection Canyon (right fork), Slickhorn Canyon, Slickrock Canyon, Ticaboo Creek, Trachyte Creek and Wilson Canyon. Of these, Slickhorn Canyon and Grand Gulch were eliminated due to very limited access (river raft only).

As the best example of hanging gardens seen in the surveyed group, Long Canyon was selected as a representative of drainages with hanging gardens. Alcove and Cow canyons and Ticaboo Creek, other examples of well-developed hanging gardens, were eliminated. However, if a representative for their areas was needed, any could be the site of further vegetation water requirement studies.

The presence of uranium and/or tar sand deposits in the drainage area of a discharging stream was considered to be a threat to its instream flow. Dark Canyon, Desha Canyon and Piute Creek Waterfall were selected as unique and widely separated examples of areas whose resources would be threatened by mineral extraction. Desha Canyon and Piute Creek Waterfall are both on the San Juan River, but Desha Creek has a drainage area of 25 square miles and Piute Creek Waterfall springs from a cliffside and runs 200 yards to meet Lake

Table IX. List of vascular plant species known to be present in the Glen Canyon National Recreation Area.*

Trees
- *Fraxinus anomalus*
- *Juniperus osteosperma*
- *Pinus edulis*
- *Quercus gambelii*

Grasses
- *Aristida longiseta*
- *Aristida* sp.
- *Bouteloua barbata*
- *Bouteloua eriopoda*
- *Bouteloua gracilis*
- *Bromus* sp.
- *Distichlis stricta*
- *Hilaria jamesii*
- *Hilaria* sp.
- *Muhlenbergia pungens*
- *Munroa squarrosa*
- *Oryzopsis hymenoides*
- *Sitanion hystrix*
- *Sporobolus airoides*
- *Sporobolus cryptandrus*
- *Sporobolus* spp.
- *Stipa comata*
- *Stipa* sp.

Shrubs
- *Artemisia arbuscula* var. *nova*
- *Artemisia bigelovii*
- *Echinocactus xeranthemoides*
- *Artemisia tridentata*
- *Artemisia* sp.
- *Atriplex canescens*
- *Atriplex confertifolia*
- *Chrysothamnus greenii*
- *Chrysothamnus nauseosus*
- *Cowania mexicana*
- *Ephedra viridis*
- *Gutierrezia microcephala*
- *Gutierrezia sarothrae*
- *Opuntia* spp.
- *Opuntia whipplei*
- *Rhus* sp.
- *Yucca angustissima*

Herbs
- *Abronia fragrans*
- *Androstephium breviflorum*
- *Aster arenosus*
- *Aster tanacetifolius*
- *Aster tephroides*
- *Astragalus breviflorum*
- *Astragalus mollisimus*
- *Calochortus nuttallii*
- *Castilleja linariifolia*
- *Chaenactis stevioides*
- *Chenopodium fremontii*
- *Chenopodium* spp.
- *Cirsium wheeleri*
- *Cordylanthus wrightii*
- *Crypthantha circumscissa*
- *Crypthantha crassisepala*
- *Crypthantha jamesii*
- *Cymopteris newberryi*
- *Delphinium scaposum*
- *Descurainia obtusa*
- *Descurainia pinnata*
- *Eriogonum cernum*
- *Eriogonum corymbosum* var. *corymbosum*
- *Eriogonum leptocladon*
- *Eriogonum umbellatum*
- *Erigeron divergens*
- *Erotia lanata*
- *Euphorbia fendleri*
- *Euphorbia melanadenia*
- *Gilia longiflora*
- *Gilia polyantha*
- *Gilia simuata*
- *Gilia* sp.
- *Helianthus* spp.
- *Hymenopappus filifolius*
- *Lepidium montanum*
- *Linum aristatum*
- *Lupinus pusilus*
- *Menzelia pumila*
- *Malocothrix glabrata*
- *Oenothera pallida*
- *Pectis papposa*
- *Penstemon* sp.
- *Plantago purshii*
- *Phacelia ivesiana*
- *Portulaca oleracea*
- *Rumex* sp.
- *Salsola kali*
- *Solidago petradoria*
- *Sphaeralcea coccinea*
- *Sphaeralcea grossulariaefolia*
- *Streptanthella longirostris*
- *Stephanomeria exigua*
- *Townsendia incana*
- *Zygadenus elegans*

*Based on a vascular plant inventory of Pinyon-Juniper Woodlands in the vicinity of nearby Navajo Mountain. By permission of Northern Arizona University, *Environmental Impact Studies of the Navajo and Kaiparowits Power Plants, 1973-1974. Third Annual Report.* Vol. I, 390 pp. NTIS Access. No. PB 242845.

Table X. List of mammals known to be present in the Glen Canyon National Recreation Area.

Common Name	Scientific Name
Carnivores:	
Coyote	*Canis latrans mearnsi*
Red Fox	*Vulpes vulpes*
Gray Fox	*Urocyon cinereoargenteus scotti*
Ring-tailed Cat	*Bassaricus astutus arizonensis*
Spotted Skunk	*Spilogale puterius gracialis*
Striped Skunk	*Mephitis mephitis estor*
Mountain Lion	*Filis concolor*
Bobcat	*Lynx rufus baileyi*
Long-legged Myotis	*Myotis volans interior*
California Myotis	*Myotis californicus stephensi*
Western Pipistrelle	*Pipistrellus hesperus hesperus*
Big Brown Bat	*Eptesicus fuscus pallidus*
Townsend's Big-eared Bat	*Plecotus townsendi pallescens*
Brazilian Free-tailed Bat	*Tadarida brasiliensis mexicana*
Pallid Bat	*Antrozous pallidus pallidus*
Northern Grasshopper Mouse	*Onychomys leucogaster pallescens*
Spotted Bat	*Euderma masculata*
Badger	*Taxidea taxus*
Merriam Shrew	*Sorex mirriami*
Black-footed Ferret	*Mustela nigripes*
Hervivores (Primary Consumers):	
Mule Deer	*Odocoileus hemionus cooki*
Antelope	*Antilocopra americana*
Black-tailed Jack Rabbit	*Lepus californicus texianus*
Desert Cottontail	*Sylvilagus auduboni warreni*
White-tailed Prairie Dog	*Cynomys gunnisoni zuniensis*
Spotted Ground Squirrel	*Citellus spilosoma cryptospilotus*
Rock Squirrel	*Citellus variegatus grammurus*
White-tailed Antelope Squirrel	*Citellus leucurus cinnamomeus*
Colorado Chipmunk	*Eutamias quadrivittatus hopiensis*
Valley Pocket Gopher	*Thomomys bottae aureus*
Silky Pocket Mouse	*Perognathus flavus hopiensis*
Apache Pocket Mouse	*Perognathus apache apache*
Ord's Kangaroo Rat	*Dipodomys ordii longipes*
Western Harvest Mouse	*Reithrodontomys megalotis*
Canyon Mouse	*Peromyscus crinitus auripectus*
Deer Mouse	*Peromyscus maniculatus*
Brush Mouse	*Peromyscus boylii rowleyi*
Rock Mouse	*Peromyscus nasutus nasutus*
Pinyon Mouse	*Peromyscus truei truei*
Stephen's Woodrat	*Neotoma stephensi relicta*
White-throated Woodrat	*Neotoma albigual laplataensis*
House Mouse	*Mus musculus*

ble XI. List of bird species known to be present in the Glen Canyon National Recreation Area.*

mmon Name	Scientific Name	Winter Resident	Summer Resident	Permanent Resident
rkey Vulture	*Cathartes aura*		x	
arp-shinned Hawk	*Accipiter striatus*	x		
oper's Hawk	*Accipiter cooperii*		x	
d-tailed Hawk	*Buteo jamaicensis*			x
rruginous Hawk	*Buteo regalis*	x		
lden Eagle	*Aquila chrysaetos*			x
airie Falcon	*Falco mexicanus*			x
rlin	*Falco columbarius*	x		
arrow Hawk	*Falco sparverius*			x
ugh-legged Hawk	*Buteo lagopus*		x	
rsh Hawk	*Circus syaneus*	x		
mmon Nighthawk	*Chordeiles minor*		x	
rrowing Owl	*Athene cunicularia*		x	
reech Owl	*Otus asio*			x
eat Horned Owl	*Bubo virginianus*			x
urning Dove	*Zenaidura macroura*			x
sser Goldfinch	*Carduelis psaltria*		x	
rk Bunting	*Calamospiza melanccorys*	x		
stern Meadowlark	*Sturnella neglecta*			x
stern Kingbird	*Tyrannus verticalis*		x	
rned Lark	*Eremophilia alpestris*			x
untain Bluebird	*Sialia currucoides*	x		
arling	*Sturnus vulgaris*	x		
tton's Vireo	*Vireo huttoni*		x	
ay Vireo	*Vireo vicinior*		x	
ack-throated Gray Warbler	*Dendroica nigrescens*		x	
use Sparrow	*Passer domesticus*			x
tt's Oriole	*Icterus parisorum*		x	
own-headed Cowbird	*Molothrus ater*		x	
atic Tanager	*Piranga flava*		x	
ack-headed Grosbeak	*Pheucitus melanocephalus*		x	
use Finch	*Carpodacus mexicanus*			x
ne Siskin	*Carduelis pinus*		x	
fous-sided Towhee	*Pipilo erythrophtalmus*			x
own Towhee	*Pipilo fuscus*			x
rk Sparrow	*Chondestes grammacus*		x	
ack-throated Sparrow	*Amphispixo bilineata*			x
rk-eyed Junco	*Junco hyemalis*	x		
ay-headed Junco	*Junco caniceps*			x
pping Sparrow	*Spizella passerina*		x	
ewer's Sparrow	*Spizella breweri*		x	
ack-chinned Sparrow	*Spizella atrogularis*		x	
ite-crowned Sparrow	*Zonotrichia leucophyrs*	x		
ugh-winged Swallow	*Stelgidopteryx rufficollis*		x	
iff Swallow	*Petrochelidon pyrrhonota*		x	
eller's Jay	*Cyanocitta stelleri*			x

able XI (continued)

ommon Name	Scientific Name	Winter Resident	Summer Resident	Permanent Resident
crub Jay	*Aphelocoma coerulescens*			x
ommon Raven	*Corvus corax*			x
ommon Crow	*Corvus brachyrhynchos*			x
inon Jay	*Gymnorhinus cyanocephalus*			x
ountain Chickadee	*Parus gambeli*	x		
lain Titmouse	*Parus inornatus*			x
ushtit	*Psaltriparus minimus*			x
hite-breasted Nuthatch	*Sitta carolinensis*			x
ewick's Wren	*Thryomanes bewickii*			x
anyon Wren	*Catherpes mexicanus*			x
ock Wren	*Salpinctes obsoletus*		x	
ockingbird	*Mimus polyglottos*		x	
rissal Thrasher	*Toxostoma dorsale*		x	
age Thrasher	*Oreoscoptes montanus*		x	
merican Robin	*Turdus migratorius*			x
estern Bluebird	*Sialia mexicana*	x		
ownsend's Solitaire	*Myadestes townsendi*	x		
uby-crowned Kinglet	*Regulus calendula*	x		
hainopepla	*Phainopepla nitens*		x	
orthern Shrike	*Lanius excubitor*	x		
oggerhead Shrike	*Lanius ludovicianus*	x		
hite-throated Swift	*Aeronautes saxatalis*			x
lack-chinned Hummingbird	*Archilochus alexandri*		x	
road-tailed Hummingbird	*Selasphorus platycercus*		x	
ommon (Red-shafted) Flicker	*Colaptes cafer*			x
airy Woodpecker	*Picoides villosus*			x
adder-backed Woodpecker	*Picoides scalaris*			x
sh-throated Flycatcher	*Myiarchus cinerascens*		x	
ay's Phoebe	*Sayornis saya*		x	
ray Flycatcher	*Empidonax wrightii*		x	
iolet-green Swallow	*Tachycineta thalassina*		x	
esper Sparrow	*Pooecetes gramineus*		x	
ong Sparrow	*Melospiza melodia*		x	
age Sparrow	*Amphispiza belli*		x	
rewer's Sparrow	*Spizella breweri*		x	

Lists compiled from the following sources:

he AOU Check-list of North American Birds. American Ornithologists Union, 5th Ed. (updated) 1957.

rue, Chris, 1974. *Density in Areas of Secondary Succession on Powerline Rights of Way; Secondary Succession Along Major Transmission Lines Rights of Way: A Progress Report.*

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Powell, having a drainage area of essentially zero. Dark Canyon has a drainage area of 269 square miles, making it the largest area to sustain a perennial stream. It is also located in the northernmost section of GCNRA.

Those drainages that contained unique characteristics of scenic, scientific or historic interest were set aside as critical reaches when the presence of water contributed to their appeal. Bowns Canyon, supporting very well-developed riparian vegetation and hanging gardens, is also the site of several archaeological discoveries. Chaol Creek has a beautiful waterfall. Since it and Navajo Creek are very similar in size and drainage characteristics, Chaol Creek was selected due to the additional presence of a unique scenic feature. Coyote Gulch was identified for its scenic beauty in a heavily used hiking area. Forbidding Canyon is the host of Rainbow Bridge, one of the main tourist attractions in GCNRA. Iceberg Creek had signs of a beaver community along with thriving riparian vegetation. It is also heavily used by boat campers. Lake Canyon is unique of all the drainages surveyed for its geomorphology. Stream action is eroding through deposits of an ancient lake, exposing sandy bluffs and a wide, flat alluvial valley thick with willow growth. Wilson Canyon is the best example of a drainage never impacted by lake inundation, its lake interface being a six-foot cliff. Beaver signs were observed and water life was present. The area, although easily accessed from the lake, is minimally impacted by hikers and the drainage is small. Of all the drainages surveyed, this is the best site for a riparian vegetation study, being close to Dangling Rope, easily accessed and of a limited area.

The remaining drainages all sustain low discharge, mostly seeping over slickrock, making quantification extremely hard. The drainages identified as critical reaches all sustain flows measurable by either a pygmy current meter or a weir.

Recommendations

Many strategies to reserve instream flows rely on determination of the minimum flows required to support fish or wildlife. The data needed to establish claims of minimum flows required to support the flora and fauna of GCNRA does not exist. This lack of data presents a serious problem for the Park Service should a challenge to water rights be mounted by another agency. Immediate efforts should be made to determine the following:

1. Water needs of various species of vegetation.
2. Effect of flooding on tamarisk control.
3. Fish, wildlife and vegetative species types present within the GCNRA.
4. Endangered species preservation requirements.
5. Locations/descriptions of unique scenic features in GCNRA.
6. Continuation of the data base started in this study.

This data base could be used to support instream flow reservation strategies, and also meet the ongoing research mission of GCNRA. The acquisition of this data could be through currently funded projects. Obtaining this data also supports the Level II management plan objective: "to provide the richest possible interpretive experience to visitors of the recreation area."

Flow monitoring with no specific application of data in mind would be next to useless. Each flow monitoring program is tailor designed to answer specific questions. Data acquired without these specific parameters will not be applicable in a water-rights litigation. Support data such as that listed above, however, could be applied anywhere in the recreation area where these species occurred. This data would be the backbone of further study in any specific area which had its instream flow needs under scrutiny.

One immediate possibility is to continue the stream survey. A way to do this with minimum funding is to use already available park service personnel. Rangers and interpreters are stationed throughout the recreation area. Their use would minimize the necessary travel which would be needed if only one parkwide base were used (as in this study). As a normal part of their jobs they visit many parts of the recreation area. Many are also interested in the outdoors on a personal level. A standard form could be produced with blanks for drainage characteristics. As drainages are visited, the forms can be filled out and returned to resource management. Repeat visits would be especially valuable for generating wet/dry drainage data. Resource management could maintain a central file and as funds allow, generate an alphabetical data base which includes each stream and all the data known about it. This data base could be a useful tool in the planning stages of any field project requiring information on a specific drainage or larger area. Other resource management needs could be incorporated, such as abundance of cattle signs, human litter concentration and number of campsites. Archaeoogical and scenic sites would be noted also.

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Appendix A

Following are tables which list all drainages used to set up preliminary data pool for final stream survey site selection. These are listed alphabetically. Map references are provided, as well as calculated drainage area, area drained and geologic occurrence for each drainage. T and U indicate the presence of tar sands or uranium. SJR = San Juan River; ER = Escalante River.

Also following is a list of the geologic units occurring in the Lake Powell area, from oldest to youngest in age. Included is a detailed description of each unit and a list of canyons where outcrops of the unit may be found (Geology, Structure, and Uranium Deposits of the Escalante Quadrangle, 1973). Since the drainages often cut through many miles of length, outcrop occurrence may be outside the park boundary, but still within the drainage regime. SJR = San Juan River; ER = Escalante River; WC = Wahweap Creek.

Table A-I. All Major Drainages Into Lake Powell and its Tributaries Occurring Within Recreation Area Boundaries.

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Alcove Canyon: SJR	1.17	Gray Mesa	Navajo, Kayenta
---	Antelope Creek	97.28	Gray Mesa	Navajo
I-744	Aztec Creek	84.32	Navajo Mtn.	Navajo, Kayenta
I-744	Blue Notch Canyon	20.0	Grand Gulch Plateau	Kayenta/Wingate
I-744	Bowdie Canyon	30.24	Dark Mesa Plateau	Hermosa, Rico, Moenkopi, Chinle, Cedar Mesa, U
I-744	Bowns Canyon	5.76	Waterpocket/Straight Cliffs	Navajo
I-744	Bullfrog Creek	253.76	Tarantula Mesa, Mt. Pennell, Ellsworth	Navajo, Summerville, Entrada, Morrison, Cedar Mtn/ Brushy Basin, Mancos Shale, Dakota, Igneous, Diorites
I-744	Castle Creek: SJR	79.7	Clay Hills	Moenkopi, Chinle, Kayenta, Wingate, Navajo
I-744	Cedar Mesa Canyon	49.3	Mancos Mesa	Kayenta/Wingate, Navajo, U
I-744	Cha Canyon: SJR	16.5	Navajo Mtn.	Chinle, Moenave/Wingate, Kayenta, Navajo, Morrison, U
I-744	Chaol Canyon	77.0	Gray Mesa	Navajo
I-744	Clear Creek: ER	4.5	Lower Kaiparowits Plateau	Navajo
OC #15	Clearwater Canyon	20.6	Orange Cliffs/The Block	Hermosa, Rico, Cedar Mesa, Organ Rock, White Rim, Chinle, Wingate, Kayenta, Navajo, T, U
I-744	Copper Canyon: SJR	115.7	Monitor Mesa, Monument Valley, Hoskinni Mesa	Cedar Mesa, De Chelly, Organ Rock, Monekopi, Shinarump, Petrified Forest, Wingate, Navajo, U

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Cottonwood Canyon	6.6	Wilson Mesa	Kayenta, Navajo
OC #15	Cove Canyon	26.1	The Block	Moenkopi, Shinaraump, Chinle, Wingate, Kayenta, Navajo, U
I-744	Cow Canyon	18.1	W. Waterpocket Fold	Navajo
I-744	Coyote Creek: ER	136.2	Straight Cliffs	Navajo, Carmel, Entrada, Summerville, Tropic Shale/Dakota
I-744	Crystal Spring Canyon	4.6	between Moki & Cedar Canyons	Navajo, Carmel
I-744	Dark Canyon	269.3	Dark Mesa Plateau	Hermosa, Rico, Cedar mesa, White Rim, Moenkopi, T
	Davis Gulch: ER	7.5	Straight Cliffs	Navajo, Carmel, Summerville, Entrada, Morrison, Tropic Shale/Dakota
I-744	Deep Canyon: SJR	14.4	Hawkeye Natural Bridge	Chinle, Moenave/Wingate, Kayenta, Navajo, Morrison, U
I-744	Desha Canyon: SJR	25.3	Navajo Mountain	Chinle, Moenave/Wingate, Kayenta, Navajo, Morrison, U
I-759	Dungeon Canyon	6.1	Cummings Mesa	Navajo, Carmel, Entrada, Morrison
I-744	East Moody Canyon	25.4	Colt Mesa	Chinle, Kayenta/Wingate, Navajo, T, U
I-744	Explorer Canyon: ER	2.7	W. Waterpocket Fold	Navajo
---	Face Canyon	17.0	between Navajo Creek and Cummings Mesa	Navajo
I-744	Farley Canyon	4.8	Browns Rim	Cedar Mesa, White Rim, Moenkopi, T

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Fifty Mile Creek: ER	7.5	Lower Straight Cliffs	Navajo, Carmel, Entrada, Summerville, Morrison, Tropic Shale, Dakota
I-744	Forbidding Canyon	12.1	Navajo Mountain	Navajo
I-744	Forgotten Canyon	12.2	between Moki & Cedar	Navajo, Carmel
I-744	Forty Mile Creek	63.8	Forty Mile Ridge	Navajo, Carmel, Entrada, Summerville, Morrison, Tropic Shale/Dakota
I-744	Four Mile Canyon	13.6	Mt. Holmes	Chinle, Kayenta/Wingate, Navajo, Carmel, Igneous Diorites, U
I-744	Grand Gulch: SJR	192.2	Grand Gulch Plateau	Halgaito Tongue, Cedar Mesa
I-744	Gunsight Canyon	11.4	Middle Kaiparowits	Navajo, Entrada, Summerville, Morrison, Tropic Shale/Dakota
I-744	Hall's Creek	150.4	Tarantula Mesa, Swap Mesa, Wagon Box Mesa	Chinle, Kayenta, Wingate, Navajo, Carmel, Summerville, Entrada, Morrison, Tununk Shale, Dakota, U
I-744	Hansen Creek	129.0	Mt. Ellsworth, Hillers, Coal Bed Mesa	Carmel, Entrada, Morrison, Cedar Mt., Brushy Basin, Tununk, Dakota, Mancos, U
I-744	Iceberg Canyon	4.5	between San Juan and Moki Canyon	Kayenta, Navajo, Carmel
I-744	Indian Creek	3.4	lower Kaiparowits Plateau	Navajo
I-58	John's Canyon: SJR	33.4	Grand Gulch Plateau	Rico, Hermosa, Halgaito Tongue, Cedar Mesa
I-744	Knowles Canyon	5.0	between Moki & Cedar	Kayenta, Wingate, Navajo

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
	Labyrinth Canyon	7.1	between Navajo Creek and Cummings Mesa	Navajo
I-744	Lake Canyon	40.3	between San Juan & Moki Can.	Navajo, Carmel
I-744	Last Chance Creek	165.0	mid-eastern Kaiparowits	Summerville, Entrada, Morrison, Tropic, Dakota, Straight Cliffs, Wahweap, Kaiparowits
I-744	Little Valley Canyon	210.1	eastern Kaiparowits	Summerville, Entrada, Morrison, Tropic, Dakota, Straight Cliffs
I-744	Llewellyn Gulch	5.1	lower end Straight Cliffs	Navajo, Carmel, Entrada, Morrison, Tropic Shale, Dakota
I-744	Long Canyon	17.8	Waterpocket Fold	Navajo
I-744	Middle Moody Canyon	75.5	Colt Mesa	Kaibab Limestone/White Rim, Moenkopi, Chinle, Kayenta, Wingate, Navajo, T, U
I-744	Mike's Canyon: SJR	33.3	Clay Hills	Moenkopi, Chinle, Kayenta/Wingate, Kayenta, Navajo, U
I-744	Moki Canyon	81.1	Clay Hills, Mancos Mesa	Chinle, Kayenta, Wingate, Navajo, Carmel, Entrada, U
I-758	Mtn. Sheep Canyon	16.2	Cummings Mesa	Navajo, Carmel, Entrada, Morrison
I-744	Nasja Creek: SJR	9.4	Navajo Mountain	Navajo, Carmel
	Navajo Creek	210.4	Gray Mesa	Navajo
I-744	Neskahi Wash: SJR	37.4	Piute Mesa	Shinarump, Petrified Forest, Mossbank, Moenave, Wingate, Kayenta, Navajo, U

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Nokai Wash: SJR	181.0	No Man's Mesa	White Rim, Organ Rock, Moenkopi, Shinarump, Petrified Forest, Moenave, Wingate, Kayenta, T, U
I-17	North Wash	145.3	East Henry Mtns.	Chinle, Wingate, Kayenta, Navajo, Carmel, U
I-744	Oljeto Wash: SJR	476.8	Monument Valley, Oljeto Mesa	Cedar Mesa, Organ Rock, Shinarump, Moenkopi, U
I-744	Padre Canyon	4.5	middle Kaiparowits Plateau	Navajo, Entrada, Summerville, Morrison, Tropic, Dakota
I-744	Piute Canyon: SJR	244.5	Navajo Mtn., Piute Mesa	Petrified Forest/Mossback, Kayenta, Navajo, U
I-744	Piute Farms Wash:SJR	26.9	Monitor Mesa, Monument Valley	Cedar Mesa, Organ Rock, Moenkopi, Shinarump, U
I-744	Red Canyon	171.4	Red House Cliffs, Clay Hills, West Grand Gulch Plateau	Organ Rock, Moenkopi, Chinle, Kayenta, Wingate, U
I-744	Ribbon Canyon	6.4	Wilson Mesa	Kayenta, Navajo
I-744	Rock Canyon	19.5	The Block	Cedar Mesa, White Rim/Organ Rock, Moenkopi, Chinle, Navajo, T
I-744	Rock Creek	35.2	SE Kaiparowits Plateau	Navajo, Carmel, Entrada, Morrison, Tropic, Dakota, Straight Cliffs
I-744	Rockhouse Gulch:SJR	39.5	Monument Valley	Cedar Mesa, Shinarump, U
I-744	Scorpion Gulch	13.6	Scorpion Flat	Kayenta, Wingate, Navajo
I-744	Seven Mile Creek	7.4	Ticaboo Mesa	Kayenta, Wingate, Navajo, Carmel, Entrada
I-744	Sheep Canyon	4.5	Dry Mesa	Rico, Cedar Mesa

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Slate Creek	67.7	Henry Mtns: Hillers/Pennell	Moenkopi, Navajo, Carmel, Entrada, Cedar Mtn., Brushy Basin, Tununk, Dakota, Mancos, Igneous Diorite
I-58	Slickhorn Canyon:SJR	45.8	Grand Gulch Plateau	Rico, Halgaito, Cedar Mesa
I-744	Slick Rock Canyon	7.7	between SJR & Moki Canyon	Kayenta, Navajo
I-744	Smith Fork	23.0	Mt. Ellsworth	Kayenta, Wingate, Navajo, Carmel, Entrada, Mancos, Igneous Diorites
I-744	Steer Gulch: SJR	70.2	Red House Cliffs	Cedar Mesa, Organ Rock, Moenkopi
I-744	Steven's Canyon	28.8	W. Waterpocket Fold	Chinle, Kayenta, Wingate, Navajo, U
I-744	Swett Creek: TC	33.0	Henry Mtns: Hillers/Pennell	Navajo, Carmel, Entrada, Cedar Mtn., Brushy Basin, Tununk/Dakota, Igneous Diorite, U
I-744	Ticaboo Creek	26.2	Ticaboo Mesa, Mts. Ellsworth and Holmes	Chinle, Kayenta, Wingate, Navajo, Igneous Diorites, U
I-744	Trachyte Creek	182.6	Henry Mtns.	Moenkopi, Chinle, Kayenta, Wingate, Navajo, Carmel, Entrada, Cedar Mtn/Brushy Basin, Tununk, Dakota, Igneous Diorites, U
I-744	Twilight Canyon	15.5	lower end Straight Cliffs	Navajo, Carmel, Summerville, Morrison, Tropic/Dakota, Dakota
I-744	Two Mile Canyon	4.5	Mt. Holmes	Chinle, Kayenta, Wingate, Navajo, Carmel, Igneous Diorites, U
I-744	Wahweap Creek	147.2	W. Kaiparowits/Canaan Mtn.	Navajo, Carmel, Entrada, Summerville

Table A-I (continued)

Map Ref.	Drainage Name	Area (sq. mi.)	Name of Area Drained	Geology of Area, T, U
I-744	Warm Creek	214.4	midwest Kaiparowits, Canaan Mtn.	Navajo, Carmel, Summerville, Entrada, Morrison, Tropic, Dakota, Straight Cliffs, Wahweap
I-758	Wetherill Canyon	21.4	Cummings Mesa	Navajo, Carmel, Entrada, Morrison
I-759	West Canyon Creek	31.2	Cummings Mesa	Navajo, Entrada, Carmel, Morrison
I-744	Whirlwind Draw: SJR	16.6	Red House Cliffs	Cedar Mesa, Organ Rock, Moenkopi
I-744	White Canyon	293.1	Grand Gulch Plateau	Cedar Mesa, Organ Rock, White Rim, Moenkopi, Kayenta, Wingate, U, T
I-744	Wilson Canyon: SJR	3.7	Wilson Mesa	Moenave, Wingate, Kayenta, Navajo

Table A-II. Composition and Occurrence of Geologic Units.

Name of Unit	Age	Occurrence in Drainage of GCNRA	Description
Hermosa	Pennsylvanian	SJR, Dark, Sheep, Bowdie, Clearwater	fossiliferous cherty marine limestone; micaceous sandstone; shale; gypsum
Rico	Pennsylvanian	SJR, Dark, Sheep, Bowdie, Clearwater	cherty fossiliferous marine limestone, fluvial fieldspathic sandstone, siltstone
Cutler Formation	Permian		fine-grained silty sandstone, fossiliferous dolomitic marine sandstone
CF: White Rim SS	Permian	Nokai, White, Farley, Dark, Clearwater, Rock, Moody, Silver Falls	tar sands
CF: De Chelly SS	Permian	Copper	eolian sandstone
CF: Organ Rock Tongue	Permian	Nokai, Copper, Piute Farms, Oljeto, Steer, Whirlwind, Red, White, Rock	siltstone, fine-grained sandstone
CF: Cedar Mesa SS	Permian	Copper, Piute Farms, Rockhouse, Oljeto, Johns, Slickhorn, Grand, Steer, Whirlwind, White, Farley, Sheep, Bowdie, Dark, Clearwater, Rock	sandstone, sandy siltstone
CF: Halgaito Tongue	Permian	Grand Gulch	siltstone, silty sandstone, limestone, limey siltstone
Kaibab Limestone	Permian	Moody, Silver Falls	dolomitic limestone, sandstone, siltstone
Moenkopi Fm.	Triassic	Nokai, Copper, Piute Farms, Oljeto, Steer, Whirlwind, Castle, Mikes, White, Farley, Dark, Clearwater, Rock, Swett, Slate, Moody, Silver Falls	siltstone, calcareous sandstone, petroliferous sandstone (Circle Cliffs), marine limestone, evaporite tongues
Chinle Formation	Triassic	Cha, Desha, Deep, Castle, Mikes, Moki, Red, Clearwater, Cove, North, Rock, Swett, Two Mile, Four Mile, Ticaboo, Halls, Stevens, East Moody, Moody, Silver Falls	sandy top, limey/bentonitic middle

Table A-II (continued)

Name of Unit	Age	Occurrence	Description
CF: Petrified Forest/Moss Back Member	Triassic	Piute, Neskahi, Nokai, Copper	bentonitic mudstone, muddy sandstone, limestone/chert conglomerates, mudstone, 3rd U_3O_8 producer
CF: Shinarump Mbr	Triassic	Neskahi, Nokai, Copper, Piute Farms, Rockhouse Gulch, Clearwater, Cove	fluvial sandstone, siltstone, uranium/vanadium, Best U_3O_8 producer
Wingate Sandstone	Triassic	Cha, Desha, Deep, Neskahi, Nokai, Copper, Castle, Mikes, Wilson, Moki, Knowles, Cedar Mesa, Red, White, Cove, Clearwater, East, North, Swett, Two Mile, Four Mile, Ticaboo, Seven Mile, Smith, Halls, Stevens	calcareous eolian sandstone
Moenave Formation	Triassic(?)	Cha, Desha, Deep, Neskahi, Nokai, Wilson	micaceous sandstone, siltstone, mudstone
Kayenta Fm.	Triassic(?)	Cha, Desha, Deep, Piute, Neskahi, Moki, Nokai, Castle Creek, Mikes, Wilson, Red, Cottonwood, Ribbon, Iceberg, Slick Rock, Knowles, Cedar, White, Clearwater, Cove, North, Swett, Two Mile, Four Mile, Ticaboo, Seven Mile, Smith, Halls, Navajo, Stevens	fluvial sandstone, siltstone, shale, freshwater limestone
Navajo SS	Triassic(?)	Not Present: Nokai, Piute, Farms, Johns, Rockhouse, Oljeto, Gypsum, Lime, Grand, Slickhorn, Steer, Whirlwind, Red, White Farley, Sheep, Bowdie, Dark, Hansen, Last Chance, Little Valley, Wiregrass, Coyote	eolian sandstone, cherty magnesium limestone lens
Carmel Fm.	Jurassic	West, Dungeon, Wetherill, Mtn. Sheep, Nasja, Iceberg, Lake, Moki, Forgotten, Crystal Spring, North, Swett, State, Maidenwater, Two Mile, Four Mile, Seven Mile, Smith, Hansen, Halls, Harris, Wahweap, Coyote, Twenty Five Mile, Forty Mile, Fifty Mile, Davis, Llewellyn, Twilight, Dry Rock, Warm	limey siltstone, sandstone, limestone, gypsum

Table A-II (continued)

Name of Unit	Age	Occurrence	Description
Entrada	Jurassic	West, Dungeon, Wetherill, Mtn. Sheep, Swett, Slate, Seven Mile, Smith, Hansen, Bullfrog, Halls, Harris, 25 Mile, Coyote, Forty Mile Creek, Fifty Mile, Davis, Dry Rock, Last Chance, Little Valley, Padre, Gunsight, Warm, Wahweap, Wiregrass Spring, Coyote (WC), Llewellyn	fine eolian sandstone, silty sandstone, siltstone
Summerville	Jurassic	Halls, Coyote (ER), Forty Mile, Fifty Mile, Davis, Twilight, Last Chance, Warm, Little Valley, Padre, Gunsight, Wahweap	shaly siltstone, sandstone, mudstone, glauconite marine sandstone, limestone
Morrison Formation	Jurassic		
MF: Brushy Basin	Jurassic	Swett, Slate, Hansen, Bullfrog	bentonitic sandstone/mudstone, chert pebbles
MF: Salt Wash Mbr	Jurassic	Near Henry Mtns.	mudstone, siltstone, uranium, 2nd best U_3O_8
Dakota Sandstone	Cretaceous	Swett, Slate, Hansen, Bullfrog, Halls, Harris, 25 Mile, Coyote (ER), Forty Mile, Fifty Mile, Davis, Llewellyn, Twilight, Dry Rock, Last Chance, Little Valley, Padre, Gunsight, Warm	coarse sandstone and quartzite, mudstone, shale, coal
Tropic Shale	Cretaceous	Harris, 25 Mile, Coyote (ER), Forty Mile, Fifty Mile, Davis, Llewellyn, Twilight, Dry Rock, Last Chance, Little Valley, Padre, Gunsight, Warm, Wahweap, Coyote (WC)	calcareous marine shale, bentonite, fossilization, limestone, sandstone, mudstone
Mancos Shale	Cretaceous	Slate, Smith, Bullfrog	
MS: Masuk Mbr	Cretaceous		silty sandstone, carbonaceous shale
MS: Emery SS	Cretaceous		carbonaceous shale, coal, mudstone, sandstone

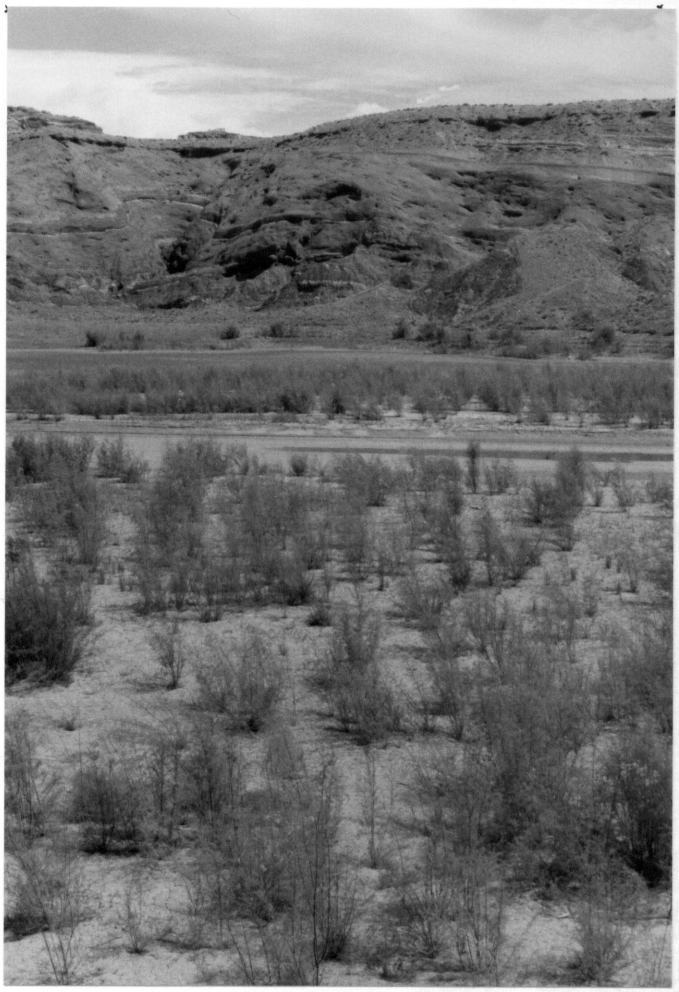
Table A-II (concluded)

Name of Unit	Age	Occurrence	Description
MS: Blue Gale Shale	Cretaceous		marine shale, bentonite, limestone, shaly sandstone
MS: Ferron SS	Cretaceous		shale, coal, sandstone, uranium, 5th producer
MS: Tununk Shale	Cretaceous	Swett, Hansen, Halls	marine mudstone, shale, bentonite
Straight Cliffs	Cretaceous	Harris, 25 Mile, Last Chance, Little Valley, Warm, Wahweap, Coyote (WC)	conglomeratic sandstone, shale, mudstone, coal
Wahweap	Cretaceous		mudstone, sandstone
Kaiparowits	Cretaceous	Harris, 25 Mile, Last Chance, Warm, Wahweap, Coyote (WC)	arkosic and biotitic silty sandstone, mudstone, limestone, sandstone
Intrusive Igneous	Tertiary	Henry Mtns.	gray diorite porphyry, monzonite porphyry

Library
Glen Canyon National Recreation Area

Appendix B

Photographs of selected critical reaches identified as part of this study

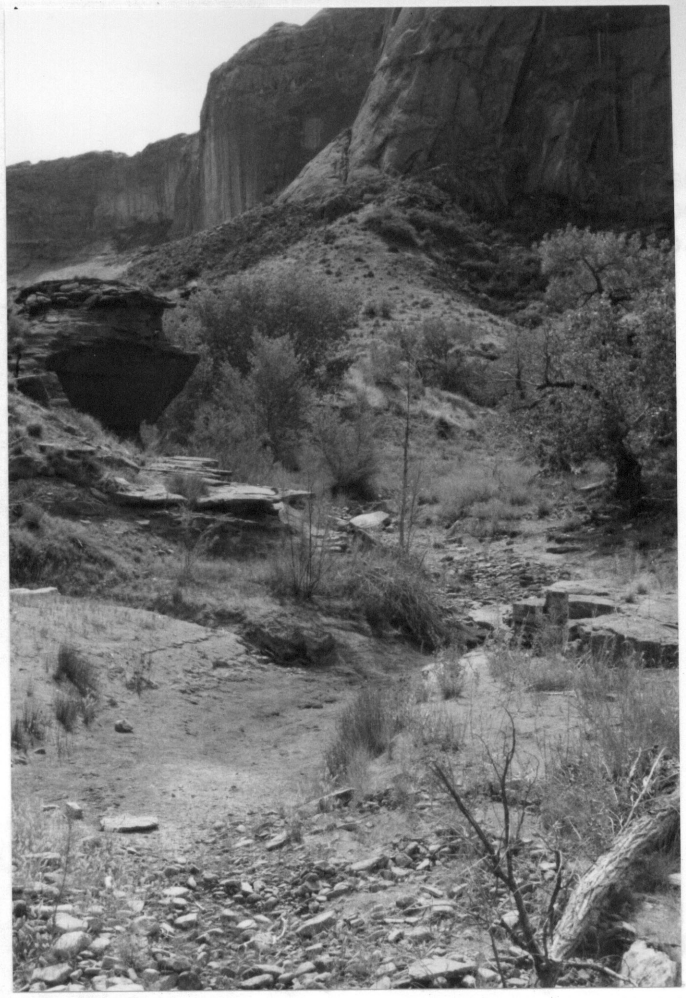


Bullfrog Creek
(lake/dry creek bed interface



Bullfrog Creek (above lake/creek bed interface).

Forgotten Canyon
(dry, good riparian
growth)

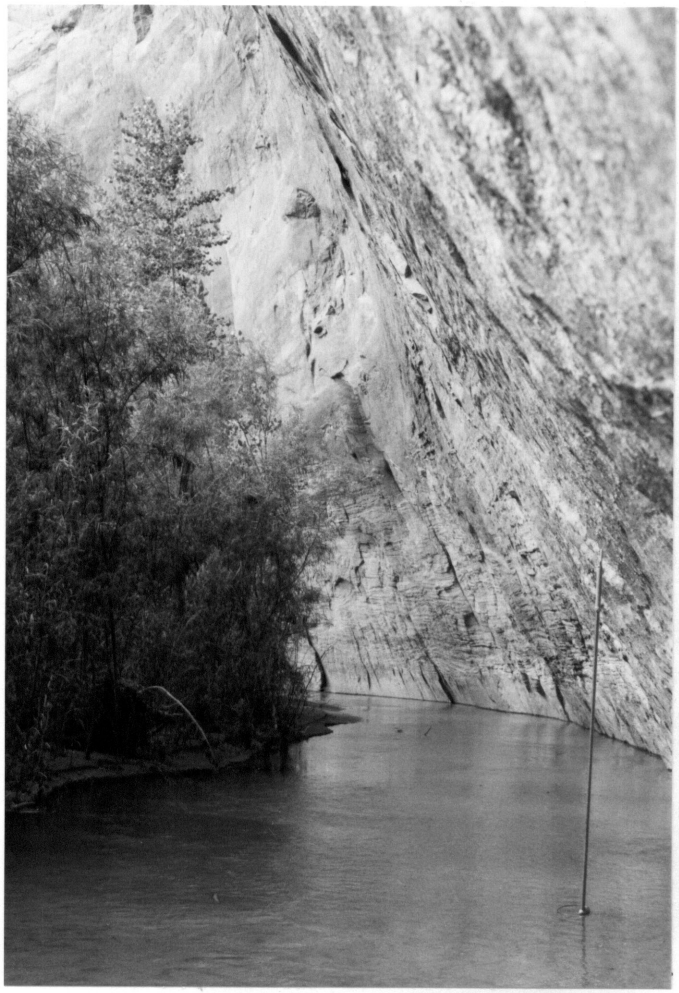




Hansen Creek (stream/lake interface)



Hansen Creek
Sampling point
shown by backpack



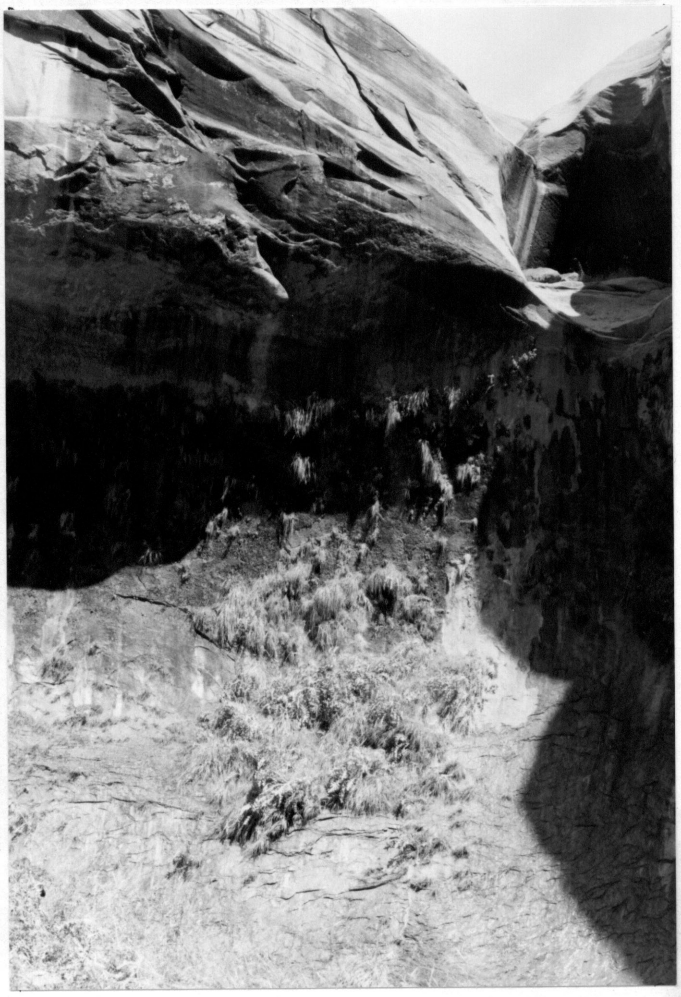
Lake Canyon, typical section
Wide sandy bottom confined
by cliff and sandy bluffs.
Current meter rod for scale.



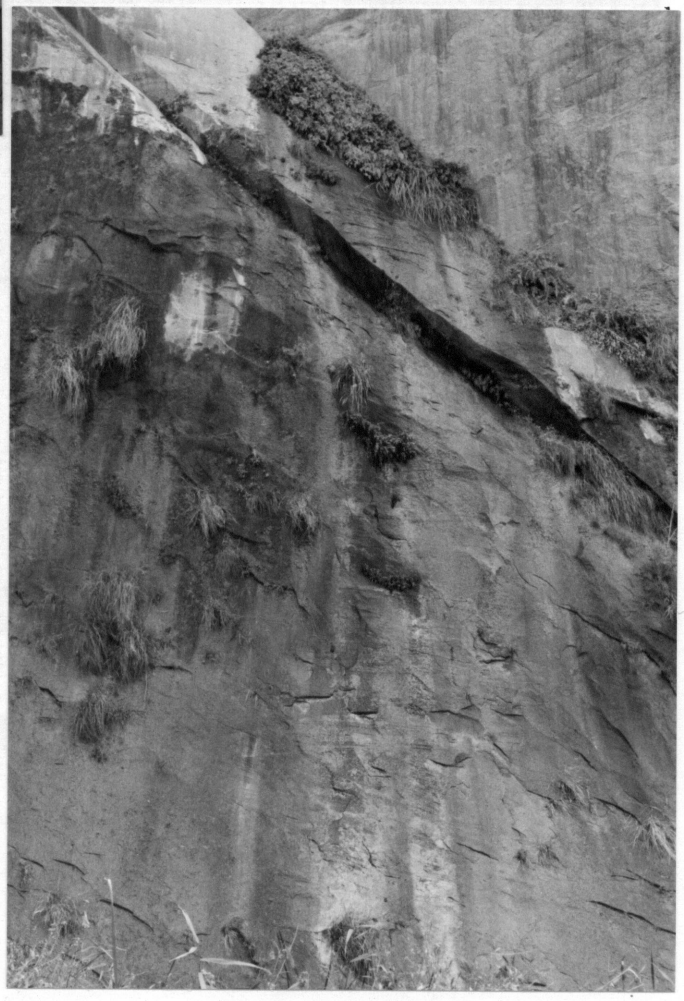
Lake Canyon - typical section



Lake Canyon - typical section



Long Canyon - pour off



Long Canyon - seep

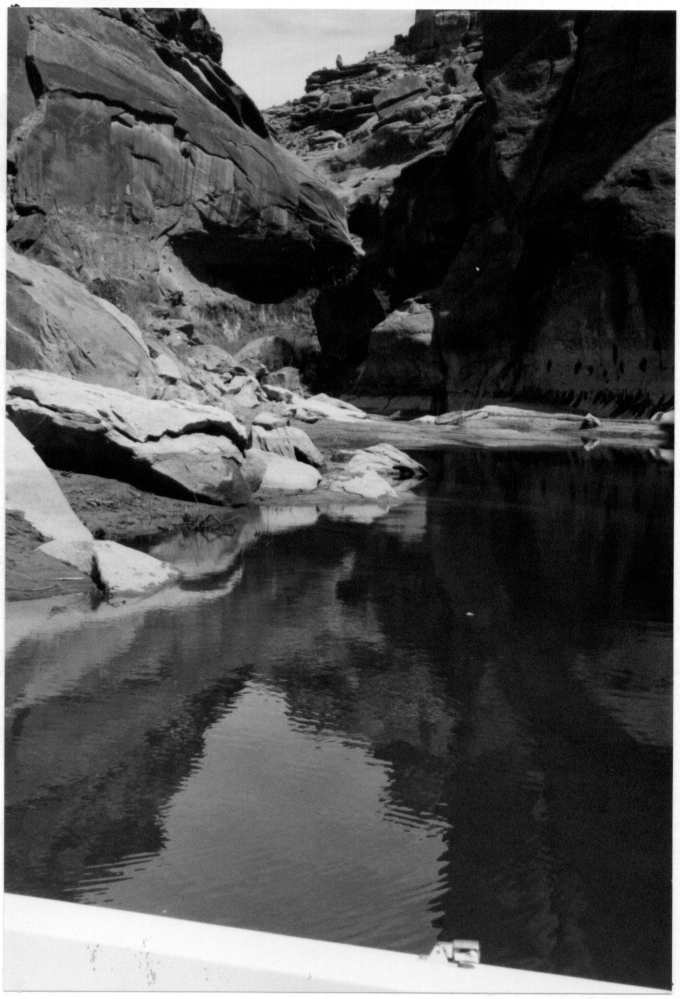


Long Canyon - Large seeps with author for scale



Long Canyon - vegetation

Long Canyon from lake





Long Canyon with pour offs and seeps

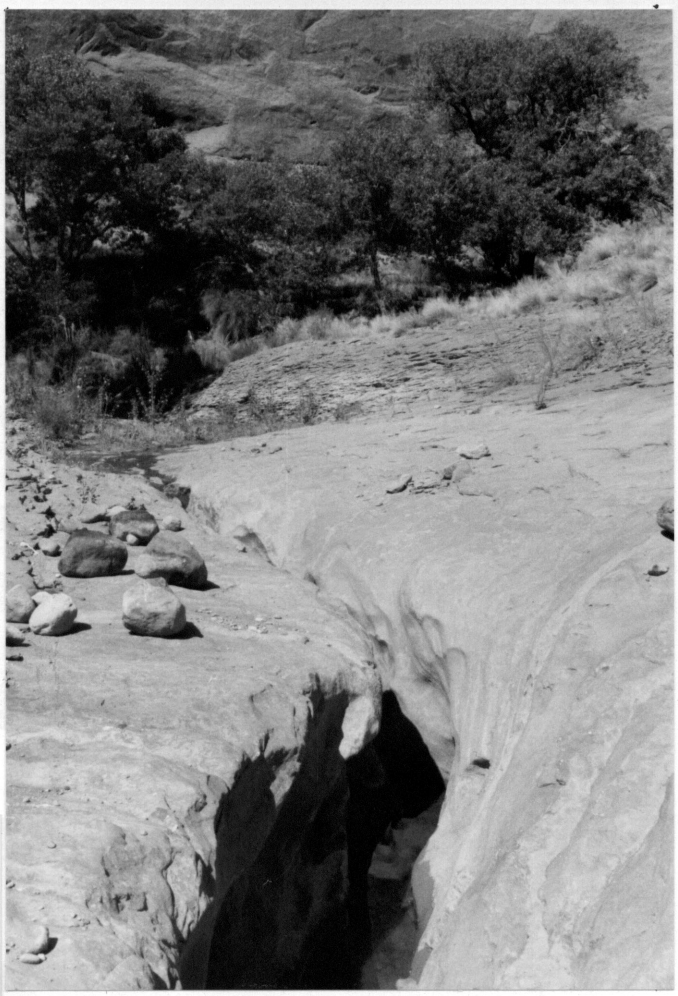


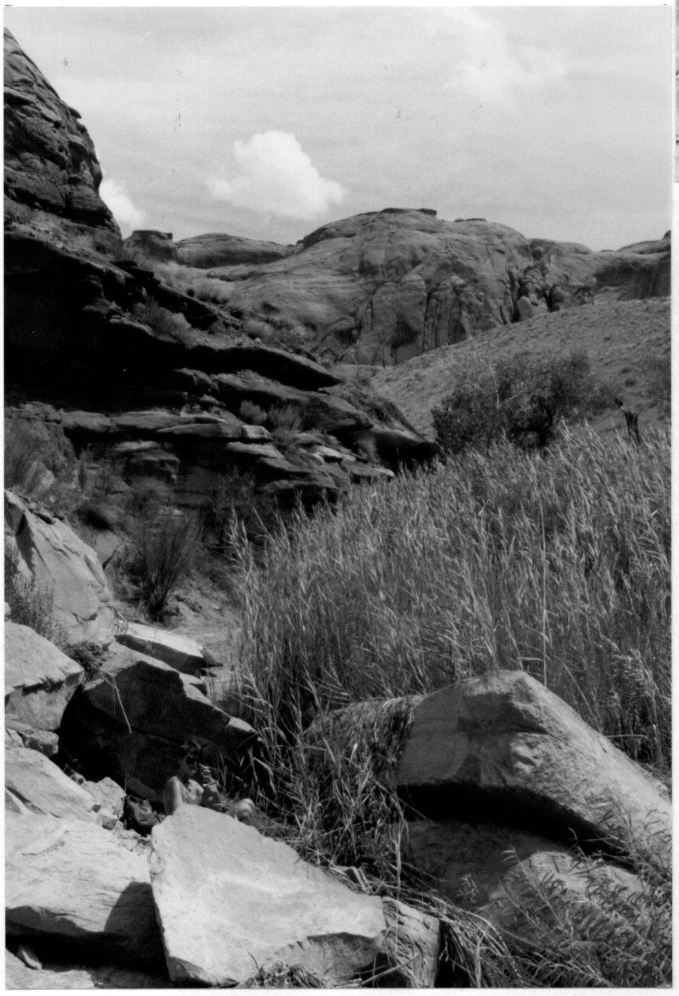
Long Canyon pool at base of pour off.



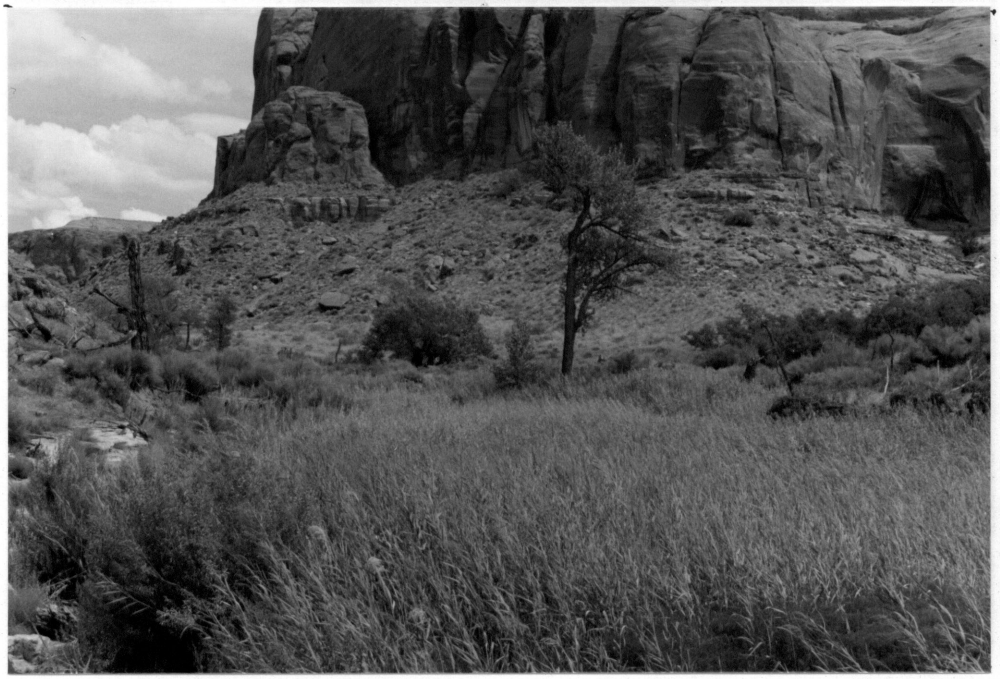
Moki Canyon - No visible flow

Reflection Canyon, right fork

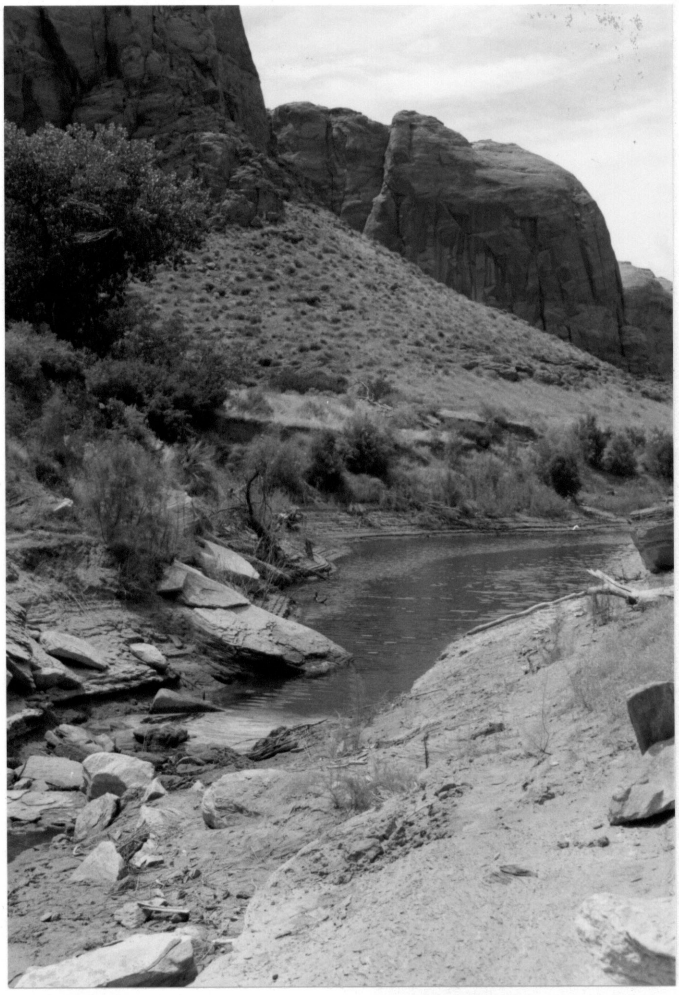




Slickrock Canyon
sampling point above
lake/pour-off contact



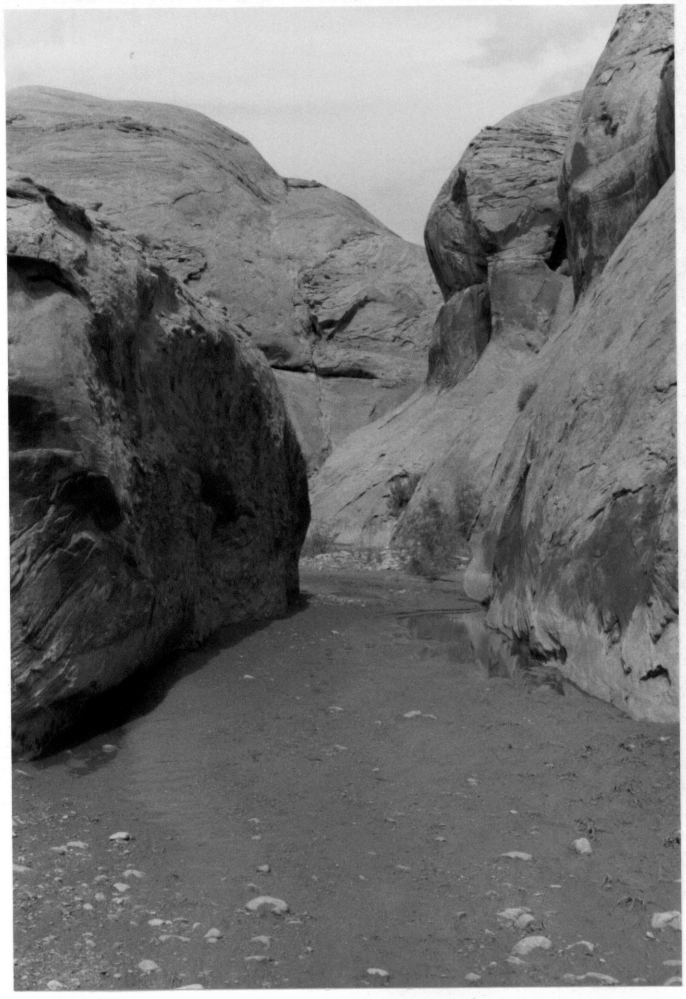
Slickrock Canyon - typical vegetation



Slickrock Canyon
pour-off into lake at left



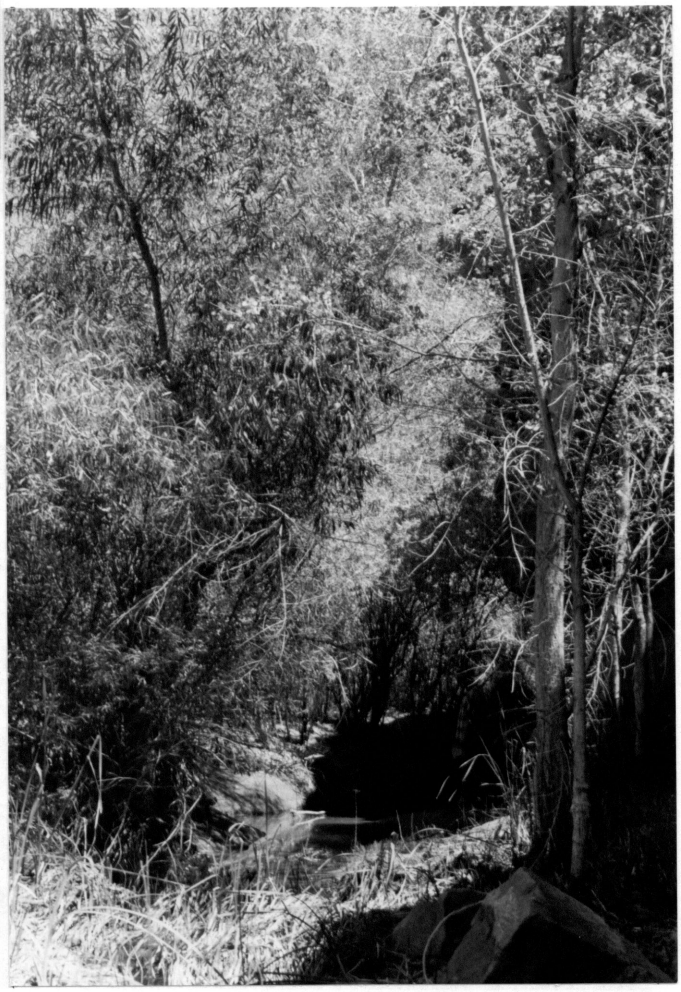
Slickrock Canyon



Smith Fork
No visible flow
remnants of runoff



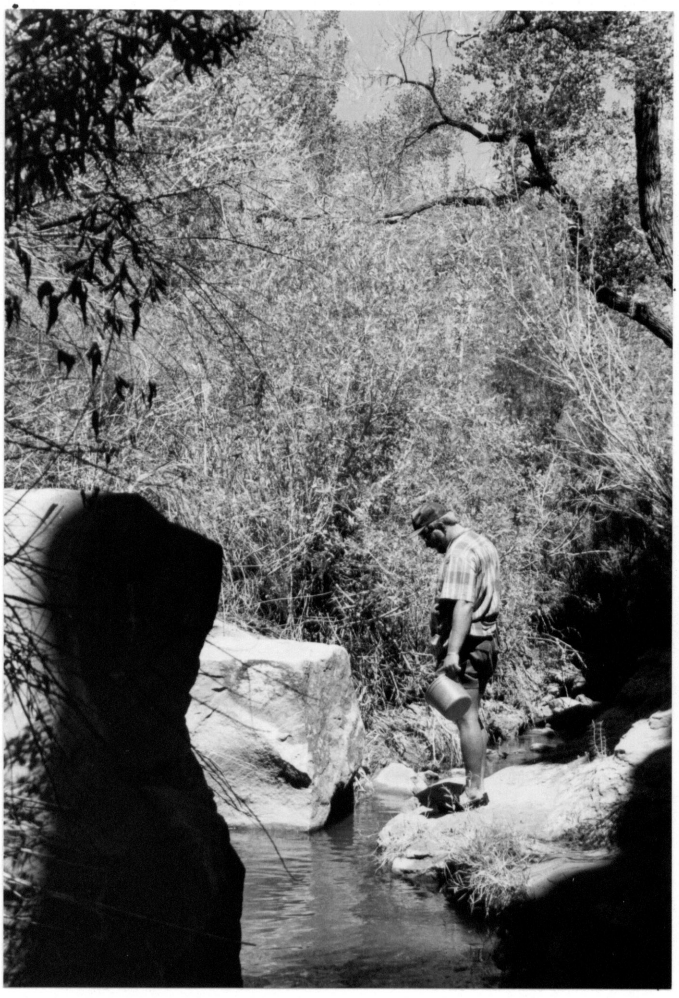
Smith Fork



Wilson Canyon
typical section



Wilson Canyon
typical section



Wilson Canyon
typical section