II. DESCRIPTION OF THE ENVIRONMENT

A. GENERAL

The Colorado Plateau is the regional setting for the Grand Canyon. The plateau is a vast, semi-arid land of raised plains and basins typical of the Southwestern United States. Approximately half of the land on the plateau is federally administered by the National Park Service, Bureau of Land Management, and U.S. Forest Service. The remaining land is owned primarily by Native Americans. The Grand Canyon lies on the south-central edge of the plateau.

The 1,218,375 acres within Grand Canyon National Park are adjacent to the Colorado River in northern Arizona. Within the park is 277 miles of the Colorado River, from the Paria River confluence to the Grand Wash Cliffs. The 277-mile-long Grand Canyon ranges from 1 to 25 miles in width and is up to 1 mile deep. Elevations range from 1,200 feet at the western boundary where the Colorado River enters Lake Mead, to 9,165 feet on the North Rim.

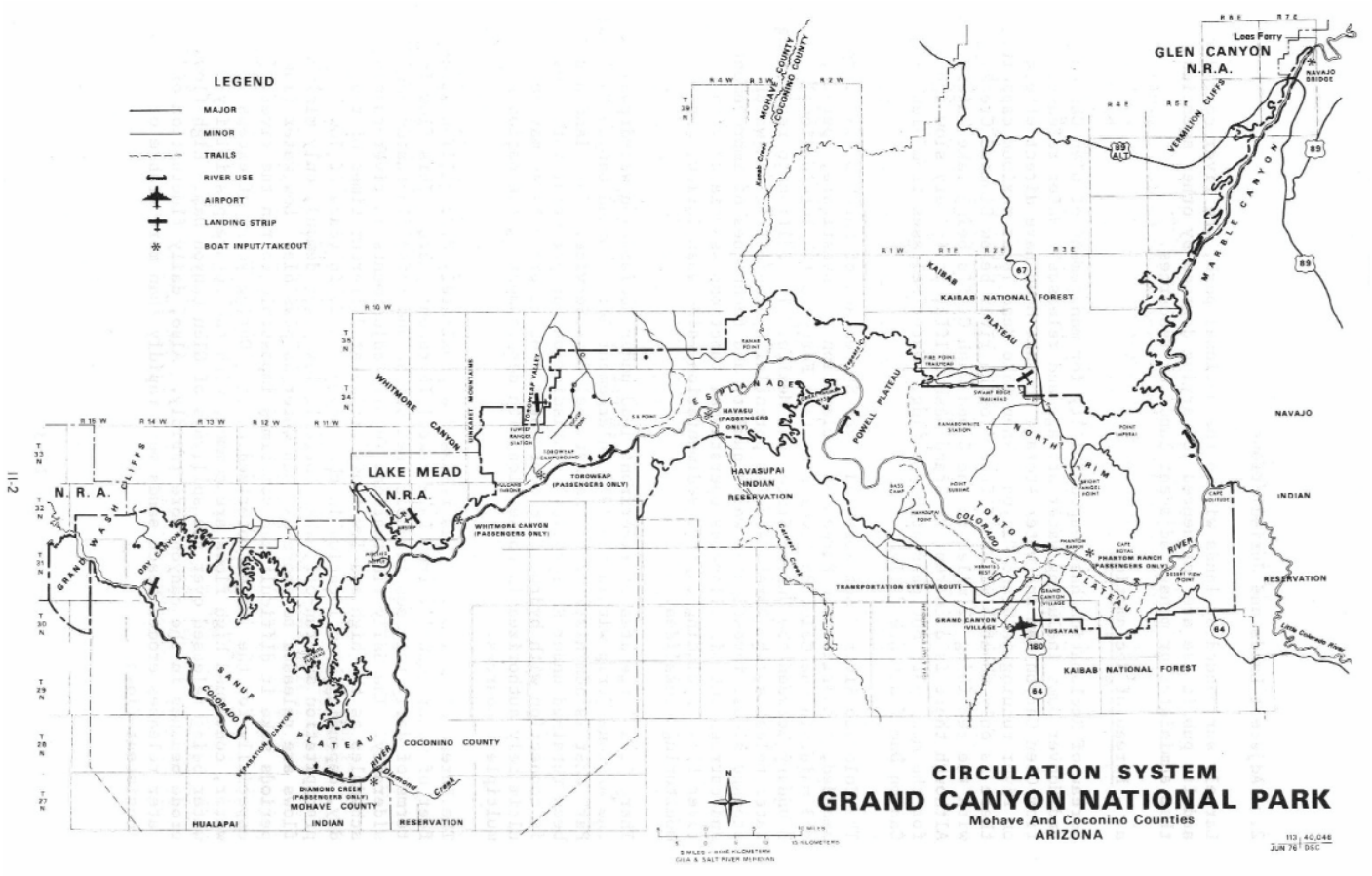
Public Law 93-620, dated January 3, 1975, incorporated Marble Canyon National Monument; Grand Canyon National Monument; Grand Canyon National Park; portions of Lake Mead National Recreation Area, the Kaibab National Forest, national resource lands (Bureau of Land Management); and other lands into the present park.

The park is bounded on the north by Kaibab National Forest and the Arizona Strip (Bureau of Land Management), on the east by the Navajo Indian Reservation, on the south by Kaibab National Forest and the Havasupai and Haulapai Indian Reservations, and on the west by Lake Mead National Recreation Area.

1. Access

The Colorado River is accessible for boat launching and takeouts in only a few places. Lees Ferry, the primary boat launch site, is accessible from U.S. Highway 89A. Diamond Creek, a primary takeout location, is accessible by a gravel road from Interstate 40 at Peach Springs. Pierce Ferry, South Cove, and Temple Bar which are the remaining takeout locations are accessible from Interstate 40 and 15.

Visitors may also hike or ride a mule into the canyon to meet or exit from river trips. At least nine trails are available: Salt Trail from the Navajo Indian Reservation to the Little Colorado River, Tanner Trail, Hance Trail, North and South Kaibab Trails, Bright Angel Trail, Hermit Trail, Bass Trail, Tapeats-Thunder River Trail, Havasu Trail, and Whitmore Wash Trail. Mule rides are available only on the Kaibab, Bright Angel and Whitmore Wash Trails. For major access points and circulation, see map page II-2. For specific river locations, refer to Colorado River Corridor map, pages I-4 through I-6.


LEGEND
MAJOR
MINOR
TRAILS
RIVER USE
AIRPORT
LANDING STRIP
BOAT INPUT/TAKEOUT
GLEN CANYON N.R.A.
Lees Ferry
LAKE MEAD N.R.A.
N. R. A.
KAIBAB NATIONAL FOREST
KAIBAB PLATEAU
HAVASUPAI INDIAN RESERVATION
NAVAJO INDIAN RESERVATION
COCONINO COUNTY
MOHAVE COUNTY
HUALAPAI INDIAN RESERVATION
GRAND CANYON VILLAGE
TUSAYAN
CIRCULATION SYSTEM
GRAND CANYON NATIONAL PARK
Mohave And Coconino Counties
ARIZONA

2. Adjacent Lands and Jurisdictions

Largely surrounded by lands within the national park, the river corridor and its public use are influenced to varying degrees by other agencies that administer or manage adjacent lands or resources.

a. Bureau of Reclamation

Bureau of Reclamation has responsibility for management of Glen Canyon and Hoover Dams including water storage and releases. Water releases from Glen Canyon Dam and water storage in Lake Mead have direct effect on river running in Grand Canyon. When Lake Mead is at maximum capacity, there is only about 5 miles of free-flowing river below Diamond Creek, with the remaining 42 miles to the Grand Wash Cliffs being lake waters. Although there is a current to Grand Wash Cliffs, it is very slow and for the most part not perceptibly moving. Water releases from Glen Canyon Dam fluctuate daily.

The Colorado River Front Work and Levee System Act of March 3, 1925, as amended, authorizes the Bureau of Reclamation to investigate, operate, and maintain the Colorado River from Lees Ferry to the International Boundary between the United States and Mexico. In addition to regulating water releases, the Bureau studies potential hydroelectric and water storage sites, investigates water quality and techniques of improvement, and carries out miscellaneous operational functions associated with river flow, including gaging, sedimentation, side wash inflow, and monitoring rockslides.

There is a large area of riverfront land under Reclamation withdrawal in the Arizona Strip within the 1975 Enlargement Act of Grand Canyon National Park that is administered by the National Park Service. This land has been retained under Reclamation's jurisdiction for potential future uses in connection with hydroelectric or water storage projects as may be ultimately authorized in connection with development of the Nation's multiple resources.

The Bureau of Reclamation has released approximately 8.23 million acre-feet of water annually from Lake Powell in recent years. This flow in terms of daily releases in cubic feet per second (cfs) fluctuates considerably. The daily fluctuations require adjustments in river-running schedules as the high and low flows arrive at different times of the day, depending upon location in the canyon. Also in years of low precipitation and run-off, when there is low power demand, only minimum flows are released to store as much water as possible. Low water flow periods make it difficult and sometimes impossible to run the river, especially for the larger motorized boats. During years of excess water, continued high flows are common, with the future possibility of water being released over the spillways of Glen Canyon Dam. High flows erode beaches in the canyon more rapidly. Also, daily fluctuation of water releases erodes beach sands more rapidly than more stable or consistent flows.

Coordination with the Bureau of Reclamation is necessary to keep river runners informed on water release rates from Glen Canyon Dam and the level of Lake Mead. The Bureau of Reclamation will also be advised on the effects of water releases on the Grand Canyon environment and river running activities.

b. Glen Canyon National Recreation Area

Most Grand Canyon river trips launch just above the mouth of the Paria River at Lees Ferry within Glen Canyon National Recreation Area.

Until l929, Lees Ferry was the only regularly used river crossing between Hite, Utah, and Pierce Ferry, Arizona. There are several historic ranch and ferry buildings at the site which are visited by river runners and other tourists. Many fishermen launch at Lees Ferry and fish upstream as far as the dam.

The most significant activity at Lees Ferry is launching Colorado River trips destined to run through the Grand Canyon. On a typical summer day, the area is filled with passengers, noncommercial river runners, and logistical personnel who drive shuttle cars, buses or trucks, and assemble and launch boats.

There is a permanent National Park Service ranger stationed at Lees Ferry with additional seasonal personnel at various times. All Grand Canyon river trips launching at the ferry are checked by the ranger to ensure compliance with the requirements of the Superintendent of Grand Canyon National Park.

c. Navajo Indian Reservation

The 12.5-million acre Navajo Indian Reservation borders the east bank of the Colorado River in the Marble Canyon section of the park from River Mile O to River Mile 61.8 at the confluence of the Little Colorado River. The area from the river to the rim is a tribal park and is also within the authorized boundary of Grand Canyon National Park. These lands may be added to the park through the consent of the Navajo Tribe. The primary land use on the reservation adjacent to the park is livestock grazing and the sale of native arts and crafts to tourists.

River runners using this area occasionally explore side canyons and hike into and out of the canyon via the Little Colorado River gorge and the Salt Trail.

d. Havasupai Indian Tribe

The Havasupai Traditional Use Lands in Grand Canyon National Park are located between the south bank of the Colorado River from River Mile 116 to River Mile 165 and 1/4 mile back from the canyon rim around Great Thumb Mesa from Royal Arch Creek to National Canyon. Use of these lands

by the Havasupai is subject to agreement between the Havasupai Tribe and the National Park Service. The National Park Service regulates all public use. Many river trips exchange passengers at Havasu Creek. Hiking into or out of Havasu Canyon to meet or leave the trip necessitates an overnight stay. A hiking permit and reservation must be obtained from the National Park Service at Grand Canyon in order to camp on traditional use lands.

On the Havasupai Indian Reservation, a fee is charged for crossing tribal lands. In addition, there is a per person, per night camping fee. All arrangements should be made with the Havasupai Tourist Enterprises, Supai, Arizona. No camping is allowed in Havasu Canyon National Park lands, which extends about four miles back from its confluence with the Colorado River. It is also possible for a person to day hike either into or out from a river trip through Havasu Canyon. The National Park Service informs the Havasupai Tourist Enterprise of river runners planning ingress or egress through Havasu Canyon.

e. Hualapai Indian Reservation

The Hualapai Tribe occupies a 992,000-acre reservation bounded on the east by the Havasupai Reservation and on the north by the river from River Mile 165 near National Canyon on the south bank to River Mile 273.

Diamond Creek at River Mile 225, located on the reservation, provides the first road permitting vehicle access to the river below Lees Ferry. This road is used by a majority of river users, especially non-motorized parties, as a takeout point. It is also a launching point for trips running only the Lower Gorge. The Hualapai Tribe charges a fee for river takeouts at Diamond Creek and helicopter landings on tribal land above Diamond Creek. This fee is subject to change and will be published yearly along with the operating requirements.

All river runners will be notified in permit conditions or operating requirements that the Hualapai Tribe owns the land within the Grand Canyon above the river high water line on the south bank to the south rim between River Mile 165 and River Mile 273. Any hiking, camping or other use of the Hualapai Tribal lands must be approved by the Hualapai Tribal Council. Helicopter landings for river trip takeouts on Hualapai Tribal lands require prior approval of the Tribal Council.

f. Lake Mead National Recreation Area

Lake Mead National Recreation Area is located adjacent to the lower end of the Grand Canyon and is administered by the National Park Service. When filled to capacity, Lake Mead backs into Grand Canyon National Park about 47 miles. There is considerable boating and fishing on these waters. Many of the river-running expeditions continue through the Lower Gorge into Lake Mead and terminate at Pierce Ferry about three miles beyond the Grand Wash Cliffs. Some trips go on to South Cove or

Temple Bar. Use of launch ramps and facilities at Pierce Ferry, South Cove, Temple Bar by river runners requires close coordination with the National Park Service at Lake Mead. Management activities that change river runner use levels of Lake Mead or their need for more or less logistical facilities will be communicated to Lake Mead National Recreation Area in a timely manner.

A National Park Service ranger resides at Meadview near Pierce Ferry, and patrols the Lower Gorge of the Grand Canyon. This ranger is responsible for visitor protection, law enforcement, search and rescue, and visitor use statistics. The rangers for Lake Mead National Recreation Area and Grand Canyon National Park maintain close liaison and coordinate patrol efforts.

B. GEOLOGY

The Grand Canyon is the deepest and most extensive canyon found in the plateau country and is a world-renowned scenic spectacle. The exposed rock layers represent all of the eras of geologic time and contain evidence of the evolution of life through more than 600 million years of earth history. The oldest dated rocks in the canyon approach 2,000 million years in age and, thus, the observer comes metaphorically face to face with the beginnings of time.

All of the individual plateaus within the Plateau Province are elongated in a north-south direction and bounded on the east and west by sharp structural breaks and folds. These major zones occur at intervals ranging from 15 to 40 miles apart across northern Arizona. The Grand Canyon is an east-west cross section through several of these plateaus, providing a window through which the geologic history of the region may be viewed.

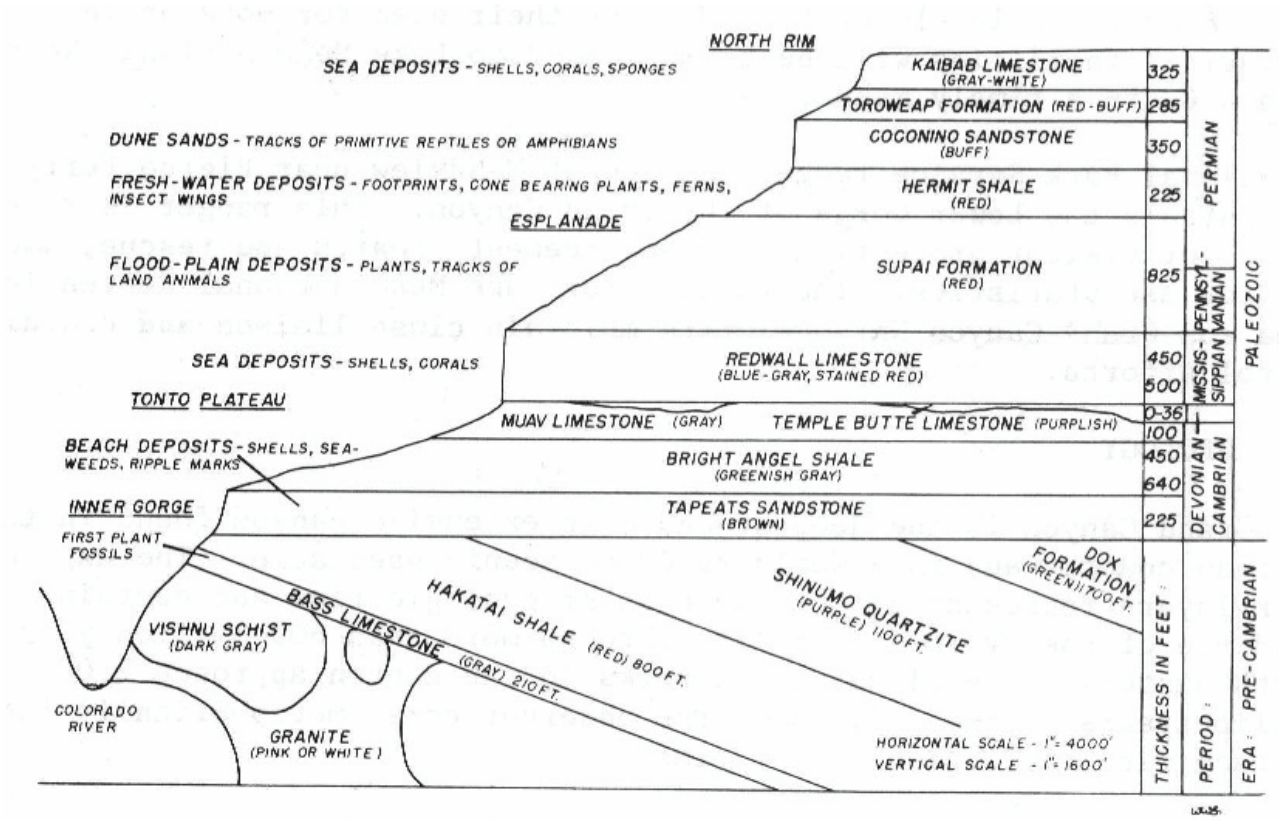
Chemical weathering is minimal in the semi-arid climate of the canyon, and horizontal strata erode into a series of alternating steep slopes and near vertical cliffs. The metamorphic rocks of the inner gorges present a relatively uniform face to erosion and form nearly unclimbable cliffs and steep, jagged slopes.

A generalized geological cross section of the canyon is illustrated on page II-7 and the structural divisions of the canyon on page II-8.

C. SOILS

Few areas within the park have well developed soil profiles. A shallow skin of dirt, covering bedrock, appropriately describes the soils throughout the area.

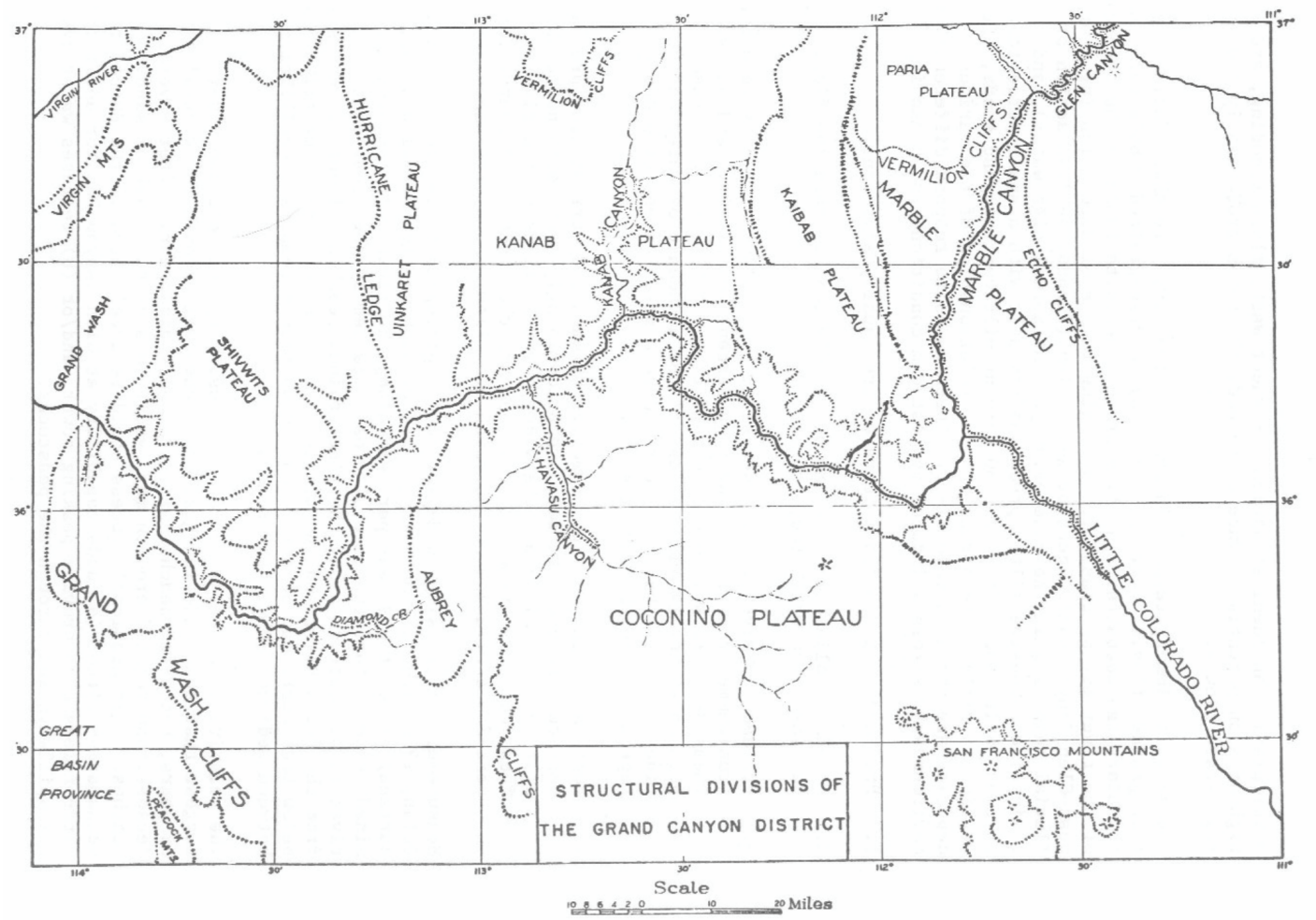
Alluvial deposits along the Colorado River combine with colluvial deposits to form the major transported soils of the Inner Canyon. The large areas of bedrock, shallow soils, and relatively sparse vegetative



GENERALIZED

GEOLOGIC SECTION

AT GRAND CANYON VILLAGE


VIRGIN RIVER
VIRGIN MTS
HURRICANE
LEDGE
VINKARET
PLATEAU
VERMILION CLIFFS
KANAB CANYON
KANAB PLATEAU
PARIA PLATEAU
GLEN CANYON
KAIBAB PLATEAU
VERMILION CLIFFS
MARBLE CANYON
MARBLE PLATEAU
ECHO CLIFFS
GRAND WASH
SHIVWITS PLATEAU
HAVASU CANYON
AUBREY
DIAMOND CR
GRAND WASH CLIFFS
GREAT BASIN PROVINCE
COCONINO PLATEAU
LITTLE COLORADO RIVER
SAN FRANCISCO MOUNTAINS
CLIFFS
BLACK MTS
STRUCTURAL DIVISIONS OF
THE GRAND CANYON DISTRICT
Scale
10 8 6 4 2 0 10 20 Miles

cover provide an ideal situation for sheet wash, flash flooding, and high erosion potential. Once disturbed, the soils erode easily and regenerate slowly.

The areas in immediate association with the river are characterized by fine-grained fluvial terraces (beaches), coarse-grained cobble bars, and tributary fan deposits. The fine-grained deposits found on the terraces of the river may be classified according to age of deposition (pre- or post-Glen Canyon Dam), agent of deposition (floods, aeolian action or fluvial reworking in the zone below present normal high water), and grain size (cohesive silts, predominantly silt with a small percentage of clay; silt-sand, with about 30 percent silt content; and sands, with negligible silt). The normal spatial relationships of the various deposits are shown on page II-10. These deposits respond differently to environmental stresses induced by post-dam conditions and human impact.

1. Pre- and post-dam flood terraces are usually silt-sand.

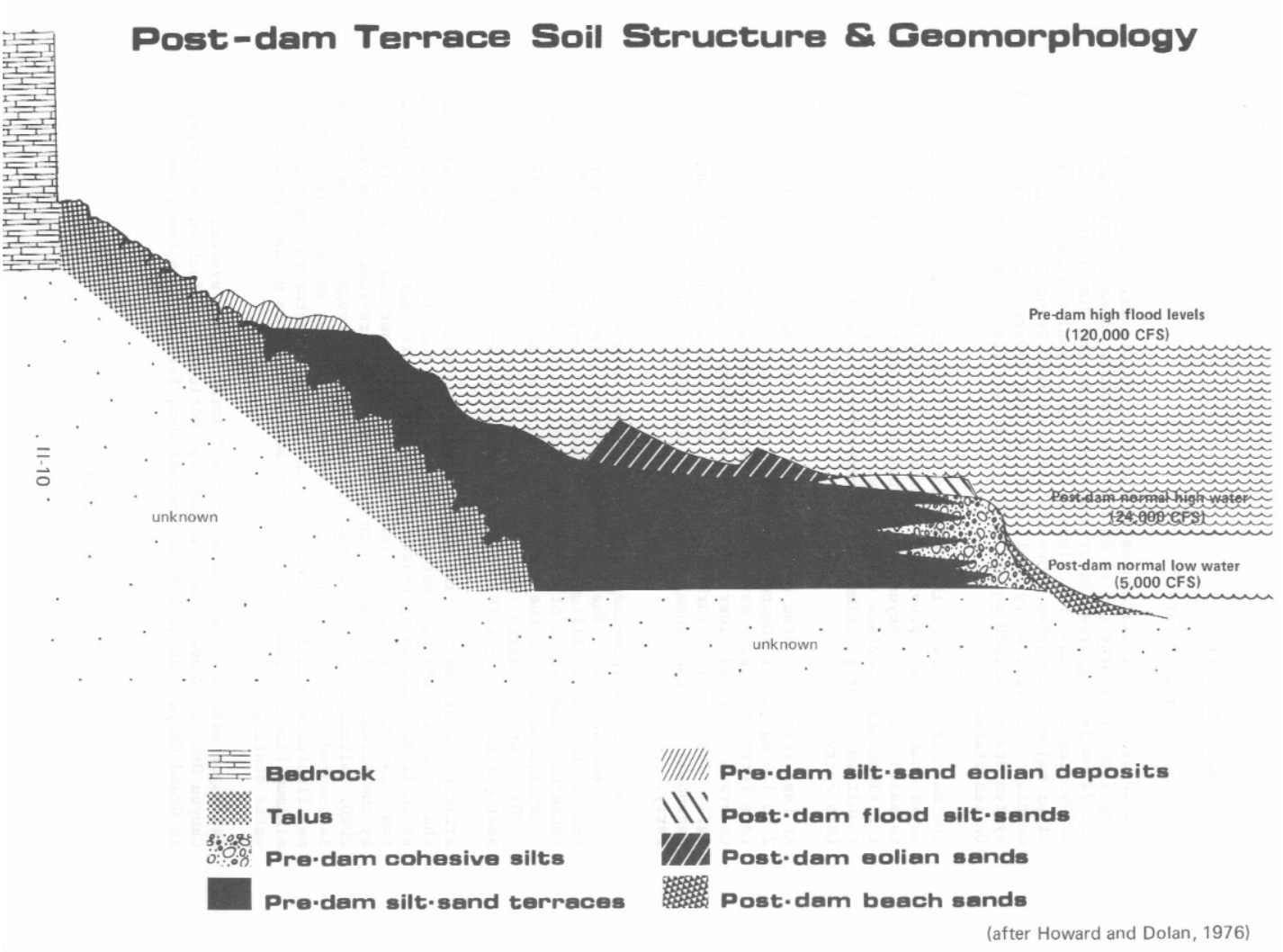
2. Pre-dam aeolian deposits are but little coarser than the flood terraces from which they are derived.

3. Pre-dam cohesive silt was deposited by mild summer floods resulting from summer runoff carrying high percentages of clays and silts. These deposits seldom extend more than a few feet above present high water levels and, because of the abundance of water and the fine substrate, have been covered to a great extent by a dense vegetative growth since the dam.

4. Post-dam beach deposits, reworked by wash and current from pre-dam terraces and bed material, are predominantly sand, with noticeable silt content only along the wide, quiet sections of the river. These deposits are well sorted and are the predominant source for post-dam aeolian deposits, which are likewise coarse grained.

Measurements made using an 8-year aerial photographic record (Howard and Dolan, 1976) indicate an average rate of back wasting (erosion of beach surface) of about 0.9 feet per year along the river. It has been determined, however that the lateral erosion caused by the clear post-dam river is not uniform along the fine-grained beaches. Input of sediment from the Paria River and the Little Colorado River, and other tributaries below Lees Ferry may be sufficient to sustain a temporary equilibrium between sediment supply and removal.

Tile relatively low rates of lateral erosion by the Colorado River suggest that abundant fine-grained beaches will remain for several tens of years, but a few beaches will gradually disappear. After several decades, dam related erosion may result in a virtual lack of sandy beaches. This erosional process could be accelerated if the Bureau of Reclamation either (a) adds capability at Glen Canyon Dam for additional water releases to provide peaking power, and/or (b) releases water over the spillways and through the penstocks.


Post-dam Terrace Soil Structure & Geomorphology
Pre-dam high flood levels
(120,000 CFS)
Post-dam normal high water
(24,000 CFS)
Post-dam normal low water
(5,000 CFS)
II-10
unknown
unknown
Bedrock
Talus
Pre-dam cohesive silts
Pre-dam silt-sand terraces
Pre-dam silt-sand eolian deposits
Post-dam flood silt-sands
Post-dam eolian sands
Post-dam beach sands
(after Howard and Dolan, 1976)

D. WATER RESOURCES

1. The Colorado River

The Colorado River originates in the Rocky Mountains. It is 1,450 miles long from its source to the Gulf of California. A major tributary is the 720-mile-long Green River which begins in the Wind River Mountains of Wyoming and joins the Colorado River in Canyonlands National Park. Other major tributaries above its entrance into Grand Canyon include the Gunnison, Dolores, Dirty Devil, and San Juan Rivers. The Colorado River system drains 245,000 square miles or one-twelfth of the continental United States.

The mainstream flow of the Colorado River through Grand Canyon Park is water that has been previously impounded by Lake Powell. Water is released from Glen Canyon Dam through gates located about 200 feet below the fluctuating surface of the lake. Waters originating from this depth result in a yearly maximum water temperature range of 42°F to 48°F at Lees Ferry.

At Lees Ferry, the mean concentration of suspended sediment ranges from 2 to 124 mg/l. At Phantom Ranch, approximately 87 river miles below Lees Ferry, and below several important tributaries (Paria River, Little Colorado River and Clear Creek), the turbidity ranges from 6 to 47,100 mg/l. The amount of turbidity of the river through the Grand Canyon is dependent upon the annual runoff into the Colorado River below Lees Ferry.

Historic virgin (pre-dam) flows have ranged from 4.4 to 21.9 million acre-feet annually. The 10-year mean virgin (pre-dam) flow has ranged from 11.6 to 18.8 million acre-feet annually. Opinions thus differ concerning the period of record that best predicts future runoff. The significance lies in the fact that a period of about 25 years (1906 1930) of predominantly above-average runoff has been followed by a 40 year period (1931 - 1970) of predominantly below-average runoff.

Article III of the Colorado River Compact requires that, "The States of the Upper Division will not cause the flow of the river at Lees Ferry to be depleted below an aggregate of 75 million acre-feet for any period of ten consecutive years." Current usage in the Upper Basin is projected by the Bureau of Reclamation to be 5.8 million acre-feet by the year 2000. Although the flow of the Colorado River through the Grand Canyon is assured by the Colorado River Compact, the daily and seasonal flows may fluctuate greatly as reservoir and energy commitments are met. A minimum flow of 3,000 cubic feet per second (cfs) is needed for whitewater boating.

Ten major dams are now located on the Colorado River system. Glen Canyon Dam and Hoover Dam have the most noticeable effect on the river in Grand Canyon National Park. Hoover Dam, forming Lake Mead, has

backed water to Mile 240 or for 37 miles into the park. This portion of the river has changed from a stream to a lake system.

Before Glen Canyon Dam, the flow at Lees Ferry varied from 700 cfs to 200,000 cfs. The average silt load was 500,000 tons per day at Phantom Ranch. The pre-dam river temperature varied from near freezing to 80°F. Its tributaries, the Paria River and the Little Colorado River, are the principal contributors of silt. Present flows through dam vary between 1,000 cfs to 32,000 cfs at Lees Ferry. The present silt load is about 80,000 tons per day, less than one-sixth the pre-dam load. The Colorado River flows at an average 4.5 miles per hour (mph) with velocities up to 30 mph in the rapids. The total descent of the river from Lees Ferry to the Grand Wash Cliffs is approximately 2,200 vertical feet or about 7 feet per mile.

2. Water Quality

In addition to the Colorado River, other major water sources in the canyon are the following springs or tributaries: Paria River (River Mile 0); Vasey's Paradise (River Mile 32); Little Colorado River (River Mile 61.8); Bright Angel Creek (River Mile 87); Shinumo Creek (River Mile 108); Royal Arch Creek (River Mile 116); Tapeats Creek (River Mile 134); Deer Creek (River Mile 136); Kanab Creek (River Mile 143); Havasu Creek (River Mile 157); Diamond Creek (River Mile 225); and Spencer Creek (River Mile 246). All of these water sources are easily accessible, and some are frequently used for drinking water by river runners and hikers.

The water quality of the Colorado River, its tributaries and associated springs and seeps, can be evaluated on the basis of five major criteria: (a) levels of contamination by total coliforms: (b) concentrations of specific trace elements; (c) total dissolved salt concentrations; (d) concentrations of biotic and abiotic parameters that could lead to hypereutrophication (nutrient enrichment and rapid growth of undesirable organisms); and (e) known levels of pollutants added by direct or indirect human contact.

The State of Arizona has established water quality standards for surface waters. The standards for the primary uses of full and partial body contact, domestic supply, cold and warm water fishery, aquatic life and wildlife uses are applicable to Grand Canyon National Park (see Table 9).

Recent investigations on the water quality in Grand Canyon National Park indicate that, in general, unpolluted conditions exist (Cole and Kubly, 1976; Czarnecki et al., 1976; Decon and Baker, 1976; and Sommerfeld et al., 1976). However, during certain periods of the year, during peak flood flows or at specific tributary sites, contaminants are in excess of U.S. Public Health Service (USPHS) standards for human drinking water. These potential problem areas and situations are discussed below under each of the major criteria used for evaluating the water quality of the system.

TABLE 9

SUMMARY OF ARIZONA WATER QUALITY CRITERIA FOR DESIGNATED USES

Standard	Full Body Contact	Partial Body Contact	Domestic & Industrial Water Supply	Cold Water Fishery	Warm Water Fishery	Agri—culture & Industry	Aquatic Life & Wildlife
FECAL COLIFOUMS (No. 1100 ml.)							
Geometric Mean	200	1000	1000	1000	1000	1000	1000
90% value (for 5 samples over 30 days)	400	2000	2000	2000	2000	2000	2000
Range	6.5—8.6	6.5—8.6	None	6.5—B.6	6.5—8.6	None	6.5—8.6
Maximum change	+0.5	+0.5	None	+0.5	+0.5	None	+0.5
TURBIDITY (JTU)							
Streams	Lowest practical value		None	10	50	None	Lowest practi—cable value
Lakes	Lowest practical value		None	10	25	None	Lowest practi-cal value
DISSOLVED OXYGEN *(mg/1)*							
Minimum	None	None	None	6.0	6.0	None	None
TEMPERATURE (0F)							
Maximum change	5°	5°	None	2°	5°	None	No temperature Interference
Maximum	93°	93°	None (winter) (summer)	55° 70°	93°	None	No temperature Interference
TOXICS *(mg/1)*							
Arsenic	0.050	0.050	0.050	0.050	0.050	None	0.050
Barium	1.000	1.000	0.100	0.500	0.500	None	0.500
Boron	None	None	None	None	None	1.000	None
Cadmium	0.010	0.010	0.010	0.010	0.010	None	0.010
Chromium (hexavalent)	0.050	0.050	0.050	0.050	0.050	None	0.050
Copper	1.000	1.000	0.100	0.050	0.050	None	0.050
Cyanide	0.200	0.200	0.200	0.100	0.100	None	0.100
Mercury	0.005	0.005	0.005	0.005	0.005	None	0.005
Lead	0.050	0.050	0.050	0.050	0.050	None	0.050
Phenol	0.001	0.001	0.001	0.001	0.001	None	0.001
Selenium	0.010	0.010	0.010	0.010	0.010	None	0.010
Silver	0.050	0.050	0.050	0.050	0.050	None	0.050
Zinc	5.000	5.000	5.000	0.500	0.500	None	0.500
RADIOACTIVITY (pCi/mg)							
Combined Radium 226 & 228	None	None	5	None	None	None	None
Gross alpha particle activity	None	None	15	None	None	None	None
Tritium	None	None	20,000	None	None	None	None
Strontium 90	None	None	8	None	None	None	None

a. Levels of Contamination by Total Coliform

U.S. Public Health Service standards for water for human consumption recommend that coliform levels not exceed 1 coliform (c) /100 ml. The desirable criteria set by the Federal Water Pollution Control Administration (U.S.D.I., 1968) for raw surface waters is less than 100/ c/100ml., and the permissable limit is 10,000 c/100ml. Both "desirable" and "permissible" waters can be used for human consumption if treated.

Total coliform concentration levels of the Colorado River and the 11 most popular tributaries and springs for four sampling periods in 1975 are presented on pages II-15 and 16.

The total coliforms found in the Colorado River and the tributaries and springs are extremely variable, ranging from nondetectable to more than 400 c/100ml.

Indications of pollution occasionally occur under special conditions.

- Paria River, Bright Angel, Shinumo, Havasu, and Diamond Creeks show occasional presence of pollution-indicator algal associations (Blinn et al., 1976).

- Potential health hazards may exist at some river campsites in the form of high total coliform counts, possibly due to seepage from porta-potty disposal (Deacon and Baker, 1976).

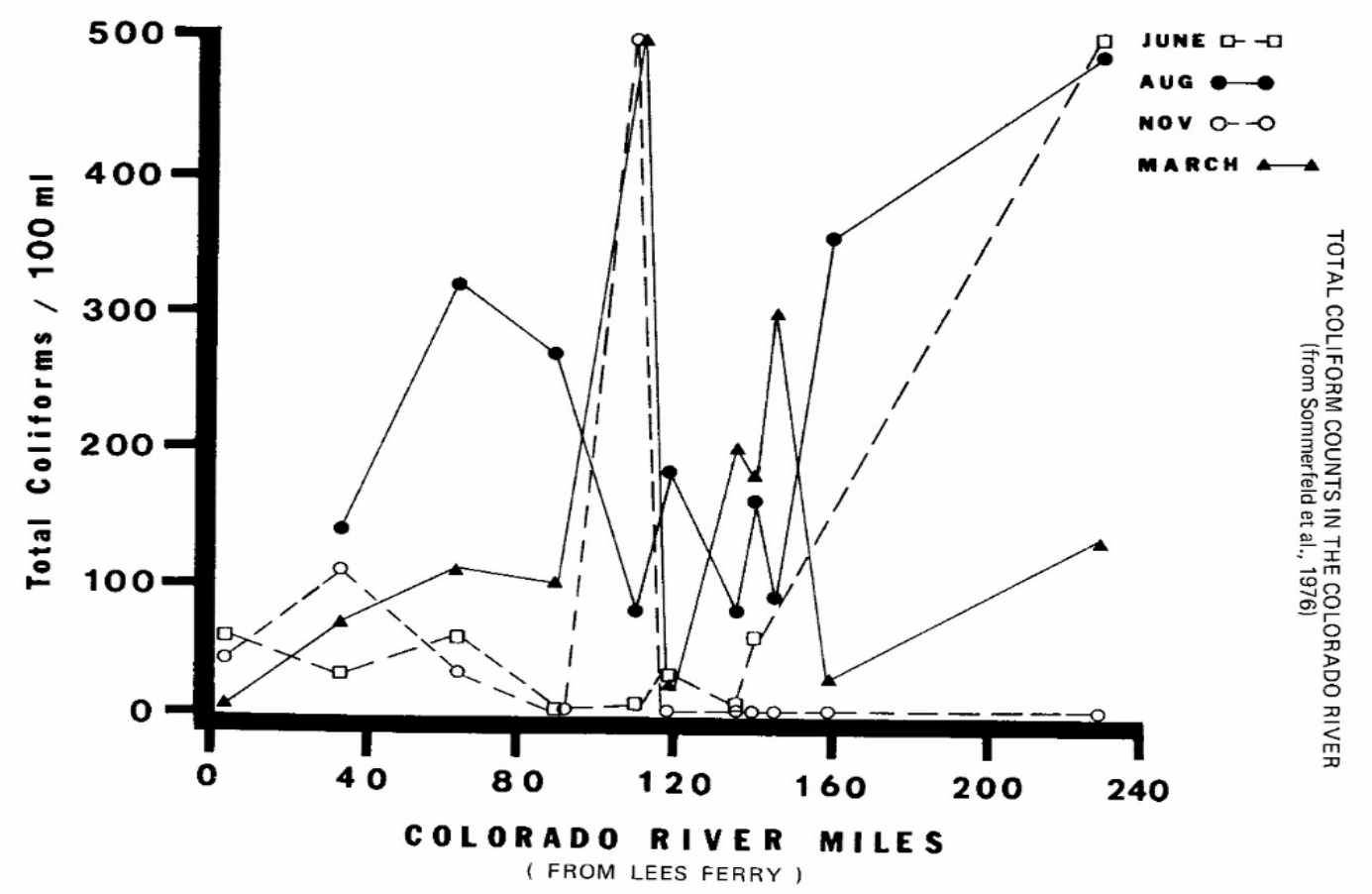
- Total viable coliform bacterial numbers exceeded desirable water quality standards at several river sampling sites and in most of the tributaries throughout the year (Sommerfeld et al., 1976).

- Heavily used tributaries generally had total coliform numbers that exceeded desirable water quality criteria (Sommerfeld et al., 1976).

No data are available on fecal coliforms within the Colorado River or its tributaries within the Grand Canyon. Therefore, it cannot be determined whether or not these waters are within Arizona water quality standards. From available data it does not appear that there are any significant problems with State standards relative to specific element concentrations within these waters.

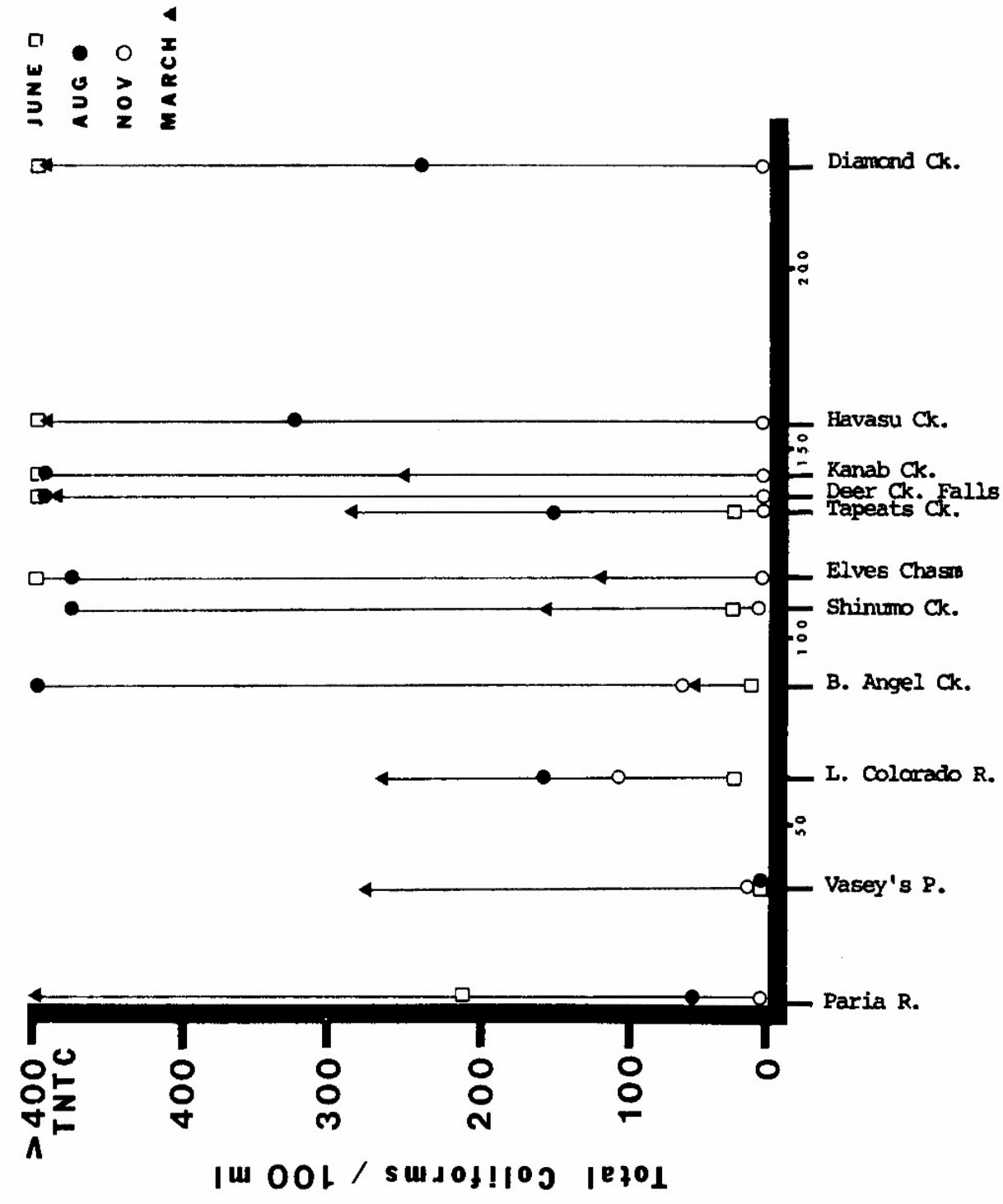
b. Concentrations of Specific Trace Elements

Natural surface waters contain dissolved minerals that reflect the type of substrata the waters have contacted and the duration of that contact. Streams may reflect the chemical characteristics of surface runoff, as well as ground water that enters the springs or seep.



TOTAL COLIFORM COUNTS IN THE COLORADO RIVER
(from Sommerfeld et al., 1976)

TOTAL COLIFORM COUNT IN THE TRIBUTARIES OF THE COLORADO RIVER
(from Sommerfeld et al., 1976)



Of fifteen elements surveyed, (boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, potassium, sodium, and zinc), only two, iron and manganese, were ever found to exceed recommended drinking water standards (EPA Water Quality Criteria, 1972). These elements were found in excess of the standards only in the Little Colorado River drainage during high and sustained floods. Neither iron nor manganese are known to be health hazards, particularly at these concentrations.

c. Total Dissolved Salt Concentration

The salinity of the Colorado River is in excess of present health standards (500 mg/liter) for sustained human consumption (US Public Health Service, 1962). The USPHS allows, however, a twofold increase in salinity for occasional consumption. The salinity levels found in the Colorado River range from 623 to 644 mg/liter, and thus fall within the criteria for occasional consumption. For the tributaries and springs, complete data are not available; however, it is known that the Little Colorado River is essentially a sodium chloride water. However, the normal, clear water flow of the Little Colorado River is insufficient to change the total salt concentration of the Colorado River.

d. Concentration of Biotic and Abiotic Parameters That Could Lead to Hypereutrophication

The Colorado River is rich in essential plant nutrients and has the potential to be a productive system (Cole and Kubly, 1976). Yet all the aquatic studies to date indicate that the entire system is relatively unproductive with low population densities of the primary producers (phytoplankton, etc.) (Sommerfeld et al., 1976). Reasons hypothesized for the low productivity are the low water temperatures and the high and variable degree of turbidity (Cole and Kubly, 1976; Deacon and Baker, 1976).

e. Known levels of Pollutants Added by Direct or Indirect Human Contact

Emissions from motorized watercraft on the Colorado River cause at least short-term water quality degradation. Oil and gasoline can be spilled into the Colorado River at Lees Ferry from boat servicing facilities. Ruptured gasoline tanks can also leak during motorized trips through the canyon. On the average, an estimated 20 to 35 percent of the fuel used in outboard motors is wasted in the exhaust. Laboratory studies of pollutants from outboard motor exhaust indicate that approximately 0.23 pounds of petroleum residue, as measured by non-volatile suspended solids, are wasted per gallon of fuel consumed. The turbulence caused by the propeller creates conditions ideal for dispersion of the waste material into the water.

It has been estimated that approximately 25,000 gallons of gasoline are used annually on the motorized trips. Therefore, approximately 5,750 pounds of petroleum residue are dumped in the Colorado River annually. However, even this amount when compared to the volume of water flow in the river has not been enough to be measurable.

A water quality monitoring program for the park is ongoing, to establish base data in reference to the Water Quality Standards for the State of Arizona. Details of this monitoring work are outlined in the Grand Canyon National Park, 208 Water Quality Project Plan of Action.

E. CLIMATE

The Grand Canyon has many climates depending primarily on the elevation. Average annual precipitation varies from more than 25 inches along the forested North Rim (9,000 feet) to less than 9 inches on the desert of the Inner Canyon (2,400 feet). About 16 inches per year fall on the South Rim (7,000 feet). The North Rim receives more precipitation in winter than in summer. The South Rim and the Inner Canyon receive about equal amounts during the two seasons. The spring and fall are relatively dry in all three areas. Summer precipitation is usually received from thunderstorms that form over the heated canyon almost every afternoon from early July until the end of August. Although these storms are capable of producing locally heavy downpours, they rarely last more than 30 minutes and usually cease completely shortly after sundown.

Winter precipitation varies greatly from year to year in both amount and frequency. It is associated with middle latitude storms moving eastward from the Pacific Ocean and normally falls in gentle to moderate showers which may persist for several days. However, severe storms with heavy snow and strong winds can strike. Most of the winter precipitation on the North and South Rims occurs as snow. Snowfall is a rarity in the Inner Canyon and averages less than 1 inch per year.

As a general rule, the temperature increases as one descends into the canyon. However, during the winter months there are short periods of temperature inversion when clouds fill the canyon and cold air drains into and is trapped within the canyon while the rims are being warmed by sunshine. Based on an elevation gradient of 4,800 feet and a dry adiabatic lapse rate of 5.4°F/1,000 feet, the average adiabatic temperature change between the rim and the river is approximately 26°F. The air in the canyon is considered to be conditionally stable in August and September; statically unstable in June and July and statically stable for the rest of the year. The hourly temperatures at the rim and the river approach each other to within a few degrees in the hour just preceding sunrise.

The data in table 10 summarizes the annual temperatures for the Grand Canyon area. In addition to the river canyon data, temperatures are also presented for the North and South Rim and the Desert View weather

TABLE 10
MEAN PRECIPITATION AND TEMPERATURE
GRAND CANYON NATIONAL PARK

Months	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MEAN MAXIMUM TEMPERATURES (°F)												
Inner Canyon	56	62	71	82	92	101	106	103	97	84	68	57
Tuweep 49	50	61	68	79	89	95	92	85	74	61	49	
Desert View	40	43	49	57	69	79	84	81	73	61	49	39
South Rim	41	45	51	60	70	81	84	82	76	65	52	43
North Rim	37	39	44	52	62	73	77	75	69	58	45	40
MEAN MONTHLY TEMPERATURES (°F)												
Inner Canyon	46	52	59	69	77	86	92	89	83	72	57	47
Tuweep	38	40	47	54	64	73	80	78	71	60	48	39
Desert View	30	33	38	44	56	65	71	69	61	50	39	30
South Rim	30	33	38	46	54	64	69	67	61	50	39	31
North Rim	26	28	34	40	48	56	62	60	54	45	35	30
MEAN MINIMUM TEMPERATURES (°F)												
Inner Canyon	36	42	48	56	63	72	78	75	69	58	46	37
Tuweep	26	30	34	40	49	58	65	63	56	46	35	29
Desert View	21	23	27	31	42	51	59	56	59	39	30	21
South Rim	18	21	25	32	39	47	54	53	47	36	27	20
North Rim	15	18	24	28	34	40	46	45	39	31	24	20
MEAN PRECIPITATION (Inches)												
Inner Canyon	.72	.73	.79	.48	.31	.28	.79	1.31	.88	.69	.51	.82
Tuweep	1.10	.90	1.25	.73	.40	.40	1.28	1.97	.79	.80	.77	1.31
Desert View	1.00	.94	1.52	.75	.50	.32	1.29	1.34	.99	1.39	.80	1.72
South Rim	1.32	1.53	1.37	.92	.65	.46	1.87	2.28	1.50	1.21	.95	1.61
North Rim	3.28	3.17	3.12	1.67	.97	.76	1.86	2.53	1.81	1.50	1.44	2.62

stations. Comparison of this data dramatically demonstrates the marked differences in temperatures from rim to river.

F. AIR QUALITY

Natural dust particles, water vapor, chemicals given off by growing plants, and the refraction of light all combine to form a haze which is a natural part of the Grand Canyon environment. The predominant wind direction above the rims is from the southwest. Below the rims, there is little large-scale horizontal air movement; the deep, narrow configuration of the canyon forms a relatively closed air system of over 5,000

Available information indicates that dustfall and sulfation rates, as well as the levels of sulphur dioxide, nitrogen oxides, lead, benzene, organics, and total oxidants are all low to very low (see Table 11).

Because of its almost pristine purity, the air in Grand Canyon can be degraded by introducing pollutant levels which would be considered negligible in metropolitan areas. Visible ranges often exceed 190 kilometers (118 miles) in the exceptionally clean atmosphere above the canyon. Very small increases in atmospheric pollutants can significantly decrease visibility through air of this clarity and thus degrade the esthetic values of the park. Because of this, the area has been established as a Class I area under Public Law 95-95, the Clean Air Act Amendment of 1977. Air visibility measurements are being taken to monitor any changes relative to current visibility.

The air moves primarily up and down canyon at very low velocities, making the potential for removal of air pollutants very low. Most of the higher wind velocities encountered in the canyon are not due to the exchange of canyon air with air above the rims, but rather the movement of a limited volume of local air back and forth within the canyon. The slow circulation of air and low dispersive capabilities increase toward the level of the Colorado River. Each night within the canyon inversion layers or stable environmental lapse rates increase the stagnation of air circulation.

G. NOISE

A sound survey made on Labor Day in 1971 at points along the South Rim, by Dr. Charles H. Black of Northern Arizona University, reported that the drone of aircraft engines could be heard almost continuously. The aircraft were a mixture of fixed-wing and helicopter tour planes, private planes, military aircraft, and high altitude commercial craft. Automobile noises were the most pervasive at overlooks and within Grand Canyon Village.

Black found that in general the ambient noise levels ranged from about 45 to 50 decibels (dBA) in remote backcountry areas, to around 70 dBA in late afternoon on the front steps of the El Tovar Hotel.

TABLE 11 -- AIR QUALITY DATA AVAILABLE GRAND CANYON VILLAGE AND VICINITY
1962 —— 1972

Pollutant	Grand Canyon EPA Mean	Annual Phoenix Mean	Grand Canyon Waither 's Data	EPA Standard—1[1]	EPA Standard—2[2]	Arizona Standard
Total particulates	34 (n = 56)	108—265	18	75[3]	60[3]	60[3]
Dustf all ug/cm^2/day	-	11.5	5.3	-	-	-
Sulphur Dioxide ug/m^3	10	calO	calO	80[4]	-	50[4]
Sulfation rate ug/cm^2/day	-	1.75	0.38	-	-	-
Nitrogen Dioxide ug/m	21 (n—58)	168	22	100[4]	100[4]	100[4]
Total oxidants ug/m^3	-	17.5	10.4	160[5]	160[5]	80[5]
*Lead ug/m^3	0.15	3.12	-	-	-	-
Benzene soluble organics ug/m^3	1.0	-	-	-	-	-
Benzopyrene ug/m^3	0.11	-	-	-	-	-

* 1969 data. n = number of data points
1. Level of pollutant which, if exceeded, endangers "public health"
2. Level of pollutant which, if exceeded, endangers "public welfare"
3. Annual geometric mean
4. Annual arithmetic mean
5. Maximum 1—hour concentration

While the sounds from motor vehicles and aircraft are the most disruptive along roadways, at overlooks and in the developed areas of the park, the sounds from aircraft and outboard motors are the most disruptive in backcountry and river areas. Outboard motor noise was studied in 1973 by Drs. D. N. Thompson, A. J. Rogers, Jr., and F. Y. Borden of the University of Pennsylvania. They found that sound pressure and levels of the motors, measured at head level in the boatman's station, ranged from 83 to 89 dBA, compared with background levels of 35 to 45 dBA. This borders on, but does not exceed, present health standards, although it can cause significant shifts in the hearing threshold. In the presence of motor noise, natural environmental sounds or the almost unnatural lack of sound in the canyon can rarely be sensed by river runners. The study concluded that outboard motor noise was a deterrent to normal, relaxed conversations that one should expect in such an environment, a safety hazard in motorized raft operation, and a potential health hazard to boatmen.

H. VEGETATION

Along both banks of the Colorado River exists a dynamic riparian (streamside) community. The riparian habitat includes all the vegetation from the river's edge, outward toward the canyon walls. Riparian vegetation may be defined as "those species of plants which are there only because of the presence of the river." Glen Canyon and Hoover Dams have strikingly influenced the structure and integrity of this habitat in Grand Canyon.

Prior to the construction of Glen Canyon Dam, the Colorado River was a silt-laden river, warm in summer and cold in winter; the river's flow could fluctuate anywhere from almost no flow during dry summers to an excess of 200,000 cfs during spring floods (Fenneman, 1931). Now the river, as it originates from the bottom of Lake Powell, is clear and perpetually cold (42-48°F) and diurnally tidal, as water releases are based on power demands; rarely does the flow fluctuate outside a range from 1,000 cfs to 32,000 cfs. As a result, the natural biotic system of portions of the riparian zone has been severely altered and subsequently replaced by a new, "exotic" system.

Prior to and during the construction of Glen Canyon Dam, numerous studies were undertaken to provide a data base and to determine what resources would be lost by the inundation of Glen Canyon (Woodbury et al., 1959). Unfortunately, there were no studies undertaken on what changes would occur in Grand Canyon. By using data gathered during a brief pre-dam botanical study of the river environs (Clover and Jotter, 1944) and through analysis of pre-dam habitat photographs, Karpiscak (1976) has been able to reconstruct what was present along the banks of the Colorado River prior to the influence of the dam (Carothers et al., 1977)

1. Pre-Dam Riparian Vegetation

Before the dams, there existed three distinct zones of vegetation which paralleled the river from Lees Ferry to the Grand Wash Cliffs (see illustration, page II-25). The zone closest to the river (Zone 3), and hence subjected to annual flooding, was composed partially of many ephemeral herbaceous species that were adapted to periodic disturbance, and partially of some mesophytic woody plants such as seep willow and desert broom (Baccharis spp.), and the true willows (Salix spp.), that would make a futile attempt to become established before the next scouring flood. Above the ephemeral zone was a belt of vegetation whose lower boundaries were delineated by the high water line of major floods which would periodically scour away all vegetation growing below the zone. Typical plant species of this high water line zone (Zone 2) were Apache plume (Fallugia paradoxa), redbud (Cercis occidentalis), hackberry (Celtis reticulata), honey mesquite (Prosopis juliflora), and acacia (Acacia greggii). On the talus slopes (Zone 1) above this zone lived desert species that were not influenced by the river environment below; e.g., brittle bush, Encelia farinosa; various cacti, creosote bush (Larrea tridentata), Mormon tea, (Ephedra trifurca spp.).

2. Post-Dam Vegetation

The construction of Hoover Dam inundated the two lower vegetational zones and much of the desert vegetation of the upper zone upstream from the dam to River Mile 240. Within a few years, however, a new zone consisting almost exclusively of saltcedar (Tamarix chinensis) appeared at the edge of Lake Mead.

The significant reduction in high flood waters in the Colorado River below Glen Canyon Dam has permitted the development of a new riparian community that extends from Lees Ferry (River Mile 0) to the backwaters of Lake Mead (River Mile 240). This rapidly proliferating community (Zone 4) is composed of saltcedar (Tamarix), arrowweed (Pluchea sericca), coyote willow (Salix exigua), four species of baccharis, and hundreds of species of herbaceous plants. In most areas, this new community occupies all of the former ephemeral zone (Pre-dam Zone 3), while in other locations, particularly where the bedrock has always been close to the river, there are no discernible changes between the pre- and post-dam vegetational patterns. Above the new riparian community and below the high water line community is now found another distinct zone (Zone 3) of ephemeral plants; red brome (Bromus rubens), tansy mustard (Descurainia pinnata), fescue (Festuca spp.), and the composite Chaenactis fremontii, to mention only a few. Two exotic species, Russian thistle (Salsola kali) and camelthorn (Alhagi camelorum) also proliferate in this zone. The majority of campable beaches are within this zone and many of the species typical of this zone are indicators of disturbed areas.

Preliminary investigations indicate that the woody vegetation particularly Apache plume, redbud, hackberry, and mesquite of Zone 2 is beginning to

die back. Although the high water floods of pre-dam days only rarely reached the lower limit of this zone, it may have been of sufficient frequency to provide nourishment. The high water flows now never approach the lower limits of this community, and each year more and more of the plants appear to be dying.

The vegetation in Zone 1 remains unaffected by the changes in flow of the river. This zone is characterized by hackberry trees, brittle bush, Mormon tea, yucca, century plant, blackbrush, various cactus and many grasses and forbs in the upper canyon. The vegetation expression of this zone changes in the lower canyon largely due to the drop in elevation to creosote bush, ocotillo cactus, large barrel cactus, but still includes blackbrush, brittle brush, Mormon tea, and a variety of grasses and forbs.

3. Vegetational and Topographic Habitats

Within the inner gorge, six topographical and eight vegetational habitat types have been delineated as follows:

Rocky Outcroppings, Cliff Faces, and Upper Talus Slopes: These areas generally provide as nesting areas the minimum of essentials for the survival of many animals.

Lower Talus Slopes and Bench: This type exists above the historic floodline, and can be divided into talus and bench as separate entities. Erosion of upper areas provides sufficient soil for sparse plant growth, which is limited by the lack of enduring moisture within the root zone.

Upper Terraces: Commonly called "benches," these pre-dam fluvial deposits just below the old high water line are no longer eroding due to the absence of flooding. They provide one of the most fertile habitats in the canyon. These areas show high incidence of invasion by native and exotic plant species.

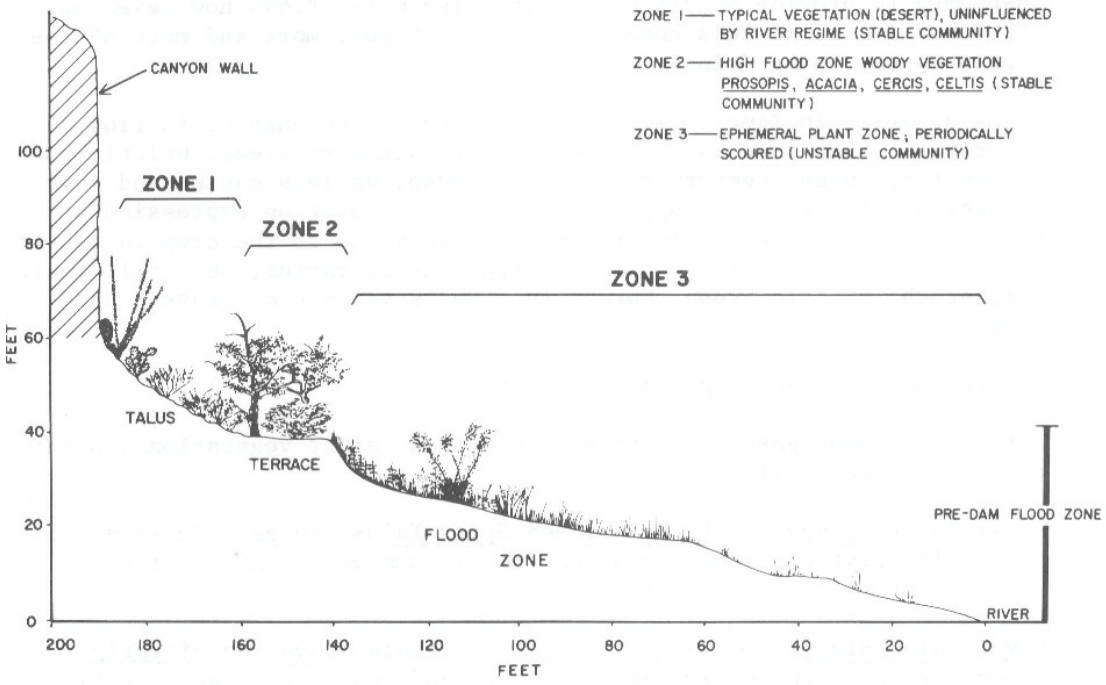
Lower Terraces: Fluvial deposits formed prior to the construction of Glen Canyon Dam are now eroding because of the reduced sediment load of the river. This may cause a stabilized condition where marsh species will increase. These post-dam areas increase the size of the cattail marsh habitat and are the sole nesting sites for some riparian animals of the canyon.

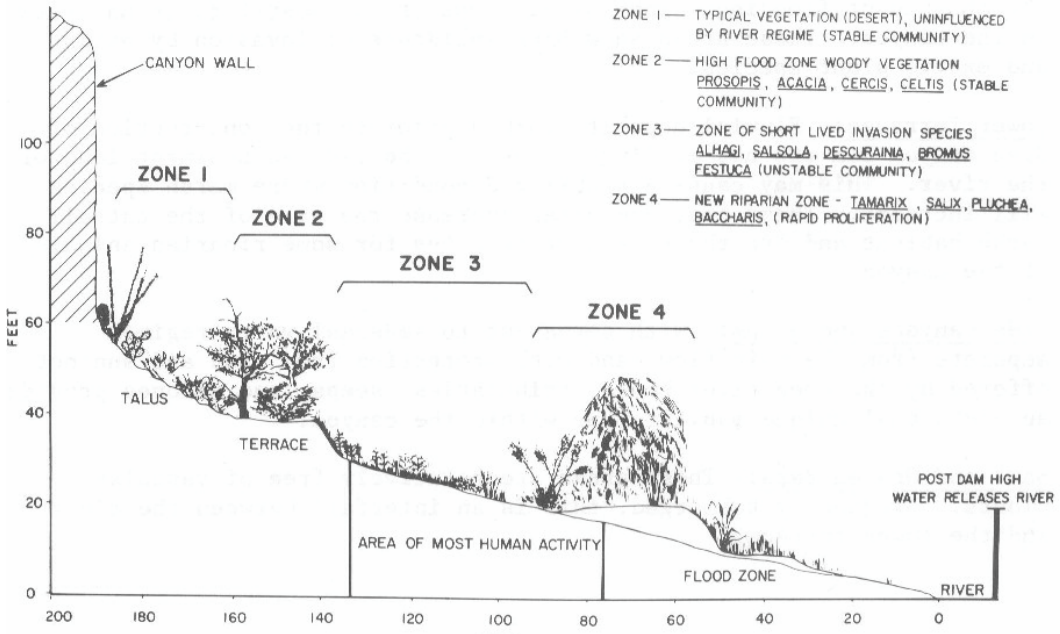
Side Canyons and Seeps: With permanent to seasonal water regimes separate from the main flow, and with protection from wind and sun not offered by the open river banks, tributaries, seeps, and alcoves provide an additional unique habitat type within the canyon.

Sand and Gravel Bars: These areas are relatively free of vascular plants. Frequently submerged, this is an interfall between the river and the lower terraces.

PRE-DAM AND POST-DAM RIPARIAN VEGETATION

(from Carothers et al., 1976)





The vegetational habitats which may be found in association with the topographical habitat types are as follows:

Sparse Vegetation: This type is characterized by rock outcroppings, cliff faces, upper talus, and sand and gravel bars.

Decidious Forest: Found in side canyons, seeps and upper and lower terraces. Characterized by mature cottonwood (Populus fremontii), box elder (Acer negundo), willow and redbud. Dense to sparse ground cover occurs as an herbaceous understory.

Evergreen Scrub: Found in side canyons, seeps, lower terraces, and upper terraces characterized by arrowweed, seep willow (Baccharis spp.), with immature willow and saltcedar often in dense stands.

Deciduous Scrubs: Found in upper terraces and lower talus slopes and benches with acacia, mesquite, Apache plume, and closed ground cover.

Deciduous Dwarf Scrubs: Found in upper talus, lower talus, and benches, with brittle brush, Mormon tea, cheat grass (Bromus tectorum), and the composite Chaenactis.

Seasonal Marsh: Often found in a transition between the river and lower terrace includes scarlet monkeyflower (Mimulus spp.), cattail (Typha spp.), and horsetail rush (Equisetum spp.).

Evergreen Savanna: Found in upper talus slopes, lower talus slopes, and benches characterized by yucca (Yucca spp.), agave (Agave spp.), cholla (Opuntia spp.), barrel cactus (Ferocactus); sparse to moderate ground cover.

Desert Scrub: Found in upper talus slopes, lower talus slopes, and benches, are creosote bush, bur-sage (Franseria spp.), blackbush (Coleogyne ramosissma), and ocotillo (Fouquieria splendens) are found here along with a sparse ground cover (Carothers et al., 1976).

A complete catalogue of the plant species known to occur within the inner gorge includes 807 species of vascular plants representing 92 families. A number of species, such as saltcedar, camelthorn and Russian thistle have been introduced from the eastern hemisphere and are termed exotics. Others are endemic, (known only from the area) such as Schribner's needle grass (Stipa scribneri) and bittercress (Cardamine parviflora). Most representative species are of wide geographic distribution and are plants common to the upper and lower Sonoran life zones and their related riparian communities (Carothers and Aitchison, 1976).

4. Ecologically Sensitive Areas

Ecologically sensitive areas within the river corridor can be defined as "areas with high density and/or diversity of plant and animal life

and/or areas that provide a unique element required for the reproduction and survival of indigenous plant and/or animal populations." Ecologically sensitive areas that have been identified to date are presented in Table 12. They represent biotic resources that are unique to the Grand Canyon riparian system. (Also, refer to map, pages 1-4 through I-6.)

I. WILDLIFE

1. Amphibians and Reptiles

Amphibians are not well represented in the Inner Canyon. The arid surface conditions that almost exclusively pervade the entire area, preclude high densities and wide distributions. The amphibians that are present demonstrate a high degree of specialization for desert environments.

Reptiles, especially lizards, appear to flourish in the riparian habitats of the Grand Canyon. The abundance of saltcedar seems to benefit the populations of such species as the desert spiny lizard (Sceloporus magister), western whiptail (Cnemidophorus tigris), and western rattlesnake (Crotalus viridis).

Common reptiles and amphibians known from the immediate river environs are:

Red-spotted toad	Bufo punctatus
Woodhouse's toad	Bufo woodhousei
Chuckwalla	Sauromalus obesus
Desert spiny lizard	Sceloporus magister
Side-blotched lizard	Uta stansburiana
Western whiptail	Cnemidophorus tigris
Gopher snake	Pituophis melanoleucus
Common kingsnake	Lampropeltis getulus
(Grand Canyon) Western rattlesnake	Crotalus viridis abyssus

(after Carothers and Aitchison, 1976, Suttkus et al., 1976)

2. Birds

Approximately 284 species of birds have been recorded in the Grand Canyon region (Brown, et al., 1978), an area encompassing not only Colorado River and its riparian habitat, but also the wide variety

TABLE 12
ECOLOGICALLY SENSITIVE AREAS ALONG THE COLORADO RIVER

Name	Mile	Side of River or Location
House Rock Marsh	17.5	South
Stantons Cave	31.8	North
Vasey's Paradise	31.9	North
Buck Farm Canyon	40.8	North
Spring Canyon	41.2	North
43-Mile	43.2	South
Saddle Canyon	47.5	North
Nankoweap	52.0 - 53.0	North
Kwagunt Canyon	56.0	North
Little Colorado River	61.5	South
Hopi Salt Mines	52 - 64	South
Furnace Flats	65.6	South
Cardenas Marsh	71.0	South
Red Canyon	46.6	South
Clear Creek	84.0	North
Phantom Ranch	87.5	North
Garden Creek	89.0	South
Monument Creek	93.5	South
Hermit Creek	95.0	South
Boucher Creek	96.5	South
Shinumo Creek	108.8	North
Elves Chasm-Royal Arch Creek	116.5	South
Blacktail 122 Mile Creek	122.0	North
Stone Creek	132.0	North
Tapeats Creek Thunder River (Mi. Tapeats and Thunder River Caves)	133.7	North
Deer Creek	136.2	North
Kanab Creek	143.5	North
Matkatamiba	147.9	South
Havasu Canyon	156.8	South
National Canyon	166.5	South
Fern Glenn	168.0	North
Mohawk Canyon	171.5	South
Lava Falls	179.5	South
185-Mile	185.5	North
Granite Park	208.6	South
Juniper Seep	215.0	North
Three Springs Canyon	216.0	South
Surprise Canyon	248.4	South
Maxson Canyon	252.4	South
Burnt Canyon	259.3	North
Spencer Canyon	246.0	South
Emery Falls	274.4	South
Rampart Cave	275.0	South
Grapevine Wash	279.0	South

(Taken from Carothers and Aitchison, 1976)

habitat types found throughout the Grand Canyon area. The riparian habitat of the Inner Canyon contains its distinct assemblage of breeding birds, yet during the non-breeding or migratory season, the riparian areas are frequented by birds that breed in all Grand Canyon habitats and some that breed elsewhere throughout the United States and Canada. The riparian habitat of the Inner Canyon provides a natural corridor for migratory movements of birds on their way to or from breeding grounds.

The very depth and size of the entire Grand Canyon system provide for striking climatic differences between canyon bottom and canyon rim. Generally, the spring and fall weather along the Colorado River is much more hospitable than that of either rim. The deciduous riparian vegetation enjoys a longer growing season providing insects with a longer period of food, which in turn provides a predictable food source for some migrating birds.

A total of 41 species are known to breed within the river corridor. Of these, 27 species utilize the riparian vegetation as nesting habitat. The remaining 14 species nest in association with the surrounding desert scrub, the vertical cliffs or the loose talus slopes of the inner gorge.

The riparian vegetation is preferred by 74 percent of the total population of breeding birds in the inner gorge; only two bird species are permanent residents. Thus, it may be generalized that the summer resident species of the Inner Canyon are almost exclusively restricted to the narrow belt of riparian vegetation along the river, while the permanent residents are restricted to or prefer the desert scrub, talus or vertical steep cliffs adjacent to the riparian habitat. The species most dramatically affected by the new stabilized vegetative community are: Willow flycatcher (Empidonax traillii), Bell's Vireo (Vireo bellii), yellow warbler (Dendroica petechia), common yellowthroat (Geothlypis trichas), yellow-breasted chat, (Icteria virens), northern oriole (Icterus galbula), brown-headed cowbird (Molothrus ater), and blue grosbeak (Guiraca caerulea). These species account for about 14 percent of the total breeding bird population along the Colorado River. They will continue to increase in density as long as the vegetation below the old high waterline continues to proliferate. They probably did not occur with significant frequencies along the river during the pre-dam era. Other species that are equally dependent upon this green vegetation such as the lazuli bunting (Passerina amoena) and indigo bunting (Passerina cyanea) might be expected to begin utilizing this vegetation along the banks of the river as well as the heavily vegetated tributaries in which they are now found (Carothers et al., 1976).

The most common breeding bird of the river corridor is the Lucy's warbler (Vermivora luciae) accounting for almost 20 percent of the total population of breeding birds. The house finch (Carpodacus mexicanus) is the second most common species (15 percent) followed by the canyon wren (Catherpes mexicanus) (11 percent) whose distinctive song is commonly heard by river runners. See Appendix E for a summary of breeding bird

species known to occur in the river corridor, their preferred habitats and relative densities.

The exotic house sparrow (Passer domesticus) and common starling (Sturnus vulgaris) breed in the Inner Canyon but almost always in association with human habitation, e.g., Phantom Ranch, Indian Gardens and Havasu Village. Recent exception to this restricted distribution was the occurrence of a breeding pair of house sparrows at Deer Creek Falls Campground, River Mile 136. This campsite is one of the most heavily used areas by river runners (Carothers et al., 1976).

3. Mammals

Within the riparian zone of the Colorado River approximately 22 species of terrestrial mammals and 18 species of bats are known to occur. The most common mammals are the rodents, with 13 species inhabiting the riparian, semi-riparian or desert habitats. On the beach and terrace habitats rodents are the most common mammals, comprising an average density of about 20 individuals per acre (Carothers and Aitchison, 1976). The bats have been little studied, and are present in very high densities, utilizing rock cliffs for roosting sites, the river for drinking, and the insects associated with the riparian habitat for food. Carnivorous mammals; i.e., bobcats (Lynx rufus), coyotes (Canis latrans), foxes (Urocyon spp.), and mountain lions (Felis concolor) are uniform in distribution, but extremely rare. Spotted skunks (Spilogale putorius) ringtails (Bassariscus astutus), and rock squirrels (Spermophilus variegatus) are common scavengers throughout the canyon but especially concentrated in popular camping areas. The rock squirrels have reached such high population densities in some campgrounds; e.g., Indian Gardens, that they have become pests, robbing food from backpackers and destroying camping gear. The larger mammals are represented by the mule deer (Odocoileus hemionus) and the bighorn sheep (Ovis canadensis).

The most conspicuous exotic animal within the Inner Canyon is the feral ass or wild burro (Equus asinus). This animal was introduced into the canyon area during the late 1800's by early explorers and prospectors. When the mineral exploration subsided and national park status precluded further mineral exploitation in the canyon, the animals were released. Since 1923, resource managers have attempted to reduce or eliminate the feral burro from the Grand Canyon, but direct reduction was halted in the late 1960's. The impact inflicted on the native ecosystem by this feral equine has been determined to be extensive (Carothers et al., 1976). Feral horses (Equus caballus), owned by Havasupai Indians, are known to occur in central Grand Canyon. They are not found along the Colorado River corridor.

See Appendix F for a summary of the mammals known to occur in the river corridor, their preferred habitats and relative abundance.

4. Fishes

The Colorado River has only a few native fish species. Because of the post-dam changes in the river environment, the Colorado River squawfish (Ptychocheilus lucius) and the humpback chub (Gila spp.) may possibly be nearing extinction. These native fish depended on the seasonal fluctuation of water temperatures to breed; cold, stabilized temperatures now limits breeding to warm side streams.

Known fish species of the Colorado River in Grand Canyon and its tributaries are:

Native Species

Flannel mouth sucker	Catostomus latipinnis
Bluehead sucker	Pantosteus discobolus
Bonytail chub	Gila elegans
Humpback chub	Gila cypha
Colorado squawfish	Ptychocheilus lucius
Speckled dace	Rhinichthys osculus

Exotic Species

Threadfin shad	Dorosoma petenense
Rainbow trout	Salmo gairdneri
Brown trout	Salmo trutta
Cutthroat trout	Salmo clarki
Eastern brook trout	Salvelinus fontinalis
Coho salmon	Oncorhynchus kisutch
Carp	Cyprinus carpio
Fathead minnow	Pimephales promelas
Red shiner	Notropis lutrensis
Channel catfish	Ictalurus punctatus
Black bullhead	Ictalurus melas
Rio Grande killifish	Fundulus zebrinus
Green sunfish	Lepomis cyanellus
Large mouth bass	Micropterus salmoides
Bluegill	Lepomis machrochirus
Golden shiner	Notemigonus crysoleucas
Mosquito fish	Gambusia affinis

(after Suttkus et al., 1976)

Carp and various chubs, shiners, minnows, bullheads, bass, and other fish have been introduced to the Colorado River in varying quantities. Rainbow, brook, and brown trout have been introduced into Bright Angel, Clear, Shinumo, Garden, and Tapeats Creeks. Plantings have been made as recently as 1967 in cooperation with the Arizona Game and Fish Department. Earlier efforts to establish trout in Havasu Creek were not successful.

Stocking still occurs at Lees Ferry, Arizona, where five to seven inch rainbow trout are planted from one to two times a year. Lees Ferry is less than 1 mile from the park boundary on the Colorado River. Trout are known to migrate along the length of the Colorado River in the park. Being carnivorous, they place pressure on the young of the endangered native species, but the impact of this factor is not known at this time.

Stocking has also occurred and will continue at Lake Mead. Coho salmon (Oncorhynchus kisutch), rainbow trout, striped bass (Morone saxitilis), and walleye (Stizostedion vitreum) ilave been stocked since 1968. Coho salmon, rainbow trout, smallmouth bass (Micropterus dolomjeui), walleye, and striped bass all move from the lake into the lower park, and as the river continues to alter from the pre-dam system, they will probably increase in abundance. There is no quantative data on fish densities in

5. Insects

Canyon habitats support a great diversity of both aquatic and terrestrial insect species. To date more than 260 families of insects have been recorded along the river corridor and tributaries.

The post-Glen Canyon Dam cold waters of the Colorado River have prevented an influx of aquatic species in the usually clear-running mainstream. Thus far, only two families of Diptera (Simuliidae and Cnironomidae) are commonly found in the main channel. The aquatic Hemiptera and Coleoptera which are occasionally found along the banks of the river may best be considered litoral, as are several dipteran families. Tributaries provide most of the habitat for aquatic species in the Inner Canyon but differences between tributaries are great. Ion concentrations, pH, water temperature, turbidity, water flow, isolation, elevation, and tributary location within Grand Canyon all affect aquatic insect populations, and as yet insufficient data have been gathered to present a composite description of the distribution of insect species.

Terrestrial species are concentrated in the riparian vegetation between Zone 2 and the river, with a great deal of activity in the recently stabilized Zone 4. The population dynamics of some insect species in Zones 3 and 4 appear to be changing irregularly, apparently in adjustment to the post-dam invasion of plant species. Climax balance or regularity in population fluctuations remains to be shown for certain species of Orthoptera, llemiptera, Coleoptera, Neuroptera, Lepidoptera, and Diptera. Climax balance of these species of insects is apparently closely related to exotic plant species such as saltcedar and camelthorn which are undoubtedly undergoing a gradual incorporation into the overall community. Lately, certain Acrididae (most notably Schistocera shoshoni), Cicadellidae and Buprestidae species have expanded their use of saltcedar.

Formicid species (Pogonomyrmex spp.) and various dipteran species are among the more commonly encountered insects in beach areas, their

concentrations being related in part to human use. While bothersome, they do not pose a significant health hazard.

Almost no information exists on the population levels of poisonous arthropods other than insects, though two families of Scorpionida and black widow spiders (Latrodectus spp.) are quite common in Zones 1 through 3 throughout the canyon.

Diversities and densities of insects in the xeric Zone 1 are lower and probably more stable than those in the riparian zones.

The obsolete viceroy (Limenitis archippus obsoletus) found in Grand Canyon is being considered for inclusion on the list of endangered species. The monitoring program will continue to evaluate its status. (Carothers et al., 1976; Cole and Kubly, 1976).

J. RARE, ENDANGERED, AND THREATENED SPECIES

Along the river corridor, the bald eagle (Haliaeetus leucocephalus), the American peregrine falcon (Falco peregrinus anatum), brown pelican (Pelecanus occidentalis), the humpback chub (Gila spp.) and the Colorado River squawfish (Ptychocheilus lucius) are on the list of endangered fauna, maintained by the Secretary of the Interior.

The status of the three endangered bird species in the national park has recently been reviewed (Carothers and Johnson, 1975). Peregrine falcons are permanent residents of the canyon, although few in numbers. They utilize the river corridor for hunting, primarily preying on waterfowl and swifts. The other two are either transient (bald eagle) or accidental (pelican).

The endangered fish species are "endangered" because of the drastic changes in their habitat that have taken place since the impoundment Lake Powell by Glen Canyon Dam. These changes include the increases non-native fish populations, which are believed to be competing with native fishes for necessary resources (Minckley and Blinn, 1976). The Colorado River squawfish may, in fact, already be extinct in Grand Canyon, as none were encountered during exhaustive searches in 1974, 1975, 1976, 1977, and 1978. The humpback chub is now restricted in distribution to the mouth of the Little Colorado River.

The spotted owl (Strix occidentalis) and the prairie falcon (Falco mexicanus), known occupants or visitors to the river corridor, were considered "threatened" species by the U.S. Fish and Wildlife Service in the 1973 edition of "Threatened Wildlife of the United States." They have not, however, been recorded as threatened species in the official Fish and Wildlife Service list of "Endangered and Threatened Wildlife and Plants," Federal Register, July 14, 1977.

The prairie falcon is an occasional resident of the Grand Canyon area and its numbers in the park seem to be declining in keeping with the national trend (Carothers and Johnson, 1975).

Several other species exist along the Colorado River in Grand Canyon whose status in Arizona may be in jeopardy in the near future (Arizona Game and Fish Department, 1976). These include the following:

Desert bighorn sheep	(Ovis canadensis)
Snowy egret	(Egretta thula brewsteri)
Black-crowned night heron	(Nycticorax nycticorax hoactli)
Osprey	(Pandion haliaetus carolinensis)
Bonytail chub	(Gila elegans)
Desert tortoise	(Gopherus agassizi)
Gila monster	(Heloderma suspectum)

It is believed that river otter (Lutra canadensis) at one time frequented the Colorado River in Grand Canyon. However, there have been no sitings of this animal in the Grand Canyon for many years.

The fish and reptile species listed above, encountered during the research projects, are susceptible to disturbances initiated by increased human use of the riparian zone. The National Park Service and the U.S. Fish and Wildlife Service have jointly recommended the bonytail chub for endangered status and the razorback or humpback sucker for threatened status under the Endangered Species Act of 1973.

2. Plants

A number of endangered or threatened species of plants are known from Grand Canyon National Park. Species endemic to the area or species much diminished in range or habitat and listed as Endangered in House Document 94-51, "Report on Endangered and Threatened Plant Species of the United States," are:

Goldenweed	Haplopappus salicinus
Draba	Draba asprella var. kaibensis
Plains cactus	Pediocactus bradyi
Scouler catchfly	Silene rectiramea
Milkvetch	Astragalus cremnophylax
Phacelia	Phacelia filiformis
Wild buckwheat	Eriogonum darrovii
Wild buckwheat	Eriogonum zionis var. atwoodi
Wild buckwheat	Eriogonum zionis var. coccineum
Primrose	Primula hunnewellii
Mustard	Sisymbrium kearneyi

The following plants in Grand Canyon National Park are recommended for consideration as a threatened species in House Document 94-51:

Paint-brush	Castilleja kaibabensis
Prickle-poppy	Argemone arizonica
Crossosoma	Crossosoma parviflorum
Beavertail cactus	Opuntia basilaris var. longeareolata
Fleabane	Erigeron lobatus
Goldenweed	Haplopappus subintegra
Actinea	Hymenoxys subintegra
Draba	Draba asprella var. stelligera
Phacelia	Phacelia serrata
Agave	Agave utahensis var. kaibabensis
Flowering ash	Fraxinus cuspidata var. macropetala
Milkvetch	Astralagus troglodytus
Primrose	Primula specuicola
Wild buckwheat	Eriogonum densum
Wild buckwheat	Eriogonum ovalifolium var. vineum
Columbine	Aquilegi desertorum
Wild rose	Rosa stellata
Palmer amsonia	Amsonia palmeri
Clematis	Clematis hirsutissima var. arizonica
Cymopterus	Cymopterus newberryi
Encelia	Encelia frutescens var. resinosa
Nama	Nama retrorsum
Scurf-pea	Psoralea epipsila

Very little is known regarding the distribution and abundance of the endangered and threatened species of plants in Grand Canyon National Park. The bulk of the available information has come from recent ecological studies performed throughout the river corridor (Carothers and Aitchison, eds., 1976). Although more complete information on these species and their critical habitat is not available, it is possible that human interference in the form of river recreation is not significantly adversely effecting the survival of these plants.

K. THE CULTURAL RESOURCES

1. Archeology

Archeological resources in Grand Canyon constitute a primary scientific and historic value. The more than 1,200 known Indian ruins within the national park indicate and represent the adaptation of man to his environment over the past 4,000 years in the Grand Canyon region. The initial occupation of the canyon began about 4,000 years ago, and is represented by the Grand Canyon Split-Twig Figurine Complex occupation of dry caves. These deposits contain split-twig figurines which are found only in a few other locations in the southwest. An apparent lull in human occupation followed, with primary occupation in the canyon occurring between

A.D. 700 and 1200. During this time, Anasazi to the north and east, and Cohonina to the south and west, used the plateaus for their agriculturally based way of life. The Anasazi occupied the depths of the canyon as well. In the historic period, Hualapai, Havasupai and Paiute evidenced the only use of the canyon by the surrounding Indian tribes. These various cultures all left evidence of their life styles upon the land.

Archeological surveys of the river corridor were completed in 1978 (Euler, 1979).

At the present time, over 50 prehistoric archeological sites have been recorded adjacent to the Colorado River from Lees Ferry to the Grand Wash Cliffs and Lake Mead. In addition to the presence of sites adjacent to the river, other important cultural resources have been located in tributary canyons. Dozens of ruins have been identified in virtually every major drainage of the Colorado River system. Many of these sites are undergoing rapid and irreversible impact, some due to natural erosive forces, but in other instances considerable impact is due to visitor activities. Nineteen commonly visited archeological sites include a number of pueblo ruins, rock shelters, pictographs, masonry granaries, caves, and sacred Indian sites.

Sites in danger of disturbance by natural forces (erosion through flash flooding) or by the trampling activities of the feral ass are located throughout the lower Grand Canyon. Many of these sites are within the river corridor.

Although 10 archeological sites are eligible for nonimation to the National Register of Historic Places, no sites within the river corridor are presently listed on the register. Site evaluation and preparation of nomination forms is now underway. Compliance with Executive Order 11593 is expected within the next few years.

2. History

Although the archeological record indicates a very early human interaction with the Grand Canyon, it has been only during the past 75 years that extensive organized activity has occurred. The historic resources of Grand Canyon relate primarily to the establishment and development of the national park.

Recorded history of the Grand Canyon began with its discovery in 1540 by Don Lopez de Cardenas, one of Coronado's captains, and 12 followers who were seeking the fabled wealth of the Seven Cities of Cibola. Fathers Dominguez and Escalante crossed the Colorado River in Glen Canyon in 1776 and in that same year Francisco Tomas Garces visited the Havasupai Indians during a traverse south of Grand Canyon. American fur traders made forays into the Grand Canyon region during the early 19th century.

After the war with Mexico, the United States acquired the region in 1848 by the Treaty of Guadalupe Hidalgo. The first comprehensive report on Grand Canyon resulted from the work of a War Department expedition of 1857-58 headed by Lieutenant Joseph C. Ives. His mission was to ascend the Colorado River and report on its navigability.

Major John Wesley Powell and nine companions won lasting fame as a result of their daring descent by boat of the Colorado River in 1869. Their trip began at Green River, Wyoming, and ran the river through the Grand Canyon. Powell repeated the trip again in 1871-72, as far as Kanab Creek. These scientific explorations gathered worthwhile information in spite of the hardships involved. A U.S. Army expedition led by Captain George Wheeler passed immediately south of the canyon in 1871 as they were mapping potential railway routes.

Along the river corridor there are no historic sites that are presently on the National Register of Historic Places. Below is a list of currently known sites within the river corridor which require historic evaluation. Some of these sites may meet the national register criteria when they are more fully evaluated.

Name of Site

Brown Inscription
Cave Springs Rapid Historic Site
Bert Loper's Boat
Grave of Peter Hansbrough (1889) and Boy Scout (1946)
Grave of Willie Taylor
Beamer's Cabin
Tanner Mining Camp
Hance Cabin
Asbestos Canyon Mining Camp
Phantom Ranch
Bass' Winter Camp and Cable Crossing
Shinumo Canyon Mining Camp
Hakatai Canyon Mining Camp
Havasu Canyon Mines

Other sites, not immediately adjacent to the Colorado River but easily accessible to river runners and backcountry users that need investigation, include Hermit Camp, Boucher Camp, and Bat Cave Guano Mine.

L. RIVER RECREATION

The Colorado River through Grand Canyon is one of eight stretches of recreation rivers on the Colorado-Green River system. It is one of more than 44 stretches of recreational rivers in the western United States.

In Grand Canyon, the Colorado River has unique characteristics which set it apart from other rivers. It is the longest stretch of river for

recreational use entirely within a national park. It is surrounded by more than 1 million acres of land with little human development. Some of the world's most difficult and exciting white water occurs here. The Colorado River's isolation in the mile deep gorge of Grand Canyon gives it wilderness qualities which enhance in addition to river running, off river hiking, climbing, sightseeing, and solitude.

Prior to the early 1960's, there was little need to be concerned with resource impacts along the river. Most park visitors were concentrated on the South Rim of the canyon, and to a lesser extent, the North Rim. Relatively few visitors entered the canyon, and when they did it was usually on the Kaibab and Bright Angel Trails. Few visitors hiked in the backcountry or ran the river, and attention to these activities was minimal.

In 1963, the gates of Glen Canyon Dam were closed, forming Lake Powell, and river management problems began to appear. In addition to changing the biotic regimen of the Colorado River and its associated habitats, Glen Canyon Dam also drastically altered the maximum and minimum flow of the river and the silt concentrations. The dam also changed the timing of flows. Pre-dam flows were so high during spring run-off that river running was difficult. On some years, flow volume dropped so drastically that by September there was too little water for river running. The more consistent flows and clear water resulted in the Colorado River below Glen Canyon Dam becoming one of the most sought after whitewater recreation rivers in the Western Hemisphere. Simultaneously other factors encouraged growth in river running: emerging interest in wilderness experience, increased mobility and leisure time, expanding numbers of people with river-running expertise, and an increased amount and variety of, as well as improvement in equipment.

In late 1969, the National Park Service became concerned with the increase in river running activity. Before 1953, fewer than 200 people had run the Colorado River through The Grand Canyon (Johnson and Martin, 1976). In 1967, 2100 people ran the river and river running was becoming a thriving business. By 1973, 22 commercial boating companies and noncommercial river runners carried over 15,000 people down the river, an increase of almost 700 percent in 6 years (see Table 13). The number of river runners in 1972 alone exceeded the total number for the 100 years from 1869 (Powell trip) through 1968. Twenty one of the commercial river running operations are authorized to run the river from Lees Ferry to Pierce Ferry and other points on upper Lake Mead. The Hualapai Tribe is authorized to run only from Diamond Creek to Pierce Ferry and other points on upper Lake Mead.

1. User Days and Allotments

For 1973, a ceiling was placed on the number of user days (one user day equals one person on the river for one day), to allow time to determine what the effect this use was having on the resources and on the visitor's experience.

The commercial allotment for 1972 was 105,000 user days. Of these, only 88,135 were used, so for 1973 the allotment was set at 89,000, an overall reduction of 16 percent. This level has been maintained to the present time. Noncommercial river runners used 7,600 user days in 1972 and that level has been their ceiling to the present time. These use limits and allocations for commercial and noncommercial river running were for that section of the river from Lees Ferry to Diamond Creek. There were no use limits established for the Lower Gorge below Diamond Creek. User days are not counted against allocations for those trips continuing on below Diamond Creek.

The number of user days allocated to individual concessioners was based on their actual levels of use in 1972. Most concessioners concessioners allotment was reduced by 16 percent in 1973 from the 1972 allotment figure (see Table 14). The Hualapai Tribe are not included in Table 14 since they are not under a user day limit because they operate only in the Lower Gorge below Diamond Creek.

Table 13
TRAVEL ON THE COLORADO RIVER THROUGH THE GRAND CANYON
FROM 1867 TO THE PRESENT (AFTER NASH, 1976)

Year			
1867	1[1]	1957	135
1869-1940	73	1958	80
1941	4	1959	120
1942	8	1960	205
1943	0	1961	255
1944	0	1962	372
1945	0	1963-1964	44[2]
1946	0	1965	547
1947	4	1966	1,067
1948	6	1967	2,099
1949	12	1968	3,609
1950	7	1969	6,019
1951	29	1970	9,935
1952	19	1971	10,385
1953	31	1972	16,432
1954	21	1973	15,219[3]
1955	70	1974	14,253
1956	55	1975	14,305
		1976	13,912
		1977	11,830
		1978	14,356

1. Some contend that James White, a trapper fleeing from Indians, floated the Grand Canyon on a makeshift log raft two years before the expedition of John Wesley Powell.

2. Travel on the Colorado River in these years was curtailed by the completion of Glen Canyon Dam upstream and the resultant disruption of flow.

3. The downturn in visitation was the result of the institution by management of a quota system. The numbers applying for the available private permits continued to rise annually.

Table 14
CURRENT ALLOCATION OF AVAILABLE PASSENGER DAYS (PD) TO EACH OF THE 21 CONCESSIONERS

Company	1972 P/D Allot	P/D Use	P/D Allot	1973 P/D Use	1976 Use	1977 Use	1978 Use	# Trips 1978
WEST	12000	13125	10080	10052	10153	8455	10086	50
HATCH	12000	11689	10080	10034	8297	6761	9746	70
SAND	12000	10636	10080	10039	10011	9302	10496*	52
ARTA	11000	9775	9240	9096	9241	7577	9155	41
GRCE	10000	11000	8400	8347	9470*	6290	8458	24
CROS	8000	3560	6720	5297	4349	3343	5156	40
WHIT	4500	4589	3780	3765	3476	3114	3758	21
TOUR	4500	4515	3780	3734	3755	3524	3593	25
CANY	4000	2893	3360	3344	3409	2876	3304	23
GRCD	3600	2329	3025	2979	2944	3416*	4117*	16
ARIZ	3000	3050	2600	2609	3078	2600	2924*	18
WILD	3000	721	2520	2526	2478	2470	2542*	9
FORT	2600	1391	2200	2213	2054	1844	2377*	12
MOKI	2400	1241	2050	1466	2190	2200*	2312*	14
GEOR	2300	1414	2000	1988	2015	1974	2365*	7
COLO	2000	1879	1800	1819	1951*	1916*	1876	17
HARR	2000	975	1680	1570	1580	1565	1506	11
KENS	2000	600	1680	1449	1629	1457	1700*	8
OARS	1600	1218	1600	1589	1603	2518*	1617*	10
OUTD	1200	738	1200	1215	1206	1129	1209	7
GRCY	1300	784	1125	1134	1117	1469	1105	6
	105000	88135	89000	86264	85006	75800	89362	481

Any significant departures in excess of allocated use were covered by borrowing or was deducted from the following year allocation.

The 7,600 user days allocated for noncommercial river runners sector has been dispensed by a variety of methods. In 1972 and 1973, user days were assigned on a first-come, first-served basis. In 1974-75, postmark priority and a no-repeat rule was tried. In 1976, the no-repeat rule was dropped and a lottery was established. Considerable controversy has pervaded the decision on both commercial and noncommercial disbursements since 1972, becoming more intense and widespread in 1976 and continuing to the present.

The percentage of user days allocated between commercial and noncommercial user days has generated much controversy, including two lawsuits that are still pending. The following tables show the allocation of use between commercial (92 percent) and noncommercial (8 percent) river runners. Table 15 presents the number of noncommercial user days and table 16 the allocated and actual user days used for all 22 commercial outfitters from 1972 and 1976.

Commercial use did not reach the total allotment level until 1978. However, the data indicate clearly that some concessioners could use more user days than they are currently allotted while others do not use their total allotment. At the same time, 81,448 user days were denied the noncommercial applicants in 1976. National Park Service files contain many complaint letters from unsuccessful noncommercial applicants, but none from people indicating they could not book a commercial trip. The data on applications received and user days issued to noncommercial river runners are not realistic. For example, there were over 1200 application blanks sent out for 1977, with 507 completed applications submitted and 37 permits issued. Some of those who requested applications desired a trip, but did not submit an application due to the limited chance of drawing a permit, and other related reasons. Also, duplicate applications were included in the 507 submitted. The demand for noncommercial trips appears to be greater, but the data are inadequate to determine the extent of demand.

Commercial use was increasing at a rapid rate prior to 1973 when the ceiling was imposed. There is no question that this use would be at a much higher level today had it been allowed to operate in a free market situation where concessioners were allowed to increase trips freely in response to demand. How much higher use might have been is entirely speculative.

In summary, it appears that noncommercial user interest is most intense at this time, but comparative demand, noncommercial to commercial, cannot be accurately assessed.

2. Levels and Distribution of Use

The maximum commercial user days allotted each month cannot exceed 25 percent of the concessioner's annual allotment. A maximum of 150 commercial

Table 15
NUMBER OF NONCOMMERCIAL PERMIT APPLICATIONS
AND PERMITS GRANTED FROM 1972 THROUGH 1978

Year	Number of Applications	Number of User Days Requested	Number of Permits Granted	Number of User Days granted	
1972	47	7,611	47	7,611	
1973	74	14,193	49	7,833	
1974	84	17,115	41	7,638	
1975	173	33,569	42	7,679	
1976	425	89,084	36	7,636	
1977	507	86,862	40	7,766	
1978	370	73,834	37	7,477	
1979	441	86,346	47*	7,600*	

* Estimates

Table 16
TOTAL USER DAYS ALLOTTED VERSUS TOTAL USER DAYS
USED BY COMMERCIAL RIVER RUNNERS FROM 1972 TO 1978

Year	Number of Days Allotted	Number of Days Used	Number of Days Not Used
1972	105,000	88,135	16,865
1973	89,0008	86,264	2,736
1974	89,000	84,159	4,841
1975	89,000	84,709	4,291
1976	89,000	85,006	3,994
1977	89,000	75,800	13,200*
1978	89000	89,362	- - - -

* Extremely low water year

passengers, and one party of up to 15 private users (average in 1978 was 11.2), is permitted to depart from Lees Ferry on any single day. The maximum number of commercial passengers per type of boat ranges from 6 to 20, and the maximum number of passengers per commercial trip is 40 (average in 1978 was 21.4). Commercial trips are not permitted to average more than 40 river miles per day.

Current use levels range from 80 to 940 people leaving Lees Ferry each week with up to 200 people launching on a single day (including crew, research, and administrative personnel). The majority of river trips launch Mondays and Tuesdays, and most of the allotments are used in June through August (see Tables 17 and 18). Little use occurs between October and March.

3. Lower Gorge

The use levels and allotments discussed above apply only to the first 225 miles of the river. The portion of river from Diamond Creek to Grand Wash Cliffs is currently not under use allotment.

This section of the river was added to the park in January 1975 (Grand Canyon National Park Enlargement Act, P.L. 93-620) and has a history of use and management that is substantially different than upstream from Diamond Creek. In 1978, (under permit from NPS and auspices of the Hualapai Tribe) an estimated 500 passengers took trips from Diamond Creek to Lake Mead. In addition, approximately 6,000 commercial passengers who annually start their trip at Lees Ferry continue past Diamond Creek down river to Lake Mead. There are no data available on the numbers of noncommercial passengers that float from Diamond Creek to Lake Mead, but an estimated 100 trips launch at Diamond Creek annually.

Motor boats also run upriver to Diamond Creek at the present time, but are not permitted to continue beyond this point. Fishing and water skiing also occur below Separation Rapids (Mile 240). This area is considered to be a portion of Lake Mead, and approximately 12,000 persons, other than river runners, engage in lake recreation yearly.

M. THE NATURE AND EFFECT OF EXISTING USE PATTERNS

Rapid irreversible physical and ecological changes are occurring in the riparian resources of the Colorado River as a result of the present visitor use levels and patterns. The irreversible changes are not necessarily a simple function of the total number of visitors, but more importantly, of use patterns and activities (Carothers and Aitchison, 1976).