Ecosystem Research Institute

VOLUME I
WATER RESOURCES ASSESSMENT
CANYONLANDS NATIONAL PARK
NEEDLES DISTRICT AND ADJACENT BLM LANDS

Prepared For

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1.0 INTRODUCTION

Planned development adjacent to Canyonlands National Park and upstream on the Colorado River and increasing recreational use have the potential to affect the aquatic and riparian environment through increased erosion, pollution, water constituent changes and alteration of stream flow. Three major activities may contribute to the problem. These are:

1. Construction and operation of a high level nuclear waste repository adjacent to the park.

2. Increased human use or recreation as a result of repository construction and operation as well as generally increasing recreational use on the Colorado River and within the park.

3. Upstream development in the Colorado River system.

A 400 acre site within one mile of Canyonlands National Park is being considered by the Department of Energy (DOE) for a high level nuclear waste repository. The Paradox Formation underlying this region would be mined and spent nuclear waste disposed in this formation. Alternative proposed routes for railroad and haul roads to the repository roughly parallel the east park boundary and the Colorado River. High level nuclear waste would be transported to the repository and mined salt from the Paradox Formation would be hauled away from the site using these transportation corridors.

The proposed railway would cross the Colorado River upstream from the Park and all drainages from these corridors and the repository flow into the park and the Colorado River. There is potential for any spills or pollution to adversely affect the water quality of the Colorado River and the drainages leading to it.

Water required for repository construction and operations may be taken from the Colorado River or tributaries and aquifers which feed it. Depending on the amount of water diverted and its source, volume and quality of surface and groundwater resources within the park could be affected.

Recreational use is high in the Colorado River with at least 5,764 park visitors per year. The construction and operation of the repository will introduce many more people into the area, thereby potentially increasing recreational use both in the Colorado River and all areas adjacent to and within the park. This additional human activity will increase erosion and waste leading to potential deterioration of the water sources in the park.

Upstream development on the Colorado River from the oil shale industry, dams and other projects may also alter the volume or quality of water in the Colorado River. The cumulative impact of all these developmental factors surrounding Canyonlands National Park may result in effects to two endangered species of fish, the Colorado River squawfish (Ptychocheilus lucius) and the humpback chub (Gila cypha). Other endangered species including the Peregrine Falcon (Falco peregrinus) and Bald Eagle (Haliaeetus leucocephales) may also be affected.

1.1 OBJECTIVES

It is the concern with these activities and the potential degradation of water sources and their quality within Canyonlands National Park that prompted this study. The required objectives of this study were threefold.

1. Inventory surface and groundwater resources of the Colorado River system within that portion of Canyonlands National Park, Utah, that may be directly or indirectly affected by the construction and operation of a high level nuclear waste facility adjacent to the national park.

2. Provide baseline data on surface and groundwater quality, including standard biological, physical and chemical parameters.

3. Design a long-term water quality monitoring program with special emphasis on the Lavender Canyon, Davis Canyon, Indian Creek and Salt Creek drainages within the national park.

1.2. TASKS

Several tasks were necessary to successfully meet the project objectives. These included:

1.2.1. Prework Conference This conference with a National Park Service Overview Committee was held prior to the instigation of any field efforts to provide for contractor orientation, study coordination and detailed exchange of information and ideas between the NPS Overview Committee and the

Contractor's representatives.

1.2.2. Literature Search and Data Compilation

A literature search was conducted to identify pertinent sources of information which would provide an inventory of surface water and groundwater resources in areas in and adjacent to Canyonlands National Park identified by the NPS as potentially being affected by development of the nuclear waste repository. This task involved consultation with agencies administering the lands in and adjacent to Canyonlands National Park including the National Park Service, Bureau of Land Management, U.S. Forest Service, Bureau of Reclamation and the U.S. Geological Survey. Data was collected from these sources in the form of reports and data tape for compilation into a single source of information for the area of interest.

1.2.3. Field Investigation

A single field investigation was conducted in the area of interest with efforts focused in and around the Needles District of Canyonlands National Park (Figure 1.2-1). Principle drainages of interest visited included Davis Canyon, Lavender Canyon, Indian Creek, Salt Creek and the Colorado River.

Many of the historical sources identified from the literature were visited during this field investigation. The limitations of time and budget precluded visiting all documented sources, but a majority of those in the drainages of interest were visited.

1.2.4. Water Quality Monitoring Guidelines

The results of tasks 1.2.1, 2 and 3 provided the basis for development of quidelines for long-term monitoring of water quality. These guidelines are detailed in a separate document entitled "Water Resources Monitoring

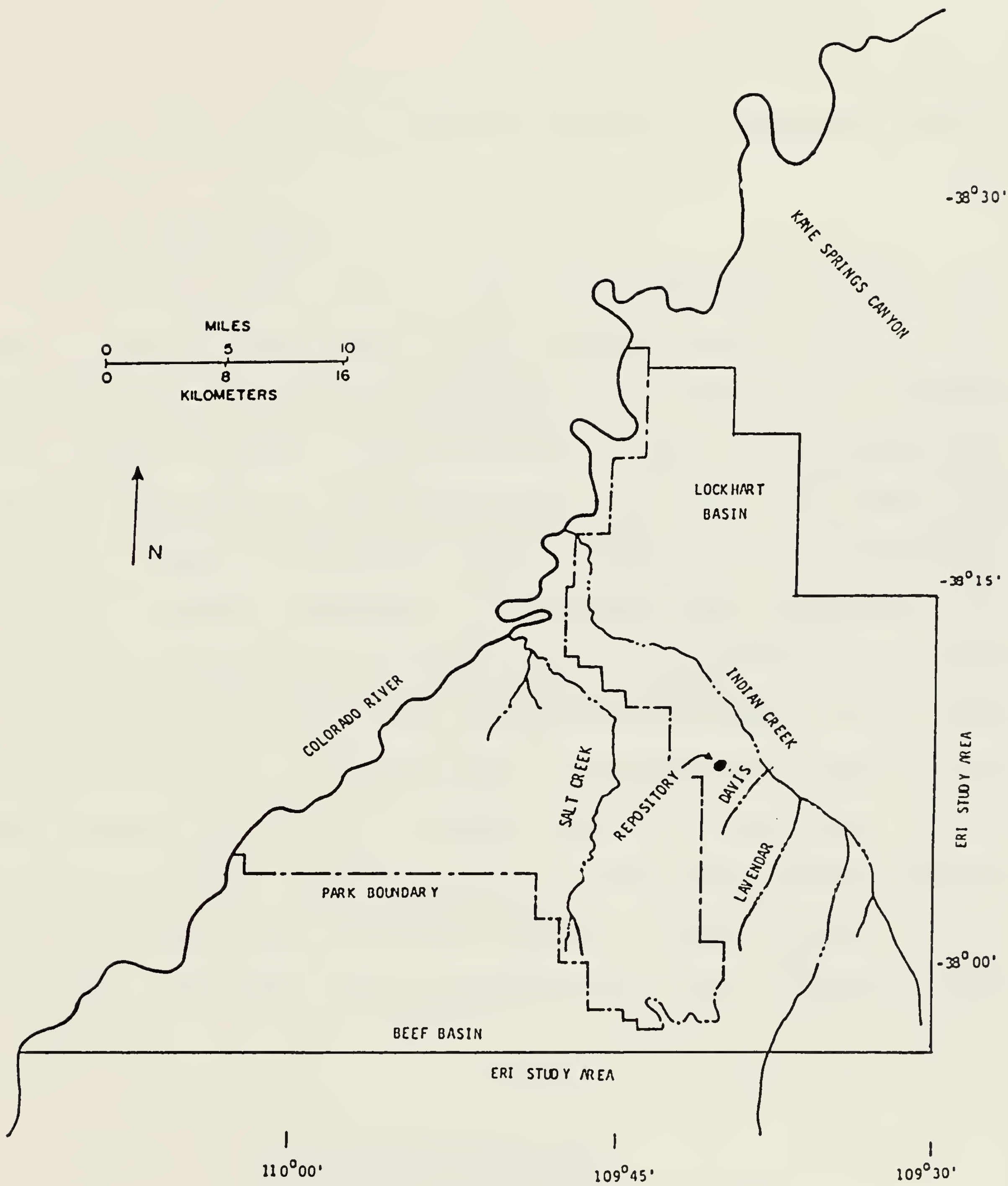


Figure 1.2-1. ERI study area.

Guidelines, Needles District and adjacent BLM lands. Canyonlands National Park".

1.2.5. Final Report

The results of tasks 1.2.1, 2 and 3 are summarized in this final report, which is organized to provide a concise historical description of the water resources of Canyonlands National Park in the area of interest with sufficient detail to be useful and informative to the general park employee without access to the computerized data base. The report also serves as an index to the detailed historical data base for the data manager involved in making quantitative interpretations and comparisons for monitoring. A detailed map of water resources is presented with this report to provide the basis for the future expansion and refinement of the water resources data base for the entire park. A documented data tape containing the historical data records for the water resources in the study area is furnished. The final report is presented in four separate volumes which are tailored to the general resources manager, the data analyst and the individuals performing routine monitoring and data collection. These volumes are:

Volume I — WATER RESOURCES ASSESSMENT
CANYONLANDS NATIONAL PARK
NEEDLES DISTRICT AND ADJACENT BLM LANDS

Volume II — WATER RESOURCES
MONITORING GUIDELINES
CANYONLANDS NATIONAL PARK
NEEDLES DISTRICT AND ADJACENT BLM LANDS

Volume III — WATER RESOURCES DESCRIPTIONS AND DATA BASE
CANYONLANDS NATIONAL PARK

NEEDLES DISTRICT AND ADJACENT BLM LANDS

Volume IV WATER RESOURCES
PHOTOGRAPHIC RECORD
CANYONLANDS NATIONAL PARK
NEEDLES DISTRICT AND ADJACENT BLM LANDS

2.0 BACKGROUND INFORMATION

2.1 THE SETTING

The area of concern includes the Colorado River drainage within that portion of Canyonlands National Park and contiguous BLM land which may be impacted by construction and/or operation of the proposed nuclear waste facility. Specifically, the area includes: 1) The Colorado River between Shafer Canyon and Hite Marina; 2) The Needles District of Canyonlands National Park; and 3) Portions of BLM and Forest Service land contiguous to the eastern boundary of the Needles District. Special emphasis has been directed at identifying and describing water resources within Lavender, Davis, Indian Creek and Salt Creek drainages. The area of concern is delineated in Figure 1.2-1. This section discusses the climate, hydrology, physiography, geology and historical information of the study area.

2.1.1 Climate

The climate of the study area is arid to semi-arid. Annual precipitation in lower elevations of the study area is normally less than 8 inches while mean annual precipitation at higher elevations surrounding Canyonlands National Park may exceed 10 inches. Slightly more precipitation falls in the summer than in winter months (Sumsion and Bolke 1972). A major portion of summer precipitation is from intense local thunderstorms.

Temperatures in the Needles District range from less than -10°F (-23°C) to greater than 100°F (38°C). The average annual temperature is about 53°F

(11°C). Average annual potential evapotranspiration greatly exceeds precipitation and is about 41 inches (Richter 1980).

2.1.2 Physiography

The study area is located within the Canyonlands section of the Colorado Plateau Physiographic Province. Elevation ranges from above 7600 feet in headwater positions of Butler Wash to less than 4000 feet at Hite Marina. The setting includes stratified, variegated rock formations dissected by erosion to form plateaus, mesas, buttes, canyons, spires, columns and alcoves.

The physiography of the study area includes residual, colluvial and alluvial positions. Residual positions include the crests of plateaus and buttes. Residual positions are characterized by expansive exposures of sedimentary bedrock with small areas of shallow soil over bedrock. Residual areas consitute the primary physiographic position of the study area.

Colluvial positions are a response to the influence of gravity and comprise nearly vertical escarpment slopes. Upper portions of canyon walls are often sheer exposures of geologic strata while steep accumulations of talus weathered from overlying geologic strata form at the base of escarpment slopes. Colluvial positions constitute transitions from residual upland positions to alluvial positions.

Alluvial positions are characterized by relatively deep, unconsolidated mineral deposits weathered from upland positions and transported to canyon bottoms by flowing water. Unconsolidated wind deposited (aolean) sediments, generally in association with alluvial deposits, also occur in the study

area.

2.1.3 Hydrology

The Colorado and Green Rivers are the only perennial streams in the study area. Indian Creek and Salt Creek are the major emphemeral drainages. Very restricted permeabilities of upland geologic formations results in flow through even the smallest canyon and trough positions in association with runoff from snowmelt and summer thunderstorms. Small depressions in level bedrock strata (potholes) afford an additional water source to wildlife and hikers for short periods throughout the warm season.

Groundwater sources in the Canyonlands area appear to be primarily a result of local recharge. Alluvial groundwater results from surface runoff from upland positions while bedrock aquifers are believed to be a response to water infiltration through joints and bedding planes associated with geologic strata. Alluvial aquifers often extend above the surface in ephemeral drainages for short periods after precipitation events and may be available to wildlife for extended durations where the alluvium is shallow (alluvial rise) over bedrock highs.

Springs and seeps constitute water discharge points from bedrock aquifers. Seeps occur throughout the study area but normally discharge water at such a small rate that they constitute a water source to only the very patient. Springs which discharge measurable amounts of water are much less frequent. The occurrence of many springs and seeps in positions at or near the bottoms of canyons often makes distinguishing these water sources form alluvial rises difficult. During runoff events, water from surface

runoff and bedrock aquifers mix. Discussions of the hydrologic characteristics for distinct geologic formations follow.

2.1.4 Geology Consolidated geologic formations occurring in the study area range from Jurassic to Pennsylvanian in age. Alluvial positions are of recent Quaternary age. Characteristics of rock types and the degree of continuity of strata generally determine hydrologic characteristics. General characteristics of geologic formations are discussed in order of increasing age from the present. The statigraphic positions of geologic formations are identified in Figure 2.1-1. Discrete characteristics of geologic formations within the area of concern are now discussed.

2.1.4.1 Unconsolidated Geologic Units Unconsolidated mineral sediments within the study area include alluvium, aeolian and landslide deposits of Quaternary age.

Alluvial deposits are perhaps the most ubiquitous type within the study area. Sediments originate in the weathering of contiguous consolidated rocks and are redistributed primarily by water. Textural classifications range from cobble and gravel size fractions to sands, silts and clays. Characteristics of alluvium reflect those of parent materials. Alluvial materials occur in drainage positions and range in depth from a few feet to greater than 20 feet (Richter 1980).

Alluvial positions constitute the primary routes of surface runoff form contiguous rock outcrops to primary fluventic systems. Sustained flow is common in alluvium of Indian Creek drainage while numerous ephemeral "rises" occur along Cottonwood, Salt, Lavender and Davis Canyons.

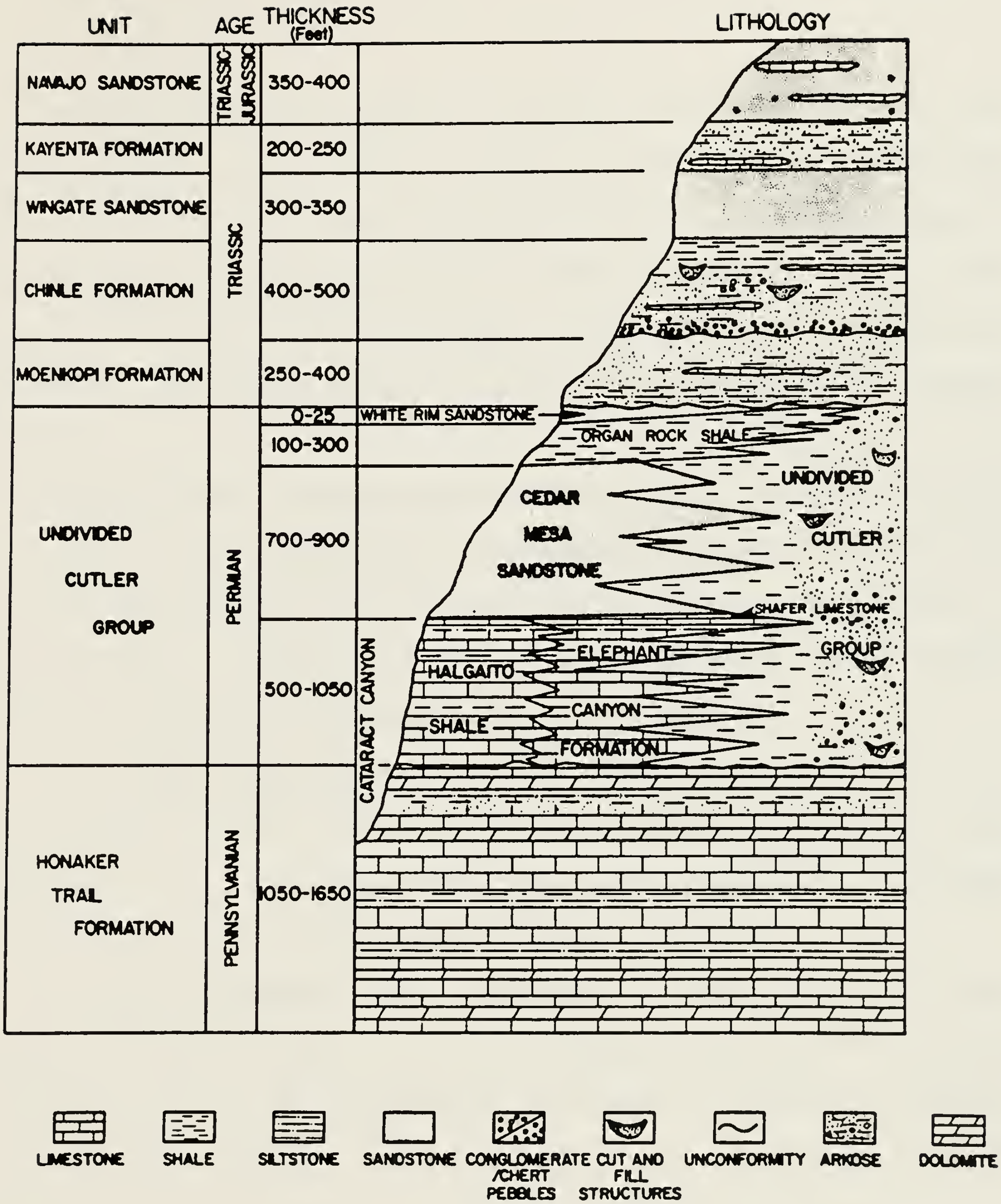


Figure 2.1-1. Ages, lithologies and thicknesses of the rocks exposed in the part of Canyonlands National Park east of the Colorado River and contiguous Bureau of Land Management lands, Utah. (Reproduced from Richter, 1980)

Landslide deposits are common at the base of escarpment slopes, notably in the Colorado River Canyon. As noted on one evening when temperatures were near freezing, the roar of jet aircraft flying over the region seems to be effectively increasing the number and extent of landslide deposits within the park. Landslide deposits may cover springs and seeps emitting from underlying consolidated strata but are normally not associated with water sources.

Aeolean deposits are those deposited under the influence of wind and are mostly coarse grained sand. The deposits accumulate in protected lee positions throughout the study area but are most extensive northeast of Squaw Flats and southwest of Gibson Dome. No water sources have been identified associated with landslides or aeolean deposits.

2.1.4.2 Glen Canyon Group The Glen Canyon Group consists of two massive-bedded aeolean formations separated by a formation of fluvial origin (Molenaar 1971). In descending order the three strata are: 1) Navajo Sandstone, 2) Kayenta Formation and 3) Wingate Sandstone.

A. Navajo Sandstone Navajo Sandstone is late Triassic to early Jurassic in age and ranges in thickness from 200 to 450 feet. The formation is comprised of fine-grained sandstone laminated in massive, crossbedded strata characteristic of aeolean deposits. The occurrence of Navajo Sandstone within the study area is limited to Harts Point, Hatch Point and mesas between Davis, Lavender, Cottonwood and Indian Creek Canyons.

The interstitial permeability of Navajo Sandstone is among the highest of any lithologic unit in the Canyonlands area and averages about 35 gallons/day-foot (Huntoon 1979). Infiltration of water through partings

between bedding planes and joints also constitutes potential sources of ground water recharge. Although extensive areas of Navajo Sandstone occur on Hatch Point and Harts Point, its occurrence is otherwise restricted to isolated buttes elevated above the surrounding land in the eastern portion of the study area. The dissected topography, very restricted recharge area and relatively rapid drainage result in little potential for water sources in Navajo Sandstone except along Hatch and Harts points. Richter (1980) identified several water sources associated with Navajo Sandstone in headwater positions of tributary drainages of Harts Draw.

B. Kayenta Formation This stratum is late Jurassic in age and ranges from 200 to 250 feet thick. It is comprised of fine to medium-grained sandstone with interbedded siltstone, limestone and shale in lower portions of the stratum. Molenaar (1971) divides the Kayenta Formation into an upper slope-forming unit and a lower cliff-forming unit. The occurrence of the Kayenta Formation is limited to mesas in the eastern portion of the study area.

Huntoon (1979) combines the upper 50 feet of the Kayenta Formation and the overlying Navajo Sandstone into a single hydrologic unit. Permeability characteristics of the upper portion of the Kayenta Formation are similar to the overlying Navajo Sandstone. The lower portion of the Kayenta Formation is comprised of relatively impermeable shales and siltstones and is limiting to the downward percolation of water. Identified springs and seeps emanating from the Navajo-Kayenta hydrologic unit are restricted to the Hatch and Harts Points area (Ritcher, 1980).

C. Wingate Sandstone The Wingate Sandstone is late Triassic to early Jurassic in age and forms prominent cliffs ranging up to 350 feet in height. It is comprised of fine-grained, reddish-brown sandstone with massive structure interrupted by occasional nearly vertical fracture joints. The formation has resulted form consolidation of aeolean deposits.

Low permeability through the overlying Kayenta Formation and very low intergranular permeabilities of Wingate Sandstone preclude saturated zones in this formation although small short term discharges may occur through vertical joints. Richter (1980) identified several water sources associated with the Wingate formation along escarpment slopes of Harts Point and Hatch Point. Richter concludes that the Wingate Sandstone only acts as an aquifer where fractured.

2.1.4.3 Chinle Formation The Triassic Chinle Formation underlies the Wingate Sandstone and forms lower positions of escarpment slopes of Harts Point, Hatch Point and Bridger Jack Mesa. It ranges in thickness from about 350 to 650 feet and is often covered with colluvial material eroded from overlying Wingate and Kayenta Formations. The Chinle Formation generally forms a slope of variegated red, purple, green, yellow and grey clayey sandstones and siltstones. Gypsum and other soluble forms of salt are generally associated.

The intergranular permeability of the Chinle formation is very low. The occurrence of the Chinle Formation is restricted to eastern portions of the study area and does not constitute a source of bedrock aquifers although the quality of surface runoff entering Lavender, Davis and Indian Creeks are apparently affected by the salts of the Chinle Formation.

2.1.4.4 Moenkopi Formation The Moenkopi Formation weathers to ledgy slopes subtending the Chinle Formation. It is composed of thin to medium beds of siltstone, fine-grained sandstone and thin layers of mudstone. The formation comprises minor areas in the eastern portion of the study area.

The Moenkopi Formation may constitute a confining layer to subtending saturated zones although some water infiltration occurs through broadly spaced joints. Intergranular permeability in this stratum is minimal. No water sources associated with the Moenkopi Formation have been identified in the study area by these or other investigators.

2.1.4.5 Cutler Group The Permian age Cutler Group constitutes the dominant geologic type of the study area. It is characterized by complexly intertongued and gradational units. Within the study area, constituents of the Cutler Group are: 1) Organ Rock Shale, 2) Cedar Mesa Sandstone, 3) Undivided Cutler-Cedar Mesa Sandstone transition, 4) Halgaito Shale-Elephant Canyon Formation transition and 5) Halgaito Shale as defined by Huntoon et al. (1982). The undivided Cutler Group, Cedar Mesa Sandstone and Elephant Canyon-Halgaito formations undivided comprise a single hydrologic unit characterized by a sequence of permeable water bearing zones and confining layers integrated by fracture joints and partings between bedding planes (Richter 1980).

A. Organ Rock Shale The Organ Rock Shale is of Permian age and is comprised of reddish brown siltstones and sandy shales 250 to 400 feet thick. The stratum is restricted to slopes in the eastern portion of the study area. The best exposures of Organ Rock Shale are near North and South Sixshooter peaks.

Intergranular permeability through Organ Rock Shale is low while some local runoff may infiltrate through joints and bedding planes. Even when fractured, this formation constitutes a confining layer due to shales and clays sealing the fractures. No water sources were identified within the Organ Rock Shale by these or other investigators.

B. <u>Cedar Mesa Sandstone</u> The Cedar Mesa Sandstone constitutes a dominant geologic type of the study area. It is composed of massive, cross-bedded sandstones and generally forms intricately dissected plateus and escarpment slopes. The thickness of the formation ranges from 200 to 1200 feet.

The formation is permeable through the intergranular matrix as well as through partings between joints and bedding planes. Although other authors (Richter 1980; Huntoon 1979) indicate intergranular permeability in the Cedar Mesa Sandstone, the retention of water in potholes for sustained periods following precipitation events indicates that intergranular permeability may not be significant in recharging ground aquifers. Numerous springs and seeps have been identified by these and other investigators in this formation. As observed by Richter (1980) most water sources identified occur in association with faults, joints and partings between bedding planes.

C. <u>Undivided Cutler-Cedar Mesa Sandstone Transition</u> This geologic type forms intricately dissected mesas and escarpment slopes in the northern portion of the study area. The Undivided Cutler Group is composed of arkosic sandstones and white marine sandstones with interbedded red shales. It intertongues with Cedar Mesa Sandstone in the northern portion of the

study area.

Richter (1980) identified many springs and seeps emanating from the Undivided Cutler-Cedar Mesa Sandstone transition. Hydrologic characteristics of the geologic unit appear similar to that previously described for the Cedar Mesa Sandstone.

D. Elephant Canyon Formation This formation of the Cutler Group is Permian in age and is comprised of limestone and dolomite interlayered with sandstone, siltstone and thin beds of crystalline salts. Sediments originated in marine environments and range in thickness from about 500 to 1100 feet thick. The strata outcrops in the Colorado River Canyon and lower portions of tributary canyons upstream from the confluence with Red Lake Canyon. Downstream from Red Lake Canyon, the Elephant Canyon Formation intertongues with Halgaito Shale.

The Elephant Canyon Formation constitutes a water bearing zone of slightly to very saline water where saturated. Permeability is mostly between bedding planes and through joints. Richter (1980) integrates the Cutler, Cedar Mesa Sandstone, Elephant Canyon and contiguous Halgaito Shale into a single hydrologic unit.

E. Halgaito Shale-Elephant Canyon Transition This transition consists of intertonguing beds of marine sediments characteristic of the Elephant Canyon Formation and terrestrial sediments of the Halgaito Shale. It forms upper positions of the Colorado River Canyon between Red Lake Canyon downstream to Gypsum Canyon. Hydrologic characteristics are those described for constituent types.

F. Halgaito Shale This strata is comprised of reddish brown and purple arkosic sandstones, red siltstones, claystones and conglomerates with thin beds of limestone. It occurs in the Colorado River Canyon downstream from Gypsum Canyon and forms ledges and slopes.

Permeability of Halgaito Shale is primarily through joints and between bedding planes. Where saturated, the formation yields slightly saline to very saline water.

2.1.4.6 Hermosa Group Two formations included in the Hermosa Group are distinguished within the study area. The Honaker Trail Formation is underlain by very thick layers of the Paradox Formation which constitutes the oldest formation which outcrops in the study area. The Hermosa Group is of Pennsylvanian age.

A. Honaker Trail Formation This formation is composed of thick-bedded, dark grey limestones interbedded with cherty limestones, shales and sandstones 1050 to 1500 feet thick. Sediments are of mixed marine and terrestrial origin. The formation is exposed along lower portions of canyon walls along the Colorado River from The Loop downstream almost to Hite. The zone between Honaker Trail marine sediments and contrasting land sediments has been referred to as the "Rico Formation".

Permeability in the Honaker Trail Formation is primarily through widely spaced partings between bedding planes and widely spaced joints. Where saturated, the formation yields slightly to very saline water.

B. Paradox Formation The Paradox Formation is composed of salt, anhydrite and gypsum interbedded with euxinic black shales and limestones. Outcrops of the formation are restricted to small salt domes in the Colorado

River Canyon between the confluences of Red Lake and Palmer Canyons. The Paradox Formation is the oldest geologic unit which outcrops in the study area.

The presence of soluble salts throughout the Paradox Formation indicates that the strata is essentially impermeable to water. No water sources have been identified in the study area which are in association with the Paradox Formation.

2.2 HISTORICAL WATER RESOURCES INVESTIGATIONS

Previous investigations of the water resources of Canyonlands National Park east of the Colorado River have been few. The major sources of historic information include Sumsion and Bolke (1972), Richter (1980) and Conner and Kepner (1983). Additional sources of data include records on file in the USGS Watstore System of the NAWDEX (National Water Data Exchange). Data recorded in Watstore included contributions from the Bureau of Land Management, Bureau of Reclamation, Environmental Protection Agency, National Park Service, United States Geological Survey, State of Utah and private sources.

Prior to 1972, investigations in the study area were primarily geological in nature and only briefly and qualitatively addressed the water resources in the study area. The first quantitative information presented on the water resources in the Needles District and contiguous BLM lands was in a U.S. Geological Survey Report by Sumsion and Bolke (1972).

Sumsion and Bolke (1972) studied and characterized many of the water resources in the Island-in-the-Sky and Needles Districts between 1967 and

1970. They discussed the regional geology and hydrology and summarized the hydrologic and chemical characteristics of the Green and Colorado Rivers. In addition they evaluated water usage in the Park and made recommendations for future water supply. Water quality data was presented for springs and wells in the Needles District.

Chemical quality of groundwater from wells in the Needles District was good. Dissolved solids content generally ranged between 305-926 milligrams per liter. Wells drilled below rocks of Permian age, generally below the Elephant Canyon Formation, were projected to contain saline water with high dissolved solids content (>35,000 mg/l). Of the 15 springs investigated in the Needles District, all contained potable water (TDS between 54-583 mg/l) except for Lower Jump Spring in Salt Creek (TDS=2180 mg/l). A summary of the sources and parameters measured by Sumsion and Bolke is presented in Tables 2.2-1 and 2.2-2.

Sumsion and Bolke (1972) projected that no additional water supply development would be needed for the Needles District until after 1980. They projected that of the springs investigated in their study, Lost Canyon Spring would be the most likely for development.

Richter (1980) performed the most comprehensive investigation of the water resources in the eastern part of Canyonlands National Park and contiguous BLM lands. He described the aquifers and their permeability characteristics, groundwater circulation and water quality. He also discussed potential areas for developing groundwater supplies within the study area.

Table 2.2-1. Water sources characterized by Sumsion and Bolke (1972) ERI Code in parentheses ( ).

Springs	Wells	Other
Big Spring (BS-4)	Needles Well No. 2 (W-2)	Rainpool
Dorius Spring (EC-3)	Needles Well No. 3 (W-3A)	
Echo Spring (BS-1)	Needles Well No. 5 (W-5)	
Hannover Spring (BS-2)		
Little Spring (LS-1)		
Loop Trail Spring (MS-3)		
Lost Canyon Spring (LO-2)		
Lower Big Spring (BS-5)		
Lower Jump Spring (SC-21)		
Lower Little Spring (LS-2)		
Peekaboo Spring (SC-11)		
Soda Spring (BS-3)		
Squaw Spring (SQ-2)		

Table 2.2-2. Chemical and physical parameters used by Sumsion and Bolke (1972) to characterize water resources.

Chemical	Physical
Bicarbonate (HCO_3)	Altitude
Calcium (Ca)	Discharge
Chloride (Cl)	Geologic Formation
Dissolved solids (TDS)	Location
Fluoride (Fl)	
Hardness ($CaCO_3$)	
Iron (Fe)	
Magnesium (Mg)	
Nitrate (NO_3)	
pH	
Potassium (K)	
Silica (SiO_2)	
Specific Conductance	
Sodium (Na)	
Sulfate (SO_4)	

Water quality data was presented for thirty-five locations within the study area including twenty-nine springs, three rises and three wells. Data from Sumsion and Bolke (1972) was included. Water sources with data reported are listed in Table 2.2-3. Parameters reported were the same as these documented by Sumsion and Bolke (1972) and listed in Table 2.2-2. Four water sources exceeded the 2000 mg/l dissolved solid standard for potable water. These were Kane Creek Seep, Lockhart Canyon Spring, Lower Jump Spring and an unnamed seep.

Richter classified the water from these major aquifers using this data. The classification was based upon water type as determined by the relative concentration of major anions and cations. Table 2.2-4 is a reproduction of Richter's classification. Of particular interest to the Needles' District are those sources listed under the Cutler Aquifer.

The alluvial aquifers or rises, generally contained water of good potable quality with low TDS (<400 mg/l). The Cutler Aquifer contained waters of highly variable quality, ranging from fresh to very saline. Springs discharging from local Cedar Mesa systems contained water of excellent quality (<350 mg/l) due to prior leaching of salts. Lavender Canyon sources contained higher than normal sodium, chloride and sulfate. This was postulated to suggest leakage from the overlying Organ Rock Shale.

Groundwater found in springs in Beef Basin, in the upper 50 feet of the Elephant Canyon - Halgaito Formation, had similar chemical characteristics as elevated Cedar Mesa Formations. It was then assumed that groundwaters in the upper 50 feet of the Elephant Canyon - Halgaito formations are the same waters encountered in elevated Cedar Mesa sandstone. Groundwaters in the

Table 2.2-3. Water sources characterized by Richter (1980).

Alluvial Aquifer	ERI Code
Davis Canyon Rise	DC-8
Lost Canyon Rise	LO-2
Rain Pool Rise	LS-1A
Navajo-Kayenta Aquifer	
Pritchett Canyon Spring #1	
Pritchett Canyon Spring #2	
Wingate Aquifer	
Harts Draw Springs	
Kane Creek Seep	K-3
Kane Springs Canyon Spring	K-1
Trough Canyon Spring	K-2
Cutler Aquifer	
Big Spring	BB-3
Big Springs	BS-4
Cave Spring	SQ-3
Dorius Spring	EC-3
Dripping Spring	
Echo Spring	BS-1
Hangover Spring	BS-2
Home Water Spring	BB-1
Little Home Water Spring	BB-4
Little Spring	LS-1
Lockhart Canyon Spring	LK-8
Loop Trail Spring	MS-3
Lower Big Spring	BS-5
Lower Jump Spring	SC-21
Lower Little Spring	LS-2
North Home Spring	BB-2
Needles Well No. 2	W-2
Needles Well No. 3	W-3A
Needles Well No. 5	W-5
Paul Bunyan Spring	HC-1
Peekaboo Spring	SC-11
Soda Spring	BS-3
South Spring	BB-6
Squaw Spring	SQ-2
Stanley Spring	BB-5

Table 2.2-4. Classification and variation in chemical characteristics of waters from selected springs, seeps, rises and wells in the part of Canyonlands National Park east of the Colorado River and contiguous Bureau of Land Management lands, Utah. Reproduced from Richter (1980).

Source	Number of Samples[a]	Water Type[b]	Change in average concentration (meq/l) of major ions with increase in depth in stratigraphic section
Alluvial aquifers	3	calcium-sodium-potassium-bicarbonate	---
Navajo-Kayenta aquifer	2	no dominant proportion of major ions	↑Ca, Na, K, Cl, NO_3, SO_4 ↓Mg, HCO_3
Wingate aquifer	4	calcium-magnesium-sodium-bicarbonate	↑Mg, HCO_3 SO_4 ↓Ca, Na, K, Cl, NO_3
Cutler aquifer (local Cedar Mesa systems)	9	calcium-magnesium-bicarbonate	↑Mg, Na, K, SO_4, Cl, NO_3 ↓Ca, HCO_3
Cutler aquifer (Cedar Mesa Sandstone)	9	calcium-magnesium-sodium bicarbonate	↑Mg, Na, K, SO_4, Cl, NO_3 ↓Ca, HCO_3
Cutler aquifer (Elephant Canyon-Halgaito formations undivided)	6	calcium-sodium-potassium-bicarbonate	↑Na, K, Mg, Cl, NO_3, SO_4 ↓Ca, HCO_3
Cutler aquifer (undivided Cutler group)	2	sodium-calcium-chloride-sulfate	↑Na, K, Ca, Mg, SO_4, Cl, ↓HCO_3, NO_3

[a]Chemical analyses of samples are listed in Table V .

[b]Water type according to relative proportion of major ions. Method after Piper (1944).

[c]↑ and ↓ denote increase and decrease, respectively, in the major ion concentration relative to the concentration in the overlying water bearing unit.

basal Elephant Canyon - Halgaito Formations undivided and the undivided Cutler Group were generally saline. The most likely source for the saline waters encountered in the Cutler Group is upward circulation from the underlying Paradox Formation.

Richter (1980) also presented a summary of prospects for developing groundwater resources. Areas with good potential for development are shown in Figure 2.2-1 taken from Richter (1980) and include areas containing saturated, permeable rocks and dependable perennial springs. Within the Needles District, two areas were recommended for future test drilling for water development. The first choice was near Cave Spring in Salt Creek. Squaw Flats was also suggested.

The most recent study of water resources in the Needles District and adjacent areas was a joint effort by the National Park Service and Bureau of Land Management (Conner and Kepner 1983). This study marked the beginning of attempts to monitor water quality in high use areas of Arches and Canyonlands National Parks. The report presents data on water quality and biology obtained during a single survey in August and September, 1983. A total of ten water sources were sampled in the Needles District (Table 2.2-5). Parameter values were field determined using portable equipment. See Table 2.2-6 for a list of parameters.

Results of water quality analyses were different from those of Richter (1980) and were presumed to be due to temporal or spatial fluctuations.

Biological sampling within Needles District consisted of three seine hauls taken at IC-14 near the mouth of Indian Creek. Fish captured included (1) red shiner and (1) speckled dace.

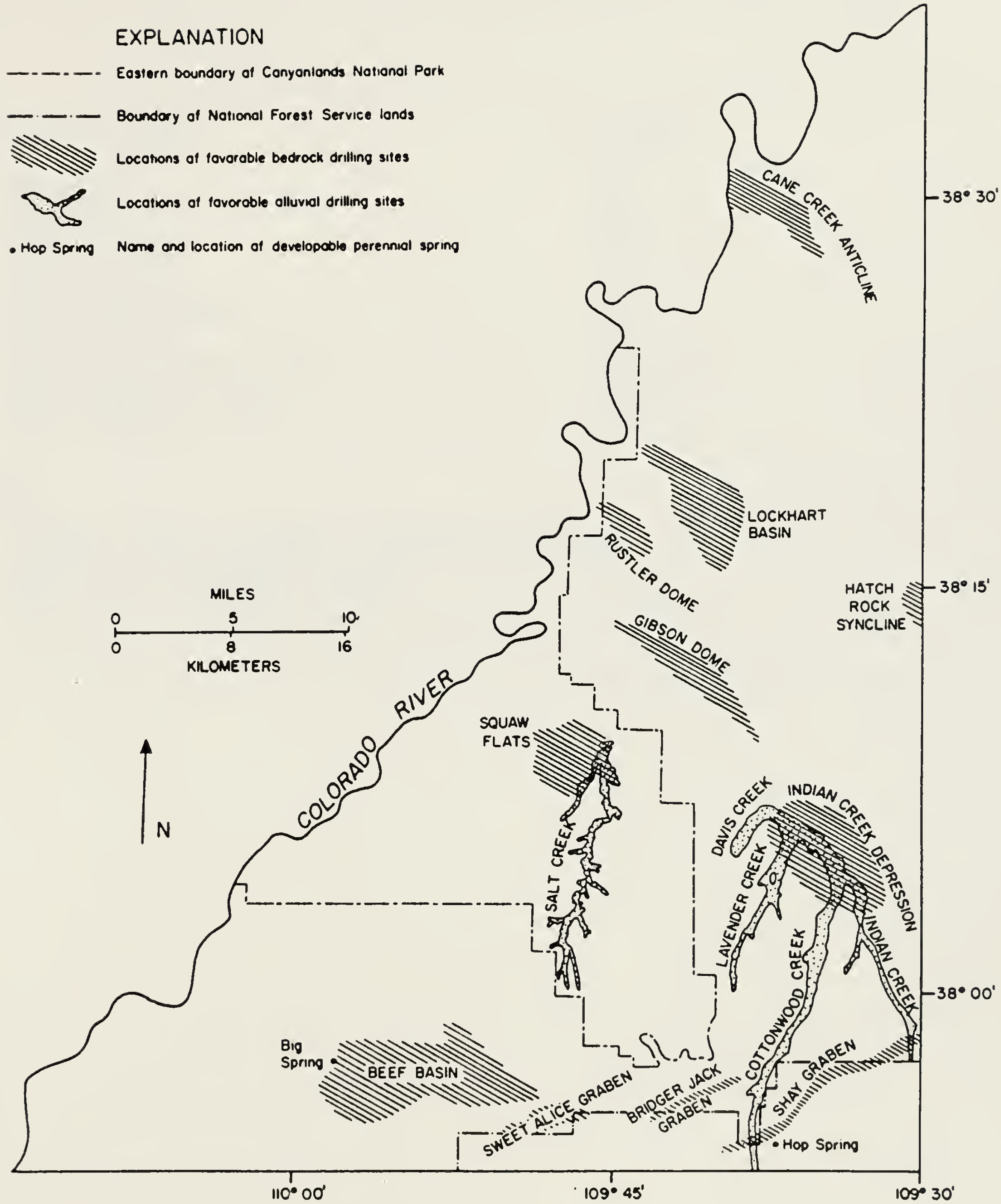


Figure 2.2-1. Index map showing target areas for test wells and developable perennial springs in the part of Canyonlands National Park east of the Colorado River and contiguous lands, Utah. Reproduced from Richter (1980).

Table 2.2-5. Water sources characterized by Conner and Kepner (1983).

Springs and Rises	ERI Code
Big Spring	BS - 4
Cave Spring	SQ - 3
Davis Canyon	DC - 2A
Indian Creek	IC - 14
Little Spring	LS - 1
Lost Canyon Spring	LO - 2
Pothole Point	MS - 5
Salt Creek @ Kirks Cabin	SC - 8E
Salt Creek Upper Jump	SC - 8D
Squaw Canyon	SQ - 2
Rivers	
Colorado River confluence with Lathrop Canyon	
Colorado River confluence with Green River	C - 2
Green River at Mineral Bottom	G - 2
Green River confluence with Colorado River	G - 1

Table 2.2-6. Chemical and physical parameters used by Conner and Kepner (1983) to monitor water sources.

Parameters
Discharge
Dissolved Oxygen
Nitrate (NO_3)
Orthophosphate (PO_4-P)
pH
Specific Conductance
Sulfate (SO_4)
Temperature

Conner and Kepner (1983) recommended that future water quality studies in the Park include seasonal sampling to account for variations in seasonality. They also recommended that coliforms, TDS, fluoride and trace metals be included to determine the suitability of backcountry waters as potable sources for recreationists.

Huntoon (1977) conducted a study to determine the hydrogeologic feasibility of developing groundwater supplies in the northern part of Canyonlands National Park and Bridges National Monument. His study did not include the Needles District.

3.0 METHODS

3.1 INTRODUCTION

Field investigations were performed in April and May, 1983. Methods for field investigations, laboratory methods and data analyses are subsequently discussed.

3.2 FIELD INVESTIGATIONS

The fundamental objectives of the field investigation were to inventory, describe and sample surface and groundwater resources in that portion of Canyonlands National Park (CNP) and contiguous BLM land that may be affected by the construction and/or operation of a high level nuclear waste repository. The primary area of concern included Davis Canyon, Lavender Canyon, the Indian Creek drainage, the Salt Creek drainage and that portion of CNP east of, and including, the Colorado River (Figure 1.2-1). Specific objectives of the field investigation were:

1. To describe and refine locations of historical water sources in the area of concern.

2. To identify and describe additional water sources within the primary area of concern.

3. To sample water sources for Level 1 or Level 2 analysis.

4. To develop concepts for the hydrologic system which may be integrated into a design to monitor effects of the proposed development.

3.2.1 Descriptions and Level 1 Analyses

These analyses were performed for each water source visited. Locations of each historic source were documented and locations refined as accurately as possible using the most detailed USGS topographic maps available (15') and within the limitations of time allowed for field exploration. New sources were sought, also within time constraints allowed. Previously undocumented water sources encountered were also described.

At each water source location, descriptive information and data were recorded on field data sheets (Figure 3.2-1). This information was recorded for all sites. Date, location (Township, Range, Section), field investigators name, source name, analytical measurements, physical characteristics and descriptive parameters were recorded at each source.

3.2.1.1 Analytical Measurements These are chemical and physical parameters measured by portable field instruments. They included temperature at a point near the emergence of the water source, dissolved oxygen, electrical conductivity and pH. Instruments used to measure these parameters were:

A.	Temperature	Mercury Bulb Thermometer
		Model 4000 Hydrolab
B.	Dissolved Oxygen	Yellow Springs Instruments (YSI) Model 54A Oxygen Meter

CANYONLANDS FIELD DATA
LEVEL 1 ANALYSES

Source Code: __________; Date: ____________; Technician: _________

Location (should also be marked on field maps): T _____, R _____, S _____, 1/4 _____;

Name of Source (if known): ___________________________

Analytical Measurements

Temperature (at source): ________ °C pH: __________

Dissolved Oxygen: ____________ mg/l

Conductivity

Standard		Sample	
Temperature	EC	Temperature	EC
______ °C	_____ μmhos	______ °C	____ μmhos

Physical Characteristics

Water Source Type (spring, seep, rise, stream, river): ___________________

Flow Characteristics:

Depth: __________ cm Width: ____________ m

Velocity: ___________ m/second Flow Volume: __________ l/minute

Substrate Fractions (not applicable to springs):

Dominant: _______________; Interstitial: ________________;

Descriptive Parameters

Photographs: Roll No. __________; Frame(s) __________;

General Description (position and condition):

Additional Notes:

Figure 3.2-1. Data sheet used for recording field information for each water source visited.

	Model 4000 Hydrolab
C. Electrical Conductivity	YSI Model 33 Salinity-Conductivity-Temperature Meter
	Model 4000 Hydrolab
D. pH	VWR Scientific Model 55 Digital Mini pH meter

Dissolved oxygen meters were calibrated for temperature and elevation at each source. The pH meter was calibrated in pH 4.0, 7.0, 9.0 standard solutions before each use.

3.2.1.2 Physical Characteristics These parameters characterized the water source as to type (spring, seep, rise, stream or river), flow volume and substrate size.

A. Source Type classifications followed the definitions given by Richter (1980) for springs, seeps and rises. These are repeated here.

1. Spring - a measurable discharge of groundwater to the ground surface or rock outcrop.

2. Seep - discharge of groundwater at such a small rate it is not possible to measure the discharge although it wets the surface.

3. Rise - water discharged from alluvium into a stream channel where the water in the alluvium flows to the surface as a result of thinning of the alluvium over bedrock highs.

Streams and rivers were considered as perennial sources (flowing year round). Therefore, all perennial sources other than the Colorado and Green Rivers were classed as streams. The ERI field investigation occurred during late April and early May, 1984 during a period of rains as well as when groundwater levels were high and evapotranspiration low. As a consequence, it was not possible to be completely confident of each classification. Best judgement was used in each case, but further verification should be made during drier periods.

B. Flow Volume was measured or estimated by a variety of methods. These included: (1) Marsh-McBirney magnetic flux flow meter, (2) V-notch weir, (3) collection in a marked container over a timed interval, and (4) estimates using the "floating stick" method or visual estimates based on experience only. The methods for each flow measurement are delineated in the data report.

On larger streams, flow volume was calculated from measurements of width and depth coupled with average velocity measured using the Marsh-McBirney meter. Springs and smaller streams were dammed using a V-notch 90° triangular weir (Stock 1955). Flow volume was then calculated using the following equation:

$$Q = 2.52\ H^{2.47}$$

where: Q = discharge (cfs)
H = height of water in the notch (feet)

Small springs, particularly those dripping or falling from rock outcrops were measured by collecting water in a container over a timed interval. Flow volume per unit time was then calculated. Flow volume for some sources, such as Big Spring Canyon while in flood were estimated.

C. Substrate Fractions, or the sizes of the two major substrate groups were visually estimated and recorded. Dominant substrate consisted of that present in largest amount in the source. Interstitial substrate (usually smaller size fractions) was that occurring in the next greatest amount. Size classes were based upon a modified Wentworth scale (Wentworth 1922 and Cummins 1962) and are presented in Table 3.2-1.

Table 3.2-1. Substrate size classification.

Size Class	Description	Diameter (mm)
Clay	sticky, usually compact	<0.0039
Silt	usually loose, sticky	0.0039-0.0625
Sand	gritty	0.0625-2
Gravel	small, generally round or oval	2-64
Cobble		64-256
Boulder		>256
Bedrock	solid rock	--

3.2.1.3 Descriptive Parameters Each water source visited was photographed for the record except for the few instances in which a camera was unavailable. Descriptive information was then recorded including the position of the water source within the drainage and other locational details. Information about the general condition of the water source was recorded at the field observers discretion. Riparian vegetation was noted where present.

3.2.2 Descriptions and Level 2 Analyses

A limited number of locations (22) were selected for Level 2 analyses. Sources were selected based upon, (1) location up and down gradient from the proposed repository site, (2) potential drinking water sources for park and backcountry use, and (3) relative permanence.

3.2.2.1 Data collected at each Level 2 source consisted of descriptions and Level 1 data as described above and four separate groups of samples (1) biological, (2) macrochemistries, (3) metals and (4) radiological. In addition, at the Colorado and Green River sample sites, interstitial sediment, benthic organic matter, sediment organic and macroinvertebrate samples were taken. A list of analyses undertaken in each group are presented in Table 3.2-2. Metals analyses were an optional work element which NPS elected not to perform at this time. Collected samples are being held at the ERI facility in Logan, Utah.

Table 3.2-2. Analyses conducted for Level 2 sample sites.

Biological	
1.	Total coliforms
2.	Fecal coliforms
3.	Chlorophyll a
Radiological	
1.	Gross alpha (suspended U-natural)
2.	Gross beta (suspended C_s 137)
Macrochemistry	
1.	Alkalinity as $CaCO_3$
2.	Total suspended solids @ 105°C
3.	Total nitrogen as N
4.	Ammonia (NH_3-N)
5.	Nitrate (NO_3-N)
6.	Nitrite (NO_2-N)
7.	Total phosphorous as P
8.	Orthophosphate (PO_4-P)
9.	Total organic carbon
10.	Total hardness as $CaCO_3$
11.	Sodium
12.	Chloride
13.	Sulfate
14.	Dissolved solids

3.2.2.2 Methods of Collection The following briefly describe collection methods used for each type of sample.

A) Biological Samples Water samples for coliforms and chlorophyll a were collected in labeled sterile whirlpak bags. Bags were then protected by double bagging in Ziploc bags. Samples were kept in the dark and placed on ice as soon as possible. Samples were held on ice until delivered to the ERI laboratory in Logan, Utah.

B) Macrochemistry Samples Water samples were placed in two-liter plastic bottles which had been acid washed prior to the field trip. These bottles were labeled with date, site location and time. Prior to collecting samples, the bottles were rinsed with water from the source then filled with well mixed water from the source. Two drops of chloroform were added to reduce microbial activity. The bottles were shaken and placed in ice-filled coolers as soon as possible.

C) Metals Samples Water samples were hand pumped through a 0.45 micron filter into 100 ml sample bottles which had been acid washed. The sample bottles contained four or five drops of concentrated nitric acid.

D) Radiological Samples Two liter radiological sample bottles with prepared labels were obtained from the State of Utah Department of Health Laboratory in Salt Lake City. These bottles contained one milliliter of nitric acid. In addition, a 50 ml sample bottle was provided. At each sample site, both bottles were filled with water from the source.

E) Macroinvertebrates and Benthic Organic Matter In Colorado and Green River sources, macroinvertebrate samples were taken using a Surber sampler which samples 1 ft^2 area. Samples were placed in

labeled Ziploc bags and preserved with 10% formalin. Rose Bengal dye was added to each sample to stain the macroinvertebrates to facilitate sorting. The benthic organic matter associated with each macroinvertebrate sample was collected with the invertebrate sample.

F) Interstitial Sediment and Sediment Organic Matter At each location adjacent to macroinvertebrate samples in the Colorado and Green Rivers, a 4.6 cm diameter Lexan core tube was used to collect sediments for size fraction and organic content analysis in the laboratory. Samples were placed in labeled Ziploc bags for transport to the laboratory.

3.2.3 Fisheries Investigation

Although not required by the contract, it was decided that a brief fishery survey be made at appropriate locations in the Indian Creek and Salt Creek drainages while other data collection efforts gave field crews the opportunity to be in the area. Areas at the mouth of Salt Creek and Indian Creek which had previously yielded fish were seined using a 15' x 1/4" mesh seine. Three locations in Indian Creek were electrofished with a Coffelt 110-volt DC backpack generator shocker. These were downstream from Dugout Ranch including:

1. Confluence of Lavender Canyon (LC-15)
2. Highway 211 crossing (IC-6)
3. Site IC9 about 3.5 km downstream of Highway 211

No fish have been reported in Indian Creek between Dugout Ranch and one mile above the confluence with the Colorado River. It was felt important to provide additional information on the fishery of Indian Creek as it is the drainage potentially most affected by the repository.

3.3 LABORATORY METHODS

Methods are described by reference to readily available sources where standard methods were used. All chemical analyses were performed by state of Utah certified laboratories following state and EPA approved analytical and quality control procedures.

3.3.1 Chemical, Radiological and Microbiological Analyses

Table 3.3-1 presents the method reference and laboratory performing each chemical analysis.

3.3.2 Macroinvertebrates and Benthic Organic Matter

Benthic macroinvertebrate samples were floated in a sugar-water solution and poured through a USA Standard No. 60 Testing Sieve to separate organic from inorganic materials. Insects were then sorted from the organic material. The coarse particulate organic matter (CPOM) or benthic organic matter and macroinvertebrate samples was dried at 105°C for 24 h and weighed on a top-loading Mettler Balance to the nearest 0.01 g.

Each macroinvertebrate sample was then processed under a binocular dissecting microscope equipped with a calibrated ocular micrometer. Each invertebrate was identified to the family level and length measured to the nearest 1 mm. All samples remain preserved in the ERI reference collection.

Table 3.3-1. Summary of methods and analyzing agencies for chemical analyses.

Parameter	Methods Reference	Laboratory
Alkalinity as $CaCO_3$	Std Methods[1] p.253-257	ERI[2]
Total Suspended Solids	Std Methods p.94-96	ERI
Total Nitrogen as N	Solorzano&Sharp[3]p.751-754	ERI
Ammonia (NH_3-N)	Std Methods p.363-366	ERI
Nitrate (NO_3-N)	Std Methods p.370-373	ERI
Nitrite (NO_2-N)	Std Methods p.380-383	ERI
Total Phosphorous as P	Std Methods p.413-415	ERI
Orthophosphate (PO_4-P)	Std Methods p.420-421	ERI
Total Organic Carbon	Std Methods p.471-475	UWRL[4]
Total Hardness as $CaCO_3$	Std Methods p.194-199	ERI
Sodium	Std Methods p.152-155	ERI
Chloride	Std Methods p.271-273	UWRL
Sulfate	Std Methods p.439-440	ERI
Dissolved Solids	Std Methods p.92-94	ERI
Gross Alpha	Std Methods p.574-579	USHL[5]
Gross Beta	Std Methods p.574-579	USHL
Total Coliforms	Std Methods p.806-812	ERI
Fecal Coliforms	Std Methods p.814-817	ERI
Chlorophyll a	Std Methods p.929-939	ERI

(1) Standard Methods, 1980, 15th Edition, Am. Public Health Assoc., 1134 pgs.

(2) Ecosystem Research Institute, 975 So. State Hwy, Logan, Utah.

(3) L.Solarzano and J.H. Sharp, 1980 Determination of total dissolved Nitrogen in natural waters. Limnol. Oceanogr. 25(4):751-754.

(4) Utah Water Research Laboratory, Utah State University, UMC82, Logan, Utah.

(5) Utah State Health Laboratory, Salt Lake City, Utah.

3.3.3 Interstitial Sediment and Sediment Organic Matter

Samples were dried at 105°C for 24 h and sieved into five size fractions (Table 3.3-2). Approximately 1 g of the smallest sediment size fraction (<0.125 mm) was redried in a preweighed crucible for 24 h at 105°C, cooled in a dessicator to room temperature, and weighed to the nearest 0.00001 g on an analytical balance. The samples were then burned in a preheated muffle furnace at 500°C for 20 min, cooled and reweighed. The weight loss on ignition was calculated as sediment organic matter.

Table 3.3-2. Size fractions used for classifying interstitial sediment samples.

Fraction No.	Size (mm)
1	>12.5
2	> 4.0
3	> 2.0
4	> 0.5
5	> 0.25

3.4 DATA ANALYSIS METHODS

3.4.1 Macroinvertebrate Number and Biomass Determinations

The number and biomass of macroinvertebrates per square meter in six groups as well as the total number and biomass was calculated by location by sampling period. A mean for each of these values for each location (usually 2 or 3) was calculated.

Most invertebrates are placed into one of four functional groups (herbivore, detritivore, omnivore and predator) based on food type. Those that are terrestrial in habit are lumped in a terrestrial category while those that cannot be identified completely enough are placed in a category labeled 'Other'. Only larva, nymph, pupa and adult life stages are considered in this analysis.

The mean number and biomass in each of the six groups for a given location and date were calculated as follows:

$$\text{Number in group}_i\ (\#\text{'s}/m^2) = \frac{1}{n} \sum_{j=1}^{n} N_{ij} / A$$

$$\text{Biomass in group}_i\ (mg/m^2) = \frac{1}{n} \sum_{j=1}^{n_i} B_{ij} / A$$

where: n = number of replicates taken

N_{ij} = number of invertebrates of group $_i$ in replicate $_j$

B_{ij} = biomass of all invertebrates in group $_i$ in replicate $_j$

A = area (m^2) of benthic sample

The total numbers and biomass for a given location and date were calculated as the sum of the numbers and biomass in the six groups.

The biomass of all individuals in group i for a given sample replicate was calculated by summing the estimated biomass of all individuals in group i in replicate j.

The biomass of an individual invertebrate was estimated as follows:

$$\text{Biomass (mg)} = a\ (\text{len})^b$$

where: len = length (mm) of body of invertebrate

a and b = appropriate weight-length relationship constants (Table 3.4-1.

3.4.2 Cluster Analyses

In an attempt to look for similarities in water quality between locations, cluster analyses were performed. Cluster analysis uses quantitative or qualitative attributes of objects to determine which of the objects are most similar. Resemblance coefficients are calculated between each pair of objects using the attributes of each. These coefficients measure how similar each pair of objects are. The resemblance coefficients are then used to cluster the objects into groups that are similar.

Table 3.4-1. Weight-length constants for macroinvertebrates (Smock 1980).

Order	Order Code	a	b
Coleoptera	COL	.1528	2.18
Diptera	DIP	.0054	2.43
Ephemeroptera	EPH	.0066	2.88
Hemiptera	HEM	.0314	2.40
Megaloptera	MEG	.0029	2.75
Odonata	ODO	.0140	2.78
Plecoptera	PLE	.0023	3.39
Trichoptera	TRI	.0019	3.12
General Terrestrial	TER	.0300	2.62
All Others	(all others)	.0190	2.46

In this study, two levels of cluster analyses were conducted: 1) at the level of drainages; and 2) at the level of individual springs and wells. The first analysis was conducted to see which drainages had water sources that were similar, while the second was done to see which specific sites were most similar.

In this analysis, water sources were the objects that were clustered. Chemical properties of the water sources were used as attributes for clustering. Those water sources with the most similar chemical properties should cluster together.

At the drainage level, water source sites within each drainage were combined to generate drainage-wide sources of clustering. The list of all water quality parameters measured were reduced to eight which included all the major drainages that were sampled. They were hardness, conductivity, pH, chloride, sulfate, calcium, magnesium and sodium. This reduction in parameters considered was due to the sporadic sampling of individual water sources. All data collected for each drainage was averaged to produce a mean value for the given chemical attribute.

At the level of individual water sources, a group of water quality attributes were selected for the cluster analysis which would include the greatest number of sources. Again, sporadic sampling reduced the number of chemical attributes that could be used. A total of five were included in the analysis (hardness, conductivity, pH, chloride and sulfate). A mean value was calculated for each source from all the data collected.

A variety of methods are available for calculating resemblance coefficients and for clustering the resulting coefficients (Romesburg 1984).

In both levels of analysis, the data was first normalized. This allows for attributes with different ranges of values and units to be weighed equally in cluster analysis (Romesburg 1984). Two different resemblance coefficients were then calculated; 1) Pearson product-moment correlation coefficient, and 2) the average Enclidean distance (see Romesburg 1984, for discussion of formula). These were then clustered using two different methods: 1) single linkage, and 2) UPGMA (unweighted pair-group method using arithmetic averages), (see Romesburg 1984, for discussion of these formulas). The resulting combination of clustering method and resemblance coefficient which produced the most discernable groupings was selected for each of the two levels of analysis. A computer program created by K. Marshall (Romesburg and Marshall 1984) was used to do the calculations involved in these analyses.

4.0 RESULTS AND DISCUSSION

4.1 FIELD INVESTIGATION

Field investigations commenced in April, 1984 and were conducted according to methods described in Section 3.0. Three major drainages were the focus of field efforts. These were: 1) Colorado River from Potash, Utah upstream from Canyonlands National Park to Hite Marina, Lake Powell; 2) Indian Creek and two ephemeral tributaries in Davis and Lavender Canyons; and 3) Salt Creek and three ephemeral tributaries Big Spring Canyon, Little Spring Canyon and Squaw Canyon. Other miscellaneous sites were visited. See Figures 1.2-1 and 4.2-1 (in map pocket) for study area boundaries and water source locations.

During this field investigation, ERI crews visited a total of 107 sites. Seventy-nine (79) of these had been located in previous investigations and twenty-eight (28) were newly identified by ERI. Thirty-three (33) of the historical sites visited were dry, rendered unidentifiable by runoff or not at the location indicated. Most sites visited were documented with photographs to facilitate future identification and for comparisons for monitoring. One complete set of duplicate slides is included as Volume IV. The alpha numeric coding system for slide reference is described in Volume IV.

Adverse conditions encountered during the field investigations included heavy snowfall and rain with large quantities of runoff. This hindered efforts to document or characterize the nature of many sources in drainage channels, particularly springs and rises.

4.2 SUMMARY OF WATER RESOURCES IN THE PROJECT AREA

Prior to the field investigation, historical references including Conner and Kepner (1983), Richter (1980), Sumsion and Bolke (1972) as well as BLM (Moab), NPS and USGS records were searched to identify known water resources within the project area. One hundred sixty-nine (169) water sources were identified. Twenty-eight (28) previously unidentified locations were characterized by ERI, bring the total number of sources to 197.

Each source was classified as a spring, seep, rise, stream, well, river, rainpool or lake. This classification was based upon ERI observations of sites visited. For sites not visited, the historical record was used. The total number of each source type is shown in Table 4.2-1.

Basic information needed to locate and describe each water source was organized into a systematic reference table (Table 4.2-2).

This table provides the water resources manager a systematic numbering system, location information and codes for computer data access, source description, historical references and type of data available for each of the 197 documented water sources. The details of each table heading are described in footnotes to the table.

Important features of this table include a basic systematic water source numbering system which can be expanded to include more information as desired by NPS. The basic numbering system is described in Figure 4.2-1.

In addition each water source with a quantitative data base which has been placed on magnetic tape has been given a latitude and longitude location code. The data tape has been prepared compatible with the USGS

Table 4.2-1. Summary of water source classifications for the Needles District, Canyonlands National Park and adjacent areas.

Source Type	Number
Spring	124
Seep	8
Rise	44
Well	7
River	7
Stream	2
Lake	2
Undescribed	2
Rainpool	1
Total:	197

Table 4.2-2. Summary of historic and current information for water sources within the Needles District and adjacent areas potentially affected by the Nuclear Waste Repository.

DRAINAGE AND LOCATION DESCRIPTION													DATA STATUS[8]						
														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	BASIC	DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
BEEF BASIN WASH (GYPSUM CANYON DRAINAGE)																			
BB-1	Spring	Cedar Mesa	FS	32	18	24	BB	37°59'10"	109°54'00"	6400	Richter(43)		Q		D				Home Water Spring
BB-2	Spring	Halgaito Elephant Cny	FS	32	18	28	BD	37 58 05	109 56 55	6000	Richter(44)		Q		0				North Home Spring
BB-3	Spring	Halgaito Elephant Cny	FS	32	18	29	DB	37 57 35	109 57 35	6000	Richter(45)		Q		0				Big Spring
BB-4	Spring	Cedar Mesa	FS	32	18	27	BC	37 56 05	109 56 10	6080	Richter(46)		Q		0				Little Home Water Spring
BB-5	Spring	Cedar Mesa	FS	32	18	36	AA	37 57 30	109 53 05	6320	Richter(47)		Q		D				Stanley Spring
BB-6	Spring	Halgaito Elephant Cny	FS	32	18	33	CD	37 56 42	109 56 55	6140	Richter(48)		Q		D				
BB-7	Spring	Cedar Mesa	FS	32	18	36	C	37 56 50	109 53 40	6240	Richter(49)								South Spring
BIG SPRING CANYON - TRIBUTARY OF LOWER SALT CREEK																			
BS-1	Seep	Cedar Mesa	NPS	31[9]	19	3	BD	38°06'58"	109°49'07"	5270	Richter(36), ERI, Sumsion	F	Q		D				Echo Spring
BS-1A	Seep	Cedar Mesa	NPS	30½	19	33		38 07 15	109 49 40	5040	ERI	E	Q						
BS-2	Spring	Cedar Mesa	NPS	30½	19	34	CA	38 07 28	109 49 28	5200	Richter(33), ERI, Sumsion	F	Q		D				Hangover or[10] Hanover Spring
BS-3	Spring	Cedar Mesa	NPS	30	19	27[11]	CD	38 08 30	109 49 25	5130	Richter(28), ERI, Sumsion	N	Q		D				Soda Spring
BS-4	Spring	Cedar Mesa[12]	NPS	30	19	26	CB[12]	38 08 50	109 48 55	5080[12]	Richter(29), ERI, Sumsion, Connor(7)	F	Q		D				Big Spring
BS-5	Spring	Alluvium[13] Cedar Mesa	NPS	30	19	15	AD	38 10 41	109 49 07	4780	Richter(19), ERI Sumsion	F	Q		D				Lower Big Spring
BS-6	Spring	Alluvium Cedar Mesa	NPS	30	19	15	AD	38 10 45	109 49 03	4760	Richter, ERI	F							
BS-7	Spring	Alluvium Elephant Cny	NPS	30	19	15	AA	38 10 55	109 49 06	4720	ERI	E	Q	B					-
BS-8	Seep	Elephant Cny	NPS	30	19	10	DD	38 11 13	109 49 07	4640	ERI	E		B					
BS-9	Spring	Elephant Cny	NPS	30	19	10	DB	38 11 18	109 49 12	4400	Richter(18), ERI	F		B					
BS-10	Rise	Elephant Cny	NPS	30	19	3	DA	38 12 18	109 48 55	4160	ERI	F		B					Needs Verification

Table 4.2-2. (Continued).

SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	DATA STATUS[8] FLOW	CHEMICAL BASIC	CHEMICAL DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
BUTLER WASH - TRIBUTARY OF RED LAKE CANYON																			
BW-1	Spring	Cedar Mesa	NPS	32	19	21	AC				Richter								
BW-2	Spring	Cedar Mesa	NPS	32	19	9	BB				Richter								
BW-3	Spring	Cedar Mesa	NPS	32	19	4	C				Richter								
BW-4	Spring	Cedar Mesa	NPS	31	19	29	CD				Richter								
BW-5	Spring	Cedar Mesa	NPS	31	19	20	C				Richter								
BW-6	Spring	Cedar Mesa	FS	32	19	6	BD				Richter								
BW-7	Spring	Cedar Mesa	FS	31	19	31	CB				Richter								
BW-8	Spring	Cedar Mesa	FS	31	18	36	AC				Richter								
BW-9	Spring	Cedar Mesa	FS	31	18	35	BA				Richter								
DAVIS CANYON - TRIBUTARY OF INDIAN CREEK																			
DC-1	Spring	Cedar Mesa	NPS	31	20	33	DC				Richter								
DC-2	Spring	Cedar Mesa	NPS	31	20	33	DA				Richter								
DC-2A	Rise	Alluvium	BLM	31	20	34	DD	38°01'55"	109°42'10"	5360	Conner(2)	F			D				Location Needs Verification
DC-3	Spring	Cedar Mesa	BLM	31	20	23	D				Richter, ERI	N							
DC-4	Spring	Cedar Mesa	BLM	31	20	24	B	38 04 17	109 40 40	5280	Richter, ERI	F	Q		D	Bio	Rad		
DC-5	Rise	Alluvium	BLM	31	20	24/13		38 05 12	109 39 20	5600	Richter, ERI	F							
DC-6	Spring	Cedar Mesa	BLM	31	20	13	DC				Richter, ERI	N							
DC-7	Spring	Cedar Mesa	BLM	31	20	13	DA				Richter, ERI	N							
DC-8	Rise	Alluvium	BLM	31	21	18	BA	38 05 16	109 39 25	5200	Richter(40), ERI	N			D				Davis Canyon Rise

Table 4.2-2. (Continued).

SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI STATUS[7]	FLOW	CHEMICAL BASIC	CHEMICAL DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
	DRAINAGE AND LOCATION DESCRIPTION												DATA STATUS[8]						
DRY FORK - TRIBUTARY OF LAVENDER CANYON																			
OF-1	Spring	Cedar Mesa	BLM	32	21	18	C				Richter								
DONNELY CANYON - TRIBUTARY OF INDIAN CREEK																			
DO-1	Spring	Wingate	8LM	31	22	32	CA				Richter								
ELEPHANT CANYON																			
EC-1	Spring	Cedar Mesa	NPS	31	19	9	DD	38°05'18"	109°49'55"	5600	Richter(39), ERI	F		B					Druid Arch
EC-2	Spring	Cedar Mesa	NPS	31	19	9	BB	38 06 05	109 50 25	5440	Richter, ERI	F							
EC-3	Spring	Cedar Mesa	NPS	31	19	4	AD	38 06 46	109 49 47	5400	Richter(35), ERI Sumsion	F	Q		0				Dorius Spring
EC-4	Spring	Cedar Mesa	NPS	30	19	28	AC	38 08 00	109 50 25		Richter(27), ERI	N							
EC-5	Spring	Elephant Cny[14]	NPS	30	19	9	DB	38 11 23	109 50 20	4750	Richter, Sumsion		Q						Elephant Spring
HORSE CANYON																			
HC-1	Seep	Cedar Mesa	NPS	31	20	4	A8	38°07'03"	109°43'30"	5200	Richter(38), ERI	F	Q		0				Paul Bunyan Spring
HC-1A	Rise	Alluvium	NPS	31	20	16		38 04 44	109 43 31	5280	ERI	E	Q	8					
HC-18	Rise	Alluvium	NPS	31	19	16	A	38 05 05	109 43 25	5240	ERI	F							
HC-2	Rise	Alluvium	NPS	30½	20	32		38 07 25	109 45 45	4960	Richter, ERI	F	Q		0	Bio	Rad		

Table 4.2-2. (Continued).

			DRAINAGE AND LOCATION DESCRIPTION										DATA STATUS[8]						
														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI STATUS[7]	FLOW	BASIC	DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
HARTS DRAW																			
HD-1	Spring	Navajo	BLM	31	22	16	DC				Richter								
HD-2	Spring	Navajo	BLM	31	22	9	BC				Richter								
HD-3	Spring	Navajo	BLM	31	22	5	BA				Richter								
HD-4	Spring	Navajo	BLM	31	22	5	BA				Richter								
HD-5	Spring	Navajo	BLM	30	22	30	CO				Richter								
HD-6	Spring	Wingate	BLM	30	22	4	CO	38°12'07"	109°30'5B"	5B00	Richter(23)								
HD-7	Spring	Wingate	BLM	30	22	5	00	38 12 17	109 31 30	5800	Richter(22)								
HD-8	Spring	Wingate	BLM	30	21	13	AC				Richter								
HD-9	Spring	Wingate	BLM	29½	22	31	AB	3B 13 40	109 32 52	5800	Richter(17)				D				Harts Draw Spring
HD-10	Spring	Navajo	BLM	29½	22	31	AB				Richter								
HD-11	Spring	Wingate	BLM	29½	22	31	AB				Richter								
HD-12	Spring	Alluvium	BLM	29½	22	31	CD				Richter								
HORSE THIEF CANYON																			
HT-1	Spring	Undivided Cutler	BLM	28	20	28	AB				Richter								
HT-2	Spring	Undivided Cutler	BLM	28	20	2B	AB				Richter								
HT-3	Spring	Undivided Cutler	BLM	28	20	21	DC	38°20'40"	109°43'17"	4000	Richter(10)								
HT-4	Spring	Undivided Cutler	NPS	28	20	21	CC	38 20 43	109 43 44	4240	Richter(9)								

Table 4.2-2. (Continued).

	DRAINAGE AND LOCATION DESCRIPTION												DATA STATUS[8]						
														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	BASIC	DETAIL	BIOL	RAD	FLORA FAUNA	REMARKS
<u>INDIAN CREEK</u>																			
IC-1	Stream	Alluvium	BLM	32	22	28	BB	37°58'25"	109°31'05"	6320	BLM(159)		Q		0	Bio			Kelly Ranch
IC-2	Stream	Alluvium	BLM	32	22	8	CC	38 00 25	109 32 10	5920	BLM(158)		Q		0				Shay Canyon
IC-3	Rise	Alluvium	BLM	31	21	24	AC	38 04 14	109 33 40	5280	BLM(157a)								Dugout Ranch
IC-4	Rise	Alluvium	BLM	31	21	24	BC	38 04 15	109 34 10	5280	BLM(157b)								Dugout Ranch
IC-5	Rise	Alluvium	BLM	31	21	24	BB	38 04 27	109 34 20	5280	BLM(157c)								Dugout Ranch
IC-6	Rise	Alluvium	BLM	30	21	28	OC	38 09 06	109 37 30	4920	BLM(156), ERI	F	Q	B	0	Bio		F	Highway 211 Crossing
IC-7	Rise	Alluvium	BLM	30	21	28	AB				Richter, ERI	N							
IC-8	Rise	Alluvium	BLM	30	21	21	CA				Richter, ERI	N							
IC-9	Rise	Alluvium	BLM	30	20	1	AA	38 12 40	109 40 15	4640	BLM(155), ERI	F	Q	B		Bio		F	Lockhart Basin Road
IC-9A	Rise	Alluvium	BLM	29½	20	33	AC	38 13 25	109 40 45	4400	ERI	F	Q	B					
IC-10	Spring	Undivided Cutler	BLM	29	20	18	CC				Richter, ERI	N							
IC-11	Spring	Undivided Cutler	BLM	29	20	18	CB				Richter(13), ERI	N							
IC-12	Spring	Undivided Cutler	BLM	29	19	13	AC				Richter, ERI	N							
IC-13	Seep	Undivided Cutler	BLM	29	19	12	OC				Richter, ERI	N							
IC-14	Rise	Alluvium	NPS	29	19	12	OC	38 17 25	109 46 45	4000	BLM(154b), ERI Conner(10)	F	Q		0			F	
IC-15	Rise	Alluvium	NPS	29	19	12	BO	38 17 38	109 46 55		BLM(154a), ERI	F	Q		0	Bio	Rad	F	
<u>KANE SPRINGS CANYON</u>																			
K-1	Spring	Wingate	BLM	27	22	20	CCB	38°26'05"	109°31'55"	4800	Richter(4)		Q		D				Kane Spring Canynn Spring
K-2	Spring	Wingate	BLM	27	22	32	DBC	38 24 25	109 31 35	5200	Richter(5)		Q		D				Kane Creek Seep
K-3	Spring	Wingate	BLM	27	21	26	DBC	38 25 24	109 31 20	4600	Richter(7)		Q		D				Trough Springs

Table 4.2-2. (Continued).

													DATA STATUS[8]						
DRAINAGE AND LOCATION DESCRIPTION														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	BASIC	DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
LAVENDER CANYON - TRIBUTARY OF INDIAN CREEK																			
LC-1	Spring	Cedar Mesa	NPS	32	20	25	BA				Richter								
LC-1A	Rise	Alluvium	NPS	32	20	13	CC	37°59'30"	109°40'45"	5600	ERI	E	Q	B					
LC-2	Seep	Cedar Mesa	NPS	32	20	12	DC	38 00 15	109 40 13	5600	Richter, ERI	F							
LC-3	Spring	Cedar Mesa	NPS	32	20	12	DD				Richter, ERI	N							
LC-4	Spring	Cedar Mesa	NPS	32	20	12	DD				Richter, ERI	N							
LC-5	Spring	Cedar Mesa	NPS	32	20	14	BB				Richter								
LC-6	Spring	Cedar Mesa	NPS	32	20	11	CD				Richter								
LC-7	Spring	Cedar Mesa	NPS	32	20	11	BB	38 00 12	109 41 50	5680	Richter								
LC-8	Spring	Cedar Mesa	NPS	32	20	11	DC	38 00 23	109 41 07		Richter								
LC-9	Spring	Cedar Mesa	NPS	32	20	11	DD				Richter, ERI	F							
LC-10	Rise	Alluvium	BLM	32	21	7	BB				Richter, ERI	N							
LC-11	Rise	Alluvium	BLM	32	21	6	AC	38 01 37	109 40 15	5360	Richter, ERI	F	Q	B					
LC-12	Spring	Cedar Mesa	BLM	32	21	6	AA				Richter, ERI	N							
LC-13	Spring	Cedar Mesa	BLM	31	21	32	CB	38 02 25	109 38 35	5360	Richter(42), ERI	N			0				
LC-14	Rise	Alluvium	BLM	31	21	32	BA	38 02 40	109 38 30	5280	Richter, ERI	F	Q		0	Bio	Rad		
LC-15	Rise	Alluvium	BLM	31	21	4	D	38 06 25	109 36 50	5140	ERI	E	Q		0	Bio	Rad	F	

Table 4.2-2. (Continued).

SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV (FT)[5]	REFERENCES[6]	ERI STATUS[7]	DATA STATUS[8] FLOW	CHEMICAL BASIC	CHEMICAL DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
LOCKHART BASIN																			
LK-1	Spring	Wingate	BLM	28	20	17	CB				Richter		Q		D				
LK-2	Spring	Wingate	BLM	28	20	16	BA				Richter								
LK-3	Spring	Wingate	BLM	28	20	9	OB				Richter(14)								
LK-4	Spring	Wingate	BLM	28	20	9	CC				Richter								
LK-5	Spring	Wingate	BLM	28	20	20	AC				Richter								
LK-6	Spring	Wingate	BLM	2B	20	20	DA				Richter								
LK-7	Spring	Undivided Cutler	BLM	28	20	25	80				Richter								
LK-8	Spring	Undivided Cutler	8LM	28	20	25	BD	38°20'25"	109°41'17"		Richter(11)				D				Lockhart Canyon Spring
LK-9	Spring	Undivided Cutler	BLM	28	20	26	A8				Richter								
LK-10	Spring	Undivided Cutler	BLM	28	20	25	8B				Richter								
LK-11	Spring	Undivided Cutler	BLM	28	20	22	DD				Richter								
LK-12	Spring	Undivided Cutler	BLM	28	20	27	AB				Richter								
LK-13	Spring	Undivided Cutler	BLM	28	20	22	AC				Richter								
LK-14	Spring	Undivided Cutler	8LM	28	20	24	AC				Richter								
LK-15	Spring	Undivided Cutler	BLM	28	20	24	OB				Richter								
LK-16	Spring	Undivided Cutler	BLM	28	20	24	D8				Richter								
LK-17	Spring	Undivided Cutler	8LM	28	20	15	C8				Richter								
LK-18	Spring	Undivided Cutler	BLM	28	20	2	AB				Richter								
LK-19	Spring	Wingate Cutler	BLM	28	20	11	B8				Richter								
LK-20	Spring	Undivided Cutler	BLM	28	20	10	AB				Richter								
LK-21	Spring	Undivided Cutler	BLM	28	20	10	AC				Richter								
LK-22	Spring	Undivided Cutler	BLM	28	20	15	BB				Richter								
LK-23	Spring	Undivided Cutler	BLM	28	20	15	BC				Richter								
LK-24	Spring	Undivided Cutler	BLM	28	20	16	DB				Richter								

Table 4.2-2. (Continued).

DRAINAGE AND LOCATION DESCRIPTION													DATA STATUS[8]						
														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	BASIC	DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
LOST CANYON - TRIBUTARY OF SQUAW CANYON																			
LO-1	Spring	Cedar Mesa	NPS	31	19	15	AC	38°05'00"	109°49'00"	5800	Richter								
LO-2	Spring	Cedar Mesa Alluvium	NPS	30	20	31	CO[15]	38 07 42	109 46 02	5030[15]	Richter(34), Sumsion, Conner(5), ERI	F	Q		0				Lost Canyon Spring
LO-3	Spring	Cedar Mesa	NPS	30	20	31	CC	38 07 40	109 46 42	5120	Richter(25), ERI	N							
LITTLE SPRING CANYON - TRIBUTARY OF BIG SPRING CANYON/SALT CREEK																			
LS-1	Spring	Cedar Mesa	NPS	30	19	23	AD[16]	38°09'50"	109°47'56"	4950[16]	Richter(24), Sumsion Conner(8), ERI	F	Q		D	Bio	Rad		Little Spring
LS-1A	Rain Pool		NPS	30	19	14	OB	38 10 50	109 48 00	4800	Richter(27)				D				
LS-2	Spring	Alluvium Elephant Cny	NPS	30	19	14	AA[17]	38 11 10	109 48 21	4780	Richter(20), ERI Sumsion	F	Q		D			1	Lower Little Spring Needs Verification
LS-3	Seep	Elephant Cny	NPS	30	19	14	AO	38 11 02	109 47 48	4780	Richter, ERI	F	Q	B					
LS-4	Spring	Elephant Cny	NPS	30	19	11	CA	38 11 03	109 47 52	4400	Richter, ERI	F							
NORTH COTTONWOOD CREEK																			
NC-1	Spring	Cedar Mesa	BLM	32	21	21	8A				Richter								
NC-2	Rise	Alluvium	BLM	32	21	22	8A				Richter								
NC-3	Rise	Alluvium	BLM	32	21	15	AB				Richter								
RED LAKE CREEK																			
RL-1	Rise (backwash)	Alluvium	NPS	30	18	34	OA	38°09'35"	109°55'35"	4000	ERI	E			D	Bio	Rad		
RUSTLER CANYON																			
RC-1	Spring	Undivided Cutler	NPS	29	19	11	CC	38°17'30"	109°45'23"	4800	Richter								
RC-1B	Seep	Alluvium Un. Cutler	NPS	29	20	7	0	38 17 35	109 45 25	4160	ERI	E		B					
RC-2	Spring	Undivided Cutler	NPS	29	19	7	DB	38 17 30	109 45 35	4160	Richter, ERI	F							
RC-2B	Rise	Alluvium	NPS								ERI	E							

Table 4.2-2. (Continued).

SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	DATA STATUS[8] FLOW	CHEMICAL BASIC	CHEMICAL DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
SALT CREEK																			
SC-1	Spring	Cedar Mesa	NPS	32	20	29	AD	37°58'20"	109°44'19"	6000	Richter, Conner(4)	F							
SC-1A	Rise	Alluvium	NPS	32	20	29	AO	37 58 20	109 44 20	6000	ERI	E	Q	B					
SC-1B	Spring	Alluvium	NPS	32	20	20	00	37 58 37	109 52 22	5960	ERI	E							
SC-2	Spring	All./Cedar Mesa	NPS	32	20	20	0B	37 58 53	109 44 40	5940	Richter, ERI	F	Q		0	Bio	Rad		
SC-3	Spring	Cedar Mesa	NPS	32	20	19	AB				Richter, ERI	N							Kirks Canyon
SC-4	Rise	Alluvium	NPS	32	20	17	AA				Richter, ERI	N							
SC-5	Rise	Alluvium	NPS	32	20	8	0B				Richter, ERI	N							
SC-6	Rise	Alluvium	NPS	32	20	5	DC				Richter, ERI	N							
SC-7	Rise	Alluvium	NPS	32	20	5	CA				Richter, ERI	N							
SC-7A	Rise	Alluvium	NPS	31	20	32	CC	38 02 05	109 45 05	5680	ERI	E		B					All American Man
SC-8	Spring	Cedar Mesa	NPS	31	20	31	80	38 02 32	109 45 48	5640	Richter, ERI	N							Upper Jump
SC-8A	Spring	Cedar Mesa	NPS	31	20	31	8C	38 02 30	109 46 10	5600	ERI	E	Q	B					
SC-8B	Rise	Alluvium	NPS	31	20	31	8C	38 02 25	109 46 15	5560	ERI	E	Q	B					
SC-8C	Rise	Alluvium	NPS	31	20	31	B8	38 02 35	109 46 05	5540	ERI	E	Q	B					
SC-8D			NPS	31	20	31	AC	38 02 30	109 45 40		Conner(3)		Q		0				Needs Verification
SC-8E			NPS	31	20	31	AC	38 02 30	109 45 40		Conner(4)		Q		0				Needs Verification
SC-9	Rise	Cedar Mesa	NPS	31	20	19	80			5360	Richter, ERI	N							
SC-10	Spring	Cedar Mesa	NPS	31	20	18	8C			5200	Richter, ERI	N							
SC-10A	Rise	Alluvium	NPS	30	20	7	CA	38 05 40	109 15 57	5160	ERI	E	Q		0	Bio	Rad		
SC-10B	Spring	Cedar Mesa	NPS	31	19	13	AA	38 05 14	109 16 36	5440	ERI	N							Cowboy Spring needs verification
SC-11	Spring	Cedar Mesa	NPS	31	20	6	A0[19]	38 06 55	109 45 15	5020	Richter(37), ERI Sumsion, USGS	N	Q		0				Peekaboo Spring (buried under debris)
SC-12	Spring	Cedar Mesa	NPS	31	20	5	BB				Richter, ERI	N							
SC-13	Rise	Cedar Mesa	NPS	31	20	6	BA				Richter, ERI	N							
SC-14	Spring	Cedar Mesa	NPS	30½	20	31	BO				Richter, ERI	N							
SC-15	Rise	Alluvium	NPS	31	20	6	BA	38 07 02	109 45 45	5280	Richter, ERI	F		B					
SC-16	Seep	Cedar Mesa	NPS	31	20	6	AB				Richter, ERI	F							
SC-17	Rise	Cedar Mesa	NPS	30½	20	32	BD				Richter, ERI	F							

(CONTINUED)

Table 4.2-2. (Continued).

	DRAINAGE AND LOCATION DESCRIPTION												DATA STATUS[8]						
														CHEMICAL					
SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	BASIC	DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
SALT CREEK (continued)																			
SC-18	Rise	Alluvium	NPS	30	20	32	CO				Richter, ERI	N							
SC-19	Rise	Alluvium	NPS	30	20	20	AB	38 10 00	109 44 50	4840	Richter, ERI	F	Q		0	Bio	Rad		
SC-20	Rise	Alluvium	NPS	30	20	7	DC	38 11 00	109 46 00	4800	Richter, ERI	F	Q	B					
SC-21	Spring	Elephant Cny[20]	NPS	30	19	12	AC	38 11 38	109 47 11	4730	Richter(21), Sumsion, ERI	F	Q		0	Bio	Rad		Lower Jump needs verification
SC-22	Spring	Elephant Cny	NPS	30	19	3	AO	38 12 17	109 49 00	4240	ERI	E	Q	B					
SC-23	Spring	Elephant Cny	NPS	30	19	3	AO	38 12 20	109 49 08	4240	ERI	E	Q	B					
SC-24	Rise	Alluvium	NPS	30	19	4	AA	38 12 34	109 50 06	4000	ERI	E	Q		0	Bio	Rad	F	
SC-25	Rise	Alluvium	NPS	30	19	4	AA	38 12 37	109 50 13	4000	ERI	E		B					
SQUAW CANYON																			
SQ-1	Spring	Cedar Mesa	NPS	31	19	3	OA	38°06'43"	109°48'48"		Richter, ERI	N							Needs Verification
SQ-2	Spring	Cedar Mesa Alluvium	NPS	30	19	25	CO[21]	38 08 35	109 47 30	5060[21]	Richter(30), Conner(6), Sumsion, ERI	F	Q		0				Squaw Spring
SQ-3	Spring	Cedar Mesa	NPS	30	20	20	CO	38 09 22	109 45 10	5000	Richter(25), Conner(1), Sumsion, ERI	F	Q		0				Cave Spring
SQ-4	Exp. Core			30	20	19	OC				Pure Oil, Sumsion								
TITUS CANYON																			
TC-1	Spring	Kayenta	BLM	32	21	14	OA	38°59'10"	109°34'05"		Richter(51)								
TC-2	Spring	Kayenta	BLM	32	21	13	CA	38 59 05	109 34 35		Richter(52)								
WELLS																			
W-1	Well	Cedar Mesa	NPS	30	20	21	CB	38°09'47"	109°44'27"	4930	NPS, ERI	F							Needles Well No. 1 Salt Creek
W-2	Well	Cedar Mesa	NPS	30	20	20	OA	38 08 50	109 46 35	4940	NPS, Richter(26), Sumsion, ERI	F	Q		0	Bio	Rad		Needles Well No. 2 Salt Creek
W-3A	Well	Cedar Mesa	NPS	30	20	30	CB	38 09 40	109 44 35	5020	NPS, Richter(32) Sumsion, ERI	F	Q		0		Rad		Needles Well No. 3A Headquarters Well
W-3B	Well	Cedar Mesa		30	20	30	CB	38 09 40	109 44 35	5020	NPS, ERI	F			D		Rad		Needles Well No. 3B Headquarters Well
W-4	Well	Cedar Mesa		30	19	25	CD	38 08 35	109 47 40	5080	NPS, Richter(31), Sumsion, ERI	F	Q		0				Needles Well No. 4 Squaw Spring
W-5	Well	Hilgaito Elephant Cny		30	20	20	AC	38 09 59	109 44 50	5000	NPS, Sumsion, ERI	F	Q		D				Needles Well No. 5 Canyonlands Resort

Table 4.2-2. (Continued).

SITE CODE	WATER SOURCE TYPE[1]	GEOLOGIC TYPE[2]	OWNERSHIP[3]	T(S)[4]	R(E)[4]	S[4]	QTR[4]	LATITUDE[4]	LONGITUDE[4]	ELEV[5] (FT)	REFERENCES[6]	ERI[7] STATUS	FLOW	CHEMICAL BASIC	CHEMICAL DETAIL	BIOL	RAD.	FLORA FAUNA	REMARKS
	DRAINAGE AND LOCATION DESCRIPTION												DATA STATUS[8]						
MISCELLANEOUS																			
MS-1	Spring	Elephant Cny	NPS	29½	19	35	BC				Richter								
MS-2	Spring	Elephant Cny	NPS	29½	19	35	AO				Richter								
MS-3	Spring	Cedar Mesa[18]	NPS	29½	19	36	BB	38°13'31"	109°47'49"	4390	NPS, Richter(16), Sumsion		Q		0				Looptrail Spring
MS-4	Spring	Elephant Cny	NPS	29	19	26	AO	38 15 10	109 47 58		Richter(15)								
MS-5				30	19	23	AC	38 05 07	109 42 30		Conner(9)				0			1	Pothole Point
MS-6				30	17	9		38 06 00	110 03 00										Big Water Spring Loc. Needs Verification
GREEN RIVER																			
G-1	River	Alluvium	NPS	30	19	7	C	38°11'26"	109°53'20"	3920	Conner(1), ERI	E			D	Bio	Rad		Colorado River Confluence
G-2	River	Alluvium	NPS	26	17½			38 31 40	109 59 25		Conner(2)				D				Mineral Bottom Boat Pamp
COLORADO RIVER																			
C-0	River	Alluvium	NPS	28	19	13	A	38°22'05"	109°46'15"	3940	Conner(1)				0				Lathrop Canyon
C-1	River	Alluvium	NPS	29	19	12	BC	38 17 45	109 47 05	3920	ERI	E			0	Bio	Rad		Indian Creek
C-2	River	Alluvium	NPS	30	19	7	C	38 11 43	109 53 15	3910	ERI	E			0	Bio	Rad		Green River Confluence
C-3	River	Alluvium	NPS	30	18	34	OB	38 09 35	109 55 45	3840	ERI	E			0	Bio	Rad		Red Lake Canyon
C-4	River	Alluvium	NPS	31	18	5	AC	38 06 52	109 57 43	3760	ERI	E			D	Bio	Rad		Y-Canyon
C-5	River	Alluvium	NPS	32	17	8	OC	38 00 22	110 04 20	3280	ERI	E			0	Bio	Rad		Gypsum Canyon
C-6A	Lake	Alluvium	BuRec					38 17 43	109 47 03		ERI	E			D	Bio	Rad		Hite -
C-6B	Lake	Alluvium	BuRec					37 53 45	110 12 40										

Table 4.2-2. Footnotes.

1. Source codes defined in text following Richter (1980). Codes given in table are those reported historically except for sites visited by ERI which are given classification by ERI as of April, 1984.

2. Geologic type taken from Huntoon et al. (1982).

3. Ownership

   BLM - Bureau of Land Management
   NPS - National Park Service (Canyonlands)
   FS - U.S. Forest Service

4. Location codes

   T - Township
   R - Range
   S - Section
   QTR - Quarter sections as defined in Appendix I. Location codes for sites visited by ERI were determined as accurately as possible using 15-minute USGS topographic maps. Other location codes were taken from historical water quality records or reports. Where latitude and longitude were available from USGS records, these were used. Latitude and longitude were generally reported only for sites having water quality data. Latitude and longitude are used in the National Water Data Exchange to locate water quality records.

5. Elevations were taken from Sumsion (1972) where reported. Other elevations were estimated from 15-minute USGS topographic maps.

6. References are for historical water quality information which apply to the site. Numbers in parentheses are site codes used by the particular reference.

7. ERI status codes

   F - Historical site found during ERI April, 1984 field investigation.
   N - Historical site location visited during April, 1984 but not located.
   E - Apparently new site located by ERI during April, 1984.
   Blank - Historical site not visited during ERI field investigation.

8. Data status codes

   Q - Flow data reported
   B - Basic chemistry data reported. These generally include field parameters such as pH, dissolved oxygen, temperature and conductivity.
   O - Detailed chemistry data reported. These generally include laboratory determined parameters such as nutrients, metals, alkalinity, hardness, etc.
   Bio - Basic biological data reported. These data include chlorophyll a and/or coliform determinations.
   Rad - Radiological data reported. These are gross alpha and beta radiation.
   Flora/Fauna - Taxonomic information for periphyton(P), invertebrates(I) or fish(F) reported.

9. Location codes given by Sumsion (1972) as (0-31-19)3BO
   Richter (1980) as (0-30-19)38O

10. Source name reported by Sumsion (1972) as Hannover Spring
    Richter (1980) as Hangover Spring

11. Location codes given by Sumsion (1972) as (0-30-19)27CO
    Richter (1980) as (0-30-19)34CO

12. Location codes given by Conner (1983) as (0-30-19)26BC
    Sumsion (1972) as (0-30-19)25CB
    Richter (1980) as (0-30-19)26CB

    Geologic Formation given by Sumsion (1972) as Rico
    Richter (1980) as Cedar Mesa

    Elevation given by Conner (1983) as 5200'
    Sumsion (1972) as 5080'

13. Geologic Formation given by Sumsion (1972) as Rico
    Richter (1980) as Cedar Mesa

14. Geologic Formation given by Sumsion (1972) as Rico
    Richter (1980) as Elephant Canyon

15. Location Codes given by Conner (1983) as (0-30-20)31OC
    Sumsion (1972) as (0-30-20)31CO
    Richter (1980) as (0-30-20)31CO

    Elevations given by Conner (1983) as 5120'
    Sumsion (1972) as 5030'

16. Location codes given by Conner (1983) as UTM 4224 N 604 E
    Sumsion (1972) as (0-30-19)23AO
    Richter (1980) as (0-30-19)23OA

    Elevations given by Conner (1983) as 5000'
    Sumsion (1972) as 4950'

17. Location Codes given by Sumsion (1972) as (0-30-19)14AAB
    Richter (1980) as (0-30-19)14AOB

18. Geologic Formation given by Sumsion (1972) as Rico
    Richter (1980) as Elephant Canyon

19. Location Codes given by Sumsion (1972) as (0-31-20)6AO
    Richter (1980) as (0-31-20)5BC

20. Geologic Formation given by Sumsion (1972) as Cedar Mesa
    Richter (1980) as Elephant Canyon

21. Location Codes given by Conner (1983) as (0-30-19)25OC
    Sumsion (1972) as (0-30-19)25CO

    Elevations given by Conner (1983) as 5000'
    Sumsion (1972) as 5060'

WATSTORE System which uses the following code to identify each data set:

WATSTORE CODE: LATITUDE - LONGITUDE - STATION NUMBER

Latitude and longitude are expressed to the nearest second and stations are numbered increasing from one (1). Thus the WATSTORE code for station one (1) at latitude (37°50'10") and longitude (109°45'20") is expressed as the following 15-digit number:

375010109452001

The detail of data available on tape has also been included in Table 4.2-2 to aid the water resources manager in acquiring information. The codes include Q (discharge), B (basic water quality), D (detailed water quality), BIO (bacteriology and/or chlorophyll a), RAD (radiological) and FLORA/FAUNA as F, I, P (fish, invertebrate or periphyton). Basic water quality data includes normal field parameters such as conductivity, dissolved oxygen, pH and temperatures. Detailed water quality data includes any of the whole spectrum of laboratory analyses which were performed (nutrients, anions, cations, hardness, alkalinity, metals, etc.,).

The information presented in Table 4.2-2 provides the basic description of each source. Further information can be sought from additional sources using the table as a starting point. These are 1) WATER RESOURCES DESCRIPTIONS (Volume III), 2) WATER RESOURCES DATABASE (Volume III), 3) DATATAPE "NEEDLES" or 4) any of the original references listed in Table 4.2-2.

4.2.1 Detailed Source Descriptions

These descriptions include the following information:

ERI Code : Drainage location number (Figure 4.2-1)

Source Type : Spring, seep, etc.,

Formation : Geological zone of emergence point (Figure 2.1-1)

Position : Position within the topography i.e. stream channel, etc.

Photo : Code number for corresponding photograph(s) (Volume IV)

Substrate : Sand, cobble, etc., (Table 3.2-1)

Remarks : Notes concerning location or other field observations important to describing or characterizing the source.

This descriptive information for all sites visited by ERI is presented in Volume III - WATER RESOURCES DESCRIPTIONS AND DATABASE.

4.2.2 Database

This document (Volume III) provides the complete known historical data base in hard copy for all sources within the project area except the Colorado, Green and San Rafael Rivers. A data summary for each of these river locations is presented.

This river summary provides information for each of over 300 chemical and physical parameters for the river locations. The range of years over which data was collected for each parameter as well as the number of samples and minimum and maximum values are provided. This was done for the sake of brevity as the records for these stations were too voluminous to include. The complete data base for these locations contained on data tape is described in Volume III under USGS Gauging

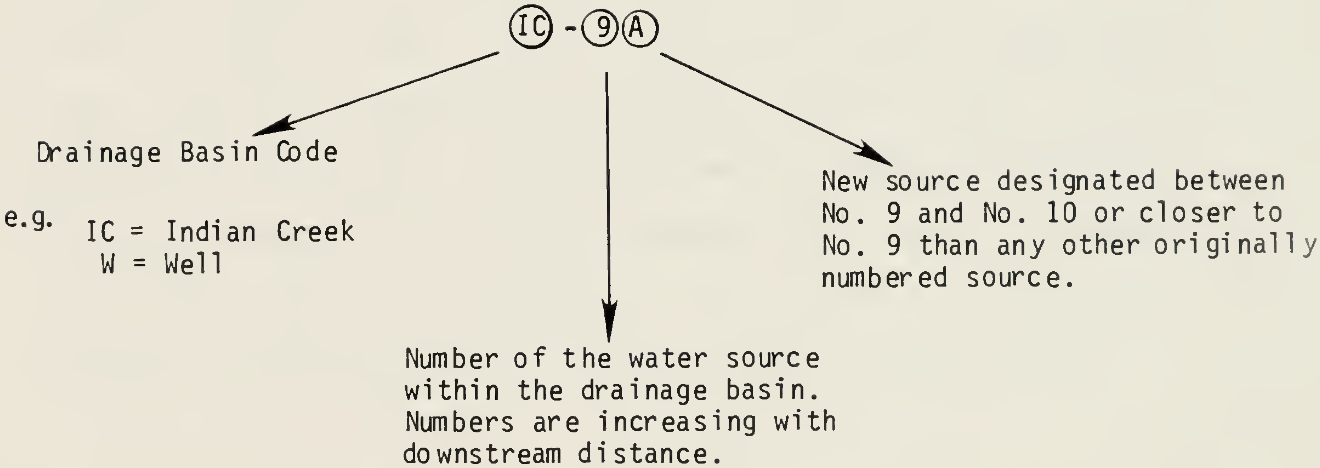


Figure 4.2-1. Numbering system for water resources.

Stations.

The remainder of the data contained within Volume III is the complete data base for non-river water sources. This hard copy is provided for ready reference for the water resouces manager. This data is also contained in the DATATAPE "NEEDLES".

The data base for the non-river water sources listed in Table 4.2-2 contains information on water quality and biology. Eighty-two (82) water sources of the 197 present in the project area have either basic or detailed data records. Most sites have been sampled only once. Few sources contain data collected over time to allow for the documentation of trends. Table 4.2-3 summarizes the number of sources for which each type of data has been reported. This table illustrates that little work has been done in the project area to provide a detailed characterization of the overall biology and water quality.

Table 4.2-3. Summary of data types available for water sources within the project area.

Data Type	Number of Sources
Basic Water Quality	22
Detailed Water Quality	62
Biology	22
Radiology	22
Flora/Fauna	8

4.2.3 Datatape "NEEDLES"

This tape of historic and current (ERI) data will supplement the information and data presented within this report and appendices. The normal management of the water resources program can function independently of the data tape using this report. However, for data retrieval, analysis or quantitative comparisons for monitoring the data tape will allow for greater speed and efficiency. The tape will be provided with the necessary documentation.

4.3 WATER QUALITY DATA SUMMARY AND ANALYSES

The understanding of spatial and temporal patterns of water quality and biology is important in the design of water quality programs. Temporal change within water sources occurs as a result of seasonal change and climatic factors such as rainfall, snowmelt and evaporation. In addition, residence time and dissolution within different geological strata, each with differing chemical characteristics, can affect water quality over time. Spatial changes occur as water flows down gradient, over and through differing soils and geologic strata and receives additions from natural or human point sources.

The data summarization and analyses that follow were developed in an attempt to provide an overview of historical trends and spatial patterns where they can be discerned. The level of analysis was limited in resolution by missing data or inconsistent data collection over time. The most complete data sets occurred at USGS gauging stations on the Green and Colorado Rivers. These allowed a look at historical trends in water quality over a long period of years. The remainder of the data base did not provide sufficient information for identifying temporal trends. An attempt to elucidate spatial trends was made by combining all the data at each station into station means regardless of the number of samples and applying cluster analysis (See 3.0 METHODS).

4.3.1 Colorado and Green Rivers

The number of physical and chemical parameters measured at the USGS stations exceeds 300. Maximum and minimum values for all parameters, period of record and number of samples represented are included in Volume III for

the following USGS stations in the vicinity of Canyonlands National Park:

1. Colorado River near Cisco, Utah
2. Colorado River above Mill Creek near Moab, Utah
3. Green River at Green River, Utah
4. San Rafael River near Green River, Utah

Volume III is intended to provide an easily referenced summary of water quality parameter values for these four locations. Graphical summaries of dominant physical and chemical characteristics of the Colorado and Green Rivers follow to demonstrate overall patterns and trends in the data. Major parameters including discharge, temperature, conductivity, suspended solids and total sediment load are presented. Selected data, including total monthly discharge and mean monthly suspended solids are presented to illustrate the contrasts between recent dry (1981) and wet (1982) years. The following data summary included data from USGS stations in the Colorado River near Cisco, Utah and the Green River near Green River, Utah.

Total annual discharge in the Colorado and Green Rivers has declined during the period of record (1895 to present). During the late 1800's until about 1930, flows in both rivers were high, approaching 9,000,000 acre-feet/year in each. Extreme flows (both highs and lows) appeared to follow an approximately four-year cycle. In 1930 low values of 3,000,000 acre-feet were approached. Since that time the overall discharge within both streams has remained lower than in pre-1935 (Figure 4.3-1). The four-year cycle of peaks and low flows has been consistent for the entire period of record. The change in overall flow could be attributed to

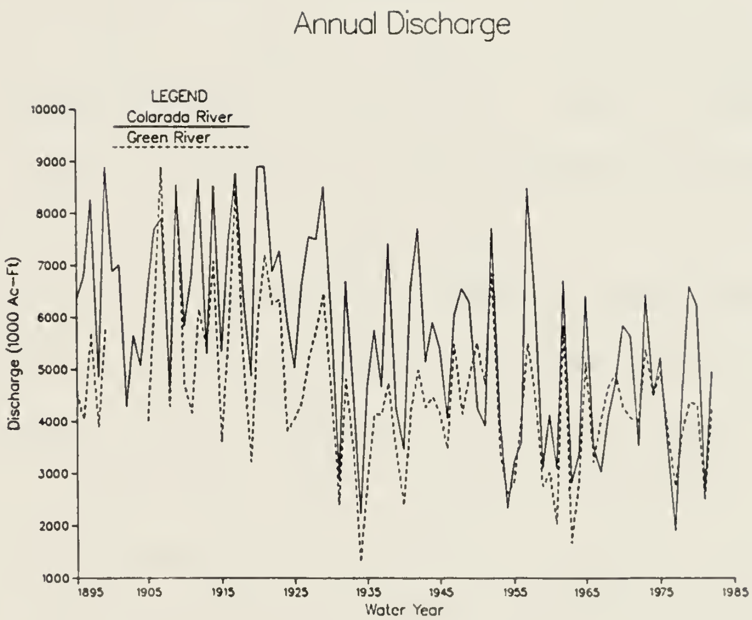


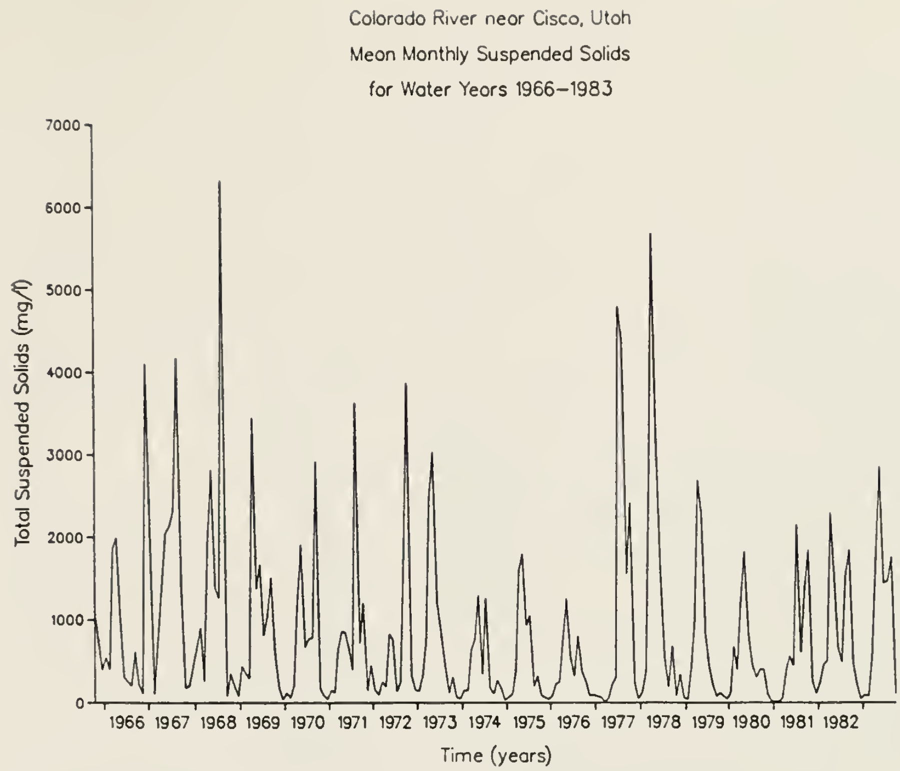
Figure 4.3-1. Annual discharge in the Colorado River near Cisco, Utah and the Green River near Green River, Utah for the period of record 1895-1982 (USGS 1983).

climatic change, upper basin development or both.

Mean monthly suspended solids (concentration) for both stations for the period of record 1964 to the present shows an annual cycle of high values corresponding to upper basin runoff (mountain snowmelt) during the June-July period (Figure 4.3-2). A secondary peak is usually observed during the lower basin runoff period (February - April). Suspended solids concentration follow a general pattern of increase during low discharge years and decrease during high water years. These values do not always follow a trend with discharge. High concentration of suspended solids may occur during either high or low water years.

A recent example occurred during 1980-1982 water years. The 1980-1981 water year, in the Colorado and Green Rivers was one of low discharge while the 1981-1982 water year was almost triple in discharge (Figure 4.3-3). The Colorado and Green Rivers each responded differently. The Green River contained high suspended solids concentration during the low water year (1980-1981) and low suspended solids concentration during the high water year (1981-1982). In the Colorado River during the same time, suspended solids concentrations followed a different pattern. Differences within the drainage basin geology or the presence of large dams on the Green River could explain these patterns.

A summary of the mean sediment load carried by the Colorado and Green Rivers for the period of record 1964 to 1983 (Figure 4.3-4) indicates that total sediment load was related to discharge. Higher discharge years generally were associated with higher sediment yields (Figure 4.3-5).



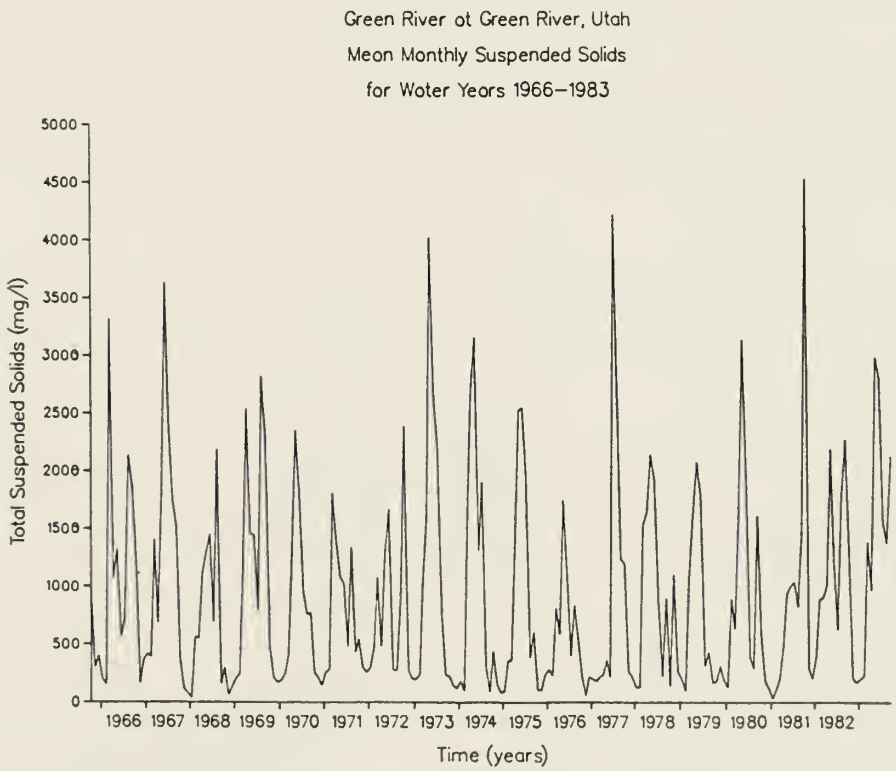


Figure 4.3-2. Mean monthly suspended solids concentration in the Colorado River near Cisco, Utah and the Green River near Green River, Utah for the period of record 1966-1983 (USGS 1983).

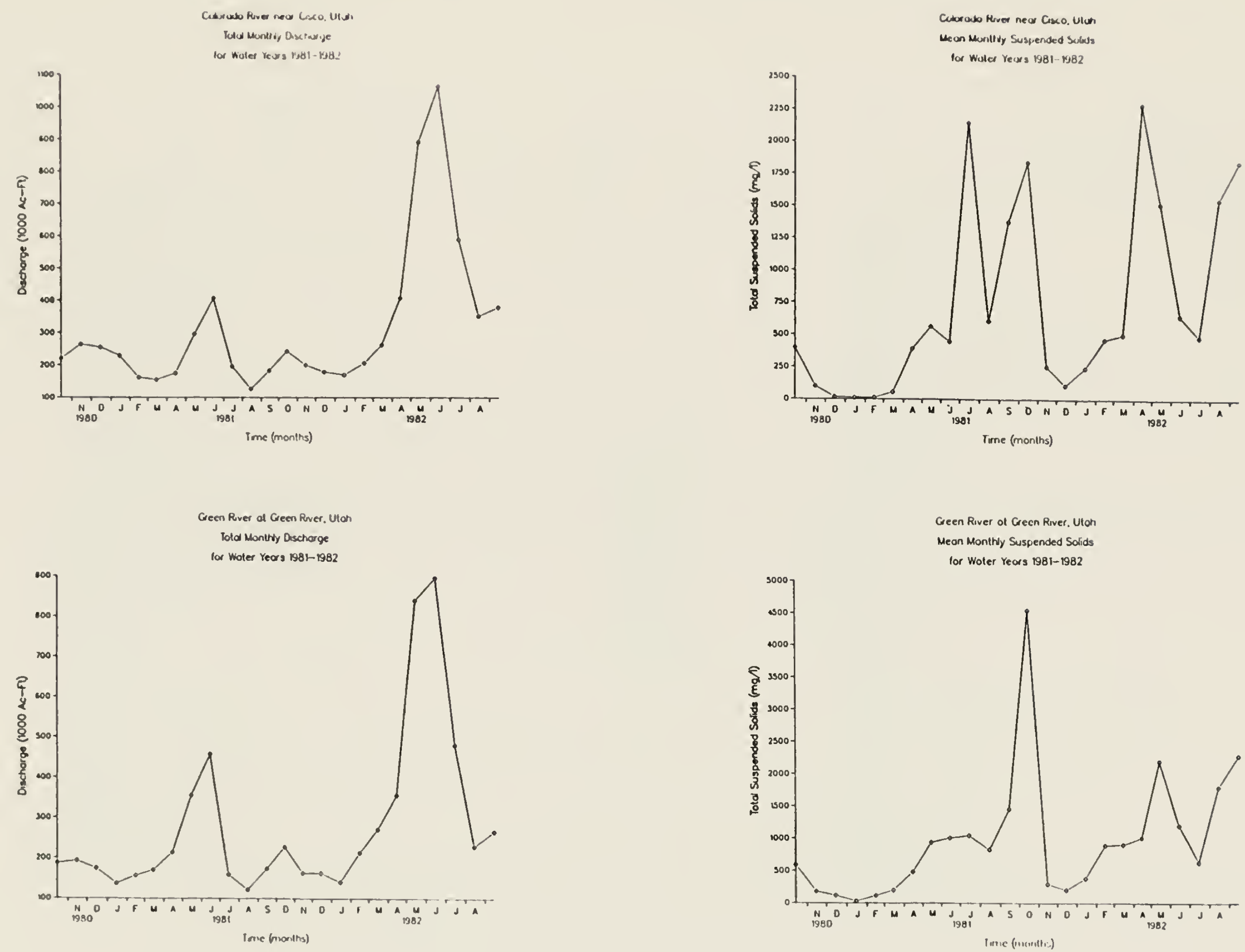
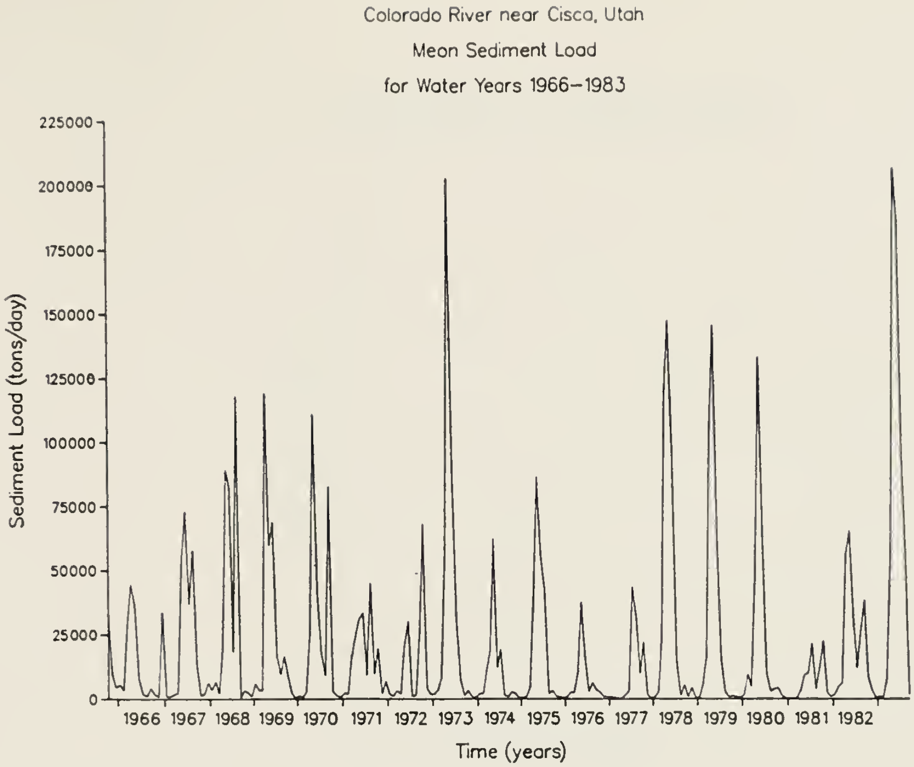


Figure 4.3-3. Total monthly discharge and mean monthly suspended solids concentration in the Colorado River near Cisco, Utah and the Green River near Green River, Utah for the period of record 1980-1982 (USGS 1983).



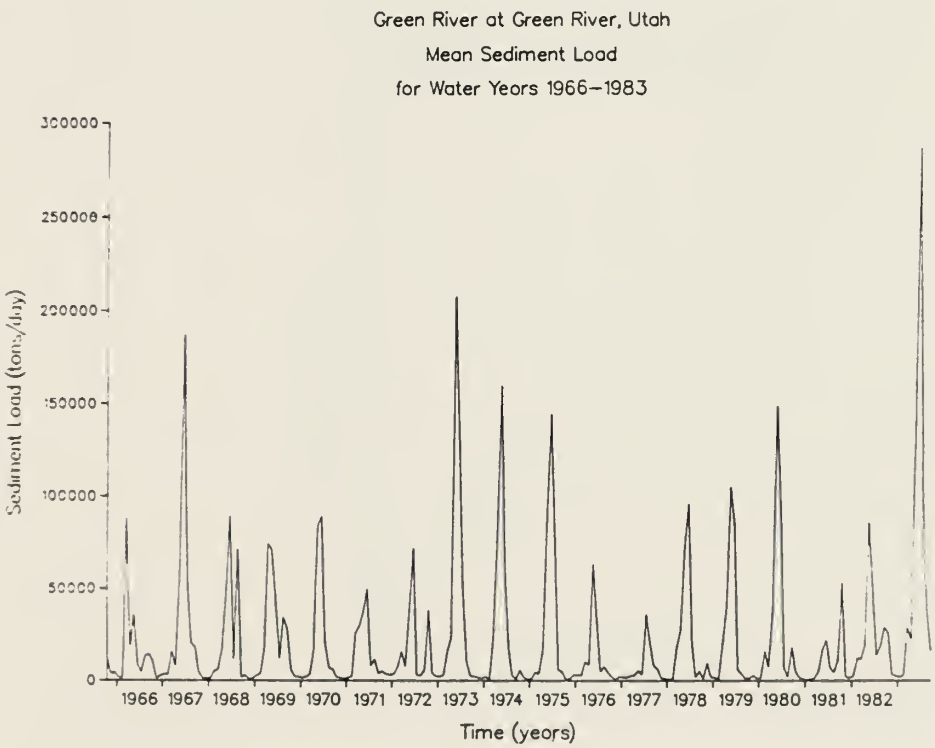
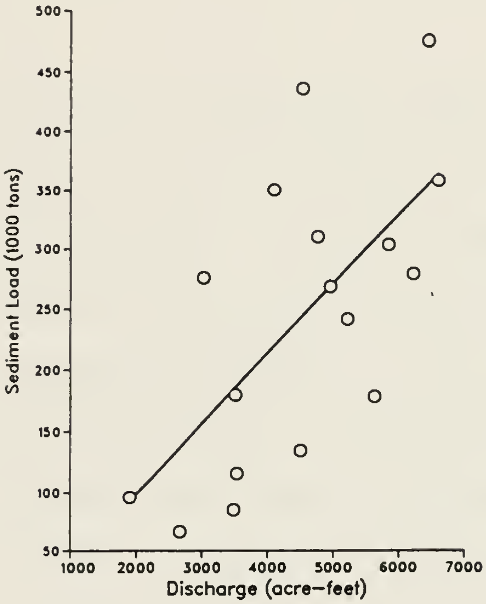


Figure 4.3-4. Mean sediment load in the Colorado River near Cisco, Utah and Green River near Green River, Utah for the period of record 1966-1983 (USGS, 1983).

Sediment Load as a Function of Discharge
Colorado River near Cisco, Utah



Sediment Load as a Function of Discharge
Green River at Green River, Utah

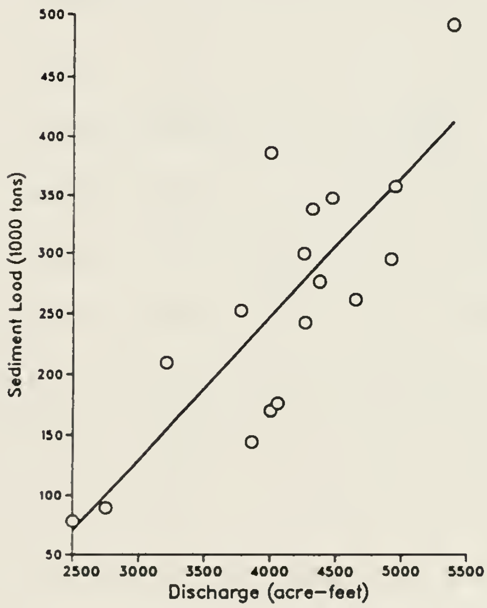


Figure 4.3-5. Sediment load in the Colorado River near Cisco, Utah and Green River near Green River, Utah as a function of discharge for the period of record 1964-1983.

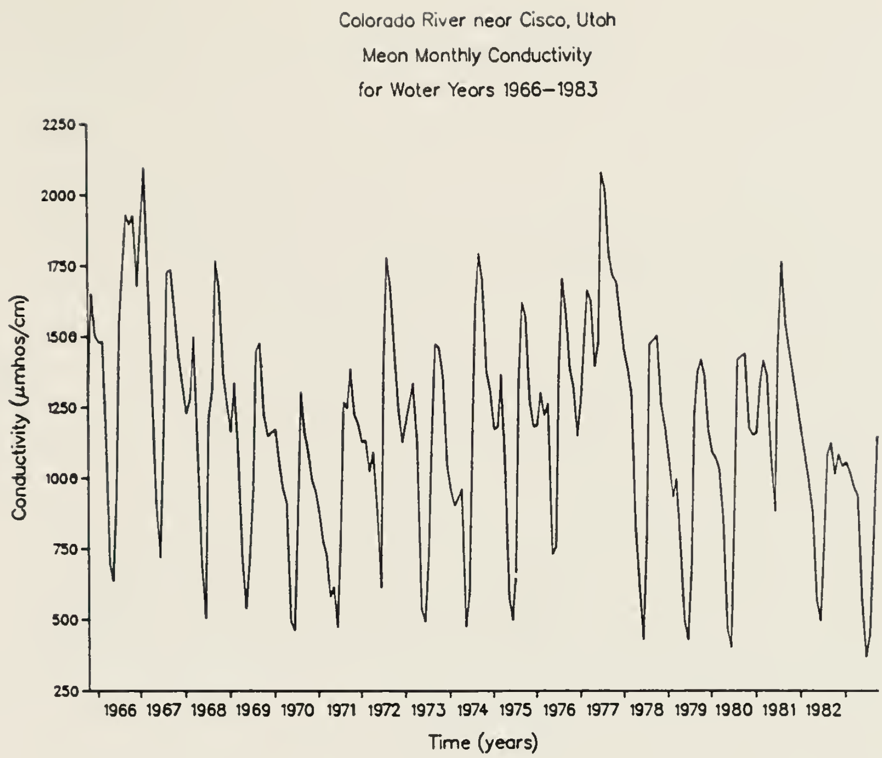
The historical patterns of mean monthly conductivity for the Colorado and Green Rivers (Figure 4.3-6) represents the content of dissolved constituents present in the water. A consistent pattern occurs within each year. As runoff occurs, dilution takes place, lowering the concentration (not total load) of dissolved constituents. This generally occurs during the June - July period of each year. During the remainder of the year with decreased flows, dissolved constituents concentrations and therefore, conductivity, were higher. Conductivities were generally higher in the Colorado River than in the Green.

The annual cycle of temperatures for the Colorado and Green Rivers (Figure 4.3-7) were similar during the period 1966-1983. An interesting trend has occurred in both rivers since 1976. The winter temperatures have increased substantially over those occurring in previous years.

4.3.2 Summary of Water Resources by Drainage

This summary includes 19 basin and sub-basin drainages and five wells within the project area. Macrochemistries which are typically used to characterize watersheds were used. Table 4.3-1 provides a summary of mean values by drainage basin for the ten macrochemistries including alkalinity, hardness, conductivity, pH, total dissolved solids, chloride, sulfate, calcium, magnesium and sodium. The number of data sets (separate sources and/or dates sampled) within each drainage is presented as well.

cluster analysis, using the Pearson product-moment correlation coefficient as the resemblance coefficient was used on this data set (Table 4.3-1) to determine which drainages were similar in macrochemistry. The clusters were produced using the UPGMA method of clustering. The



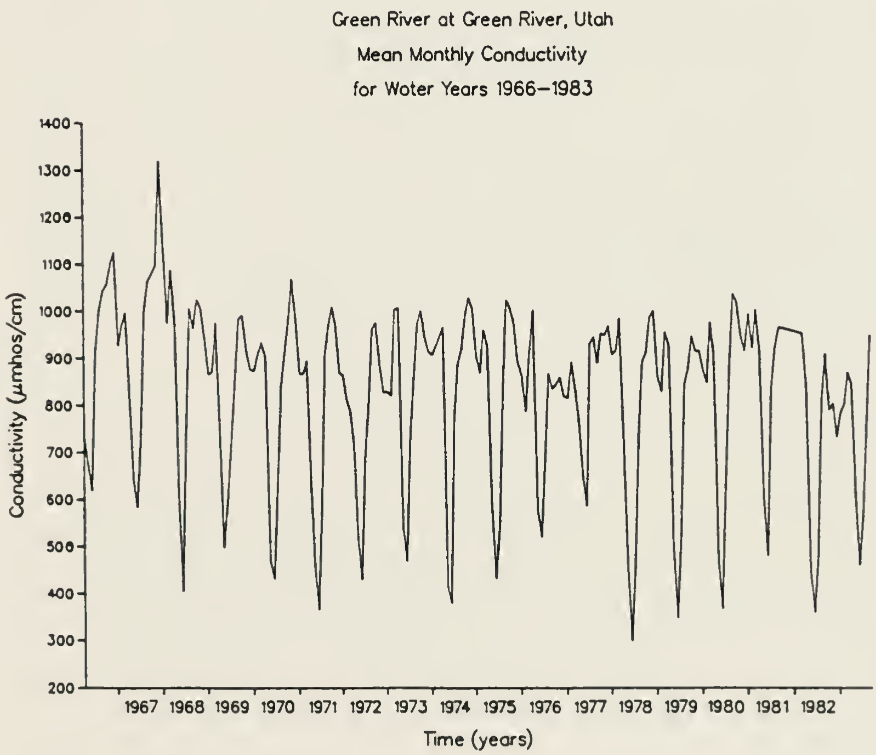
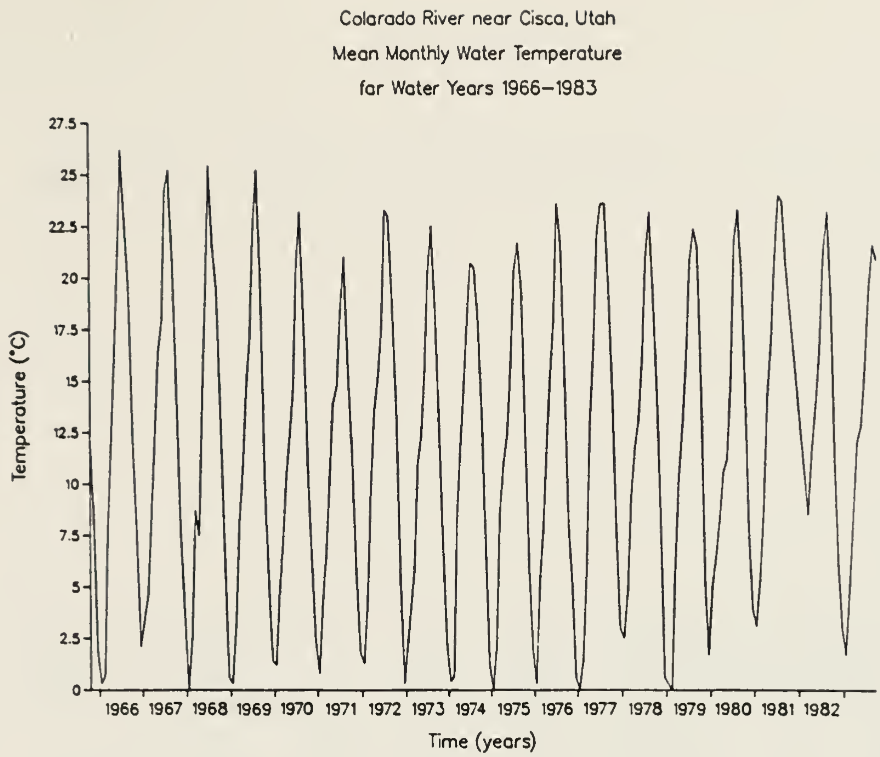


Figure 4.3-6. Mean monthly conductivity in the Colorado River near Cisco, Utah and the Green River near Green River, Utah for the period of record 1966-1983 (USGS 1983).



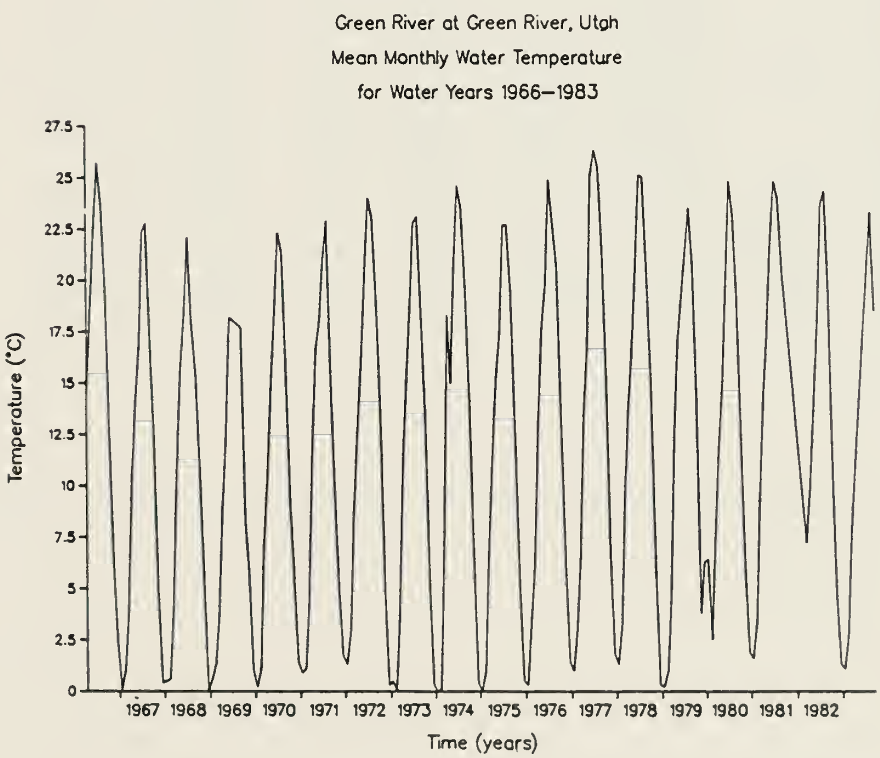


Figure 4.3-7. Mean monthly water temperatures in the Colorado River near Cisco, Utah and the Green River near Green River, Utah for the period of record 1966-1983 (USGS 1983).

Table 4.3-1. Summary of macrochemistries by drainage basin.

Drainage Code	Alkalinity (mg/l)	Hardness (mg/l)	pH	Cl- (mg/l)	SO4 (mg/l)	Conductivity (umhos/cm)	TDS (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	Na+ (mg/l)	(n)
BB		311.67	8.10	17.07	46.67	695.67		48.33	45.83	26.33	6
BS	181.80	238.20	7.82	4.21	15.68	466.44	225.80	67.22	14.23	7.60	18
DC	362.50	528.00	8.00	14.25	19.00	835.33		60.00	44.00	20.00	3
EC		221.00	8.31	3.80	1.80	285.00		69.00	12.00	3.00	5
HC	437.00	294.50	8.37	10.75	75.00	743.33		27.00	12.00	48.00	4
HD		160.00	7.80	13.00	13.00	356.00		30.00	20.00	3.80	1
IC	226.89	251.86	8.35	38.38	77.82	638.56	347.00	49.81	23.78	55.11	35
K		363.33	8.00	139.43	289.33	1456.00		47.67	58.67	179.33	3
LC	332.50	530.00	8.42	689.00	720.67	3436.40		110.00	73.00	899.50	7
LK		760.00	7.90	1100.00	1400.00	6240.00		180.00	76.00	1200.00	1
LO	275.00	338.67	7.95	10.00	17.87	611.00	361.00	71.00	34.00	15.00	4
LS	240.75	231.00	7.58	10.46	154.67	575.13	290.00	50.00	11.18	17.74	9
SC	384.50	535.10	7.94	258.67	292.12	1728.63	1269.50	35.67	64.90	300.46	20
SQ	200.00	330.00	8.14	17.40	35.80	647.20	277.00	68.67	38.00	32.00	7
W	308.74	340.00	7.75	59.44	98.52	893.00	714.67	73.13	39.90	77.27	35

Footnote: (n) = the number of data sets included in the mean.

combination of this clustering method and resemblance coefficient produced results which were clearest to interpret. To maximize the number of sites for the cluster analysis, only data sets containing values for conductivity, hardness, pH, chloride, calcium, magnesium and sodium sulfate were used. Unfortunately, the other major parameters were measured only sporadically and could not be included. The cluster analysis (Figure 4.3-8) produced two clusters at the lowest level of similarity (or greatest difference).

Comparing the means of the eight macrochemistries used in the analysis (Table 4.3-2), overall differences between the two clustered groups were evident. Cluster No. 2 exceeded Cluster No. 1 in ionic concentration for all constituents.

The classification system used by Richter (1980) following Robinove et al. (1958) places all sources with electrical conductivities between 0-1400 umhos/cm in the freshwater class with those between 1400-4000 umhos/cm as slightly saline. Based upon this, Cluster No. 1 would be characterized as representing freshwater sources while Cluster No. 2 represents slightly saline sources.

The explanation for these differences was postulated to be due to geologic differences between drainages. Table 4.3-3 summarizes the geologic strata for which data were used in the cluster analysis. There were no clear patterns although Cluster No. 1 was dominated by sources in the Cedar Mesa Formation or its alluvial positions. Clusters No. 2 and 3 contained sources within the more saline Elephant Canyon (Sumsion and Bolke 1972). Thus, the cluster analysis appears to provide a grouping of drainages based upon similarities in salinity which to some extent, even at the drainage

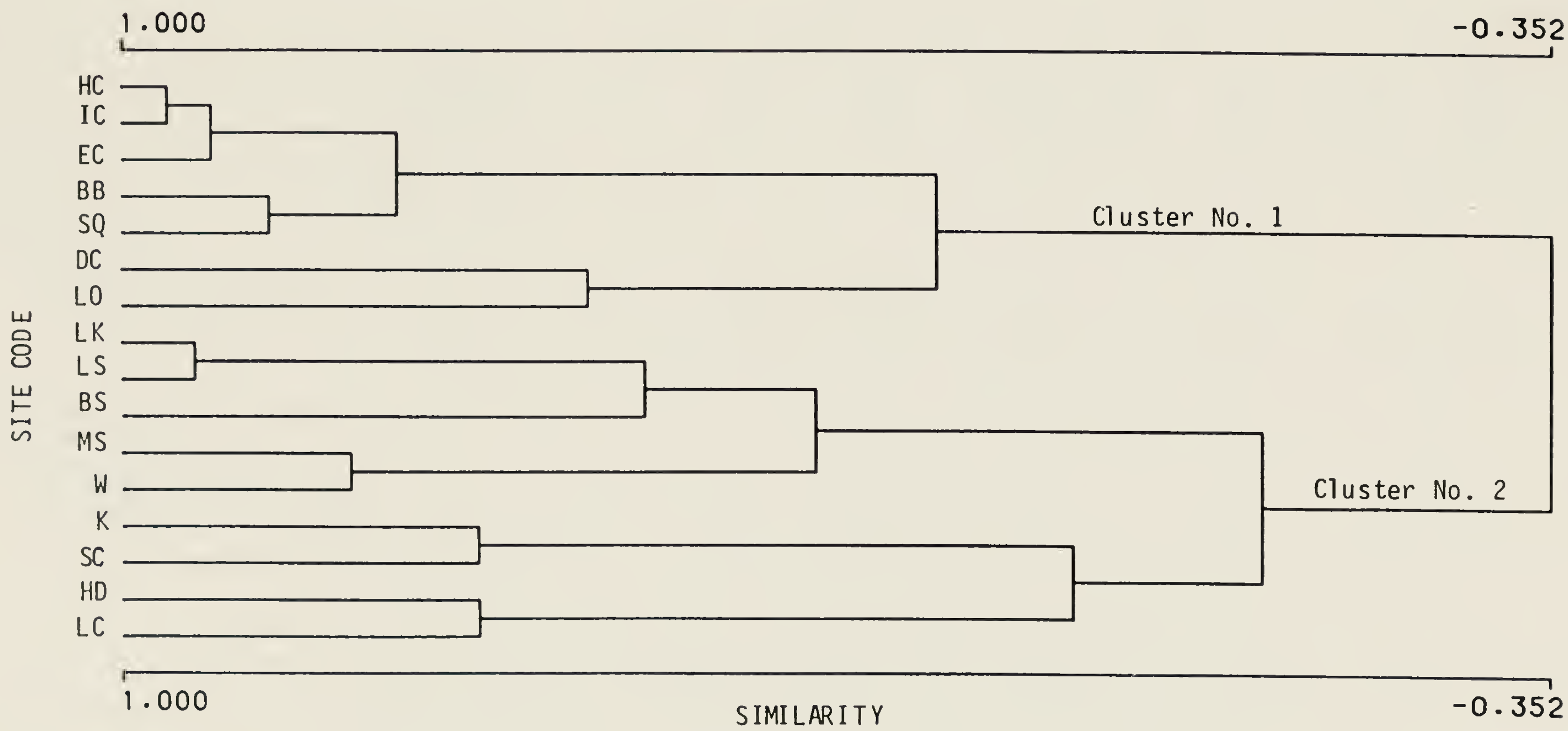


Figure 4.3-8. Cluster analysis by drainage basin.

Table 4.3-2. Means of dominant chemical parameters for clusters using drainage basin data.

	Hardness (mg/l)	pH	Cl^- (mg/l)	$SO_4^{=}$ (mg/l)	Conductivity (umhos/cm)	Ca^{++} (mg/l)	Mg^{++} (mg/l)	Na^+ (mg/l)
Cluster No.1								
Drainage BB, DC, EC, HC, IC, LO, SQ	325.1	8.17	23.5	39.1	636.6	56.2	29.9	28.5
Cluster No.2								
Drainage BS, HD, LC, LK, LS, K, SC, W, MS	436.8	7.89	273.3	416.8	1876.0	91.6	54.3	330.1

Table 4.3-3. Summary by drainage basin of geologic types for water sources clustered.

Drainage	Alluvium	Cedar Mesa	Elephant Canyon	Navajo	Wingate	Undivided Cutler
Clustar No.1						
Beef Basin Wash		X	X			
Davis Canyon	X	X				
Elephant Canyon		X				
Horse Canyon	X	X				
Indian Canyon	X					
Lost Canyon		X				
Squaw Canyon	X	X				
Clustar No.2						
Big Spring Canyon	X	X				
Hart's Draw					X	
Lavender Canyon	X	X				
Little Spring Canyon	X	X	X			
Miscellaneous Sources		X	X			
Lockhart Basin						X
Wells (Needles 2-5)		X	X			
Kane Springs Canyon					X	
Salt Creek	X	X	X			

basin level, relect overall geology. Confounding factors within the analysis were due to the use of multiseasonal samples and an uneven balance in the number of data sets from each basin.

4.3.3 Relationships Among Water Sources

Finding similar water sources up gradient and down gradient from point sources of expected pollution allow pairing of monitoring sites in a control-treatment application for detection of impacts. A second cluster analysis was undertaken to determine which water sources shared similar characteristics. This analysis used 5 of the major chemical parameters used in the drainage basin comparisons. These were conductivity, hardness, pH, chloride and sulfate. Data for all sources clustered is presently in Table 4.3-5. As with the drainages, UPGMA clustering of correlation coefficients produced the best of water sources.

The cluster analysis separated the water sources into two major clusters (Figure 4.3-9). The means of sources within each cluster indicate the differences in characteristics between these two groups (Table 4.3-6). Cluster No. 1 was typified by low ionic composition reflected in low conductivity (626.9 umhos/cm) and hardness (304.9). Cluster No. 2 represented sites with higher ionic composition reflected in high conductivity (1829.2 umhos/cm) and hardness (518.4).

The geologic source of water, contained within each measured site, did not emerge from the cluster analysis as a controlling factor (Table 4.3-7). Seasonal variation in water quality and evaporation and concentration and alluvial sites with water altered to differing degrees by biological and chemical processes induce variability into the present data base which is

Table 4.3-5. Summary of macrochemistries by water source.

Location Code	Alkalinity (mg/l)	Hardness (mg/l)	pH	Cl- (mg/l)	SO4 (mg/l)	Conductivity (umhos/cm)	TDS (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	Na+ (mg/l)
BB 1		290.00	8.10	11.00	59.00	665.00		51.00	39.00	31.00
BB 2		340.00	8.00	27.00	69.00	788.00		57.00	47.00	32.00
BB 3		360.00	8.10	23.00	58.00	820.00		53.00	55.00	31.00
BB 4		290.00	8.30	10.00	30.00	595.00		37.00	47.00	20.00
BB 5		290.00	8.00	25.00	50.00	667.00		45.00	42.00	30.00
BB 6		300.00	8.10	6.40	14.00	639.00		47.00	45.00	14.00
BS 1	230.00	137.50	8.14	3.25	11.50	463.33	250.00	74.00	9.10	5.00
BS 1A										
BS 2	49.00	56.00	7.80	1.60	3.80	220.50	61.00	18.00	2.90	0.70
BS 3	290.00	380.33	7.67	5.27	18.00	587.67	332.00	86.67	19.00	7.63
BS 4	140.00	243.33	7.72	4.10	21.00	469.67	250.00	66.50	16.50	7.90
BS 5	200.00	180.00	7.81	5.80	13.00	361.00	236.00	46.00	17.00	19.00
BS 7			7.50			540.00				
BS 8										
BS 9			7.84			584.00				
BS10			8.12			614.00				
C 0	100.00	340.00	8.20		300.00	1015.00				
C 1	195.00	217.00	8.09	37.90	118.00	628.00				
C 2	141.00	306.00	7.95	33.40	192.50	692.50				
C 3	265.00	253.00	8.49	32.30	149.00	350.00				
C 4		1326.00	8.00	29.30	137.00	420.00				
C 5	188.50	782.50	8.11	327.05	628.50	2130.00	2810.00	370.00	95.00	
C 6	146.06	261.00	8.11	39.80	180.00	797.21				
DC 2A	280.00	820.00	7.70		7.00	920.00				
DC 4	445.00	434.00	8.10	22.10	28.00	875.00				
DC 8		330.00	8.20	6.40	22.00	711.00		60.00	44.00	20.00
EC 1			8.26			320.00				
EC 3		221.00	8.34	3.80	1.80	267.50		69.00	12.00	3.00
EC 5										
G 1	218.50	324.00	8.07	20.80	236.00	649.00				
G 2	140.00	440.00	8.30		294.00	833.00				
HC 1		110.00	8.30	9.40	24.00	297.00		27.00	12.00	12.00
HC 1A			8.40			761.00				
HC 2	437.00	479.00	8.40	12.10	126.00	1172.00				84.00
HD 9		160.00	7.80	13.00	13.00	356.00		30.00	20.00	3.80
IC 1	171.38	195.00	8.55	5.29	39.38	384.50	226.00	52.75	15.20	11.38
IC 2	160.00	230.00	8.35	41.00	47.00	453.00		69.00	18.00	11.00
IC 6	269.13	264.78	8.29	54.21	98.00	751.28	468.00	47.29	28.15	77.00
IC 9			8.07			1016.50				
IC 9A			7.84			205.00				
IC14	140.00	280.00	8.60			1302.00				
IC15	487.00	606.00	8.31	15.50	53.00	350.00				
K 1		170.00	8.00	10.00	60.00	478.00		32.00	23.00	30.00
K 2		220.00	7.90	8.30	18.00	540.00		35.00	33.00	28.00
K 3		700.00	8.10	400.00	790.00	3350.00		76.00	120.00	480.00

Table 4.3-5. (Continued).

Location Code	Alkalinity (mg/l)	Hardness (mg/l)	pH	Cl- (mg/l)	SO4 (mg/l)	Conductivity (umhos/cm)	TDS (mg/l)	Ca++ (mg/l)	Mg++ (mg/l)	Na+ (mg/l)
LC 1A			8.40							
LC 2										
LC11			8.35			1035.00				
LC13		580.00	8.10	620.00	1500.00	5070.00		110.00	73.00	1100.00
LC14	315.00	520.00	8.42	646.00	301.00	3357.00				
LC15	350.00	490.00	8.63	801.00	361.00	3860.00				699.00
LK 8		760.00	7.90	1100.00	1400.00	6240.00		180.00	76.00	1200.00
LO 2	275.00	338.67	7.95	10.00	17.87	611.00	361.00	71.00	34.00	15.00
LS 1	231.00	271.50	7.50	10.73	220.25	591.00	240.00	58.00	11.00	15.67
LS 1A		70.00	7.20	4.10	22.00	150.00		25.00	1.70	2.70
LS 2	270.00	230.00	7.68	16.00	25.00	636.50	340.00	59.00	21.00	39.00
LS 3			8.10			814.00				
LS 4										
MS 3	200.00	140.00	7.80	170.00	57.00	1020.00	576.00	30.00	18.00	160.00
MS 5	60.00	100.00	8.80		5.00	198.00				
MS 6	161.00	2080.00	6.70	200.00	2240.00	3980.00		432.00	243.00	270.00
RC 1B			8.35			600.00				
RL 1	174.00	258.00	8.42	31.40	148.00	390.00				
SC 1A			8.30			500.00				
SC 2	241.00	263.00	7.40	10.40	37.00	550.00				12.00
SC 7A			8.20			830.00				
SC 8A			7.10			1341.00				
SC 8B			7.60			784.00				
SC 8C			8.40			761.00				
SC 8D	280.00	480.00	8.10		21.00	839.00				
SC 8E	220.00	430.00	7.70		12.20	714.00				
SC10A	249.00	250.00	8.50	1.20	26.00	530.00				17.00
SC11		169.00	7.35	10.50	29.00	379.00	369.00	32.00	22.35	15.10
SC15			8.00			546.00				
SC19	359.00	364.00	8.43	41.10	57.00	768.00				54.00
SC20			7.50			4650.00				
SC21	710.00	1281.50	8.29	967.00	1291.00	5680.00	2170.00	43.00	150.00	995.00
SC22			7.52			3720.00				
SC23			7.76			3000.00				
SC24	307.00	663.00	8.70	61.70	128.00	1193.00				
SC25			8.32							
SQ 2	260.00	315.00	7.82	6.20	14.50	634.50	277.00	68.00	18.00	12.00
SQ 3	140.00	340.00	8.47	23.00	50.00	655.67		69.00	48.00	42.00
W 1										
W 2	370.67	387.25	7.93	78.12	124.00	1014.50	307.00	66.20	58.18	105.80
W 3	203.00	196.00	8.50	29.00	70.00	610.00		54.00	15.00	50.00
W 3A	289.75	312.00	7.67	50.11	82.91	809.80	880.00	64.00	35.13	70.40
W 3B	262.20	309.80	7.54	39.20	62.60	700.00		90.80	20.00	38.20
W 4		244.00	7.80	6.20	18.00			68.00	18.00	12.00
W 5	461.00	595.00	7.75	156.50	265.00	1690.00	957.00	96.00	86.50	170.00

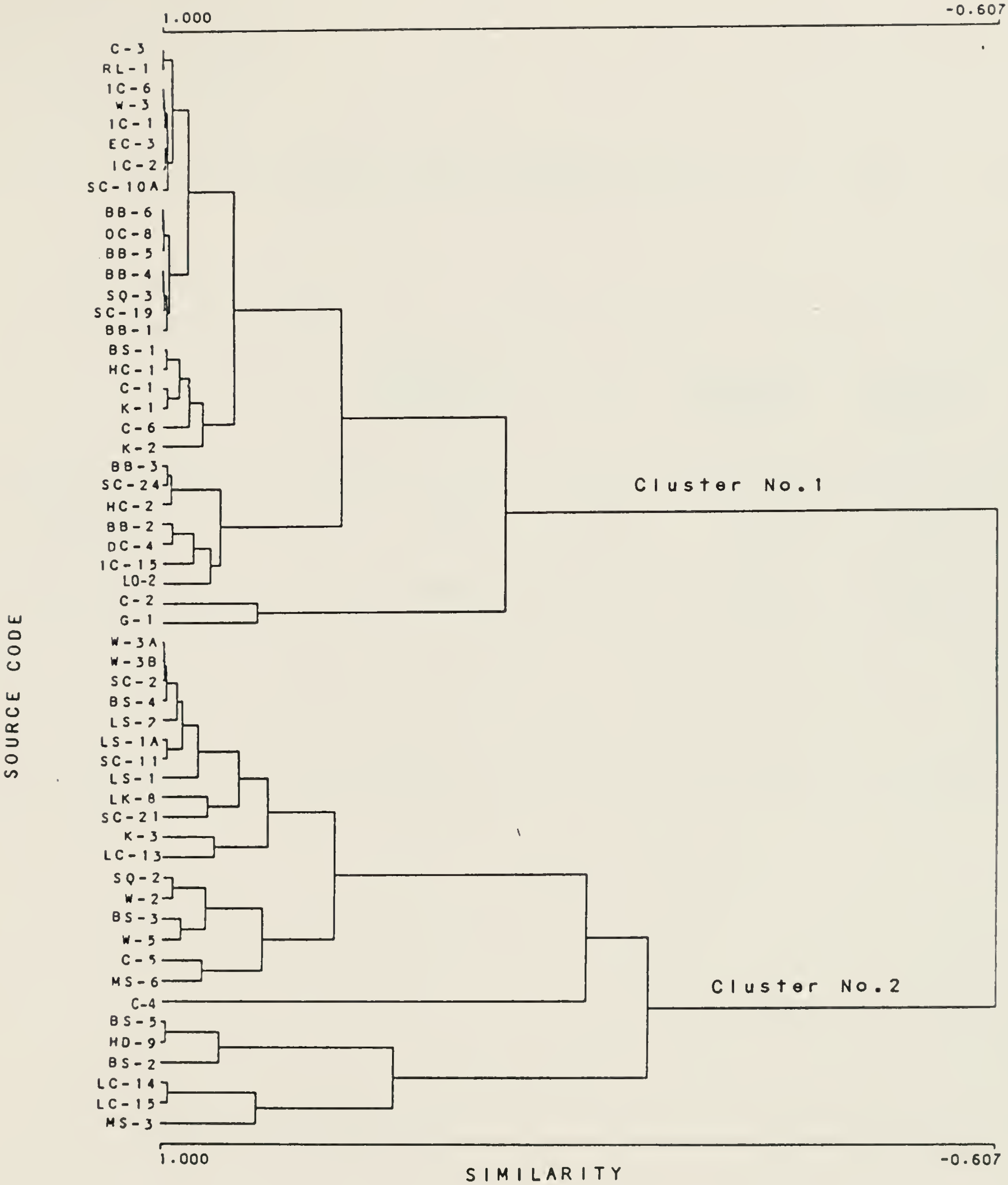


Figure 4.3-9. Cluster analysis by water source.

Table 4.3-6. Means of major chemical parameters for clustar using individual water sources.

	Electrical Conductivity (umhos/cm)	pH	Hardness ($CaCO_3$)	Chloride (mg/l)	Sulfate (mg/l)
Clustar No.1	626.9	8.23	304.9	21.3	72.8
Clustar No.2	1829.2	7.79	518.4	235.8	401.8

Table 4.3-7. Summary of water source types and associated geology for sites clustared.

	Alluvium	Cedar Mesa	Elephant Canyon	Undivided Cutler	Wingate
Clustar No.1					
Rise	12				
River	1				
Seep		2			
Spring		7	3		2
Stream	2				
Clustar No.2					
Rainpool		1			
Rise	2				
River	2				
Spring	3	8	1	1	2
Well		3	1		

probably greater than the variability between water from different geologic sources.

There were patterns within the cluster analysis. Some drainages were entirely contained within one of the two clusters while others had a majority of sources within one of the clusters. A brief discussion of each drainage follows:

A. Beef Basin data Clustered within Cluster No. 1 indicating water of low ionic composition, low conductivity and hardness. The Beef Basin sources were all classified as springs and were evenly split between the Cedar Mesa and more saline Elephant Canyon formations. The historical data for Beef Basin was collected in a single effort during 1978. All sources were consistent.

B. Big Spring Canyon, sources BS-2, BS-3, BS-4, and BS-5, clustered within Cluster No. 2 indicating high dissolved constituents while BS-1 separated into Cluster No. 1, lower dissolved constituents, mainly due to a higher pH than other Big Spring sources. The major chemistries for BS-1 fell within the ranges of BS-2, BS-3, BS-4 and BS-5. The major documented physical difference between BS-1 (a seep) and the other Big Springs Canyon sources, which are springs, is the source type. They all occur within the Cedar Mesa formation.

C. Colorado River sources were split between clusters. Two sites (C-4 and C-5) were high in hardness or conductivity relative to C-1, C-2, C-3 and C-6. This could have been due to spatial variability within the river itself as neither C-4 or C-5 occurred downstream from a flowing tributary.

D. Davis Canyon contained two sites DC-4 and DC-8 which clustered within Cluster No. 1 indicating low dissolved solids. Both sites had similar concentrations among the major chemistries but the samples for each were taken in different seasons and several years apart.

E. Elephant Canyon had data for only a single water source, EC-3. This spring in the Cedar Mesa formation clustered within Cluster No. 1 indicating low dissolved solids, and was based upon data collected during 1969.

F. Horse Canyon contained two sources with sufficient data for cluster analysis. These were HC-1, a seep in the Cedar Mesa formation, and HC-2, a rise in the alluvial valley floor. The data for HC-1 were collected during June, 1978 while data for HC-2 was collected during April, 1984. These sources were contained in Cluster No. 1 indicating better water quality with fewer dissolved constituents.

G. Indian Creek sites IC-1, IC-2, IC-6 and IC-15 had sufficient data for cluster analysis and fell within cluster No. 1. The data included several samples for each site between 1976 and 1984. Although conductivities within Indian Creek fluctuate, they are generally consistent within a location and increase with downstream distance from 384.5 umhos/cm at IC-1 to 1016 umhos/cm at IC-9, as more dissolution occurs within the drainage. Indian Creek has the largest historical data base among the two major drainages in the Needle's District.

H. Kane Springs Canyon sources K-1, K-2 and K-3 were classed as springs occurring within the Wingate formation by Richter (1980). Sources K-1 and K-2 fell within Cluster No. 1 with good water quality (low

dissolved solids) but K-3 was a saline spring with conductivity of 3350 umhos/cm (1978 data).

I. Lavender Canyon sources LC-13, LC-14 and LC-15 clustered within Cluster No. 2, representing high dissolved solids and poor water quality. LC-13 is classed as a spring in the Cedar Mesa formation while LC-14 and LC-15 are rises in the alluvial valley bottom. All have very high conductivities, ranging between 3357 umhos/cm to 5070 umhos/cm. The higher salinities in Lavender Canyon were explained by Richter (1980) as due to the salts leaching from the Chinle Formation.

J. Little Spring Canyon sources LS-1, LS-1A and LS-2 clustered within Cluster No. 2. LS-1, a spring in the Cedar Mesa formation and LS-2, a spring emerging in alluvium beneath the Elephant Canyon formation shared chemical characteristics except sulfate concentration in LS-1 was tenfold that in LS-2. LS-1A is a rainpool found by Richter (1980).

K. Lockhart Basin data base included only one source, LK-8, a saline spring (conductivity 6240 umhos/cm) located in the Undivided Cutler formation.

L. Lost Canyon contained one source with data, LO-2. LO-2 is a spring in the Cedar Mesa formation. This source clustered in Cluster No. 1 indicating good water quality.

M. Red Lake Creek contained one source with data, RL-1 near the Colorado River. This rise in alluvium was influenced by backwash from the Colorado River. RL-1 was grouped within Cluster No. 1.

N. Salt Creek contained six sources with sufficient data for clustering. SC-10A, SC-19 and SC-24 were grouped with Cluster No. 1

indicating good water quality (low dissolved constituents) while SC-2, SC-11 and SC-21 were in Cluster No. 2. The conductivity levels at SC-2, SC-10A, SC-11 and SC-19 were very similar, but SC-2 and SC-11 had substantially lower pH which placed them in Cluster No. 2. SC-21 is highly saline with recorded conductivities of 8110 umhos/cm (April 1984) and 3250 umhos/cm during May, 1969.

O. Squaw Canyon contained two sources, SQ-2 and SQ-3, with sufficient data for clustering. While the overall conductivity for both was similar, higher pH placed SQ-3 into Cluster No. 2 indicating a difference in water quality. The historical data for these sources has varied with no interpretable pattern.

P. Wells Four wells were entered into the cluster analysis. These were Wells No. 2, 3A, 3B and 5. Well No. 1 was sealed after encountering salt water during drilling. Well No. 4 is currently capped. No data was available on either Well No. 1 or No. 4. Wells 2, 3A, 3B and 5 clustered together in Cluster No. 1 indicating good water quality although Well No. 5 was higher in salinity. Well No. 5 occurs in the Halgaito-Elephant Canyon formation while Nos. 2, 3A and 3B occur in the Cedar Mesa formation.

The water quality in Well No. 3A has been tested more than the other wells, with 13 samples taken between 1965 and 1984. There has been an increasing trend in conductivity although the lowest and highest values were measured during 1968, probably during a pump test. Since that time, conductivities have increased from 480 umhos/cm in 1978 to 912 umhos/cm in 1984, although the values have varied up and down between these dates.

Well No. 3B has been sampled five times between 1971 and 1983. Conductivities in the well have increased from 505 umhos/cm in 1971 to 930 umhos/cm in 1983.

4.3.4 Comparisons with "State of Utah Public Drinking Water Regulations"

The "State of Utah Public Drinking Water Regulations" (PDWR) establish maximum contaminant levels for 35 potential contaminants (Table 4.3-8). "'Primary' standards are established for the protection of human health. 'Secondary' regulations are established to provide guidance in evaluating the esthetic qualities of drinking water. The applicable 'Primary' standards must be met by all public drinking water systems. The 'Secondary' standards are recommended levels which should be met in order to avoid consumer complaint." (quoted from PDWR). Ninety water sources within the project area were identified from the data base which had been sampled for one or more of the potential contaminants listed in the PDWR. Comparisons of the data base with regulated levels were performed to determine (1) completeness of the data base, and (2) suitability of waters in the project area for public consumption. The results of these comparisons are presented in Table 4.3-8.

None of the sites, including water supply wells in the Needles District (W-2, W-3A, W-3B and W-5) have been sampled for the complete set of water quality standards. Four of the 90 sites have been sampled for 50% or more of the regulated parameters. Of the parameters measured, the primary standard for coliform bacteria was most often exceeded with the radiological standard for gross alpha radiation occurring second in percent of time

Table 4.3-8. Primary and secondary drinking water standards from "State of Utah Public Drinking Water Regulations".

Contaminant	Maximum Contaminant Levels (mg/l)	Percent of Sites Sampled	Percent of Sites in Exceedance
INORGANIC: PRIMARY			
1 Arsenic	0.05	22	
2 Barium	1.0	8	1
3 Cadmium	0.10	8	
4 Chromium	0.05	8	
5 Fluoride	2.0	42	
6 Lead	0.05	8	
7 Mercury	0.002	8	
8 Nitrate as N	10.0	64	2
9 Selenium	0.01	21	2
10 Silver	0.05	8	
11 Sulfate	500.0	68	8
12 Total Dis. Solids	2000.0	20	2
INORGANIC: Secondary			
13 Chloride	250.00	62	
14 Color	15 units	0	
15 Copper	1.0	22	
16 Iron	0.3	19	6
17 Manganese	0.05	9	6
18 Odor	3.0	0	
19 pH	6.5-8.5	93	11
20 Zinc	5.0	9	
ORGANIC			
21 Endrin	0.002	0	
22 Lindane	0.004	0	
23 Methoxychlor	0.10	0	
24 Toxaphene	0.005	0	
25 2. 4-D	0.10	0	
26 2.4.5-TP - Silvex	0.01	0	
TURBIDITY			
27 Turbidity	5 NTU	8	6
BACTERIOLOGICAL			
28 Coliform Bacteria	1/100 ml	27	18
RADIONUCLIDES			
29 Radium 226 and 228	5 pCi/l	0	
30 Gross Alpha	15 pCi/l	26	13
31 Gross Beta	50 pCi/l	26	7
32 Strontium-90	8 pCi/l	0	
33 Tritium	20,000 pCi/l	0	

exceeded (Table 4.3-8). Sulfate was the most often sampled primary standard and, on a weighted basis (all sites sampled equally) was exceeded most often. These occurrences appeared logical.

Coliform bacteria exceedances were limited to three drainages (Table 4.3-9). These were the Colorado River, Green River and Indian Creek with its tributaries, Davis and Lavender Canyons. All locations within the Colorado River drainage, including tributary sites influenced by backwash from the Colorado River (RL-1 and SC-24), exceeded the standard. Human population centers, livestock and recreational use within and upstream from Canyonlands National Park each contribute to bacteriological contamination of the Colorado River. This applies to the Green River as well. The Indian Creek drainage with heavy livestock use occurring outside the park, vehicle access and public camping within Davis, Lavender and upper Indian Creek all contribute to the contamination of water sources within the Indian Creek drainage. Little Spring (LS-1) was the only sampled source outside the above drainages which exceeded the standard.

Radiological esceedances (gross alpha and beta) were concentrated within the Colorado River and sites impacted by the waters in the Colorado River (Table 4.3-10). The geology of southeastern Utah has a history of uranium mining and high presence of radiologic elements. The presence of higher than normal radiation is not unusual, particularly in the major drainages of the Colorado and Green Rivers which are under the influence of mining activity. It is interesting to note that radiation levels within sites influenced by these rivers was substantially higher than at non-river sites.

Table 4.3-9. Comparisons of data for water sources with state of Utah primary and secondary drinking water standards. See Table 4.3-8 for key to drinking water analysis.

Drinking Water Analysis Code

Location Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
BB 1	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BB 2	:	:	:	:		:	:	*	:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BB 3	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BB 4	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BB 5	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BB 6	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 1	:	:	:	:		:	:		:	:				:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 1A	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 2		:	:	:		:	:	:		:				:			:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 3	:	:	:	:		:	:		:	:				:	:		:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 4		:	:	:		:	:			:				:		:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 5		:	:	:		:	:			:				:			:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 7	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 8	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS 9	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
BS10	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
C 0	:	:	:	:	:	:	:		:	:		:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
C 1	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*		:	:
C 2	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*		:	:
C 3	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*	*	:	:
C 4	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*	*	:	:
C 5	:	:	:	:	:	:	:		:	:	*	*	*	:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*	*	:	:
C 6	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:	*	:	:	:	:	:	:	:	:	*	:			:	:
DC 2A	:	:	:	:	:	:	:		:	:		:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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DC 8	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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IC15	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	*	:	*	*	:	:
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K 2	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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: = No samples taken for this analysis

* = Exceeds Utah standards

= Samples did not exceed Utah standards

Table 4.3-9. (Continued).

Drinking Water Analysis Code

Location Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
LC 1A	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
LC 2	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:
LC11	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
LC13	:	:	:	:		:	:	*	:	:	*	:	*	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
LC14	:	:	:	:	:	:	:		:	:		:	*	:	:	:	:	:		:	:	:	:	:	:	:	:	*	:			:	:
LC15	:	:	:	:	:	:	:		:	:		:	*	:	:	:	:	:	*	:	:	:	:	:	:	:	:		:			:	:
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LS 1A	:	:	:	:		:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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LS 3	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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MS 6											*	:		:				:			:	:	:	:	:	:		:	:	:	:	:	:
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SC 2	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:		:	*		:	:
SC 7A	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC 8A	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC 8B	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC 8C	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC 8D	:	:	:	:	:	:	:		:	:		:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC 8E	:	:	:	:	:	:	:		:	:		:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC10A	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:		:			:	:
SC11		:	:	:		:	:			:				:		:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC15	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC19	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:		:	:	:	:	:	:	:	:		:		*	:	:
SC20	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC21		:	:	:		:	:			:	*	*	*	:			:	:		:	:	:	:	:	:	:	:		:	*		:	:
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SC23	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SC24	:	:	:	:	:	:	:		:	:		:		:	:	:	:	:	*	:	:	:	:	:	:	:	:	*	:	*		:	:
SC25	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
SQ 2		:	:	:		:	:			:				:		:	:	:		:	:	:	:	:	:	:	:	:	:	:	:	:	:
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W 5														:			*	:			:	:	:	:	:	:		:	:	:	:	:	:

: = No samples taken for this analysis
* = Exceeds Utah standards
  = Samples did not exceed Utah standards

Table 4.3-10. Radiological data for sites within the project area. Data from April, 1984 field investigations.

Site	Gross α pCi/l	Gross β pCi/l
Sites Exceeding Standard Influenced by Colorado or Green Rivers		
Colorado River		
C-1	33	50
C-2	20	37
C-3	33	52
C-4	46	89
C-5	27	89
IC-15	54	130
RL-1	22	60
SC-24	25	35
Mean	39	65.1
Green River		
G-1	91	44
Sites Exceeding Standard Not Influenced by Colorado or Green Rivers		
IC-6	17	23
SC-2	35	10
SC-19	9	78
SC-21	46	46
Mean	26.7	39.3
Sites Not Exceeding Standard		
C-6	6	23
HC-2	2	10
LC-14	3	10
LC-15	14	27
LS-1	2	11
SC-10A	5	10
W-2	7	36

The high levels of sulfates and chlorides found at sites within the project area generally reflect their presence throughout the geologic strata of the area (Richter 1980).

The high levels of sulfates and chlorides found at sites within the project area generally reflect their presence throughout the geologic strata of the area (Fichter 1990).

4.4 BIOLOGICAL PARAMETERS

The following is a description of biological parameters observed and measured at each of the water sites visited. The description is presented by drainage beginning with the upstream-most site and progressing downstream to illustrate longitudinal developments in aquatic flora and fauna. The parameters receiving emphasis are: fishes, macroinvertebrates, chlorophyll *a*, sediment organics, sediment size and benthic organics. It was not the intent of this investigation to quantify biological parameters of the water sites, and so, qualitative and descriptive information is used.

4.4.1 Salt Creek Drainage

The Salt Creek Drainage is one of two major drainages in the Needles District. It flows entirely within Canyonlands National Park and receives ephemeral or perennial flow from seven major canyons including Big Spring, Little Spring, Squaw, Lost and Horse Canyons as well as its East and West Forks.

No fish have ever been recorded from anywhere in Salt Creek or its tributaries, except for the lowermost 1 km above the Colorado River. Fish are present in this area where the Colorado River inundates lower Salt Creek. It appears that a combination of low macroinvertebrate populations, high turbidity, a constantly shifting sand/silt substrate, warm water temperatures, dramatic flow fluctuations with periodic desiccation, and high salinity levels preclude fishes from all but this lowermost kilometer of Salt Creek. The presence of several large vertical jumps or dropoffs about 1 mile upstream from the Colorado River confluence are an effective barrier to upstream migration of fishes as well. No fish were observed during this

investigation anywhere in Salt Creek above the vicinity of the confluence with the Colorado.

Macroinvertebrates are also not reported from Salt Creek or its tributaries. This is probably the result of a paucity of samples rather than a complete absence of aquatic macroinvertebrates. Synoptic samples and checks of benthos by ERI failed to reveal any invertebrate forms in the stream proper. Some macroinvertebrates were noted in the tributaries.

During the field investigation, Salt Creek maintained flow from runoff due to recent rains and snowmelt. In the upper reaches of the stream, water quality was good with low conductivities (500-800 umhos/cm), neutral to slightly basic pH and adequate dissolved oxygen to support aquatic life. These conditions in the main stream are only temporary, however, due to the ephemeral nature of the watercourse. This prevents the establishment and maintenance of abundant aquatic life. The condition of this stream is suitable only for specialized euryhaline forms. Those springs such as one at SC-1 were marked by small riparian areas with willows (Salix sp.), rushes (Jancus sp.), Cattails (Typha sp.) and elephant grass (Phragmites sp.). The stream proper was generally shallow, flat, sandy and with little emergent vegetation. A chlorophyll a reading of 0.2 ug/l at spring SC-2 (Table 4.4-1) indicates low production levels.

No springs, seeps or rises were noted at sites SC-4 and SC-5, although continuous flow was noted in the streambed. However, Salt Creek was dry for a section starting about 400 m below SC-5 to a point near All American Man, below SC-7. At this point (SC-7a), flow in the channel resumed in the form of a rise. The stream was sparsely lined with willows and cattails.

Table 4.4-1. Summary of Chlorophyll a (ug/l) by Fluorometric Method. Sampling dates 4/20/84 to 4/30/84.

Transect	N	Uncorr. Chl a		Corr. Chl a		Pheophytin a		Total Pigments	
		mean	st err	mean	st err	mean	st err	mean	st err
C1	1	6.0	0.0	4.7	0.0	2.7	0.0	7.4	0.0
C2	1	8.8	0.0	6.5	0.0	4.8	0.0	11.3	0.0
C3	1	10.0	0.0	7.6	0.0	4.9	0.0	12.5	0.0
C4	1	2.6	0.0	1.0	0.0	3.3	0.0	4.3	0.0
C5	1	8.5	0.0	7.0	0.0	3.0	0.0	10.0	0.0
C6	1	1.2	0.0	1.2	0.0	0.1	0.0	1.2	0.0
G1	1	10.3	0.0	7.8	0.0	5.1	0.0	12.9	0.0
HC2	1	1.1	0.0	1.0	0.0	0.2	0.0	1.2	0.0
IC06	1	2.5	0.0	2.2	0.0	0.7	0.0	2.9	0.0
IC15	1	4.0	0.0	3.7	0.0	0.6	0.0	4.3	0.0
LC14	1	0.6	0.0	0.6	0.0	0.0	0.0	0.6	0.0
LC15	1	1.8	0.0	1.6	0.0	0.5	0.0	2.0	0.0
LSC1	1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0
NUTR	1	0.1	0.0	0.0	0.0	0.2	0.0	0.2	0.0
RL1	1	4.1	0.0	2.9	0.0	2.4	0.0	5.3	0.0
SC	1	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.0
SC2	1	0.3	0.0	0.2	0.0	0.2	0.0	0.4	0.0
SC19	1	1.6	0.0	1.2	0.0	0.9	0.0	2.0	0.0
SC21	1	0.8	0.0	0.8	0.0	0.0	0.0	0.8	0.0
SC22	1	0.7	0.0	0.4	0.0	0.6	0.0	1.0	0.0
W2	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W3A	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

At SC-8a a small spring emerged from the east bank of Salt Creek about 0.8 km north of All American Man. The spring was marked by elephant grass, willows and large rushes. No instream fauna was noted at this spring, perhaps because of the saline nature of the water as indicated by a conductivity of 1341 umhos/cm.

At site SC-8b, a small spring entered Salt Creek from the west bank about 200 m north of the Upper Jump. The spring had an abundance of rushes and willows, many in a state of decay that apparently depressed dissolved oxygen levels to 5.0 mg/l. The conductivity of 784 umhos/cm indicated suitable conditions for many life forms but may have been a result of dilution from recent rain and snowmelt.

Much of Salt Creek in the vicinity of the Squaw Butte Ranger Station was characterized by a flat shifting sand channel lined with willows and heavy stands of tamarisk. No macroinvertebrate life was observed and the chlorophyll level measured at SC-19 (downstream from Highway 211) was 1.2 ug/l indicating low production in the area.

The first major tributary of Salt Creek below the East and West Forks is Horse Canyon. This tributary enters the stream above site SC-17. Horse Canyon was fed by primarily two rises; at HC-1a and HC-2. These rises were characterized by conductivities of (761 and 1172 umhos/cm) and pH levels of 8.4. No significant numbers of aquatic fauna or flora were noted.

The second major tributary of Salt Creek is Squaw Canyon and its tributary, Lost Canyon. This tributary enters Squaw Canyon near Cave Spring and was characterized by small pools and marshy channels. A spring was located at site LO-2 which arose from a constricted area of alluvial bottom.

The spring was marked by dense riparian vegetation including _Salix_ and _Juncus_ spp. Conductivity (500 umhos/cm) and pH (8.39) were suitable for aquatic life but evidence of periodic desiccation probably accounts for the lack of aquatic fauna.

Further downstream at site SC-20, a rise was located in an old stream meander. The rise was lined with vegetation (rushes, elephant grass) different from that of the stream proper. A conductivity of 4650 umhos/cm was recorded at this rise and no aquatic fauna was noted.

At SC-21, Salt Creek flowed over the Lower Jump in a channel of bedrock with overlying sand, gravel and interstitial silt. The stream at this point appeared devoid of instream flora or fauna. This was the nature of the stream through sites SC-22 and SC-23, about 2 km above the confluence of the Colorado River.

The last major tributary of Salt Creek was the canyon carrying the joint flow of Big Spring and Little Spring Canyon.

The latter had one identified source (LS-2), a spring source that appears perennial and supported small riparian communities of moss, algae, horsetail (Equisteum sp.), sedges (Carex sp.), cottonwoods (Populus sp.) and willows (Salix sp.). Little Spring Canyon at this site was noted to support macroinvertebrates from the orders Ephemeroptera, Hymenoptera (Gerridae), Oligochaeta and Trichoptera.

Big Spring Canyon was also characterized by a series of seeps and springs feeding a stream that is apparently ephemeral for at least a part of its length. The upper two seeps at sites BS-1 and BS-1a appeared ephemeral and did not support large riparian areas. The spring at BS-2 was large (8 m

diameter pool, 305 m deep) and had an abundance of algae. Springs located at BS-5 and BS-6 were inundated by runoff but were marked by the presence of cottonwood trees. The spring (BS-9) in the Lower Jump supported abundant mosses, algae and Aquilegia sp. No invertebrate fauna were noted in Big Spring Canyon. During the April field visit, Big Spring Canyon increased in flow from approximately 2 cfs to 100 cfs within five minutes as a flash flood from snowmelt and rains passed down the canyon.

A descent below the jump near SC-23 was impossible during this ERI investigation because of steep, rain-slickened rock cliffs. Sampling by a second crew below the jump revealed Salt Creek in a wide, shifting sand channel flowing into a very slow moving and deepened stream for about 1 km above the Colorado River. This deepened area was caused by a backup of the river into Salt Creek.

Seining in this backup area yielded five fish species (Table 4.4-2). The most significant finding was the capture of six young Colorado squawfish ranging from 38 to 53 mm total length. Since the capture date was April 27, 1984, and too early for spawning, it is almost certain that these fish belonged to the 1983 year class; hatched about August 1983. Colorado squawfish have been captured at the mouth of Salt Creek before as discussed in the Colorado River Drainage of this report section.

4.4.2 Indian Creek Drainage

Indian Creek is the largest drainage in Canyonlands National Park. It originates in the Abajo Mountains and flows northwest into the Colorado River. According to field and stocking reports (personal communication: Miles Moretti and Walt Donaldson, Utah Division of Wildlife Resources (DWR),

Table 4.4-2. Numbers of fishes seined from the mouths of Indian Creek and Salt Creek during the ERI Water Quality Survey.

Station	Date	Substrate	Species	No./100m^2	Percentage
Indian Creek (IC-15)	4/26/84	silt-sand	channel catfish	1.2	5.3
			common carp	3.6	15.9
			Colorado squawfish	0.3	1.3
			fathead minnow	2.1	9.3
			flannelmouth sucker	0.6	2.7
			red shiner	13.6	60.2
			unidentified sucker	1.2	5.3
				22.6	100.0
Salt Creek (SC-24)	4/27/84	silt-sand	black bullhead	0.4	2.5
			Colorado squawfish	1.2	7.5
			fathead minnow	2.3	14.4
			red shiner	11.9	74.4
			yellow bullhead	0.2	1.2
				16.0	100.0

August 22, 1984), rainbow trout were introduced from 1962 to 1968 and cutthroat trout were introduced in 1965 and 1968. Both species were stocked in upper Indian Creek from the Indian Creek State Park near Newspaper Rock upstream to the headwaters. Apparently, low flows, low survival and high fisherman take halted the stocking program. As recently as August 1983, two cutthroat trout were captured by electrofishing gear near Newspaper Rock.

No fish have ever been reported between in Indian Creek or its tributaries Dugout Ranch and 1 km above the Colorado River confluence. The Utah DWR cites three main reasons for their absence:

1. Lack of favorable habitat (no pools).
2. High summer water temperatures.
3. Severely eroded watershed causing high siltation.

The third factor is caused by the stream flowing through an extensive area of highly erodable and saline Chinle Formation just below Dugout Ranch.

This investigation included electrofishing efforts at three stations:

1. Confluence of Lavender Canyon (near LC-15).
2. Highway 211 Crossing (IC-6).
3. Site IC-9, about 3.5 km below Highway 211.

At all three sites, 200 m of stream was electrofished with a 110-v DC Coffelt backpack generator shocker. No fish were captured or sighted. The only location in lower Indian Creek known to support fish is the lowermost 1 km above the Colorado River. Like Salt Creek, this lower area is inundated by the Colorado River and provides good quiet-water habitat for young fishes and predaceous adults. See Table 4.4-2 for summary of fish species captured

near the mouth of Indian Creek (IC-15).

Indian Creek appeared to be a more hospitable environment to stream flora and fuana than Salt Creek, probably because of a more stable substrate (some flagstone), better habitat (some pools), and perhaps less fluctuating flows and better water quality (Table 4.3-2). Numerous macroinvertebrates were found among instream flagstones above the Highway 211 crossing at IC-6 including the orders Ephemeroptera, Trichoptera, Plecoptera and Diptera (Simuliidae). Below this highway, the substrate seemed sandier and less stable with fewer of the same macroinvertebrates.

Chlorophyll _a_ measured at sites IC-6 and IC-15 was 2.2 and 3.7 ug/l indicating low instream production in these regions. These low production levels are attributed to high instream turbidity.

The two major tributaries of Indian Creek in the vicinity of Canyonlands National Park are Lavender and Davis Canyon. These canyons drain the geographic region immediately south of the proposed nuclear repository site near South Six-Shooter Peak and are the nearest watersheds to that site.

The water in Lavender Canyon originates as a series of alluvial rises and cliff seeps, some marked by small marshy areas. The stream was intermittent during this April investigation; water was seen rising or seeping in areas only to disappear again a short distance downstream. No macroinvertebrates were noted in any of the Lavender Canyon water sources.

The stream in Lavender Canyon appears to contribute substantially to TDS and salinity levels of Indian Creek as was indicated by conductivities ranging between 1035 and 5070 umhos/cm. This parameter together with warm

water temperatures and an ephemeral nature probably preclude much aquatic life in the stream.

The other major tributary of Indian Creek is Davis Canyon. The stream in this canyon also arises as a series of seeps and rises with one major spring area at site DC-4. There was little aquatic flora and fauna noted in Davis Canyon except for that surrounding the spring complex at DC-4. This complex was marked by a series of interconnected as well as isolated pools surrounded by some cottonwood trees, and heavy stands of reeds, grasses and cattails. Macroinvertebrates noted included members of the Diptera families, Culicidae (mosquitos) and Simuliidae (blackflies); Hemiptera family Gerridae (water striders) and Odonata (damselflies and dragonflies).

The third major tributary of Indian Creek was Rustler Canyon. This canyon enters Indian Creek about 2 km above the Colorado River confluence. The stream in Rustler Canyon originated as an alluvial seep atop a 15-m jump at the head of this "box canyon". Algae and periphyton were abundant on the cliff of the jump. No surface flow was noted for some 2 km below this point, where a second alluvial rise resulted in a shortened section of surface flow. This rise was marked by a dense stand of rushes (<u>Juncus</u> sp.) about 40 m along the sandy streambed. Two suspected springs were also investigated in Rustler Canyon. Both areas were marked by dense stands of canary grass on talus slopes above the streambed. One area resulted from a dripping ledge (RC-1) and the other (RC-2) did not exhibit any surface water. No aquatic fauna were noted in Rustler Canyon.

4.4.3 Colorado River

Some biological parameters of the Colorado River within Canyonlands National Park are not well known. Little work has been done on primary production (periphyton), and secondary production (benthic macroinvertebrates and zooplankton). However, extensive fish sampling has been conducted in the river within Canyonlands National Park.

Six sample stations were established in the Colorado River to assess various physical, chemical and biological parameters. River sample sites are:

1. C-1 - above confluence of Indian Creek
2. C-2 - above confluence of Green River
3. C-3 - at confluence of Lower Red Lake Canyon
4. C-4 - at confluence of Y Canyon
5. C-5 - at confluence of Gypsum Canyon
6. C-6 - Hite Marina

Invertebrates captured at these river sites were low in numbers (Table 4.4-3). Representatives were identified from six taxonomic orders including the following:

1. Diptera (Chironomidae)
2. Ephemeroptera (Heptageniidae)
3. Oligochaeta
4. Pelecypoda
5. Plecoptera
6. Trichoptera (Lemniphilidae)

Table 4.4-3. Numbers and biomass of benthic invertebrates captured at each river location during April 24-28, 1984. Based upon samples ($1ft^2$).

Location	Size	Numbers Mean	Numbers S.E.	Biomass (mg/m^2) Mean	Biomass (mg/m^2) S.E.
C-1	3	82	62	12	7
C-2	2	5	5	9	9
C-3	2	0	0	0	0
C-4	2	5	5	1	1
C-5	2	5	5	3	3
C-6	1	2/5	0	387	0
G-1	2	16	16	9	9

Functionally, the majority of these invertebrates are omnivorous collector-gatherers, utilizing organic matter (detritus) as a food source. The sediment size associated with these invertebrate samples indicates an association with small, unstable substrates, being dominated by silt (<.25 mm) and containing a substantial amount of organic matter (Tables 4.4-4 through 4.4-6).

Fish populations in the vicinity of Indian Creek are well documented. Fish sampled in this investigation represent the usual array of species expected. Seining at the mouth of Indian Creek, 100 - 400 m above the Colorado River, yielded a total of six identified fish species (Table 4.4-2). The most abundant were red shiner (60.2%) and common carp (15.9%). One Colorado squawfish, estimated at 2-3 years of age was also caught.

At Salt Creek, about 13 river miles downstream, five fish species were captured (Table 4.4-2) including six Colorado squawfish from the 1983 year class (age group 0). The most abundant species were red shiner (74.4%) and fathead minnow (14.4%).

Colorado squawfish have been found in the vicinity of these two tributaries by a number of investigators (Tanner 1936; Sigler and Miller 1963; Taba et al. 1965; Holden 1973; Holden and Stalnaker 1975; Valdez et al. 1982). From 1979 to 1981, Valdez et al. (1982) captured 101 young-of-the-year, 8 juveniles and 2 adults between river miles 0.0 (Colorado-Green confluence) and 20.0; Indian and Salt Creeks are located at river miles 16.5 and 3.5, respectively. Nearly one-third of the young-of-the-year caught in the Colorado River in this 3-year period were found in this 20-mile reach of river. These collections strongly indicate

Table 4.4-4. Percent in each of five sediment size fractions at each river location sampled during April 24-28, 1984.

Location	N	>12.5 mm	4.-12.5 mm	.5-4. mm	.25-.5 mm	<.25 mm
C1	1	0.0	0.0	0.1	0.5	99.4
C2	1	0.0	0.0	0.0	0.3	99.7
C3	1	0.0	0.0	0.1	0.2	99.7
C4	1	82.7	10.4	1.5	0.8	4.6
C5	1	0.0	0.0	0.2	5.4	94.4
C6	1	0.0	0.0	5.3	22.7	72.0
G1	1	0.0	2.0	0.9	1.7	95.4

Table 4.4-5. Sediment organic content at river locations sampled for invertebrates during April 24-28, 1984.

Location	Sample Size (n)	Percent
C1	1	2.84
C2	1	1.79
C3	1	1.70
C4	1	1.67
C5	1	0.76
C6	1	0.83
G1	1	1.98

Table 4.4-6. Organic matter associated with invertebrate samples taken at river locations during April 24-28, 1984.

Transect	N	Weight	St. Dev.	St. Error
C1	2	55.0	65.8	46.5
C2	2	11.4	2.5	1.8
C3	2	5.6	4.5	3.2
C4	2	5.3	0.5	0.3
C5	2	1.2	1.3	0.9
C6	2	68.1	70.3	49.7
G1	2	8.8	3.4	2.4

that the Colorado River currently supports a reproducing population of the endangered Colorado squawfish in the vicinity of these two tributaries. ERI's recent collections of young squawfish further supports this. Also, the occurrence of young squawfish in these tributaries indicates that Indian and Salt Creeks are important habitat to the young fish.

4.5 RECOMMENDATIONS

During this study, many water sources were identified from the literature and located in the field. Because of storm events or season it remains uncertain which sources are perennial, and in some cases whether they are springs, seeps or rises. The identification of perennial sources will be important for the development of a consistent data base for long-term monitoring. The NPS should systematically visit each of the identified sources during base flow periods to identify their true nature.

The exact location of most sources cannot be determined using the presently available 15-minute USGS topographic maps. When 7 1/2-minute maps become available, the location of identified water sources should be accurately determined.

The lack of biological data from the aquatic systems within Canyonlands National Park was surprising. The algae and invertebrate populations associated with these sources, particularly perennial sources should be characterized as a component of any monitoring program. The change in taxa at a particular source could be a good indicator of a chemical or physical change not detected by the monitoring program.

This study has assembled the known historic data base for the project area. It is important that future data collection be appropriately identified and consistently encoded into the data base in a timely manner to provide continuity and the most complete data base possible for monitoring analysis.

With the pending development of a nuclear waste repository adjacent to the park, it is imperative that a monitoring program be instituted as quickly as possible. This will allow the collection of systematic, and therefore effective baseline data before the disturbance occurs. Several years of data may be necessary for an adiquate baseline.

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APPENDIX I

USGS WELL AND SPRING NUMBERING SYSTEM

(Reproduced from Richter, 1980)

APPENDIX A

WELL AND SPRING NUMBERING SYSTEM

Water wells, springs, seeps, and oil and gas test wells cited in this report are numbered according to the U.S. Geological Survey system that specifies the location of the site based on the Federal land subdivision system. An example is shown on Figure 13.

In this example, 28, 18, 9 bcd, 28 refers to the township, 18 to the range, and 9 to the section in which the well is located. The lower case letters that follow the section number identify a smaller tract of land within the section. The first letter, b in this example denotes a 160-acre tract, commonly called a quarter section. The second letter, c denotes a 40-acre tract, commonly called a quarter-quarter section. The third letter, d denotes a 10-acre tract or a quarter-quarter-quarter section. The letters a, b, c, and d indicate respectively the northeast, northwest, southwest, and southeast tracts of the respective subdivision.

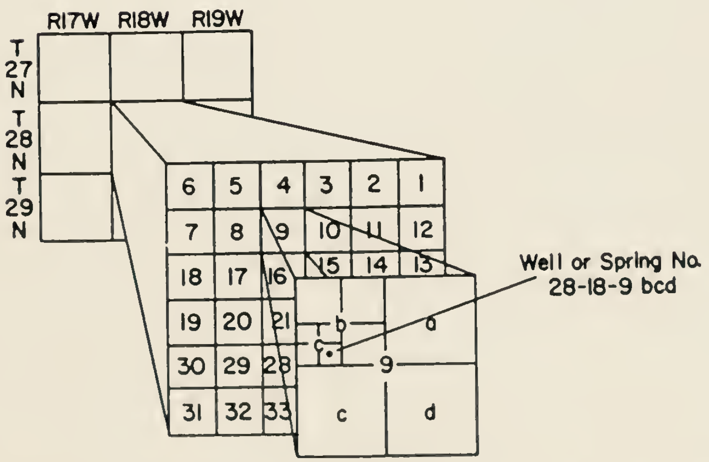

Figure 13. Example of the U.S. Geological Survey system of numbering wells and springs.