STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 83

RECONNAISSANCE OF THE QUALITY OF SURFACE WATER IN THE UPPER VIRGIN RIVER BASIN, UTAH, ARIZONA, AND NEVADA, 1981-82

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Prepared by
the United States Geological Survey
in cooperation with
the Utah Department of Natural Resources
Division of Water Rights

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CONVERSION FACTORS

For readers who prefer to use metric units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
acre	0.4047	square hectometer
	0.004047	square kilometer
acre-foot	0.001233	cubic hectometer
	1233	cubic meter
cubic foot per second	0.02832	cubic meter per second
cubic foot per second-day	0.02832	cubic meters per second-day
inches	2.54	centimeter
	25.40	millimeter
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
gallon per minute	0.06308	liters per second
mile	1.609	kilometer
square mile	2.590	square kilometer
ton per day	0.9072	metric ton per day megagram per day
ton per day per square mile	0.3502	megagrams per day per square kilometer

Temperature

degree Fahrenheit	$^{o}C= 5/9\ (^{o}F-32)$	degree Celsius
degree Celcius	$^{o}F= 9/5\ (^{o}C+32)$	degree Fahrenheit

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VIRGIN RIVER BASIN, UTAH, ARIZONA, AND NEVADA, 1981-82

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ABSTRACT

The Virgin River drainage from headwaters in Utah to Littlefield, Arizona, has an area of about 5,090 square miles in southwestern Utah, northwestern Arizona, and southeastern Nevada. In this area the river is about 110 miles long and receives water from nine major tributaries. Two tributaries, Fort Pierce Wash and Beaver Dam Wash, are ephemeral with flow occurring only from irrigation-return, floods or snowmelt, and springs in short reaches.

Outcropping geologic formations that affect water quality in the basin are fine-grained clastic and carbonate rocks of Mesozoic age.

Tributary inflow to the Virgin River during the study generally contained smaller dissolved solids concentrations than did the river and significantly diluted dissolved-solids concentrations in the river during low flow. Tributaries generally contained larger dissolved-solids concentrations than did the river during high flow, but the proportion of water from triburaries was smaller during high flow and dilution effect was relatively small.

La Verkin Hot Springs enters the river at Hurricane fault and contributes a flow of about 11 cubic feet per second. Dissolved-solids concentration of this springs is nearly 10,000 milligrams per liter with sodium and chloride constituting the major ions. Approximately 109,000 tons of dissolved solids flow from the springs annually.

During low flow, dissolved-solids concentrations in the Virgin River ranged from only 56 milligrams per liter in the North Fork Virgin River at Cascade Spring to 603 milligrams per liter upstream from La Verkin Hot Springs, and from 2,760 milligrams per liter downstream from the hot springs to 2,620 milligrams per liter at Littlefield, Arizona. During high flow, the dissolved-solids concentration upstream from La Verkin Hot Springs was 277 milligrams per liter and the range downstream from the springs was 492 to 1,120 milligrams per liter. Dissolved-solids concentrations were maximum during low flow and minimum during high flow at all sites except on some small streams near triburary headwaters. Boron concentration was less than the tolerance level of all crops upstream from La Verkin Hot Springs and was more than the tolerance level of many crops downstream from the springs.

Sodium hazard was low to medium except just downstream from La Verkin Hot Springs; the salinity hazard generally was low to high upstream from La Verkin Hot Springs and high to very high downstream from the springs.

Sediment loads ranged from 0.13 to 2,555 tons per day for 25 samples collected in August 1981 and from 0.55 to 3,582 tons per day for 14 samples collected in May 1982. These loads reflect stable stream conditions during sampling periods. Loads during flood flows have been as much as 1,930,000

tons per day for the period of record. Largest sediment loads were in the southwestern part of the basin, and largest sediment loads per square mile of drainage area were in the northeastern part of the basin where gradients are steeper.

Dissolved-oxygen concentrations ranged from 5.2 to 12.5 milligrams per liter except immediately downstream from thermal springs. Manganese concentrations were in excess of recommended limits for drinking water at several sites. Data were insufficient to identify sanitary problems but available data indicate that conditions may be degraded downstream from livestock areas. Pesticide concentrations were minimal at the few sites sampled.

INTRODUCTION

This report on the quality of surface water in the Virgin River basin from the headwaters near Navajo Lake, Utah, to Littlefield, Ariz., was prepared by the U.S. Geological Survey in cooperation with the Division of Water Rights, Utah Department of Natural Resources. The objectives of the study leading to the report were to obtain information on general chemical characteristics of surface water and to determine effects of the natural environment and water use on these characteristics. The scope of the study did not include an intensive investigation of the effects of man's activities on water quality.

Methods of Investigation

Water-quality data were obtained 1 to 5 times at 74 sites in the Virgin River basin between August, 1981 and September 1982. Fifteen additional sites were dry during all the sampling periods. The sites were numbered in consecutive upstream order, beginning at Littlefield, Arizona. The locations are shown on plate 1. Thirty-one sites were designed as key sites, and they were sampled during each of the five sampling periods, if accessible. The key sites included active gaging stations, locations at, upstream from, or downstream from major tributaries, and other locations of probable water-quality significance.

The concentrations of selected trace elements were determined semiquantitatively once at 23 sites and quantitatively once at 6 sites. The concentrations of pesticides in stream-bottom sediments were determined once at 4 sites.

Suspended-sediment samples were collected at 25 sites in August 1981, when flows were as low as 2 ft^3/s and at 14 sites in May 1982, when flows were as high as 600 ft^3/s. Sampling periods were selected when streamflow was most uniform, in order to define chemical characteristics of the river system. Sediment samples, therefore, represent only loads during uniform flow conditions.

Most streamflow measurements were made with fewer sections for velocity and depth determination than are used in standard stream-gaging procedures. This procedure was used in order to minimize the time needed for the large numbers of samples and measurements. Comparison of results of the two procedures on selected measurements were within 10 percent.

The U.S. Geological Survey began streamflow measurements at site 32 in 1909 in cooperation with the Utah State Engineer. The Geological Survey currently (1983) operates 16 stream-gaging stations in the study area and an additional 15 have been operated in the past.

Previous Studies

Patterson and Somers (1966) reported on the magnitude and frequency of floods in the Virgin River, and the U.S. Army Corps of Engineers (U.S. Department of Defense, 1973) published flood-plain information for the Virgin River and Fort Pierce Wash. Geological Survey studies concerned with water quality resulted in reports on the thermal springs of Utah (Mundorff, 1970), the disposition of water seeping from Navajo Lake (Wilson and Thomas, 1964), and a map showing the general chemical quality of surface water in parts of the study area (Price, 1980). Cordova, Sandberg, and McConkie (1972) and Cordova (1978 and 1981) reported on the chemical quality of ground water in the central Virgin River basin. Water-quality data, including trace metals and bacteria, were collected by the Geological Survey at sites 1, 17, and 32 prior to this study, the earliest being in 1949 at site 1. Water-quality and sediment data have been published annually in several series of reports of the Geological Survey (1974 and 1982).

Additional reports concerned with water quality include those by Deacon and Holden (1977), Vaughn Hansen Associates (1977), and Gebhardt (1977), and the Five County Association of Governments (1977). The U.S. Soil Conservation Service (1981) and the U.S. Bureau of Reclamation (1982) completed reports on the lower Virgin River, which includes part of the study area. Trudeau (1979) and Moore (1969) reported on Littlefield Springs and surface-water flow in the vicinity of Littlefield. The Utah Water Research Laboratory (1974) reported on planning for water quality in the Virgin River system, and Goode (1964) reported on the East Fork Virgin River.

HYDROLOGIC SETTING

Surface Drainage

The Virgin River basin (pl. 1) has an area of about 5,100 square miles, of which 3,000 are in Utah, 1,700 in northwestern Arizona, and 400 in southeastern Nevada. The river length is approximately 110 miles from its origin near Navajo Lake, Utah, to littlefield, Arizona. Nine major tributaries enter the river in the study area. They are East Fork Virgin River, North Fork Virgin River, North Creek, La Verkin Creek, Ash Creek, Leeds Creek, Fort Pierce Wash, Santa Clara River, and Beaver Dam Wash. Numerous small perennial and ephemeral tributaries enter the Virgin River and its major tributaries.

Flow in the North Fork Virgin River begins at Cascade Springs, which is partly sustained by water from Navajo Lake (Wilson and Thomas, 1964). Fort Pierce Wash, entry point for virtually all flow from Arizona, and Beaver Dam Wash, entry point for all flow from Nevada, usually are dry or have small flows. These washes, however, can have large sediment-laden flows during flash floods.

The Utah section of the study area contains about 15 reservoirs, most of which provide a small volume of water for irrigation. The three largest reservoirs are Kolob (6,900 acre-feet) on Kolob Creek about 10 miles southeast of Kanarraville; Gunlock (15,000 acre-feet) on the Santa Clara River about 1 mile south of Gunlock; and Ash Creek (12,000 acre-ft) on North Ash Creek about 9 miles south of Kanarraville. Capacity records are kept only for Ash Creek Reservoir where water is not usually released because most of it seeps into the porous basalt that underlies the reservoir. No reservoirs that are larger than stock ponds exist in the Arizona and Nevada sections of the study area.

Geology

The surface rocks in the upper Virgin River basin range in age from Precambrian to Quaternary. Similar geologic units have been grouped together for simplicity in plate 1. Groups that probably affect water quality most are the fine-grained clastic rocks of Mesozoic age, including the Tropic Shale and the Kayenta, Chinle, and Moenkopi Formations; and the carbonate rocks of Paleozoic age, including the Kaibab Limestone; Toroweap Formation; Callville, Redwall, Temple Butte, and Muddy Peak Limestones; Nopah and Bonanza King Formations; and the Muav Limestone. Although the rocks in the basin are extensively faulted, only the largest fault--Hurricane fault-- which is defined mainly by the Hurricane Cliffs, is shown on plate 1.

Topography

The drainage basin generally slopes toward the southwest in Utah, the northwest in Arizona, and the south in Nevada. Altitudes range from above 10,000 feet near the headwaters to below 1,900 feet at Littlefield. Some mountain areas have sheer slopes of several hundred feet (fig. 1). Steep stream gradients result in the erosion of large quantities of sediment, significantly affecting water quality. The terrain changes progressively downstream from high mountains and terraces to mesas and low desert land. Much of the area is virtually inaccessible. Major topographic features within the basin are Beaver Dam, Bull Valley, and Pine Valley mountains, Hurricane Cliffs, Vermillion Cliffs, and Kolob Terrace.

Soils

Most soils within the basin are sandy, sandy loam, or sandy loam with gravel, and range from shallow to deep (Mortensen and others, 1977; Richmond and Richardson, 1974) soils map. Most soils are well drained. Infertile soil in much of the basin supports little vegetation, particularly in desert areas where precipitation is meager. Some areas have virtually no soil and no vegetation.

Land Use

Recreation is a major land use. Zion National Park, several State parks, recreational areas, and mountain subdivisions for summer homes are located within the study area, mostly in Utah. Zion National Park is visited by about 1.5 million people annually including as many as 300,000 a month during the summer.

Figure 1.—Deep Creek drainage area, part of North Fork Virgin River and Zion Canyon area. Several sampling sites are located within the plateau area and in the distant canyon.

Deficiency of water precludes agricultural development in many parts of the basin. Main agricultural areas are in the vicinity of St. George and Hurricane. Limited farming also is done in the smaller valleys.

Much of the basin is used for rangeland, but sparse range growth generally limits grazing. Most of the grazing is in the forested areas, where small areas have been reseeded.

Climate

Normal annual precipitation in the basin ranges from more than 40 inches in the mountains to less than 8 inches in the low desert areas (pl. 2). Rain and melting snow in the mountains during spring and early summer provide water for downstream use. The small proportion of precipitation that falls on desert areas (mostly rain) either sinks into the porous soil or runs off as flash floods.

Temperatures generally range from 24 to -29 °Celsius near the headwaters; the mountain areas have fewer than 90 frost-free days. Temperatures generally range from 43 to -7 °Celsius in the desert areas; these areas have about 200 frost-free days (National Oceanic and Atmospheric Administration, 1981).

Water Sources and Use

Base flow of the Virgin River originates mainly from springs and seeps. Higher flows during spring and early summer result from snowmelt. Flash floods contribute little to total annual flow. Virtually all flow upstream from Littlefield originates in Utah. The small quantity of flow that occurs in Arizona and Nevada usually appears and disappears intermittently in streambeds, is ponded for stockwater, or is used for limited irrigation near the source.

Most use of water from the perennial streams is for irrigation. Water is diverted from the main channel of the Virgin River and tributaries along the entire course of the river. Largest diversions are to the Hurricane and La Verkin Canals, about 4 miles northeast of Hurricane, and the Washington Canal, about 7 miles east of St. George. Ground water is pumped for irrigation, particularly in the St. George-Hurricane area, and irrigation runoff adds to river flow downstream from these irrigated areas.

Phreatophytes along the streams consume water. The phreatophyte growth is mainly in downstream reaches where gradients are relatively flat and more soil exists.

CLASSIFICATION OF WATER FOR PUBLIC SUPPLY AND IRRIGATION

"The National Interim Primary Drinking Water Regulations*** were promulgated on December 24, 1975, in accordance with the provisions of the Safe Drinking Water Act (Public Law 93-523) *** These regulations become effective on June 24, 1977, and became in essence the standards by which all public drinking water supplies are judged" (U.S. Environmental Protection Agency 1976a, preface). The following table lists maximum contaminant levels for inorganic chemicals other than fluoride. The term "maximum contaminant level" is defined as the "maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system" (U.S. Environmental Protection Agency, 1976a, p. 5).

Contaminant	Level (milligrams per liter)
Arsenic	0.05
Barium	1.0
Cadmium	.010
Chromium	.05
Lead	.05
Mercury	.002
Nitrate (as N)	10.0
Selenium	.01
Silver	.05

When annual average of the maximum daily air temperature for the location in which the community water system is situated is the following, maximum contaminant levels (approved limits) and other recommended control limits for fluoride are (U.S. Environmental Protection Agency, 1976a, p. 5):

Temperature		Milligrams per liter			
		Recommended control limits for fluoride concentrations			
Degrees Fahrenheit	Degrees Celsius	Lower Lower	Optimum Optimum	Upper Upper	Approved limit
53.7 and below	12.0 and below	1.1	1.2	1.3	2.4
53.8 to 58.3	12.1 to 14.6	1.0	1.1	1.2	2.2
58.4 to 63.8	14.7 to 17.6	.9	1.0	1.1	2.0
63.9 to 70.6	17.7 to 21.4	.8	.9	1.0	1.8
70.7 to 79.2	21.5 to 26.2	.7	.8	.9	1.6
79.3 to 90.5	26.3 to 32.5	.6	.7	.8	1.4

Hardness of water is conventionally expressed in all water analyses made in the United States in terms of an equivalent quantity of calcium carbonate ($CaCO_3$). Some such convention is needed for hardness because this is a property imparted by several different cations, which may be present in varying proportions; however, actual presence of the indicated number of milligrams per liter in the form of $CaCO_3$ certainly should not be assumed (Hem, 1970, p. 84).

In practical water analysis, hardness is computed by multiplying the sum of milliequivalents per liter of calcium and magnesium by 50. Hardness value resulting generally is entitled "hardness as $CaCO_3$ "....or "total hardness". If hardness exceeds alkalinity (in milligrams per liter of $CaCO_3$ or other equivalent units), the excess is termed "noncarbonate hardness".... (Hem, 1970, p. 224-225).

Durfor and Becker (1964, p. 27) use the following classification for hardness:

Hardness range (milligrams per liter of calcium carbonate)	Description
0-60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

The U.S. Environmental Protection Agency produced a group of "Quality Criteria for Water" to provide a basis for judgement, other than regulatory use, for several programs that are associated with water quality. Following is a list of selected recommended limits for drinking-water supplies (U.S. Environmental Protection Agency, 1976b):

Constituent	Concentration	
	Milligrams per liter	Micrograms per liter
Beryllium	--	100
Chloride	250	--
Copper	--	1,000
Dissolved oxygen	5	--
Iron	--	300
Manganese	--	50
Sulfate	250	--
Dissolved solids	500	--

A classification for the dissolved-solids hazard in irrigation waters has been prepared by the U.S. Environmental Protection Agency (1976b, table 16). This classification is shown below:

Dissolved-solids concentration milligrams per liter	Effects or limitation
Less than 500	Usually none
500-1,000	Can be deterimental to some sensitive crops
1,000-2,000	May have adverse effects on many crops and require careful management
2,000-5,000	Can be used for tolerant plants on premeable soils, requires careful management practices

Salinity and sodium hazards of water used for irrigation are classified using a diagram developed by the U.S. Salinity Laboratory Staff (1954, p. 80). This diagram shows electrical conductivity of the water (salinity hazard) which is an indication of dissolved-solids concentration; and sodium-absorption ratio or SAR (sodium hazard), which is the relationship of sodium (Na^+), calcium (CA^{++}), and magnesium (Mg^{++}) ions expressed by the equation:

$$\frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

The assumption is made that water will be used under average soil and drainage conditions. If a large deviation from average conditions occurred, water could become unsuitable for use even though under average conditions it would be suitable for irrigation.

Boron may be a limiting factor in irrigation waters and is, therefore, considered in assessing water quality. The U.S. Environmental Protection Agency (1976b, p. 25) recommends a maximum concentration of 750 micrograms per liter of boron in water for the most boron-sensitive plants. Hem (1970, p. 329) rates irrigation water for various crops on the basis of boron concentrations in the water as shown in the following table:

Class of water		Boron (milligrams per liter)		
		Crops		
Rating	Grade	Sensitive	Semitolerant	Tolerant
1	Excellent	0.33	0.67	1.00
2	Good	.33 to .67	.67 to 1.33	1.00 to 2.00
3	Permissible	.67 to 1.00	1.33 to 2.00	2.00 to 3.00
4	Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
5	Unsuitable	1.25	2.50	3.75

Boron-sensitive crops include pears, apples, cherries, pecans, peaches, and apricots. Semitolerant crops include potatoes, barley, wheat, corn, milo, and oats. Tolerant crops include alfalfa and sugar beets.

CHEMICAL QUALITY OF SURFACE WATER

Water types are characterized in this report using an arbitrary nomenclature (Davis and DeWiest, 1966, p. 119). Major ions present as less than 20 percent of the total milliequivalents per liter of cations or anions are not used to name the water type. If any ion represents more than 60 percent of the total milliequivalents per liter of either cations or anions this ion is used alone to represent the dominant ion type. In mixed water types, ions present in greater than 20 percent but less than 60 percent of the cations or anions are listed in the order of their abundance. For example, water at site 2 during May 1982 had a 47 percent calcium, 28 percent sodium, 23 percent magnesium, and 2 percent potassium of cations and 52 percent bicarbonate, 37 percent sulfate, and 10 percent chloride of anions. This would be a calcium sodium magnesium bicarbonate sulfate water type. Bicarbonate is represented by alkalinity in tables 7 and 8 (back of report).

Streams in the Virgin River drainage flow from areas that are considerably different from each other in geology, land use, vegetation, altitude, and climate. Water quality is measurably affected by these differences. Solutes are determined by rock and soil composition, climate, biological effects of plants and animals, and water management and use as the water flows downstream. Water in the upstream reaches has relatively small concentrations of dissolved solids because much of the flow is derived from rainfall and snowmelt and has been in contact with soil and rocks for relatively short periods. Water-quality changes for two sampling periods are shown in plate 3. Changes in dissolved-solids concentration were generally gradual between sites and changes in patterns in the illustrations show the approximate location of the change in limits as represented by the patterns. Data were not available where no pattern is shown on the stream.

Classification of water for irrigation at selected sites indicates downstream change in quality of the water for irrigation (figs. 2 and 3).

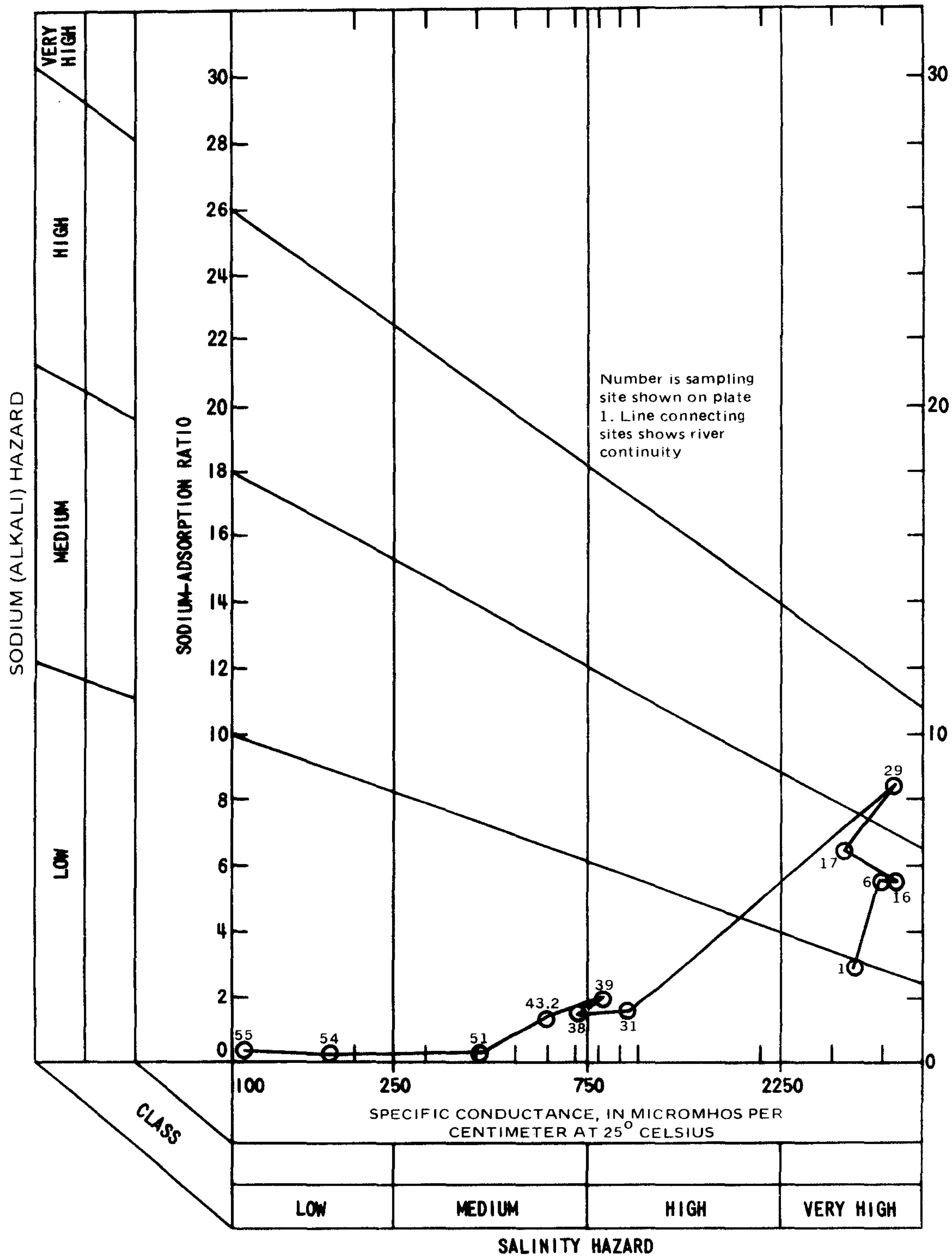

Figure 2.—Diagram showing classification of water for irrigation at selected sites on the Virgin River during low flow, August 17-31, 1981.

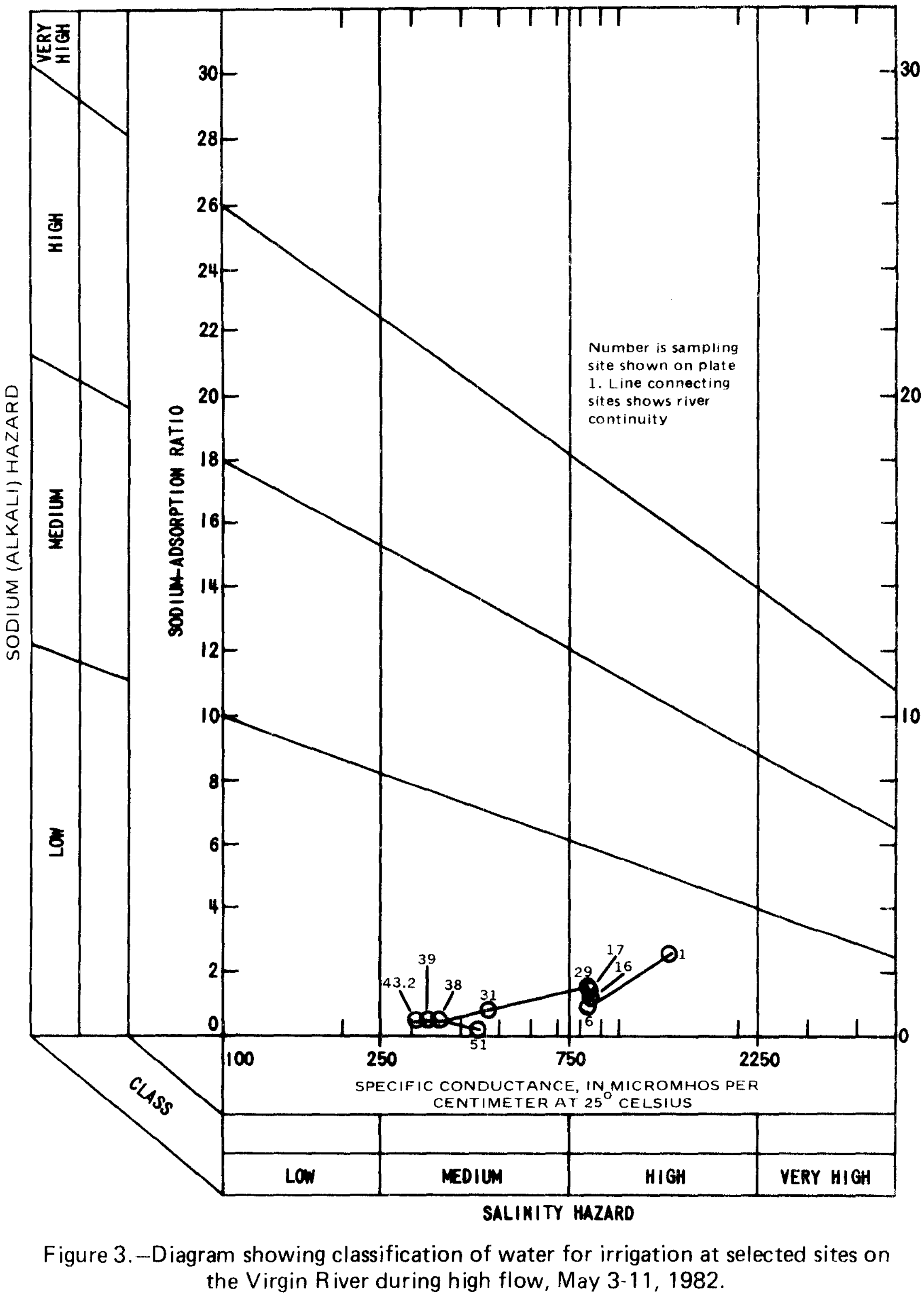

Figure 3.—Diagram showing classification of water for irrigation at selected sites on the Virgin River during high flow, May 3-11, 1982.

Changes in concentrations along the river during the five sampling periods are shown in figure 4. Dissolved-solids concentrations were affected significantly by the quantity of flow during various periods. Flows and concentrations of various constituents for sampling periods are shown in table 8. Downstream variations in the water quality are discussed in the following sections.

Dissolved Solids and Major Ions

North Fork Virgin River Drainage Area

Altitudes along the North Fork Virgin River range from about 8,900 feet at Cascade Spring to 3,800 feet at the confluence with the East Fork Virgin River. Average gradient of the river through this section is about 190 feet per mile although the gradient in some upstream reaches is much steeper.

The North Fork Virgin River begins at Cascade Spring, which emerges from the Tertiary Wasatch Formation about 6,400 feet south of Navajo Lake. Water sinks into porous basalt at the east end of Navajo Lake (fig. 5) and contributes much of the flow from Cascade Spring (Wilson and Thomas, 1964, p. 12, 13). Flow from Cascade Spring (site 54) during the investigation was lowest in October 1981 when the sink area of Navajo Lake had been dry for about 2 months and highest in August 1982 when water had covered the sink area since early summer. Dissolved-solids concentrations were largest; 139 milligrams per liter during the low October flow, but were smallest, 56 milligrams per liter, during the intermediate flow of August 1981 (table 8). In both cases the water was a calcium magnesium bicarbonate type.

Between Cascade Spring (site 54) and the head of Zion Narrows (site 51) many seeps, ephemeral streams, and small spring-sustained perennial streams enter the North Fork Virgin River. Deep snow packs and summer thunderstorms contribute most of the flow with discharge from springs and seeps comprising the base flow. Some water is diverted for irrigation of meadows, but most returns to the stream on the surface or as seepage. The area is used extensively for grazing and recreation during the summer. The dissolved-solids concentrations were between 222 and 278 milligrams per liter at site 51. Water type remained the same as at Cascade Spring.

Zion Narrows and Deep Creek area, characterized by steep canyons and sheer cliffs, was inaccessible for collecting water samples between sites 44.1, 45, 50 or 51 and site 43.2 (pl. 1). Within this area, Deep Creek, Kolob Creek, and Orderville Gulch enter the North Fork Virgin River. Terrain and water use of Deep and Kolob Creeks are similar to those of the North Fork Virgin River upstream from site 51 and water samples collected near their headwaters indicate their quality is similar to that of the North Fork. Orderville Gulch originates at a lower altitude and in a different rock formation with a resulting difference in water quality.

The Dakota Sandstone and Tropic Shale of Cretaceous age, coal-bearing formations, cropout between sites 51 and 43.2. Coal in these formations could affect quality.

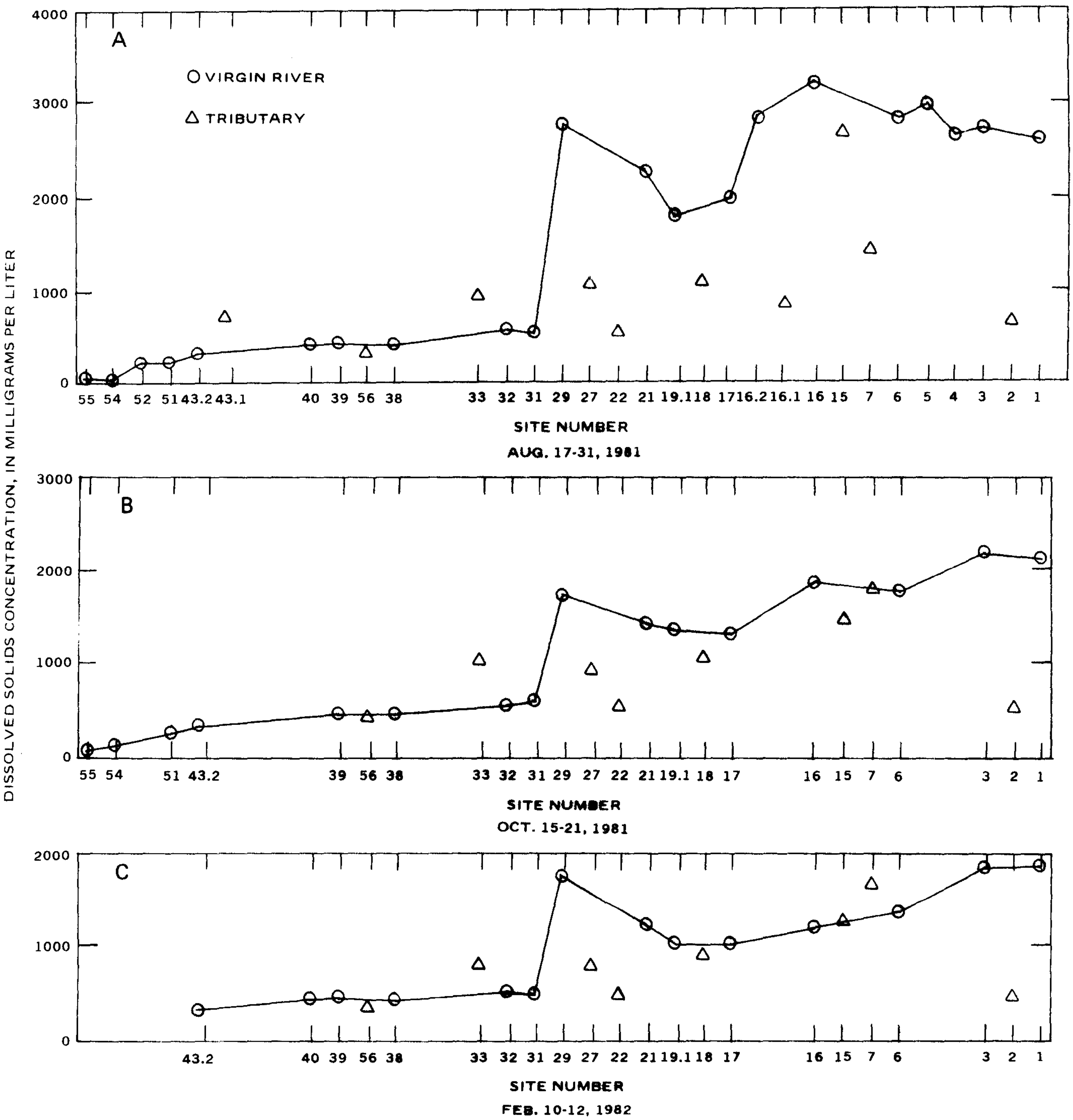

Figure 4.—Concentration of dissolved solids at selected sites.

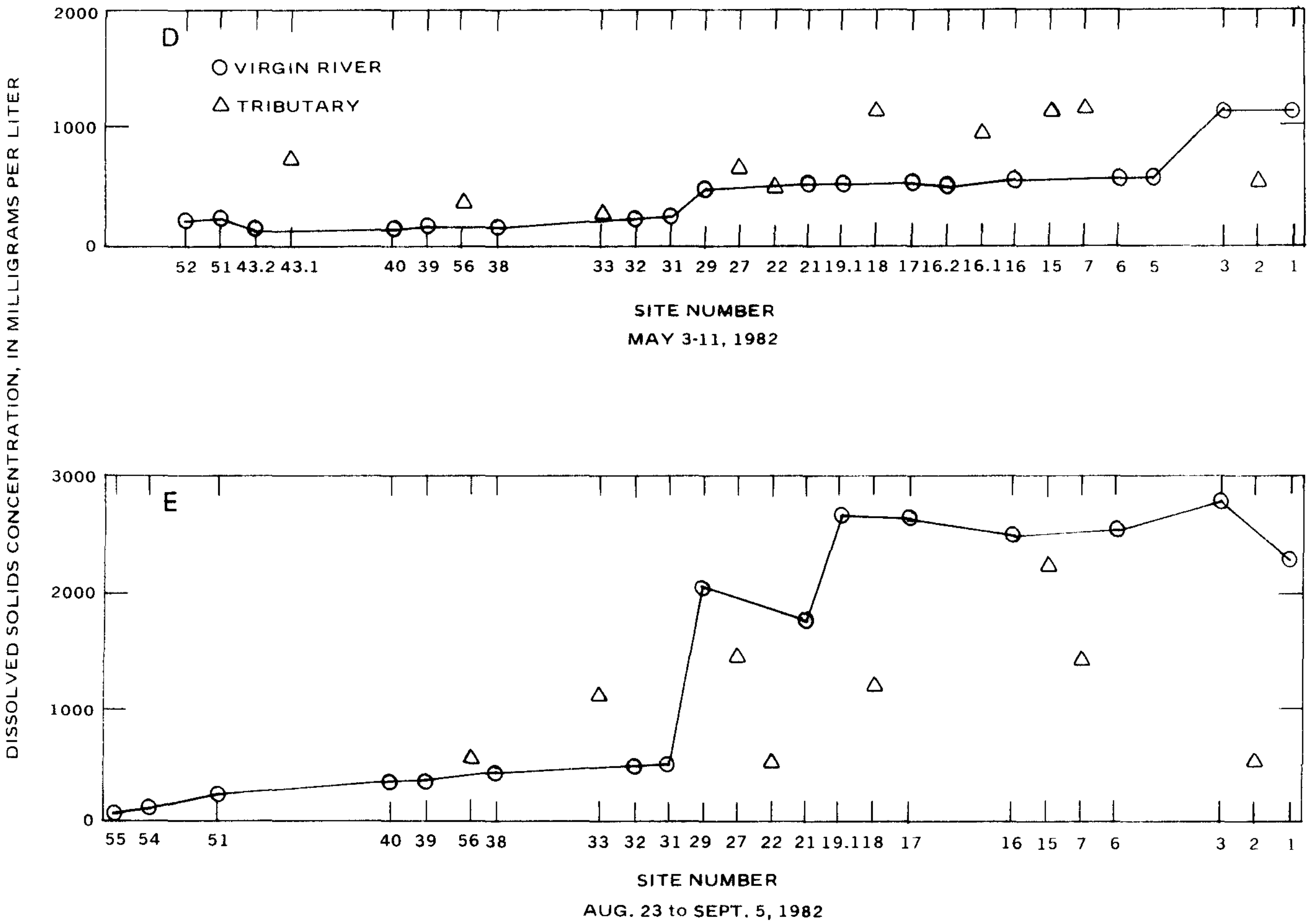

Figure 4.—Concentration of dissolved solids at selected sites—Continued.

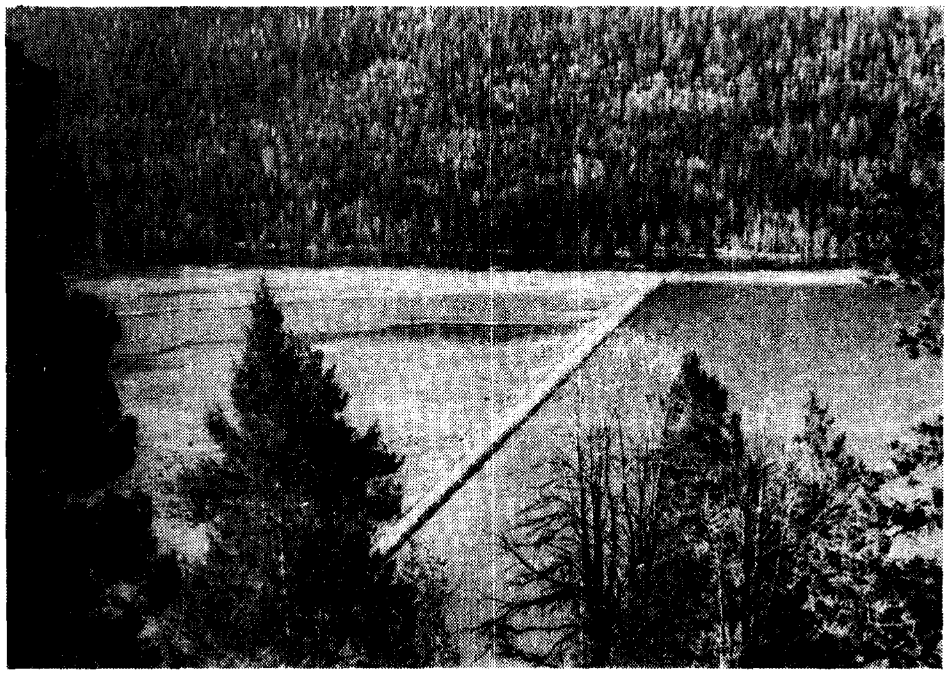

Figure 5.—Dike across east part of Navajo lake where water sinks into the lake bed, October 1982. Site 55 is at far end of dike.

Base flow through the Zion Narrows reach is composed of discharge from springs and seeps. Flow through this reach increased from 7.3 cubic feet per second at site 51 to 54 cubic feet per second at site 43.2 in October 1981, a typical period of low flow. Dissolved-solids concentration increased during all periods of low flow. Largest increases of sodium, sulfate, and chlorides changed the water to a calcium magnesium sodium bicarbonate sulfate type (table 7). Dissolved solids decreased during high flow in May 1982. Change in ions and dissolved solids are shown in plate 3.

Agricultural land along the North Fork Virgin River is located between Springdale, about 10 miles downstream from site 43.2, and site 39. This land is irrigated from small canals and ditches using water from the river, and runoff from irrigated areas returns to the river. The irrigation-return flow adds significantly to the mineral concentration of the river. Dissolved-solids concentrations increased about 30 percent between sites 43.2 and 39 during low flow and about 15 percent during high flow. Largest ion increases were sodium, sulfate, and chloride. The water was a calcium sodium magnesium chloride bicarbonate sulfate type during low flow and a calcium bicarbonate type during high flow.

Downstream increase in mineral concentration (as shown by increasing specific conductance) is shown in figures 2 and 3. In August 1981, when discharge was low, there was an increase in specific conductance of the water, but little change in SAR between sites 55 and 51 (fig. 2). In May 1982, when discharge was high, specific conductance decreased between sites 51 and 43.2, and increased slightly between sites 43.2 and 39 (fig. 3). SAR remained virtually the same along the entire reach, showing the dilution effect of the larger flow.

Change in dissolved solids during the five sampling periods are shown in figure 4. Low-flows (fig. 4, a, b, c, e) had increases in dissolved-solids concentrations, and high-flows (fig. 4, d) had little change in the concentrations from site 52 to site 39.

East Fork Virgin River Drainage Area

Altitudes along the East Fork Virgin River range from about 7,200 feet at the headwaters to 3,800 feet at confluence with the North Fork. Average gradient through this reach is about 90 feet per mile. Terrain of the East Fork drainage is less rugged than that of the North Fork drainage, although steep canyons and high cliffs make the reach from Mt. Carmel Junction (site 60) to the mouth of East Fork (site 56) generally inaccessible. Much of this drainage area is used extensively for grazing.

The Tropic Shale and Dakota Sandstone, both with veins of coal cropout between Glendale and Zion National Park. Small active and abandoned mines have been developed throughout these formations.

Headwaters of the East Fork Virgin River originate from seeps and springs, mostly in grazed meadow areas. Geologic Formations (pl. 1) and soil types are similar to those in the headwaters of the North Fork Virgin River; however, the headwaters of the East Fork have lower altitudes and less precipitation than the headwaters of the North Fork. Dissolved-solids concentrations in the East Fork upstream from site 64 were between 200 and 350 milligrams per liter which are similar to those at sites 51 and 52 on the North Fork. The water was a magnesium calcium bicarbonate type.

Land in the vicinities of Glendale, Orderville, and Mt. Carmel is irrigated with water from the East Fork Virgin River, and most of the flow through these areas is used for irrigation. Water also is diverted from upstream reaches of the East Fork and tributaries to irrigate meadows and mountain pastures. Runoff from all irrigated areas returns to the streams.

Dissolved-solids concentrations increased about 3.5 times through the irrigated areas (site 64 to site 60) during the irrigation season. Dissolved-solids concentration decreased more than 100 percent between sites 60 and 56 in August 1981 because natural inflow within this reach diluted the irrigation runoff. Flow at site 56 was more than 10 times that at site 60 (table 8). Dissolved-solids concentration were 1 to 2 times less at site 64 than at site 60 during nonirrigation periods. During these periods the dissolved-solid concentration at site 60 was less, the flow was larger, and the percent increase of natural inflow between sites 60 and 56 was less, resulting in dissolved-solid concentration decreases of less than 50 percent. Greatest decreases were in calcium, magnesium, and sulfate. Changes in ion concentration and total dissolved solids along the East Fork for high and low flow are shown in plate 3.

Virgin River Drainage Area from the Confulence of the North and East Forks to La Verkin Hot Springs

Altitudes along this reach of the river range from about 3,800 feet at the confluence of the East and North Forks to about 3,200 feet at La Verkin Hot Springs. The gradient averages 38 feet per mile. Small ephemeral and perennial streams enter the river in this reach.

Dissolved-solids concentrations were smaller in the East Fork upstream from the confluence with the North Fork (site 56) than in the North Fork upstream from the confluence for all low-flow samples except August 23, 1982 (site 49). During high flow the concentrations upstream from the confluence were larger in the East Fork than in the North Fork (fig. 4). A slight decrease in specific conductance and SAR in August 1981 at site 38 caused by mixing the East Fork and North Fork waters is shown in figure 5. Virtually no change occurred in May 1982 (fig. 3) when flow was higher in the North Fork.

The river flows in a wide meandering channel composed mostly of unstable sand from the confluence (site 38) to site 32. High discharge including flash floods can readily change channel shape and alignment. Phreatophyte growth along the channel includes cottonwood trees, willows, and salt cedar (tamarisk). Water is diverted for irrigation in this area. Predominant constituents at site 32 for five analyses during the study period (table 8 back of report) and the average of seven analyses prior to the study period (table 9) showed calcium, sulfate, and bicarbonate to be the dominant ions.

North Creek (site 33) was the only perennial tributary in this reach large enough to sample. This inflow had nearly twice the dissolved-solids concentration of the river, but discharge was so small in comparison to river flow that the dissolved solids had little effect on the river quality.

From site 32 to site 29 the river flows through a progressively deeper gorge where it erodes through higher terrain on the upthrown side of the Hurricane fault. River gradient is about the same along the entire reach between site 38 and 29 although the higher terrain gives the illusion of a steeper gradient between sites 32 and 29. The gorge is mostly in Kaibab Limestone of Permian age which crops out and forms cliffs in the vicinity of La Verkin Hot Springs. Water is diverted from the river into Hurricane and La Verkin Canals 2 miles upstream from La Verkin Hot Springs and within the gorge. Most river flow is diverted during periods of maximum irrigation. The largest quantity diverted during sampling periods of this study was about 60 percent of the total flow in August 1981.

Dissolved solids increased about 25 percent between sites 38 and 31 during low flow and about 35 percent during high flow. Specific conductance of the water increased proportinately and SAR increased slightly (figs. 2 and 3). Water along this reach generally was a calcium magnesium sodium bicarbonate sulfate type. Ion distribution at various sites is shown in plate 3.

Highly mineralized hot water from La Verkin Hot Springs (site 30) on the Hurricane fault enters the river through the bed and banks of the channel. Water temperatures in the different springs range from 38 to 42^{o} Celsius. Inflow from the springs is about 11 cubic feet per second (Mundorff, 1970, p. 44) and constitutes a large percentage of the river discharge during low flow. Major ions in the spring water are sodium and chloride, with sodium more than double calcium and magnesium and chloride about double sulfate. Mundorff (1970, p. 46) reported that annual discharge of dissolved solids from the springs to be about the same as that for the entire Virgin River basin upstream from the springs. The U.S. Bureau of Reclamation (1979, p. 1) reported that the springs discharge 109,000 tons of dissolved solids annually.

Discharge from La Verkin Hot Springs (site 30) changed water quality in the Virgin River most significantly between sites 31 and 29 during the August 1981 sample period when flow was lowest, and least significantly in May 1982 when flow was highest of the sample periods. Change in ions and dissolved-solids concentrations during these periods are shown in figures 3 and 4 and change in dissolved-solids concentrations for the five sampling periods are shown in figure 4. There was a large increase in specific conductance and SAR between sites 31 and 29 in August 1981 (fig. 2) when the spring flow was about 25 percent of total river flow. Increases were much smaller in May 1982 (fig. 3) when the spring flow was less than 2 percent of the river flow.

Boron concentrations increased from less than 100 micrograms per liter upstream from the springs to concentrations ranging from 150 to 1,300 micrograms per liter downstream from the springs. This general range persisted in the river as far downstream as Littlefield (table 3), and varied inversely with the quantity of water flowing in the river.

Mixing characteristics of La Verkin Hot Springs and Virgin River waters are shown in table 1. Data for the table were collected during low flow on September 22, 1982.

Virgin River Drainage Area from La Verkin Hot Springs to Santa Clara River

Altitudes range from 3,200 feet at La Verkin Hot Springs to 2,500 feet at Fort Pierce Wash with a gradient averaging 35 feet per mile.

Two main tributaries, La Verkin Creek and Ash Creek, enter the river from the north about 2 miles downstream from La Verkin Hot Springs. La Verkin Creek begins in the vicinity of Kolob Reservoir and drains mountainland along the east side of Hurricane fault. Outcroping geologic formations include sandstone, siltstone, and shale of Mesozoic age. Terrain is extremely rugged and the stream was inaccessible except in the downstream reach. One sampling site (27) was established at the mouth of the stream. Water at this site was a calcium magnesium sulfate bicarbonate type. Dissolved-solids concentrations ranged from 654 to 1,470 milligrams per liter. Sulfate was the ion of greatest concentration.

Ash Creek flows along the west side of Hurricane fault and is the main drainage for the east side of the Pine Valley Mountains. Geologic formations are mostly alluvium, basalt, and coarse-grained rocks. Ash Creek drainage is larger and streamflow generally is much larger than that of La Verkin Creek. Small tributaries, many ephemeral, from the Pine Valley Mountains, enter Ash Creek. Flow from snowmelt provided the only sample (site 25.1) from these tributaries. Kanarra Creek (site 26.1), a tributary in the northeastern part of the drainage, is completely diverted and used for irrigation in the Kanarraville area. This stream had a dissolved-solids concentrations of less than 300 milligrams per liter during low and high flows.

North and South Ash Creeks are the only perennial tributaries to Ash Creek. Flow from South Ash Creek is diverted for irrigation in the vicinity of Pintura. Water from North Ash Creek is impounded in Ash Creek Reservoir and mostly seeps into the basalt on which the reservoir is built. The reservoir was originally intended for irrigation but was not completed to specifications and is used mainly for flood control. Flow from Ash Creek Reservoir to Toquerville Springs, upstream from site 23, is from flash floods, snowmelt, or releases from Ash Creek Reservoir, all of which occur infrequently. All flow in Ash Creek at site 23 came from Toquerville Springs during the sample periods.

Toquerville Springs emerge from the streambed and banks of Ash Creek at the northern edge of Toquerville. Total flow from the springs, averages 20 cubic feet per second with flows from individual springs or seeps ranging to 4 cubic feet per second. Most of the water is diverted for irrigation between the springs and site 23. Origin of the springs is not known, but they are probably are sustained by underflow from Ash Creek or La Verkin Creek or both. Dissolved-solids concentrations (450 milligrams per liter) at site 23 were largest in the August 1981 sample. Proportionate ion concentrations were similar to those of La Verkin Creek with sulfate predominating.

La Verkin Creek at site 27 and Ash Creek at site 22 had significantly smaller dissolved-solids concentrations than the Virgin River at site 29 during the periods of low flow and diluted the river flow to site 21 (pl. 3). Further downstream, decreases in the river salinity occurred at site 19.1 in August and October 1981, and February 1982, probably because of fresher ground-water inflow.

Gould Wash enters the Virgin River from the south about 3 miles downstream from Ash Creek and is dry except during flash floods and return flow from irrigation in the vicinity of Hurricane. Two samples collected at the mouth of the wash (site 20.1) had dissolved-solids concentrations of 567 and 369 milligrams per liter. Concentrations of both samples were much smaller than concentrations in the river.

Leeds Creek originates in the southern part of Pine Valley Mountains and flows generally south to the Virgin River. Dissolved-solids concentration was 175 milligrams per liter in the one sample obtained at the upstream site (site 19) on Leeds Creek and ranged from 901 to 1,200 milligrams per liter for the five samples at the downstream site (site 18). The large dissolved-solids increase in the stream probably was caused by return flow from irrigation and seepage through Moenkopi and Shinarump Formations that contain considerable soluble minerals. Increases in dissolved-solids concentrations in the Virgin River between sites 19.1 and 16.2 in August 1981, and between sites 21 and 17 in August 1982, probably were caused by irrigation return and inflow from Gould Wash and Leeds Creek. Predominant constituents at site 17 for five analyses during the study (table 4) and the average of five analyses prior to the study (table 9) were sodium, sulfate, and chloride.

River flow is diverted to the Washington Canal (site 16.2) during the irrigation season. Water is used to irrigate about 4,900 acres of the more than 5,300 acres of cropland in the St. George-Washington area (Utah Division of Water Resources, 1982, p. 104).

An estimated 25,000 to 35,000 acre-feet of ground water per year seeps into streams or is pumped from wells and flows into streams in the central Virgin River area mainly in the Hurricane to St. George area (Cordova and others, 1972, p. 17). Dissolved-solids concentrations of some of the pumped water are larger than those of river water, but some inflow from seeps and springs has smaller dissolved-solids concentrations (Cordova and others, 1972, p. 54-55) compared with those at site 16.2 (table 8). Much of this spring and seep water enters the main channel directly and from small tributaries downstream from the irrigation diversion, or as return flow from irrigation between sites 16.2 and 16. These sources cause the river to regain a significant flow in relation to the quantity diverted. Dissolved-solids concentrations in the Virgin River increased 11 percent through the irrigated area.

There was a net increase in dissolved-solids concentration between sites 29 and 16 during all of the sampling periods except February 1982 (fig. 4). Sodium hazard decreased from high to medium and salinity hazard remained very high between the two sites in August 1981 when flow was low (fig. 2). Little change occurred in May 1982 when flow was high (fig. 3). Water at site 16 was a sodium calcium sulfate chloride type during low flow and a calcium sodium sulfate bicarbonate chloride type during high flow (table 7).

Fort Pierce Wash

About one-third of the Virgin River drainage is in Arizona. Water from most of this area reaches the river through Fort Pierce Wash. Virtually all land is uninhabited desert and is used for limited grazing. Altitudes generally range from 2,500 to 5,000 feet except for Mt. Trumbull (altitude 8,028 feet) at the southern edge and an area west of Hurricane fault near the Utah-Arizona border. Gradients are irrelevant along most of the channel because the wash is mainly ephemeral and flows that do occur are discontinuous. Gradient near the mouth of the channel is less than 1 foot per mile.

A subdivision and golf course presently span the channel near the mouth (fig. 6). Development along the channel was noted in a flood-plain study of the Virgin River and Fort Pierce Wash area (U.S. Department of Defense, 1973, p. 3).

Two main tributaries to the wash are Short Creek, which originates in the eastern part of the drainage and flows generally westward along the Utah-Arizona border, and Hurricane Wash, which originates in the southern part of the drainage near Mt. Trumbull and flows north along the west side of Hurricane fault. These streams are ephemeral except for a small reach of Short Creek upstream from Colorado City. This water is diverted and used for limited irrigation in that area.

Flow in Fort Pierce Wash upstream from the farmed area south of St. George comes from flash floods and runoff during the spring season. A water sample collected for this area (site 15.2) in May 1982 contained large concentrations of calcium and sulfate. Seepage and return flow from irrigation through the farmed area contribute little to flow in the wash. Dissolved-solids concentrations of the water at site 15 were similar to those of the river water at site 6 except during May 1982, when they were double those of the river.

Santa Clara River

The Santa Clara River originates on the north side of Pine Valley Mountains, flows west and then south and southeast to join the Virgin River south of St. George. Altitudes along the Santa Clara River range from about 8,000 feet in the headwaters to 2,500 feet at the mouth, with most of the altitude change being between the headwaters and Gunlock. The upstream reach has a gradient of about 175 feet per mile mostly through igneous rocks and is in a narrow canyon with little vegetation along the banks. By contrast, the downstream reach from Gunlock to the Virgin River has a gradient of about 52 feet per mile, is in a wider canyon, has medium growth of trees and willows, and flows mostly through fine- and course-grained clastic sedimentary rocks.

Water samples collected at sites 14, 14.1, and 14.2 had larger dissolved-solids concentrations in August 1981, when the flow was small, than in May 1982 when the flow was about 20 times larger than in August 1981 (table 4). Dissolved-solids concentrations decreased progressively downstream in August 1981, indicating that tributary inflow was diluting dissloved-solids load. The opposite occurred in May 1982, although little overall change was noted. Flow, with less dissolved solids, from springs entering the main channel

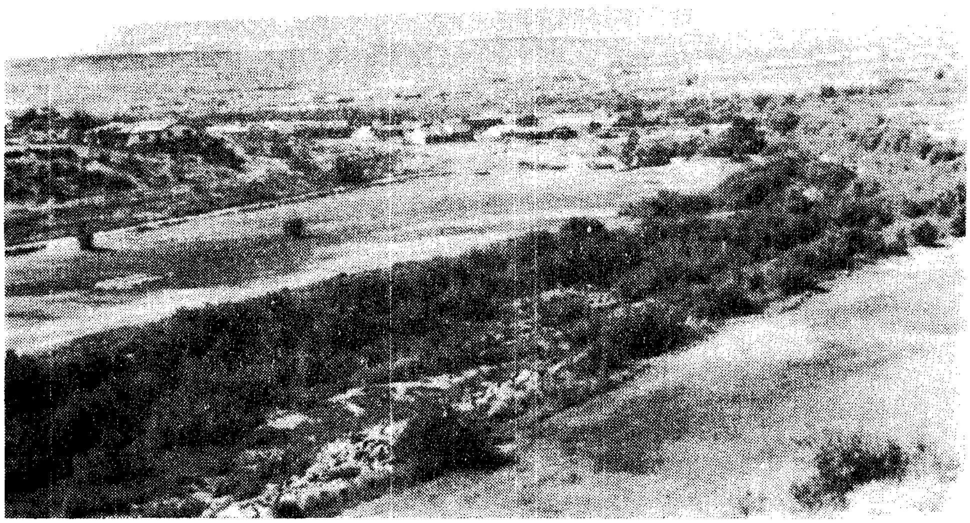

Figure 6.—Fort Pierce Wash near mouth with golf course and housing subdivisions. Site 15 is at far end of the golf course.

between sites 14.2 and 14 probably was the reason for a decrease in dissolved-solids concentations downstream in August 1981. This flow was minor and probably had a negligible effect when the streamflow was high in May 1982.

Flow usually occurs only during snowmelt. Dissolved-solids concentration of the 1 sample collected was 58 milligrams per liter, similar to that of other samples along the river upstream from site 13.3. A spring at site 13.3 flowing about one-half as much as low river flow and having more than twice the dissolved-solids concentrations, significantly increased mineral content of the river downstream from this point.

Veyo Hot Springs (site 12.1), about 6 miles upstream from Gunlock, flows from the base of a nearly vertical basalt canyon wall. Water temperature was 31 and 16 °Celsius and flow was 0.67 and 0.75 cubic foot per second for two samples collected. Mundorff (1970, p. 43, 44) reported a temperature of 98 °Fahrenheit or 37 °Celsius and a flow of 120 gallons per minute or 0.27 cubic foot per second and indicated that water may be of meteoric origin. Dissolved-solids concentration was about 25 percent greater than in the river water but the spring had virtually no effect on the river quality because of the relatively small spring inflow. Water from these springs is used in a swimming pool before entering the stream.

The Santa Clara River is diverted to a small reservoir downstream from Veyo Hot Springs for generating power and re-enters the main channel at Gunlock where it flows into Gunlock Reservoir. Several tributaries enter the main channel between the reservoir diversion and Gunlock, but little water flows as far as Gunlock except during periods of snowmelt or flash flooding. Samples were collected near the mouth of two perennial triburaries, Moody Wash (site 10) and Matgotsu Creek (site 11). Major ions in both samples were calcium and bicarbonate.

Water from Gunlock Reservoir is used for irrigation prior to entering the Virgin River. Use and return flow of this water between sites 8 and 7, mouth of the Santa Clara River, increased the dissolved-solids concentration about 500 percent. Largest ion increases were calcium, sulfate, and boron.

Virgin River Drainage Area
from Santa Clara River to Littlefield, Arizona

Altitudes along this reach of the Virgin River range from about 2,500 feet at site 6 to 1,840 feet at site 1, with about two-thirds of the change occurring in Virgin River Gorge located between the Utah-Arizona border and Littlefield, Arizona. Reaches at either end of the gorge are meandering sandy channels with considerable vegetation along the banks. The channel through the gorge is narrow and rocky with little vegetation. Many dry streambeds join the main channel along the entire reach. Inflow to the river from Fort Pierce Wash at site 15 and Santa Clara River at site 7 affected the quality of the Virgin River at site 6 during August and October 1981, and February 1982, but had little affect during May and August 1982 (fig. 4). Variations in changes were caused by combination of flows and mineral concentrations. Sodium and salinity hazards were virtually unchanged by the inflow (figs. 2 and 3). Major ions at site 16 and 6 were sodium, calcium, sulfate, and chloride during low flow. Major ions during high flow were the same with the addition of bicarbonate.

The entire river flow seeps into the streambed about 6 miles downstream from site 6 during extremely low flow, and the estimated average annual loss along this reach is 50 cubic feet per second (U.S. Bureau of Reclamation, 1982, p. 12). Geological Survey personnel measured losses of 36 to 106 cubic feet per second in 1952 and 1956. The streambed is thence dry to Virgin River Gorge where about 50 springs discharge into the river, with an additional 20 springs discharging into the river between the gorge and Beaver Dam Wash (Trudeau, 1979, pl. 3). Flow ranges from 0.1 to 3.0 cubic feet per second for individual springs, with a composit flow of about 60 cubic feet per second. Tritium analyses indicate at least two different sources of recharge to the springs; one was a minimum of 22 years old and one less than 22 years old. These sources are probably river seepage from upstream and local recharge from precipitation (U.S. Bureau of Reclamation, 1982, p. 12). Trudeau (1979, p. 50, 51) reported dissolved-solids concentrations in the springs of 2,940 milligrams per liter, with a predominance of calcium and sulfate. Bicarbonate and sodium, concentrations also were large. Temperature ranged from 22 to 27 ^{O}Celsius.

Dissolved-solids concentrations in the Virgin River decreased between sites 6 and 3 during the August 1981 sample period when the riverbed was dry along part of the reach but increased during other periods when flow between sites was continuous (fig. 4). Concentrations of all constituents increased during later periods, with the largest increases occurring in calcium, sodium, sulfate, and chloride. The section of dry riverbed was mainly through geologic formations containing significant quantities of these constituents.

Beaver Dam Wash enters the river from the northwest, 1 mile upstream from Littlefield. Headwaters are located about 50 miles north of Littlefield along the Utah-Nevada border. The stream is mostly in Utah and flows in a southerly direction. It is ephemeral except for short perennial reaches. Five sites (2 to 2.4) were sampled during the study. Reaches were discontinuous and waters were not necessarily related. All flows upstream from site 2 ranged from 2 to 5.3 cubic feet per second and contained from 200 to 500 milligrams per liter of dissolved solids. Major ions were calcium and bicarbonate. Springs near the mouth of the wash (site 2) supply the only water to the Virgin River. Flows during all sample periods were less than 6 cubic feet per second and contained less than 700 milligrams per liter of dissolved solids. Major ions at site 2 were calcium, sodium, magnesium bicarbonate, sulfate, carbonate, and bicarbonate. Little effect on water quality in the Virgin occurred by the inflow from Beaver Dam Wash.

Flow in the Virgin River increased a maximum of 9 percent between Beaver Dam Wash and Littlefield (site 1) as a result of springs and seeps entering the river. This flow, in addition to inflow from Beaver Dam Wash, caused no change in dissolved solids of the river in May 1982 between sites 3 and 1 and slight changes during other sampling periods (fig. 4). Sodium hazard was low and salinity hazard was very high in August 1981 at site 1. Water was a calcium sodium magnesium sulfate chloride type. Long-term records at site 1 include 609 analyses. Calcium and sulfate were ions with the greatest mean concentration for the period of record (1949-78) although other ions may have been predominant at specific times (table 9). Potassium and nitrogen were ions with the least mean concentration.

Trace Elements

Constituents of natural waters typically occurring in concentrations of less than 1.0 milligram per liter commonly are referred to as trace elements (Hem, 1970, p. 188). Water samples for trace-element analysis were collected at 23 sites in the Virgin River basin August 18-31, 1981. These samples were analyzed semiquantitatively for 24 constituents (table 2).[1] Based on those analyses six sites were resampled from August 23 to September 3, 1982 for quantitative analyses of 10 trace elements (table 7). The 10 trace elements analyzed for quantitatively were chosen based on previous reports of possible problems in the basin and constraints imposed by available laboratory schedules.

The Five County Association of Governments (1977) inventory of Virgin River basin sites reported sporadic problems with large concentrations of the elements arsenic, iron, manganese, and selenium. Semiquantitative and quantitative analyses for this study (table 7) showed iron or selenium concentrations less than the permissable minimum contaminant level of the U.S. Environmental Protection Agency (1972) although reported concentrations are dissolved only. One quantitative analysis (site 21, September 2, 1982) showed an arsenic concentration larger than the Utah State Division of Health (Utah Water Research Laboratory, 1974) recommended limits in the dissolved phase; but the concentration was lower than the mandatory limit. Samples from six sites in the Virgin River and tributaries had dissolved manganese concentrations larger than recommended Utah Class C stream standard concentrations and in excess of U.S. Environmental Protection Agency (1972) public-water supply and irrigation recommended limits for total manganese concentration.

Other Factors Affecting Surface-Water Quality

Fluvial Sediment

Sediment concentration depends on runoff intensity and type, and stability of watershed material. Concentration and quantity of runoff, or discharge, determines total sediment load of a stream. Relation between suspended-sediment concentration and load is expressed by the formula:

$$\text{Suspended-sediment load} = \text{discharge} \times \text{concentration} \times 0.0027.$$

Suspended-sediment load is reported in tons per day, discharge in cubic feet per second, concentration in milligrams per liter, and 0.0027 is the unit's conversion factor.

Suspended sediment in streams of Virgin River drainage mostly is transported during thunderstorms and snowmelt. Suspended-sediment loads caused by thunderstorms vary in intensity and pattern at different locations. Thunderstorms are limited in extent and usually affect only parts of the basin where they occur and the channel downstream. Loads during snowmelt may show similar patterns in larger parts of the basin.

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[1] Lead concentrations are not reported in the semiquantitative analysis table 7 because of an error in the methodology.

Suspended-sediment analyses for this study represent only concentration and loads during stable flow conditions as sampling periods were selected when streamflow was most stable. Suspended-sediment samples were collected at 25 sites in August when flows were low, and at 19 sites in May when flows generally were high. The largest load recorded during the study was 34,108 tons per day during a flood on August 24, 1982 at site 17. Sediment loads ranged from 0.06 (site 33) to 2,555 tons (site 16.2) per day in August and from 0.55 (site 77) to 3,580 tons (site 33.1) per day in May. Comparison of data for the two periods shows the greater transporting capacity of the larger streams in May. Stream discharge and suspended-sediment loads at selected sites for these periods are shown in table 8.

Sediment data were collected at six sites within the study area for various long-term periods. These data show a large variation in sediment load of the river and its tributaries. Maximum and minimum loads for periods of record at these sites are shown in table 3.

Suspended-sediment discharge during water year 1970 at site 32 is shown in table 4. During the 1970 water year total annual sediment load was near average for the 9-year period of record at site 32. It is, therefore, considered to be representative of annual sediment loads at the site.

Rapid velocities resulting from steeper gradients and large discharges increases the erosive power in upstream reaches of streams and produce larger sediment loads per square mile. The following table compares altitude changes, drainage areas, and sediment loads in upstream and downstream reaches of the Virgin River; the 1963-68 period was selected because it was the only period common to site 32 and 1:

Site no.	Stream Stream gradient (feet per mile)	Drainage Drainage area (square miles)	Sediment load: 1963-68 average: Tons per day	Sediment load: 1963-68 average: Tons per day per square mile	Sediment load: Maximum: Tons per day	Sediment load: Maximum: Tons per day per square mile
54			--	--	--	--
	121	934				
32			3,870	4.1	1,300,000	1,392
	30	4,156				
1			5,929	1.4	1,800,000	433

Dissolved Oxygen

Determination of dissolved-oxygen concentration was made during each site visit (table 4). Concentrations, excluding those at hot springs, ranged from 5.2 milligrams per liter (79-percent saturation) at site 29 in August 1981, to 12.5 milligrams per liter (105-percent saturation) at site 56 in February 1982. Dissolved-oxygen concentrations of 0.5 and 4.6 milligrams per liter were noted at the two hot springs in August 1981; however, after mixing with receiving water, the effect of the smaller dissolved-oxygen concentrations was largely negated. Dissolved-oxygen concentration at site 29, immediately downstream from La Verkin Hot Springs, was 5.2 milligrams per liter on August 25, 1981 during low flow. This is near the minimum concentration of 5.0 milligrams per liter recommended by the U.S. Environmental Protection Agency (1976b, p. 123) for maintenance of a viable fish population and is less than Utah Class C stream standards that have been applied to the Virgin River system (Utah Water Research Laboratory, 1974, p. 15). When combined with increased temperatures, this may create an avoidance barrier to fish during low flows (Warren, 1971, p. 188) and affect distribution and survival of aquatic insects (Nebeker, 1972). Dissolved-oxygen concentrations at selected sites in August 1981 are shown in figure 7.

Diurnal dissolved-oxygen periodicity was measured at 11 sites with a continuous dissolved-oxygen monitor for varying times during March and April 1982. Graphic representation of dissolved-oxygen fluctuations, combined with separate site measurements, showed that dissolved-oxygen concentrations in the basin correlated closely with water temperatures in all areas not directly affected by thermal springs. Monitor data on some tributaries showed marked increases in dissolved-oxygen concentrations during daylight hours due to photosynthetic oxygen production. Turbid conditions and the shifting nature of the sand channel in the mainstream limit aquatic vascular plant, phytoplankton, and algal growth so that the photosynthetic contribution to dissolved-oxygen concentrations is minimal. At monitoring sites on the Virgin River there was almost a direct correlation between water temperature and dissolved-oxygen concentrations without large photosynthetic daytime peaks.

Continuous monitoring downstream from La Verkin Hot Springs (site 29), February 26 to March 3, 1982, indicated an anomaly for both dissolved oxygen and water temperature. For about 1 hour each evening between 7:30 and 11:30 p.m. (local time), the dissolved-oxygen concentrations were rapidly decreased by 0.4 to 0.6 milligram per liter and after 1 hour rapidly increased to previous concentrations. A corresponding increase in water temperature of 1.3 to 1.6 $^{\circ}$Celsius was noted during each period of dissolved-oxygen decrease. An increase in specific conductance of the water also was noted on a separate monitor; but as this was an hourly monitor, it did not consistently register the increase. A similar irregularity of lesser intensity was noted during the morning hours.

Specific conductance, pH, dissolved oxygen, and water temperature were monitored at the springs during the evening of October 28, 1982. Although the hot springs pool water was observed to become very milky during the monitoring, no significant changes were noted in any of the measured properties. The oxygen depletion monitored downstream from the springs was, therefore, attributed to a brief increase in spring flow in a consistent geyser-like fashion and to incomplete mixing with surface water at the

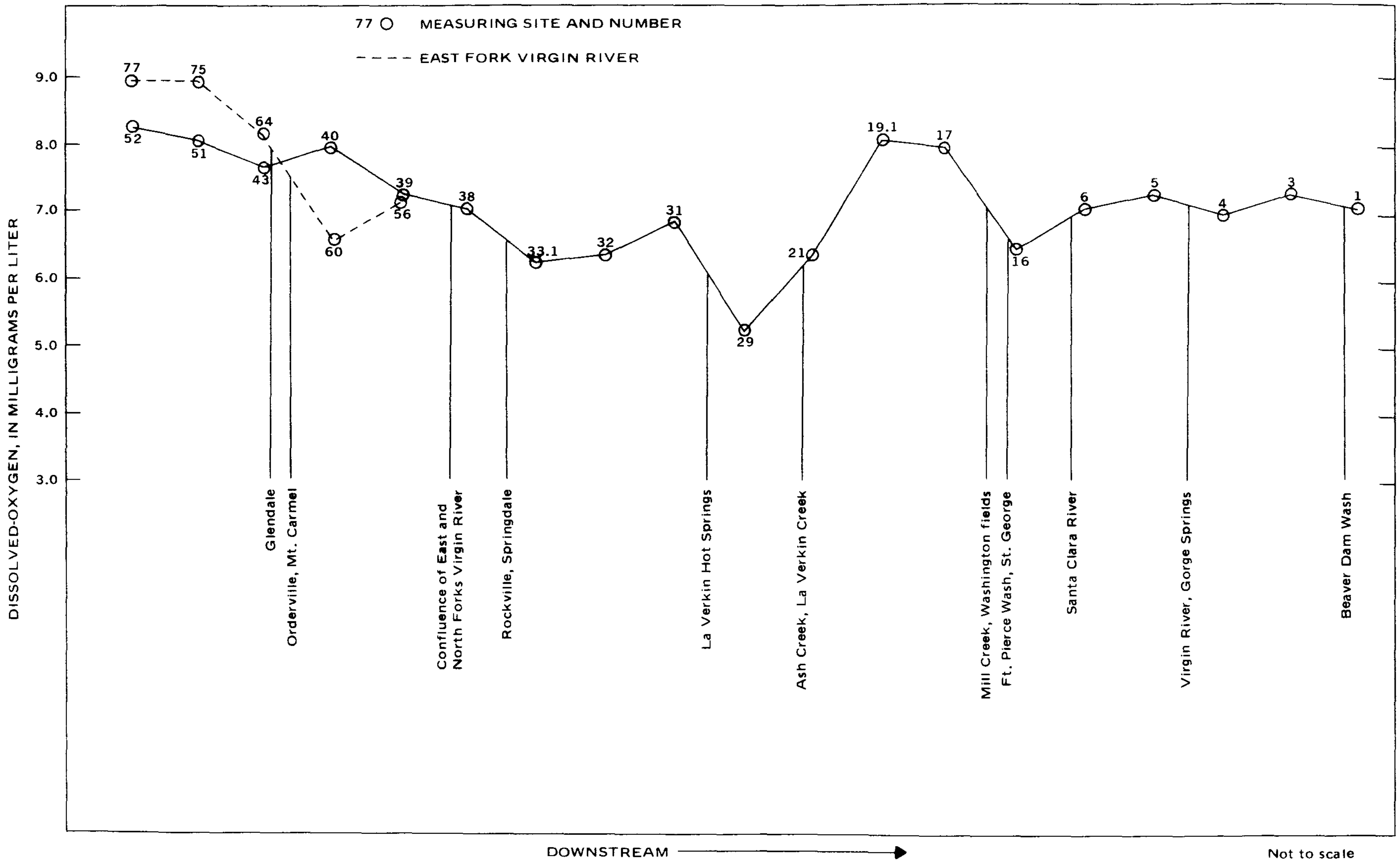

Figure 7.—Dissolved-oxygen measurements at selected sites during low flow, August 17-31, 1981.

monitoring site, as noted by measurements made at cross sections on September 22, 1982. Further study will be needed to confirm the exact cause and effect relationship.

Bacteria

Certain bacteria which inhabit the intestines of animals are widely used in detecting fecal contamination and the possible presence of pathogenic organisms. While the "indicator bacteria" themselves may not be harmful, they are considered to indicate the disease-producing potential of water. Fecal coliform bacteria are among the organisms present in the intestine and feces of warm-blooded animals and are used to indicate recent contamination. Fecal streptococcus bacteria also are present in the intestine of man and other animals and may aid in determining the origin of pollution (Slack, 1974, written commun.).

Bacterial samples were collected at 24 sites during August 18-31, 1981. Samples were analyzed using the membrane-filter method (Greeson and others, 1977). Results of the bacterial sampling are presented in table 5.

Also included in table 5 is the ratio formulated by dividing fecal coliform colony (FC) count by the fecal streptococcus colony (SC) count (both expressed as colonies per 100 milliliters of sample). The FC/FS ratio has been used as an investigation tool in pinpointing the source and location of fecal-waste contamination (American Public Health Association and others, 1976).

Determination of the origin of fecal contamination is based on the following values for the ratio (Millipore Corp., 1972, p. 36):

$$\frac{\text{Fecal coliform count (colonies per 100 milliliters)}}{\text{Fecal streptococcus count (colonies per 100 milliliters)}} = \text{FC/FS ratio}$$

$FC/FS \geq 4.0$ indicates pollution derived from human wastes.

$0.7 < FC/FS \leq 4.0$ indicates mixed pollution sources.

$FC/FS \leq 0.7$ indicates pollution primarily from livestock or poultry sources.

The U.S. Environmental Protecton Agency (1972, p. 58) recommends that fecal coliform densities in untreated surface-water sources not exceed 2,000 colonies per 100 milliliters.

Data obtained from the single sampling are not sufficient to confirm sanitary problems in the basin; however, earlier studies have documented large coliform bacteria concentrations in tributaries and in the main channel during low flow (Five County Association of Governments, 1977, p. 61).

Pesticides in Stream-bottom Materials

Analyses were made for 24 organochlorine or organophosphorus compounds in bottom-material samples at 4 sites downstream from major agricultural areas. Results of the pesticide analyses are presented in table 6. None of the compounds were present in detectable concentrations.

SUMMARY

Water quality in the upper Virgin River basin from the headwaters in Utah to Littlefield, Arizona, varies considerably. This variation results primarily from variations in geology, hot-spring inflow, and return flow from irrigation. During this study, dissolved-solids concentrations were less than 100 milligrams per liter in the headwaters of North Fork Virgin River and the Santa Clara River. Headwaters of other triburaries generally contained between 200 and 400 milligrams per liter dissolved solids. Dissolved-solids concentrations increase progressively downstream in each tributary, which increased or decreased concentrations in the receiving stream depending on relative discharges of the two streams.

Concentrations of dissolved solids in the Virgin River were large during low flow when inflow from tributaries had greatest effect on the river. Many small tributaries had larger concentrations than the river at higher flows but had little effect on the river quality because their flow was small compared to that of the river.

La Verkin Hot Springs caused the single greatest change in river quality. In the Virgin River downstream from La Verkin Hot Springs sodium hazard generally was low, but was medium to high during low flow. Salinity hazard ranged from low to high upstream from the springs and high to very high downstream from the springs. Dissolved-solids concentration downstream from the springs was nearly five times greater than upstream from the springs during the lowest flow and less than two times greater during the highest flow. Boron concentrations upstream from the spring were smaller than the tolerance level of all boron-sensitive crops; they were larger than tolerance level of many crops downstream from the springs.

Calcium was the predominant cation and sulfate the predominant anion in the river system. Sodium, magnesium, bicarbonate, and chloride were in greater concentrations in some reaches, but not as consistently present as calcium and sulfate.

Most sediment was transported by the river during thunderstorms and snowmelt. Greatest suspended-sediment loads were measured in the southwestern part of the basin with the greatest loads per square mile occurring in the northeastern part of the upper basin.

Dissolved-oxygen concentrations generally were larger than 6.0 milligrams per liter within the basin except in short reaches immediately downstream from thermal springs and in several small tributaries during low summer flows.

Manganese concentrations were in excess of recommended limits in some reaches of the river and in several small tributaries.

Data from this study were insufficient to confirm sanitary problems. These data, combined with previous studies, indicate that bacterial loads may cause degraded sanitary conditons downstream from livestock grazing areas during low flow. Pesticide concentrations were minimal at all sites sampled.

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Table 1.--Mixing characteristics of La Verkin Hot Springs and Virgin River waters

Section 1: located about 300 feet downstream from main spring area.
Section 2: located about 600 feet downstream from main spring area.

Asterisk (*) indicates small spring located on right bank about 5 feet upstream from section 1.

	Section 1			Section 2		
Distance from bank (feet)	Temperature (degress Celsius)	Specific conductance (microhmos per centimeter at 25 ^{o} Celsius)	Dissolved oxygen (milligrams per liter)	Temperature (degrees Celsius)	Specific conductance (microhmos per second at 25 ^{o} Celsius)	Dissolved oxygen (milligrams per liter)
(left bank)						
0	36	15200	3.2	26	5100	5.7
3	29	6500	4.8	26	5000	5.7
6	26	4100	5.2	26	5000	4.6
9	25	3650	6.2	25	4900	5.7
12	24	3500	6.4	24	4200	6.0
15	24	3400	6.4	24	3700	6.3
18	24	3300	6.5	24	3600	6.4
21	24	3300	6.5	23	3600	6.4
24	24	3300	6.5	23	3700	6.4
27	24	3400	6.5	22.5	3700	6.4
30	24.5	3470	6.4	23.5	3780	6.4
33	24.5	3550	6.3	24	3800	6.4
36	24.5	3600	6.2	24	3880	6.2
39	25	3800	6.2	23.5	3900	6.2
42	26	5100	5.2	22	3900	6.1
(right bank)						
*	38	15500	0.2			

Site No.	Sampling Date	Site Name	Alu-minum, (Al)	Arse-nic, (As)	Anti-mony, (Sb)	Bar-ium, (Ba)	Beryl-lium, (Be)	Bis-muth, (Bi)	Cad-mium, (Cd)	Chro-mium, (Cr)	Co-balt, (Co)	Cop-per, (Cu)	Gal-lium, (Ga)
2	8-28-81[1]	Beaver Dam Wash at mouth, Arizona	100	—	<30	100	<1	<1,000	<1	<50	<5	<10	<30
4	do.	Virgin River below Virgin River Gorge, Utah	700	—	50	30	<1	<1,000	<1	<50	<5	<10	100
	9- 3-82	do.	—	8	—	—	—	—	<1	20	—	1	--
6	8-28-81	Virgin River near Bloomington, Utah	700	—	50	100	<1	<1,000	1	<50	<5	<10	100
7	8-18-81	Santa Clara River at mouth, Utah	500	—	50	70	<1	<1,000	<1	<50	<5	<10	50
	8-23-82	do.	—	8	—	—	—	—	<1	20	—	1	--
12	8-18-81	Santa Clara River below Veyo Hot Springs, Utah	300	—	<30	100	<1	<1,000	<1	<50	<5	<10	<30
12.1	do.	Veyo Hot Springs, Utah	100	—	<30	100	<1	<1,000	<1	<50	<5	<10	30
13	do.	Santa Clara River above Veyo Hot Springs, Utah	100	—	<30	100	<1	<1,000	<1	<50	<5	<10	<30
15	8-28-81	Fort Pierce Wash at mouth, Utah	500	—	<30	100	<1	<1,000	<1	<50	<5	<10	100
	9- 2-82	do.	—	10	—	—	—	—	<1	20	--	2	--
16.1	8-20-81	Mill Creek near Washington, Utah	100	—	<30	50	<1	<1,000	<1	<50	<5	<10	<30
18	8-19-81	Leeds Creek at mouth, Utah	500	—	70	100	<1	<1,000	<1	<50	<5	<10	<30
19.1	8-31-81	Virgin River above Leeds Creek, Utah	300	—	30	70	<1	<1,000	<1	<50	<5	<10	50
20.1	8-28-81	Gould Wash at mouth, Utah	300	—	<30	100	<1	<1,000	<1	<50	<5	<10	<30
21	8-25-81	Virgin River below Ash Creek, Utah	500	—	50	100	<1	<1,000	1	<50	<5	<10	100
	9- 2-82	do.	—	31	—	—	—	—	<1	10	—	<1	--
23	8-25-81	Ash Creek below Westfield Ditch, Utah	300	—	<30	70	<1	<1,000	1	<50	<5	<10	50
	9 -2-82	do.	—	4	—	—	—	—	<1	<10	—	<1	--
27	8-25-81	La Verkin Creek at mouth, Utah	300	—	30	100	<1	<1,000	<1	<50	<5	<10	50
	9- 2-82	do.	—	5	—	—	—	—	<1	<10	--	1	--
30	8-25-81	La Verkin Hot Springs, Utah	700	—	70	50	<1	<1,000	7	<50	<5	<10	100
32	8-24-81	Virgin River at Virgin, Utah	300	—	<30	100	<1	<1,000	1	<50	<5	<10	70
33	do.	North Creek at mouth, Utah	300	—	30	100	<1	<1,000	<1	<50	<5	<10	30
39	do.	North Fork Virgin River above confluence, Utah	100	—	30	100	<1	<1,000	<1	<50	<5	<10	<30
40	do.	North Fork Virgin River near Springdale, Utah	100	—	30	100	<1	<1,000	<1	<50	<5	<10	<30
56	do.	East Fork Virgin River above confluence, Utah	100	—	<30	100	<1	<1,000	<1	<50	<5	<10	<30
60	8-20-81	East Fork Virgin River at Mt. Carmel, Utah	500	—	<30	70	<1	<1,000	<1	<50	<5	<10	<30
64	do.	East Fork Virgin River near Glendale, Utah	300	—	<30	50	<1	<1,000	<1	<50	<5	<10	<30

[1] 1981 data are semiquantitative. Results are reported from detection limit to upper concentration limit in steps of 1, 3, 5, 7, and 10. Due to rounding technique results are an estimate of one significant figure. Precision is approximately (+) or (-) one step at 68 percent confidence level and (+) or (-) two steps at 95 percent confidence level.

collected during August 1981 and August, September 1982

Micrograms per liter															
Germanium, (Ge)	Iron, (Fe)	Lead, (Pb)	Lithium, (Li)	Manganese, (Mn)	Mercury, (Hg)	Molybdenum, (Mo)	Nickel, (Ni)	Selenium, (Se)	Silver, (Ag)	Strontium, (Sr)	Tin, (Sn)	Titanium, (Ti)	Vanadium, (V)	Zinc, (Zn)	Zirconium, (Zr)
300	<5	—	50	1	—	<10	<50	—	<10	1,000	100	<5	30	<5	<5
700	10	—	500	70	—	10	<50	—	<10	5,000	700	10	<10	10	<5
—	30	4	—	110	0.1	—	—	2	—	—	—	—	—	10	—
700	10	—	500	100	—	10	<50	—	10	5,000	700	10	30	<5	<5
500	10	—	70	300	—	<10	<50	—	<10	3,000	500	7	10	<5	<5
—	11	5	—	420	<.1	—	—	2	—	—	—	—	—	11	—
100	7	—	30	7	—	<10	<50	—	<10	300	100	<5	<10	<5	<5
300	5	—	30	1	—	<10	<50	—	<10	700	300	<5	10	<5	<5
100	7	—	30	7	—	<10	<50	—	<10	300	100	<5	10	<5	<5
700	10	—	300	300	—	<10	<50	—	<10	5,000	500	10	<10	7	<5
—	20	<1	—	120	.1	—	—	1	—	—	—	—	—	20	—
100	7	—	100	10	—	<10	<50	—	<10	1,000	100	<5	<10	<5	<5
700	10	—	70	10	—	<10	<50	—	<10	3,000	500	<5	10	<5	<5
500	7	—	500	5	—	<10	<50	—	<10	3,000	300	7	<10	<5	<5
300	30	—	30	5	—	<10	<50	—	<10	1,000	100	7	<10	<5	<5
500	10	—	500	50	—	10	<50	—	10	3,000	500	10	<10	10	5
—	20	5	—	70	<.1	—	—	1	—	—	—	—	—	10	—
300	10	—	10	3	—	10	<50	—	<10	1,000	300	10	10	<5	<5
—	<3	<1	—	2	.1	—	—	1	—	—	—	—	—	3	—
500	10	—	30	100	—	<10	<50	—	<10	3,000	300	10	10	<5	<5
—	8	<1	—	210	.1	—	—	2	—	—	—	—	—	20	—
1,000	10	—	3,000	30	—	30	<50	—	<10	>10,000	700	30	10	10	<5
300	10	—	30	7	—	10	<50	—	10	1,000	300	10	<10	<5	<5
300	10	—	50	30	—	<10	<50	—	<10	3,000	300	7	10	10	<5
300	7	—	30	5	—	<10	<50	—	<10	700	100	<5	<10	<5	<5
100	<5	—	30	10	—	<10	<50	—	<10	700	100	<5	<10	<5	<5
300	<5	—	30	7	—	<10	<50	—	<10	1,000	100	<5	<10	5	<5
500	5	—	70	10	—	<10	<50	—	<10	1,000	500	<5	<10	<5	<5
300	30	—	30	30	—	<10	<50	—	<10	300	300	<5	<10	<5	<5

Table 3.--Recorded maximum and minimum suspended-sediment loads at six sites in the Virgin River drainage

			Maximum suspended sediment			Minimum suspended sediment		
Site no.	Gaging station number	Period of record	Date	Mean discharge (cubic feet per second)	Load (tons/day)	Date	Mean discharge (cubic feet per second)	Load (tons/day)
1	09415000	Oct. 1947 to Sept. 1968[1]	12- 7-66	15,200	1,800,000	6-16-62	58	6
						6-20-62	55	
*	09410000	May 1962 to Sept. 1968	9-28-62	359	540,000	many days	—	<.5
17	09408150	Mar. 1967 to June 1974	9-19-72	4,340	1,930,000	6-19-74	57	2.9
32	09406000	May 1962 to June 1971	12- 6-66	9,670	1,300,000	7-11-69	94	4.6
51	09405450	Oct. 1977 to Sept. 1982	9-10-80	49	814	9- 8-81	7.7	.07
52	09405420	Oct. 1974 to Sept. 1977	10- 2-76	31	1,080	10-20-75	6.6	.02

[1] Also monthly suspended-sediment records for 1978 water year.

Asterisk (*) indicates discontinued gaging station located between sites 8 and 8.1 prior to construction of Gunlock Reservoir.

Table 4.--Suspended sediment at site 37, Virgin River at Virgin, Utah
[Water year October 1969 to September 1970]

Day	October: Mean discharge (cubic feet per second)	October: Mean concen-tration (milligrams per liter)	October: Sediment discharge (tons per day)	November: Mean discharge (cubic feet per second)	November: Mean concen-tration (milligrams per liter)	November: Sediment discharge (tons per day)	December: Mean discharge (cubic feet per second)	December: Mean concen-tration (milligrams per liter)	December: Sediment discharge (tons per day)
1	82	1000	221	144	999	388	150	812	329
2	86	720	167	141	856	326	151	949	387
3	90	518	126	139	734	275	156	1110	468
4	92	518	129	135	600	219	161	1020	443
5	101	518	141	136	600	220	158	938	400
6	105	916	260	132	600	214	149	862	347
7	101	748	204	187	1100	555	152	792	325
8	101	611	167	174	1600	752	156	394	166
9	101	666	182	163	946	416	163	196	86
10	101	725	198	167	650	293	156	433	182
11	105	790	224	165	242	108	147	957	380
12	108	861	251	155	502	210	152	713	293
13	100	832	225	152	1040	427	146	531	209
14	103	804	224	148	2160	863	148	396	158
15	105	777	220	152	2060	845	148	295	118
16	108	751	219	259	4370	3060	148	408	163
17	110	751	223	342	3500	3230	153	564	233
18	120	751	243	257	1300	902	153	779	322
19	140	740	280	152	1090	447	152	718	295
20	135	729	266	168	915	415	161	661	269
21	140	730	276	175	768	363	150	609	247
22	162	1850	809	171	645	298	155	512	214
23	154	1550	644	164	541	240	154	430	179
24	149	1130	455	159	454	195	149	361	145
25	141	700	266	156	223	94	148	303	121
26	144	413	161	157	233	99	151	255	104
27	138	900	335	152	243	100	151	214	87
28	136	900	330	145	253	99	130	231	81
29	139	708	266	143	264	102	118	249	79
30	140	558	211	142	200	77	121	322	105
31	145	439	172	—	—	—	122	416	137
Total	3682		8095	5032		15832	4599		7072

Day	January: Mean discharge (cubic feet per second)	January: Mean concen-tration (milligrams per liter)	January: Sediment discharge (tons per day)	February: Mean discharge (cubic feet per second)	February: Mean concen-tration (milligrams per liter)	February: Sediment discharge (tons per day)	March: Mean discharge (cubic feet per second)	March: Mean concen-tration (milligrams per liter)	March: Sediment discharge (tons per day)
1	124	350	117	132	300	107	312	6800	5730
2	116	328	103	127	272	93	480	10400	13500
3	102	357	98	124	247	83	416	6100	6850
4	108	318	93	137	223	82	405	1040	1140
5	110	283	84	134	201	73	403	869	946
6	102	252	69	132	181	65	271	726	531
7	114	225	69	133	230	83	156	575	242
8	116	200	63	133	292	105	157	455	193
9	130	269	94	128	406	140	148	469	187
10	144	362	141	128	192	66	156	483	203
11	143	487	188	135	242	88	151	497	203
12	140	655	248	149	305	123	138	492	183
13	138	655	244	144	403	157	134	488	177
14	133	654	235	134	442	160	143	483	186
15	155	654	274	127	484	166	151	530	216
16	150	600	243	121	399	130	143	581	224
17	186	800	402	121	329	107	146	478	188
18	163	590	260	117	271	86	134	393	142
19	144	661	257	118	223	71	122	323	106
20	142	740	284	114	200	62	126	266	90
21	143	829	320	125	200	68	125	293	99
22	137	765	283	191	2500	1290	120	323	105
23	147	706	280	165	1500	668	124	328	110
24	150	651	264	135	814	297	124	332	111
25	145	601	235	129	442	154	136	337	124
26	137	601	222	129	240	84	131	342	121
27	136	601	221	131	310	110	127	293	100
28	137	287	106	130	400	140	119	251	81
29	124	137	46	—	—	—	124	195	65
30	119	219	70	—	—	—	129	151	53
31	131	351	124	—	—	—	120	150	49
Total	4166	—	5737	3723	—	4858	5671	—	32255

Table 4.—Suspended sediment at site 32, Virgin River at Virgin, Utah—Continued

Day	April			May			June		
	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)
1	111	150	45	116	250	78	79	150	32
2	109	181	53	119	356	114	78	265	56
3	116	176	55	139	167	63	79	40	8.5
4	114	172	53	167	78	35	76	91	19
5	116	248	78	182	242	119	80	205	44
6	126	358	122	182	750	369	95	200	51
7	148	516	206	205	2100	1160	147	3670	1460
8	143	587	227	177	1800	860	89	2200	529
9	138	668	249	191	2100	1080	91	2400	590
10	151	761	310	209	2400	1350	98	2650	701
11	166	866	388	238	2100	1350	103	1680	467
12	143	344	133	198	769	411	98	894	237
13	119	191	61	178	1280	615	89	781	188
14	120	133	43	190	1050	539	86	682	158
15	107	92	27	179	856	414	83	813	182
16	102	74	20	192	700	363	79	416	89
17	102	59	16	196	2600	1380	75	600	122
18	102	47	13	181	1240	606	76	337	69
19	103	67	19	157	592	251	74	360	72
20	103	96	27	136	333	122	74	384	77
21	97	75	20	119	292	94	84	771	175
22	101	59	16	106	248	71	83	758	170
23	98	48	13	106	258	74	83	391	88
24	92	81	20	103	375	104	81	385	84
25	97	136	36	107	257	74	82	379	84
26	112	230	70	93	143	36	81	373	82
27	184	286	142	90	212	52	85	556	128
28	167	355	160	84	61	14	92	594	148
29	133	249	89	83	49	11	88	635	151
30	121	175	57	89	39	9.4	90	678	165
31	--	--	--	84	118	27	--	--	--
Total	3641	--	2768	4596	--	11845.4	2598	--	6426.5

Day	July			August			September		
	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)	Mean discharge (cubic feet per second)	Mean concen-tration (milligrams per liter)	Sediment discharge (tons per day)
1	94	2500	635	82	3500	775	73	2520	497
2	94	2500	635	89	3800	913	85	2050	470
3	94	2500	635	102	4120	1130	87	2000	470
4	119	6600	2120	236	38200	155000	100	2000	540
5	124	1800	603	950	98000	251000	840	32000	72600
6	131	3000	1060	520	120000	168000	350	13000	12300
7	109	2600	765	240	55000	35600	150	6440	2610
8	165	14700	6510	112	4790	1450	100	3190	861
9	307	12000	11800	119	4500	1450	82	2350	520
10	351	6930	6570	113	4230	1290	79	1730	369
11	630	4000	6800	108	6020	1760	75	1440	292
12	100	752	203	106	7030	2010	79	1200	256
13	79	756	161	125	8200	2770	172	11000	5110
14	77	700	146	127	9570	3280	83	7000	1570
15	77	539	112	176	20000	9500	77	2900	603
16	89	2540	610	450	33000	40100	75	1200	243
17	92	12000	2980	150	19000	7700	78	1240	261
18	125	36000	12200	650	50000	87800	88	1290	307
19	112	17000	5140	500	65000	87800	88	1330	316
20	114	4290	1320	350	5000	4730	86	1040	241
21	336	51300	46500	300	10000	8100	85	808	185
22	263	11000	7810	360	60000	58300	88	968	230
23	102	10000	2750	150	5330	2160	92	1160	288
24	204	113000	62200	92	3930	976	88	1130	268
25	121	12100	3950	80	2890	624	81	1090	238
26	100	8720	2350	105	5000	1420	78	1060	223
27	99	6280	1680	130	14000	4910	79	978	209
28	90	4820	1170	150	6220	2520	78	903	190
29	82	3700	819	100	4610	1240	78	833	175
30	88	3350	796	83	3420	766	80	800	173
31	82	3040	673	74	2500	500	--	--	--
Total	4650	--	191703	6929	--	945574	3674	--	102615

Total discharge for year (cubic feet per second)	52961
Total suspended-sediment discharge for year (tons)	133480.9

Table 5.--Indicator bacteria sampled Aug. 18-28, 1981

Site no.	Site name	Date	Time	Discharge (cubic feet per second)	Fecal coliform (FC) (colonies per 100 milliliters)	Fecal streptococci (FS) (colonies per 100 milliliters)	FC/FS Ratio
2	Beaver Dam Wash at mouth, Ariz.	8-28-81	1030	3.7	70	5800	0.01
4	Virgin River below Virgin River Gorge Springs, Ariz.	8-28-81	1230	30.0	40	330	.12
6	Virgin River at Bloomington, Utah	8-28-81	1415	35.0	[2]6200	9300	.67
7	Santa Clara River at mouth, Utah	8-18-81	1845	4.5	[1,2]2400	[1]2100	1.1
12	Santa Clara River below Veyo Hot Springs, Utah	8-18-81	1300	2.6	[1,2]2400	550	4.4
12.1	Veyo Hot Springs, Utah	8-18-81	1400	.67	[1]<1	[1]<1	--
14.1	Santa Clara River below confluence with Right Fork, Utah	8-18-81	1100	2.8	30	[1]480	.06
14.2	Santa Clara River above campground, Utah	8-18-81	0930	.86	90	300	.30
15	Fort Pierce Wash at mouth, Utah	8-28-81	1545	2.1	[2]5000	6000	.83
16.1	Mill Creek below Washington, Utah	8-20-81	1530	1.9	[1,2]20,000	6500	3.1
18	Leeds Creek at mouth, Utah	8-19-81	1130	1.2	[1]>120	1200	--
19.1	Virgin River above Leeds Creek, Utah	8-31-81	0945	69.0	500	1600	.31
20.1	Gould Wash at mouth, Utah	8-28-81	1800	1.4	[2]26,000	44,000	.59
21	Virgin River below Ash Creek, Utah	8-25-81	1400	55.0	1200	1800	.67
23	Ash Creek below Westfield Ditch near Toquerville, Utah	8-25-81	0900	9.3	[1]30	230	.13
27	La Verkin Creek at mouth, Utah	8-25-81	1100	2.2	[1]500	1800	.28
30	La Verkin Hot Springs, Utah	8-25-81	1530	12.0	[1]20	[1]5	4.0
32	Virgin River at Virgin, Utah	8-24-81	1800	80.0	[1]1300	3700	.35
33	North Creek at mouth, Utah	8-24-81	1645	.85	[1]1400	1300	1.1
39	North Fork Virgin River above confluence, Utah	8-24-81	1345	33.0	1500	1800	0.83
40	North Fork Virgin River near Springdale, Utah	8-24-81	1115	43.0	[1]80	350	.23
56	East Fork Virgin River above confluence, Utah	8-24-81	1245	39.0	[1]60	470	.13
60	East Fork Virgin River at Mt. Carmel Junction, Utah	8-20-81	1145	3.8	[1]1000	790	1.3
64	East Fork Virgin River near Glendale, Utah	8-20-81	1000	12.0	[1]>120	[1]>200	--

[1] Based on colony count outside of the ideal range

[2] Exceeds criteria for untreated surface water intended for public-water supplies (U.S. Environmental Protection Agency, 1972)

Table 6.--Organochlorine compounds organophosphorus insecticides, PCB and PCN in stream-bottom materials

Compound and insecticide	Micrograms per kilogram (mg/kg)			
	Site name			
	Santa Clara River at mouth, Utah (site 7)	Virgin River above Fort Pierce Wash, Utah (site 16)	Virgin River above Leeds Creek, Utah (site 19.1)	East Fork Virgin River at Mt. Carmel Junction, Utah (site 60)
Aldrin	<0.1	<0.1	<0.1	<0.1
Chlordane	<1.0	<1.0	<1.0	<1.0
DDD	<.1	<.1	<.1	<.1
DDE	<.1	<.1	<.1	<.1
DDT	<.1	<.1	<.1	<.1
Diazinon	<.1	<.1	<.1	<.1
Dieldrin	<.1	<.1	<.1	<.1
Endosulfan	<.1	<.1	<.1	<.1
Endrin	<.1	<.1	<.1	<.1
Ethion	<.1	<.1	<.1	<.1
Gross PCB	<1.0	<1.0	<1.0	<1.0
Gross PCN	<1.0	<1.0	<1.0	<1.0
Heptachlor Epoxide	<.1	<.1	<.1	<.1
Heptachlor	<.1	<.1	<.1	<.1
Lindane	<.1	<.1	<.1	<.1
Malathion	<.1	<.1	<.1	<.1
Methyl Trithion	<.1	<.1	<.1	<.1
Methyl Parathion	<.1	<.1	<.1	<.1
Mirex	<.1	<.1	<.1	<.1
Methoxychlor	<.1	<.1	<.1	<.1
Parathion	<.1	<.1	<.1	<.1
Perthane	<.1	<.1	<.1	<.1
Toxaphene	<1.0	<1.0	<1.0	<1.0
Trithion	<.1	<.1	<.1	<.1

Table 7—Summary of selected

[Abbreviations: ft^3/s, cubic feet per second; umho, micromhos per centimeter

Site number: Numbers refer to sites shown on plate 1.
Gaging station number: Standard Geological Survey gaging station number. The 09 indicates all drainage in the Colorado River Basin. The remaining
Discharge range: Period of record for gaging stations, sampling periods for other sites.
Dominant cations, anions: Refer to section "Classification of water for public supply and irrigation" for methods of determination. Ca, calcium; Mg,
Irrigation supply: L-low, M-medium, H-high, VH-very high. First classification is for flow flow and second for high flow.
Water-use problems: A blank indicates that no problem is known to exist. Listings under "Public supply" are based on the recommended limits from
hazards under "irrigation supply" are based on U.S. Salinity Laboratory Staff (1954, p. 80). Boron: Range from samples taken.
Remarks: Additional sediment data are shown on table 3 for each site except 16, 19.1, 54, 55. A (-) indicates no data available.

Site No.	Gaging Station no.	Site name	Discharge: Years of record	Discharge: Range (ft^3/s)	Discharge: Average (ft^3/s)	Number of chemical analyses	Dissolved solids range (ug/L)	Specific conductance range (umho)
1	09415000	Virgin River at Littlefield, Arizona	52	38-35,200	234	5	1,120-2,620	1,620-3,500
2		Bear Dam Wash at mouth, Arizona	--	3.7-5.9	--	5	479-652	750-980
3		Virgin River above Beaver Dam Wash, Arizona	--	61-318	--	5	1,120-2,720	1,620-3,620
6	09413200	Virgin River near Bloomington, Utah	4	5.8-10,000	372	5	565-2,550	870-3,450
7		Santa Clara River at mouth, Utah	--	4.5-9.7	--	5	1,150-1,800	1,600-2,180
8	09410100	Santa Clara River below Winsor Dam, Utah	9	0-1,700	30.6	3	243-313	415-550
12		Santa Clara River below Veyo Hot Springs, Utah	--	2.4-28	--	5	155-320	255-510
13		Santa Clara River above Veyo Hot Springs, Utah	--	1.7-31	--	5	155-312	250-510
15		Fort Pierce Wash at mouth, Utah	--	2.1-36	--	5	1,110-2,690	1,510-4,020
16		Virgin River above Fort Pierce Wash, Utah	--	32-300	--	5	562-3,200	890-4,390
17	09408150	Virgin River near Hurricane, Utah	14	23-18,700	237	5	524-2,670	860-3,120
18		Leeds Creek at mouth, Utah	--	1.2-3.4	--	5	901-1,200	1,180-1,540
19.1		Virgin River above Leeds Creek, Utah	--	69-500	--	5	511-2,680	815-3,140
21		Virgin River below Ash Creek, Utah	--	55-400	--	5	531-2,280	905-3,700
22		Ash Creek at mouth, Utah	--	7.0-14	--	5	492-558	750-840
27		La Verkin Creek at mouth, Utah	--	1.9-19	--	5	791-1,470	1,100-1,930
29		Virgin River below La Verkin Hot Springs, Utah	--	46-610	--	5	492-2,760	850-4,430
31		Virgin River above La Verkin Hot Springs, Utah	--	34-600	--	5	277-603	480-950
32	09406000	Virgin River at Virgin, Utah	65	22-22,800	206	5	238-598	430-960
33		North Creek at mouth, Utah	--	.85-20	--	5	291-1,110	500-1,420
33.1		Virgin River above North Creek, Utah	--	62-600	--	5	239-556	425-880
38		Virgin River below confluence of North Fork and East Fork, Utah	--	70-750	--	5	179-457	355-740
39		North Fork Virgin River above confluence	--	33-720	--	5	192-486	340-820
40	09405500	North Fork Virgin River near Springdale, Utah	56	20-9,150	102	4	173-447	335-800
43.2		North Fork Virgin River at mouth of Zion Narrows, Utah	--	44-700	--	3	164-333	325-580
51	09405450	North Fork Virgin River above Zion Narrows, near Glendale, Utah	3	2.2-130	27.6	4	222-278	360-455
54		Cascade Springs near Hatch, Utah	--	1.0-6.0	--	3	56-139	185-220
55		Navajo Lake east of dike, near Hatch, Utah	--	--	--	3	53-77	97-135
56		East Fork Virgin River above confluence with North Fork, Utah	--	39-58	--	5	361-529	560-695
60		East Fork Virgin River at Mt. Carmel Junction, Utah	--	3.8-22	--	5	421-788	670-1,160
64	09404450	East Fork Virgin River near Glendale, Utah	15	6.3-640	20.9	5	231-331	500-580
77		East Fork Virgin River at Highway 136 bridge, Utah	--	1.4-2.1	--	5	247-284	450-475

hydrlogic data at key sites

at 25° Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter]

numbers indicate the downstream order of the stations.

magnesium; Na, sodium; HCO_3, bicarbonate; Cl, chloride; SO_4, sulfate.

U.S. Environmental Protection Agency (1976a, p. 5); Cl, chloride; N, nitrogen; NO_3, nitrate; SO_4, sulfate. Listings of salinity and sodium

Dominant cation(s)		Dominant anion(s)		Water-use problems					
				Public Supply		Irrigation Supply			
Low flow	High flow	Low flow	High flow	Dissolved solids (mg/L)	Specific ions (mg/L)	Salinity hazard	Sodium hazard	Boron (ug/L)	Remarks
Ca,Na,Mg	Ca,Na,Mg	SO_4,Cl	SO_4,Cl,HCO_3	500	SO_4,Cl 250	VH, H	M, L	370-1,100	Sediment data on table 1
Ca,Na,Mg	Ca,Na,Mg	SO_4,CO_3	HCO_3,SO_4	500	--	H, H	L, L	20-290	
Ca,Na,Mg	Ca,Na,Mg	SO_4,Cl	SO_4,Cl,HCO_3	500	SO_4,Cl 250	VH, H	L, L	390-1,200	
Na,Ca	Ca,Na	SO_4,Cl	SO_4,HCO_3	500	SO_4,Cl 250	VH, H	M, L	140-1,100	
Ca,Mg	Ca,Mg	SO_4,HCO_3	SO_4,HCO_3	500	SO_4 250	H, H	L, L	270-460	
Ca,Mg	Ca,Mg	HCO_3,SO_4	HCO_3	--	--	M, M	L, L	40-70	Dry October 1981, February 1982
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	M, M	L, L	30-110	
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	M, M	L, L	30-70	
Ca,Na	Ca,Na,Mg	SO_4,Cl	SO_4,Cl	500	SO_4,Cl 250	VH, VH	M, L	190-960	
Na,Ca	Ca,Na	SO_4,Cl	SO_4,HCO_3,Cl	500	SO_4,Cl 250	VH, H	M, L	130-1,200	
Ca,Na	Ca,Na	Cl,SO_4	HCO_3,SO_4,Cl	500	SO_4,Cl 250	VH, H	M, L	350-950	Sediment data on table 1,2
Ca,Mg	Ca,Mg	SO_4,HCO_3	SO_4,HCO_3	500	SO_4 250	H, H	L, L	230-270	
Na,Ca	Ca,Na	Cl,HCO_3	HCO_3,SO_4,Cl	500	SO_4,Cl 250	VH, H	M, L	130-920	
Na,Ca	Ca,Na	SO_4,Cl	HCO_3,SO_4,Cl	500	SO_4,Cl 250	VH, H	M, L	160-1,000	
Ca,Mg	Ca,Mg	SO_4,HCO_3	SO_4,HCO_3	500	--	H, H	L, L	60-80	
Ca,Mg	Ca,Mg	SO_4	SO_4,HCO_3	500	SO_4 250	H, H	L, L	90-200	
Na,Ca	Ca,Na	Cl,SO_4	HCO_3,Cl,SO_4	500	SO_4,Cl 250	VH, H	H, L	150-1,300	
Ca,Mg,Na	Ca,Mg	HCO_3,SO_4	HCO_3,SO_4	500	--	H, H	L, L	30-80	
Ca,Mg,Na	Ca,Mg	SO_4,HCO_3	HCO_3,SO_4	500	--	H, M	L, L	30-80	Sediment data on table 1,2
Ca,Mg	Ca,Mg	SO_4,HCO_3	SO_4,HCO_3	500	SO_4 250	H, H	L, L	60-300	
Ca,Na,Mg	Ca,Mg	SO_4,HCO_3	HCO_3,SO_4	500	--	H, M	L, L	10-70	
Ca,Mg,Na	Ca,Mg	HCO_3,SO_4	HCO_3	--	--	M, L	L, L	20-60	
Ca,Na,Mg	Ca,Mg	Cl,HCO_3,SO_4	HCO_3	--	--	H, M	L, L	20-50	
Ca,Na,Mg	Ca,Mg	HCO_3,Cl,SO_4	HCO_3	--	--	H, M	L, L	10-40	
Ca,Mg,Na	Ca,Mg	HCO_3,SO_4	HCO_3	--	--	M, M	L, L	20-30	
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	M, L	L, L	20	Sediment data on table 1 Inaccessible February 1982
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	L, L	L, L	0-10	Inaccessible February, May 1982
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	L, L	L, L	0-10	Inaccessible February, May 1982
Ca,Mg	Ca,Mg	HCO_3,SO_4	HCO_3,SO_4	--	--	M, M	L, L	40-7	
Ca,Mg	Ca,Mg	SO_4,HCO_3	HCO_3,SO_4	500	SO_4 250	H, M	L, L	30-140	
Ca,Mg	Mg,Ca	HCO_3	HCO_3	--	--	M, M	L, L	20-30	
Ca,Mg	Ca,Mg	HCO_3	HCO_3	--	--	M, M	L, L	20-30	

Table 8.—Chemical analyses and suspended-sediment loads of

[Abbreviations: ft^3/s, cubic feet per second; °C, degrees Celsius; tons/d, tons per day; umho,

Other data available: F, fluvial sediment (table 3); K, key sites, additional hydrologic (table 7); P, pesticides (table 6); S, Statistical data

Site No	Site Name	Date of collection	Discharge (ft^3/s)	Suspended sediment (tons/d)	Temperature (°C)	pH	Specific conductance (umho)	Dissolved solids, sum of constituents (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)
1	Virgin River at Littlefield, Arizona	8-28-81	71	—	26.0	7.0	3,500	2,620	20	400	120
		10-21-81	136	—	18.0	7.8	2,990	2,150	16	320	96
		2-10-82	205	—	10.5	8.2	2,580	1,870	20	240	76
		5-10-82	322	627	19.5	7.9	1,620	1,120	13	163	44
		9- 3-82	80	—	22.0	7.7	3,320	2,300	20	340	110
2	Beaver Dam Wash at mouth, Arizona	8-28-81	3.7	.13	21.5	7.4	980	652	38	95	28
		10-21-81	5.9	—	17.5	7.9	770	529	39	87	25
		2-10-82	5.0	—	17.5	7.5	805	479	37	60	23
		5-10-82	4.0	—	20.0	7.8	750	523	39	81	24
		9- 3-82	5.2	—	21.5	7.6	840	538	36	80	24
2.1	Beaver Dam Wash below Bull Valley Wash, Utah	8-28-81	3.4	—	22.0	7.8	610	455	37	77	21
		5-11-82	Dry	—	—	—	—	—	—	—	—
2.15	Bull Valley Wash at mouth, Utah	8-28-81	Dry	—	—	—	—	—	—	—	—
		5-11-82	Dry	—	—	—	—	—	—	—	—
2.2	Beaver Dam Wash at Motoqua, Utah	8-18-81	2.0	—	24.5	7.8	690	425	38	74	23
		5-11-82	2.0	—	16.0	8.4	445	319	31	58	16
2.25	East Fork Beaver Dam Wash at mouth, Utah	8-28-81	Dry	—	—	—	—	—	—	—	—
		5-11-82	Dry	—	—	—	—	—	—	—	—
2.3	Beaver Dam Wash at end of Motoqua Road, Utah	8-18-81	2.5	—	24.0	8.0	375	325	44	54	14
		5-11-82	2.5	—	16.0	8.5	400	290	37	53	13
2.4	Beaver Dam Wash below Beaver Dam State Park, Nevada	8-18-81	3.2	—	18.0	8.2	305	218	54	36	6.5
		5- 7-82	5.3	—	19.0	8.5	270	223	42	55	7.6
3	Virgin River above Beaver Dam Wash, Arizona	8-28-81	61	—	29.0	7.2	3,620	2,720	18	420	130
		10-21-81	138	—	16.5	7.8	3,130	2,200	16	320	98
		2-10-82	195	—	9.5	8.1	2,390	1,840	19	250	77
		5-10-82	318	—	19.0	7.8	1,620	1,120	14	172	46
		9- 3-82	70	—	21.5	7.7	3,670	2,790	18	420	130
4	Virgin River below Virgin Gorge Springs, Arizona	8-28-81	30	—	27.5	7.4	3,690	2,660	17	440	130
		9- 3-82	37	—	21.5	7.5	3,650	2,610	18	340	120
5	Virgin River at Atkinville Wash, Arizona	8-28-81	37	115	32.0	7.3	4,200	2,990	25	350	110
		5- 5-82	450	—	12.5	8.0	870	577	9.6	98	20
6	Virgin River near Bloomington, Utah	8-28-81	35	123	29.0	8.0	4,180	2,830	24	360	100
		10-15-81	139	—	15.5	8.0	2,630	1,780	16	230	66
		2-10-82	206	—	7.0	8.2	1,990	1,340	18	160	53
		5- 5-82	610	—	15.0	7.9	870	565	11	97	22
		9- 2-82	45	—	31.0	7.9	3,540	2,550	24	320	100
7	Santa Clara River at mouth, Utah	8-18-81	4.5	1.8	26.0	7.8	1,960	1,430	36	256	70
		10-15-81	5.1	—	16.0	7.9	2,180	1,800	32	300	94
		2-11-82	4.5	—	8.5	8.3	2,150	1,680	36	310	83
		5- 5-82	9.7	—	18.5	7.9	1,600	1,150	29	215	55
		8-23-82	5.2	—	28.0	8.0	1,890	1,420	37	260	68
8	Santa Clara River below Winsor Dam near Santa Clara, Utah	8-18-81	18	2.0	24.5	8.2	415	243	26	43	16
		10-15-81	Dry	—	—	—	—	—	—	—	—
		2-11-82	Dry	—	—	—	—	—	—	—	—
		5- 4-82	20	1.4	15.5	8.3	445	282	26	52	17
		8-23-82	11	—	24.5	8.6	550	313	26	50	16
8.1	Santa Clara River below Gunlock Reservoir, Utah	8-18-81	28	—	19.5	7.8	435	259	26	46	16
		5- 4-82	32	—	11.0	8.1	425	263	27	50	17
9	Santa Clara River at Gunlock, Utah	8-18-81	6.2	—	26.0	8.0	460	273	37	47	17
		5- 4-82	34	—	17.0	8.2	320	188	25	37	12
10	Moody Wash at mouth, Utah	8-20-81	1.2	—	23.0	7.6	465	288	48	50	16
		5- 4-82	4.3	—	18.5	7.9	440	277	44	52	15
11	Magotsu Creek at mouth, Utah	8-17-81	.17	—	25.5	7.9	780	469	42	72	32
		5- 4-82	2.6	—	17.5	8.1	700	413	35	72	26
12	Santa Clara River below Veyo Hot Springs, Utah	8-18-81	2.6	.14	25.0	7.7	510	286	35	53	20
		10-15-81	2.4	—	20.3	8.1	475	315	34	54	19
		2-12-82	3.5	—	16.0	8.4	495	320	33	56	20
		5- 6-82	32	—	12.5	8.1	250	155	22	30	9.6
		8-24-82	2.7	—	24.5	8.0	470	294	31	51	17

water samples collected in the Virgin River basin, 1981-82.--Continued

per centimeter at 25°C; mg/L, milligrams per liter; ug/L, micrograms per liter]

(table 9); T, trace metals (table 1)

Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Alkalinity (total as $CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrate (NO_3) + nitrite (NO_2) as N (mg/L)	Phosphorus, orthophosphate as P (mg/L)	Total hardness (as $CaCO_3$) (mg/L)	Noncarbonate hardness (as $CaCO_3$) (mg/L)	Sodium-absorption ratio	Dissolved boron (B) (ug/L)	Dissolved oxygen (mg/L)	Other data available
270	27	240	1,200	430	0.9	1.1	0.02	1,500	1,300	3.0	1,100	7.1	F, K, S
270	23	240	880	400	.8	.86	<.01	1,200	950	3.4	850	8.5	
250	20	270	760	340	.8	.85	.05	910	640	3.6	650	9.0	
130	12	220	440	180	.4	.44	.03	590	370	2.5	370	9.2	
290	27	251	990	370	.8	.90	--	1,300	1,100	3.5	1,100	7.6	
72	5.3	200	240	44	.5	1.9	.03	350	150	1.8	290	7.4	K, T
51	6.6	230	140	32	.6	2.2	<.01	320	90	1.3	20	6.0	
45	5.4	230	130	12	.7	1.7	.01	290	65	1.2	60	8.0	
55	4.7	220	150	31	.7	1.2	.02	300	81	1.5	130	5.9	
59	5.0	210	170	32	.6	1.2	.01	300	89	1.6	160	5.7	
36	4.3	200	140	18	.7	.13	.02	280	79	1.0	60	8.2	
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29	4.0	190	110	31	.5	.19	.03	280	90	.8	50	6.3	
22	3.3	170	68	18	.6	<.10	.01	210	41	.7	30	10.4	
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26	4.7	130	81	22	.6	.12	.02	190	63	.9	30	8.2	
21	3.6	150	59	13	.6	<.10	.01	190	36	.7	20	9.0	
19	5.8	130	<5.0	15	.5	.17	.02	120	0	.8	30	8.0	
19	5.0	130	6.0	10	.5	<.10	.02	170	39	.7	30	9.7	
290	30	240	1,200	480	.8	1.2	.02	1,600	1,300	3.2	1,200	7.2	K
280	24	200	920	420	.8	.87	<.01	1,200	1,000	3.5	880	8.2	
250	20	290	720	320	.7	.88	.05	940	650	3.5	660	10.6	
130	12	220	430	180	.4	.46	.02	620	400	2.4	390	9.1	
300	29	269	1,300	430	.9	.85	<.01	1,600	1,300	3.3	1,100	7.9	
280	28	160	1,200	470	.9	.33	<.02	1,600	1,500	3.0	1,000	6.9	T
300	30	287	1,200	430	.8	.42	.01	1,300	1,100	3.6	1,000	7.3	
450	28	240	1,200	670	.6	1.4	.09	1,300	1,100	5.4	1,100	7.2	
60	61	150	220	71	.2	.31	.03	330	180	1.5	140	9.4	
460	31	250	1,000	700	.7	1.5	.07	1,300	1,100	5.5	1,100	7.0	K, T
280	20	240	620	400	.5	.98	.02	850	610	4.2	600	8.5	
200	16	250	480	260	.5	.87	.13	620	370	3.8	450	10.9	
55	6.1	160	210	66	.3	.36	.04	330	170	1.4	140	9.9	
390	26	260	980	550	.7	.90	.21	1,200	950	4.9	950	6.3	
110	7.5	240	750	55	.3	.30	.01	930	690	1.7	370	7.9	K, P, T
130	11	260	990	81	.5	1.2	.01	1,100	880	1.7	460	11.3	
110	9.4	320	870	62	.5	1.1	.01	1,100	800	1.4	370	10.2	
72	6.8	270	560	51	.4	.38	.03	760	490	1.2	270	9.8	
99	8.2	242	740	62	.4	.39	.03	930	690	1.5	370	9.5	
19	2.8	160	23	16	.1	.12	.02	170	13	.7	60	6.7	K
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19	2.9	180	35	22	.3	.10	.01	200	20	.6	40	8.4	
19	3.0	177	78	25	.2	<.10	.02	190	32	.6	70	7.4	
18	2.8	160	24	30	.2	.03	.09	180	21	.6	50	7.6	
18	2.8	170	24	22	.2	<.10	.01	190	25	.6	60	9.3	
20	3.5	170	21	23	.2	.28	--	190	18	.7	60	7.8	
12	2.0	130	7.0	15	.2	<.10	.02	140	12	.5	50	8.9	
23	2.4	160	1.0	50	.2	.15	.02	190	31	.8	50	7.0	
21	2.0	190	6.0	22	.3	<.10	.02	190	2	.7	40	7.3	
45	5.4	250	53	69	.3	<.10	.02	310	62	1.2	110	7.2	
36	4.5	250	45	44	.3	<.10	.02	290	37	1.0	8.0	7.5	
22	4.5	150	31	24	.3	1.3	.03	210	65	.7	90	6.6	T, K
21	5.1	200	29	28	.4	.89	.02	210	13	.7	60	6.3	
21	5.3	190	33	33	.4	.88	.01	220	32	.7	110	7.8	
9.7	2.0	110	6.0	9.9	.1	<.10	.03	120	5.0	.4	30	8.9	
1.9	4.4	196	26	24	.3	.80	.02	200	1.0	.6	80	6.4	

Site No	Site Name	Date of collection	Discharge (ft^3/s)	Suspended sediment (tons/d)	Temperature (°C)	pH	Specific conductance (umho)	Dissolved solids, sum of constituents (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)
12.1	Veyo Hot Springs, Utah	8-18-81	.67	—	31.0	7.1	650	404	38	58	27
		5- 6-82	.75	—	16.0	7.9	630	387	35	56	27
13	Santa Clara River above Veyo	8-18-81	1.9	—	24.5	7.9	490	297	35	53	18
	Hot Springs, Utah	10-15-81	1.7	—	19.6	8.1	510	293	34	54	18
		2-12-82	2.9	—	13.0	8.6	490	312	32	57	19
		5- 6-82	31	1,322	12.5	8.1	250	155	22	30	9.6
		8-24-82	2.1	—	24.5	8.0	450	290	31	54	17
13.1	Santa Clara River below Baker	8-17-81	3.7	—	21.0	7.6	360	217	36	38	14
	Dam Reservoir, Utah	5- 4-82	11	—	10.0	8.0	265	162	22	32	9.6
13.2	Santa Clara River above Baker	8-17-81	5.4	—	17.5	7.6	295	180	37	33	10
	Dam Reservoir, Utah	5- 4-82	64	—	9.0	7.8	82	64	16	9.2	3.1
13.3	Spring above Baker Dam, Utah	8-17-81	2.8	—	16.5	7.2	305	187	37	34	11
		5- 4-82	4.3	—	16.5	7.7	290	197	36	35	11
14	Santa Clara River near Pine	8-17-81	3.2	—	15.5	8.1	96	67	20	9.3	4.2
	Valley, Utah	5- 4-82	58	—	4.0	7.6	44	41	13	4.7	1.8
14.1	Santa Clara River below Right	8-18-81	2.8	—	11.0	7.1	95	75	23	9.1	4.2
	Fork, Utah	5- 4-82	58	—	3.5	6.8	44	40	12	5.4	1.7
14.2	Santa Clara River above	8-18-81	.86	—	11.5	7.1	120	90	25	12	5.1
	campground, Utah	5- 4-82	36	—	2.5	6.9	37	36	11	4.0	1.4
14.3	Santa Clara-Pinto Diversion	8-18-81	Dry	—	—	—	—	—	—	—	—
	near Pinto, Utah	5- 4-82	72	—	3.0	7.7	65	58	18	7.8	1.9
15	Fort Pierce Wash at mouth,	8-28-81	2.1	43	30.0	7.7	4,020	2,690	21	410	85
	Utah	10-16-81	36	—	10.8	8.0	2,300	1,460	15	180	53
		2-10-82	17	—	6.0	8.4	1,930	1,260	16	150	48
		5- 5-82	24	—	21.0	7.9	1,510	1,110	9.4	227	36
		9- 2-82	6.0	—	29.0	7.9	3,210	2,250	20	300	67
15.1	Fort Pierce Wash at bottom of	8-28-81	Dry	—	—	—	—	—	—	—	—
	section 16, Utah	5- 5-82	40	—	28.0	7.6	2,690	2,650	6.5	580	65
15.2	Short Creek at Temple Trail,	8-28-81	Dry	—	—	—	—	—	—	—	—
	Arizona	5- 5-82	1.3	8.4	21.0	7.4	2,440	2,350	4.9	560	58
15.25	Hurricane Wash above confluence	8-28-81	Dry	—	—	—	—	—	—	—	—
	with Short Creek, Arizona	5- 5-82	Dry	—	—	—	—	—	—	—	—
15.3	Short Creek at Highway U-59	8-28-81	Dry	—	—	—	—	—	—	—	—
	Arizona	5- 5-82	Dry	—	—	—	—	—	—	—	—
16	Virgin River above Fort Pierce	8-28-81	29	—	32.0	7.7	4,390	3,200	26	380	120
	Wash, Utah	10-16-81	97	—	14.0	7.9	2,900	1,870	16	240	72
		2-11-82	182	—	7.0	7.9	1,780	1,200	16	140	50
		5- 5-82	575	—	15.0	8.0	890	562	9.4	93	21
		9- 1-82	34	—	24.0	7.8	3,400	2,510	20	310	99
16.1	Mill Creek below Washingon,	8-20-81	1.9	—	27.5	7.9	1,400	852	23	91	26
	Utah	5- 6-82	2.9	—	14.0	8.1	1,480	936	24	97	31
16.2	Washington Canal at inlet,	8-24-81	87	2,555	23.0	7.6	3,450	2,850	16	560	64
	Utah	5- 6-82	175	—	15.0	8.2	820	501	9.5	82	20
17	Virgin River near Hurricane,	8-31-81	93	449	20.0	7.9	3,120	2,000	20	190	59
	Utah	10-20-81	124	—	12.5	7.9	1,930	1,310	12	150	49
		2-11-82	220	—	9.0	8.1	1,560	1,010	15	125	42
		5- 6-82	550	2,510	16.0	8.1	860	524	9.9	86	21
		8-24-82	155	34,108	28.0	7.9	2,710	2,670	12	620	45
18	Leeds Creek at mouth, Utah	8-19-81	1.2	.81	25.5	7.9	1,540	1,100	30	170	85
		10-20-81	1.7	—	10.5	8.1	1,450	1,040	28	160	81
		2-11-82	3.4	—	12.0	8.2	1,180	901	26	123	67
		5- 7-82	1.9	.21	13.0	8.0	1,510	1,110	27	174	84
		8-23-82	1.5	—	29.5	8.0	1,500	1,200	27	180	90
19	Leeds Creek near Leeds, Utah	8-24-81	3.0	—	16.3	8.3	255	175	30	37	12
19.1	Virgin River above Leeds	8-31-81	69	304	20.0	7.9	3,140	1,820	20	200	55
	Creek, Utah	10-20-81	125	—	12.5	8.0	2,110	1,360	14	170	50
		2-11-82	215	—	9.0	8.0	1,570	1,220	14	117	39
		5- 7-82	550	1,886	11.0	8.0	825	511	9.8	8.6	21
		8-23-82	153	—	27.5	7.9	2,700	2,680	11	610	43
20.1	Gould Wash at mouth, Utah	8-28-81	1.4	—	28.0	8.5	900	567	14	92	29
		5- 7-82	2.4	—	15.5	8.2	575	369	9.0	82	17

water samples collected in the Virgin River basin, 1981-82.—Continued

Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Alkalinity (total as $CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrate (NO_3) + nitrate (NO_2) as N (mg/L)	Phosphorus, ortho-phosphate as P (mg/L)	Total hardness (as $CaCO_3$) (mg/L)	Non-carbonate hardness (as $CaCO_3$) (mg/L)	Sodium-absorption ratio	Dissolved boron (B) (ug/L)	Dissolved oxygen (mg/L)	Other data available
33	3.7	210	79	27	.3	2.7	.03	260	46	1.0	150	4.6	T
29	3.7	200	77	30	.4	1.9	.02	250	51	.9	120	7.0	
19	4.6	200	16	27	.3	.94	.03	210	6	.6	70	6.5	T, K
19	5.2	190	20	25	.4	.75	.02	210	19	.6	50	7.0	
18	5.6	180	27	41	.4	.74	.02	220	41	.6	60	8.0	
9.1	2.0	110	6.0	9.8	.1	<.10	.02	110	4.0	.4	30	9.0	
18	4.8	196	21	23	.3	.68	.02	200	9.0	.6	70	6.4	
13	2.1	140	5.0	23	.1	.27	.08	150	13	.5	30	5.9	
8.7	1.7	120	6.0	9.5	.1	<.10	.03	120	0	.4	10	8.3	
10	1.9	130	<1.0	8.8	.1	.35	.05	120	0	.4	20	7.7	
3.2	.8	39	6.0	1.8	<.1	<.10	.04	36	0	.3	10	9.4	
11	2.0	130	1.0	11	.1	.49	.04	130	0	.5	20	7.8	
11	2.3	140	6.0	9.9	.1	.32	.05	130	0	.4	20	7.6	
4.3	.5	40	2.0	2.1	.1	.11	.03	41	1.0	.3	10	8.0	
1.9	.4	21	6.0	.9	<.1	<.10	.03	19	0	.2	10	10.4	
4.1	.4	46	5.0	1.2	.2	0.0	.21	40	0	.3	10	8.4	
1.8	.4	20	6.0	1.0	<.1	<.10	.02	20	0	.2	10	10.2	
5.0	.4	62	2.0	2.6	.0	.14	.06	51	0	.3	20	8.4	
17	.4	18	6.0	.8	<.01	.10	.02	16	0	.2	10	10.7	
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2.9	1.0	31	6.0	1.9	<.1	.10	.04	27	0	.3	10	10.4	
380	25	200	1,000	640	.4	1.2	<.02	1,400	1,200	4.5	960	6.6	T. K
240	17	200	470	360	.4	.68	<.01	670	470	4.0	520	10.0	
190	15	200	450	270	.4	.64	.01	570	370	3.7	400	11.6	
68	11	130	600	73	.2	.69	.03	720	590	1.2	190	8.2	
350	24	168	870	510	.5	.96	.02	1,000	860	4.8	700	6.9	T
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73	20	59	1,800	45	.2	2.0	.03	1,800	1,700	.8	290	6.0	
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46	15	51	1,600	31	.2	1.7	.02	1,600	1,600	.5	180	7.8	
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470	33	260	1,400	610	.8	1.6	—	1,400	1,200	5.4	1,200	6.4	P, K
290	21	170	700	420	.5	.73	<.01	900	730	4.2	670	8.9	
180	15	210	410	260	.4	.67	.02	560	350	3.6	390	10.4	
59	6.1	160	200	76	.2	.29	.02	320	160	1.5	130	10.8	
390	28	286	950	540	.7	.88	.01	1,200	900	4.9	910	7.1	
150	16	190	270	160	.7	.14	.33	330	140	3.8	330	5.6	T
160	16	210	300	180	.9	.21	.03	370	160	3.9	360	9.0	
250	21	160	1,500	340	.3	.68	<.01	1,700	1,500	2.7	660	6.1	
55	5.4	180	140	79	.2	.29	.02	290	110	1.5	130	11.0	
400	27	230	570	590	.5	.85	.04	720	490	6.5	950	7.9	F. K
230	17	190	400	330	.4	.60	<.01	580	390	4.5	490	9.1	
150	14	180	330	220	.4	.61	.02	490	310	3.2	320	10.5	
65	5.6	180	140	87	.2	.30	.02	300	120	1.7	140	10.3	
150	15	178	1,500	220	.3	.48	<.01	1,700	1,600	1.6	350	6.6	
64	4.8	250	550	41	.3	.90	<.02	770	520	1.1	260	7.1	T, K
60	4.9	230	530	35	.4	.74	.01	730	500	1.1	240	9.6	
58	8.2	280	420	27	.6	.57	<.01	580	300	1.2	230	10.0	
65	5.4	280	550	31	.5	.52	.01	780	500	1.1	280	9.2	
65	5.0	214	670	35	.4	.52	<.01	820	610	1.1	270	8.0	
6.4	.9	140	<5.0	2.7	.1	.12	.05	140	2	.3	40	8.2	
380	28	350	260	660	.5	.75	<.02	730	380	6.1	920	8.0	T, P, K
230	17	210	400	350	.4	.58	<.01	630	420	4.0	500	9.3	
160	14	230	310	220	.4	.56	.01	460	230	3.2	330	10.8	
60	4.9	190	130	83	.2	.28	.02	300	110	1.6	130	10.4	
160	16	187	1,500	220	.3	.43	<.01	1,700	1,500	1.7	370	6.7	
51	8.9	190	200	56	.2	.44	.15	350	160	1.3	80	6.1	T
17	2.9	170	120	17	.1	.30	.05	270	100	.5	30	8.6	

Site No	Site Name	Date of collection	Discharge (ft^3/s)	Suspended sediment (tons/d)	Temperature (°C)	pH	Specific conductance (umho)	Dissolved solids, sum of constituents (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)
21	Virgin River below Ash Creek,	8-25-81	55	254	29.0	7.8	3,700	2,280	20	240	60
	Utah	10-20-81	128	—	13.5	7.8	2,290	1,410	14	160	52
		2-10-82	239	—	5.5	7.7	1,900	1,220	14	135	42
		5- 7-82	510	—	12.5	7.6	905	531	8.6	84	19
		9- 2-82	89	—	23.0	7.9	2,840	1,770	16	200	53
22	Ash Creek at mouth, Utah	8-25-81	7.0	1.4	19.5	7.8	840	558	40	97	39
		10-20-81	13	—	15.0	8.2	750	541	41	86	37
		2-10-82	14	—	10.0	8.4	750	499	39	83	34
		5- 7-82	11	—	17.5	8.1	705	492	38	82	33
		9- 2-82	11	—	20.0	8.4	790	533	39	88	38
23	Ash Creek below West Field,	8-25-81	9.3	—	16.5	7.6	700	450	42	79	31
	Ditch at Toquerville, Utah	5- 7-82	7.5	—	17.5	8.2	625	431	38	72	28
		9- 2-82	4.0	—	16.5	7.8	700	439	38	74	29
23.1	Wet Sandy at Anderson Ranch,	8-25-81	Dry	—	—	—	—	—	—	—	—
	Utah	5-11-82	Dry	—	—	—	—	—	—	—	—
24	South Ash Creek at mouth, Utah	8-25-81	Dry	—	—	—	—	—	—	—	—
		5-11-82	12	—	10.0	8.7	175	105	21	21	5.1
25	South Ash Creek below Mill	8-17-81	1.6	—	15.5	8.6	185	56	25	26	6.5
	Creek near Pintura, Utah	5-11-82	12	—	5.0	8.1	175	106	22	21	5.3
25.1	Leap Creek near Pintura, Utah	8-17-81	Dry	—	—	—	—	—	—	—	—
		5-11-82	2.0	—	9.0	8.5	365	240	27	45	15
25.2	North Ash Creek below Ash	8-18-81	Dry	—	—	—	—	—	—	—	—
	Creek Reservoir, Utah	5-11-82	Dry	—	—	—	—	—	—	—	—
26	North Ash Creek above Ash	8-18-81	1.5	—	24.5	8.0	505	311	48	58	20
	Creek Reservoir, Utah	5-11-82	19	—	10.5	8.5	410	261	32	46	16
		9- 2-82	1.3	—	12.5	8.3	750	482	38	92	35
26.1	Kanarra Creek at Kanarraville,	8-17-81	2.6	—	12.0	8.5	415	284	24	56	17
	Utah	5-11-82	7.2	—	7.0	8.0	475	278	14	66	16
27	La Verkin Creek at mouth,	8-25-81	2.2	.44	25.0	8.0	1,520	1,090	21	228	56
	Utah	10-20-81	5.2	—	14.5	8.0	1,250	932	16	177	50
		2-10-82	7.5	—	2.0	8.1	1,100	791	11	152	43
		5- 7-82	19	—	20.0	8.2	930	654	11	130	38
		9- 2-82	1.9	—	26.0	7.9	1,930	1,470	19	300	63
29	Virgin River below La Verkin	8-25-81	46	143	30.0	6.8	4,430	2,760	16	280	43
	Hot Springs, Utah	10-20-81	70	—	15.0	6.8	2,780	1,740	11	200	51
		2-10-82	136	—	8.5	6.5	2,780	1,760	13	184	48
		5- 5-82	510	2,750	13.5	8.3	850	492	9.1	78	17
		9- 2-82	65	—	24.0	6.8	3,320	2,060	13	210	53
30	La Verkin Hot Springs, Utah	8-25-81	11	—	41.5	6.4	13,000	9,660	28	820	160
		5- 5-82	11	—	41.5	6.1	12,600	9,840	24	880	160
31	Virgin River above La Verkin	8-25-81	34	79	26.5	8.2	910	560	12	92	30
	Springs, Utah	10-20-81	77	—	10.5	8.3	950	603	7.0	110	34
		2-10-82	151	—	3.5	8.1	820	498	10	77	30
		5- 5-82	500	3,289	12.5	8.4	480	277	8.1	60	14
		9- 2-82	53	—	19.0	8.5	810	504	11	80	30
32	Virgin River at Virgin, Utah	8-24-81	80	834	29.5	8.2	960	598	12	106	28
		10-17-81	123	—	15.5	8.3	850	564	7.2	94	35
		2-10-82	156	—	5.5	8.2	850	526	10	81	33
		5- 5-82	620	3,582	10.5	8.3	430	238	7.6	55	13
		9- 1-82	82	—	17.0	8.1	840	489	12	79	31
33	North Creek at mouth, Utah	8-24-81	.85	.06	30.5	8.1	1,350	958	20	170	47
		10-17-81	3.6	—	12.5	8.2	1,420	1,020	18	200	47
		2-10-82	6.7	—	5.5	8.3	1,160	806	15	140	38
		5- 5-82	20	15	16.0	8.4	500	291	10	57	15
		8-23-82	1.5	—	26.0	8.2	1,380	1,110	20	210	56
33.1	Virgin River above North	8-24-81	62	473	28.5	8.2	880	556	12	89	27
	Creek, Utah	10-17-81	110	—	15.5	8.3	810	523	12	82	32
		2-10-82	133	—	6.5	8.5	800	469	9.9	71	31
		5- 5-82	600	3,580	11.5	8.4	425	239	8.0	55	14
		9- 1-82	80	—	17.0	8.5	790	466	11	69	29
36	Coalpits Wash at mouth, Utah	8-24-81	Dry	—	—	—	—	—	—	—	—
		5- 5-82	Dry	—	—	—	—	—	—	—	—

water samples collected in the Virgin River basin, 1981-82.--Continued

Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Alkalinity (total as $CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrate (NO_3) + nitrate (NO_2) as N (mg/L)	Phosphorus, ortho-phosphate as P (mg/L)	Total hardness (as $CaCO_3$) (mg/L)	Non-carbonate hardness (as $CaCO_3$) (mg/L)	Sodium-absorption ratio	Dissolved boron (B) (ug/L)	Dissolved oxygen (mg/L)	Other data available
450	36	280	630	670	0.5	0.74	<0.02	850	570	6.7	1,000	6.3	T, K
260	20	240	390	370	.5	.55	<.01	610	370	4.6	540	9.6	
210	17	260	350	290	.4	.53	<.01	510	250	4.3	440	11.4	
68	5.7	190	130	100	.2	.27	.02	290	98	1.8	160	9.5	
350	26	277	460	490	.5	.56	.01	720	440	5.7	820	8.1	
26	3.1	200	220	11	.2	.31	.01	400	200	.6	70	7.4	K
26	3.4	190	210	20	.2	.77	<.01	370	180	.6	60	9.4	
21	3.3	180	190	16	.2	.87	.01	350	170	.5	60	9.9	
21	2.5	190	180	18	.2	.69	.02	340	150	.5	60	7.8	
24	3.0	196	200	19	.2	.85	.02	380	180	.6	80	7.7	
21	2.2	110	170	35	.1	.90	.04	330	220	.6	50	7.9	T
18	2.4	140	160	25	.2	.62	.01	300	160	.5	50	8.3	
19	2.9	141	170	18	.2	.75	.02	300	160	.5	60	8.2	
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3.5	.4	79	<5.0	1.5	<.1	<.10	.03	73	0	.2	10	9.6	
4.4	.6	92	1.0	3.6	.1	.10	.00	92	0	.2	10	8.2	
3.8	.3	78	<5.0	1.6	<.1	<.10	.04	74	0	.2	10	10.5	
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8.1	.8	170	5.0	4.9	.1	<.10	.02	170	4.0	.3	30	9.2	
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16	2.4	190	33	18	.1	.22	.02	230	37	.5	30	6.7	
12	2.3	130	66	8.1	.1	.17	.03	180	51	.4	30	9.6	
23	2.6	161	170	22	.2	.54	<.01	370	210	.6	60	9.2	
9.1	1.7	140	83	7.0	.1	.38	.03	210	70	.3	20	8.2	
7.2	1.3	170	64	5.9	.2	.26	.02	230	61	.2	20	8.4	
42	4.8	150	630	17	.2	.18	.00	800	650	.7	170	6.8	T, K
40	4.4	150	530	23	.2	.32	<.01	650	500	.7	140	10.4	
33	3.7	180	420	18	.2	.44	<.01	560	380	.7	110	12.3	
22	3.9	160	340	12	.2	.18	.01	480	320	.5	90	7.8	
47	5.9	132	920	32	.3	.57	<.01	1,000	880	.7	200	7.3	
580	43	210	690	960	.7	.48	.02	960	750	8.2	1,300	5.2	K
330	26	300	460	480	.5	.40	<.01	710	410	5.4	680	9.1	
350	29	310	430	520	.6	.48	<.01	660	350	6.3	790	9.4	
63	8.7	170	120	95	.2	.23	.02	260	95	1.8	150	8.5	
440	32	329	480	630	.6	.32	<.01	740	410	7.0	1,000	6.4	
2,300	150	2.0	2,100	4,100	2.8	.14	.06	2,700	--	19	870	.5	T
2,300	150	1,020	2,100	3,600	2.9	<.10	.05	2,900	1,800	19	5,200	1.1	
51	4.6	160	230	43	.2	.21	.05	350	190	1.3	80	6.8	
46	3.9	160	250	54	.2	.48	<.01	410	250	1.1	60	9.7	
51	4.4	170	180	41	.2	.56	<.01	320	150	1.4	70	12.1	
18	2.4	140	72	17	.1	.23	.02	210	67	.6	30	9.1	
50	4.2	159	180	51	.2	.40	.02	320	160	1.3	80	8.2	
53	5.0	150	240	61	.2	.62	.03	380	230	1.3	80	6.3	F, T, K
51	4.5	170	210	58	.2	.49	<.01	380	210	1.2	60	8.5	
50	4.5	180	180	57	.3	.47	<.01	340	160	1.3	60	11.4	
10	2.0	140	55	10	.1	.26	.03	190	51	.3	30	10.1	
48	4.0	150	170	53	.2	.41	<.01	320	170	1.3	80	8.2	
54	8.0	150	530	37	.1	.23	.03	620	470	1.0	270	9.0	T, K
54	5.8	160	560	37	.2	.60	<.01	690	530	.9	230	9.6	
53	5.3	170	430	18	.2	.82	<.01	510	340	1.1	170	11.6	
15	2.1	99	120	12	.1	.13	.02	200	110	.5	60	9.0	
57	9.0	132	640	40	.2	.10	<.01	760	620	1.0	300	8.8	
52	5.1	170	230	26	.2	.43	<.01	330	160	1.3	60	6.2	K
49	4.5	180	180	53	.2	.48	<.01	160	32	1.3	50	8.6	
48	4.3	170	150	50	.3	.42	<.01	310	140	1.3	50	11.0	
10	1.9	150	49	10	.1	.23	.02	200	45	.3	10	11.0	
48	4.0	178	150	46	.2	.39	.02	290	110	1.3	70	8.2	
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Site No	Site Name	Date of collection	Discharge (ft^3/s)	Suspended sediment (tons/d)	Temperature (°C)	pH	Specific conductance (umho)	Dissolved solids, sum of constituents (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)
37	Horse Valley Wash at mouth,	8-24-81	Dry	—	—	—	—	—	—	—	—
	Utah	5- 4-82	Dry	—	—	—	—	—	—	—	—
38	Virgin River below confluence	8-24-81	70	83	26.2	8.3	740	418	11	60	27
	of North Fork and East Fork,	10-20-81	93	—	9.0	8.3	650	457	11	62	30
	Utah	2-11-82	126	—	4.0	8.2	670	429	9.5	58	28
		5- 4-82	750	1,869	9.5	8.4	355	179	6.7	47	9.6
		9- 1-82	80	—	17.0	8.5	740	415	11	60	27
39	North Fork Virgin River above	8-24-81	33	39	24.5	8.0	820	461	11	59	26
	confluence with East Fork,	10-20-81	42	—	8.5	8.3	720	470	11	63	26
	Utah	2-12-82	50	—	2.5	8.2	780	486	9.5	61	26
		5- 4-82	720	1,928	8.5	8.4	340	192	7.1	47	9.6
		8-23-82	65	7,125	21.5	8.4	520	352	8.5	58	17
39.1	Oak Creek below Park	8-24-81	Dry	—	—	—	—	—	—	—	—
	Headquarters, Utah	5- 4-82	Dry	—	—	—	—	—	—	—	—
40	North Fork Virgin River near	8-24-81	43	—	18.5	8.2	790	437	11	56	25
	Springdale, Utah	2-11-82	49	—	4.5	8.2	800	447	9.3	61	24
		5- 4-82	720	1,608	7.0	8.3	335	173	6.9	46	9.4
		8-23-82	65	2,568	19.0	8.4	495	341	11	60	17
41	Pine Creek at mouth, Utah	8-24-81	Dry	—	—	—	—	—	—	—	—
		5- 4-82	Dry	—	—	—	—	—	—	—	—
41.1	Clear Creek below Co-op Creek,	8-24-81	Dry	—	—	—	—	—	—	—	—
	near East Zion Entrance	5- 4-82	Dry	—	—	—	—	—	—	—	—
	Station, Utah										
42	Birch Creek at mouth, Utah	8-24-81	Dry	—	—	—	—	—	—	—	—
		5- 4-82	Dry	—	—	—	—	—	—	—	—
43.1	Weeping Rock at trail, Utah	8-19-81	.70	—	19.0	8.0	1,250	733	12	62	29
		5- 4-82	.40	—	16.0	7.8	1,180	709	11	63	30
43.2	North Fork Virgin River at	8-19-81	44	12	20.5	8.2	580	333	11	54	24
	mouth of Zion Narrows, Utah	10-17-81	54	—	8.6	8.6	540	336	11	59	24
		2-11-82	45	—	6.0	8.3	550	340	9.9	60	24
		5- 4-82	700	—	6.0	8.5	325	164	6.7	46	9.2
44.1	Ordervile Gulch at road	8-20-81	.70	—	16.0	8.3	680	419	8.9	65	40
	crossing, Utah	5- 3-82	.50	—	16.5	8.5	850	522	8.0	78	47
45	Kolob Creek below reservoir,	8-24-81	Dry	—	—	—	—	—	—	—	—
	Utah										
46	Kolob Creek above reservoir,	8-17-81	.70	—	17.5	8.4	460	281	6.8	82	15
	Utah										
50	Deep Creek at road crossing 1	8-20-81	2.0	—	16.5	8.3	415	236	8.3	75	16
	mile east of county line, Utah										
51	North Fork Virgin River above	8-20-81	7.5	—	16.0	8.4	420	250	12	54	24
	Zion Narrows near Glendale,	10- 8-81	7.3	—	14.5	8.5	435	278	12	55	26
	Utah	5- 3-82	34	—	14.5	8.0	455	246	8.5	53	23
		8-23-82	13	—	22.0	8.4	360	222	12	45	22
52	North Fork Virgin River below	8-20-82	9.3	—	14.5	8.2	385	237	12	54	22
	Bullock Canyon near	5- 3-82	42	—	12.0	8.1	435	222	7.9	54	21
	Glendale, Utah										
54	Cascade Springs near Hatch,	8-20-81	2.5	—	12.0	8.8	185	56	4.0	26	7.9
	Utah	10- 8-81	1.0	—	8.0	7.7	220	139	5.6	36	10
		8-23-82	6.0	—	13.5	7.8	211	118	3.7	31	7.4
55	Navajo Lake east of dike near	8-20-81	—	—	18.0	9.0	105	53	.99	11	6.5
	Hatch, Utah	10-12-81	—	—	3.0	9.3	97	63	1.9	12	6.6
		8-23-82	—	—	20.0	8.6	135	77	2.4	20	6.9
56	East Fork Virgin River above	8-24-81	39	118	24.5	8.0	620	384	12	60	28
	confluence with North Fork,	10-20-81	58	—	8.5	8.5	570	404	12	61	34
	Utah	2-12-82	47	—	2.5	8.3	560	361	9.6	55	30
		5- 4-82	50	46	17.5	8.2	660	378	11	54	32
		8-23-82	53	—	22.0	8.3	695	529	11	97	28
57	Meadow Creek at Highway U-15,	8-24-81	Dry	—	—	—	—	—	—	—	—
	Utah	5- 4-82	Dry	—	—	—	—	—	—	—	—
60	East Fork Virgin River at	8-20-81	3.8	2.6	23.5	8.0	1,160	788	11	118	71
	Mount Caramel Junction,	10-12-81	21	—	13.0	8.3	920	635	11	112	55
	Utah	2-11-82	22	—	4.5	8.2	670	421	9.0	76	46
		5- 3-82	14	12	18.5	8.4	870	539	9.2	82	55
		8-31-82	9.6	—	19.0	8.1	1,110	705	11	110	64

Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Alkalinity (total as $CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrate (NO_3) + nitrate (NO_2) as N (mg/L)	Phosphorus, ortho-phosphate as P (mg/L)	Total hardness (as $CaCO_3$) (mg/L)	Non-carbonate hardness (as $CaCO_3$) (mg/L)	Sodium-absorption ratio	Dissolved boron (B) (ug/L)	Dissolved oxygen (mg/L)	Other data available
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48	4.0	160	130	41	0.2	0.21	0.02	260	100	1.4	60	7.0	K
52	4.6	180	130	57	.2	.42	<.01	280	98	1.5	40	10.3	
48	3.3	190	100	66	.3	.41	<.01	260	70	1.4	50	11.4	
9.2	1.6	130	13	13	.1	.21	.02	160	27	.3	20	9.7	
47	3.6	168	110	54	.2	.33	<.01	260	93	1.4	60	8.4	
67	3.5	140	110	100	.1	.14	--	250	110	2.0	50	7.2	T, K
65	3.8	170	110	89	.2	<.09	<.01	260	94	1.9	40	9.8	
71	3.6	200	100	94	.2	<.10	.02	260	59	2.1	50	11.9	
7.7	1.6	130	22	18	.1	.21	.02	160	27	.3	20	9.9	
35	4.0	167	89	39	.2	.12	.03	210	48	1.1	50	7.3	
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62	3.3	160	95	88	.1	<.10	<.02	240	83	1.9	40	7.9	T, K
65	3.5	170	94	84	.2	<.10	<.01	250	81	2.1	40	11.6	
7.6	1.5	130	12	10	<.1	.22	.03	150	24	.3	<.10	10.5	
33	3.7	168	73	42	.2	.10	.01	220	52	1.0	40	8.4	
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150	6.3	170	170	200	.3	.26	.02	270	100	4.3	90	8.2	
150	5.6	180	160	180	.3	.14	.01	280	100	4.3	90	7.7	
30	2.8	150	85	35	.1	.16	.02	230	84	.9	30	7.6	K
27	2.7	160	83	33	.2	<.09	<.01	250	85	.8	20	9.4	
27	2.7	170	83	31	.2	<.10	<.10	250	71	.8	20	11.1	
4.5	1.4	130	11	6.4	.1	.22	.02	150	23	.2	30	10.6	
21	3.4	190	160	5.8	.1	.11	.01	330	140	.6	50	7.4	
23	3.6	210	230	6.1	.2	<.10	.02	390	180	.6	60	7.4	
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3.4	2.1	230	30	2.7	.1	.24	.03	270	37	.1	10	6.2	
2.3	1.2	210	<5.0	2.2	.1	.11	.01	250	43	.1	10	7.5	
8.1	1.5	180	39	2.1	.1	.11	.01	230	54	.3	20	8.0	F, K
8.6	1.4	210	44	3.5	.2	.15	.02	240	34	.3	20	8.2	
4.8	1.2	190	39	2.3	.2	<.10	.02	230	37	.2	20	8.1	
5.4	1.5	177	27	2.0	.2	<.10	<.01	200	26	.2	20	7.0	
3.0	1.4	200	21	3.0	.2	.13	.02	230	25	.1	0	8.2	
2.2	.9	190	20	1.7	.2	<.10	.01	220	31	.1	10	8.6	
1.1	.5	92	<1.0	2.0	.1	.20	.02	97	5	.1	0	8.7	K
1.5	.6	130	<5.0	1.8	.1	.13	.03	130	1	.1	0	8.8	
1.1	.4	104	10	1.0	<.1	.19	<.01	110	4	0	<10	7.5	
.9	.4	46	<5.0	.7	0	.12	.02	54	8	.1	0	10.7	K
1.2	.3	58	<5.0	1.1	<.1	.03	.03	57	0	.1	<10	8.4	
1.0	.3	68	<5.0	1.0	<.1	.10	<.01	78	10	.1	<10	9.4	
26	4.4	150	140	19	.1	1.0	<.02	270	120	.8	50	7.1	T, K
28	5.1	170	140	18	.3	.83	<.01	290	120	.8	40	10.6	
23	4.2	180	110	18	.3	.69	<.01	260	81	.7	40	12.5	
28	3.7	160	130	20	.3	.65	.01	270	110	.8	60	8.2	
31	5.4	125	260	17	.3	.88	.01	360	230	.8	70	7.4	
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--	--	--	--	--	--	--	--	--	--	--	--	--	
41	8.3	200	390	19	.2	2.0	.02	590	390	.8	140	6.5	T, P, K
27	5.5	300	230	9.9	.4	.74	<.01	510	210	.6	70	8.4	
14	3.6	240	120	6.7	.5	.29	<.01	380	140	.4	30	10.8	
22	3.8	260	200	8.8	.4	.31	<.01	430	170	.5	50	9.3	
32	6.2	306	280	12	.4	1.2	<.01	540	230	.7	100	8.1	

Table 8.--Chemical analyses and suspended-sediment loads of

Site No	Site Name	Date of collection	Discharge (ft^3/s)	Suspended sediment (tons/d)	Temperature (°C)	pH	Specific conductance (umho)	Dissolved solids, sum of constituents (mg/L)	Dissolved silica (SiO_2) (mg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)
61	Muddy Creek at mouth, Utah	8-20-81	Dry	--	--	--	--	--	--	--	--
		5- 3-82	2.8	--	21.0	8.2	1,500	1,040	8.9	120	96
63	Dry Wash at mouth, Utah	8-20-81	Dry	--	--	--	--	--	--	--	--
		5- 3-82	Dry	--	--	--	--	--	--	--	--
64	East Fork Virgin River near Glendale, Utah	8-20-81	12	2.2	13.5	8.0	500	231	9.4	58	36
		10-12-81	20	--	9.5	8.5	520	331	9.7	62	38
		2-12-82	17	--	2.5	8.1	500	300	8.6	52	36
		5- 3-82	28	30	13.5	8.2	580	312	8.6	61	38
		8-31-82	13	--	14.0	8.2	500	266	9.4	54	25
65	Lydia's Canyon at mouth, Utah	8-19-81	Dry	--	--	--	--	--	--	--	--
		5- 3-82	2.9	--	16.0	8.0	540	346	9.3	64	43
68	Right Fork Lydia's Canyon at Roads end, Utah	8-19-81	1.0	--	16.0	8.3	460	250	8.8	47	37
		5- 3-82	2.4	--	9.5	8.4	500	262	7.5	53	34
69	East Fork Virgin River above Lydia's Canyon, Utah	5- 3-82	25	--	13.0	7.9	560	281	8.3	58	36
70	Stout Canyon at mouth, Utah	8-19-81	5.4	--	12.0	8.1	450	246	8.9	55	33
		5- 3-82	13	--	10.5	8.3	560	275	7.8	59	35
75	East Fork Virgin River above Stout Canyon, Utah	8-19-81	5.0	--	12.5	8.4	440	244	8.9	50	33
		5- 3-82	7.3	--	10.0	8.2	550	286	8.6	58	36
77	East Fork Virgin River at Highway 136 bridge, Utah	8-19-81	1.8	--	10.0	7.5	465	247	9.0	56	33
		10-12-81	2.1	--	8.5	8.2	470	263	8.9	57	34
		2-11-82	1.4	--	9.5	7.8	450	273	8.2	55	32
		5- 3-82	2.0	.55	10.0	8.0	475	284	8.9	58	33
		8-31-82	1.5	--	12.0	7.7	460	257	8.1	56	33

water samples collected in the Virgin River basin, 1981-82.--Continued

Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Alkalinity (total as $CaCO_3$) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrate (NO_3) + nitrate (NO_2) as N (mg/L)	Phosphorus, ortho-phosphate as P (mg/L)	Total hardness (as $CaCO_3$) (mg/L)	Non-carbonate hardness (as $CaCO_3$) (mg/L)	Sodium-absorption ratio	Dissolved boron (B) (ug/L)	Dissolved oxygen (mg/L)	Other data available
--	--	--	--	--	--	--	--	--	--	--	--	--	
65	5.5	230	590	11	.3	<.10	<.01	700	470	1.2	70	7.7	
--	--	--	--	--	--	--	--	--	--	--	--	--	
--	--	--	--	--	--	--	--	--	--	--	--	--	
5.6	2.3	170	15	3.9	.4	.12	<.02	270	100	.1	30	8.1	T, K
4.9	2.6	280	30	14	.5	.12	<.01	310	31	.1	20	8.6	
4.8	2.3	270	28	5.0	.5	<.10	<.01	280	8.0	.1	20	11.5	
4.3	1.9	270	30	5.2	.5	<.10	<.01	310	39	.1	20	8.9	
4.8	2.3	223	22	4.3	.5	<.10	<.01	280	56	.1	30	8.1	
--	--	--	--	--	--	--	--	--	--	--	--	--	
4.2	26	290	44	4.1	.6	<.10	.02	340	47	.1	30	7.1	
1.8	1.2	250	20	2.5	.1	.11	.01	260	13	.1	10	8.2	
1.9	.6	260	6	2.0	.2	<.10	.02	270	12	.1	<10	8.7	
4.3	1.5	260	11	5.5	.4	<.10	.01	290	33	.1	20	9.0	
2.1	1.4	220	9.0	1.8	.3	.13	.02	270	47	.1	10	8.5	
2.1	.9	260	11.0	2.6	.3	<.10	<.01	290	31	.1	10	8.9	
3.6	1.6	250	<5.0	5.2	.4	.14	.02	260	11	.1	10	8.9	
4.9	1.4	270	6.0	8.6	.4	.10	.01	290	23	.1	20	9.3	
2.6	1.3	230	<1.0	5.7	.4	.23	.01	280	46	.1	20	8.9	K
3.1	1.2	250	<5.0	5.6	.5	.21	.01	280	26	.1	20	8.5	
2.5	1.4	270	5.0	5.0	.6	.17	<.01	270	0	.1	20	9.1	
3.9	1.2	270	6.0	9.6	.5	.11	<.01	280	11	.1	20	8.6	
2.8	1.3	232	10	5.6	.5	.12	<.01	280	44	.1	30	8.6	

Table 9.--Descriptive statistics of water-quality data at sites 1, 17, and 32
[Coefficient of variance: A unitless measure of variability calculated by the formula,

$$\frac{\text{Standard deviation}}{\text{Mean}} \times 100.]$$

Abbreviations used: ft^3, cubic feet per second; umho, micromhos; mm of hg, millimeters of mercury; °C, degrees Celsius; JTU, Jackson Tubidity Unit; FTU, Formazin Turbidity Unit; mg/L, milligrams per liter; UM-MF, micrometers-membrane filter; col/100 mL, colonies per 100 milliliters; KF agar, a base for culture media; pCi/L as K_4O, Pico curies per liter; fet-fld, fixed end point-field determination; acre-ft, acre feet; ug/L, micrograms per liter; cells/mL, cells per milliliter

Parameter	Number of analyses	Mean	Standard deviation	Minimum value	Maximum value	Coefficient of variance
		Site 1				
Discharge (ft^3/s)	716	393.89	1342.27	40.00	27200.00	340.77
Streamflow, instantaneous (ft^3/s)	300	540.14	982.38	50.00	10600.00	181.88
Specific conductance (umho)	686	2705.28	712.26	268.00	4650.00	26.33
pH (units)	612	8.03	2.15	7.00	27.00	26.75
Barometric pressure (mm of Hg)	18	713.61	18.43	651.00	741.00	2.58
Temperature, air (°C)	14	19.89	8.75	9.50	41.00	43.99
Temperature (°C)	360	18.34	6.31	5.00	30.60	34.42
Turbidity (JTU)	21	565.10	755.83	20.00	3100.00	133.75
Turbidity (FTU)	4	35.82	33.42	6.30	80.00	93.29
Oxygen, dissolved (mg/L)	65	8.91	1.30	6.60	13.00	14.58
Oxygen, dissolved (percent saturation)	15	83.96	30.95	6.60	103.00	36.86
Coliform, fecal, 0.45 UM-MF (cols/100 mL)	4	958.50	988.89	14.00	2000.00	103.17
Coliform, fecal, 0.7 UM-MF (cols/100 mL)	21	618.62	747.72	30.00	3000.00	120.87
Streptococci, fecal, KF agar (cols/100 mL)	20	3968.40	4813.23	108.00	15000.00	121.29
Streptococci, fecal, (cols/100 mL)	5	11095.98	19639.70	110.00	45999.91	177.00
Hardness (mg/L as $CaCO_3$)	607	1051.58	347.08	27.00	2250.00	33.00
Hardness, noncarbonate (mg/L $CaCO_3$)	611	971.15	603.65	120.00	3470.00	62.16
Calcium, dissolved (mg/L as Ca)	412	304.24	81.41	79.00	685.00	26.76
Magnesium, dissolved (mg/L as Mg)	411	97.18	41.39	18.00	313.00	42.59
Sodium, dissolved (mg/L as Na)	512	236.21	62.48	34.00	443.00	26.45
Percent sodium	454	30.77	6.47	7.00	46.00	21.03
Sodium-adsorption ratio	566	3.11	.67	.60	5.50	21.55
Sodium + potassium dissolved (mg/L as Na)	108	307.42	270.99	49.00	1170.00	88.15
Potassium 40 dissolved (pCi/L as K_4O)	8	12.95	4.09	6.90	21.00	31.58
Potassium, dissolved (mg/L as K)	344	23.45	6.60	3.30	47.00	28.15
Carbonate fet-fld (mg/L as CO_3)	384	.11	1.38	.00	20.00	1266.91
Alkalinity field (mg/L as $CaCO_3$)	261	243.71	45.77	52.00	425.00	18.78
Carbon dioxide dissolved (mg/L as CO_2)	138	9.96	8.76	.00	48.00	87.96
Sulfate, dissolved (mg/L as SO_4)	609	862.65	323.67	.90	1960.00	37.52
Chloride, dissolved (mg/L as Cl)	609	353.71	287.74	43.00	2460.00	81.35
Fluoride, dissolved (mg/L as F)	152	.82	.30	.20	1.90	36.34
Bromide dissolved (mg/L as BR)	113	.45	.24	.18	1.00	54.15
Silica, dissolved (mg/L as SiO_2)	399	22.26	15.35	8.70	128.00	68.97
Solids, residue at 180°C, dissolved	507	1990.81	581.89	477.00	4250.00	29.23
Solids, sum of constituents, dissolved (mg/L)	211	1932.80	595.89	397.00	2890.00	30.83
Solids, dissolved (tons per acre-ft)	605	27.37	174.51	0.59	1410.00	637.51
Solids, dissolved (tons per day)	599	1055.53	1043.07	260.00	12000.00	98.82
Nitrogen, nitrate, total (mg/L as N)	11	.58	.30	.11	.96	50.79
Nitrogen, nitrate, dissolved (mg/L as N)	57	.47	.23	.05	.93	47.95
Nitrogen, nitrate, total (mg/L as NO_3)	207	2.17	1.03	.20	5.60	47.54
Nitrogen, nitrate, total (mg/L as N)	14	.02	.01	.01	.04	58.85
Nitrogen, nitrate, dissolved (mg/L as N)	16	.01	.00	.01	.03	46.70
Nitrogen, nitrate, dissolved (mg/L as NO_2)	16	.03	.03	.00	.10	78.67
Nitrogen, NO_2 + NO_3, total (mg/L as N)	18	.55	.28	.12	.98	51.77
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	75	.45	.29	.00	1.40	64.21
Nitrogen, ammonia, total (mg/L as N)	14	.08	.07	.01	.22	81.20
Nitrogen, ammonia, dissolved (mg/L as N)	14	.08	.06	.00	.21	72.02
Nitrogen, ammonia, dissolved (mg/L as NH_4)	14	.11	.08	.00	.27	71.80
Nitrogen, ammonia + organic, dissolved (mg/L as N)	14	.65	.35	.28	1.70	53.47
Nitrogen, organic, total (mg/L as N)	12	1.56	1.59	.41	5.90	102.10
Nitrogen, organic dissolved (mg/L as N)	14	.57	.34	.24	1.60	60.89
Nitrogen, NH_4 + organic suspended, total (mg/L as N)	14	1.03	1.25	.00	4.40	121.62

Table 9.--Descriptive statistics of water-quality data at sites 1, 17, and 32--Continued

Parameter	Number of analyses	Mean	Standard deviation	Minimum value	Maximum value	Coefficient of variance
	Site 1--Continued					
Nitrogen, ammonia + organic total (mg/L as N)	17	1.17	0.83	0.18	2.80	70.48
Nitrogen, total (mg/L as NO_3)	18	8.84	6.69	1.40	31.00	75.70
Phosphorus, total (mg/L as P)	18	.66	1.24	.01	5.20	188.33
Phosphorus, total (mg/L as PO_4)	14	2.00	4.19	.00	16.00	209.17
Phosphorus, dissolved (mg/L as P)	30	.03	.02	.01	.06	61.47
Phosphorus, ortho, dissolved (mg/L as P)	50	.03	.02	.00	.13	82.37
Phosphorus, ortho, dissolved (mg/L as PO_4)	74	.07	.07	.00	.40	103.54
Arsenic, total (ug/L as As)	5	9.80	2.28	7.00	13.00	23.27
Arsenic, suspended total (ug/L as As)	3	4.33	1.53	3.00	6.00	35.25
Arsenic, dissolved (ug/L as As)	26	6.12	1.97	1.00	9.00	32.15
Barium, dissolved (ug/L as Ba)	26	157.31	98.94	90.00	400.00	62.89
Boron, total recoverable (ug/L as B)	2	4040.00	5600.28	80.00	8000.00	138.62
Boron, dissolved (ug/L as B)	266	769.52	255.20	.31	1400.00	33.16
Cadmium, total recoverable (ug/L as Cd)	3	7.33	11.02	.00	20.00	150.21
Cadmium, suspended recoverable (ug/L as Cd)	3	4.00	5.29	.00	10.00	132.29
Cadmium, dissolved (ug/L as Cd)	6	3.33	8.16	.00	20.00	244.95
Chromium, total recoverable (ug/L as Cr)	5	14.00	13.42	.00	30.00	95.83
Chromium, suspended recoverable (ug/L as Cr)	5	8.00	10.95	.00	20.00	136.93
Chromium, dissolved (ug/L as Cr)	8	8.50	9.90	.00	20.00	116.46
Cobalt, total recoverable (ug/L as Co)	5	23.80	42.86	.00	100.00	180.10
Cobalt, suspended recoverable (ug/L as Co)	5	13.60	20.84	.00	50.00	153.23
Cobalt, dissolved (ug/L as Co)	5	.40	.89	.00	2.00	223.61
Copper, total recoverable (ug/L as Cu)	5	24.60	16.90	2.00	47.00	68.72
Copper, suspended recoverable (ug/L as Cu)	5	20.00	19.66	.00	47.00	98.30
Copper, dissolved (ug/L as Cu)	25	2.12	1.90	.00	8.00	89.62
Iron, total recoverable (ug/L as Fe)	16	2688.75	7246.29	.00	26000.00	269.50
Iron, suspended recoverable (ug/L as Fe)	3	5080.00	8590.98	110.00	15000.00	169.11
Iron, dissolved (ug/L as Fe)	29	28.96	20.76	10.00	90.00	71.68
Iron, (ug/L as Fe)	12	72.50	192.08	.00	680.00	264.93
Lead, total recoverable (ug/L as Pb)	3	82.33	103.23	7.00	200.00	125.38
Lead, suspended recoverable (ug/L as Pb)	3	48.67	47.25	7.00	100.00	97.08
Lead, dissolved (ug/L as Pb)	17	61.70	171.72	.00	600.00	278.29
Manganese, total recoverable (ug/L as Mn)	5	474.00	571.86	30.00	1100.00	120.65
Manganese, suspended recoverable (ug/L as Mn)	5	460.00	584.51	10.00	1100.00	127.07
Manganese, dissolved (ug/L as Mn)	28	29.28	33.01	.00	180.00	113.03
Mercury, total recoverable (ug/L as Hg)	5	.18	.18	.10	.50	99.38
Mercury, suspended recoverable (ug/L as Hg)	5	.02	.04	.00	.10	223.61
Mercury, dissolved (ug/L as Hg)	8	.18	.14	.10	.50	79.36
Selenium, total (ug/L as Se)	5	1.80	.45	1.00	2.00	24.84
Selenium, suspended total (ug/L as Se)	5	.20	.45	.00	1.00	223.61
Selenium, dissolved (ug/L as Se)	26	1.46	.51	1.00	2.00	34.78
Zinc, total recoverable (ug/L as Zn)	5	70.00	56.57	20.00	140.00	80.81
Zinc, suspended recoverable (ug/L as Zn)	5	54.00	61.07	.00	130.00	113.10
Zinc, dissolved (ug/L as Zn)	26	22.42	9.24	.00	40.00	41.23
Phytoplankton, total (cells/mL)	6	815.00	982.79	140.00	2400.00	120.59

Table 9.--Descriptive statistics of water-quality data at sites 1, 17, and 32--Continued

Parameter	Number of analyses	Mean	Standard deviation	Minimum value	Maximum value	Coefficient of variance
		SITE 17				
Discharge (ft^3/s)	138	695.06	1370.16	48.00	8949.98	197.13
Streamflow, (ft^3)	74	189.21	158.26	40.00	905.00	83.64
Specific conductance (umho)	91	2049.34	834.63	270.00	3999.99	40.73
pH (units)	5	7.96	.09	7.90	8.10	1.12
Barometric pressure (mm of Hg)	5	683.60	7.76	674.00	695.00	1.14
Temperature, air (°C)	4	18.12	13.24	.00	28.00	73.07
Temperature (°C)	205	16.53	8.07	3.00	85.00	48.82
Oxygen, dissolved (mg/L)	4	8.48	1.59	6.60	10.30	18.74
Hardness (mg/L as $CaCO_3$)	5	778.00	537.70	300.00	1700.00	69.11
Hardness, noncarbonate (mg/L $CaCO_3$)	1	352.00	--	352.00	352.00	--
Calcium, dissolved (mg/L as Ca)	5	242.80	214.39	86.00	620.00	88.30
Magnesium, dissolved (mg/L as Mg)	5	43.00	14.00	21.00	59.00	32.56
Sodium, dissolved (mg/L as Na)	5	218.00	124.53	65.00	400.00	57.12
Percent sodium	4	36.75	16.80	16.00	54.00	45.72
Sodium-adsorption ratio	5	3.74	2.08	1.60	6.50	55.72
Potassium, dissolved (mg/L as K)	5	16.72	7.71	5.60	27.00	46.09
Carbonate fet-fld (mg/L as CO_3)	1	.00	--	.00	.00	--
Sulfate, dissolved (mg/L as SO_4)	5	605.20	523.50	140.00	1500.00	86.50
Chloride, dissolved (mg/L as Cl)	5	311.40	185.08	87.00	590.00	59.43
Fluoride, dissolved (mg/L as F)	5	.42	.19	.20	.70	45.80
Silica, dissolved (mg/L as SiO_2)	5	15.38	5.75	9.90	23.00	37.39
Solids, residue at 180°C dissolved (mg/L)	1	1400.00	--	1400.00	1400.00	--
Solids, sum of constituents, dissolved (mg/L)	4	1626.00	920.88	524.00	2670.00	56.64
Solids, dissolved (tons per ac-ft)	5	2.15	1.09	.71	3.63	50.94
Solids, dissolved (tons per day)	5	709.00	260.00	439.00	1120.00	37.94
Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	4	.56	.23	.30	.85	41.38
Phosphorus, ortho, dissolved (mg/L as P)	4	.02	.01	.01	.04	70.71
Phosphate, ortho, dissolved (mg/L as PO_4)	2	.09	.04	.06	.12	47.14
Boron, dissolved (ug/L as B)	5	476.00	297.62	140.00	950.00	62.53
		SITE 32				
Discharge (ft^3/s)	171	806.13	1863.40	48.00	9220.02	231.15
Streamflow, instantaneous (ft^3/s)	41	175.95	128.46	76.00	620.00	73.01
Specific conductance (umho)	42	787.00	138.10	430.00	1000.00	17.55
pH (units)	7	8.08	.21	7.80	8.30	2.62
Barometric pressure (mm of Hg)	4	665.75	7.93	658.00	674.00	1.19
Temperature, air (°C)	4	23.62	8.09	18.50	35.50	34.23
Temperature (°C)	173	17.00	7.24	1.50	29.50	42.58
Oxygen, dissolved (mg/L)	4	8.28	1.56	6.30	10.10	18.84
Hardness (mg/L as $CaCO_3$)	7	365.43	88.38	190.00	456.00	24.19
Hardness, noncarbonate (mg/L $CaCO_3$)	3	297.33	84.36	201.00	358.00	28.37
Calcium, dissolved (mg/L as Ca)	7	100.29	30.38	55.00	143.00	30.30
Magnesium, dissolved (mg/L as Mg)	7	28.00	9.31	13.00	42.00	33.25
Sodium, dissolved (mg/L as Na)	7	43.00	16.86	10.00	61.00	39.21
Percent sodium	4	19.75	6.55	10.00	24.00	33.17
Sodium-adsorption ratio	7	1.00	.39	.30	1.30	38.73
Potassium, dissolved (mg/L as K)	5	3.90	1.14	2.00	5.00	29.24
Carbonate fet-fld (mg/L as CO_3)	3	.00	.00	.00	.00	--
Sulfate, dissolved (mg/L as SO_4)	7	248.43	123.73	55.00	402.00	49.80
Chloride, dissolved (mg/L as Cl)	7	37.98	27.11	8.60	66.00	71.37
Fluoride, dissolved (mg/L as F)	5	.20	.07	.10	.30	35.36
Silica, dissolved (mg/L as SiO_2)	5	9.56	2.32	7.20	12.00	24.32
Solids, residue at 180°C, dissolved (mg/L)	3	699.67	14.47	683.00	709.00	2.07
Solids, sum of constituents, dissolved (mg/L)	4	472.25	162.67	238.00	598.00	34.45
Solids, dissolved (tons per acre-ft)	7	.77	.23	.32	.96	29.44
Solids, dissolved (tons per day)	7	3542.32	6578.78	108.00	17650.23	185.72
Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	4	.44	.15	.26	.62	33.86
Phosphorus, ortho, dissolved (mg/L as P)	4	.02	.01	.01	.03	57.74
Phosphate, ortho, dissolved (mg/L as PO_4)	2	.09	.00	.09	.09	.00
Boron, dissolved (ug/L as B)	5	60.00	21.21	30.00	80.00	35.36

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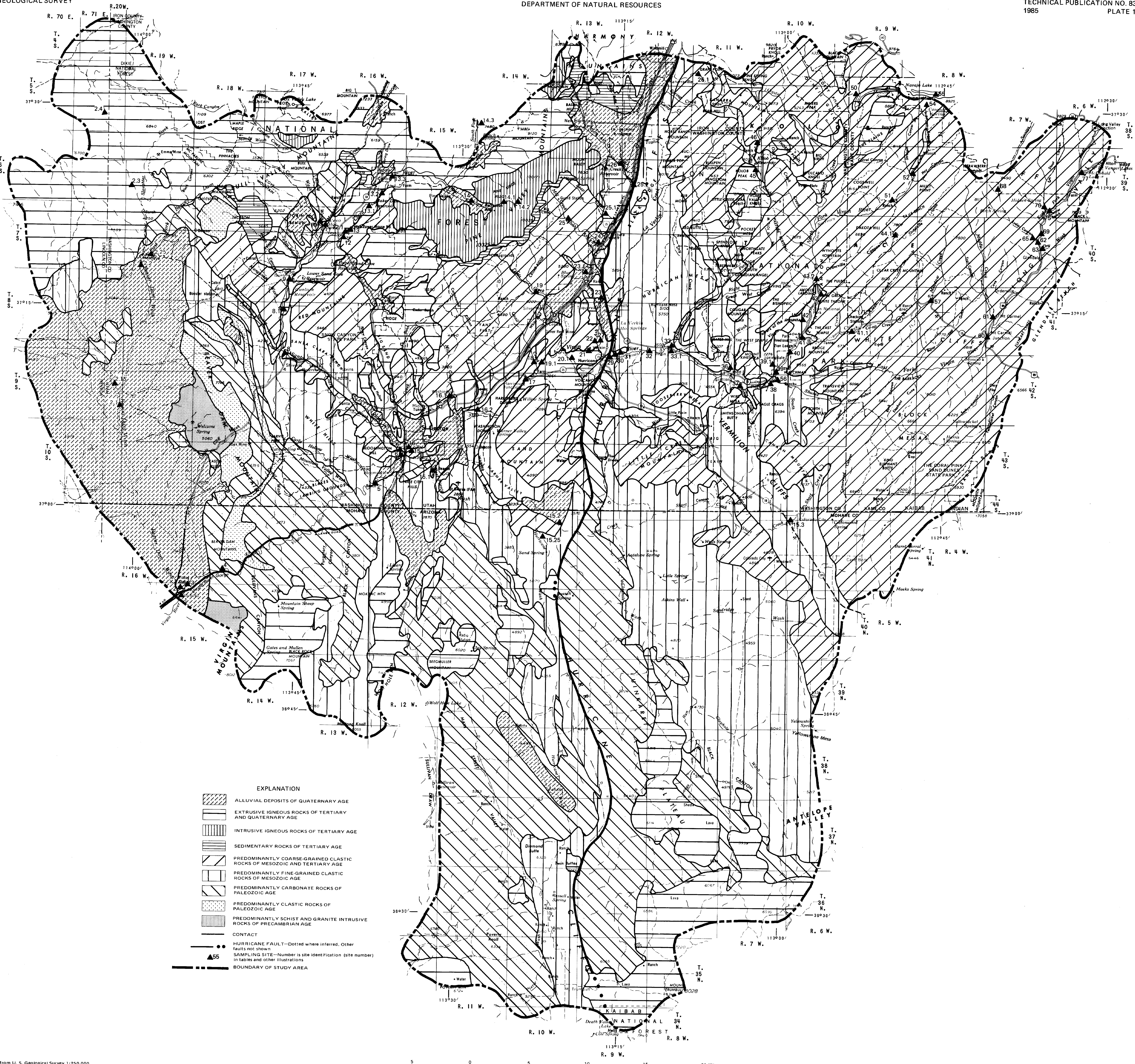
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Prepared in cooperation with the
STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

TECHNICAL PUBLICATION NO. 83
1985
PLATE 1



Base from U. S. Geological Survey 1:250,000
Grand Canyon, 1953, (revised 1970), Arizona,
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MAP SHOWING GENERALIZED GEOLOGY AND LOCATION OF WATER-QUALITY SAMPLING SITES
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UNITED STATES DEPARTMENT OF THE INTERIOR
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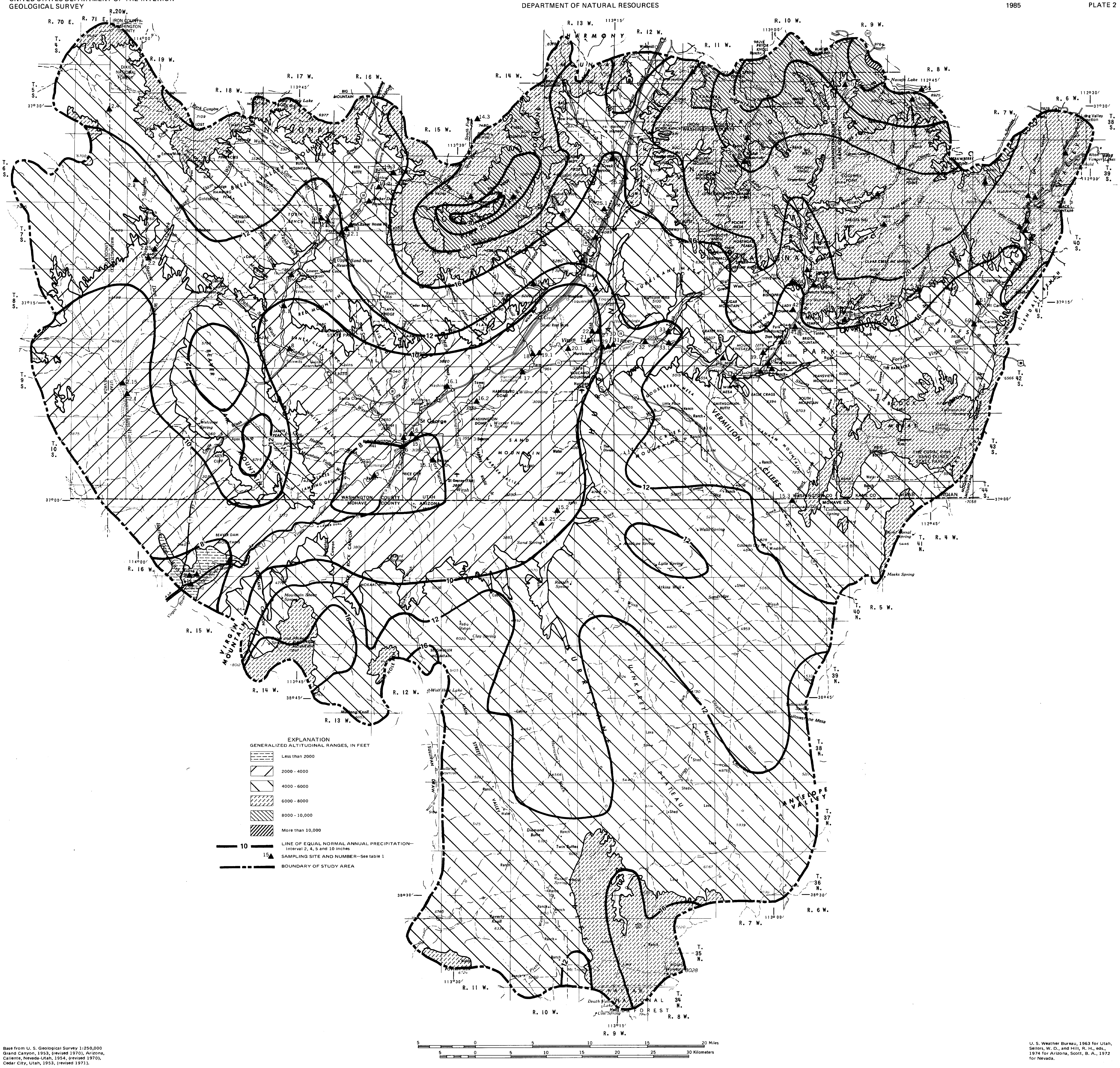
TECHNICAL PUBLICATION NO. 83
1985 PLATE 2



Base from U. S. Geological Survey 1:250,000 Grand Canyon, 1953, (revised 1970), Arizona, Caliente, Nevada-Utah, 1954, (revised 1970), Cedar City, Utah, 1953, (revised 1971).

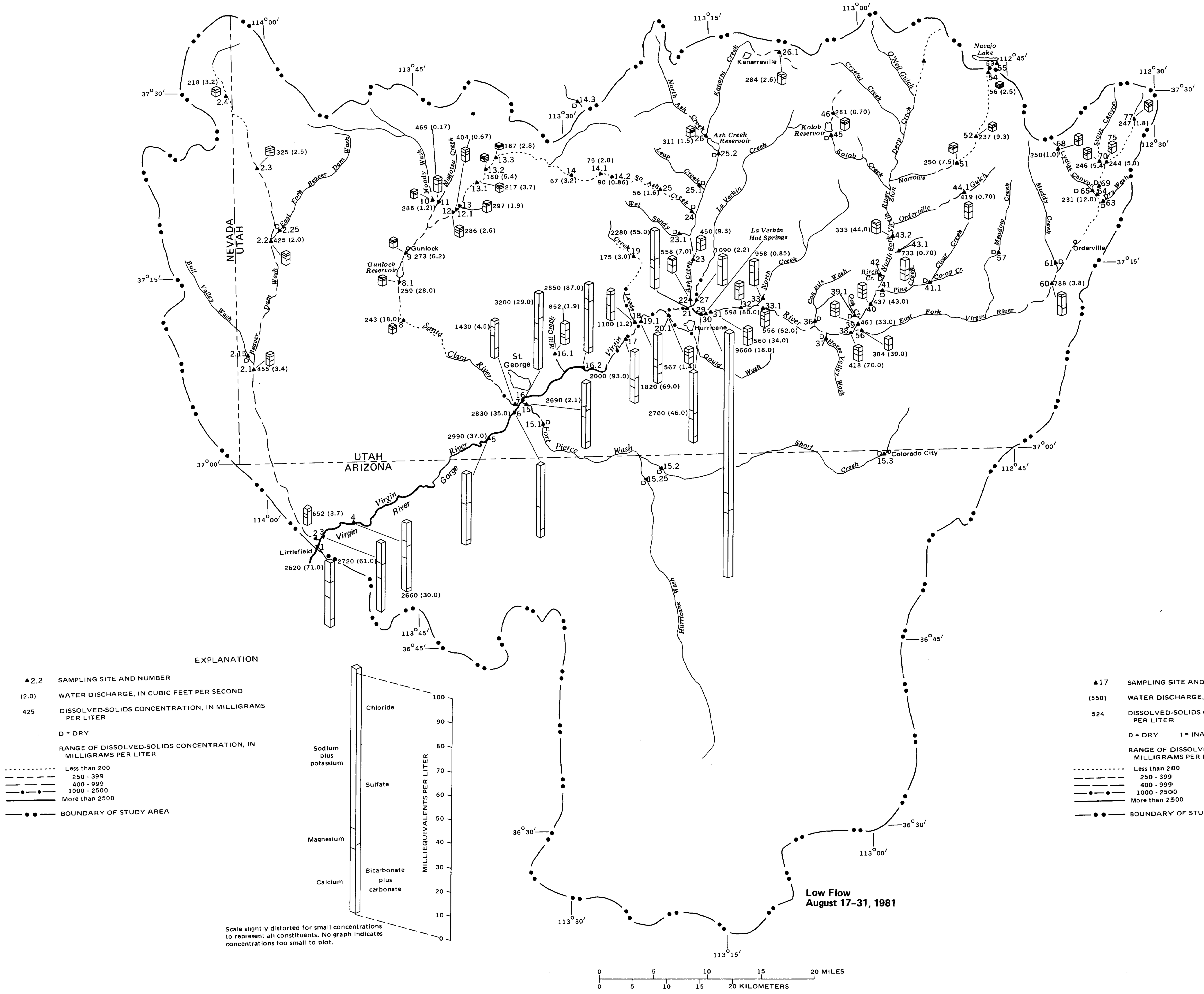
U. S. Weather Bureau, 1963 for Utah, Sellers, W. D., and Hill, R. H., eds., 1974 for Arizona, Scott, B. A., 1972 for Nevada.

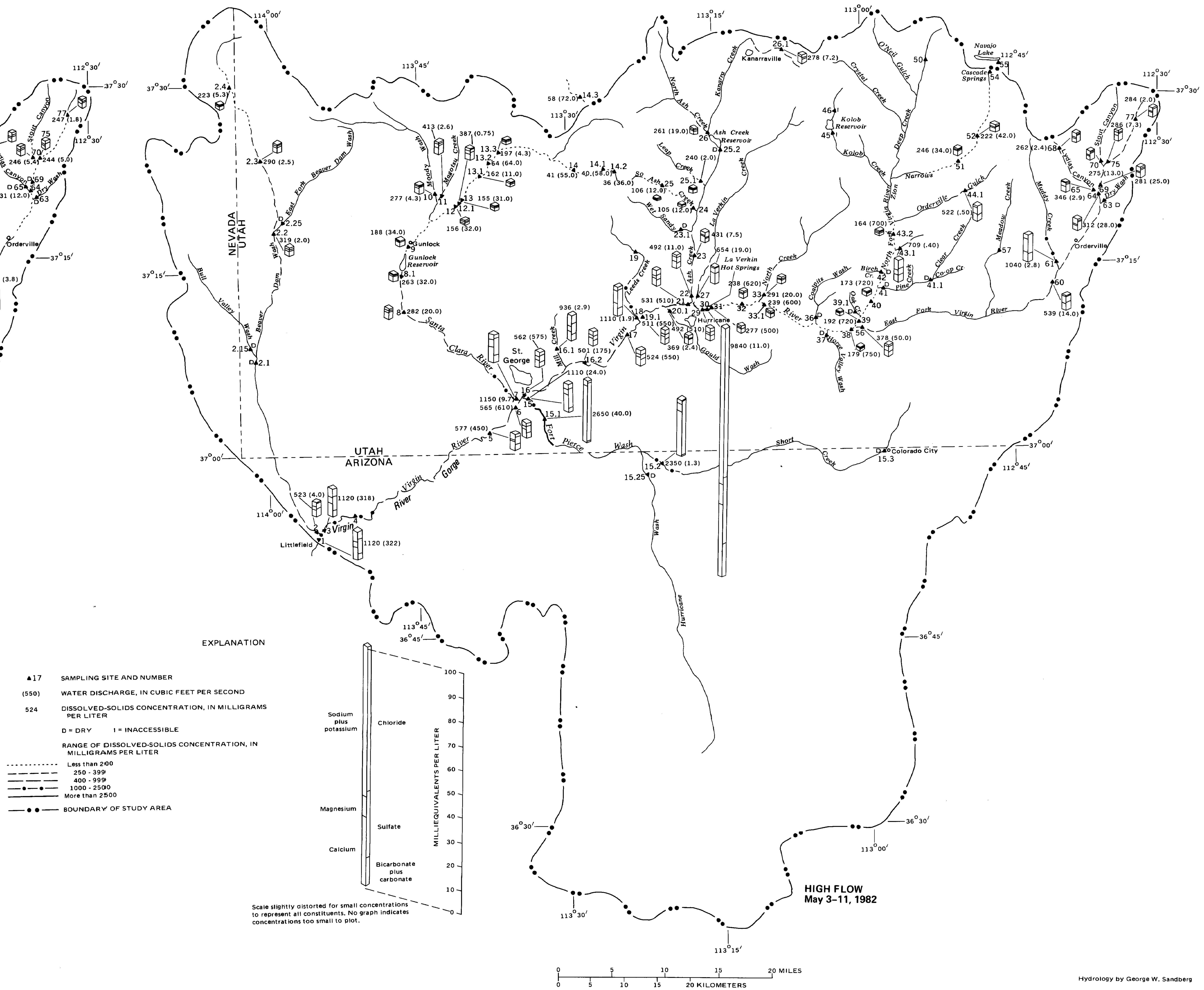
GENERALIZED ALTITUDINAL ZONES AND 1931-60 NORMAL ANNUAL PRECIPITATION.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Prepared in cooperation with the
STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

TECHNICAL PUBLICATION NO. 83
1985
PLATE 3





Hydrology by George W. Sandberg

CHEMICAL CHARACTERISTICS AND DISCHARGE OF SURFACE WATER AT SELECTED SITES DURING LOW FLOW, AUGUST 17-31, 1981 AND DURING HIGH FLOW, MAY 3-11, 1982.