INTRODUCTION

PURPOSE AND SCOPE

The study area in south-central Utah (fig.1) is noted for its large coal reserves in the Alton, Kolob, and Kaiparowits Plateau coal fields. The area also is noted for its scenic beauty and general scarcity of water. Although there has been very little development of the coal resources through 1983, there is a potential for large-scale development with both surface- and underground-mining methods. Mining of coal could have significant effects on the quantity and quality of the water resources. The purpose of this atlas is to define the surface- and ground-water resources of the area and to identify the potential effects on these resources by coal mining.

This atlas is based mainly on a reconnaissance conducted from October 1980 to September 1983 by the U.S. Geological Survey in cooperation with the U.S. Bureau of Land Management. Hydrologic data collected during the study include measurements of streamflow, well and spring inventories, and chemical analyses of surface and ground water. The hydrologic data, along with some data collected during earlier studies, are included in a separate report (Plantz, 1983).

PREVIOUS HYDROLOGIC STUDIES

A number of hydrologic studies have included all or parts of the Kolob, Alton, and Kaiparowits Plateau coal fields. Reports from several of the studies were used to prepare this atlas, and they should be useful references to readers dealing with water-related problems in the area. All reports cited in this atlas are listed on sheet 2. Marine (1963) described the ground-water resources of Bryce Canyon National Park, which borders on the Alton coal field. Goode (1964, 1966, and 1969) described ground-water conditions in western Kane County and in the Escalante area. The hydrology of the Navajo Lake area was studied by Wilson and Thomas (1964). Feltis (1966) compiled data on ground water in bedrock in the Colorado Plateau in Utah, which includes most of the study area. Carpenter and others (1967) described ground-water conditions in the upper part of the Sevier River basin, and Hahl and Mundorff (1968) studied quality of surface water in the Sevier River basin. Several large springs on the Markagunt Plateau are included in Mundorff's (1971) compilation of nonthermal springs in Utah. Bjorklund and others (1978) described ground-water conditions in Cedar and Parowan Valleys, and Cordova (1981) described ground-water conditions in the upper Virgin River and Kanab Creek basins.

A series of maps that show the general availability and chemical quality of surface and ground water in the Kaiparowits Plateau coal field were prepared by Price (1977a, 1977b, 1978, and 1979). A similar series of maps were prepared by Price (1980, 1981, 1982a, and 1982b) for the Alton and Kolob coal fields. Sandberg (1979) studied the hydrology of a part of the Alton coal field.

GEOGRAPHIC SETTING

The study area includes about 4,500 mi^2 in parts of Garfield, Iron, Kane, and Washington Counties, Utah. The largest communities and their approximate populations during 1980 (in parentheses) are Cedar City (10,947), Parowan (1,840), Escalante (654), Tropic (335), and Henrieville (167). Panguitch (1,343) is in the Sevier River valley about 6 mi north of the study area, and Kanab (2,132) is in the Kanab Creek valley about 10 mi south of the area (U.S. Department of Commerce, 1980, p. 5 and 6).

Most of the land in the area is Federally owned and administered by the Bureau of Land Management, the Forest Service, and the National Park Service. Nearly all of the coal is Federally owned. Several of Utah's most popular tourist attractions are wholly or partly in the study area. They include Bryce Canyon and Zion National Parks, Cedar Breaks National Monument, Lake Powell, Glen Canyon National Recreation Area, and Dixie National Forest.

The study area is characterized by broad plateaus, terraces, and benches that are dissected by deep, narrow stream canyons. Principal physiographic features include the Kolob Terrace; the Markagunt, Paunsaugunt, and Kaiparowits Plateaus; the cliffs that border the plateaus; and the deep, narrow stream canyons. Altitudes range from less than 4,000 ft above sea level in the area inundated by Lake Powell to about 11,000 ft on the Markagunt Plateau.

About 75 percent of the study area is in the Colorado River Basin and is drained mainly by the Escalante, Paria, and Virgin Rivers, and by Kanab, Wahweap, Warm, and Deep Creeks. The remainder of the area is in the Great Basin and is drained mainly by the Sevier River, and by Coal, Summit, Center, and Parowan Creeks (fig. 1).

CLIMATE

Climate in the study area ranges from arid in the lower altitudes to subhumid on the highest plateaus. Normal annual precipitation varies from less than 6 in. near Lake Powell to more than 40 in. on the Markagunt Plateau (fig. 1). Winter precipitation commonly occurs as snow, which accumulates to depths of more than 10 ft. at the highest altitudes. Summer precipitation commonly occurs during localized thunderstorms, which can produce more than an inch of rain in less than an hour.

Total annual precipitation varies markedly from year to year. At Cedar City, for example, it has ranged from 4.95 in. during 1959 to 18.76 in. during 1941. At Bryce Canyon National Park, it has ranged from 7.25 in. during 1950 to 24.11 in. during 1941. (See U.S. Department of Commerce, 1957, p. 4 and 5; 1965, p. 5).

Evaporation rates in the area are large. The annual rate of evaporation exceeds the annual rate of precipitation, even in the highest plateau areas. May–October pan evaporation ranges from about 40 in. on the Markagunt Plateau to about 65 in. in the lower altitudes near Lake Powell. (See figure 1.) The relatively large evaporation rates significantly decrease the quantity of water that otherwise would runoff in streams or be recharged to the ground-water system.

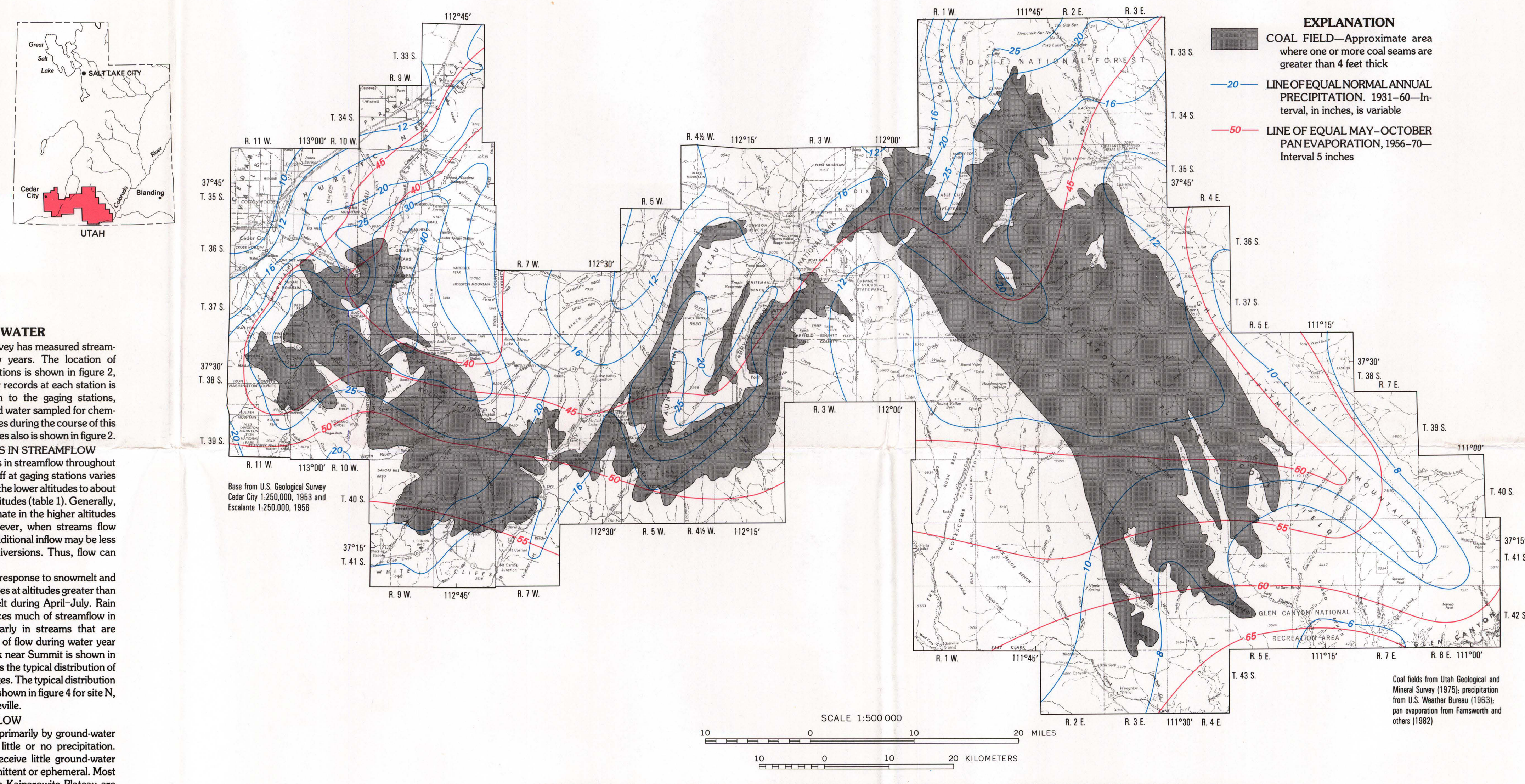

Figure 1.—MAP SHOWING LOCATION OF COAL FIELDS, NORMAL ANNUAL PRECIPITATION, AND MAY–OCTOBER PAN EVAPORATION

SURFACE WATER

The U.S. Geological Survey has measured streamflows in the area for many years. The location of continuous-record gaging stations is shown in figure 2, and a summary of streamflow records at each station is listed in table 1. In addition to the gaging stations, streamflow was measured and water sampled for chemical analyses at many other sites during the course of this study; the location of these sites also is shown in figure 2.

GENERAL VARIATIONS IN STREAMFLOW

There are large variations in streamflow throughout the study area. Average runoff at gaging stations varies from less than 1 in. per year in the lower altitudes to about 10 in. per year in the higher altitudes (table 1). Generally, the flow of streams that originate in the higher altitudes increases downstream. However, when streams flow through low-altitude areas, additional inflow may be less than evapotranspiration or diversions. Thus, flow can decrease downstream.

Streamflow fluctuates in response to snowmelt and rain. Most runoff from drainages at altitudes greater than 8,000 ft results from snowmelt during April–July. Rain during thunderstorms produces much of streamflow in the lower altitudes, particularly in streams that are intermittent. The distribution of flow during water year 1980 at site G, Summit Creek near Summit is shown in figure 3; the hydrograph shows the typical distribution of flow from high-altitude drainages. The typical distribution of flow at a low-altitude site is shown in figure 4 for site N, Henrieville Creek near Henrieville.

LOW FLOW

Streamflow is sustained primarily by ground-water discharge during periods of little or no precipitation. Many streams in the area receive little ground-water discharge, and they are intermittent or ephemeral. Most of the streams that drain the Kaiparowits Plateau are intermittent as shown in figure 2. The intermittent streams commonly convey storm runoff or water issuing from a single spring; consequently they have no flow along extensive reaches during parts of most years.

Seven-day low-flow frequency curves for gaging stations with 5 or more complete years of record are shown in figure 5. The curves show the annual minimum mean flow for 7 consecutive days for selected recurrence intervals. The recurrence interval is the average time, in years, between flow that will average less than the indicated rate. The relatively flat curves, such as for site I on Coal Creek, indicate large quantities of ground-water discharge along streams. Conversely, the relatively steep curve for site L on Pine Creek indicates a small quantity of ground-water discharge; in fact, the stream is dry at the gaging station at times during some years.

The low-flow frequency curves can be used to determine the potential of streams for water supply and waste dilution. The curves also can be used to determine the effects of mining on streamflow because the curves will become flatter when flows are increased by mine discharge.

PEAK FLOW

Information on peak flows of specific recurrence intervals is needed for a variety of projects including the design of bridges, culverts, holding ponds, and embankments, and to identify flood-prone areas. Flood data are needed to decrease costs associated with over design and to eliminate disruption of services or even loss of life associated with under design. Maximum flows recorded at gaging stations commonly are two to three orders of magnitude larger than average flows (table 1.)

Flood-frequency curves for selected gaging stations are shown in figure 6. The curves show the average interval, in years, between floods that equaled or exceeded a given discharge. The recurrence interval is an average value and does not mean that floods occur with any regularity. It is possible, for example, to have two floods of the 10-year recurrence-interval magnitude in successive years or even in the same year. On the average, a flood with a 10-year recurrence interval will be equaled or exceeded about 10 times in 100 years and has a 10-percent chance of being equaled or exceeded in any 1 year.

The reader is referred to a statewide study of peak flow by Thomas and Lindskov (1983) for methods of estimating peak flows from basin characteristics and for methods to transfer peak-flow values from gaged to ungaged sites on the same stream. In addition, Thomas and Lindskov (1983) describe procedures for mapping areas inundated by floods of selected recurrence intervals.

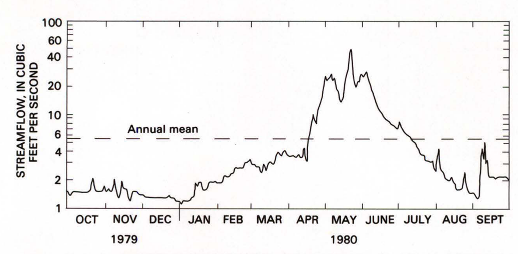

Figure 3.—HYDROGRAPH OF STREAMFLOW DURING WATER YEAR 1980 AT SITE G, SUMMIT CREEK NEAR SUMMIT

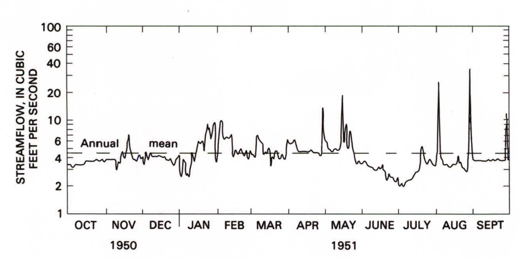

Figure 4.—HYDROGRAPH OF STREAMFLOW DURING WATER YEAR 1951 AT SITE N, HENRIEVILLE CREEK NEAR HENRIEVILLE

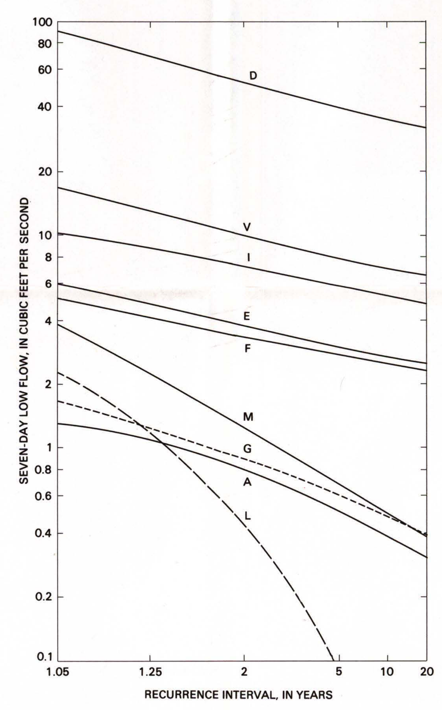

Figure 5.—SEVEN-DAY LOW-FLOW FREQUENCY CURVES FOR GAGING STATIONS WITH 5 OR MORE COMPLETE YEARS OF RECORD. (Site-identification letters are those used in table 1 and in figure 2.)

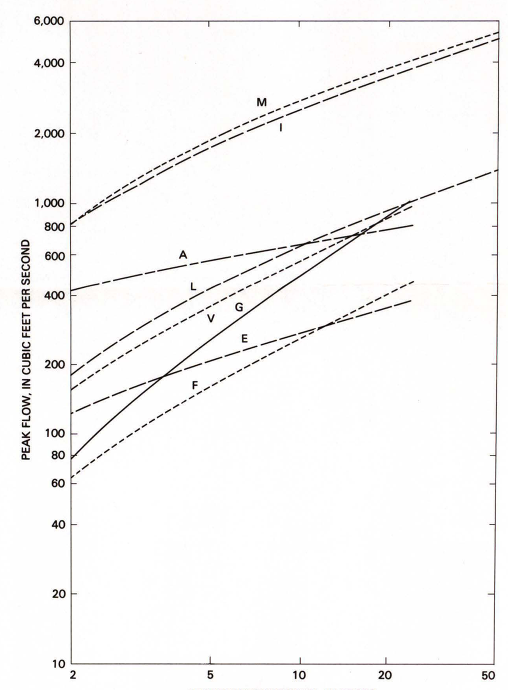

Figure 6.—FLOOD-FREQUENCY CURVES FOR SELECTED GAGING STATIONS (Site-identification letters are those used in table 1 and in figure 2.)

QUALITY

The chemical quality of surface water throughout the study area is shown by the water-quality diagrams in figure 2. Where data are available more than one diagram is shown for a site in order to define the differences in water quality with time and with stream discharge. As shown in figure 2, there were marked areal differences in water quality; however, water quality at most sites generally did not vary markedly with time or with stream discharge. The complete chemical analyses are listed by Plantz (1983, table 7).

Water in the headwaters of most perennial streams contained less than 500 mg/L (milligrams per liter) of dissolved solids. The predominant cation usually was calcium, and the pH and alkalinity indicated that bicarbonate was the predominant anion. Water in intermittent streams commonly contained greater than 2,000 mg/L of dissolved solids; the predominant cation in most water was sodium, and the predominant anion was sulfate.

Ground water in the area generally is more saline than direct runoff. As ground water moves from recharge areas toward natural discharge areas along streams, it dissolves minerals from the rock through which it moves. The discharge of ground water, especially from Cretaceous rocks, contributes significantly to the salinity of surface water during base flow. The salinity of surface water also is increased by irrigation-return flows, especially return of water used to irrigate soils on the Tropic Shale. The outcrops of geologic units and quality of ground water are discussed on sheet 2.

Annual sediment yields vary from less than 0.1 to more than 3.0 acre-ft/mi^2 (U.S. Department of Agriculture, 1973). The higher well-vegetated plateaus generally have the smallest sediment yields. The largest sediment yields are from sparsely-vegetated areas underlain by easily erodible shale and mudstone.

Table 1.—*Summary of streamflow records at gaging stations*

[mi^2, square miles; ft, feet; in.,inch; ft^3/s, cubic feet per second; acre-ft/yr, acre-feet per year; in/yr, inches per year.]

Site identi-fication	Downstream number	Station name	Drainage area (mi^2)	Period of record (water year)	Altitude of gage (ft)	Mean annual precipitation (in.)	Average discharge ft^3/s	Average discharge acre-ft/yr	Average discharge in/yr	Extremes: Maximum (ft^3/s)	Extremes: Date	Extremes: Minimum (ft^3/s)	Extremes: Date
		GREAT BASIN											
A	10173450	Mammoth Creek above West Hatch Ditch, near Hatch	105	1964–82	7,300	24	([1]) 49.0	35,500	6.34	652	June 6, 1979	0.06	Dec. 25, 1977
B	10173900	Duck Creek near Hatch	—	1953–59	8,530	—	—	—	—	226	June 6, 1958	.04	During winter months for most years
C	10174000	Assay Creek above West Fork, near Hatch	—	1954–59	—	—	—	—	—	419	May 11, 1958	13.0	Jan. 22 to Mar. 30, 1956
D	10174450	Sevier River near Hatch	340	1911–28, 1939–82	6,870	23	([1])125	90,560	5.00	1,490	May 26, 1922	20.0	Aug. 30, 31; Sept. 1, 7–9, 1977
E	10183900	East Fork Sevier River near Ruby's Inn	71.6	1961–82	7,860	22	16.9	12,240	3.20	448	May 23, 1980	0	Feb. 26 to Mar. 10, 1964
F	10241470	Center Creek above Parowan Creek, near Parowan	11.6	1964–82	6,900	22	6.22	4,510	7.29	353	Aug. 10, 1965	1.4	July 16, 1972; Jan. 24, 1979
G	10241600	Summit Creek near Summit	24.0	1964–82	6,310	22	4.16	3,010	2.36	858	Aug. 6, 1971	.05	Feb. 5–7, 1971
H	10241800	Ash Down Creek near Cedar City	13.1	1957–61	7,540	—	—	—	—	1,000	Aug. 3 1959	1.7	Nov. 23, 1958
I	10242000	Coal Creek near Cedar City	80.9	1917–19, 1936–82	6,000	29	([1]) 32.4	23,470	5.44	4,620	July 23, 1969	.30	Nov. 5, 14, 17, 26, 1959; Feb. 17, 1960; Feb. 24, 1961
		COLORADO RIVER BASIN											
J	09335500	North Creek near Escalante	90	1950–55	6,100	20	7.64	5,530	1.15	3,610	Aug. 21, 1952	0	Aug. 6, 1956; Nov. 25–27, 1952; Dec. 1, 1953
K	09336500	Birch Creek near Escalante	36	1950–51	6,090	—	([1])	—	—	1,010	July 12, 1954	.01	July 13, 14, 1955
L	09337000	Pine Creek near Escalante	68.1	1950–55, 1957–82	6,400	23	4.55	3,300	.91	1,010	Aug. 2, 1967	0	No flow at times in some years
M	09337500	Escalante River near Escalante	320	1909–13, 1942–55, 1971–82	5,670	18	([1]) 15.0	10,870	.64	3,450	Aug. 1953	.07	Dec. 24, 1978
N	09381000	Henrieville Creek near Henrieville	29	1950–55	6,100	—	—	—	—	3,360	July 31, 1953	0	Nov. 22, Dec. 22 1952
O	09381500	Paria River near Cannonville	220	1950–55	5,440	—	([1])	—	—	5,160	Aug. 16, 1955	0	No flow for many days each year
P	09403620	Mill Creek near Glendale	4.81	1975–77	6,820	—	—	—	—	147	Aug. 17, 1977	.06	Jan. 26, 1977
Q	09403630	Skutumpah Creek near Glendale	14.8	1975–77	—	—	—	—	—	314	Aug. 17, 1977	0	No flow during most winter months
R	09403640	Intermediate Drainage near Glendale	2.49	1975–77	6,120	—	—	—	—	42	Sept. 26, 1976	0	No flow most days
S	09403650	Thompson Creek (upper station) near Glendale	9.8	1975–77	6,420	—	—	—	—	700	Aug. 18, 1977	.09	Aug. 28–30, 1977
T	09403660	Thompson Creek (lower station) near Glendale	16.6	1975–77	6,300	—	—	—	—	700	Aug. 18, 1977	.06	Aug. 31, Sept. 1, 1977
U	09403670	Thompson Creek near Glendale	19.2	1980–81	6,050	—	—	—	—	1,030	Aug. 14, 1981	.23	July 31 to Aug. 9, 1981
V	09404450	East Fork Virgin River near Glendale	69.2	1966–82	5,900	33	20.7	15,000	4.06	640	July 27, 1976	6.3	June 18, 1977
W	09405300	Crystal Creek near Cedar City	10.2	1956–60	8,320	—	7.23	5,230	9.63	1,300	Aug. 19, 1959	.10	July 6–9, 1957
X	09405420	North Fork Virgin River below Bullock Canyon near Glendale	29.6	1974–82	6,420	30	18.5	13,400	8.49	225	Oct. 2, 1977	2.6	Aug. 3, 1977
Y	09405450	North Fork Virgin River above Zion Narrows, near Glendale	45.5	1978–82	6,000	—	—	—	—	242	Aug. 23, 1982	2.2	Aug. 12, 1981

[1] Diversions upstream from station.

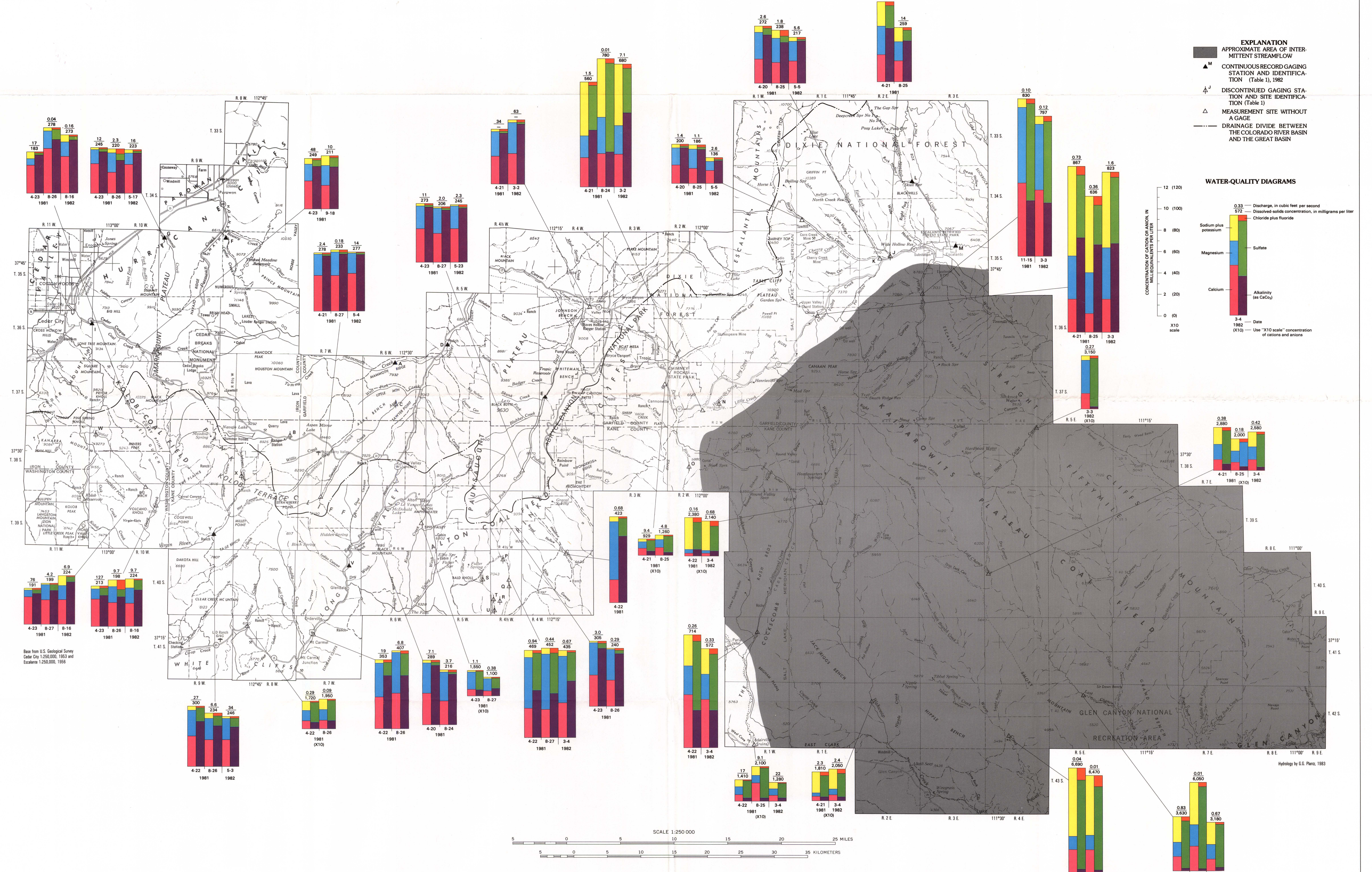

Figure 2.—MAP SHOWING SURFACE-WATER DATA-COLLECTION NETWORK, WATER QUALITY, AND AREA OF INTERMITTENT STREAMFLOW

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HYDROLOGIC RECONNAISSANCE OF THE KOLOB, ALTON, AND KAIPAROWITS PLATEAU COAL FIELDS, SOUTH-CENTRAL UTAH

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