

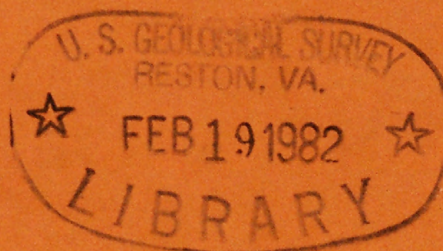
(200)
R290
no. 81-138

HYDROLOGIC MONITORING IN THE COAL FIELDS OF
CENTRAL UTAH, AUGUST 1978-SEPTEMBER 1979

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS

OPEN-FILE REPORT 81-138



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



HYDROLOGIC MONITORING IN THE COAL FIELDS OF
CENTRAL UTAH, AUGUST 1978-SEPTEMBER 1979
By Gregory C. Lines and Gerald G. Plantz

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS

OPEN-FILE REPORT 81-138

Salt Lake City, Utah
1981

CONTENTS

	Page
Abstract.	1
Introduction	1
Scope and objectives	1
Previous investigations.	2
Downstream gaging-station numbers.	2
Physical and geologic setting	2
Hydrologic setting.	4
Precipitation and evaporation.	4
Surface water.	4
Ground water	5
Price River basin	6
Pleasant Valley Creek.	6
Beaver Creek	11
Willow Creek	14
Spring Canyon	15
North Fork of Gordon Creek	17
Coal Creek	20
Soldier Creek	23
Grassy Trail Creek	27
Horse Canyon	32
San Rafael River basin	35
Huntington Creek and Crandall and Tie Fork Canyons	35
Cottonwood Creek	39
Dirty Devil River basin	46
Quitcupah Creek and Christiansen Wash	46
Conclusions	53
References cited.	55

ILLUSTRATIONS

[Plate is in pocket]

Plate 1. Map showing the location of the study area in Utah and the locations of Federal coal leases, active underground coal mines, and hydrologic monitoring sites in the Wasatch Plateau, Book Cliffs, and Emery coal fields, 1979.

Figure 1. Diagrammatic geologic column of rocks in the coal fields of central Utah. 3

2-30. Graphs showing:

- | | |
|---|---|
| 2. Discharge of Pleasant Valley Creek at gaging station 09310700, 1979 water year | 7 |
| 3. Base flow of Pleasant Valley Creek and its relationship to mining activities | 8 |

ILLUSTRATIONS--Continued

Page

Figures 2-30. Graph showing--Continued

4. Relationship of major dissolved chemical constituents and discharge of Pleasant Valley Creek at gaging station 09310700, August 1978-September 1979.	10
5. Base flow of Beaver Creek and its relationship to geology	14
6. Base flow of Willow Creek and its relationship to geology and mining activities	16
7. Discharge in Spring Canyon at gaging station 09313040, 1979 water year	16
8. Relationship of major dissolved chemical constituents and discharge in Spring Canyon at gaging station 09313040, August 1978-September 1979.	19
9. Base flow of North Fork of Gordon Creek.	20
10. Discharge of Coal Creek at gaging station 09313965, 1979 water year	21
11. Base flow of Coal Creek and its relationship to geology and mining activities.	23
12. Discharge of Soldier Creek at gaging station 09313975, 1979 water year	24
13. Base flow of Soldier Creek and its relationship to geology and mining activities	25
14. Relationship of major dissolved chemical constituents and discharge of Soldier Creek at gaging station 09313975, August 1978-September 1979.	27
15. Discharge of Grassy Trail Creek at gaging station 09314340, 1979 water year	28
16. Base flow of Grassy Trail Creek and its relationship to geology and mining activities.	29

ILLUSTRATIONS--Continued

	Page
Figures 2-30. Graphs showing--Continued	
17. Relationship of major dissolved chemical constituents and discharge of Grassy Trail Creek at gaging station 09314340, August 1978-September 1979	31
18. Discharge in Horse Canyon at gaging station 09314374, 1979 water year.	32
19. Base flow in Horse Canyon and its relationship to geology and mining activities	33
20. Discharge in Crandall Canyon at gaging station 09317919, 1979 water year.	36
21. Discharge in Tie Fork Canyon at gaging station 09317920, 1979 water year.	36
22. Discharge of Huntington Creek at gaging station 09318000, 1979 water year.	37
23. Base flow of Huntington Creek and its relationship to geology and mining activities	38
24. Relationship of major dissolved chemical constituents and discharge of Huntington Creek at gaging station 09318000, August 1978-September 1979.	43
25. Discharge of Cottonwood Creek at gaging station 09324200, 1979 water year.	44
26. Base flow of Cottonwood Creek and its relationship to geology and mining activities	46
27. Discharge of Quitchupah Creek at gaging station 09331900, 1979 water year.	48
28. Discharge in Christiansen Wash at gaging station 09331950, 1979 water year.	48
29. Base flow of Quitchupah Creek and its relationship to geology and mining activities	49
30. Relationship of major dissolved chemical constituents and discharge of Quitchupah Creek at gaging station 09331900, August 1978-September 1979.	52

TABLES

	Page
Table 1. Summary of chemical constituents and bacteria in water at gaging station 09310700 on Pleasant Valley Creek, August 1978 through September 1979.	9
2. Benthic invertebrates collected at gaging stations in the Wasatch Plateau, Book Cliffs, and Emery coal fields, August 1978 through September 1979	12
3-13. Summaries of chemical constituents and bacteria in water, August 1978 through September 1979, at gaging station:	
3. 09313040 in Spring Canyon.	18
4. 09313965 on Coal Creek	22
5. 09313975 on Soldier Creek.	26
6. 09314340 on Grassy Trail Creek	30
7. 09314374 in Horse Canyon	34
8. 09317919 in Crandall Canyon.	40
9. 09317920 in Tie Fork Canyon.	41
10. 09318000 on Huntington Creek	42
11. 09324200 on Cottonwood Creek	45
12. 09331900 on Quitichupah Creek	50
13. 09331950 in Christiansen Wash.	51

CONVERSION FACTORS

Most values are given in this report in inch-pound units. For those readers who may prefer to use metric units, the conversion factors for the terms used in this report are listed below. Multiply the inch-pound unit by the factor to obtain the metric equivalent.

<u>Unit</u>	<u>Inch-pound</u> <u>Abbreviation</u>	<u>Conversion</u> <u>factor</u>	<u>Metric unit</u>
Acre		0.4047	Square hectometer
Acre-foot	acre-ft	0.001233	Cubic hectometer
Cubic foot per second	ft ³ /s	0.02832	Cubic meter per second
Cubic foot per second per square mile	(ft ³ /s)/mi ²	0.0733	Cubic meter per second per square kilometer
Foot	ft	0.3048	Meter
Gallon per minute	gal/min	0.06309	Liter per second
Inch	in.	25.40	Millimeter
		2.540	Centimeter
Micromho	μmho	1.000	Microsiemen
Mile	mi	1.609	Kilometer
Square foot	ft ²	0.0929	Square meter
Square mile	mi ²	2.590	Square kilometer
Ton (short, 2,000 pounds)		0.9072	Megagram (metric ton)

Chemical concentration and water temperature are given in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in parts per million.

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation: °F=1.8(°C)+32.

HYDROLOGIC MONITORING IN THE COAL FIELDS OF CENTRAL UTAH, AUGUST 1978-SEPTEMBER 1979

by

Gregory C. Lines and Gerald G. Plantz

ABSTRACT

Surface-water quantity and quality were observed at 12 gaging stations downstream from mined and lease areas in the Wasatch Plateau, Book Cliffs, and Emery coal fields in central Utah. Measurements of base flow were made at 52 additional sites in the region. The report describes the hydrologic setting of this important coal region and summarizes the surface-water data collected at the monitoring sites from August 1978 through September 1979. Coal mining and lease activities in each of the monitored basins also are described.

Where possible, hydrologic impacts of coal mining are evaluated. Impacts include increases in streamflow and degradation of surface-water quality due to water discharged from underground mines. Other impacts include removal of water from ground-water storage, changes in the natural ground-water flow system, and possibly the diminution of spring flows.

Adequacy of the monitoring network to detect hydrologic changes due to mining is evaluated. In order to fully assess and quantify the impacts, comprehensive studies and monitoring of the ground-water system and water produced in mines are needed.

INTRODUCTION

Scope and Objectives

In August 1978, the U.S. Geological Survey began operation of 12 gaging stations downstream from mining areas and areas leased for mining in the Wasatch Plateau, Book Cliffs, and Emery coal fields in central Utah. (See pl. 1.) At that time there were 17 producing mines and 73,500 acres of Federal land leased for coal mining in the Wasatch Plateau, 4 mines and 37,400 acres in the Book Cliffs, and 2 mines and 33,900 acres in the Emery coal field. The 12 gaging stations were part of a network designed to aid in the definition of the hydrology of the coal areas and to determine the hydrologic impacts of coal mining. Stream discharge, chemical quality of water, sediment, and benthic invertebrates were monitored at each station. The monitoring network also included discharge measurements twice a year during periods of base flow at 52 other sites, generally upstream from the gaging stations. At 13 of the 52 base-flow measurement sites, water samples were collected in August 1978 and August 1979 for chemical analyses.

Daily discharges at the 12 gaging stations and periodic chemical analyses and suspended-sediment concentrations for those stations are published annually (U.S. Geological Survey, 1980). The purposes of this report, which covers the period August 1978-September 1979, are to define the surface-water hydrology in each of the monitored basins, to summarize coal-mining activities in each basin, and to point out, where possible, the hydrologic impacts of the mining.

Adequacy of the monitoring network to detect the hydrologic impacts, along with recommended modifications and needs for additional study, also are discussed. This report is the first in a planned biennial series.

Previous Investigations

Several hydrologic studies were conducted in the coal fields of central Utah during the 1970's. The quality of surface water in the Price River and Dirty Devil River basins is summarized by Mundorff (1972 and 1979). Hydrologic conditions in the Wasatch Plateau and Book Cliffs coal fields are described by Waddell, Contratto, Sumsion, and Butler (1979). Hydrologic data from the coal fields are included in reports by Waddell, Vickers, Upton, and Contratto (1978) and Sumsion (1979).

Data from two other hydrologic studies in the area were used in this report. T. W. Danielson (U.S. Geological Survey, written commun., 1980) supplied data that were collected in 1978 and 1979 during a hydrologic study of the coal area in the upper drainages of Huntington and Cottonwood Creeks in the Wasatch Plateau. G. C. Lines and D. J. Morrissey (U.S. Geological Survey, written commun., 1980) supplied hydrologic data that were collected in the Emery coal field during 1978 and 1979.

Downstream Gaging-Station Numbers

Gaging stations operated by the U.S. Geological Survey are assigned an eight-digit number. The first two digits, 09, indicate that the streams in the study area are all in the Colorado River Basin. The last six digits indicate the relative downstream order in the basin.

PHYSICAL AND GEOLOGIC SETTING

The altitude of the Wasatch Plateau ranges from about 6,000 to 11,000 ft above sea level and the Book Cliffs range from about 6,000 to 10,000 ft. The Price River canyon is the physiographic boundary between the two areas. Land surface in the Emery coal field ranges from about 6,000 to 8,000 ft above sea level.

Rocks that crop out in the study area consist mainly of sandstone, mudstone, and shale as shown diagrammatically in figure 1. For geologic maps of the area, the reader is referred to Williams and Hackman (1971) and Witkind, Lidke, and McBroome (1978).

The Ferron Sandstone Member of the Mancos Shale of Cretaceous age is the oldest coal-bearing unit of economic importance in the study area. The Ferron crops out along a ridge that forms the eastern boundary of Castle Valley. Along the outcrop, the Ferron ranges in thickness from about 80 ft in the northern part of Castle Valley to about 850 ft in the southern part (Lupton, 1916, pl. IV). The Ferron dips beneath the surface of Castle Valley, the Wasatch Plateau, and the Book Cliffs at angles ranging from 2 to 10 degrees. Surface mining has been proposed for the Emery coal field, but through 1979 coal has been recovered from the Ferron only with underground mining. No coal of economic importance exists in the Ferron north of about the latitude of the town of Moore.

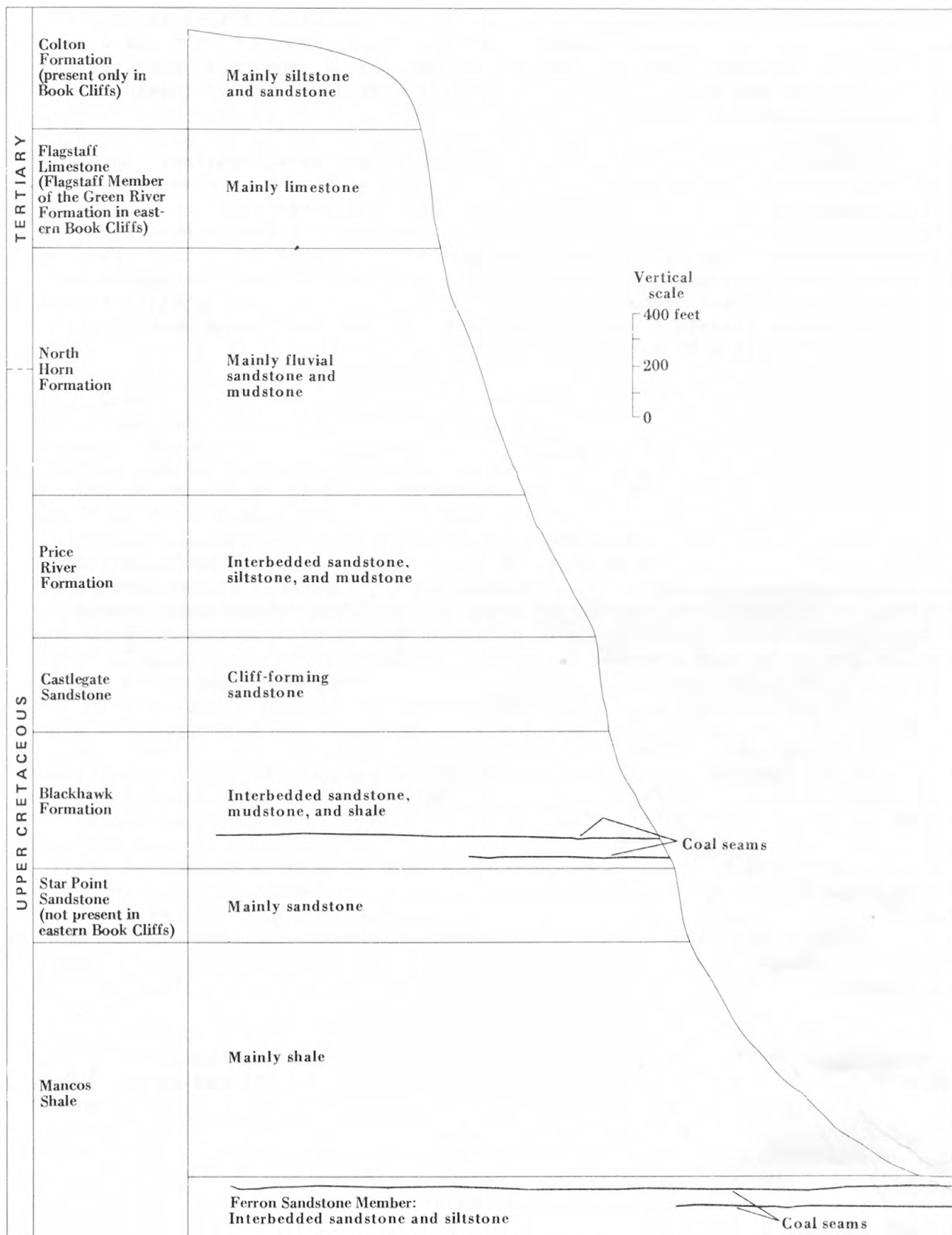


Figure 1.— Diagrammatic geologic column of rocks in the coal fields of central Utah.

Shales in the Mancos that overlie the Ferron Sandstone Member generally mark the western and northern edges of Castle Valley, but they crop out along streams several miles upstream from the mouths of most canyons in both the Wasatch Plateau and Book Cliffs. Those easily eroded shales form badland topography in parts of Castle Valley.

The Blackhawk Formation of Cretaceous age is the most important coal-producing unit in Utah. Coal is mined from the Blackhawk in the Wasatch Plateau and Book Cliffs with underground techniques. Except for some areas of the Book Cliffs where the Blackhawk intertongues with the Mancos Shale, the Blackhawk is underlain by the Star Point Sandstone of Cretaceous age. The Blackhawk in most areas is overlain by about 2,000 ft of mainly sandstone and mudstone. The highest areas of the Wasatch Plateau are capped by cliff-forming limestone in the Flagstaff Limestone of Tertiary age, and in the Book Cliffs usually by the Colton Formation of Tertiary age.

HYDROLOGIC SETTING

Precipitation and Evaporation

Average annual precipitation ranges from about 12 to 40 in. on the Wasatch Plateau, from about 12 to 20 in. on the Book Cliffs, and from about 8 to 20 in. on the Emery coal field (U.S. Weather Bureau, [1963]). The wide variation in precipitation across the study area generally reflects variations in altitude. In the higher areas of the Wasatch Plateau, about 80 percent of the annual precipitation falls as snow during most years (T. W. Danielson, written commun., 1980). Evaporation also varies with altitude, but it averages about 40 in. per year in the study area (Waddell and others, 1979, p. 23).

Surface Water

The western part of the Book Cliffs and approximately the northern two-thirds of the Wasatch Plateau are drained by streams tributary to the Price and San Rafael Rivers, both of which flow into the Green River. The Emery coal field and the southern Wasatch Plateau are drained by tributaries to the Dirty Devil River, which flows into the Colorado River. The flow of streams that head in the Book Cliffs is small in comparison to that of major streams that head in the Wasatch Plateau and reflects differences in precipitation. Major streams that drain the Wasatch Plateau are perennial as they flow across Castle Valley, whereas many of the streams that drain the Book Cliffs are perennial only at higher altitudes. The flow of streams across Castle Valley in the Emery area is augmented by seepage of water that had been diverted for irrigation.

During most years, 50 to 70 percent of the streamflow from the Wasatch Plateau and Book Cliffs is from April through June, resulting from the melting of snow that fell the previous October through April (Waddell and others, 1979, p. 27). Most of the water from the major streams is diverted for irrigation in Castle Valley.

The streamflow deteriorates in quality along the edges of the mountain fronts because of water diversions, waste disposal, consumptive use, and irrigation of poorly drained, saline soils of the Mancos Shale. In the mountains, dissolved-solids concentrations generally range from about 100 to 600 mg/L, whereas in Castle Valley concentrations range from about 600 to more than 6,000 mg/L. Monitoring sites for this study are upstream from major surface diversions, except for Huntington Creek and streams in the Emery coal field.

The study area contains 53 reservoirs and lakes with storage capacities exceeding 100 acre-ft, all except one being in the Wasatch Plateau. The two largest, Scofield Reservoir in the Price River drainage and Joes Valley Reservoir in the Cottonwood Creek drainage, have capacities of about 74,000 and 62,000 acre-ft.

Ground Water

Ground-water data in the study area consist largely of discharge measurements and chemical analyses of spring and mine water. In the Emery coal field, however, the Ferron Sandstone Member has been tapped by wells for public supply for the town of Emery, for a coal-washing plant, for stock watering, and for testing and monitoring.

Potentiometric-surface and water-quality data for the Ferron Sandstone Member indicate that the largest source of recharge near the town of Emery is subsurface inflow from the Wasatch Plateau, most of which is transmitted through a permeable fractured zone near the eastern edge of southern Castle Valley (G. C. Lines and D. J. Morrissey, written commun., 1980). Water moves from areas of subsurface recharge toward the Ferron outcrop where it is discharged mainly by leakage to alluvium along streams and by leakage to adjoining rocks in the Mancos Shale. Dewatering of the underground Emery Mine was the largest man-made discharge from the Ferron during 1979, and it averaged about 0.7 ft³/s.

Dissolved-solids concentrations in water in the Ferron Sandstone Member range from less than 500 to more than 20,000 mg/L in Castle Valley. Increased concentrations generally reflect increased distances from recharge areas (G. C. Lines and D. J. Morrissey, written commun., 1980).

The largest quantity and best quality water is available from the Ferron Sandstone Member in the Emery area. Wells that would fully penetrate the Ferron near Emery, if pumped, could be expected to produce 100 to 500 gal/min. However, in approximately the northern two-thirds of Castle Valley, the Ferron would probably yield no more than 10 gal/min to individual wells (G. C. Lines and D. J. Morrissey, written commun., 1980).

Studies in the Wasatch Plateau and Book Cliffs indicate that most recharge to the ground-water system at higher altitudes is discharged by a large number of springs that issue from the Flagstaff Limestone, the North Horn Formation of Cretaceous and Tertiary age, and the Price River Formation of Cretaceous age close to the recharge areas. The downward movement of ground water commonly is impeded by relatively impermeable mudstone and siltstone, and water is discharged where the less permeable rocks crop out at land surface. Discharge of springs at higher altitudes commonly is on the order of 1 to 20 gal/min. It is not known if these upper water-bearing zones are perched.

Along faults where rock permeability has been increased by fracturing, water percolates downward. Although springs are not common in the Castlegate Sandstone of Cretaceous age and the coal-bearing Blackhawk Formation, there are a few springs in the Wasatch Plateau issuing from faults in the Star Point Sandstone that discharge more than 100 gal/min. Two springs in the Huntington Creek drainage, which issue from faults in the Star Point, provide part of the public-water supply for the town of Huntington.

Large quantities of water also flow into underground coal mines in the Wasatch Plateau and Book Cliffs, and mine discharges were the largest sources of manmade discharge from the Blackhawk Formation during 1979. The largest quantities of water are usually encountered where the mines intercept faults or fractured rock. The average discharge from the mines is unknown, but several discharge more than $0.2 \text{ ft}^3/\text{s}$. Some mines discharge water continuously and others intermittently. Mines that have encountered no ground water usually have extended only a short distance underground from the edges of deeply incised canyons where the Blackhawk Formation is drained.

Water from most springs and mines in the Wasatch Plateau and Book Cliffs contains about 200 to 800 mg/L of dissolved solids. Water from mines in the Book Cliffs in the northeastern part of the study area contains on the order of 2,000 mg/L of dissolved solids. There are large variations in water quality within each geologic unit, but not enough is known about the ground-water system to explain these variations. They are undoubtedly related, however, to differences in lithology, time in contact with water-bearing units, and the flow path between recharge and discharge areas.

PRICE RIVER BASIN

Pleasant Valley Creek

Pleasant Valley Creek, a tributary to the Price River, originates in the Wasatch Plateau at an altitude of about 9,600 ft. Gaging station 09310700 is about 0.2 mi south of the town of Scofield and 2 mi south of Scofield Reservoir at an altitude of about 7,700 ft. Drainage area at the gaging station is 29.1 mi^2 .

During 1979, about 6,000 acres of Federal coal was leased in the Pleasant Valley Creek basin, and three underground coal mines (Belina Nos. 1 and 2 and Utah No. 2) were operated by Valley Camp Coal Co. Past underground mining in the basin, particularly near the town of Clear Creek and in Winter Quarters Canyon, has been extensive.

Active mines in the basin all produce water, but most of the water is consumed by the mining operations. Discharge from active mines is unknown. Discharge from one abandoned mine in the town of Clear Creek averaged about $0.3 \text{ ft}^3/\text{s}$ during the latter part of 1979 (K. M. Waddell, oral commun., May 1980). Water discharged from the Utah No. 2 Mine contained 482 mg/L of dissolved solids in September 1975, and the predominate dissolved chemical constituents were calcium, magnesium, and bicarbonate (Waddell and others, 1979, table 9).

Discharge records at gaging station 09310700 during the 1979 water year were good¹ except for periods of ice effect, when they were poor. As shown in figure 2, daily discharge during the water year ranged from 1.6 ft³/s on September 8 to 98 ft³/s on May 24, and it averaged 8.5 ft³/s. Runoff in the basin averaged 0.29(ft³/s)/mi² during the water year. Total discharge during the water year at the station was 6,160 acre-ft, of which about 60 percent occurred during the spring-snowmelt period. Peaks in discharge during summer and fall were caused by thunderstorms.

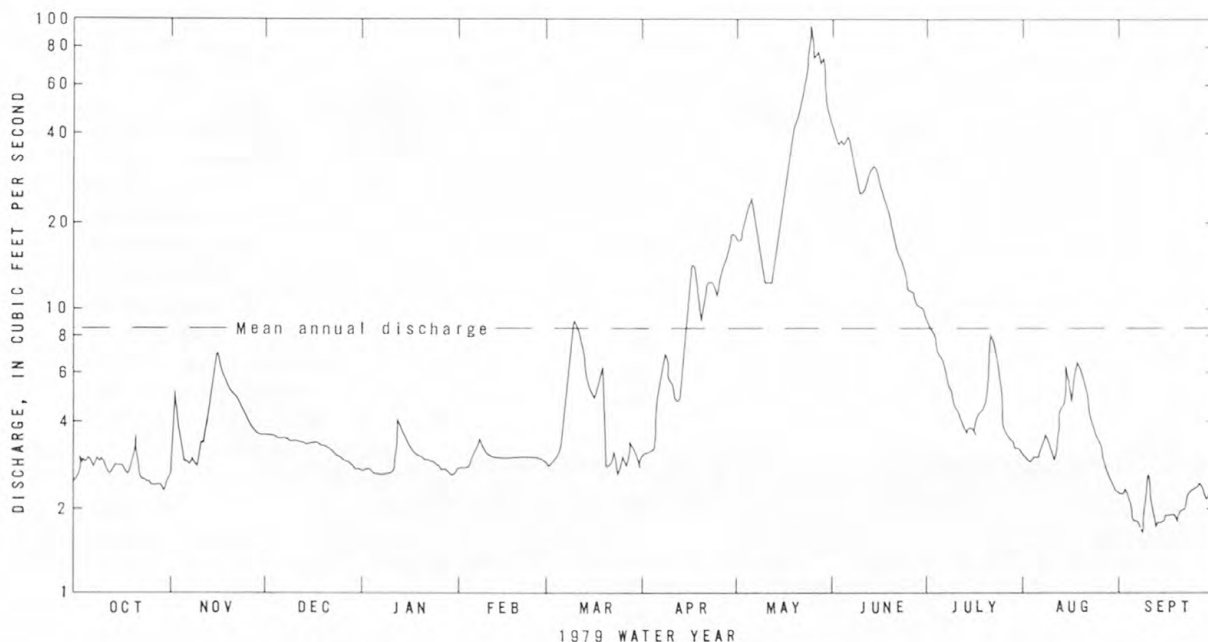


Figure 2.— Discharge of Pleasant Valley Creek at gaging station 09310700, 1979 water year.

Three sets of base-flow measurements were made on Pleasant Valley Creek and major tributaries as shown in figure 3. The measurements indicate that most of the flow at the gaging station was due to inflow from Boardinghouse, Eccles, and Winter Quarters Canyons.

Pleasant Valley Creek flows in an alluvial valley along the Pleasant Valley fault system and in several locations crosses the subsurface contact between the Star Point Sandstone and the Blackhawk Formation. Numerous seeps issue from the Star Point Sandstone along the edges of the valley, suggesting that losses in streamflow in reaches downstream from Boardinghouse Canyon were due to leakage to the alluvium and evapotranspiration rather than leakage to bedrock.

¹The U.S. Geological Survey considers records at gaging stations to be "excellent," when 95 percent of the computed daily discharges are within 5 percent of the actual discharge; "good," within 10 percent; "fair," within 15 percent; and "poor," less than 15 percent accuracy.

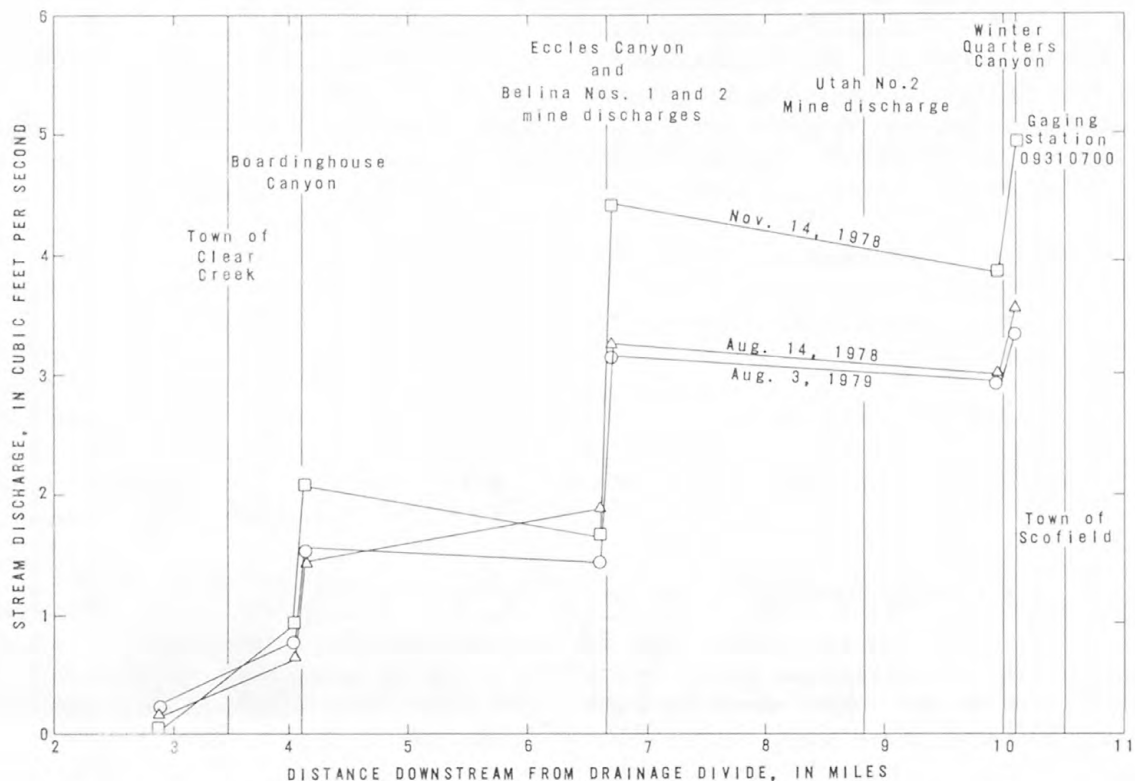


Figure 3.— Base flow of Pleasant Valley Creek and its relationship to mining activities.

From August 1978 through September 1979, water samples were collected monthly at the gaging station on Pleasant Valley Creek, and the results are summarized in table 1. Analyzed chemical constituents, except for phenols, were at lower concentrations than standards for public-water supplies (U.S. Environmental Protection Agency, 1976) and at concentrations normally found in unpolluted surface water. Concentrations of phenols were consistently higher than the 1962 drinking-water standard of 1 µg/L (U.S. Public Health Service, 1962, p. 7). Source of the phenols is unknown. According to McKee and Wolf (1963, p. 237), phenols are obtained commercially from coal tar but can also be found in mountain streams from decaying vegetation and "countless" other sources.

The predominant dissolved chemical constituents in water at the gaging station, as shown in table 1 and figure 4, were calcium and bicarbonate. Percentages of the major dissolved constituents were fairly stable through the 1979 water year, although dissolved-solids concentrations were lowest during the spring-snowmelt period.

Seven samples of suspended sediment were collected at the gaging station on Pleasant Valley Creek from August 1978 through September 1979. The observed suspended-sediment concentrations ranged from 10 mg/L on August 25, 1978, to 1,300 mg/L on May 18, 1979. Sediment discharge ranged from 0.08 to 147 tons per day on the same dates. Suspended-sediment concentrations generally were largest during periods of large discharge, but not enough data are available to define the relationship of stream discharge to suspended-sediment concentration.

Table 1.--Summary of chemical constituents and bacteria in water at gaging station 09310700 on Pleasant Valley Creek, August 1978 through September 1979

	Parameters and constituents	No. of analyses	Mean	Minimum-maximum
	Discharge (cubic feet per second)	14	-	1.9-32
	Water temperature (degrees Celsius)	13	8.0	0.0-18.0
	Specific conductance (micromhos per centimeter)	14	523	315-620
	pH (units)	14	-	8.1-8.5
Milligrams per liter	Dissolved solids, sum of constituents	14	306	165-355
	Oxygen, dissolved (O ₂)	14	9.4	7.7-11
	Carbon dioxide, dissolved (CO ₂)	14	2.1	1.4-3.9
	Alkalinity (CaCO ₃)	14	230	130-270
	Bicarbonate (HCO ₃)	14	271	168-326
	Carbonate (CO ₃)	14	4	0-16
	Oil and grease	4	.2	0-1.0
	Nitrogen, dissolved (N)	3	.52	0.34-0.64
	Nitrogen, organic dissolved (N)	5	.3	0.05-0.60
	Nitrogen, ammonia dissolved (N)	5	.03	0-0.14
	Nitrogen, nitrite dissolved (N)	5	.008	0-0.01
	Nitrogen, nitrate dissolved (N)	5	.13	0-0.26
	Nitrogen, ammonia + organic suspended total (N)	5	.13	0.02-0.29
	Nitrogen, nitrite + nitrate dissolved (N)	5	.14	0.01-0.27
	Nitrogen, ammonia + organic total (N)	5	.4	0.2-0.6
	Phosphorus, total (P)	5	.04	0.01-0.11
	Phosphorus, ortho dissolved (P)	5	.01	0-0.03
	Carbon, organic dissolved (C)	4	3.3	1.9-7.2
	Hardness, (as CaCO ₃)	14	280	160-330
	Hardness, (as noncarbonate CaCO ₃)	14	48	7-73
	Calcium, dissolved (Ca)	14	72	44-88
	Magnesium, dissolved (Mg)	14	23	11-28
	Sodium, dissolved (Na)	14	5.9	2.6-8.8
	Sodium-adsorption-ratio	14	.15	0.1-0.2
	Potassium, dissolved (K)	14	2.8	1.2-7.5
	Chloride, dissolved (Cl)	14	8.6	4.1-14
	Sulfate, dissolved (SO ₄)	14	49	18-79
	Fluoride, dissolved (F)	5	.2	0.1-0.2
	Silica, dissolved (SiO ₂)	14	6.7	4.9-7.7
Micrograms per liter	Arsenic, dissolved (As)	5	.6	0-1
	Boron, dissolved (B)	5	20	0-60
	Chromium, dissolved (Cr)	5	2	0-10
	Iron, dissolved (Fe)	5	60	10-210
	Lead, dissolved (Pb)	5	9	0-30
	Manganese, dissolved (Mn)	5	38	20-60
	Strontium, dissolved (Sr)	5	210	140-260
	Zinc, dissolved (Zn)	5	13	3-30
	Lithium, dissolved (Li)	5	10	0-20
	Selenium, dissolved (Se)	5	.2	0-1
	Phenols	5	4	2-7
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	5	262	15-490
	Streptococci, fecal	5	300	23-1,200

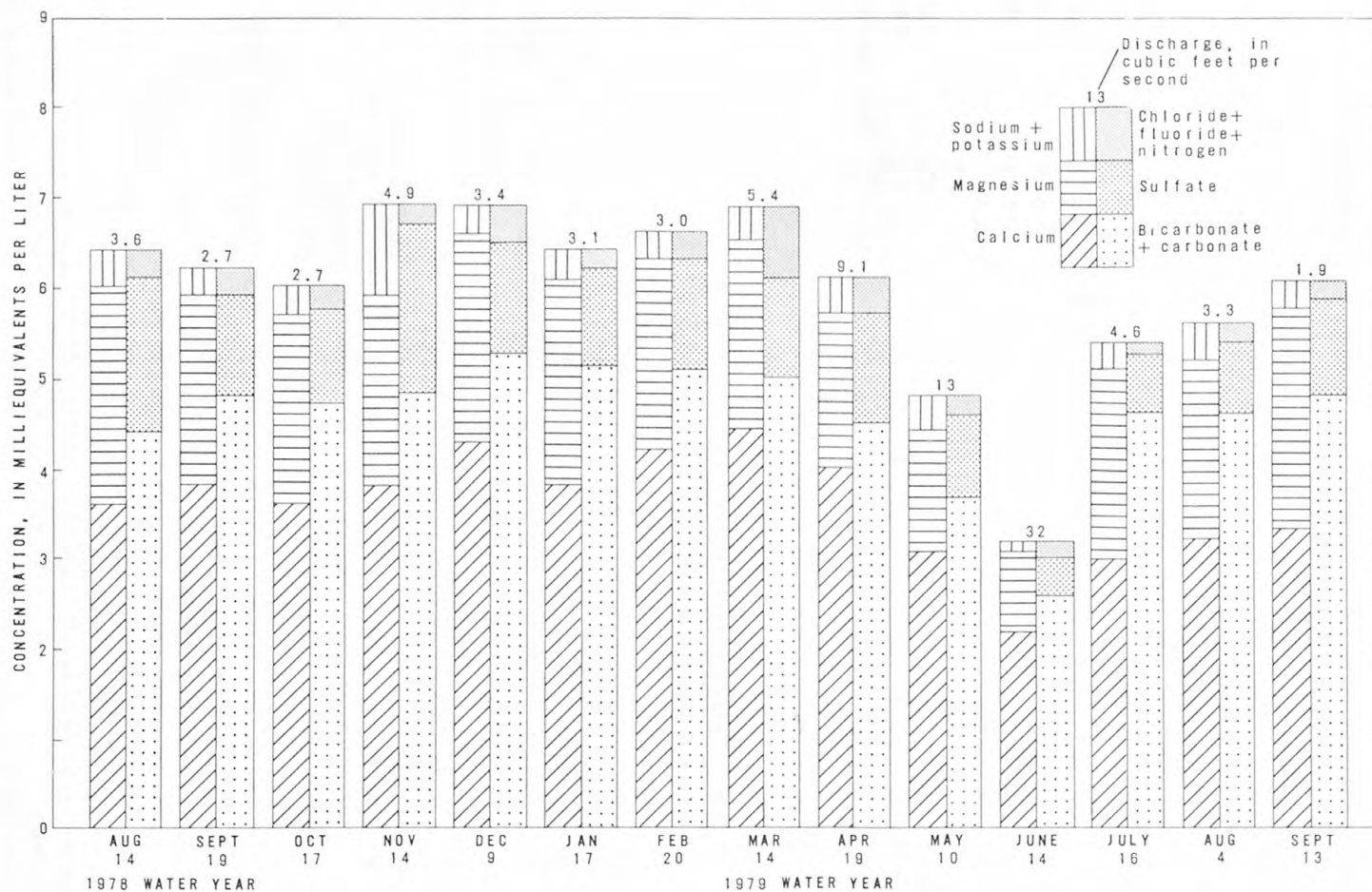


Figure 4.— Relationship of major dissolved chemical constituents and discharge of Pleasant Valley Creek at gaging station 09310700, August 1978-September 1979.

Benthic invertebrates were sampled at the gaging station three times. Table 2 is a listing of organisms identified by phylum, class, order, and family, the wet weight of organisms in each sample, and the diversity index¹ by order. Samples represent those organisms collected from 3 ft² of stream bottom using a Surber sampler in riffle areas. A diverse group of organisms was present in each of the samples, indicating a healthy, unpolluted environment.

Beaver Creek

Beaver Creek originates in the Wasatch Plateau on the Blackhawk Formation at an altitude of about 9,200 ft. The stream crosses progressively younger geologic units; and at its mouth at the Price River, it is flowing on the Flagstaff Limestone at an altitude of about 7,100 ft.

During 1979, the Gordon Creek Mine, as shown on plate 1, extended from the drainage of the North Fork of Gordon Creek into the upper Beaver Creek drainage. Most of the water produced in the mine is consumed by the mining operations, and water is discharged intermittently into a tributary to the North Fork of Gordon Creek. Approximately 600 acres of Federal coal in the upper part of the Beaver Creek drainage was leased during 1979. Approximately 90 percent of the coal in the remainder of the drainage was Federally owned and 10 percent State and privately owned.

The gaging station near the mouth of Beaver Creek (09312700) is part of the U.S. Geological Survey statewide network and not a part of this study. Daily discharges at the station during the 1979 water year ranged from 0.01 ft³/s during many days in the fall and winter to 41 ft³/s during 5 days in mid-May. No water samples were collected for chemical analyses at the station during the 1979 water year; but observed specific conductance of the water ranged from 300 to 630 micromhos, indicating that dissolved solids ranged from about 200 to 400 mg/L.

Water in Beaver Creek at the uppermost base-flow measurement site (pl. 1) contained 207 and 209 mg/L of dissolved solids during measurements in August 1978 and 1979. The predominate dissolved chemical constituents were calcium and bicarbonate.

¹Diversity, or the evenness of distribution of aquatic organisms, gives some indication of the environmental condition of the stream (the quality of water and the types of material in the streambed). Diversity was computed for each sample by phylogenetic order using the Shannon-Weiner approximation:

$$\text{Diversity index} = - \sum P_i \log_2 P_i,$$

where P_i is the probability of occurrence of the i^{th} order. The probability (P_i) is equal to N_i/N_s , where N_i is the number of individuals in each order and N_s is the total number of individuals in all orders (Lium, 1974, p. 382).

Table 2.-Benthic invertebrates collected at gaging stations in the Wasatch Plateau.

Numbers of organisms collected from 3 square feet of stream bottom.
Station number: See text for explanation of downstream numbering system.
Wet weight: Weight of benthic invertebrates, per unit area of stream bottom, in grams per square meter.
Diversity index by order: Numerical expression of evenness of distribution of aquatic organisms. See p. 10 for further explanation.
Organism: Identified by phylum, class, order, or family.

Date	Organisms																										
	Annelida	Oligochaeta	Arthropoda	Arachnida	Acarina	Insecta	Hemiptera	Odonata	Aeshnidae	Coleoptera	Curculionidae	Dryopidae	Dytiscidae	Elmidae	Hydrophilidae	Diptera	Ceratopogonidae	Chironomidae	Culicidae	Dolichopodidae	Empididae	Ephydriidae	Muscidae	Psychodidae	Phagionidae	Simuliidae	Stratiomyidae
09310700 Pleasant Valley Creek below																											
9-19-78	168			8										616				896								232	
3-14-79	4													284		12		404			4		4				
6-14-79														7				138									5
09313040 Spring Canyon below																											
9-20-78	30			2									3	1	2		11	338	1	3	4	2	13				137
3-13-79	22												1				3	133					1				
6-14-79											1		65		21			1,113			1	5	19				210
9-13-79													1					172					4				44
09313965 Coal																											
8-16-78				1									2					64			7		1				166
8-2-79													28					240			64		4				3,620
09313975 Soldier Creek below																											
8-16-78			1															17			1						8
11-17-78																		14									1
8-2-79			1										6	1				38			13		1				562
09314340 Grassy Trail																											
9-23-78	106			4									2					174			1		8				1
3-13-79	31																	63									
6-14-79	1																	3									
9-14-79	2			2														123			1		1				1
09314374 Horse Canyon																											
9-24-78	1			89												19	553			14		13					71
6-11-79																	8										10
09317919 Crandall Canyon at																											
8-12-78	2			12									1					284									22,040
11-16-78	12			1										3				8						1			1
8-6-79				10										13				9									304
09317920 Tie Fork Canyon																											
8-13-78	2			26										8				167			4			1			982
11-18-78	23			17										5				254			19	3		4			90
8-6-79	3			11										13				77									13
09318000 Huntington Creek																											
8-13-78	1			21										57		2	82				1		2		1	13	
9-22-78	1			29			1						5				589				6				4	49	
10-22-78				26			6										128				21				1	4	
11-17-78	11			25												1	110				17				8		
1-18-79	5			13													11				4				2		
2-19-79	1			2													11										
3-16-79																	2								1		
4-20-79																	192				1				2		
5-11-79	3																8								2		
7-18-79				7		2						2		76			64								2	5	
8-7-79	1			35										152			87								5	7	
9-18-79	4			8										90			534				6				6		
09324200 Cottonwood Creek above																											
8-15-78				2									1	1	1		1	33									65
11-19-78																	1	9									
8-5-79													24	4				100			44						68
09331900 Quitchupah																											
9-26-78	1																	19					1				1
9-17-78				2												10	176				10						2
09331950 Christiansen																											
9-27-78				16													48	480			176		48				4,144
3-15-79	6			2													3	41			7						6
6-12-79				17													53	81	25								20
9-17-79								2										452			1						3

Book Cliffs, and Emery coal fields, August 1978 through September 1979

...	Tabanidae	Tipulidae	Ephemeroptera	Hemiptera	Gerridae	Odonata	Gomphidae	Trichoptera	Lepidoptera	Plecoptera	Megaloptera	Odonata	Coenagrionidae	Mollusca	Bivalvia	Nuculoidae	Sphaeriidae	Gastropoda	Basommatophora	Lymnaeidae	Physidae	Planorbidae	Nematoda	Platyhelminthes	Turbellaria	Triladida	Wet weight	Diversity index by order	
Winter Quarters Canyon, at Scofield, Utah																													
-	32	912	-	-	-	-	-	120	-	-	-	-	-	-	-	-	8	-	-	-	40	-	-	-	-	-	7.4	2.1	
-	-	252	-	-	-	-	-	124	-	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.9	2.1	
-	-	203	-	-	-	-	-	26	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	7.5	1.4	
Sowbelly Gulch, at Helper, Utah																													
-	3	18	-	-	-	-	-	26	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8	0.9	
-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.39	1.1	
-	2	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.6	.4	
-	1	3	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	.4	
Creek near Helper, Utah																													
-	-	464	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.68	1.6	
-	-	6,404	-	8	-	-	-	204	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19.4	1.1	
mine, near Wellington, Utah																													
-	-	98	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19	1.3	
-	-	16	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.13	1.2	
-	-	1,005	-	1	-	-	-	181	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	1.4	
Creek at Sunnyside, Utah																													
-	-	7	-	-	-	-	-	95	-	-	-	-	171	-	-	-	-	-	-	-	1	-	-	-	-	-	3.6	-	
-	-	1	-	-	-	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	.55	1.3	
-	-	8	-	-	-	-	-	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	.91	1.9	
-	-	43	-	-	-	-	-	117	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	1.7	
near Sunnyside, Utah																													
-	-	5	-	-	-	-	-	15	-	-	-	1	9	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	0.8	
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.07	.3	
mouth, near Huntington, Utah																													
-	12	1,144	-	-	-	-	-	16	-	62	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	39.8	-	
-	12	101	-	-	-	-	-	8	-	27	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2.7	-	
-	4	410	-	-	-	-	-	10	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.1	1.4	
near Huntington, Utah																													
-	7	541	-	-	-	-	-	21	-	25	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3.3	1.7	
-	56	381	-	-	-	-	-	38	-	76	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	2	3.1	1.8	
-	7	295	-	-	-	-	-	34	-	50	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.9	1.8	
near Huntington, Utah																													
-	-	96	-	-	-	-	-	18	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.47	2.4	
-	-	121	-	-	-	-	-	59	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	1.9	
-	8	733	-	-	-	-	-	148	-	29	-	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	2.9	-	
-	6	683	-	-	-	-	-	173	-	69	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	5.4	2.0	
-	-	37	-	-	-	-	-	17	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.44	2.5	
-	-	11	-	-	-	-	-	5	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.08	2.3	
-	1	11	-	-	-	-	-	7	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	2.1	
-	-	171	-	-	-	-	-	2	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	1.3	
-	-	81	-	-	-	-	-	2	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.6	1.2	
-	5	114	-	-	-	-	-	26	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4	2.1	
-	1	285	-	-	-	-	-	10	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	1.8	
-	-	14	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.4	1.0	
Straight Canyon, near Orangeville, Utah																													
1	-	458	-	-	-	-	-	27	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.54	1.1	
-	170	189	-	-	-	-	-	58	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	1.5	
-	4	508	-	-	-	-	-	244	-	124	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.9	1.9	
Creek near Emery, Utah																													
-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	0.04	1.1	
-	-	-	-	-	-	-	8	358	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.3	1.1	
Wash near Emery, Utah																													
-	-	-	-	-	-	-	-	144	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15.0	0.2	
-	-	-	-	-	-	-	-	5	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	.50	1.3	
-	-	-	-	-	-	-	-	3	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.27	.6	
-	-	-	-	-	-	-	-	368	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4	1.0	

Three sets of base-flow measurements (fig. 5) indicate that the upper reaches of Beaver Creek gain water as the stream crosses the Blackhawk Formation and the upper part of the Castlegate Sandstone. In the lower reaches, between the measurement site at mile 6 and the gaging station, the flow of Beaver Creek declined; and water was apparently lost to geologic units younger than the Castlegate Sandstone.

Willow Creek

Willow Creek originates in the Book Cliffs on the Green River Formation of Tertiary age, which overlies the Colton Formation, at an altitude of about 9,200 ft. The stream crosses older geologic units, and at its mouth at the Price River it is on the Blackhawk Formation at an altitude of about 7,200 ft.

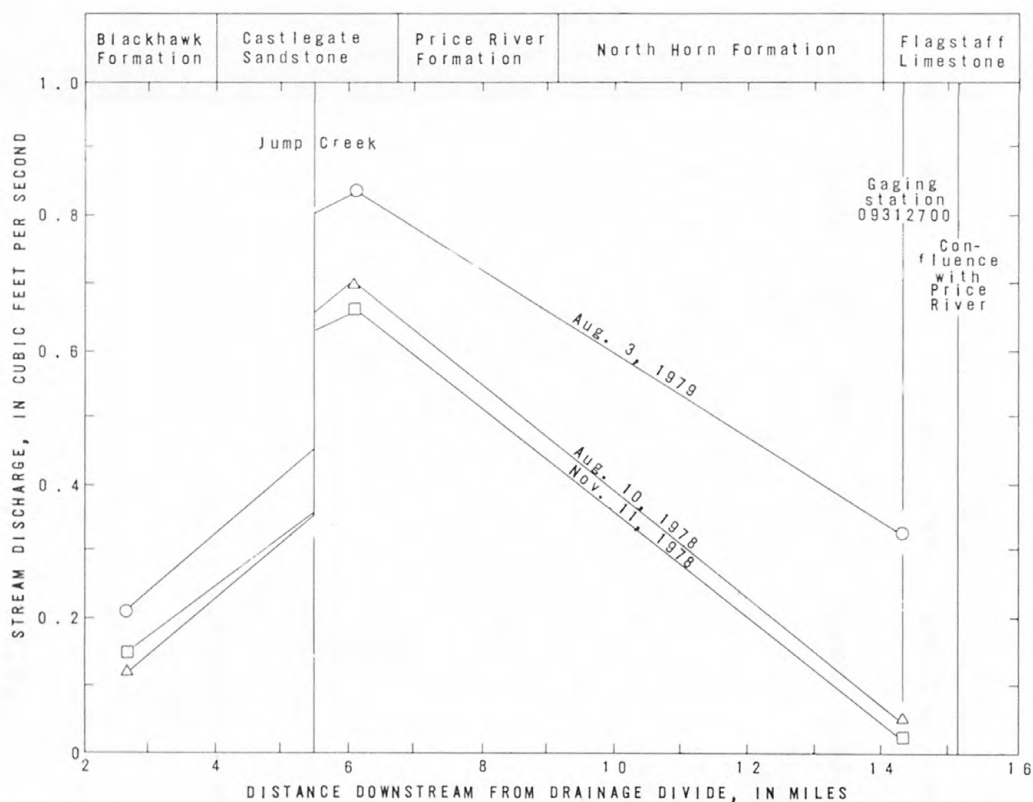


Figure 5.—Base flow of Beaver Creek and its relationship to geology.

Mining has been concentrated in the lower part of the basin at the Braztah Mines, as shown on plate 1. Water discharge from the mines is unknown. During 1979, approximately 3,500 acres of Federal coal were leased in the Willow Creek drainage. The remainder of the drainage was about evenly split between unleased Federal coal and coal that was State and privately owned.

The gaging station on Willow Creek (09312800) is operated as part of the U.S. Geological Survey statewide network and is not part of this study. Daily discharge at the station ranged from 0.47 ft³/s on December 9 and 10, 1978, to 198 ft³/s on May 6, 1979; and the discharge averaged 20.3 ft³/s during the water year.

Monthly specific-conductance measurements at the station ranged from 600 micromhos on May 17, 1979, to 1,150 micromhos on September 19, 1979, indicating that dissolved solids ranged from about 400 to 800 mg/L during the 1979 water year. Water at the mouth of Willow Creek contained 844 and 602 mg/L of dissolved solids during base-flow measurements in August 1978 and 1979, and the major dissolved constituents were calcium, magnesium, and sulfate.

Base-flow measurements (fig. 6) between the gaging station (09312800) and the mouth of Willow Creek twice indicated little change in flow in the reach. However measurements made on August 3, 1979, indicated that the flow increased by about 70 percent in the same reach. Reasons for this variation are not known. All three sets of measurements indicate that a substantial part of the base flow at the mouth is seepage from geologic units younger than the Price River Formation upstream from the gaging station.

Spring Canyon

Spring Canyon, a tributary to the Price River, originates in the Wasatch Plateau at an altitude of about 9,600 ft. Gaging station 09313040 is about 1.4 miles west of the town of Helper (pl. 1) on the Mancos Shale below coal-bearing rocks in the Blackhawk Formation, at an altitude of about 6,100 ft. Drainage area at the gaging station is 23.0 mi².

During 1979, coal was mined at a number of levels in the Braztah Mines. Mine discharge into Spring Canyon is intermittent, and the total discharge is unknown; but most of the mine water is consumed in the mining operations. In the past, extensive underground mining was done in the upper part of the basin near the abandoned towns of Mutual and Reins. During 1979, all the approximately 2,000 acres of Federal coal in the basin was leased. Coal in the remainder of the basin was State and privately owned.

Discharge at the gaging station in Spring Canyon during the 1979 water year is shown in figure 7. Discharge records at the gaging station were good, except during periods of winter ice when they were poor. Discharge averaged 0.12 ft³/s and totaled 90 acre-ft during the water year. Runoff in the basin averaged 0.005 (ft³/s)/mi² during the water year. Daily discharge at the gage ranged from 0.04 ft³/s during several days to 2.4 ft³/s on November 2, 1978, during a storm.

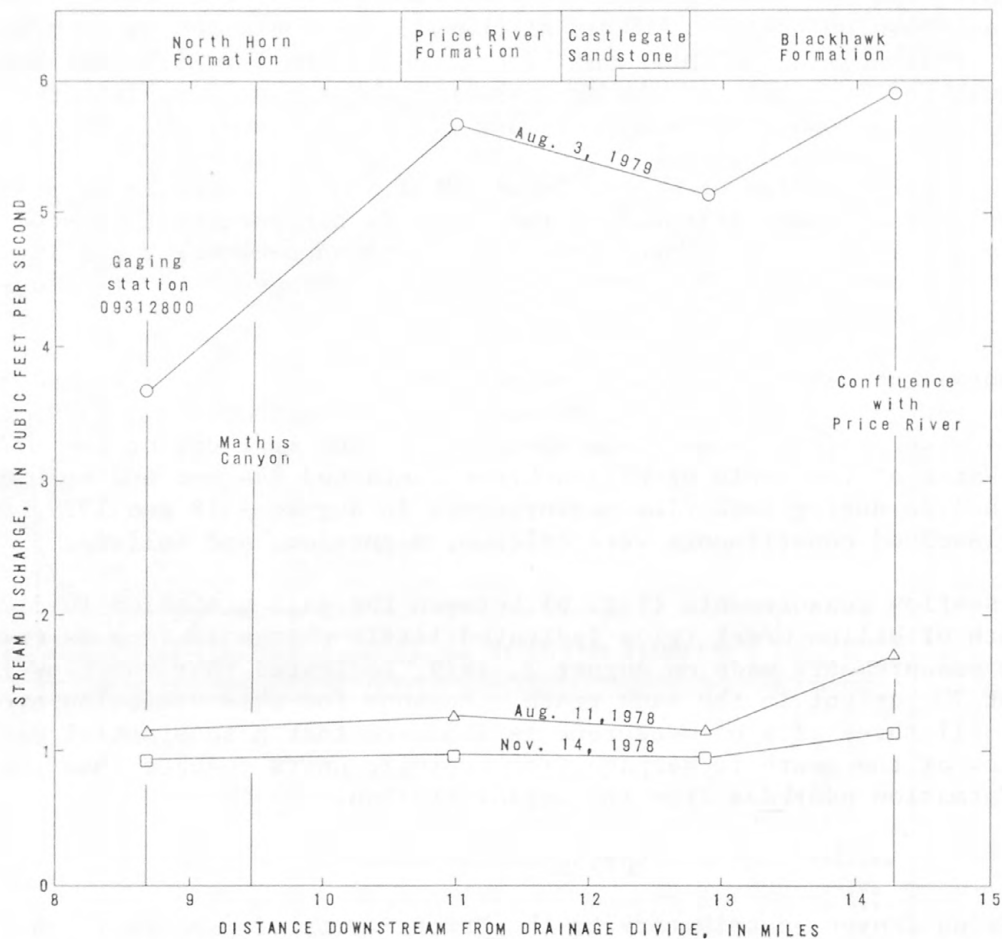


Figure 6.— Base flow of Willow Creek and its relationship to geology and mining activities.

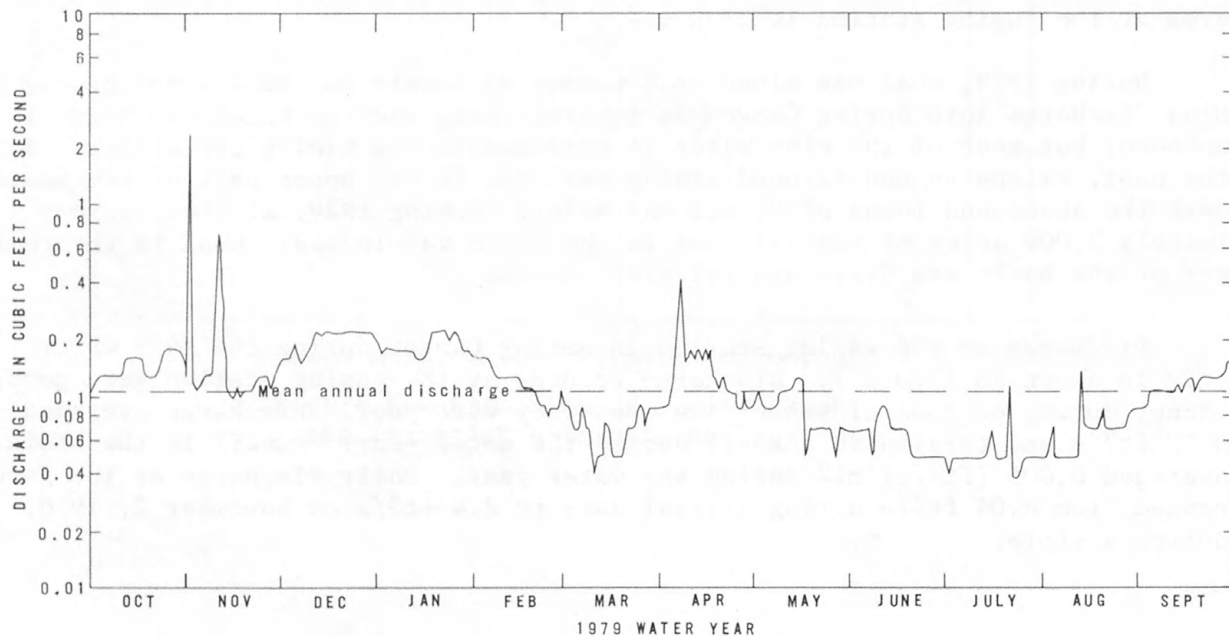


Figure 7.— Discharge in Spring Canyon at gaging station 09313040, 1979 water year.

Benthic invertebrates were sampled four times at the gaging station in Spring Canyon (table 2). They were not as diverse as those sampled at the gaging station on Pleasant Valley Creek (09310700), thus reflecting poorer quality water in Spring Canyon.

The uppermost part of the drainage basin is underlain by the North Horn Formation, but base-flow measurements and other field observations indicate that the upper reaches of Spring Canyon and its tributaries are ephemeral and flow only in response to rainfall, snowmelt, or mine discharge. Base flow at the gaging station is from seepage from alluvium and the Mancos Shale in the reach extending about 1 mi upstream from the gage.

Chemical analyses of water collected at the gaging station are summarized in table 3, and the relationship of major dissolved chemical constituents and stream discharge is shown in figure 8. Water sampled in Spring Canyon at the gaging station was typical of water in the Mancos Shale. Dissolved-solids concentrations usually were greater than 2,000 mg/L, and the predominant dissolved chemical constituents were magnesium and sulfate. Concentrations of strontium exceeded 1 mg/L, which is a larger amount than normally present in surface water (Hem, 1970, p. 196). Concentrations of selenium were higher than concentrations found in other streams in the Book Cliffs and Wasatch Plateau.

Six suspended-sediment samples were collected at the gaging station from August 1978 through September 1979. The observed suspended-sediment concentrations ranged from 14 mg/L on August 24, 1978, to 444 mg/L on March 13, 1979. Sediment discharge ranged from less than 0.01 to 0.07 tons per day on the same dates.

North Fork of Gordon Creek

The North Fork of Gordon Creek heads in the Wasatch Plateau on the Blackhawk Formation at an altitude of about 9,400 ft. From the headwaters, the stream flows across progressively older geologic units.

The Gordon Creek Mine is mainly in the drainage of the North Fork of Gordon Creek, but the mine extends into the upper part of the Beaver Creek drainage. Water is discharged from the mine intermittently, and the total discharge is unknown. Water from the Gordon Creek Mine contained 796 mg/L of dissolved solids in October 1976, and the predominant dissolved chemical constituents were calcium, magnesium, bicarbonate, and sulfate (Waddell and others, 1979, table 9). During 1979, approximately 500 acres of Federal coal was leased in the drainage. Except for about 1,000 acres near the abandoned town of National, coal in the remainder of the basin is Federally owned.

Base-flow measurements shown in figure 9 indicate that the North Fork of Gordon Creek is a perennial stream in the area of active mining. Much of the flow at the measurement site farthest downstream on the North Fork is contributed by Coal Canyon, which also heads on the Blackhawk Formation; but the North Fork also receives some ground-water seepage where it crosses the upper part of the Mancos Shale. Mine discharge was not observed when base-flow measurements were made.

Table 3.--Summary of chemical constituents and bacteria in water at gaging station 09313040 in Spring Canyon, August 1978 through September 1979

	Parameters and constituents	No. of analyses	Mean	Minimum-maximum
	Discharge (cubic feet per second)	14	-	0.01-0.23
	Water temperature (degrees Celsius)	14	13.0	4.0-26.0
	Specific conductance (micromhos per centimeter)	14	2,900	2,700-3,200
	pH (units)	14	-	8.1-8.5
Milligrams per liter	Dissolved solids, sum of constituents	14	2,280	1,960-2,830
	Oxygen, dissolved (O ₂)	14	9.0	6.9-11.2
	Carbon dioxide, dissolved (CO ₂)	14	5.3	2.2-14
	Alkalinity (CaCO ₃)	14	380	220-440
	Bicarbonate (HCO ₃)	14	480	400-530
	Carbonate (CO ₃)	14	1	0-16
	Oil and grease	5	.2	0-1.0
	Nitrogen, dissolved (N)	3	5.9	5.4-6.8
	Nitrogen, organic dissolved (N)	5	.7	0.4-1.5
	Nitrogen, ammonia dissolved (N)	5	.004	0-0.01
	Nitrogen, nitrite dissolved (N)	5	.02	0.01-0.03
	Nitrogen, nitrate dissolved (N)	5	8.5	5.0-21.0
	Nitrogen, ammonia + organic suspended total (N)	5	.20	0-0.49
	Nitrogen, nitrite + nitrate dissolved (N)	5	8	5-21
	Nitrogen, ammonia + organic total (N)	5	.76	0.61-0.98
	Phosphorus, total (P)	5	.03	0.01-0.12
	Phosphorus, ortho dissolved (P)	5	.01	0-0.03
	Carbon, organic dissolved (C)	5	5.3	2.6-12.0
	Hardness, (as CaCO ₃)	14	1,540	810-2,100
	Hardness, (as noncarbonate CaCO ₃)	14	1,170	410-1,700
	Calcium, dissolved (Ca)	14	200	110-230
	Magnesium, dissolved (Mg)	14	250	130-380
	Sodium, dissolved (Na)	14	160	120-360
	Sodium-adsorption-ratio	14	1.8	1.3-5.5
	Potassium, dissolved (K)	14	18	3.1-24
	Chloride, dissolved (Cl)	14	84	36-120
	Sulfate, dissolved (SO ₄)	14	1,270	980-1,500
	Fluoride, dissolved (F)	5	.4	0.4-0.5
	Silica, dissolved (SiO ₂)	14	11	8-15
Micrograms per liter	Arsenic, dissolved (As)	5	-	1
	Boron, dissolved (B)	5	400	0-720
	Chromium, dissolved (Cr)	5	4	0-10
	Iron, dissolved (Fe)	5	20	10-30
	Lead, dissolved (Pb)	5	30	0-81
	Manganese, dissolved (Mn)	5	26	10-40
	Strontium, dissolved (Sr)	5	1,200	1,000-1,300
	Zinc, dissolved (Zn)	5	20	10-30
	Lithium, dissolved (Li)	5	180	150-190
	Selenium, dissolved (Se)	5	14	11-21
	Phenols	5	1.4	0-3
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	2	-	8-31
	Streptococci, fecal	2	-	130-270

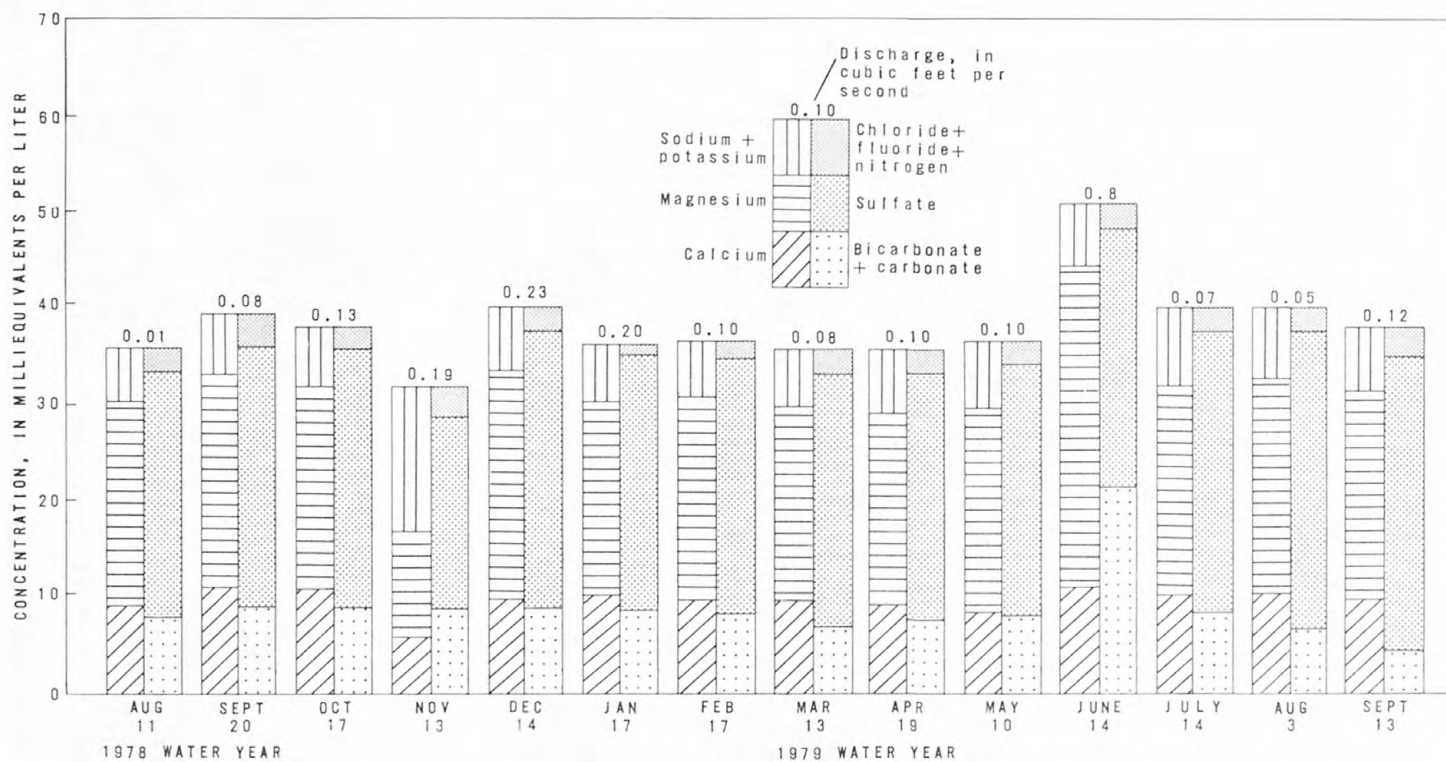


Figure 8.—Relationship of major dissolved chemical constituents and discharge of Spring Canyon at gaging station 09313040, August 1978–September 1979.

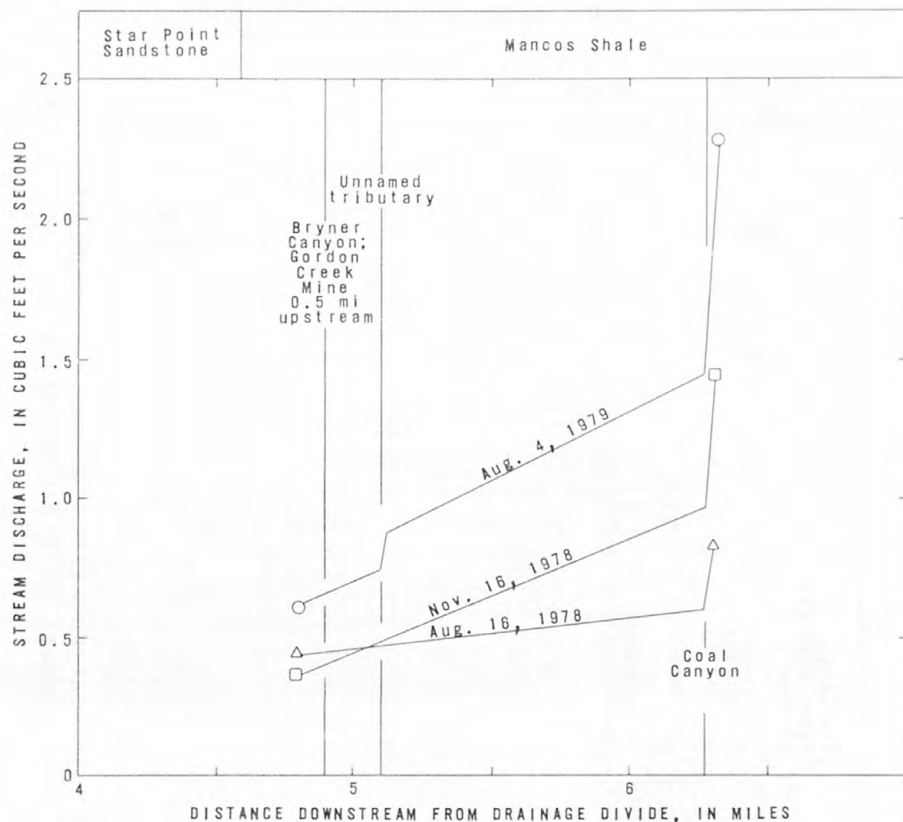


Figure 9.—Base flow of North Fork of Gordon Creek.

Water in the North Fork downstream from Coal Canyon contained 440 and 435 mg/L of dissolved solids during measurements in August 1978 and August 1979. The predominant dissolved chemical constituents were calcium, magnesium, and bicarbonate.

Coal Creek

Coal Creek originates in the Book Cliffs at an altitude of about 8,800 ft, and it is the first perennial stream east of the Willow Creek drainage. The gaging station on Coal Creek (09313965) is on the Star Point Sandstone downstream from coal beds in the Blackhawk Formation at an altitude of about 6,400 ft. The drainage area of the basin at the gaging station is 25.3 mi² (pl. 1).

During 1979, there was no active coal mining in the Coal Creek basin, and only about 100 acres of Federal coal was leased. Minerals in most of the basin are under State and private ownership. The Knight Ideal Mine, an abandoned underground coal mine, is 0.9 mi upstream from the gaging station.

Gaging station 09313965 was not operated during the winter because of access problems. The discharge record at the station during the 1979 water year (fig. 10) is rated as good. The minimum observed daily discharge during the water year was 0.41 ft³/s during the first part of October 1978. The maximum observed daily discharge during the year was 70 ft³/s during the snowmelt

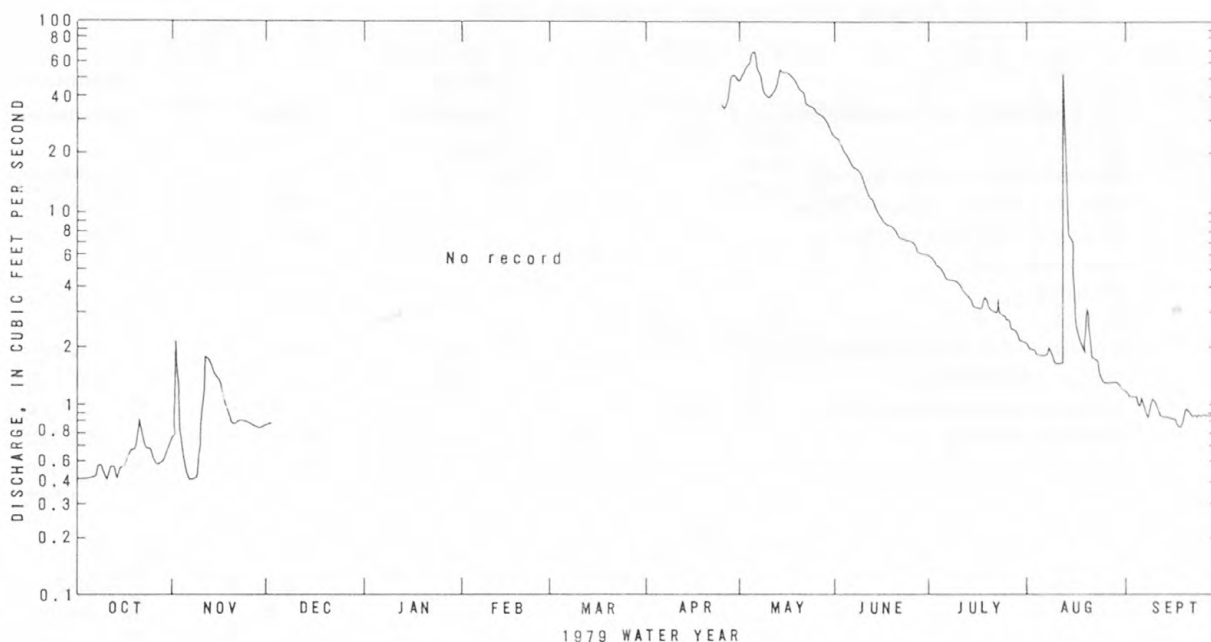


Figure 10.— Discharge of Coal Creek at gaging station 09313965, 1979 water year.

period in the first part of May. During the summer of 1979, the discharge gradually decreased, but it peaked again on August 13 during a thunderstorm.

Base-flow measurements were made in August and November 1978 and August 1979. Two of the sets of measurements, shown in figure 11, indicate that the discharge of Coal Creek in the reach between the mouth of Clearwater Creek (near the contact between the Castlegate Sandstone and the Blackhawk Formation) and the gaging station increased a few tenths of a cubic foot per second. The other set of measurements, made on August 16, 1978, indicate a slight loss of streamflow in the same reach. The cause of these slight variations is not known.

Chemical analyses of water collected at the gaging station on Coal Creek are summarized in table 4. All seven samples were collected during summer and fall, and the analyses indicate little variation in water quality. Dissolved-solids concentrations ranged from 540 to 640 mg/L. All analyzed chemical constituents, except phenols, were within concentrations recommended by the drinking-water standards of the U.S. Public Health Service (1962).

Four samples of suspended sediment were collected, and the concentrations ranged from 2 to 136 mg/L. Observed sediment discharge ranged from less than 0.01 to 0.48 tons per day. Suspended-sediment discharge and concentration were probably higher during spring runoff than during the summer and fall when the four samples were collected.

Table 4.--Summary of chemical constituents and bacteria in water at gaging station 09313965 on Coal Creek, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Milligrams per liter	Discharge (cubic feet per second)	7	-	0.49-3.9
	Water temperature (degrees Celsius)	7	10.0	0.0-22.0
	Specific conductance (micromhos per centimeter)	7	966	849-1,100
	pH (units)	7	-	8.5-9.0
	Dissolved solids, sum of constituents	7	607	540-640
	Oxygen, dissolved (O ₂)	7	9.1	6.9-11.2
	Carbon dioxide, dissolved (CO ₂)	7	1.4	0.7-2.0
	Alkalinity (CaCO ₃)	7	320	280-350
	Bicarbonate (HCO ₃)	7	350	310-380
	Carbonate (CO ₃)	7	22	12-41
	Oil and grease	3	-	0
	Nitrogen, dissolved (N)	1	-	0.72
	Nitrogen, organic dissolved (N)	3	8.2	0.29-24.0
	Nitrogen, ammonia dissolved (N)	3	.03	0-0.07
	Nitrogen, nitrite dissolved (N)	3	-	0
	Nitrogen, nitrate dissolved (N)	3	.17	0.13-0.25
	Nitrogen, ammonia + organic suspended total (N)	3	1.3	0-4.0
	Nitrogen, nitrite + nitrate dissolved (N)	3	.17	0.13-0.25
	Nitrogen, ammonia + organic total (N)	3	9.5	0.25-28
	Phosphorus, total (P)	3	.02	0-0.04
	Phosphorus, ortho dissolved (P)	3	-	0
	Carbon, organic dissolved (C)	3	19	3.4-50
	Hardness, (as CaCO ₃)	7	360	340-380
	Hardness, (as noncarbonate CaCO ₃)	7	42	10-86
	Calcium, dissolved (Ca)	7	53	49-61
	Magnesium, dissolved (Mg)	7	56	51-59
	Sodium, dissolved (Na)	7	80	51-95
	Sodium-adsorption-ratio	7	1.8	1.2-2.2
	Potassium, dissolved (K)	7	5.4	3.2-12
	Chloride, dissolved (Cl)	7	20	16-22
	Sulfate, dissolved (SO ₄)	7	190	160-220
	Fluoride, dissolved (F)	3	.4	0.4-0.5
	Silica, dissolved (SiO ₂)	7	8.2	7.2-8.8
Micrograms per liter	Arsenic, dissolved (As)	3	1.7	1-2
	Boron, dissolved (B)	3	150	130-160
	Chromium, dissolved (Cr)	3	3	0-10
	Iron, dissolved (Fe)	3	13	10-20
	Lead, dissolved (Pb)	3	9	0-19
	Manganese, dissolved (Mn)	3	30	6-80
	Strontium, dissolved (Sr)	3	550	510-570
	Zinc, dissolved (Zn)	3	-	< 3
	Lithium, dissolved (Li)	3	40	30-50
	Selenium, dissolved (Se)	3	2	1-4
	Phenols	3	2	0-3
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	2	-	87-330
	Streptococci, fecal	2	-	78-1,880

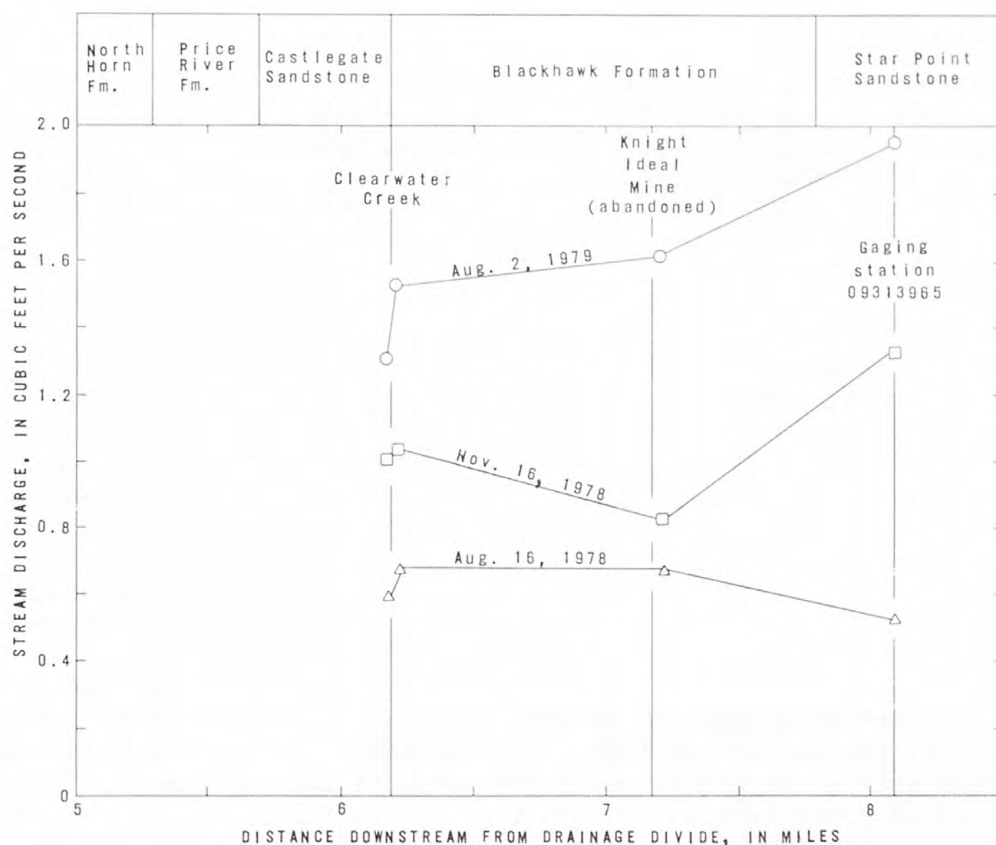


Figure 11.— Base flow of Coal Creek and its relationship to geology and mining activities.

Benthic invertebrates collected at the gaging station on Coal Creek are listed in table 2. The diversity of organisms in Coal Creek was intermediate to the diversities found in Pleasant Valley Creek and in Spring Canyon, thus reflecting the relative environmental condition of the streams.

Soldier Creek

The Soldier Creek drainage, east of Coal Creek, originates in the Book Cliffs at an altitude of about 8,400 ft. The gaging station (09313975) is about 0.1 mi downstream from the Soldier Creek Mine at an altitude of about 6,500 ft. The drainage area at the gaging station is 17.7 mi² (pl. 1).

The Soldier Creek Mine is the only active coal mine in the basin. Most of the water produced in the mine is consumed in the mining operation, and water is discharged from the mine intermittently. Discharge from the mine is unknown. Approximately 3,000 acres of Federal coal was leased in the lower part of the basin during 1979. Coal in the upper part of the basin in T. 12 S. is mainly State and privately owned.

The gaging station on Soldier Creek (09313975) was operated during non-winter periods during water year 1979, and the discharge is shown in figure 12. The smallest observed daily discharge during the water year was 0.27 ft³/s on October 1, 1978 and the daily discharge peaked at 46 ft³/s on April 29, 1979. As at Coal Creek, the discharge gradually receded following the snowmelt period, except for summer thunderstorms. The discharge record at the gaging station during the 1979 water year is rated as good.

Base-flow measurements for three periods are shown in figure 13. Although measurements were variable in the reach through the Castlegate Sandstone and the upper part of the Blackhawk Formation, in all cases, stream discharge increased through the middle part of the Blackhawk Formation (in the reach from the measurement site at mile 5.3 to the gaging station below the Soldier Creek Mine). Only on August 2, 1979, was the inflow from Pine Canyon a significant part of the discharge measured at station 09313975 on Soldier Creek.

A summary of chemical analyses of water collected at station 09313975 is listed in table 5, and the relationship between the major dissolved chemical constituents and the discharge of Soldier Creek is shown in figure 14. A comparison of the analyses with similar data for the adjacent Coal Creek drainage indicates that the water quality is more variable in Soldier Creek during low-flow periods in the summer and fall. This probably indicates a difference in at least some sources of ground-water discharge in the two basins. Observed dissolved-solids concentrations ranged from 384 to 627 mg/L, and the concentrations were generally inversely related to stream discharge. Although changes in dissolved-solids concentrations were due to changes in all the major constituents, the main changes were in concentrations of sodium, magnesium, and sulfate.

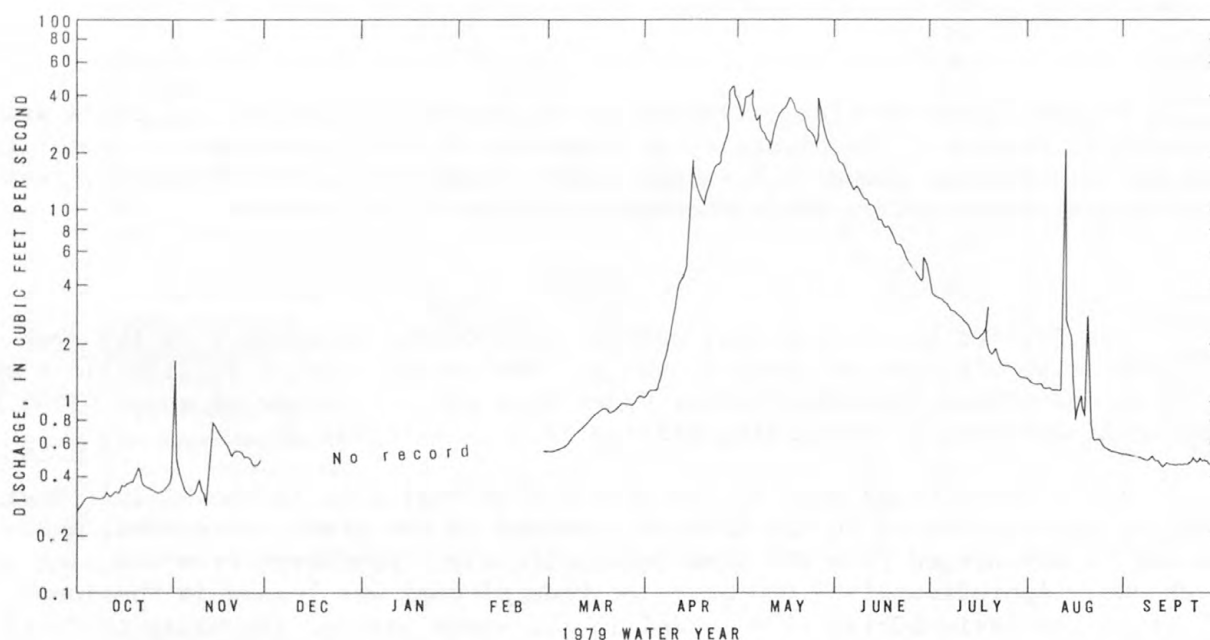


Figure 12.— Discharge of Soldier Creek at gaging station 09313975, 1979 water year.



Figure 13.— Base flow of Soldier Creek and its relationship to geology and mining activities.

Table 5.--Summary of chemical constituents and bacteria in water at gaging station 09313975 on Soldier Creek, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Discharge (cubic feet per second)		7	-	0.35-2.2
Water temperature (degrees Celsius)		7	14.0	0.0-22.0
Specific conductance (micromhos per centimeter)		7	813	563-1,020
pH (units)		7	-	8.4-8.7
Milligrams per liter	Dissolved solids, sum of constituents	7	518	384-627
	Oxygen, dissolved (O ₂)	7	8.1	6.8-10.8
	Carbon dioxide, dissolved (CO ₂)	7	1.8	1.2-2.9
	Alkalinity (CaCO ₃)	7	300	210-370
	Bicarbonate (HCO ₃)	7	344	240-448
	Carbonate (CO ₃)	7	14	4-26
	Oil and grease	1	-	0
	Nitrogen, dissolved (N)	1	-	0.46
	Nitrogen, organic dissolved (N)	3	.32	0.27-0.39
	Nitrogen, ammonia dissolved (N)	3	.03	0-0.07
	Nitrogen, nitrite dissolved (N)	3	.003	0-0.01
	Nitrogen, nitrate dissolved (N)	2	.005	0-0.01
	Nitrogen, ammonia + organic suspended total (N)	3	.07	0.06-0.1
	Nitrogen, nitrite + nitrate dissolved (N)	3	.04	0-0.11
	Nitrogen, ammonia + organic total (N)	3	.42	0.34-0.56
	Phosphorus, total (P)	3	.03	0.01-0.06
	Phosphorus, ortho dissolved (P)	3	.003	0-0.01
	Carbon, organic dissolved (C)	3	13	3.4-31
	Hardness, (as CaCO ₃)	7	290	150-350
	Hardness, (as noncarbonate CaCO ₃)	7	2	0-16
	Calcium, dissolved (Ca)	7	45	31-56
	Magnesium, dissolved (Mg)	7	43	18-51
	Sodium, dissolved (Na)	7	69	39-91
	Sodium-adsorption-ratio	7	1.8	1.0-2.2
	Potassium, dissolved (K)	7	3.6	2.1-5.9
	Chloride, dissolved (Cl)	7	13	9.2-16
	Sulfate, dissolved (SO ₄)	7	130	88-180
	Fluoride, dissolved (F)	3	-	0.4
	Silica, dissolved (SiO ₂)	7	8.0	7.5-9.2
Micrograms per liter	Arsenic, dissolved (As)	3	1.7	1-2
	Boron, dissolved (B)	3	107	100-110
	Chromium, dissolved (Cr)	3	-	0
	Iron, dissolved (Fe)	3	7	0-10
	Lead, dissolved (Pb)	3	6	0-18
	Manganese, dissolved (Mn)	3	30	10-40
	Strontium, dissolved (Sr)	3	450	400-500
	Zinc, dissolved (Zn)	3	11	3-20
	Lithium, dissolved (Li)	3	-	20
	Selenium, dissolved (Se)	3	2	1-3
	Phenols	3	.7	0-2
Bacteria (colonies per 100 milliliters)				
Coliform, fecal		2	-	56-87
Streptococci, fecal		2	-	52-1,080

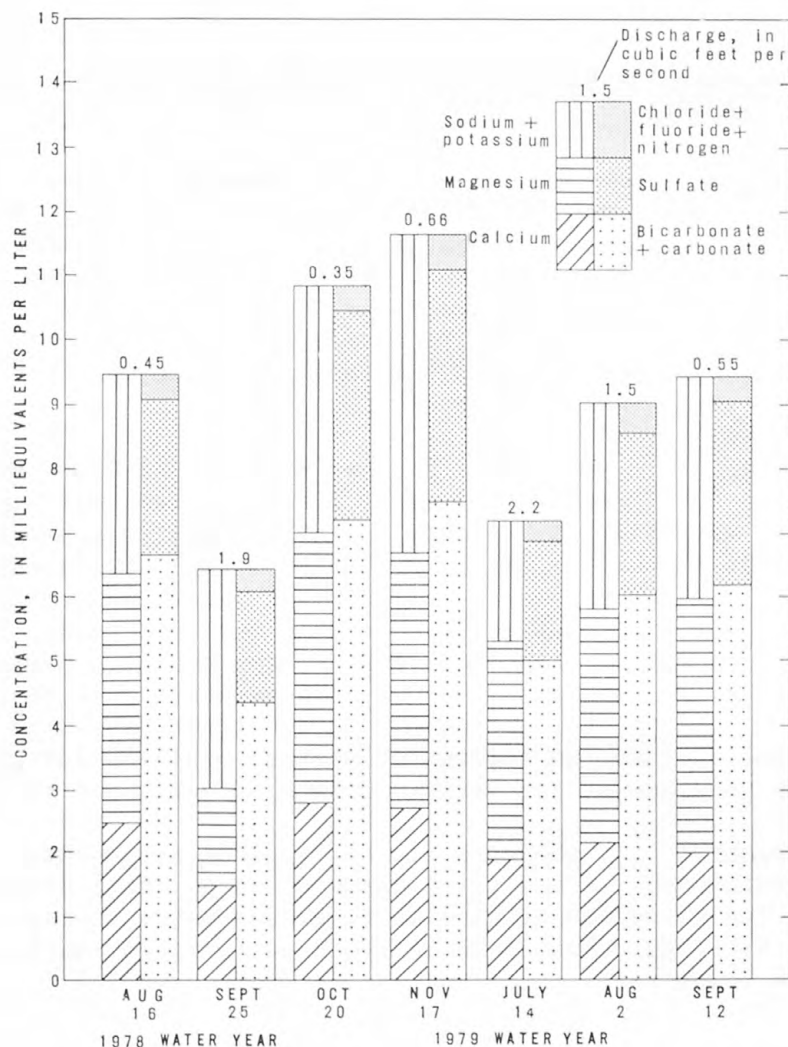


Figure 14.— Relationship of major dissolved chemical constituents and discharge of Soldier Creek at gaging station 09313975, August 1978–September 1979.

Four suspended-sediment samples were collected, and concentrations ranged from 62 to 257 mg/L. Observed sediment discharge ranged from 0.06 to 0.62 tons per day. The disturbed areas around surface facilities at the Soldier Creek Mine have been observed to yield significant quantities of sediment during periods of surface runoff, and this could partly explain the higher concentrations and sediment discharges observed at the Soldier Creek station than at the station on Coal Creek.

Benthic invertebrates collected at the Soldier Creek station, listed in table 2, were similar and about as diverse as those collected at Coal Creek. The diversity index at both sites is indicative of an environmental condition intermediate between that found at a mountain site, like the station on Pleasant Valley Creek, and a station on the Mancos lowlands, like Spring Canyon.

Grassy Trail Creek

Grassy Trail Creek originates in the Book Cliffs at an altitude of about 9,950 ft. The gaging station (09314340) is near the mouth of Whitmore Canyon

in the town of Sunnyside at an altitude of about 6,540 ft. The drainage area at the station is 40.1 mi² (pl. 1).

Kaiser Steel Corp. operated the Sunnyside Mines in the lower part of the basin during 1979. The underground mines, as shown on plate 1, extend beyond the surface drainage divides of Grassy Trail Creek. Water is intermittently discharged from the mines at two locations upstream from the gaging station. Discharge from the mines is not known precisely, but it probably averages about 1 ft³/s. Approximately 2,000 acres of Federal coal in the basin was leased in 1979, and the remainder of the basin is about equally split between unleased Federal coal and coal that is State and privately owned.

Discharge at gaging station 09314340 on Grassy Trail Creek during the 1979 water year is shown in figure 15, and daily discharge ranged from a low of 0.14 ft³/s on January 2 to a high of 80 ft³/s on May 28. The discharge averaged 7.02 ft³/s, and runoff in the basin average 0.18 (ft³/s)/mi² during the water year. Unlike other streams in the Book Cliffs, snowmelt runoff in Grassy Trail Creek peaked during the latter part of May rather than during late April or early May. This was probably due to the higher altitude of the drainage basin. Discharge at the station on Grassy Trail Creek also was more variable than that of other streams in the Book Cliffs, reflecting the intermittent discharge of water from the Sunnyside Mines. Discharge records at station 09314340 during the 1979 water year are rated as good except for periods of ice effect, when they were fair.

Base-flow measurements, shown in figure 16, indicate substantial gains in flow in Grassy Trail Creek in the reach between Grassy Trail Reservoir and the gaging station. The gains are attributed to ground-water seepage from rocks younger than the Castlegate Sandstone in the upper part of the reach and to mine discharges in the lower part.

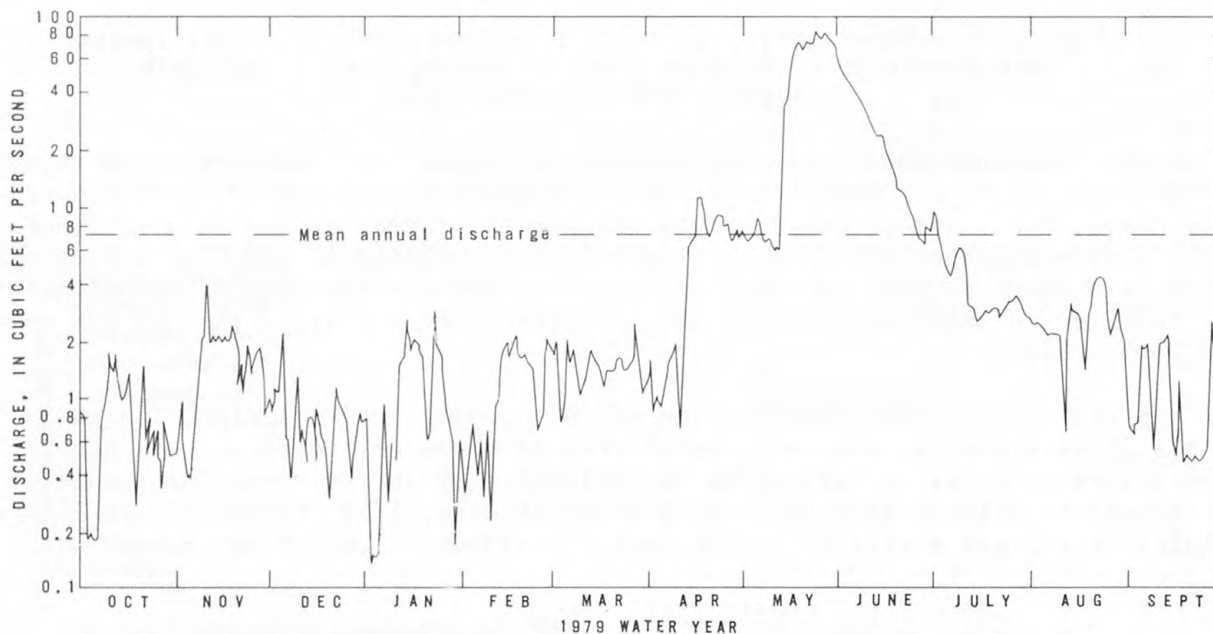


Figure 15.—Discharge of Grassy Trail Creek at gaging station 09314340, 1979 water year.

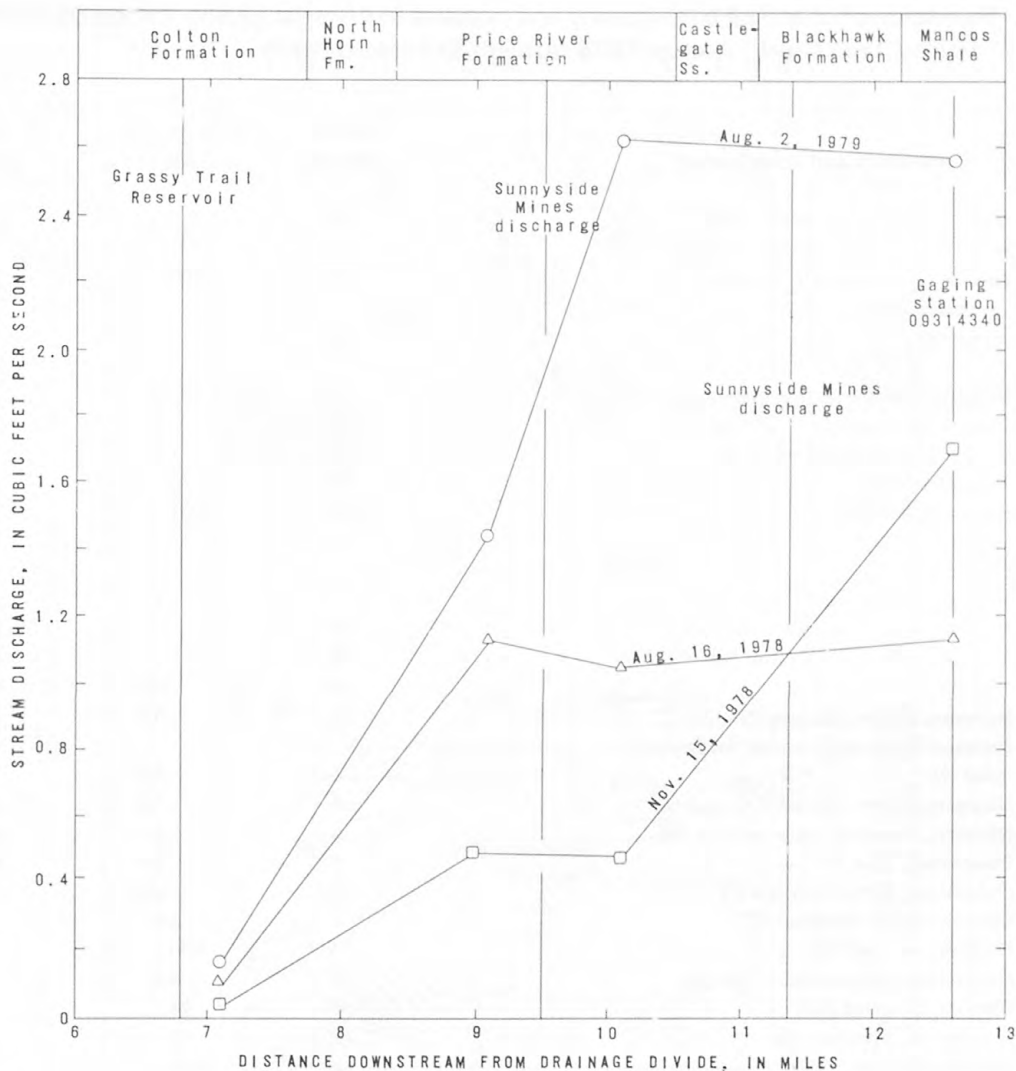


Figure 16.— Base flow of Grassy Trail Creek and its relationship to geology and mining activities.

Chemical analyses of water collected from Grassy Trail Creek at station 09314340 are summarized in table 6, and the relationship between major dissolved chemical constituents and stream discharge is shown in figure 17. Observed dissolved-solids concentrations ranged from 359 to 1,810 mg/L and generally were inversely related to stream discharge. Part of the large seasonal variation in water quality is attributed to the intermittent discharge of large quantities of water from the Sunnyside Mines. The mine water, according to Waddell, Contratto, Sumsion, and Butler (1979, p. 74), contained about 1,600 mg/L of dissolved solids during 1975-77. Several chemical constituents, including sulfate, lead, phenols, and dissolved solids, commonly exceeded the drinking-water standards of the U.S. Public Health Service (1962).

Six suspended-sediment samples were collected, and concentrations ranged from 4 mg/L on March 13, 1979, to 113 mg/L on December 10, 1978. Observed suspended-sediment discharge ranged from less than 0.01 to 4.4 tons per day.

Table 6.--Summary of chemical constituents and bacteria in water at gaging station 09314340 on Grassy Trail Creek, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Milligrams per liter	Discharge (cubic feet per second)	15	-	0.15-23
	Water temperature (degrees Celsius)	15	9.0	2.0-19.0
	Specific conductance (micromhos per centimeter)	15	1,690	587-2,600
	pH (units)	15	-	8.6-9.1
	Dissolved solids, sum of constituents	15	1,160	359-1,810
	Oxygen, dissolved (O ₂)	15	9.4	7.8-11.2
	Carbon dioxide, dissolved (CO ₂)	15	1.5	0.7-2.5
	Alkalinity (CaCO ₃)	15	470	240-670
	Bicarbonate (HCO ₃)	15	507	254-770
	Carbonate (CO ₃)	15	32	14-75
	Oil and grease	5	.20	0-1.0
	Nitrogen, dissolved (N)	3	.42	0.37-0.46
	Nitrogen, organic dissolved (N)	6	.26	0.16-0.36
	Nitrogen, ammonia dissolved (N)	6	.06	0-0.21
	Nitrogen, nitrite dissolved (N)	6	.02	0.01-0.04
	Nitrogen, nitrate dissolved (N)	6	.14	0-0.35
	Nitrogen, ammonia + organic suspended total (N)	6	.03	0-0.06
	Nitrogen, nitrite + nitrate dissolved (N)	6	.16	0.01-0.36
	Nitrogen, ammonia + organic total (N)	6	.31	0.18-0.54
	Phosphorus, total (P)	6	.02	0.01-0.03
	Phosphorus, ortho dissolved (P)	6	.002	0-0.01
	Carbon, organic dissolved (C)	6	3.0	2.0-4.9
	Hardness, (as CaCO ₃)	15	300	220-350
	Hardness, (as noncarbonate CaCO ₃)	15	5.7	0-53
	Calcium, dissolved (Ca)	15	44	24-56
	Magnesium, dissolved (Mg)	15	46	34-54
	Sodium, dissolved (Na)	15	300	23-530
	Sodium-adsorption-ratio	15	7.7	0.6-14
	Potassium, dissolved (K)	15	6.0	1.5-15
	Chloride, dissolved (Cl)	15	34	3.2-77
	Sulfate, dissolved (SO ₄)	15	430	78-730
	Fluoride, dissolved (F)	6	.7	0.1-1.0
	Silica, dissolved (SiO ₂)	15	9.8	6.5-15
Micrograms per liter	Arsenic, dissolved (As)	6	-	1.0
	Boron, dissolved (B)	6	200	0-370
	Chromium, dissolved (Cr)	6	-	0
	Iron, dissolved (Fe)	6	20	0-30
	Lead, dissolved (Pb)	6	20	0-55
	Manganese, dissolved (Mn)	6	20	0-30
	Strontium, dissolved (Sr)	6	420	290-610
	Zinc, dissolved (Zn)	6	10	0-20
	Lithium, dissolved (Li)	6	50	0-80
	Selenium, dissolved (Se)	6	.7	0-1
	Phenols	6	.7	0-2
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	6	11	0-34
	Streptococci, fecal	6	331	92-760

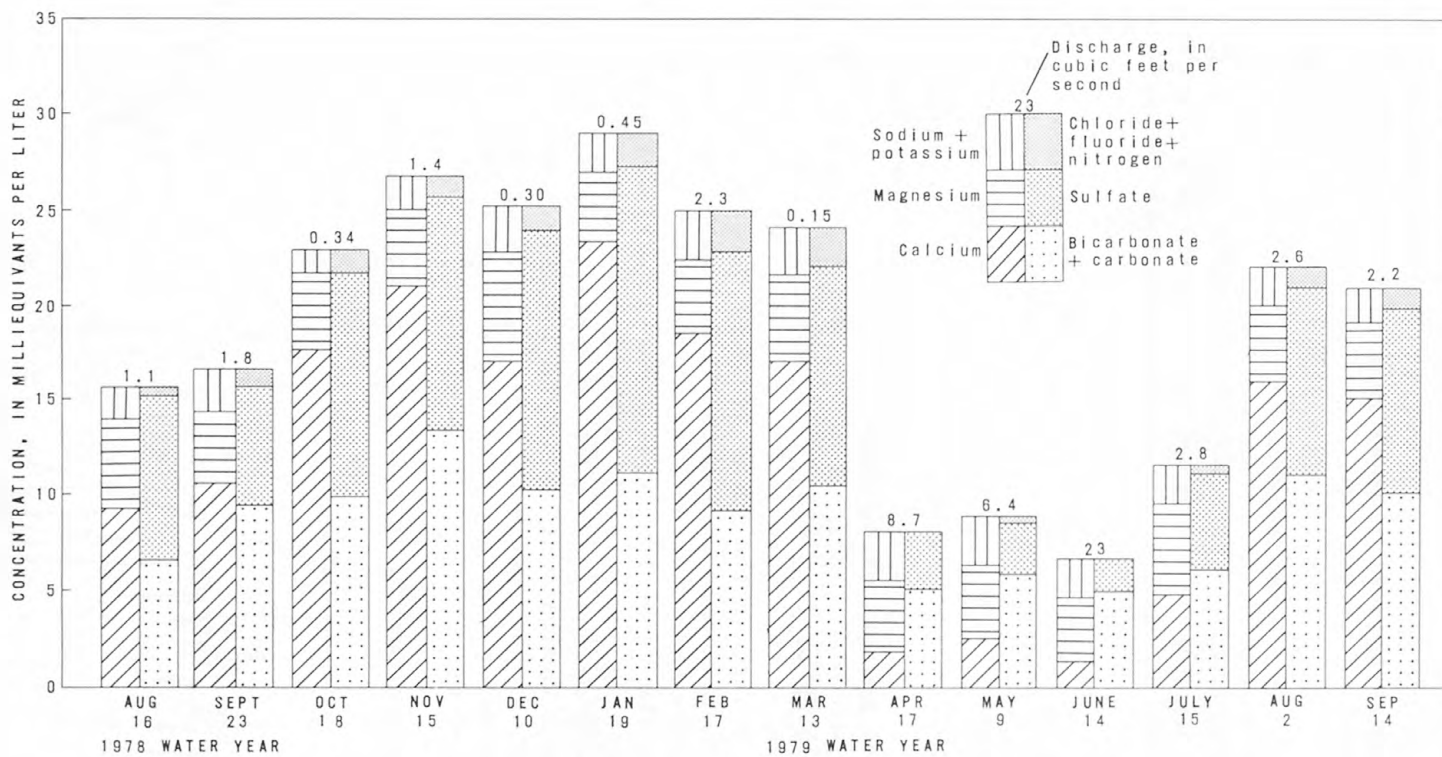


Figure 17.—Relationship of major dissolved chemical constituents and discharge of Grassy Trail Creek at gaging station 09314340, August 1978–September 1979.

Although the water in Grassy Trail Creek was of poorer chemical quality than the water sampled at other streams in the Book Cliffs (table 2), the benthic invertebrates at station 09314340 were more diverse than at the other streams. This is attributed to a more varied habitat and bottom material in Grassy Trail Creek that consisted of sand, gravel, and boulders. By contrast, the bottom material at other sampling sites in the Book Cliffs consisted largely of finer materials or bedrock outcrop.

Horse Canyon

Horse Canyon originates in the Book Cliffs at an altitude of about 9,600 ft. The gaging station (09314374) is about 0.4 mi downstream from the Geneva Mine at an altitude of about 6,200 ft. The drainage area at the gage is 12.5 mi² (pl. 1).

The Geneva Mine was operated by the U.S. Steel Corp. during 1979. As shown on plate 1, the underground mining was concentrated in the lower part of the Horse Canyon drainage, but it extended into adjacent surface basins. Water was discharged from the mine intermittently, and although the discharge is not known precisely, it probably averaged about 0.2 ft³/s. Approximately 800 acres of Federal coal was leased in the basin during 1979. The remainder of the coal in the basin is State and privately owned.

Discharge at gaging station 09314374 downstream from the mine during the 1979 water year is shown in figure 18. Mean discharge during the water year was 0.40 ft³/s, and runoff in the basin averaged 0.032 (ft³/s)/mi². Horse Canyon at the gaging station is an intermittent stream, and during 5 days in February and March 1979 there was no flow at the station. As at Grassy Trail Creek, streamflow at the Horse Canyon station is quite variable and reflects the intermittent discharge of water from the Geneva Mine. Snowmelt runoff at the station peaked during the later part of April 1979, but the largest daily discharge at the Horse Canyon station during the 1979 water year was 2.1 ft³/s on November 11, 1978, as the result of a storm. Discharge records at the station during the 1979 water year are rated as good except for periods of ice effect, when they were fair.

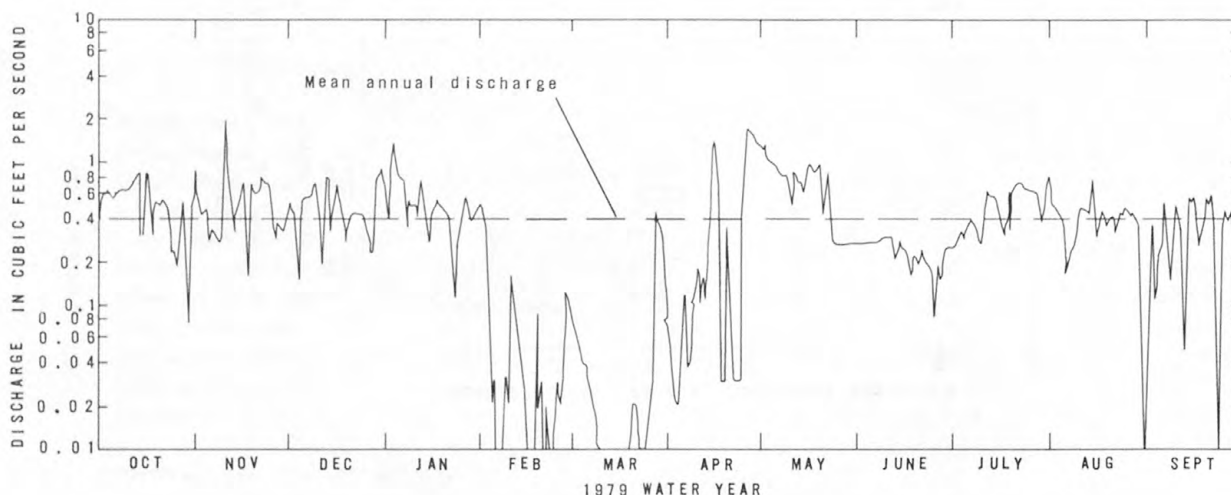


Figure 18.— Discharge in Horse Canyon at gaging station 09314374, 1979 water year.

The three sets of base-flow measurements shown in figure 19 indicate that Horse Canyon twice was dry below the South Fork on the Price River Formation. In the reach between the middle of the Castlegate Sandstone and station 09314374, the discharge of Horse Canyon increased. The increase mostly was due to mine discharge.

Chemical analyses of water collected at station 09314374 in Horse Canyon are summarized in table 7. Observed dissolved-solids concentrations ranged from 953 to 4,220 mg/L, but they were usually about 2,000 mg/L. The predominant dissolved chemical constituents were sodium and sulfate. Most of the water sampled at the station, except during spring snowmelt, was discharged from the Geneva Mine a short distance upstream. The Mancos Shale is interbedded with the Blackhawk Formation in this area of the Book Cliffs, and dissolved-solids concentrations in the mine water are higher than in other areas of the Wasatch Plateau and Book Cliffs.

Six suspended-sediment samples were collected from August 1978 through September 1979, and concentrations ranged from 10 to 748 mg/L. Observed suspended-sediment discharge at station 09314374 ranged from less than 0.01 to 1.3 tons per day and was highest during the spring-snowmelt period.

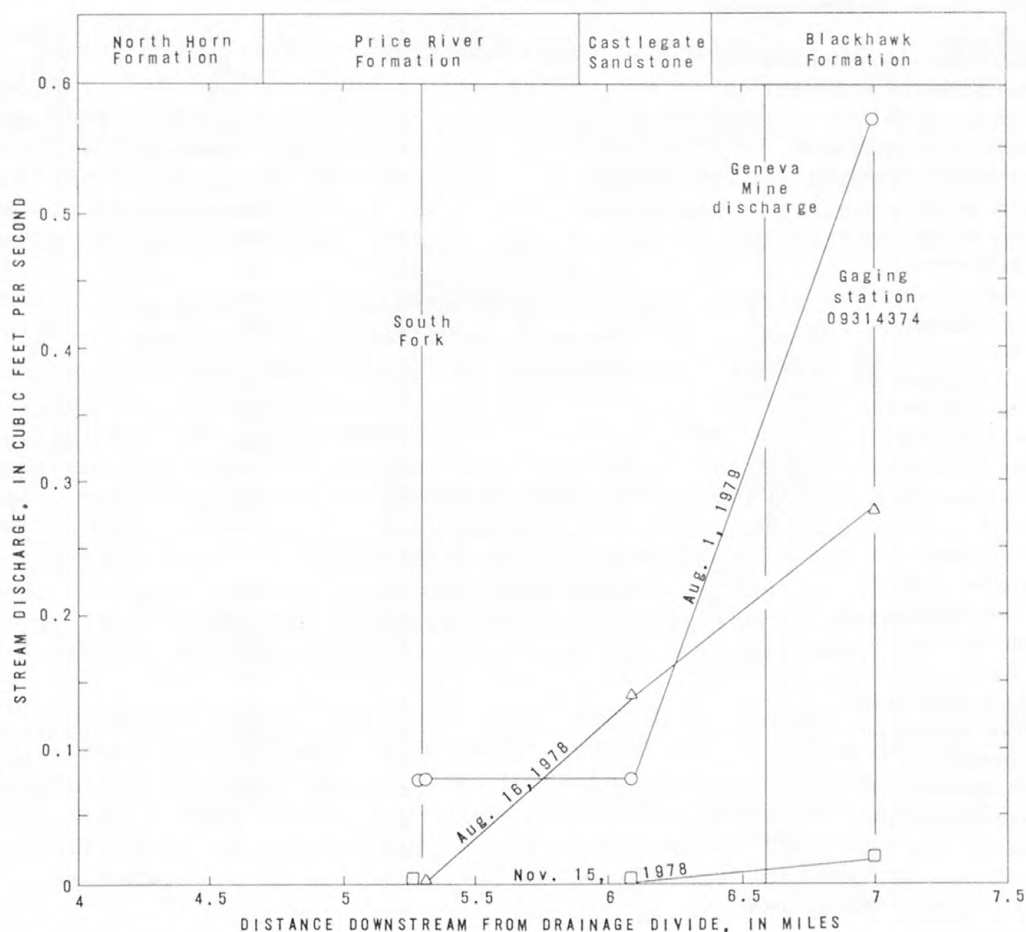


Figure 19.— Base flow in Horse Canyon and its relationship to geology and mining activities.

Table 7.--Summary of chemical constituents and bacteria in water at gaging station 09314374 in Horse Canyon, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Discharge (cubic feet per second)		12	-	< 0.01-1.20
Water temperature (degrees Celsius)		12	18.0	6.0-27.0
Specific conductance (micromhos per centimeter)		12	2,800	1,390-7,000
pH (units)		12	-	8.5-8.7
Milligrams per liter	Dissolved solids, sum of constituents	12	1,960	953-4,220
	Oxygen, dissolved (O ₂)	12	7.8	6.1-10.6
	Carbon dioxide, dissolved (CO ₂)	12	2.1	1.2-4.7
	Alkalinity (CaCO ₃)	12	350	290-380
	Bicarbonate (HCO ₃)	12	398	338-444
	Carbonate (CO ₃)	12	16	8-26
	Oil and grease	3	-	0
	Nitrogen, dissolved (N)	2	-	0.83-0.89
	Nitrogen, organic dissolved (N)	4	.31	0.20-0.46
	Nitrogen, ammonia dissolved (N)	4	.19	0-0.42
	Nitrogen, nitrite dissolved (N)	4	.03	0.02-0.06
	Nitrogen, nitrate dissolved (N)	4	.54	0.19-1.20
	Nitrogen, ammonia + organic suspended total (N)	4	.16	0.08-0.25
	Nitrogen, nitrite + nitrate dissolved (N)	4	.57	0.21-1.20
	Nitrogen, ammonia + organic total (N)	4	.66	0.50-0.85
	Phosphorus, total (P)	4	.02	0-0.04
	Phosphorus, ortho dissolved (P)	4	.005	0-0.02
	Carbon, organic dissolved (C)	4	4.0	1.8-8.8
	Hardness, (as CaCO ₃)	12	790	420-1,600
	Hardness, (as noncarbonate CaCO ₃)	12	440	99-1,400
	Calcium, dissolved (Ca)	12	98	61-210
	Magnesium, dissolved (Mg)	12	130	65-260
	Sodium, dissolved (Na)	12	360	130-1,000
	Sodium-adsorption-ratio	12	5.7	1.4-12.0
	Potassium, dissolved (K)	12	11	5.7-26
	Chloride, dissolved (Cl)	12	160	18-1,500
	Sulfate, dissolved (SO ₄)	12	960	440-1,300
	Fluoride, dissolved (F)	4	.3	0.2-0.4
	Silica, dissolved (SiO ₂)	12	11	10-15
Micrograms per liter	Arsenic, dissolved (As)	4	-	1
	Boron, dissolved (B)	4	260	0-360
	Chromium, dissolved (Cr)	4	5	0-10
	Iron, dissolved (Fe)	4	20	10-30
	Lead, dissolved (Pb)	4	15	0-47
	Manganese, dissolved (Mn)	4	15	10-20
	Strontium, dissolved (Sr)	4	1,400	1,100-2,000
	Zinc, dissolved (Zn)	4	20	10-30
	Lithium, dissolved (Li)	4	200	50-630
	Selenium, dissolved (Se)	4	1.2	0-3
	Phenols	4	1.2	1-2
Bacteria (colonies per 100 milliliters)				
Coliform, fecal		2	-	3-5
Streptococci, fecal		1	-	84

Benthic invertebrates were sampled at station 09314374 in the summers of 1978 and 1979, and the organisms are listed in table 2. The small diversity index for each sample reflects the poor quality of water and intermittent flow at the station.

SAN RAFAEL RIVER BASIN

Huntington Creek and Crandall and Tie Fork Canyons

The uppermost parts of the Huntington Creek drainage basin are at altitudes above 10,000 ft and are underlain by the Flagstaff Limestone. The gaging station on Huntington Creek (09318000) is on the Mancos Shale at an altitude of about 5,950 ft. The drainage area at the station, which is 1 mi downstream from the coal-fired Huntington Power Plant, is 187 mi² (pl. 1).

Crandall and Tie Fork Canyons, tributaries to Huntington Creek, were also gaged during the 1979 water year. The gaging station near the mouth of Crandall Canyon (09317919) is on the Star Point Sandstone at an altitude of 7,350 ft, and drainage area at the station is 5.7 mi² (pl. 1). The station near the mouth of Tie Fork Canyon (09317920) also is on the Star Point Sandstone at an altitude of about 7,400 ft, and the drainage area at the station is 11.7 mi² (pl. 1).

During 1979, three underground mines produced coal in the Huntington Creek drainage. Two of the mines extend across surface drainage divides. The Deer Creek Mine extends into the Cottonwood Creek drainage; and the Hiawatha Mine, most of which is in the Miller Creek and Cedar Creek drainages, extends into the upper drainage of Tie Fork Canyon. Approximately 20,000 acres of Federal coal was leased during 1979 in the Huntington Creek drainage, and about 90 percent of the remaining unleased coal in the basin was Federally owned.

The Deer Creek and Hiawatha Mines are the largest producers of water in the basin, but the total discharge from the two mines is not known precisely. Discharge from the Deer Creek Mine was estimated to have averaged about 0.16 ft³/s and contained about 600 mg/L of dissolved solids during 1978 (Utah Power and Light Co., written commun., March 1980). During 1979, water from the Deer Creek Mine was totally consumed for cooling at the coal-fired Huntington Power Plant. Discharge from the Hiawatha Mine from mid-1975 to mid-1978 ranged from about 0.9 to 2.5 ft³/s (T. W. Danielson, written commun., 1980). Water was discharged from the Hiawatha Mine at Mohrland Station in the Cedar Creek drainage, and it contained 671 mg/L of dissolved solids in September 1975 (Waddell and others, 1979, table 9). Most water produced in the Co-op Mine was consumed by the mining operations, and the discharge was intermittent.

Discharges during the 1979 water year at the gaging stations in Crandall and Tie Fork Canyons are shown in figures 20 and 21. The discharge record at each station is rated as good except during periods of ice effect, when it is poor. When flow exceeded the flume capacities (about 6 ft³/s), which are used for controls at the gages, the discharge record at the Tie Fork station is rated as fair, and it is rated as poor at the Crandall Canyon station.

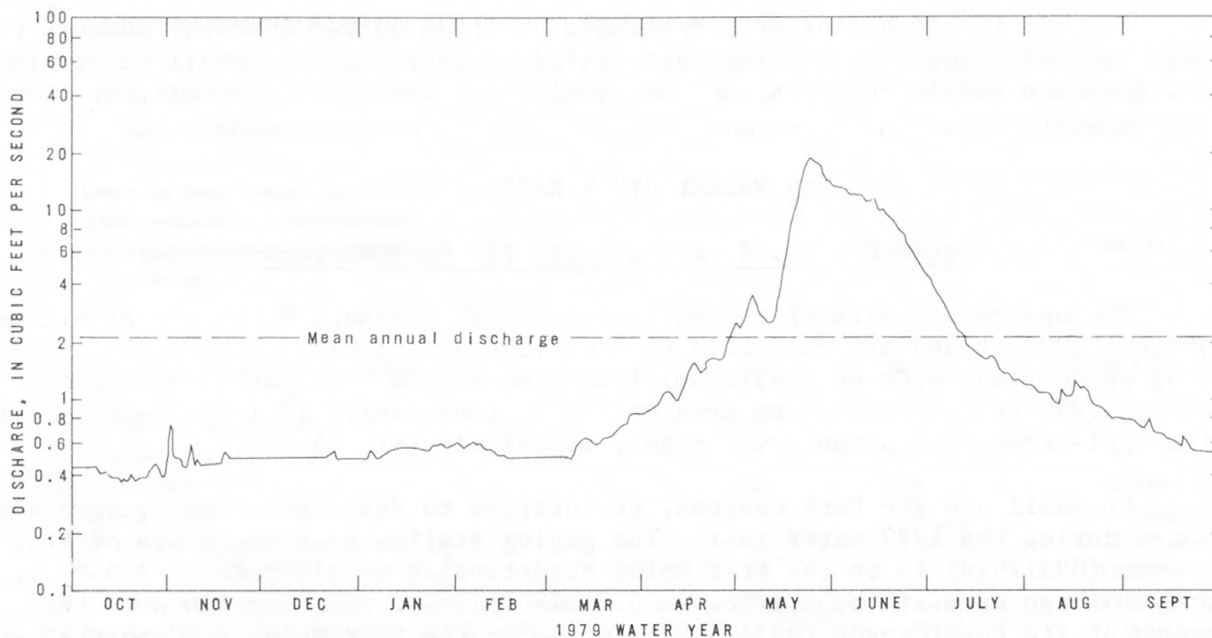


Figure 20.— Discharge in Crandall Canyon at gaging station 09317919, 1979 water year.

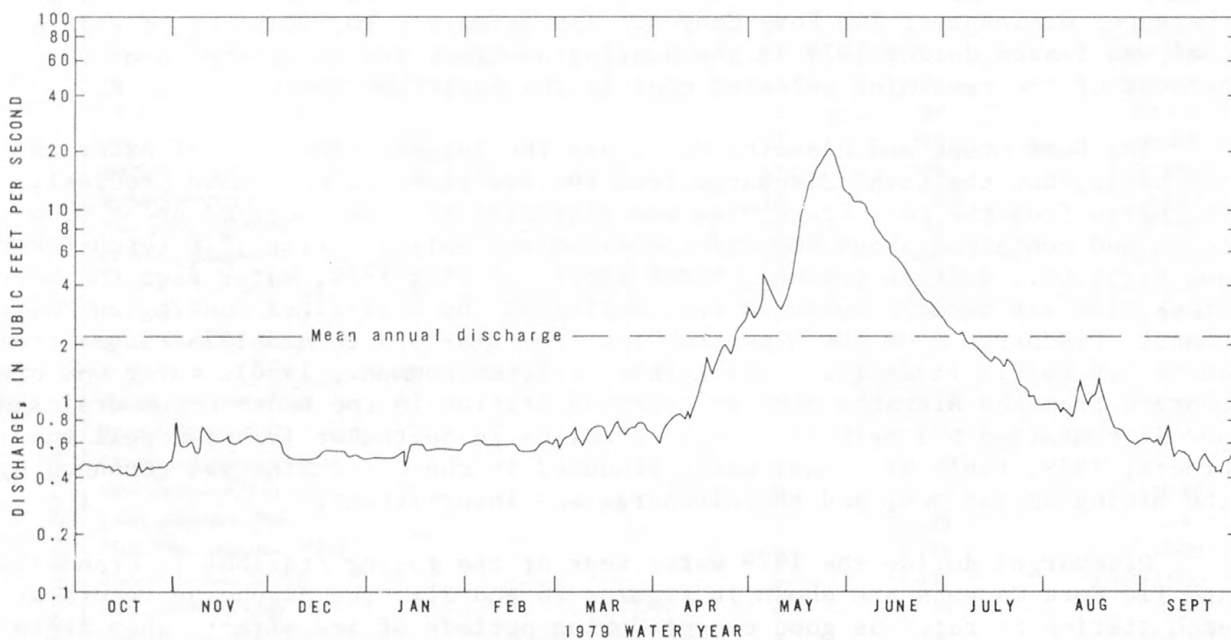


Figure 21.— Discharge in Tie Fork Canyon at gaging station 09317920, 1979 water year.

Although Tie Fork Canyon has a drainage area about twice the size of the Crandall Canyon drainage, the discharges at the two gaging stations were similar. At both stations, mean flow during the 1979 water year was about $2 \text{ ft}^3/\text{s}$, and daily discharge ranged from about 0.4 to $20 \text{ ft}^3/\text{s}$. About 80 percent of the runoff at both stations occurred during the snowmelt period between April and July. Runoff during the water year averaged $0.38 (\text{ft}^3/\text{s})/\text{mi}^2$ in the Crandall Canyon basin but only $0.17 (\text{ft}^3/\text{s})/\text{mi}^2$ in the Tie Fork basin. The smaller runoff in the Tie Fork basin may have been due to less precipitation, the aspect and physical features of the basin, increased ground-water recharge, or dewatering of the Hiawatha Mine.

Discharge at station 09318000 on Huntington Creek during the 1979 water year is shown in figure 22. Streamflow at the station is regulated by several reservoirs in the upper part of the basin. Daily discharge during the water year ranged from $7 \text{ ft}^3/\text{s}$ on November 27, 1978, to $333 \text{ ft}^3/\text{s}$ on May 28, 1979, and it averaged $77.4 \text{ ft}^3/\text{s}$. Runoff in the basin averaged $0.41 (\text{ft}^3/\text{s})/\text{mi}^2$ during the water year. The discharge record during the year is rated as good except during periods of ice effect, when it is poor.

Base-flow measurements, shown in figure 23, indicate that the inflow from the Left Fork of Huntington Creek contributed a significant part of the flow at station 09318000. Comparatively little water was added to Huntington Creek by the other tributaries. Because of errors inherent in the discharge measurements and the magnitude of the discharge, it is inconclusive as to whether there were gains or losses in streamflow in the reach of Huntington Creek between the mouth of the Left Fork and the measurement site at mile 29.3. The losses in the reach downstream from mile 29.3 are mainly due to the diversion of water to the Huntington Power Plant, which averaged about $15 \text{ ft}^3/\text{s}$ during 1979.

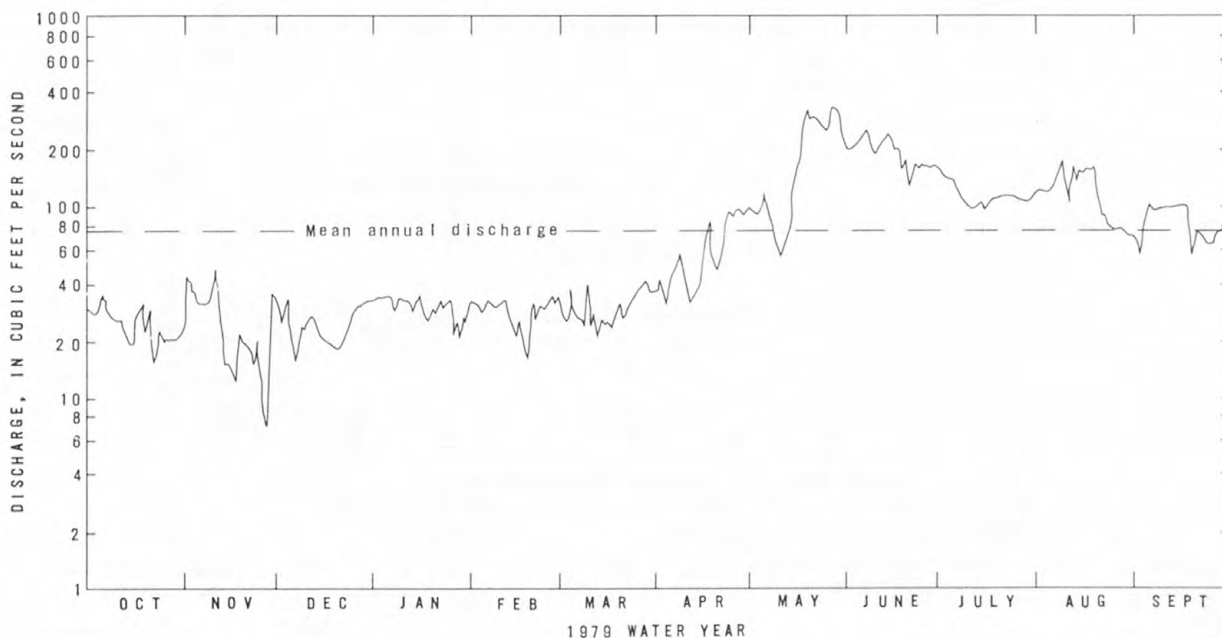


Figure 22.— Discharge of Huntington Creek at gaging station 09318000, 1979 water year.

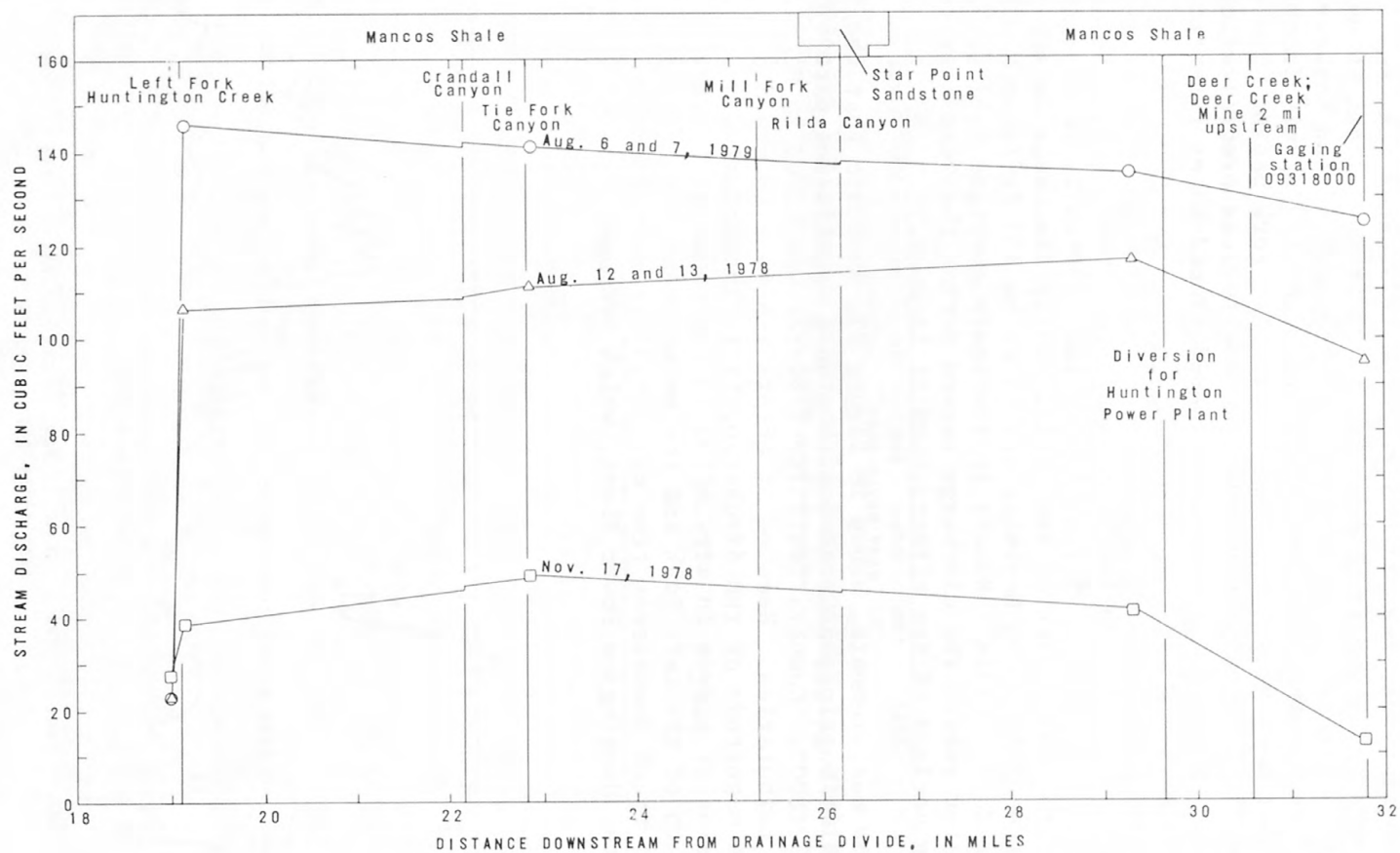


Figure 23.— Base flow of Huntington Creek and its relationship to geology and mining activities.

Summaries of chemical analyses of water collected at the stations in Crandall and Tie Fork Canyons and on Huntington Creek are listed in tables 8, 9, and 10. Water at all three stations generally was of excellent chemical quality, and dissolved-solids concentrations averaged less than 300 mg/L. Phenols at the three stations, however, commonly exceeded the limit of 1 µg/L for drinking water recommended by the U.S. Public Health Service (1962).

The relationship of major dissolved chemical constituents and the discharge of Huntington Creek at station 09318000 is shown in figure 24. Dissolved-solids concentrations were generally inversely related to stream discharge, and the predominant dissolved chemical constituents were calcium, magnesium, and bicarbonate. The proportions of dissolved sodium and sulfate generally increased during periods of low flow.

Fourteen suspended-sediment samples were collected at station 09318000 on Huntington Creek from August 1978 through September 1979, and concentrations ranged from 29 to 181 mg/L. Observed suspended-sediment discharge at the station ranged from 1.8 tons per day on February 18, 1979, to 66 tons per day on June 13, 1979. Sediment concentrations generally increased with increased stream discharge, but insufficient data are available to compute daily sediment discharge.

Suspended-sediment samples were collected at stations 09317919 and 09317920 in Crandall and Tie Fork Canyons in August and November 1978 and in August 1979. In Crandall Canyon, the concentration ranged from 49 to 60 mg/L, and observed sediment discharge ranged from 0.08 to 0.15 tons per day. In Tie Fork Canyon, the concentration ranged from 12 to 66 mg/L, and observed sediment discharge ranged from 0.02 to 0.17 tons per day. Suspended-sediment concentrations and discharges at both stations were probably higher during the snow-melt period than during the summer and fall when samples were collected.

The excellent chemical quality of water at the three stations is reflected in the diverse group of benthic invertebrates that were collected at each site (table 2). At Huntington Creek, the diversity index for 10 samples ranged from 1.0 to 2.5. When diversity indices were less than about 2, it was usually due to an increase of organisms in one or more families in the orders Diptera (true flies) or Ephemeroptera (mayflies).

Cottonwood Creek

Cottonwood Creek originates in the Wasatch Plateau at an altitude of about 10,200 ft. The uppermost part of the basin is underlain by the Flagstaff Limestone, and the gaging station (09324200) is on the Star Point Sandstone at an altitude of about 6,950 ft. Drainage area above the station is 21.9 mi² (pl. 1).

During 1979, the Trail Mountain Mine was the only producing mine in the basin upstream from the gaging station. Most of the water produced in the underground mine was consumed by the mining operation, and mine discharge was intermittent. Coal in the basin is about 90 percent Federally owned, and approximately 2,200 acres of Federal coal upstream from the station were leased during 1979.

Table 8.--Summary of chemical constituents and bacteria in water at gaging station 09317919 in Crandall Canyon, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Discharge (cubic feet per second)		7	-	0.39-1.7
Water temperature (degrees Celsius)		7	10.0	0.0-18.5
Specific conductance (micromhos per centimeter)		7	469	441-520
pH (units)		7	-	8.4-8.7
Milligrams per liter	Dissolved solids, sum of constituents	7	270	244-303
	Oxygen, dissolved (O ₂)	7	8.6	7.2-10.8
	Carbon dioxide, dissolved (CO ₂)	7	1.2	0.8-2.0
	Alkalinity (CaCO ₃)	7	220	197-250
	Bicarbonate (HCO ₃)	7	254	230-302
	Carbonate (CO ₃)	7	8	4-14
	Oil and grease	2	-	0
	Nitrogen, dissolved (N)	1	-	0.27
	Nitrogen, organic dissolved (N)	3	.24	0.16-0.36
	Nitrogen, ammonia dissolved (N)	3	.04	0.02-0.07
	Nitrogen, nitrite dissolved (N)	3	-	0
	Nitrogen, nitrate dissolved (N)	3	.02	0-0.05
	Nitrogen, ammonia + organic suspended total (N)	3	.03	0-0.06
	Nitrogen, nitrite + nitrate dissolved (N)	3	.02	0-0.05
	Nitrogen, ammonia + organic total (N)	3	.29	0.22-0.40
	Phosphorus, total (P)	3	.01	0-0.02
	Phosphorus, ortho dissolved (P)	3	.007	0-0.01
	Carbon, organic dissolved (C)	3	2.5	1.4-3.5
	Hardness, (as CaCO ₃)	7	260	230-280
	Hardness, (as noncarbonate CaCO ₃)	7	32	23-43
	Calcium, dissolved (Ca)	7	53	48-59
	Magnesium, dissolved (Mg)	7	29	25-33
	Sodium, dissolved (Na)	7	5.2	4.5-6.0
	Sodium-adsorption-ratio	7	.1	0.1-0.2
	Potassium, dissolved (K)	7	1.8	1.3-4.1
	Chloride, dissolved (Cl)	7	4.5	3.9-5.1
	Sulfate, dissolved (SO ₄)	7	35	31-40
	Fluoride, dissolved (F)	3	-	0.1
	Silica, dissolved (SiO ₂)	7	6.3	5.7-6.6
Micrograms per liter	Arsenic, dissolved (As)	3	.7	0-1.0
	Boron, dissolved (B)	3	50	20-60
	Chromium, dissolved (Cr)	3	-	0
	Iron, dissolved (Fe)	3	7	0-20
	Lead, dissolved (Pb)	3	9	0-15
	Manganese, dissolved (Mn)	3	4	1-10
	Strontium, dissolved (Sr)	3	200	190-210
	Zinc, dissolved (Zn)	3	9	3-20
	Lithium, dissolved (Li)	3	4	0-7
	Selenium, dissolved (Se)	3	.3	0-1
	Phenols	3	1.3	0-2
Bacteria (colonies per 100 milliliters)				
Coliform, fecal		3	28	1-73
Streptococci, fecal		3	369	14-1,000

Table 9.--Summary of chemical constituents and bacteria in water at gaging station 09317920 in Tie Fork Canyon, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Milligrams per liter	Discharge (cubic feet per second)	7	-	0.42-1.7
	Water temperature (degrees Celsius)	7	6.5	0.0-13.0
	Specific conductance (micromhos per centimeter)	7	480	420-530
	pH (units)	7	-	8.4-8.7
	Dissolved solids, sum of constituents	7	285	248-318
	Oxygen, dissolved (O ₂)	7	9.5	8.3-11.0
	Carbon dioxide, dissolved (CO ₂)	7	1.3	0.9-1.8
	Alkalinity (CaCO ₃)	7	240	210-270
	Bicarbonate (HCO ₃)	7	280	240-304
	Carbonate (CO ₃)	7	10	2-14
	Oil and grease	2	-	0
	Nitrogen, dissolved (N)	1	-	0.32
	Nitrogen, organic dissolved (N)	3	.20	0.12-0.30
	Nitrogen, ammonia dissolved (N)	3	.01	0-0.02
	Nitrogen, nitrite dissolved (N)	3	.007	0-0.01
	Nitrogen, nitrate dissolved (N)	2	-	0.13-0.19
	Nitrogen, ammonia + organic suspended total (N)	3	.5	0-1.5
	Nitrogen, nitrite + nitrate dissolved (N)	3	.1	0.1-0.2
	Nitrogen, ammonia + organic total (N)	3	.7	0.1-1.8
	Phosphorus, total (P)	3	.01	0-0.02
	Phosphorus, ortho dissolved (P)	3	.003	0-0.01
	Carbon, organic dissolved (C)	3	4.0	1.2-7.9
	Hardness, (as CaCO ₃)	7	270	230-310
	Hardness, (as noncarbonate CaCO ₃)	7	33	17-56
	Calcium, dissolved (Ca)	7	59	51-68
	Magnesium, dissolved (Mg)	7	31	25-33
	Sodium, dissolved (Na)	7	4.0	3.3-4.5
	Sodium-adsorption-ratio	7	-	0.1
	Potassium, dissolved (K)	7	2.2	1.7-4.6
	Chloride, dissolved (Cl)	7	4.5	3.9-5.0
	Sulfate, dissolved (SO ₄)	7	34	28-39
	Fluoride, dissolved (F)	3	-	0.1
	Silica, dissolved (SiO ₂)	7	6.4	6.0-6.9
Micrograms per liter	Arsenic, dissolved (As)	3	.3	0-1
	Boron, dissolved (B)	3	30	20-40
	Chromium, dissolved (Cr)	3	3	0-10
	Iron, dissolved (Fe)	3	20	10-40
	Lead, dissolved (Pb)	3	9	0-19
	Manganese, dissolved (Mn)	3	4	1-10
	Strontium, dissolved (Sr)	3	240	210-260
	Zinc, dissolved (Zn)	3	20	4-50
	Lithium, dissolved (Li)	3	5	0-9
	Selenium, dissolved (Se)	3	.3	0-1
	Phenols	3	3.7	1-8
Bacteria (colonies per 100 milliliters)				
Coliform, fecal		3	448	3-1,330
Streptococci, fecal		3	462	28-900

Table 10.--Summary of chemical constituents and bacteria in water at gaging station 09318000 on Huntington Creek, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Milligrams per liter	Discharge (cubic feet per second)	16	-	13-216
	Water temperature (degrees Celsius)	16	9.0	1.0-16.0
	Specific conductance (micromhos per centimeter)	16	410	300-570
	pH (units)	16	-	8.2-8.7
	Dissolved solids, sum of constituents	16	242	166-343
	Oxygen, dissolved (O ₂)	16	9.7	7.4-11.4
	Carbon dioxide, dissolved (CO ₂)	16	1.4	0.7-2.5
	Alkalinity (CaCO ₃)	16	190	140-220
	Bicarbonate (HCO ₃)	16	219	162-266
	Carbonate (CO ₃)	16	6	0-16
	Oil and grease	12	.03	0-0.2
	Nitrogen, dissolved (N)	9	.44	0.22-0.64
	Nitrogen, organic dissolved (N)	15	.21	0.03-0.38
	Nitrogen, ammonia dissolved (N)	15	.008	0-0.03
	Nitrogen, nitrite dissolved (N)	15	.007	0-0.02
	Nitrogen, nitrate dissolved (N)	15	.19	0.02-0.39
	Nitrogen, ammonia + organic suspended total (N)	15	.37	0-4.4
	Nitrogen, nitrite + nitrate dissolved (N)	16	.18	0.01-0.40
	Nitrogen, ammonia + organic total (N)	15	.57	0.05-4.6
	Phosphorus, total (P)	15	.03	0-0.08
	Phosphorus, ortho dissolved (P)	16	.02	0-0.12
	Carbon, organic dissolved (C)	15	4.2	1.9-11
	Hardness, (as CaCO ₃)	16	217	150-290
	Hardness, (as noncarbonate CaCO ₃)	16	31	0-72
	Calcium, dissolved (Ca)	16	55	43-68
	Magnesium, dissolved (Mg)	16	19	11-29
	Sodium, dissolved (Na)	16	6.4	2.5-15
	Sodium-adsorption-ratio	16	.2	0.1-0.4
	Potassium, dissolved (K)	16	1.3	0.5-3.0
	Chloride, dissolved (Cl)	16	5.3	2.7-11
	Sulfate, dissolved (SO ₄)	16	35	15-80
	Fluoride, dissolved (F)	16	.1	0.1-0.2
	Silica, dissolved (SiO ₂)	16	4.2	2.0-5.9
Micrograms per liter	Arsenic, dissolved (As)	16	.6	0-2.0
	Boron, dissolved (B)	16	40	10-70
	Chromium, dissolved (Cr)	15	3	0-20
	Iron, dissolved (Fe)	15	10	10-20
	Lead, dissolved (Pb)	16	26	0-98
	Manganese, dissolved (Mn)	15	8	0-30
	Strontium, dissolved (Sr)	16	150	90-210
	Zinc, dissolved (Zn)	16	8	0-30
	Lithium, dissolved (Li)	16	7	0-10
	Selenium, dissolved (Se)	16	.4	0-2
	Phenols	15	2.7	1-9
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	15	9	0-52
	Streptococci, fecal	15	46	4-240

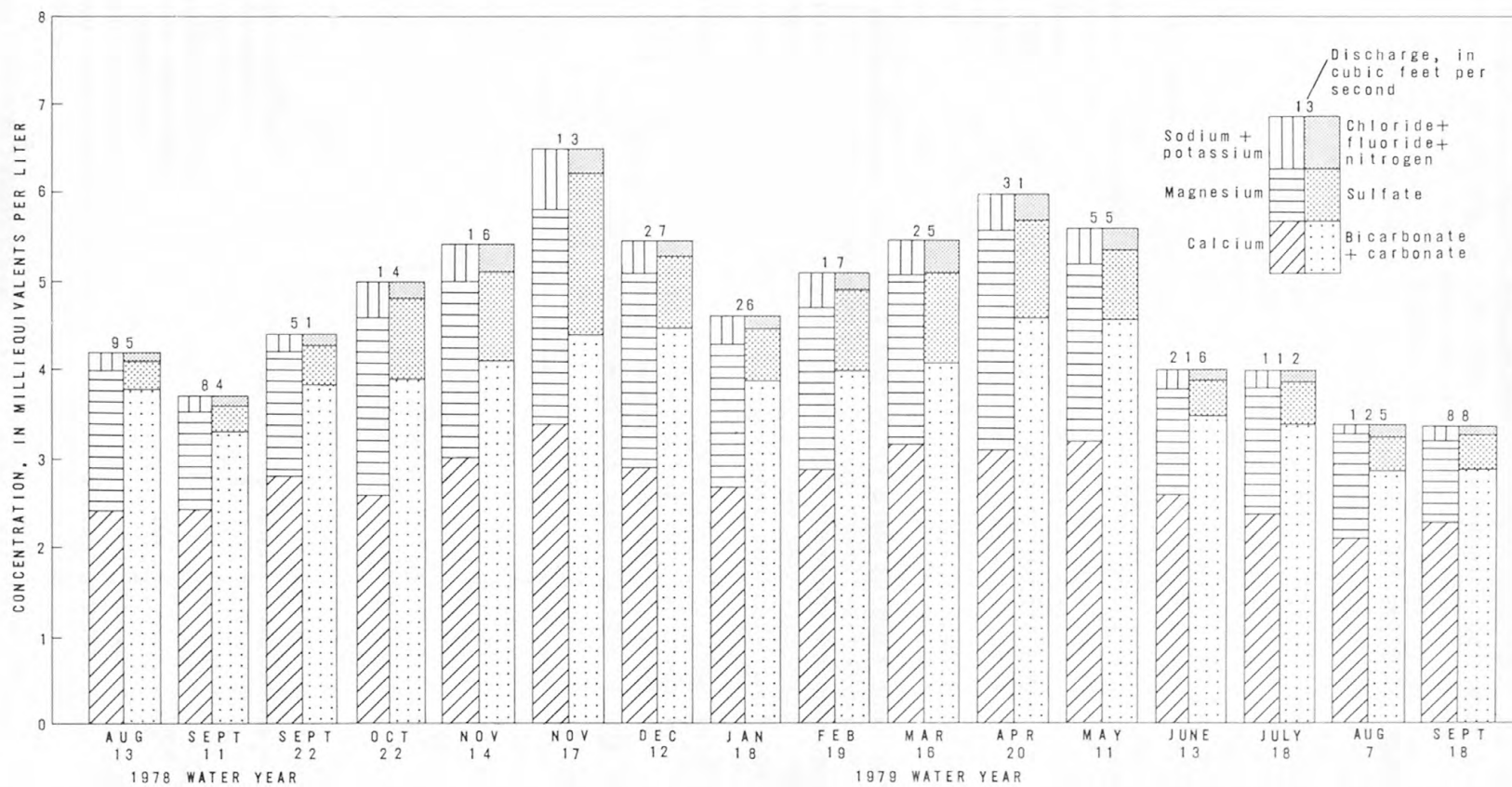


Figure 24.— Relationship of major dissolved chemical constituents and discharge of Huntington Creek at gaging station 09318000, August 1978-September 1979.

Discharge at the gaging station on Cottonwood Creek during the 1979 water year is shown in figure 25. Discharge records at the gaging station were good except during periods of ice effect, when they were poor. The discharge averaged $0.87 \text{ ft}^3/\text{s}$, and daily discharge ranged from $0.22 \text{ ft}^3/\text{s}$ during the first part of October 1978 to $5.2 \text{ ft}^3/\text{s}$ on May 24 and 25, 1979. Runoff in the basin during the water year averaged $0.04 (\text{ft}^3/\text{s})/\text{mi}^2$.

Field observations indicate that the upper part of Cottonwood Creek and many of its tributary streams are ephemeral and flow only in response to thunderstorms and snowmelt. Cottonwood Creek at station 09324200 is perennial. Baseflow measurements, shown in figure 26, indicate that there are significant gains in flow in Cottonwood Creek where it crosses the Blackhawk Formation.

Chemical analyses of water collected at station 09324200 are summarized in table 11. Observed dissolved-solids concentrations ranged from 296 to 341 mg/L in the seven samples collected during the summer and fall of 1978 and 1979. As at the stations in the Huntington Creek drainage, the predominate dissolved chemical constituents were calcium, magnesium, and bicarbonate. All analyzed chemical constituents were within the limits recommended by the U.S. Public Health Service (1962) for drinking water.

Suspended-sediment samples were collected in August and November 1978 and in August 1979. Suspended-sediment concentrations ranged from 5 to 130 mg/L, and the observed suspended-sediment discharge ranged from less than 0.01 to 0.20 tons per day. Suspended-sediment discharge was probably greater during the snowmelt period than when the samples were collected.

The diversity of benthic invertebrates collected at station 09324200 indicates the excellent chemical quality of water and perennial nature of the stream (table 2). As in other streams in the Wasatch Plateau, most of the organisms were in the orders Diptera and Ephemeroptera.

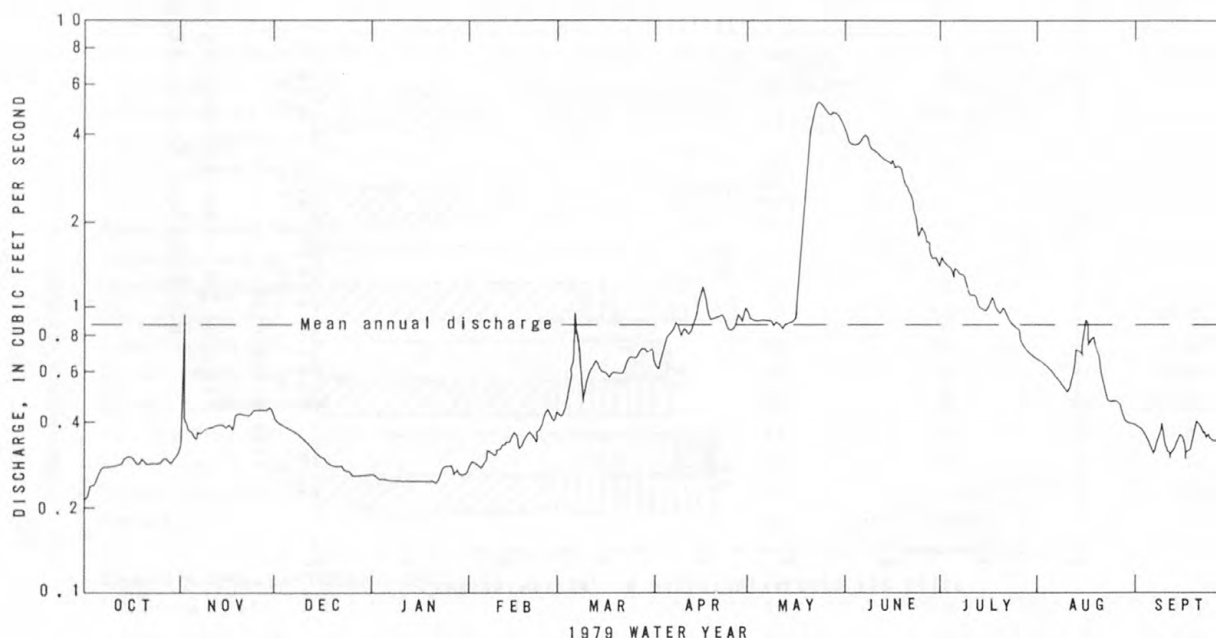


Figure 25.— Discharge of Cottonwood Creek at gaging station 09324200, 1979 water year.

Table 11.--Summary of chemical constituents and bacteria in water at gaging station 09324200 on Cottonwood Creek, August 1978 through September 1979

	Parameters and constituents	No. of analyses	Mean	Minimum-maximum
	Discharge (cubic feet per second)	7	-	0.20-0.94
	Water temperature (degrees Celsius)	7	12.5	0.0-19.5
	Specific conductance (micromhos per centimeter)	7	540	500-570
	pH (units)	7	-	8.6-8.9
Milligrams per liter	Dissolved solids, sum of constituents	7	318	296-341
	Oxygen, dissolved (O ₂)	7	8.4	7.0-11.2
	Carbon dioxide, dissolved (CO ₂)	7	.9	0.7-1.1
	Alkalinity (CaCO ₃)	7	250	230-280
	Bicarbonate (HCO ₃)	7	267	242-308
	Carbonate (CO ₃)	7	16	10-24
	Oil and grease	3	-	0
	Nitrogen, dissolved (N)	1	-	0.22
	Nitrogen, organic dissolved (N)	3	.24	0.13-0.38
	Nitrogen, ammonia dissolved (N)	3	.03	0.01-0.07
	Nitrogen, nitrite dissolved (N)	3	.003	0-0.01
	Nitrogen, nitrate dissolved (N)	3	.20	0.08-0.31
	Nitrogen, ammonia + organic suspended total (N)	3	.09	0-0.22
	Nitrogen, nitrite + nitrate dissolved (N)	3	.10	0.08-0.31
	Nitrogen, ammonia + organic total (N)	3	.36	0.18-0.67
	Phosphorus, total (P)	3	.007	0-0.01
	Phosphorus, ortho dissolved (P)	3	.003	0-0.01
	Carbon, organic dissolved (C)	3	4.5	1.5-10
	Hardness, (as CaCO ₃)	7	280	250-300
	Hardness, (as noncarbonate CaCO ₃)	7	30	17-50
	Calcium, dissolved (Ca)	7	45	38-55
	Magnesium, dissolved (Mg)	7	40	38-44
	Sodium, dissolved (Na)	7	15	13-20
	Sodium-adsorption-ratio	7	.4	0.3-0.5
	Potassium, dissolved (K)	7	2.8	1.9-6.1
	Chloride, dissolved (Cl)	7	9.4	8.5-11
	Sulfate, dissolved (SO ₄)	7	50	40-61
	Fluoride, dissolved (F)	3	.1	0.1-0.2
	Silica, dissolved (SiO ₂)	7	6.8	6.5-7.0
Micrograms per liter	Arsenic, dissolved (As)	3	-	1
	Boron, dissolved (B)	3	50	30-60
	Chromium, dissolved (Cr)	3	-	0
	Iron, dissolved (Fe)	3	7	0-10
	Lead, dissolved (Pb)	3	50	0-130
	Manganese, dissolved (Mn)	3	1.7	< 1-2
	Strontium, dissolved (Sr)	3	330	300-370
	Zinc, dissolved (Zn)	3	-	< 3
	Lithium, dissolved (Li)	3	17	10-20
	Selenium, dissolved (Se)	3	-	1
	Phenols	3	1	0-3
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	2	-	13-24
	Streptococci, fecal	2	-	81-2,000

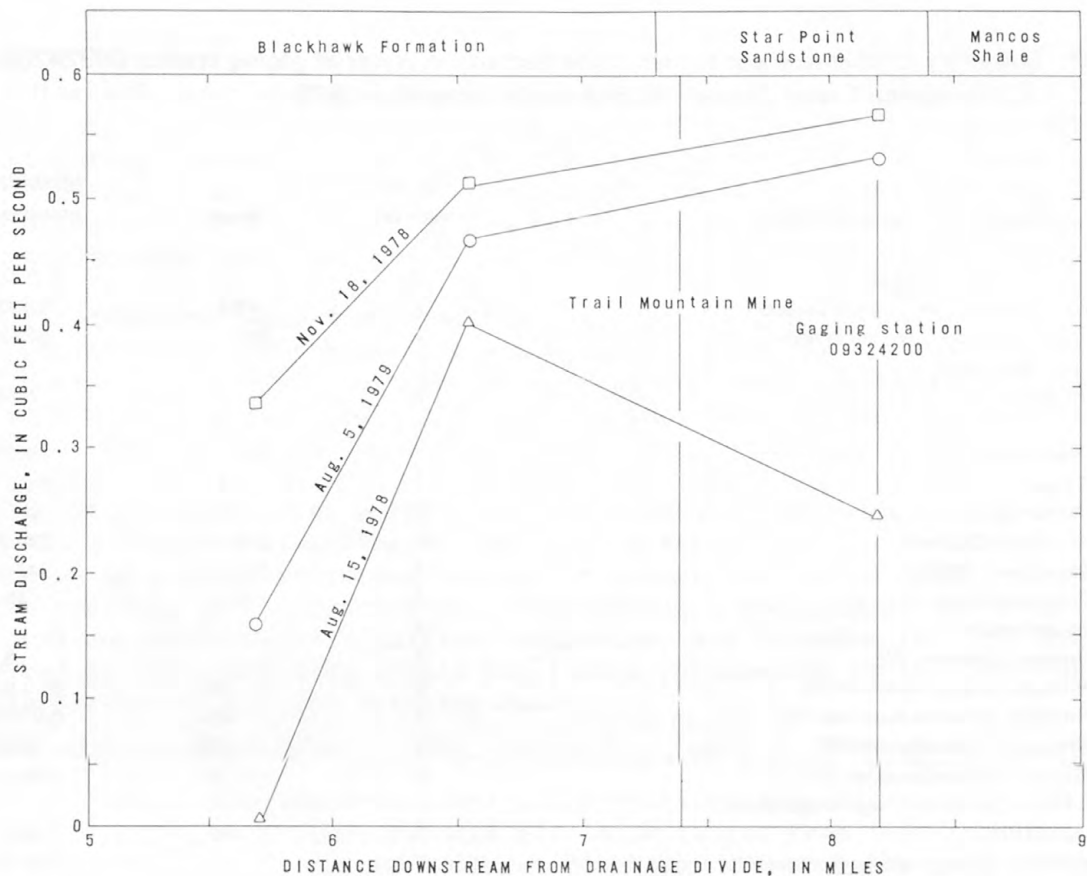


Figure 26.— Base flow of Cottonwood Creek and its relationship to geology and mining activities.

DIRTY DEVIL RIVER BASIN

Quitcupah Creek and Christiansen Wash

Quitcupah Creek originates on the Flagstaff Limestone in the southern part of the Wasatch Plateau at an altitude of about 10,400 ft. The gaging station (09331900) is on the Ferron Sandstone Member of the Mancos Shale near the Emery Mine at an altitude of about 5,900 ft. Drainage area at the station is 104 mi² (pl. 1).

Christiansen Wash, a tributary to Quitcupah Creek, originates on the Wasatch Plateau on the Castlegate Sandstone at an altitude of about 8,750 ft. The gaging station on Christiansen Wash (09331950) is on the Ferron Sandstone Member about 0.25 mi upstream from the mouth at an altitude of about 5,920 ft. Drainage area of Christiansen Wash at the gage is 13.6 mi² (pl. 1).

In the Quitcupah Creek drainage in the Wasatch Plateau, about 6,400 acres of Federal coal was leased during 1979; coal in the remainder of the basin was approximately 80 percent unleased Federal coal and 20 percent State and privately owned. In the Emery coal field, approximately 1,600 acres of

Federal coal was leased during 1979 in the Quitchupah Creek and Christiansen Wash drainages upstream from the gaging stations. A surface coal mine has been proposed for 430 acres immediately upstream from the station on Christiansen Wash.

During 1979, coal was mined with underground techniques in the Quitchupah Creek drainage in the Wasatch Plateau at the Convulsion Canyon Mine (operated by Coastal States Energy Co.) and in the Emery coal field at the Emery Mine (operated by Consolidation Coal Co.). Both mines produced more water than could be consumed by the mining operations. Total discharge from the Convulsion Canyon Mine is unknown, but it has been measured at more than $0.2 \text{ ft}^3/\text{s}$. A sample of water collected in September 1976 from the Convulsion Canyon Mine contained 276 mg/L of dissolved solids (Waddell and others, 1979, table 9), and a sample collected in May 1979 contained 394 mg/L. In both samples, the predominant dissolved chemical constituents were magnesium, calcium, and bicarbonate.

Discharge from the Emery Mine averaged about $0.7 \text{ ft}^3/\text{s}$ during 1979 (G. C. Lines and D. J. Morrissey, written commun., 1980). The water discharged from the Emery Mine is of poor chemical quality. A sample collected in September 1976 contained 5,100 mg/L of dissolved solids (Waddell and others, 1979, table 9), and samples collected in February and September 1979 contained 4,780 and 3,040 mg/L (G. C. Lines and D. J. Morrissey, written commun., 1980). In all three samples, the predominant dissolved chemical constituents were sodium and sulfate.

Discharges at stations 09331900 and 09331950 on Quitchupah Creek and Christiansen Wash during the 1979 water year are shown in figures 27 and 28. Discharge records are rated as fair at station 09331900 and good at station 09331950, except during periods of ice effect, when they are poor at both stations. Daily discharge at the station on Quitchupah Creek ranged from $1.1 \text{ ft}^3/\text{s}$ during several days in October 1978 to $45 \text{ ft}^3/\text{s}$ on November 2, 1978; and it averaged $6.73 \text{ ft}^3/\text{s}$. Runoff in the Quitchupah Creek basin averaged $0.06 (\text{ft}^3/\text{s})/\text{mi}^2$ during the 1979 water year. Daily discharge at the station on Christiansen Wash ranged from $0.43 \text{ ft}^3/\text{s}$ on January 7, 1979 to $20 \text{ ft}^3/\text{s}$ on May 6, 1979; and it averaged $2.75 \text{ ft}^3/\text{s}$. Runoff in the Christiansen Wash basin averaged $0.20 (\text{ft}^3/\text{s})/\text{mi}^2$ during the 1979 water year. Flow at the two stations is quite variable because of irrigation and the extended snowmelt period that begins in the lower part of both basins in the winter.

Both Quitchupah Creek and Christiansen Wash are perennial streams at the gaging stations, but west of about U.S. Highway 10 Christiansen Wash is ephemeral and flows only in response to thunderstorms or snowmelt. Base-flow measurements made on Quitchupah Creek, shown in figure 29, indicate that the discharge increases where the stream crosses the Mancos Shale, except in the reach upstream from U.S. Highway 10 when water is diverted for irrigation. The gains in streamflow at the times when measurements were made were due mainly to the return of irrigation water (ground-water seepage and overland flow); at other times, mine discharge was a significant part of the flow at the gaging station.

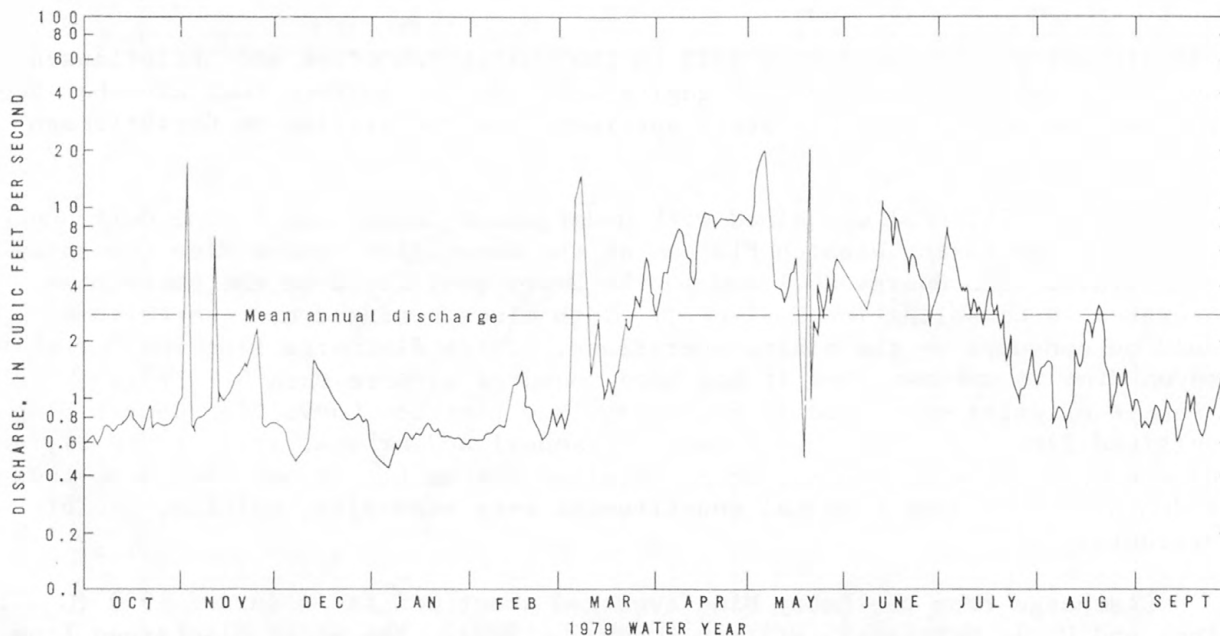


Figure 28.— Discharge in Christiansen Wash at gaging station 09331950, 1979 water year.

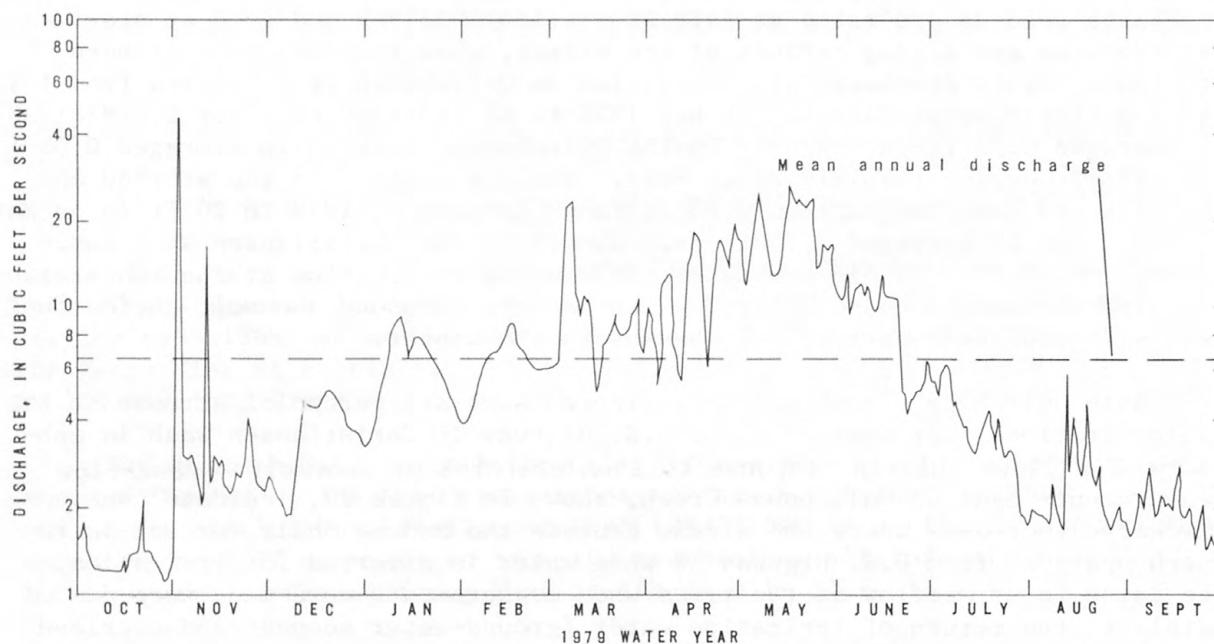


Figure 27.— Discharge of Quitchupah Creek at gaging station 09331900, 1979 water year.

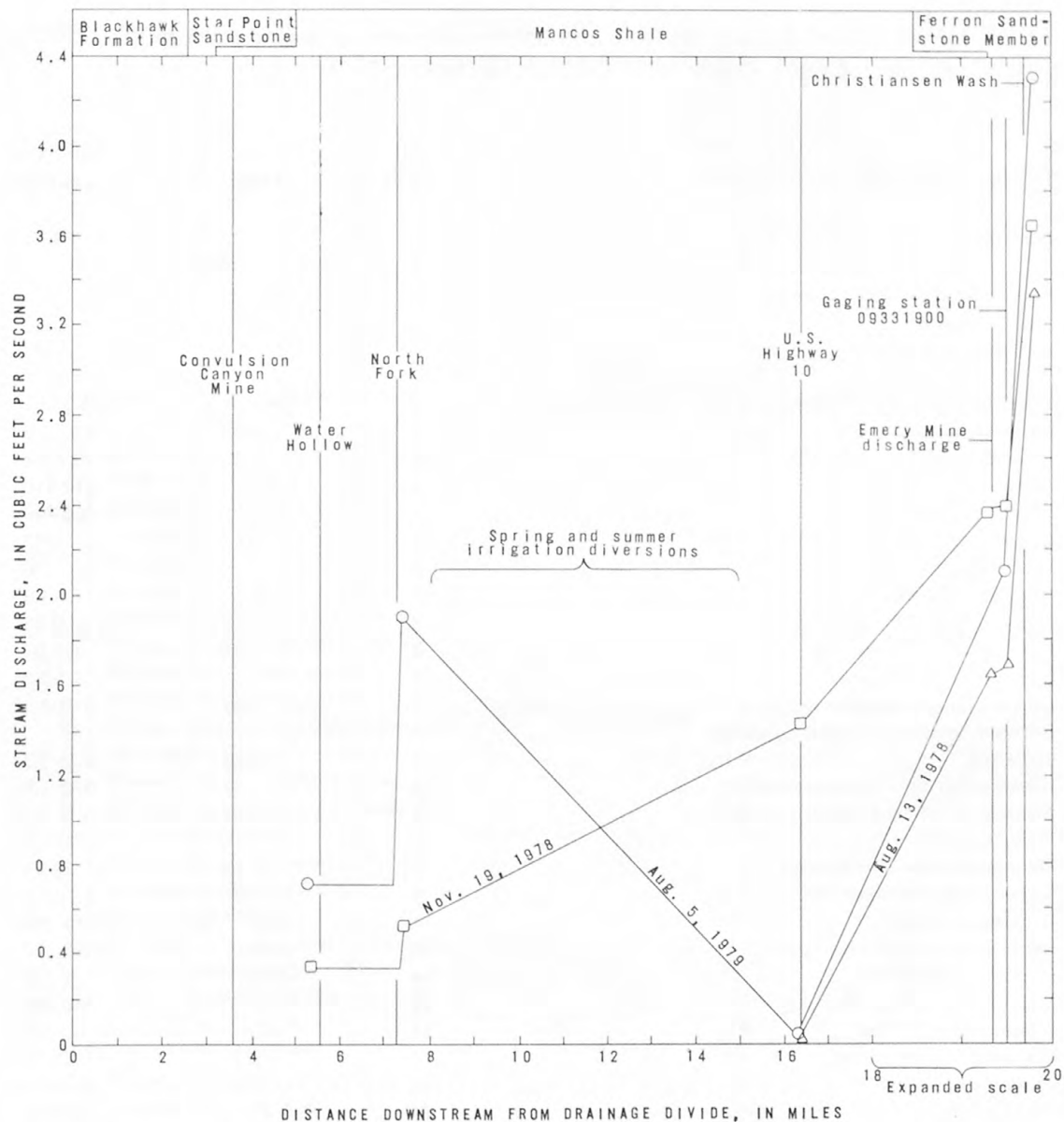


Figure 29.— Base flow of Quitchpah Creek and its relationship to geology and mining activities.

Chemical analyses of water collected at stations 09331900 and 09331950 are summarized in tables 12 and 13. The chemical quality of water at both sites varied considerably. Observed dissolved-solids concentrations varied from 696 to 3,960 mg/L in Quitchpah Creek and from 582 to 4,470 mg/L in Christiansen Wash. As shown in figure 30, dissolved-solids concentrations generally were inversely related to stream discharge at the station on Quitchpah Creek. Dissolved-solids concentrations were lower during the winter and spring because of snowmelt runoff and the absence of irrigation. During the irrigation season in the summer and fall, dissolved-solids concentrations increased with the addition of mainly dissolved sodium and sulfate.

Table 12.--Summary of chemical constituents and bacteria in water at gaging station 09331900 on Quitchupah Creek, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Milligrams per liter	Discharge (cubic feet per second)	14	-	1.4-13
	Water temperature (degrees Celsius)	14	13.0	0.0-26.0
	Specific conductance (micromhos per centimeter)	13	2,150	1,080-4,030
	pH (units)	14	-	8.1-8.8
	Dissolved solids, sum of constituents	14	1,660	696-3,960
	Oxygen, dissolved (O ₂)	14	9.0	6.3-11.8
	Carbon dioxide, dissolved (CO ₂)	14	2.3	0.7-4.2
	Alkalinity (CaCO ₃)	14	300	212-410
	Bicarbonate (HCO ₃)	14	357	250-496
	Carbonate (CO ₃)	14	4	0-12
	Oil and grease	5	-	0
	Nitrogen, dissolved (N)	3	1.3	1.0-1.9
	Nitrogen, organic dissolved (N)	5	.39	0.24-0.57
	Nitrogen, ammonia dissolved (N)	5	.01	0-0.03
	Nitrogen, nitrite dissolved (N)	5	.2	0.1-0.2
	Nitrogen, nitrate dissolved (N)	5	.97	0.41-1.5
	Nitrogen, ammonia + organic suspended total (N)	5	.56	0.13-1.3
	Nitrogen, nitrite + nitrate dissolved (N)	5	.97	0.42-1.5
	Nitrogen, ammonia + organic total (N)	5	.97	0.44-1.7
	Phosphorus, total (P)	5	.36	0.11-0.85
	Phosphorus, ortho dissolved (P)	5	.02	0-0.04
	Carbon, organic dissolved (C)	5	7.3	2.7-13.0
	Hardness, (as CaCO ₃)	14	630	350-1,700
	Hardness, (as noncarbonate CaCO ₃)	14	330	110-1,300
	Calcium, dissolved (Ca)	14	120	72-230
	Magnesium, dissolved (Mg)	14	84	40-280
	Sodium, dissolved (Na)	14	300	99-700
	Sodium-adsorption-ratio	14	5.1	2.3-12
	Potassium, dissolved (K)	14	5.7	0.9-17.0
	Chloride, dissolved (Cl)	14	62	21-120
	Sulfate, dissolved (SO ₄)	14	900	280-2,500
	Fluoride, dissolved (F)	5	.5	0.4-1.0
	Silica, dissolved (SiO ₂)	14	8.5	6.3-14.0
Micrograms per liter	Arsenic, dissolved (As)	5	1	0-2
	Boron, dissolved (B)	5	290	20-680
	Chromium, dissolved (Cr)	5	8	0-20
	Iron, dissolved (Fe)	5	14	10-20
	Lead, dissolved (Pb)	5	8	0-38
	Manganese, dissolved (Mn)	5	16	10-20
	Strontium, dissolved (Sr)	5	2,200	900-4,800
	Zinc, dissolved (Zn)	5	10	0-20
	Lithium, dissolved (Li)	5	110	50-180
	Selenium, dissolved (Se)	5	4	2-5
	Phenols	4	1.5	0-3
	Bacteria (colonies per 100 milliliters)			
	Coliform, fecal	5	310	10-1,100
	Streptococci, fecal	5	4,100	160-17,000

Table 13.--Summary of chemical constituents and bacteria in water at gaging station 09331950 in Christiansen Wash, August 1978 through September 1979

Parameters and constituents		No. of analyses	Mean	Minimum-maximum
Discharge (cubic feet per second)		14	-	0.65-11
Water temperature (degrees Celsius)		14	8.5	0.0-20.0
Specific conductance (micromhos per centimeter)		14	3,270	910-5,550
pH (units)		14	-	8.1-8.7
Milligrams per liter	Dissolved solids, sum of constituents	14	2,400	582-4,470
	Oxygen, dissolved (O ₂)	14	9.8	7.8-11.8
	Carbon dioxide, dissolved (CO ₂)	14	2.8	1.3-6.0
	Alkalinity (CaCO ₃)	14	330	180-430
	Bicarbonate (HCO ₃)	14	400	210-514
	Carbonate (CO ₃)	14	6	0-18
	Oil and grease	5	.2	0-1
	Nitrogen, dissolved (N)	3	7.9	3.1-11
	Nitrogen, organic dissolved (N)	5	1.3	0.45-1.8
	Nitrogen, ammonia dissolved (N)	5	.02	0-0.06
	Nitrogen, nitrite dissolved (N)	5	.06	0.03-0.08
	Nitrogen, nitrate dissolved (N)	5	11.8	1.6-23
	Nitrogen, ammonia + organic suspended total (N)	5	.7	0-1.5
	Nitrogen, nitrite + nitrate dissolved (N)	5	11.8	1.6-23
	Nitrogen, ammonia + organic total (N)	5	2.0	0.67-3.2
	Phosphorus, total (P)	5	.19	0.02-0.48
	Phosphorus, ortho dissolved (P)	5	.01	0-0.03
	Carbon, organic dissolved (C)	5	16	11-24
	Hardness, (as CaCO ₃)	14	1,100	280-1,700
	Hardness, (as noncarbonate CaCO ₃)	14	740	98-1,300
	Calcium, dissolved (Ca)	14	160	53-260
	Magnesium, dissolved (Mg)	14	160	35-300
	Sodium, dissolved (Na)	14	370	97-720
	Sodium-adsorption-ratio	14	4.7	2.4-7.6
	Potassium, dissolved (K)	14	8.0	2.7-17
	Chloride, dissolved (Cl)	14	63	11-150
	Sulfate, dissolved (SO ₄)	14	1,400	270-2,900
	Fluoride, dissolved (F)	5	.6	0.4-0.7
	Silica, dissolved (SiO ₂)	14	10	5.5-15
Micrograms per liter	Arsenic, dissolved (As)	5	.6	0-1
	Boron, dissolved (B)	5	380	200-590
	Chromium, dissolved (Cr)	5	6	0-20
	Iron, dissolved (Fe)	5	30	20-50
	Lead, dissolved (Pb)	5	14	0-59
	Manganese, dissolved (Mn)	5	120	10-270
	Strontium, dissolved (Sr)	5	2,040	1,100-2,900
	Zinc, dissolved (Zn)	5	16	10-20
	Lithium, dissolved (Li)	5	260	110-370
	Selenium, dissolved (Se)	5	26	3-60
	Phenols	5	1.8	0-5
Bacteria (colonies per 100 milliliters)				
Coliform, fecal		5	420	5-900
Streptococci, fecal		5	10,400	125-37,000

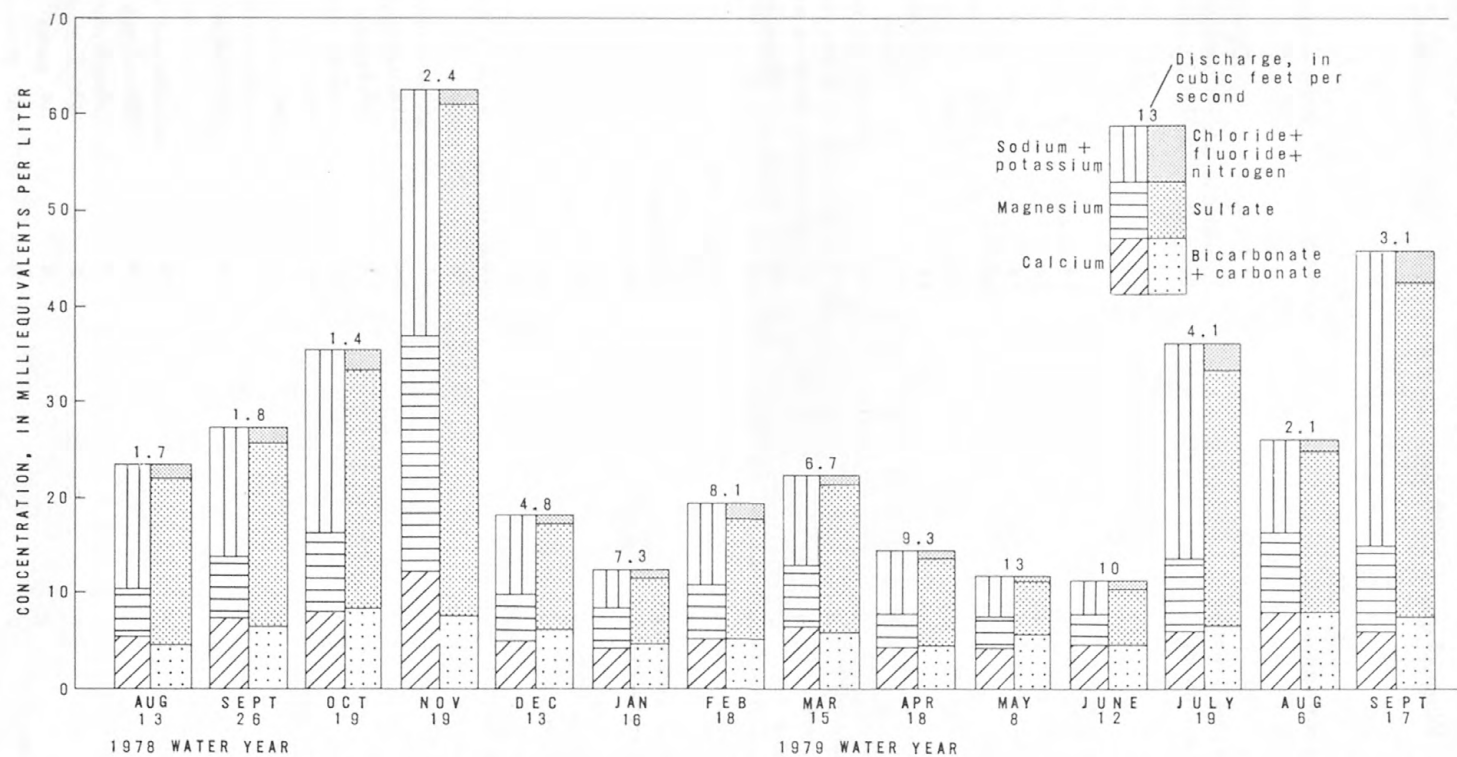


Figure 30.—Relationship of major dissolved chemical constituents and discharge of Quitchupah Creek at gaging station 09331900, August 1978–September 1979.

Concentrations of strontium averaged about 2 mg/L in water at both stations, which is a larger amount than is normally present in surface water in the United States (Hem, 1970, p. 196). Selenium also was present in relatively large concentrations in Christiansen Wash. Both the strontium and selenium are probably derived from leaching of saline rocks in the Mancos Shale, which underlies much of both stream basins.

Eighteen suspended-sediment samples were collected at the station on Quitchupah Creek from August 1978 through September 1979. The observed suspended-sediment concentrations ranged from 111 mg/L on August 24, 1978, during a period of base flow, to 30,200 mg/L on March 6, 1979, during a period of snow-melt. Observed suspended-sediment discharge in Quitchupah Creek ranged from 0.18 to 4,120 tons per day on the same dates. Twelve suspended-sediment samples were collected at the station in Christiansen Wash, and concentrations ranged from 3 mg/L on August 24, 1978, to 2,540 mg/L on March 6, 1979. Observed suspended-sediment discharge ranged from 0.01 to 326 tons per day. Suspended-sediment discharge generally increases with stream discharge at both stations (G. C. Lines and D. J. Morrissey, written commun., 1980), but the relationship is not well enough defined to compute daily sediment discharges.

Benthic invertebrates collected at the stations on Quitchupah Creek and Christiansen Wash are listed in table 2. The relatively small diversity of organisms at both sites reflects the poor quality of water in the streams.

A study of the ground-water system in the Emery coal field indicates that dewatering of the Emery Mine has lowered the potentiometric surface in the upper part of the Ferron Sandstone Member several tens of feet in the area near the mine (G. C. Lines and D. J. Morrissey, written commun., 1980). Declining water levels in wells that tap the Ferron in the Emery area indicate that much of the water discharged from the mine has been derived from storage in the aquifer. A digital-computer model of the system (Morrissey and others, 1980) indicates that some of the mine discharge has been balanced by an increase in subsurface recharge, but natural discharge from the aquifer along streams probably has not changed significantly. Land subsidence at the Emery Mine apparently has not been a problem through 1979.

CONCLUSIONS

Coal mining has affected the water resources of the coal fields of central Utah. However, hydrologic changes often are not detectable (or at least cannot be quantified) with the existing monitoring network and current understanding of the hydrologic system. Some impacts, such as a major degradation of surface-water quality due to mine discharge, could be detected in most areas. The degree of degradation, however, could not be quantified in most instances due to a lack of information on the quantity and quality of mine discharges. Other impacts, such as the diminution of spring discharge, could probably only be detected if the change was on the order of 10 to 20 percent of the base flow at the gaging station. If the change in spring flow were great enough, base-flow measurements throughout a monitored basin probably would indicate the general area that had been impacted; but the diminution of flow of individual springs could not be quantified in most cases.

Water discharged from underground mines produces many of the same changes in the hydrologic system as do discharging wells. Theis (1957, p. 3) points out that water discharged from a well must be balanced by an increase in recharge to the ground-water system, by a decrease in natural discharge from the system, by a decrease of ground water in storage, or by a combination of all these. Ground-water storage has been depleted around all water-producing mines in the region; although except for the Emery Mines, historic water-level data are not available to define the extent and degree of the depletion.

Land subsidence and rock fracturing above underground mines also have the potential to change the natural ground-water flow system and recharge-discharge relationships. Diminution of spring flow could infringe upon prior rights to the water. Full assessment of the impacts of mine dewatering on springs and the base flow of streams requires a more thorough understanding of the ground-water system than is currently available for most areas.

The water discharged from underground mines in the region is of poorer chemical quality during most periods of the year than the surface water upstream from points of mine discharge. It is not known, however, how much of the mine water would naturally have been discharged through springs and seeps and what would have been its quality.

In some areas, such as along the lower reaches of Grassy Trail Creek and Horse Canyon, streamflow apparently has been significantly increased by mine discharges. Here too, the degree of change is uncertain as premining-streamflow conditions are not known. The land surface above underground mines in the Wasatch Plateau and Book Cliffs may have subsided, resulting in an increase in natural recharge that may have served to balance a large proportion of the water discharged from the mines. However, the degree of hydraulic connection between the coal-bearing Blackhawk Formation and overlying water-bearing zones, and how this connection might be changed by subsidence, are not known.

In 1980, four additional stations were added to the monitoring network in Eccles Canyon near Scofield (09310800), on Willow Creek near Castle Gate (09312900), on the Price River near Martin (09313000), and on Dugout Creek near Sunnyside (09313985). At the beginning of the 1981 water year a station was added to the network in Convulsion Canyon near Emery (09331850); stations also were added on Thompson Creek (09403670) and Sink Valley Wash (09403950), both near Glendale in the Alton coal field about 120 mi southwest of Emery.

Continued monitoring of discharge and water quality at all stations should be useful in detecting major changes that may occur in the future, particularly in basins yet to be extensively mined. Minor changes in water quality probably can be detected and quantified only with monitoring of mine discharges. To fully assess hydrologic impacts throughout a mine basin, comprehensive studies are needed to define aquifer characteristics, potentiometric surfaces, directions of ground-water movement, hydraulic connection between water-bearing zones, and recharge-discharge relationships. Monitoring of water levels in properly constructed observation wells that each tap a single water-bearing zone is needed near mines in the Wasatch Plateau and Book Cliffs. A detailed study of the past and present occurrence and quality of water in the underground mines also is needed.

REFERENCES CITED

- Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 1473, 363 p.
- Lium, B. W., 1974, Some aspects of aquatic insect population of pools and riffles in gravel bed streams in Western United States: U.S. Geological Survey Journal of Research, v. 2. no. 3, p. 379-384.
- Lupton, C. T., 1916, Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier Counties, Utah: U.S. Geological Survey Bulletin 628, 88 p.
- McKee, J. E., and Wolf, H. W., 1963, Water quality criteria: California State Water Resources Control Board Publication 3A [2d ed.], 548 p.
- Morrissey, D. J., Lines, G. C., and Bartholoma S. D., 1980, Three-dimensional digital-computer model of the Ferron sandstone aquifer near Emery, Utah: U.S. Geological Survey Water-Resources Investigations 80-62, 101 p.
- Mundorff, J. C., 1972, Reconnaissance of chemical quality of surface water and fluvial sediment in the Price River basin, Utah: Utah Department of Natural Resources Technical Publication 39, 55 p.
- _____, 1979, Reconnaissance of chemical quality of surface water and fluvial sediment in the Dirty Devil River basin, Utah: Utah Department of Natural Resources Technical Publication 65, 123 p.
- Sumsion, C. T., 1979, Selected coal-related ground-water data, Wasatch Plateau-Book Cliffs areas, Utah: U.S. Geological Survey Open-File Report 79-915 (duplicated as Utah Basic-Data Report 32), 25 p.
- Theis, C. V., 1957, The source of water derived from wells, essential factors controlling the response of an aquifer to development: U.S. Geological Survey Ground Water Notes 34, 16 p. (published in 1940 by American Society of Civil Engineering in Civil Engineering, p. 277-280).
- U.S. Environmental Protection Agency, 1976, National interim primary drinking water regulations: Washington, D.C., U.S. Government Printing Office, 159 p.
- U.S. Geological Survey, 1980, Water resources data for Utah, water year 1979: Water-Data Report UT-79-1, 604 p.
- U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Publications 956, 61 p.
- U.S. Weather Bureau, [1963], Normal annual and May-September precipitation (1931-60) for the State of Utah: Map of Utah, scale 1:500,000.

- Waddell, K. M., Contratto, P. K., Sumsion, C. T., and Butler, J. R., 1979, Hydrologic reconnaissance of Wasatch Plateau-Book Cliffs coal-fields area, Utah: U.S. Geological Survey Open-File Report 79-988, 85 p. (to be duplicated as Water-Supply Paper 2068).
- Waddell, K. M., Vickers, H. L., Upton, R. T., and Contratto, P. K., 1978, Selected hydrologic data, 1931-77, Wasatch Plateau-Book Cliffs coal-fields area, Utah: U.S. Geological Survey Open-File Report 78-121 (duplicated as Utah Basic-Data Release 31), 33 p.
- Williams, P. L., and Hackman, R. J., 1971, Geology, structure and uranium deposits of the Salina Quadrangle, Utah: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-591, scale 1:250,000, 2 sheets.
- Witkind, I. J., Lidke, D. J., and McBroome, L. A., 1978, Preliminary geologic map of the Price $1\frac{1}{4} \times 2\frac{1}{4}$ Quadrangle, Utah: U.S. Geological Survey Open-File Report 78-465, scale 1:250,000, 2 sheets.

DEPARTMENT OF T
UNITED STATES (

20
S.

*Hemib
Res
S Fk Mude*

39°00'—

T.
21
S.



USGS LIBRARY-RESTON



3 1818 00070209 0