QUANTITY AND QUALITY OF STREAMFLOW IN THE WHITE RIVER BASIN, COLORADO AND UTAH

By Jeanne M. Boyle, Kenneth J. Covay, and Daniel P. Bauer

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Dallas L. Peck, Director

For additional information write to:

Colorado District Chief
U.S. Geological Survey
Box 25046, Mail Stop 415
Denver Federal Center
Lakewood, CO 80225

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

For the convenience of readers who may want to use International System of Units (SI), the data may be converted using the following factors:

Multiply inch-pound units	*By*	*To obtain SI units*
barrel (petroleum, 1 barrel = 42 gallons)	0.1590	cubic meter
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
cubic foot per second	0.02832	cubic meter per second
cubic foot per second per square mile	0.01093	cubic meter per second per square kilometer
ton (short)	0.9072	megagram

Degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ °C+32$$

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The water quality and flow of existing streams in the White River basin, located in northwestern Colorado and northeastern Utah, are adequate for present uses, but future development (such as energy) may affect stream quality and quantity. This paper describes present conditions as a baseline to enable planners to allocate available water and to measure changes in quantity and quality of water in the future. The White River basin contains extensive energy resources consisting of oil, natural gas, coal, and oil shale. Large quantities of water will be required for energy-resource development and associated municipal and industrial uses.

An average of 70 percent of the annual flow in the White River occurs during May, June, and July as a result of snowmelt runoff. The annual flow in Piceance Creek, a tributary to the White River, has a more uniform distribution throughout each year. The 7-day, 10-year low-flow discharges per square mile and the 1-day, 25-year high-flow discharges per square mile are larger in the eastern part of the basin than in the western part. Flow-duration curves indicate that high flows in the White River and the North and South Fork White Rivers result mainly from snowmelt runoff and that base flow is sustained throughout the year by ground-water discharge from the alluvial and bedrock aquifers. Tributaries to the White River have high flows resulting from snowmelt runoff and thunderstorm activity. The base flow is sustained primarily by discharge from springs.

Water type varies in the basin; however, calcium and sodium are the dominantly occurring cations and sulfate and bicarbonate are the dominantly occurring anions. Computed total annual dissolved-solids loads in the White River range from 31,800 tons per year in the North Fork White River to 284,000 tons per year at the mouth. These dissolved-solids loads were estimated using a relation with daily discharge but also can be estimated using a relation with specific conductance. Oil-shale development could change the dissolved-solids loads and concentrations in the basin. A 10-percent increase to a 14-percent decrease of the dissolved-solids load could result at the mouth of the White River near Ouray, Utah. This corresponds to a 5-percent increase to a 10-percent decrease in dissolved-solids concentration. The seasonal pattern of stream temperatures was found to fit a harmonic curve.

page 3 follows

Harmonic-mean temperature, amplitude, and the phase angle for 20 stations were estimated by regression analysis. Harmonic-mean temperature (*HM*) and amplitude (*A*) were found to be related to average basin elevation (*X*) by the equations: $HM = 22.8-(0.0018 \times X)$ and $A = 18.0-(0.0011 \times X)$. Water temperature also was found to be directly related to air temperature. Suspended-sediment discharge in the basin ranges from 0.24 ton per day at a discharge of 90 cubic feet per second in the South Fork White River at Buford to 130,000 tons per day at a discharge of 1,150 cubic feet per second in the White River upstream from Rangely. Seven chemical constituents (alkalinity, calcium, chloride, magnesium, potassium, sodium, and sulfate) at five stations on the White River were regressed against discharge and specific conductance. The standard errors of estimate ranged from 6.3 to 95.1 percent. Benthic invertebrates sampled at six stations indicate that the upstream reaches of the White River are not polluted.

1.0 INTRODUCTION

1.1 Objective

ASSESSMENT OF SURFACE-WATER RESOURCES WAS MADE SO POTENTIAL ENVIRONMENTAL EFFECTS CAN BE EVALUATED

Current stream quantity and quality data are presented to describe the surface-water hydrology in the White River basin.

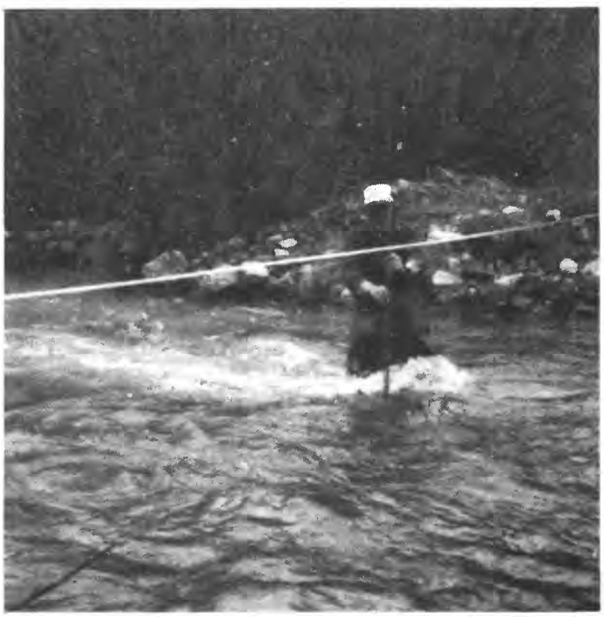
This report provides hydrologic information, using a brief text with accompanying maps, charts, graphs, or other illustrations for each of a series of water-resources related topics. The information is presented for use by State and county planners, consulting engineers, and mine operators.

The purpose of this report is to describe selected stream-quantity and stream-quality data within the White River basin. The report is part of a 4-year assessment of the White River basin from water years 1981 through 1984. The objectives of the 4-year assessment are: (1) To describe the hydrology of the basin prior to substantial energy development and (2) to evaluate some of the environmental effects of energy-resource development on the quantity and quality of the surface water. Photographs (fig. 1.1-1) show U.S. Geological Survey personnel collecting various types of hydrologic data.

There are continuing and increasing concerns regarding the water requirements for energy development within the Rocky Mountain region. The White River basin, as part of the Rocky Mountain region, contains large energy resources in the form of oil shale, coal, oil, and natural gas. Because of the present and anticipated development of these resources, large quantities of water will be required for mining, processing, transportation, and municipal and industrial uses. Increasing competition for available water is expected between agricultural operations, planned mining operations, and expanded municipal and industrial uses. It, therefore, becomes important to assess existing water-resource information to enable planners to allocate water based on the amount and quality of water available, and to establish a baseline from which to measure changes in quantity and quality of water in the future so to protect this resource.

Servicing a rain gage

Sampling bed material



Measuring streamflow by wading

Figure 1.1-1.--U.S. Geological Survey personnel collecting water-resource data.

AREA HAS EXTENSIVE ENERGY RESOURCES

The White River basin, located in northwestern Colorado and northeastern Utah, contains extensive reserves of oil shale, coal, oil, and natural gas.

Energy developments are taking place or are being planned in Colorado and Utah. Particular attention is focused on the White River basin because of extensive existing and planned energy-resource development that may affect surface-water quantity and quality. The White River basin is located in northwestern Colorado and northeastern Utah (fig. 1.2-1). The surface area of the basin is 5,120 square miles, 74 percent of which is in Colorado and 26 percent in Utah. The White River flows to the east and drains into the Green River in Utah. Most of the tributaries, such as the South Fork White River, Piceance Creek, and Yellow Creek, drain from the south into the White River.

Existing energy production from the area consists primarily of oil and natural gas, with some coal (fig. 1.2-2). Rio Blanco County, Colo., containing the Rangely oil and natural gas fields, ranks first in Colorado for production of these two resources. Two major coalfields of the area are the Dansforth Hills coalfield near Meeker, Colo., and the lower White River coalfield near Rangely, Colo. The coal from these areas primarily consists of a highly volatile bituminous type.

The most extensive underdeveloped natural resource in the basin is the extensive oil-shale deposits in the Green River Formation of Tertiary age. The Green River Formation is within the Piceance basin in Colorado, the Uinta basin in Utah, and the Green River and Washakie basins in Wyoming. Oil resources in these areas are about 2 trillion barrels (Donnell, 1965).

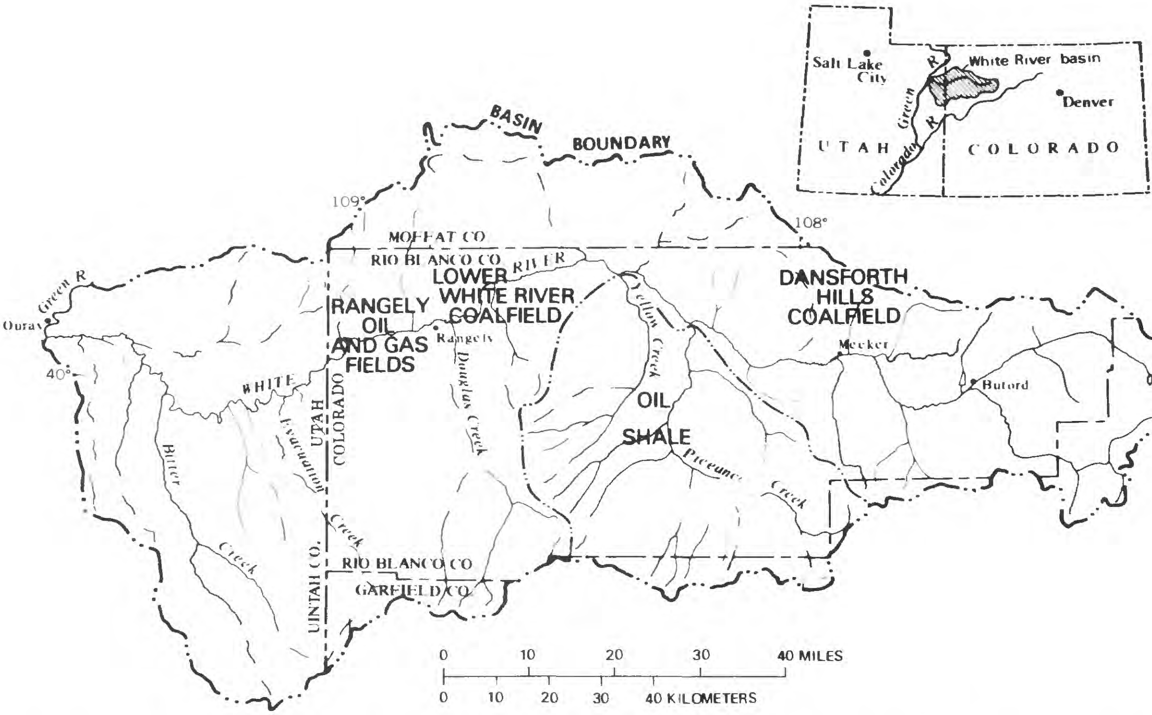


Figure 1.2-1.--Geographic features and location of energy resources.

Oil and gas field near Rangely, Colo.

Coal mine north of Meeker, Colo.

Oil-shale development at Tract Cb in the Piceance Creek basin near Rio Blanco, Colo.

Figure 1.2-2.--Energy-resources development.

2.0 GENERAL FEATURES

2.1 Geology

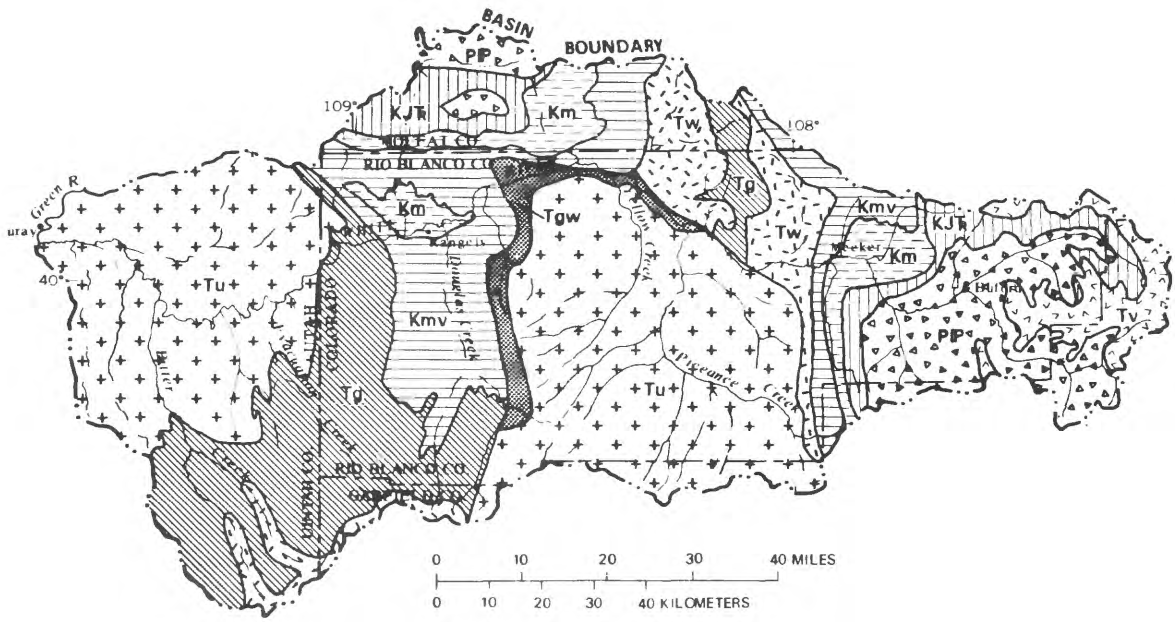
ROCKS RANGING IN AGE FROM PALEOZOIC TO CENOZOIC ARE EXPOSED IN BASIN

Paleozoic rocks are found mainly in the eastern part of the basin, Mesozoic rocks in the eastern and central part, and Tertiary rocks throughout the basin.

A generalized geologic map of the White River basin is shown in figure 2.1-1. Rock outcrops in the basin range in age from the Pennsylvanian Period of the Paleozoic era to the Tertiary Period of the Cenozoic Era.

Paleozoic rocks are comprised of Permian and Pennsylvanian sedimentary rocks. These rocks are exposed in the eastern and north-central part of the basin. Mesozoic sedimentary rocks include the Mesaverde Group and Mancos Shale of Cretaceous age. Coal deposits are found in the Mesaverde Group. Other Mesozoic rocks consist of Cretaceous, Jurassic, and Triassic sedimentary rocks. Mesozoic rocks are exposed in the eastern and central part of the basin.

The principal sedimentary formations of Tertiary age are the Wasatch, Green River, and Uinta Formations. These rocks occur in the central and western part of the basin. Rich oil-shale deposits are found in the Green River Formation of Utah and Colorado. Other Tertiary rocks consisting of basalt and mixed tuff and breccia also occur in the extreme eastern part of the basin.



EXPLANATION

ERA	DURATION (MILLIONS OF YEARS)	SYMBOL AND FORMATION
Cenozoic	63	Tv Tertiary volcanics Tu Uinta Formation Tg Green River Formation Tw Wasatch Formation Tgw Green River and Wasatch Formation, Undivided
Mesozoic	177	Kmv Mesaverde Group Km Mancos Shale KJTR Cretaceous, Jurassic, and Triassic sedimentary rocks
Paleozoic	330	PP Permian and Pennsylvanian sedimentary rocks

——— CONTACT

Figure 2.1-1.--Generalized bedrock geology.

PRECIPITATION IS VARIABLE IN THE AREA

Twenty-two inches of annual precipitation occurs in the eastern mountainous part of the basin and only about 7 inches occurs in the western semiarid part.

Average annual precipitation in the White River basin generally increases with elevation and ranges from about 7 inches in the west to about 22 inches in the east (fig. 2.2-1) (National Climatic Data Center, 1982). Monthly graphs of precipitation at four stations are shown to illustrate the west-to-east change. These extremes in precipitation result from the variation in elevation and the aspect of slopes for the area. The confluence of the White River and the Green River is at an elevation of only about 4,900 feet above sea level; however, the eastern boundary of the basin reaches elevations of more than 12,000 feet above sea level.

Precipitation in the basin consists primarily of snowfall in the winter months and thunderstorms in the summer months. Melting of accumulated snowfall, principally in the higher elevations, provides the main source of streamflow. The summer thunderstorms can occur as cloud bursts with intense, but short-duration precipitation, providing small quantities of runoff to sustain streamflow in the area.

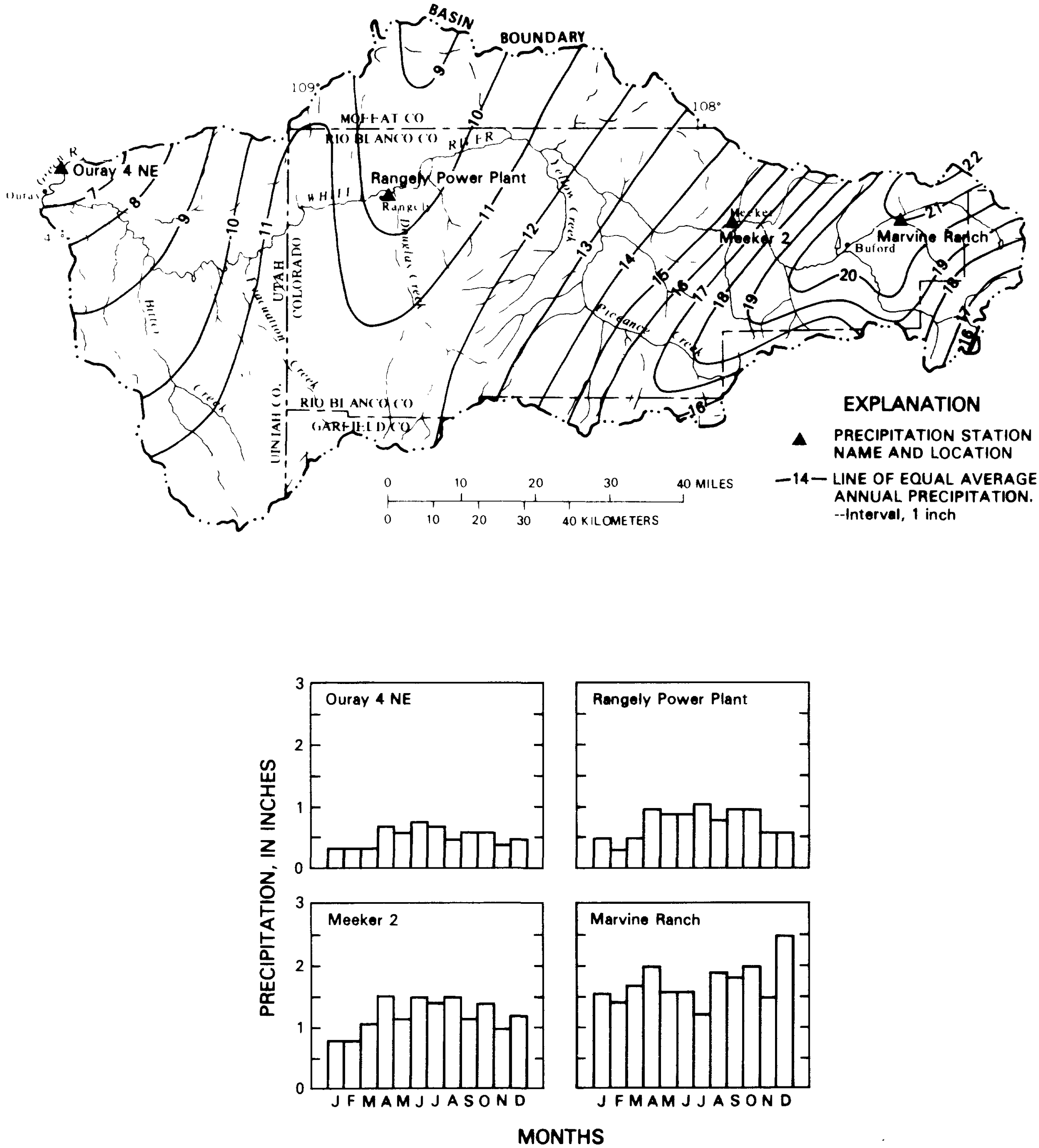


Figure 2.2-1.--Average annual precipitation and average monthly precipitation at four stations.

3.0 HYDROLOGIC NETWORK

SURFACE-WATER INFORMATION IS AVAILABLE FOR 95 LOCATIONS

The U.S. Geological Survey has collected surface-water quantity and quality information throughout the White River basin.

Discharge, chemical, sediment, or biological data are available for 95 stations in the White River basin. The location of the 95 surface-water hydrologic monitoring stations is shown in figure 3.0-1. Many of these stations were established to obtain hydrologic data from coal, oil, natural-gas, and oil-shale areas. Information about the drainage area, period of record, and type of data collected is summarized in section 8.0. The hydrologic data can be obtained from published U.S. Geological Survey annual reports "Water Resources Data for Colorado" and "Water Resources Data for Utah." The information also is readily available through the U.S. Geological Survey National Water Data Exchange (NAWDEX).

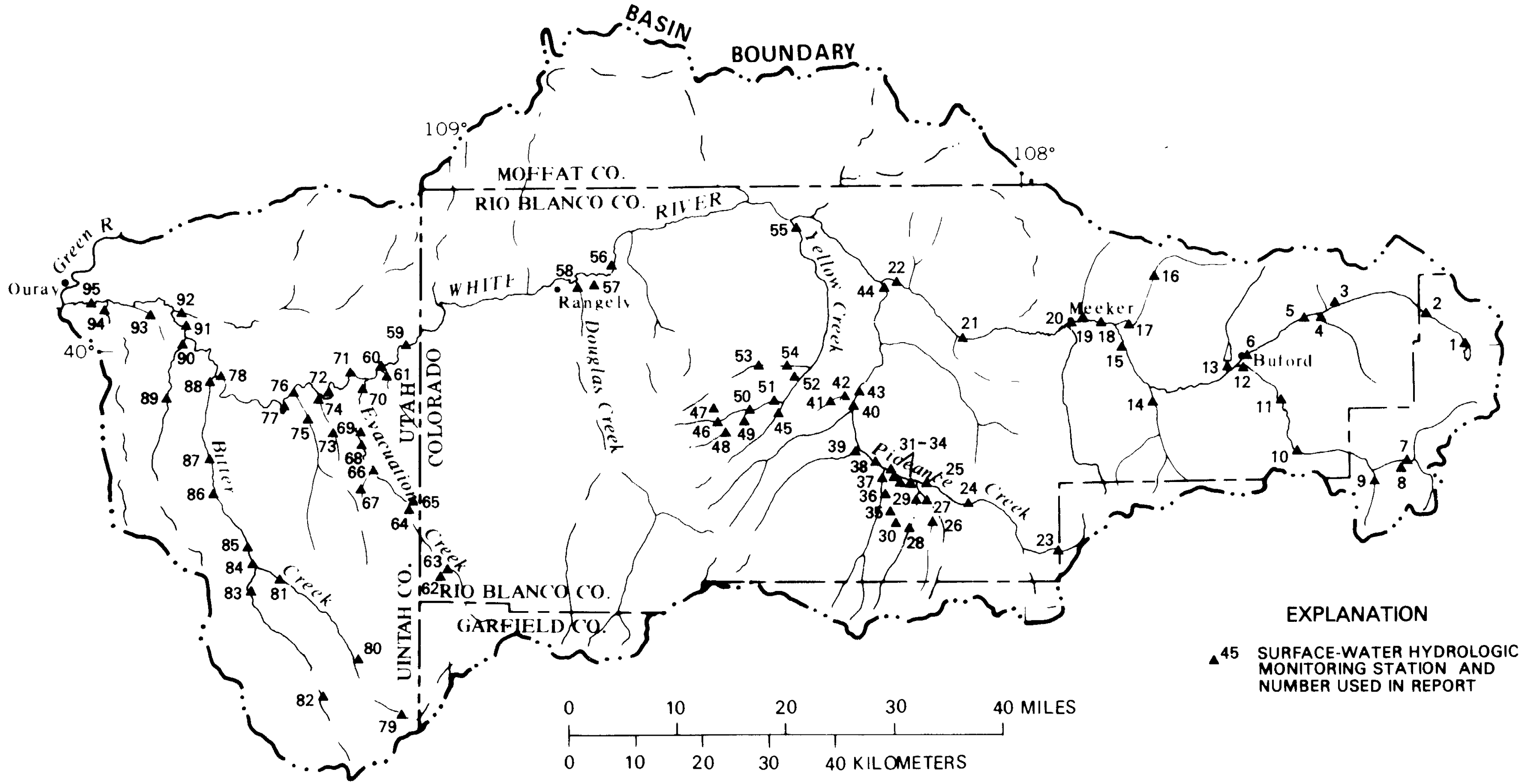


Figure 3.0-1.--Location of surface-water hydrologic monitoring stations.

4.0 QUANTITATIVE CHARACTERISTICS OF STREAMFLOW

4.1 Monthly Flow Variation

STREAMFLOW VARIES SEASONALLY IN MOST STREAMS

Most of the streamflow in the White River occurs during the spring. Streamflow in Piceance Creek is distributed more uniformly throughout the year.

Most streamflow within the White River basin occurs during the spring as a result of snowmelt runoff, as illustrated in figure 4.1-1. For example, at the mouth of the White River, about 65 percent of the annual flow occurs during May, June, and July; and upstream, 75 percent of the flow occurs in the South Fork White River, near Buford, Colo., during the period. The South Fork station is at a higher elevation, and the larger streamflow percentage reflects a greater contribution from snowmelt runoff. The monthly data summary for the Piceance Creek station illustrates a more uniform distribution of streamflow throughout each year and a less pronounced effect of snowmelt runoff in the spring.

A box plot provides a method to summarize a set of data in terms of a few easily obtained and understood numbers. The range of data is represented by its extremes, that is, the smallest and largest values. On the example plots of monthly streamflow (fig. 4.1-1), the extremes are depicted by the short horizontal lines at the ends of the dashed lines for each month. The median is shown as the horizontal line inside each box plot and the upper and lower boundaries of each box depict the 25th and 75th percentiles of the given monthly data. Twenty-five percent of the data values are less than the 25th percentile and 25 percent of the data values are greater than the 75th percentile. The differences between the percentile values and the median value indicate the distribution of the data about the median value.

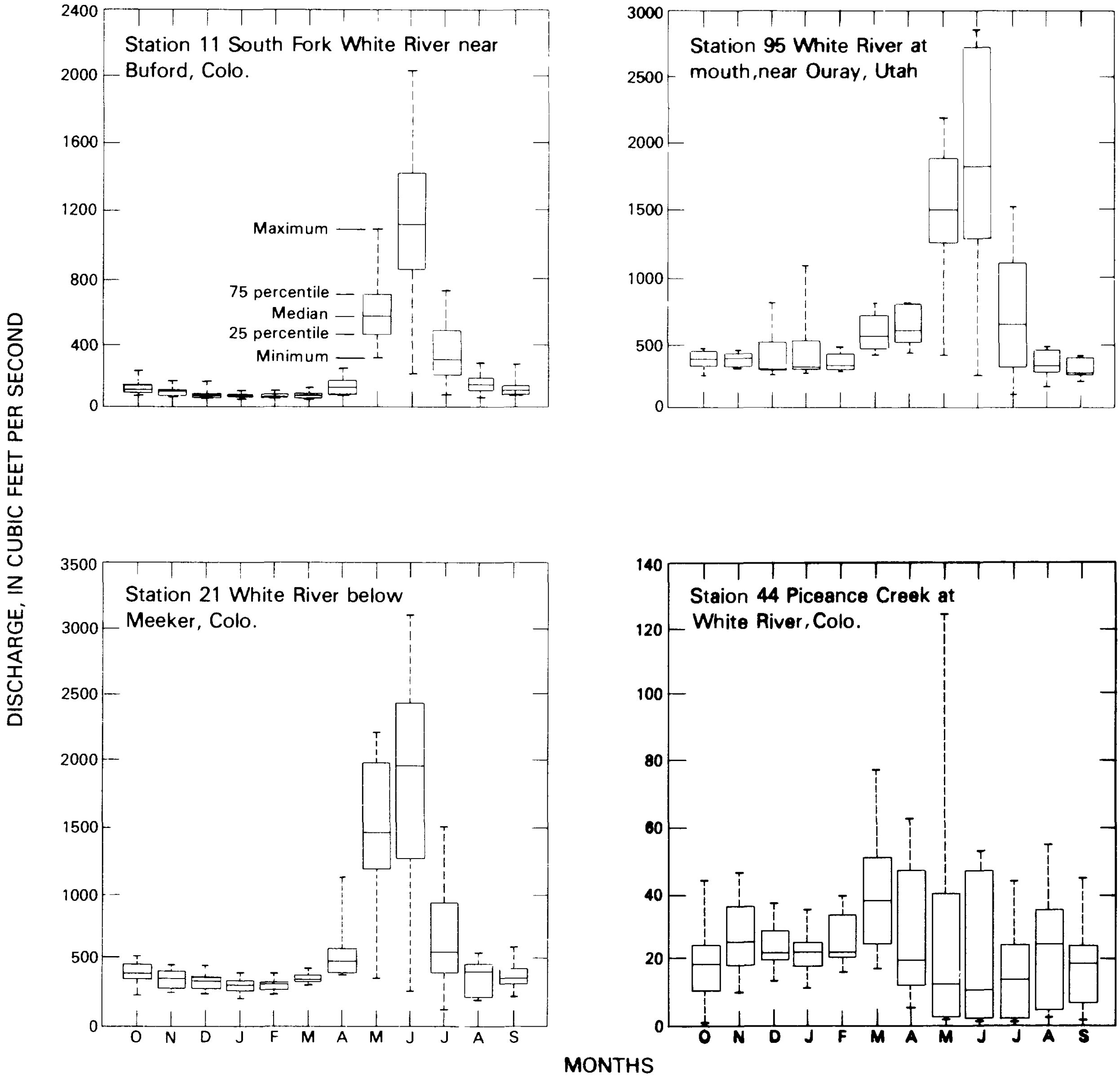


Figure 4.1-1. Discharge box plots showing seasonal variation of flow at four streamflow-gaging stations.

LOW-FLOW AND HIGH-FLOW CHARACTERISTICS VARY MARKEDLY

The low-flow values are smaller in the western part of the basin than in the eastern part. The high-flow values generally are larger for stations at lower elevations.

Areal variations of selected streamflow characteristics are indicated in table 4.2-1 for 25 mainstem and tributary stations in the White River basin. These stations were selected at various locations to represent a range of climatic, geologic, and vegetative conditions.

The average annual flow per square mile of drainage area varies considerably within the basin. The larger values generally are characteristic of streams at the higher elevations in the eastern part of the basin and primarily reflect the larger quantities of annual precipitation. The smaller values are characteristic of streams in the western part of the basin where annual precipitation is smaller.

Low-flow characteristics commonly are used to evaluate the adequacy of a stream to assimilate industrial or municipal wastes or both, to preserve a suitable aquatic environment, and to fulfill water-supply requirements. A common low-flow statistic used for this is the 7-day low flow that occurs, on the average, once every 10 years. This particular low-flow statistic varied markedly for the stations analyzed. The 7-day, 10-year low-flow discharges per square mile are larger in the eastern part of the basin than in the western part because many of the streams in the western part do not flow for part of the year.

High-flow characteristics commonly are used to evaluate flood-flow frequencies and to determine flood plains. High-flow values result from snowmelt or from thunderstorms. The 1-day, high-flow discharges that occur, on the average, once every 25 years, vary throughout the basin but mainly are greater in the eastern part than in the western part. The largest high-flow discharges in the White River basin usually result from thunderstorms, which generally do not occur at stations at the higher elevations; snowmelt runoff usually produces the maximum streamflow each year for these stations. High flows at stations at the lower elevations can result either from snowmelt or from thunderstorms.

Table 4.2-1.--*Streamflow characteristics at selected gaging stations*

Station number used in report	Station name	Drainage area (square miles)	Average annual flow (cubic feet per second)	Average annual flow (cubic feet per second per square mile)	7-day, 10-year low flow (cubic feet per second)	7-day, 10-year low flow (cubic feet per second per square mile)	1-day, 25-year high flow (cubic feet per second)	1-day, 25-year high flow (cubic feet per second per square mile)
1	North Fork White River below Trappers Lake, Colo.------------------------	19.5	28	1.4	6.0	0.31	454	23
2	North Fork White River above Ripple Creek, near Trappers Lake, Colo.------------	62.5	96	1.5	38	.61	581	9.3
3	Lost Creek near Buford, Colo.----------------	21.5	22	1.0	.73	.03	602	28
4	Marvine Creek near Buford, Colo.-------------	59.7	92	1.5	38	.64	377	6.3
5	North Fork White River near Buford, Colo.----	220	290	1.3	100	.46	1,980	9.0
6	North Fork White River at Buford, Colo ------	260	308	1.2	110	.42	2,330	9.0
7	South Fork White River at Budge's Resort, Colo -------------------------------	52.3	101	1.9	20	.39	2,120	41
8	Wagonwheel Creek at Budge's Resort, Colo.-------------------------------	7.36	7.0	.95	---	---	224	30
10	South Fork White River near Budge's Resort, Colo.-------------------------------	128	196	1.5	---	---	3,710	29
11	South Fork White River near Buford, Colo.----	152	260	1.7	72	.47	2,710	18
12	South Fork White River at Buford, Colo.------	177	254	1.4	76	.43	2,310	13
13	Big Beaver Creek near Buford, Colo.----------	34.1	15	.44	.04	0	376	11
14	Miller Creek near Meeker, Colo.--------------	57.6	18	.31	6.7	.12	181	3.2
15	White River above Coal Creek, near Meeker, Colo.-------------------------------	648	546	.84	51	.08	4,030	6.2
16	Coal Creek near Meeker, Colo.----------------	25.1	5.2	.21	.54	.02	100	4.0
18	White River near Meeker, Colo.---------------	755	620	.82	180	.24	4,580	6.1
21	White River below Meeker, Colo.--------------	1,024	621	.61	159	.16	4,010	3.9
44	Piceance Creek at White River, Colo.---------	630	25	.04	.82	0	265	.42
55	Yellow Creek near White River, Colo.---------	262	1.9	.01	.24	0	714	2.7
56	White River above Rangely, Colo.-------------	2,773	656	.24	128	.05	4,770	1.7
59	White River near Colorado-Utah State line, Colo.--------------------------	3,680	636	.17	---	---	6,820	2.5
70	Evacuation Creek near Watson, Utah-----------	284	1.6	.01	.01	0	96	.34
71	White River near Watson, Utah----------------	4,020	695	.17	125	.03	4,900	1.2
85	Bitter Creek near Bonanza, Utah--------------	324	1.4	<.01	---	---	102	.32
95	White River at mouth, near Ouray, Utah-------	5,120	662	.13	28	.01	5,920	1.2

FLOW DURATION DETERMINED FOR 10 SELECTED STREAMFLOW-GAGING STATIONS

Flow-duration curves for North Fork White River at Buford, Colo., and White River at mouth near Ouray, Utah, indicate streamflow consists of snowmelt runoff and substantial flow from alluvial and bedrock aquifers, whereas flow-duration curves for Piceance Creek at White River, Colo., and Yellow Creek near White River, Colo., indicate streamflow consists of snowmelt runoff, thunderstorm runoff, and base flow from springs.

Flow-duration curves show the percentage of time that flow rates are equaled or exceeded. Flow-duration data for 10 streamflow-gaging stations in the White River basin are presented in table 4.3-1. Duration curves for four of the gaging stations are shown in figure 4.3-1.

The shape of the flow-duration curve gives an indication of the nature of the flow. A steeply sloping curve indicates variable flow mainly from surface runoff. A gently sloping curve indicates contributions from ground-water or surface-water storage. A steep slope at the lower end of the curve indicates little ground-water contribution to base flow, whereas a flat slope at the lower end indicates substantial ground-water contribution to base flow.

The North Fork White River at Buford, Colo., and the White River at mouth near Ouray, Utah, are approximately 212 river miles apart, yet the shapes of the flow-duration curves are very similar. The steep slope of the curves at the upper end is most likely the result of snowmelt runoff. The curves then flatten out, indicating sustained base flow probably from ground-water discharge from the alluvial aquifer and bedrock aquifers.

The shapes of the flow-duration curves for Piceance Creek at White River, Colo., and Yellow Creek near White River, Colo., tributaries to the White River, are somewhat different from the previous two curves discussed. The flatter shape of the upper end is probably due to some snowmelt and some thunderstorm activity. The base flow, however, at these two stations is primarily from springs. In the case of Piceance Creek, the slope of the curve flattens slightly on the lower end, indicating a sustained base flow. In the case of Yellow Creek, the curve steepens sharply on the lower end. This could indicate that some of the springs cease flowing in late summer.

Table 4.3-1.--*Flow duration at 10 selected streamflow-gaging stations*

Station number used in report	Station name	Percent of time discharge, in cubic feet per second, equaled or exceeded						
		95	90	75	70	50	25	10
6	North Fork White River at Buford, Colo.-------------	130	140	160	170	190	290	710
12	South Fork White River at Buford, Colo.-------------	85	90	100	110	120	180	620
15	White River above Coal Creek, near Meeker, Colo.-----	160	210	260	270	320	440	1,400
18	White River near Meeker, Colo.-----	250	270	310	320	370	540	1,500
21	White River below Meeker, Colo.-----	250	280	330	340	400	530	1,400
44	Piceance Creek at White River, Colo.	2.1	3.3	10.0	13.0	23.0	34.0	46.0
55	Yellow Creek near White River, Colo.	0.3	0.5	0.9	1.1	1.5	2.1	2.8
56	White River above Rangely, Colo.----	260	300	360	370	430	540	1,500
59	White River near Colorado-Utah State line, Utah--	270	300	350	360	410	530	1,200
95	White River at mouth, near Ouray, Utah-------	250	270	340	360	410	570	1,400

White River downstream from Rangely, Colorado

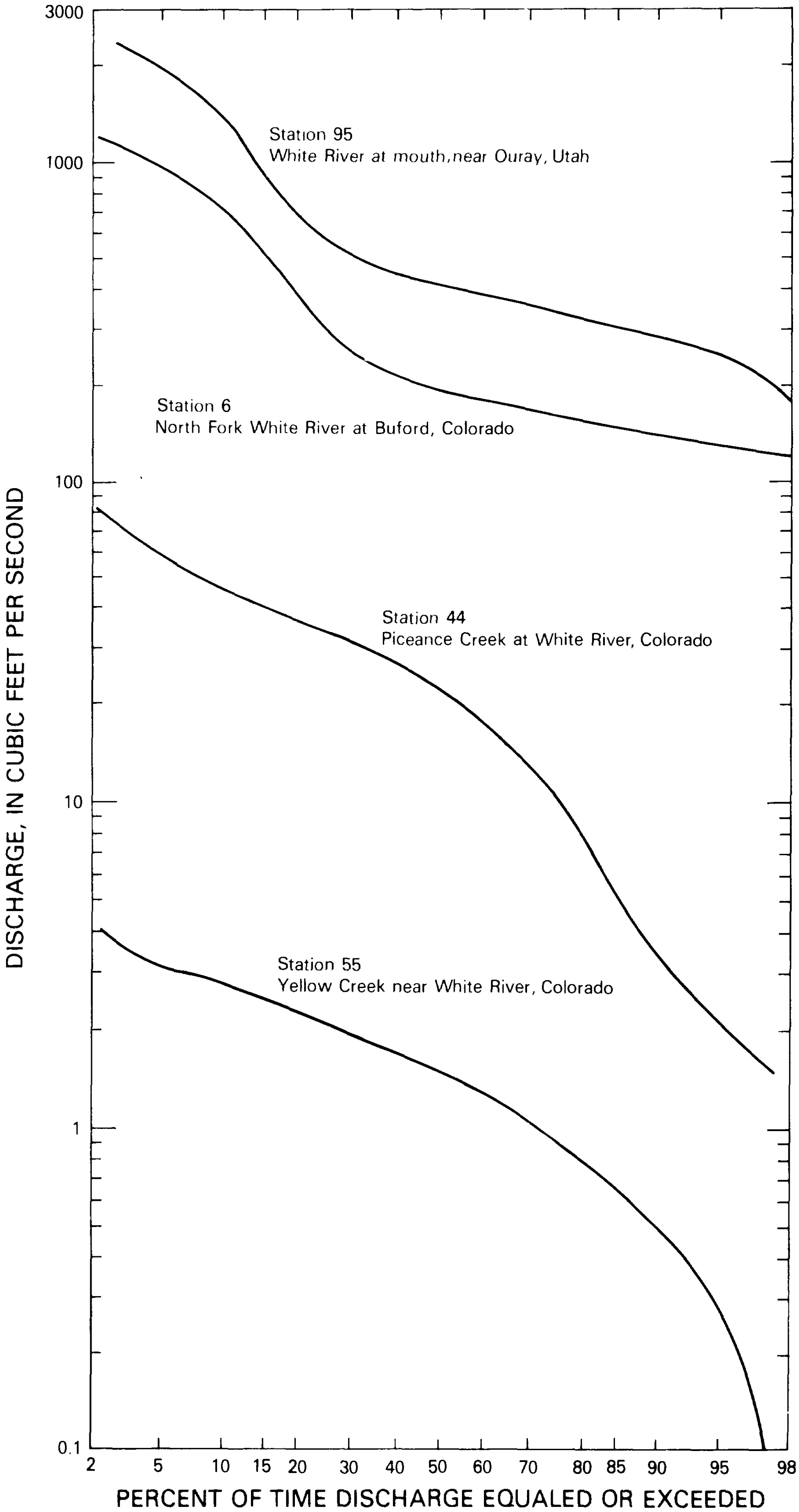


Figure 4.3-1.--Duration curves for four selected streamflow-gaging stations.

5.0 RECONNAISSANCE OF SURFACE-WATER QUALITY

5.1 Sampling Sites

CHEMICAL DETERMINATIONS WERE MADE AT 45 SITES

Water samples were analyzed for major chemical constituents, nutrients, and trace elements to describe water quality.

A low-flow, water-quality reconnaissance was conducted in August 1981. Samples were collected at 45 sites for chemical analysis (fig. 5.1-1). Fourteen sites were on the White River and 31 sites were on tributaries. Twenty-five of the sampling sites are streamflow-gaging stations. Sampling-site selection was based on geology and land-use patterns in the basin. The station identification numbers and names are listed in tables 5.1-1 and 5.1-2.

The drainage area upstream from the farthest downstream site, M-14, White River at mouth, is 5,120 square miles. Elevation ranges from about 12,000 feet in the headwaters upstream from site M-1, North Fork White River at Trappers Lake outlet, to 4,900 feet at site M-14. The length of the White River from site M-14 to site M-1 is 216 river miles. For this report, the North Fork White River is considered an extension of the main channel of the White River and is not considered a tributary. Major tributaries are the South Fork White River, Piceance Creek, and Yellow Creek.

The chemical composition of streams reflects the effects of the rocks and minerals with which the water comes in contact. Entrained gases and nutrients also contribute to the chemical characteristics of streams. The data-collection program consisted of sampling water for major chemical constituents, nutrients, and dissolved and total-recoverable trace elements, and sampling bed material for trace elements. Onsite determination of water temperature, specific conductance, pH, dissolved oxygen, and water discharge were made at all sites.

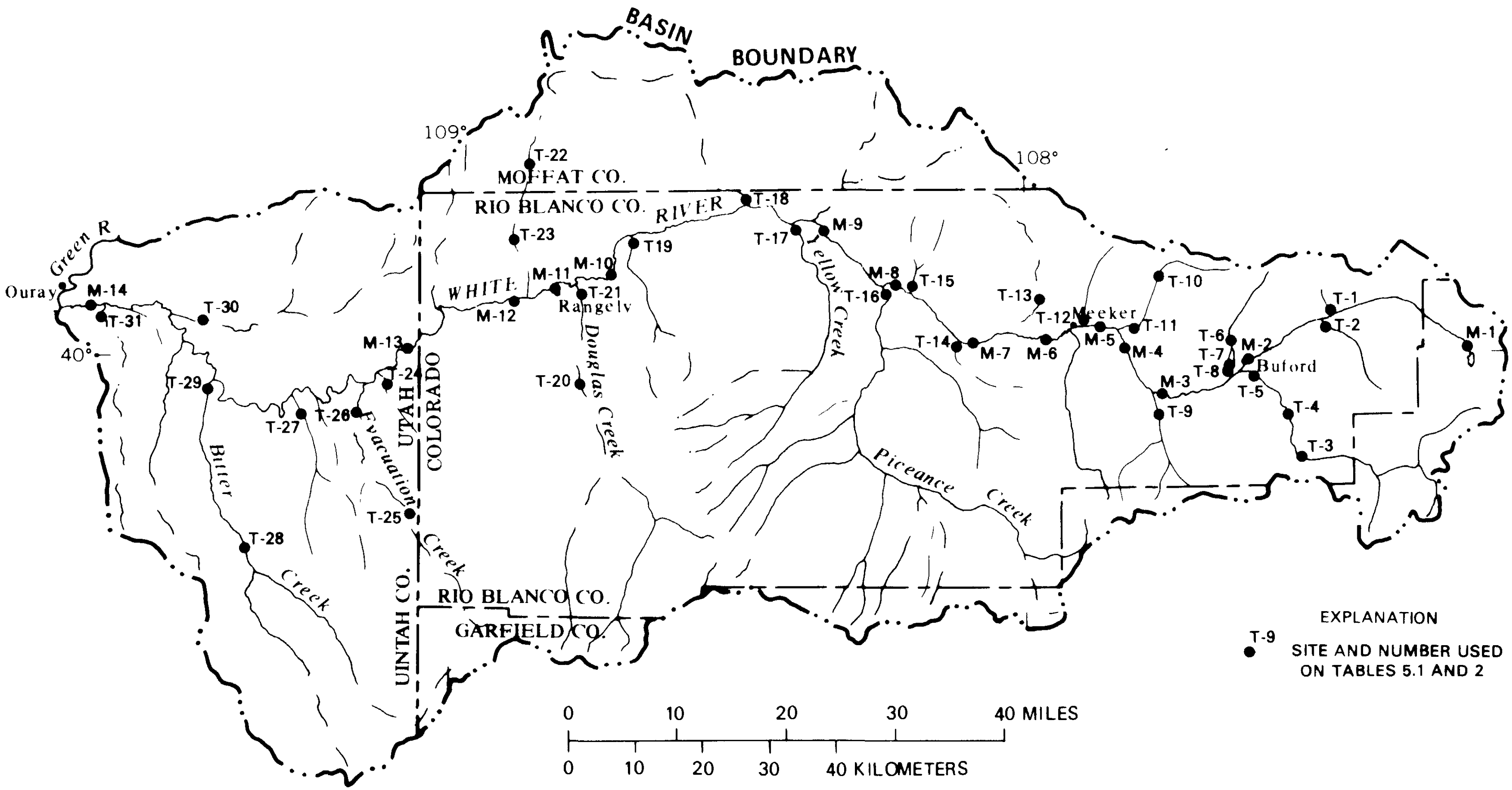


Figure 5.1-1.--Location of water-quality reconnaissance sampling sites, August 1981.

Table 5.1-1.--*White River water-quality reconnaissance sites*

Site number in figure 5.1-1	U.S. Geological Survey identification number	Station name	River miles from confluence with Green River
M-1	395949107134900	North Fork White River at Trappers Lake Outlet, near Buford, Colo.---------	216.0
M-2	09303000	North Fork White River at Buford, Colo.	190.1
M-3	395643107461200	White River above Miller Creek, near Buford, Colo.---------	179.0
M-4	09304200	White River above Coal Creek, near Meeker, Colo.---------	171.2
M-5	09304500	White River near Meeker, Colo.---------	169.8
M-6	400113107574500	White River at Highway 13 Bridge, below Meeker, Colo.---	166.4
M-7	09304800	White River below Meeker, Colo.---------	152.6
M-8	400543108132600	White River above Piceance Creek, at White River, Colo.----	142.1
M-9	400945108203900	White River below Piceance Creek, near Meeker, Colo.---------	140.5
M-10	09306300	White River above Rangely, Colo.--------	99.1
M-11	400535108485700	White River at Highway 64 Bridge, below Rangely, Colo.--	89.1
M-12	400439108523400	White River below Stinking Water Creek, below Rangely, Colo.--	83.6
M-13	09306395	White River near Colorado-Utah State line, Utah------	67.8
M-14	09306900	White River at mouth, near Ouray, Utah------------------	3.8

Table 5.1-2.--*Tributary water-quality reconnaissance sites*

Site number in figure 5.1-1	U.S. Geological Survey identification number	Station name	River miles of tributary confluence at the White River from confluence with the Green River
T-1	09302450	Lost Creek near Buford, Colo.--------	198.9
T-2	09302500	Marvine Creek near Buford, Colo.---	197.5
T-3	395121107304400	South Fork White River above South Fork Camp, near Bridges Resort, Colo.-	-----
T-4	09303500	South Fork White River near Buford, Colo.----------------	-----
T-5	09304000	South Fork White River at Buford, Colo.----------------	188.2
T-6	395923107383300	Big Beaver Creek above Lake Avery, near Buford, Colo.---	-----

Table 5.1-2.--*Tributary water-quality reconnaissance sites*--Continued

Site number in figure 5.1-1	U.S. Geological Survey identification number	Station name	River miles of tributary confluence at the White River from confluence with the Green River
T-7	395812107384800	Lake Avery Bottom Outlet and Diversion Ditch near Buford, Colo.----------------	-----
T-8	395813107384500	Lake Avery Spillway near Buford, Colo.---	187.7
T-9	09304150	Miller Creek near Buford, Colo.--------	179 0
T-10	400557107454900	Coal Creek below Ninemile Draw, near Meeker, Colo.--------	-----
T-11	09304480	Coal Creek below Little Beaver Creek, near Meeker, Colo.--------	171.0
T-12	09304550	Curtis Creek near Meeker, Colo.--------	168.0
T-13	400351107583000	Strawberry Creek near Meeker, Colo.---	157.1
T-14	400025108063100	Hay Gulch near Meeker, Colo.--------	146.0
T-15	400415108113600	Blacks Gulch near Meeker, Colo.--------	143.9
T-16	09306222	Piceance Creek at White River, Colo.---	140.5
T-17	09306255	Yellow Creek near White River, Colo.---	125.0
T-18	401203108283800	Wolf Creek near Rangely, Colo.-------	119.5
T-19	400925108405600	Spring Creek near Rangely, Colo.-------	104.8
T-20	395740108461600	Douglas Creek above No Name Draw, near Rangely, Colo.-------	-----
T-21	09306380	Douglas Creek at Rangely, Colo.-------	92.4
T-22	401505108513700	Stinking Water Creek near Blue Mountain, Colo ------	-----
T-23	400514108512000	Stinking Water Creek near CPC, near Rangely, Colo -------	85 0
T-24	09306405	Hell's Hole Canyon at mouth, near Watson, Utah---------	59.3
T-25	09306410	Evacuation Creek above Missouri Creek, near Dragon, Utah----	-----
T-26	09306430	Evacuation Creek near mouth, near Watson, Utah---------	58 0
T-27	09306625	Asphalt Wash near mouth, near Watson, Utah-----------------	43 0
T-28	09306800	Bitter Creek near Bonanza, Utah--------	-----
T-29	09306850	Bitter Creek at mouth, near Bonanza, Utah-----------------	26.8
T-30	09306878	Coyote Wash near mouth, near Ouray, Utah-----------------	16.9
T-31	09306885	Cottonwood Wash near mouth, near Ouray, Utah-----------------	5.8

WATER TYPE CHANGES IN THE WHITE RIVER

Water in the upstream reaches of the White River is a calcium bicarbonate type but changes to a sodium calcium sulfate bicarbonate type downstream.

Major ions are mineral constituents that are dissolved in water in relatively large quantities. The major ions in the White River consist of the cations calcium, magnesium, and sodium; and the anions bicarbonate, chloride, and sulfate. In naming water types, the names of the single cation and anion are used if they account for 50 percent or more of the total cations and anions. An example of this would be a calcium bicarbonate type water. Water in which no one cation or anion constitutes as much as 50 percent of the total is a mixed type and is identified by the names of all the important cations and anions. An example would be a calcium sodium bicarbonate sulfate type water.

The chemical composition of the White River by percentage of cations and anions with respect to river miles is shown in figure 5.2.1.1-1. Calcium is the dominant cation in the river upstream from Meeker from river mile 216 to river mile 171. The percentages of magnesium and sodium tend to decrease in this reach of the river. Bicarbonate is the dominant anion between river miles 216 and 171. In this reach, calcium bicarbonate is the water type. At river mile 170, the effects of the Meeker Dome, located 3 miles east of Meeker, Colo., are apparent. Water seeping from the Meeker Dome contributes large concentrations of dissolved solids to the White River. The percentage of sodium and chloride increases and the percentage of calcium, bicarbonate, and sulfate decreases. At river mile 166, the percentages of chloride and sulfate are similar to their upstream proportions.

At river mile 140.5, Piceance Creek joins the White River. The percentages of calcium and magnesium decrease, but the percentage of sodium increases. Bicarbonate and sulfate are codominant anions. The water is a sodium calcium bicarbonate sulfate type.

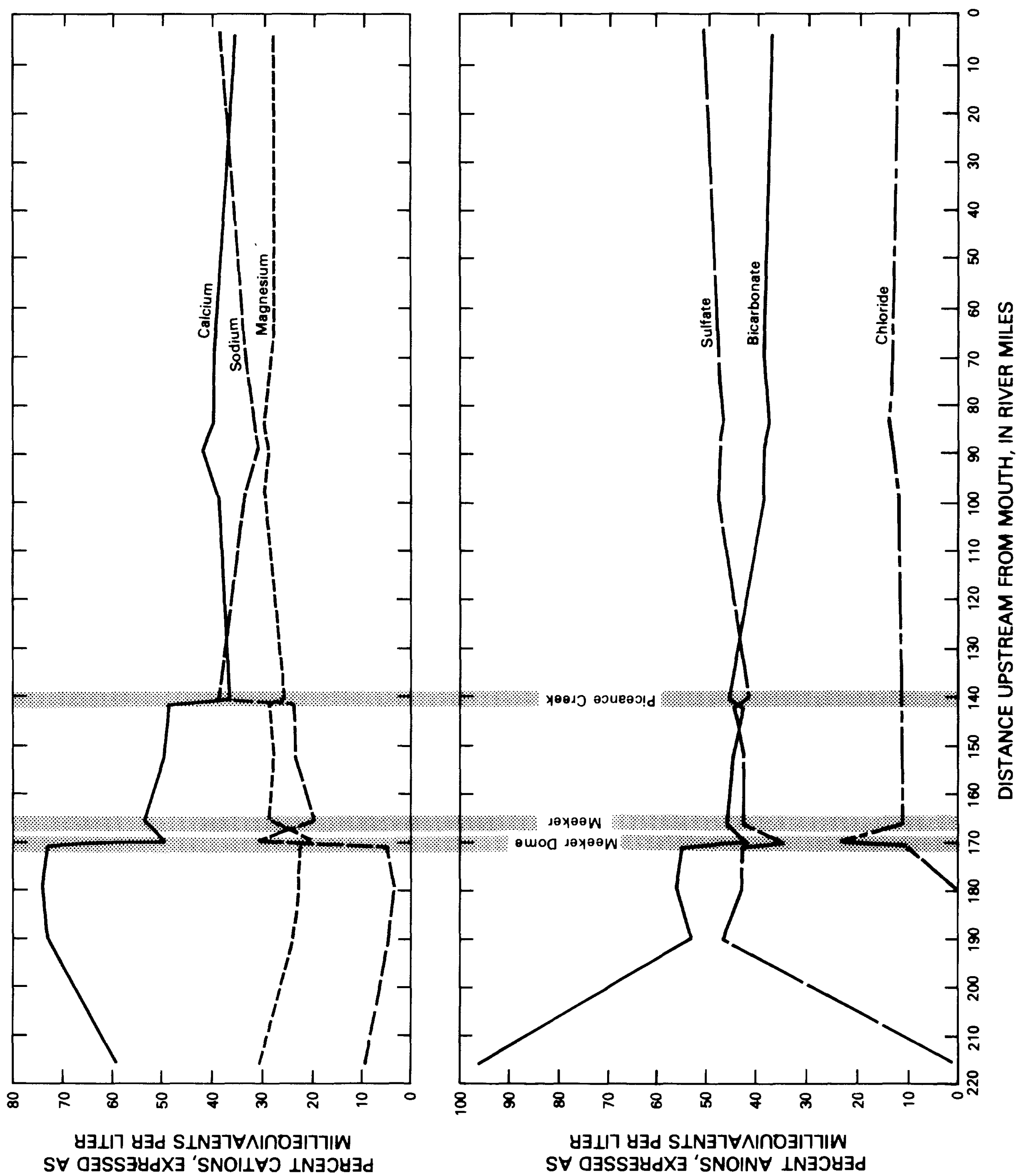


Figure 5.2.1.1-1.--Water-composition changes in the White River, August 1981.

5.2.1.2 Spatial Variations

WATER-QUALITY CHARACTERISTICS VARY AREALLY IN THE BASIN

Dissolved-solids concentrations range from 56 to 13,400 milligrams per liter, and specific conductance ranged from 80 to 14,000 micromhos per centimeter at 25° Celsius.

Regional water-quality characteristics for low-flow conditions are indicated in figure 5.2.1.2-1. Dissolved solids, specific conductance, and tributary water types are indicated with respect to river miles. Specific conductance is a measure of the ability of water to conduct an electrical current and is expressed in micromhos per centimeter at 25° Celsius. Specific conductance is related to the number and type of ions in solution and can be used to approximate the dissolved-solids concentration in the water.

Dissolved-solids concentrations increase in a downstream direction. Along the White River, the dissolved-solids concentration ranged from 56 mg/L (milligrams per liter) at site M-1 to 588 mg/L at site M-14. The corresponding specific-conductance values ranged from 80 to 870 micromhos per centimeter at 25° Celsius. The tributary streams commonly contributed high concentrations of dissolved solids, but due to dilution, this did not cause much change on the main stem under these conditions. Upstream from site M-5, White River near Meeker, dissolved-solids concentrations of all 11 tributaries were less than 1,000 mg/L. Downstream from site M-5, the dissolved-solids concentrations of all the tributaries exceeded 2,100 mg/L with the largest concentration, 13,400 mg/L, occurring at site T-29, Bitter Creek at mouth. Despite the large dissolved-solids contributions from the tributaries, the dissolved-solids concentration in the White River never exceeded 588 mg/L, the concentration downstream at site M-14.

The water types of the tributaries vary throughout the basin. Calcium bicarbonate is the dominant water type of the tributaries upstream from river mile 180, upstream from the mouth of Miller Creek, except for calcium sulfate type water at site T-6, Big Beaver Creek above Lake Avery. Downstream from river mile 180, the water types can be described as mixed-cation, mixed-anion types. The cations calcium, sodium, and magnesium usually exchange dominance as do the anions bicarbonate and sulfate.

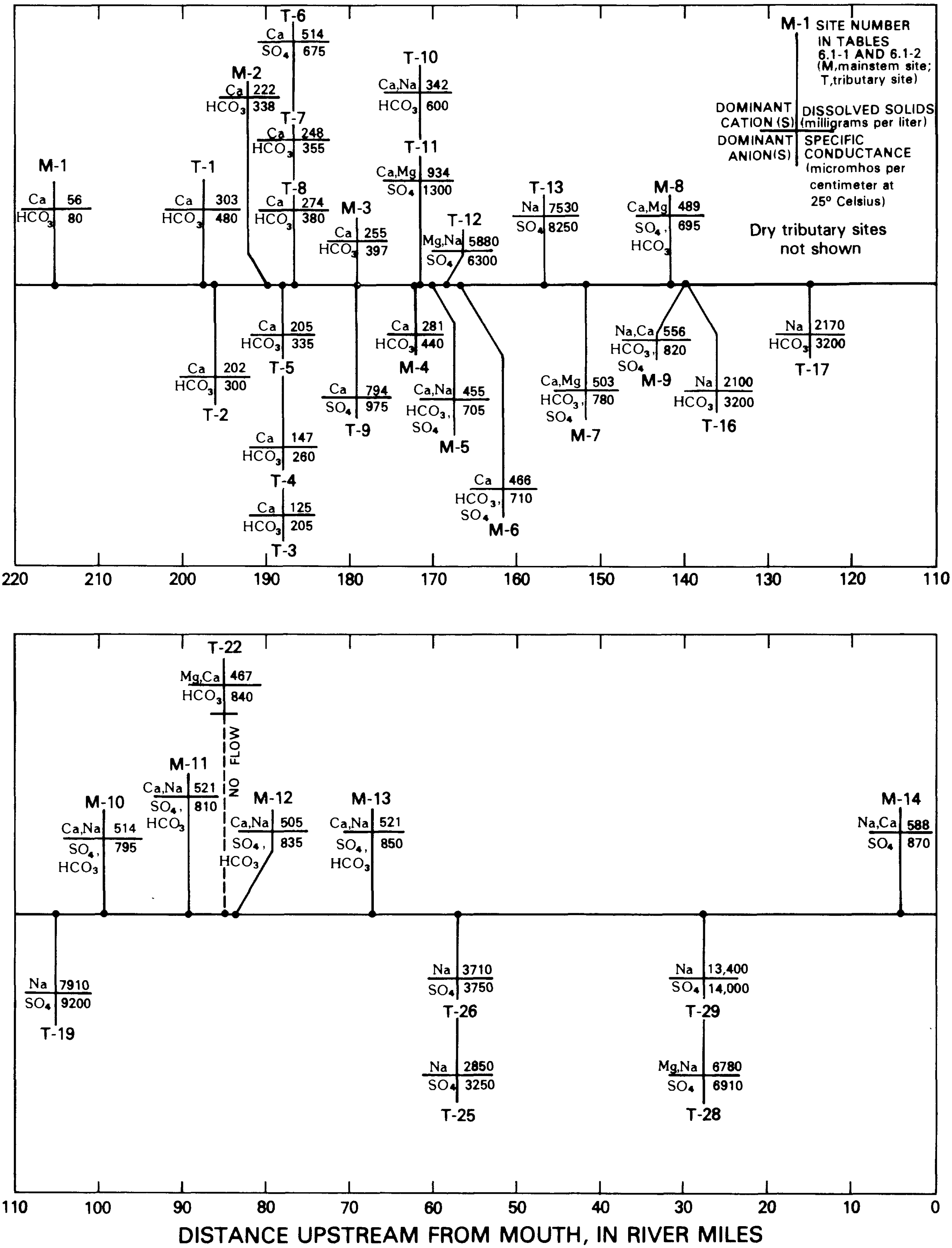


Figure 5.2.1.2-1.--Water-quality characteristics in the White River basin, August 1981.

5.2.2 Dissolved-Solids Discharge

STREAM DISCHARGE, SPECIFIC CONDUCTANCE, AND CONCENTRATION OF DISSOLVED SOLIDS INCREASE IN A DOWNSTREAM DIRECTION DURING LOW FLOW

During low flows, dissolved-solids concentrations in the White River increase significantly due to inflows from the Meeker Dome and Piceance Creek.

Stream discharge, specific conductance, and dissolved-solids concentration are plotted against river miles in figure 5.2.2-1. This analysis represents low-flow conditions only. Stream discharge increased from the headwaters, river mile 216, to White River above Miller Creek, river mile 179. The decrease in stream discharge between river mile 179 to 171, at the mouth of Coal Creek, probably was the result of irrigation withdrawal. Dissolved-solids concentration gradually increased until river mile 171, where it abruptly increased from 280 to 455 milligrams per liter within 1 river mile. This large increase was due to ground-water discharge from the Meeker Dome. The maximum stream discharge of 250 cubic feet per second occurred at river mile 153 downstream from Meeker and coincided with a slight increase in dissolved-solids concentration.

Flow from Piceance Creek contributed a large increase in dissolved-solids concentration at river mile 141. Downstream from river mile 141, stream discharge slightly decreased until about river mile 85 downstream from Rangely. This probably was the result of withdrawals for irrigation. Dissolved-solids concentration also decreased in the reach between river miles 141 and 100. Between river mile 85 and the mouth, dissolved-solids concentration and stream discharge gradually increased. Under normal conditions an increase in stream discharge will result in a decrease in dissolved-solids concentration. This anomaly, which exists between dissolved-solids concentration and stream discharge between river miles 141 and 99, can most likely be attributed to extensive withdrawals for irrigation and irrigation return flow during summer base-flow conditions. The increase in dissolved-solids concentration and specific conductance at river mile 99 was due to the chemical characteristics of the outcrop of Mancos Shale.

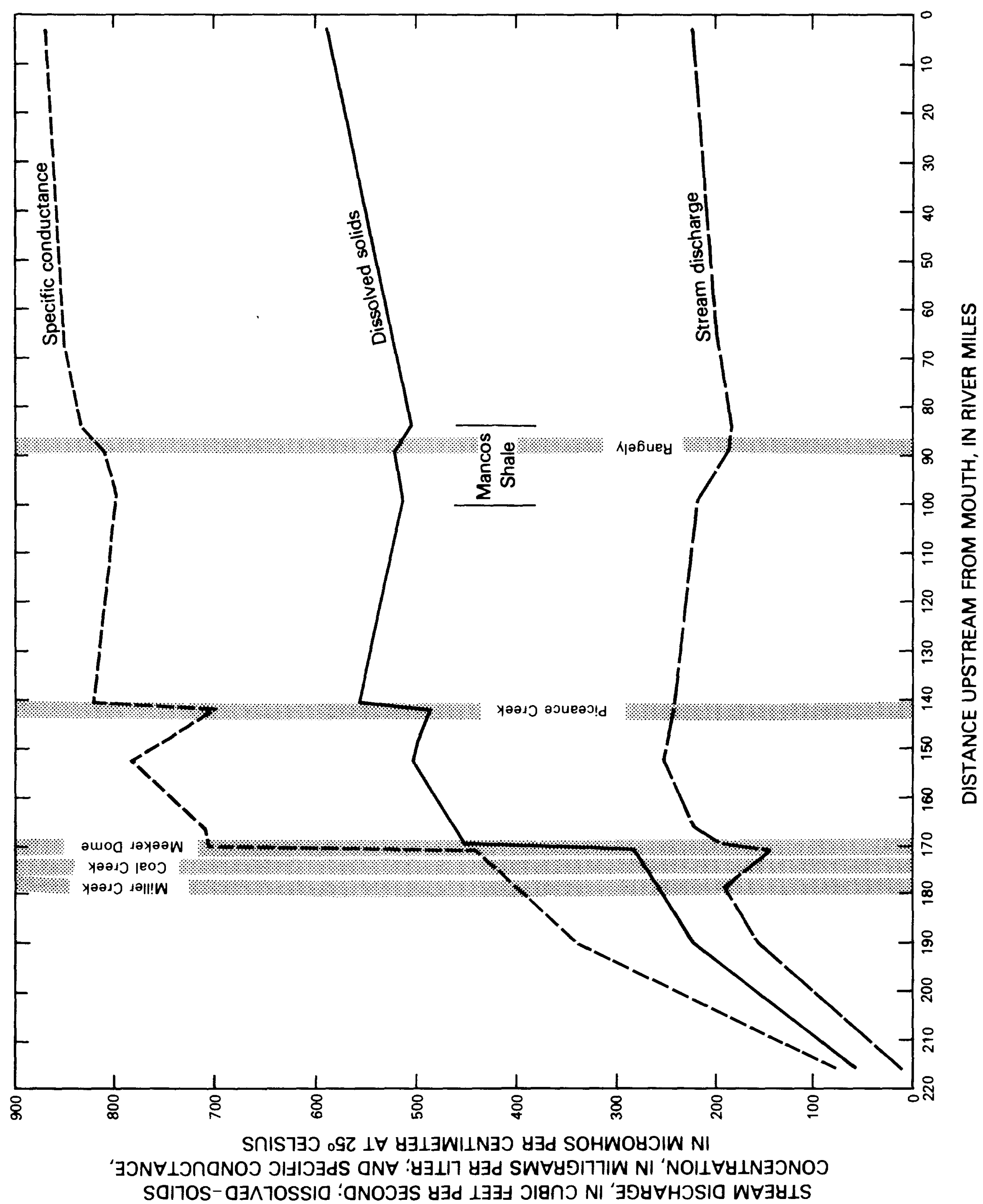


Figure 5.2.2-1. Specific conductance, dissolved-solids concentration, and stream discharge.

STREAM TEMPERATURE, pH, AND PERCENT SATURATION OF DISSOLVED OXYGEN CHANGE ALONG THE WHITE RIVER

Stream temperature abruptly increases downstream from Meeker, whereas dissolved oxygen and pH change gradually.

Variations in stream temperature, pH, and percent saturation of dissolved oxygen along the White River are shown in figure 5.2.3-1. The data were collected during 3 days. The minimum measured stream temperature of 13.0°C occurred downstream from the Meeker Dome, and the maximum of 22.5°C occurred at the mouth. There was only a slight variation in pH in the White River. The minimum pH of 7.7 occurred at river mile 153 downstream from Meeker, and the maximum pH of 8.6 occurred at river mile 67.5 downstream from the Colorado-Utah State line. Only 4 of the 14 measured pH values along the White River were less than 8.0. Percent saturation of dissolved oxygen varied from a minimum of 98 percent to a maximum of 132 percent.

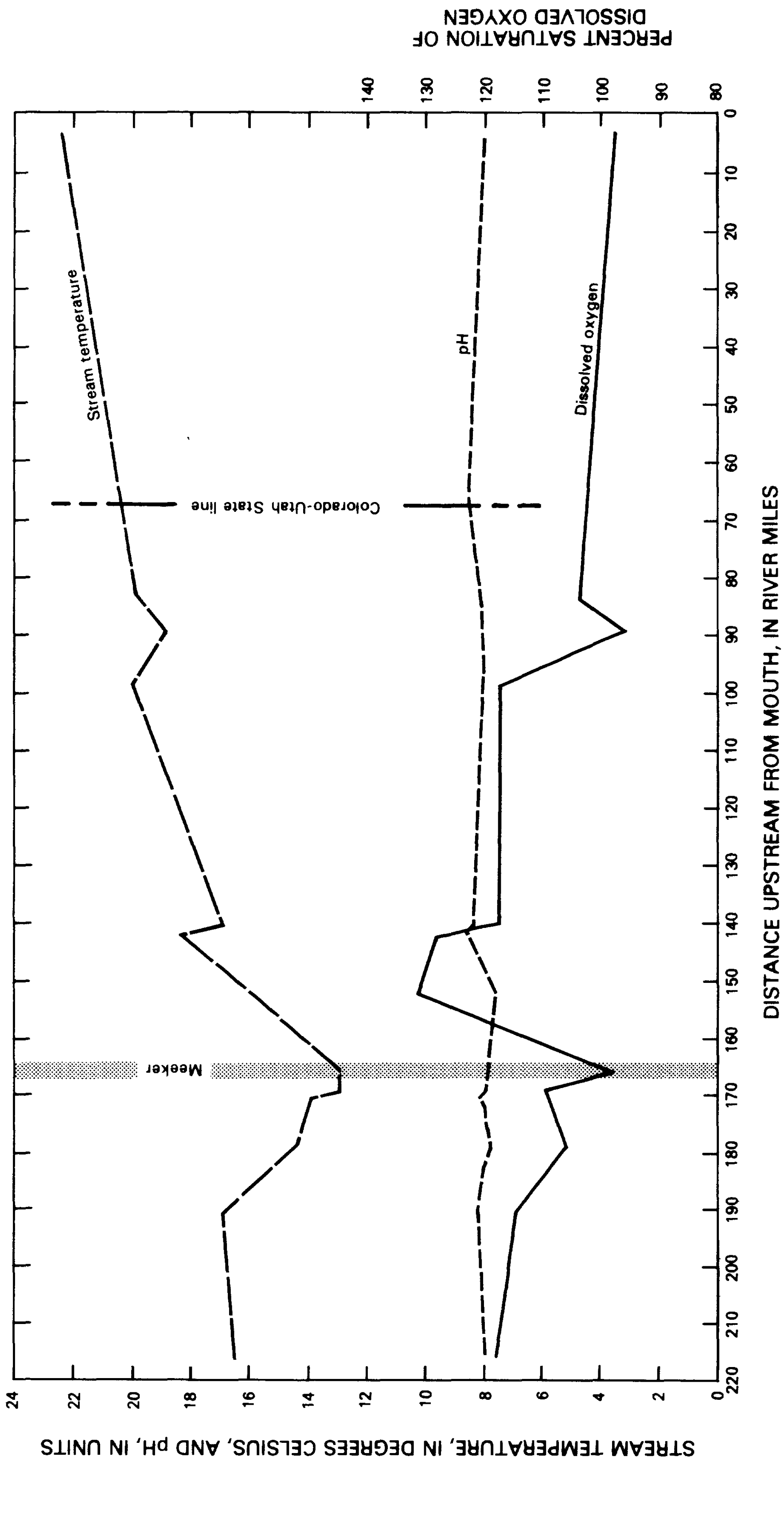


Figure 5.2.3-1.--Stream temperature, pH, and percent saturation of dissolved oxygen.

ALGAL-GROWTH POTENTIAL, DISSOLVED NITROGEN AND PHOSPHORUS CONCENTRATIONS VARY IN THE WHITE RIVER BASIN

Algal-growth potential usually can be related to concentrations of dissolved nitrogen and dissolved phosphorus.

Algal-growth potential and dissolved-nitrogen and dissolved-phosphorus concentrations along the White River are shown in figure 5.2.4-1. Algal-growth potential can give an indication of available algal-growth substances or nutrients. The data in figure 5.2.4-1 indicate that the White River is enriched with nitrogen but contains little phosphorus.

Algal-growth potential ranged from 0.3 to 2.5 mg/L (milligrams per liter). This variation may be due to irrigation return flow, which possibly is a nutrient source. In some instances, algal-growth potential and dissolved-nitrogen and dissolved-phosphorus concentrations peak at the same point, such as at river mile 171 near the Meeker Dome, and at river mile 89 near Rangely. Dissolved-nitrogen concentration ranged from 0.41 to 1.0 mg/L. Dissolved-nitrogen concentration steadily increased from river mile 84 to the mouth. Dissolved-phosphorus concentration remained steady at 0.01 and 0.02 mg/L, except at river miles 171 and 89 where the concentrations increased to 0.06 and 0.05 mg/L.

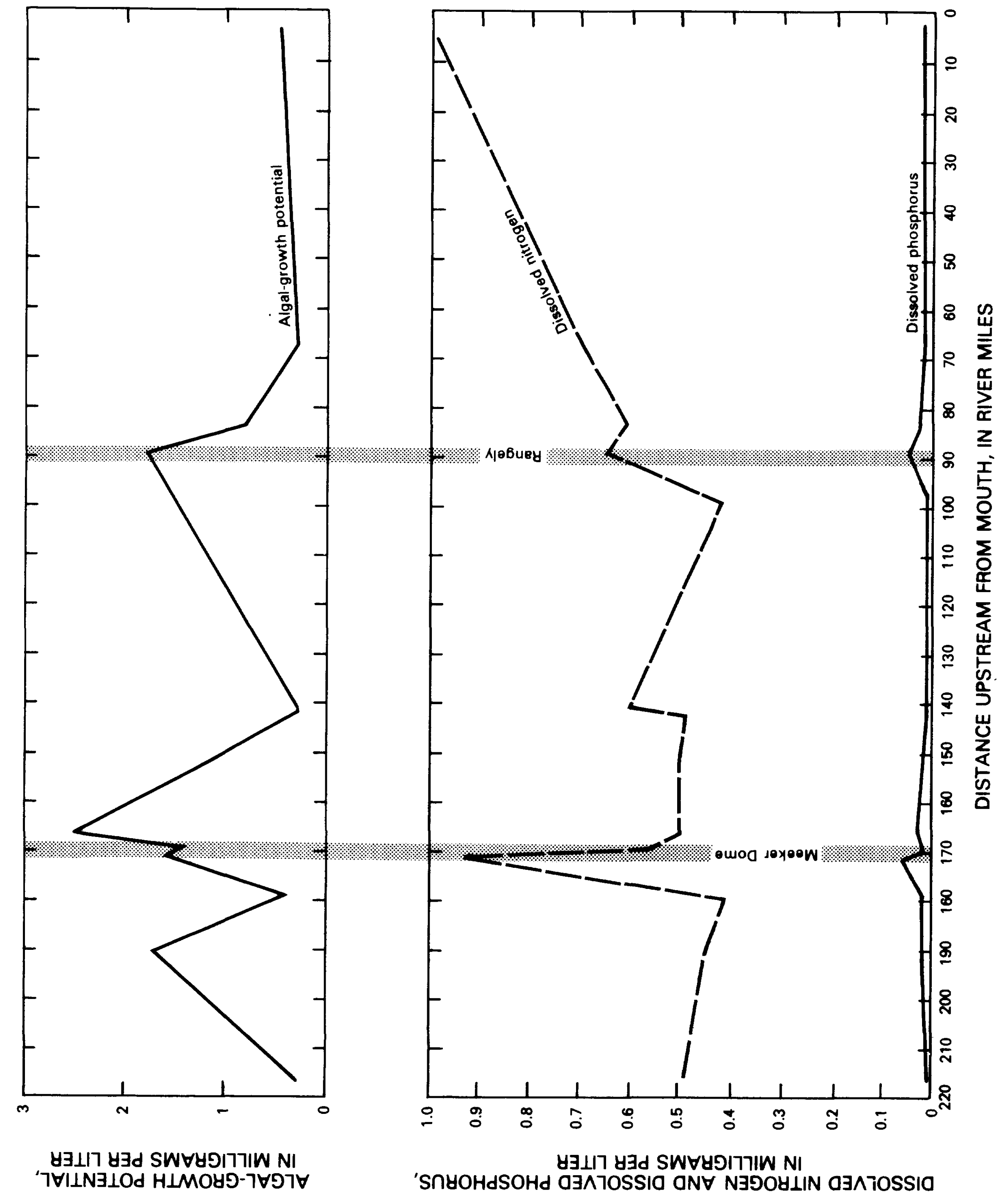


Figure 5.2.4-1.--Algal-growth potential and concentrations of dissolved nitrogen and phosphorus.

5.2.5.1 Concentrations in Bed Material

TRACE ELEMENTS ANALYZED IN BOTTOM SEDIMENTS OF THE WHITE RIVER

Trace-element concentrations in bed material varies with respect to river miles.

Concentrations of trace elements collected in bed material of the White River are shown in figure 5.2.5.1-1. Bottom sediments are integrators of trace elements because they are in continuous contact with trace elements in the dissolved and suspended state. Trace elements are mainly derived from soils and rocks within the drainage basin and usually are found in concentrations of less than 1.0 milligram per liter. In large concentrations, certain trace elements can be toxic, but in small concentrations many are beneficial as micronutrients to animals and plants. The variation in concentration of the trace elements in the White River bed material is considered a result of the complex geology and the interaction of water with the minerals and not a result of mine drainage or drainage from mine spoils.

The trace-element concentrations in bed material vary with respect to river miles. Concentrations increased abruptly downstream from the Meeker Dome. Arsenic, chromium, copper, iron, and manganese concentrations continued to increase between the Meeker Dome and the inflow of Piceance Creek. Barium, mercury, nickel, and zinc concentrations fluctuated within this reach. Arsenic, barium, copper, and mercury concentrations increased at Rangely between river miles 100 and 90, whereas concentrations of all the others decreased. Downstream from river mile 80, the trace-element concentrations generally stabilized.

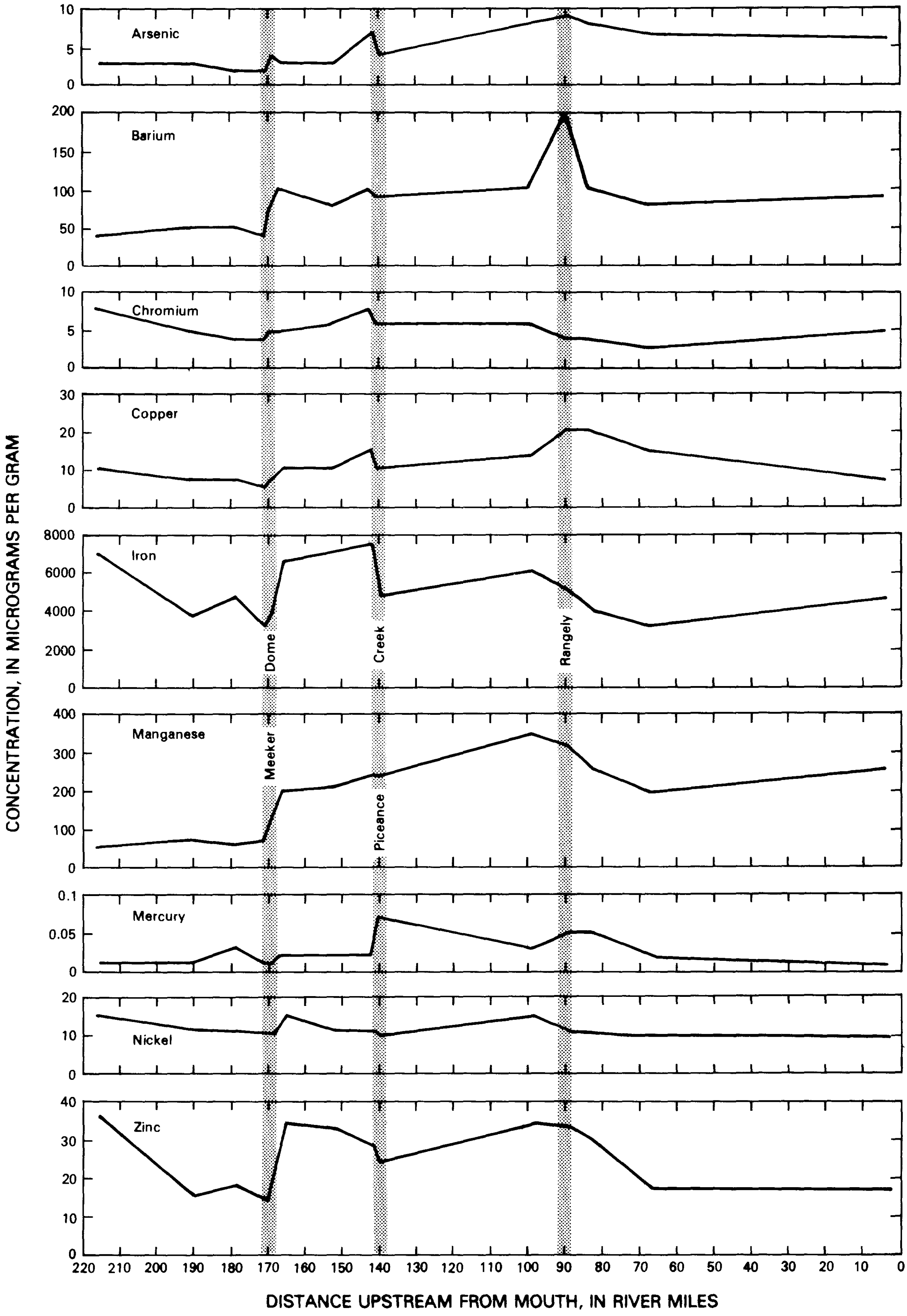


Figure 5.2.5.1-1.--Trace-element concentrations in bed material.

5.2.5.2 Total-Recoverable Concentrations

TOTAL-RECOVERABLE TRACE-ELEMENT CONCENTRATIONS VARY IN THE WHITE RIVER

Total-recoverable trace-element concentrations are related to the geology of the White River basin.

Total-recoverable concentrations of selected trace elements along the White River are shown in figure 5.2.5.2-1. Total-recoverable concentrations consist of the dissolved plus suspended components. Trace elements generally are those constituents which occur in concentrations of less than 1.0 milligram per liter. Some trace elements can accumulate in the food chain and have long-term harmful effects. Differences in trace-element concentrations in the White River probably are due to differences in geology rather than industrial activity.

Variation of total-recoverable trace-element concentration is evident with respect to river miles. All trace-element concentrations increased in the Meeker Dome area except for lead and zinc. Concentrations of these two elements increased about 10 river miles upstream from the Meeker Dome. The increase in trace-element concentrations in the Meeker Dome area could be related to the river flowing in contact with the Mancos Shale. Between the Meeker Dome and Piceance Creek, the trace-element concentrations remained relatively constant or decreased, as in the case of total-recoverable nickel. In this area, the White River flows over the Mesaverde Group, Green River Formation and the Wasatch Formations. At the confluence of Piceance Creek and the White River, total-recoverable aluminum, iron, and molybdenum increased slightly. Between Piceance Creek and the Rangely area, all trace elements increased except total-recoverable molybdenum and total-recoverable zinc. Downstream from the Rangely area, the White River flows through the Mesaverde Group and the Mancos Shale. All of the trace-element concentrations had slight to abrupt increases in this area. Between Rangely and the mouth, all trace-element concentrations continued to increase except for molybdenum. Downstream from Rangely, the White River also flows through the Green River Formation and the Uinta Formation.

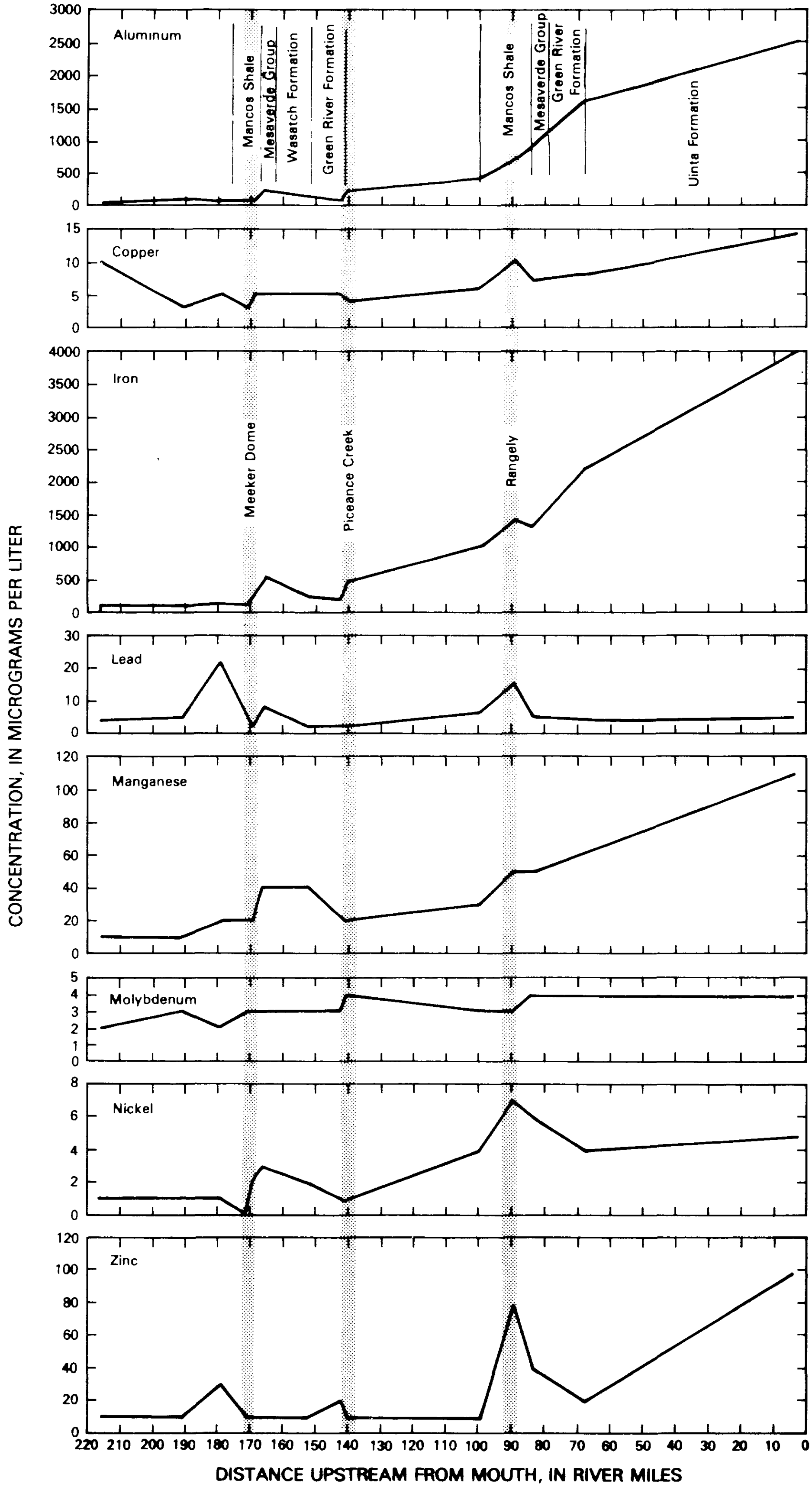


Figure 5.2.5.2-1.--Total-recoverable trace-element concentrations.

6.0 HISTORIC QUALITY OF SURFACE WATER

6.1 Dissolved Solids

6.1.1 General Analysis

DISCHARGE AND TIME CAN BE USED TO ESTIMATE DISSOLVED-SOLIDS CONCENTRATIONS

Monthly mean dissolved-solids loads and total annual loads were computed at 21 streamflow-gaging stations.

Estimates of dissolved-solids concentrations provide useful information necessary to design and operate reservoirs, irrigation systems, and municipal and industrial water facilities. Streams with a large concentration of dissolved-solids have poorer water quality than streams with a small concentration. The dissolved-solids concentration of streams in the White River basin is related to many factors. One of the most important is the volume of water available in the stream for dilution. In general, dissolved-solids concentration is inversely related to discharge: the larger the discharge, the smaller the dissolved-solids concentration because there is a larger volume of water with which to dilute the solid particles.

Water-quality samples usually are collected periodically, but streamflow is recorded daily at gaging stations. Daily concentrations of dissolved-solids of streams can be estimated based on the multiple variable relation between daily streamflow and periodic water-quality samples. Seasonal variation of dissolved-solids concentration, not directly related to the quantity of streamflow, is accounted for in the relation by the inclusion of harmonic functions of time.

Daily dissolved-solids concentration is estimated from daily streamflow and time using an equation developed by Delong (1977):

$$\mathrm{Log}(C) = B_0+B_1\sin(\alpha t)+B_2\cos(\alpha t)+ [B_3+B_4\sin(\alpha t)+B_5\cos(\alpha t)]\ \log(Q) \qquad \text{(eq. 6.1.1-1)}$$

where

C = daily dissolved-solids concentration, in milligrams per liter;
B_0,B_1,B_2,B_3,B_4,B_5 = regression coefficients;
$\alpha = 2\pi/365 \approx 0.0172$, in radians per day;
t = day of water year; and
Q = streamflow, in cubic feet per second.

Regression coefficients determined at 21 streamflow-gaging stations (fig. 6.1.1-1) within the White River basin that had sufficient data for analysis are listed in table 6.1.1-1. Also included in the table are the standard error of estimate and the number of years of streamflow record for each station.

Table 6.1.1-1.--*Regression coefficients and statistics for the relation between daily dissolved-solids concentration and daily discharge*

Station number used in report	B_0	B_1	B_2	B_3	B_4	B_5	SE[1]	Years of record (water years)
6	3.042	-0.770	0.098	-0.314	0.362	-0.050	6.7	36
12	2.570	-.340	-.159	-.161	.156	.078	9.3	31
15	2.617	-.616	.032	-.085	.256	-.016	6.6	20
20	3.340	-.599	-.083	-.293	.227	.024	6.8	3
21	3.434	-.469	-.054	-.318	.171	.030	11	20
25	2.924	.015	.046	-.083	-.017	.066	7.4	7
37	2.952	-.001	.014	-.033	-.019	-.009	1.8	7
38	3.121	-.019	-.068	-.152	.027	.072	8.9	7
39	3.124	-.021	-.024	-.094	.014	.062	8.3	6
40	3.284	-.000	-.080	-.198	-.011	.086	11	17
44	3.482	-.274	-.020	-.240	.174	.026	14	13
46	2.745	-.110	.116	-.094	-.094	.051	21	7
55	3.460	.046	-.056	-.239	-.154	.135	11	9
56	3.414	-.714	.224	-.272	.274	-.088	14	9
59	3.308	-.344	-.149	-.235	.138	.049	13	5
70	3.451	.022	-.044	-.095	.036	-.017	28	7
71	3.126	-.635	.207	-.161	.256	-.085	16	58
85	3.749	.044	-.052	-.132	-.009	.003	16	11
88	4.046	-.058	.028	-.502	-.214	.185	12	7
92	3.543	-.132	1.125	-1.312	.276	-1.288	5.3	5
95	3.317	-.381	-.089	-.223	.153	.023	17	7

[1]SE = Standard error of estimate, in percent of the mean.

Monthly mean dissolved-solids loads can be computed from daily streamflow records using equation 6.1.1-1 in the following relation (Delong, 1977):

$$\bar{L} = (b/d) \sum_{j=1}^{d} C_j Q_j \qquad \text{(eq. 6.1.1-2)}$$

where

$\bar{L}$ = monthly mean load, in tons per day;
b = 0.0027 (conversion factor to tons per day);
d = days per month;
j = day of month;
C_j = daily dissolved-solids concentration, in milligrams per liter; and
Q_j = daily discharge, in cubic feet per second.

Monthly mean dissolved-solids loads and the total annual load at the 21 streamflow-gaging stations are listed in table 6.1.1-2. On the basis of the data in table 6.1.1-2, peak monthly mean dissolved-solids load usually occurs during spring runoff in April, May, or June. Also, for stations on the White River, the total annual load increases in the downstream direction.

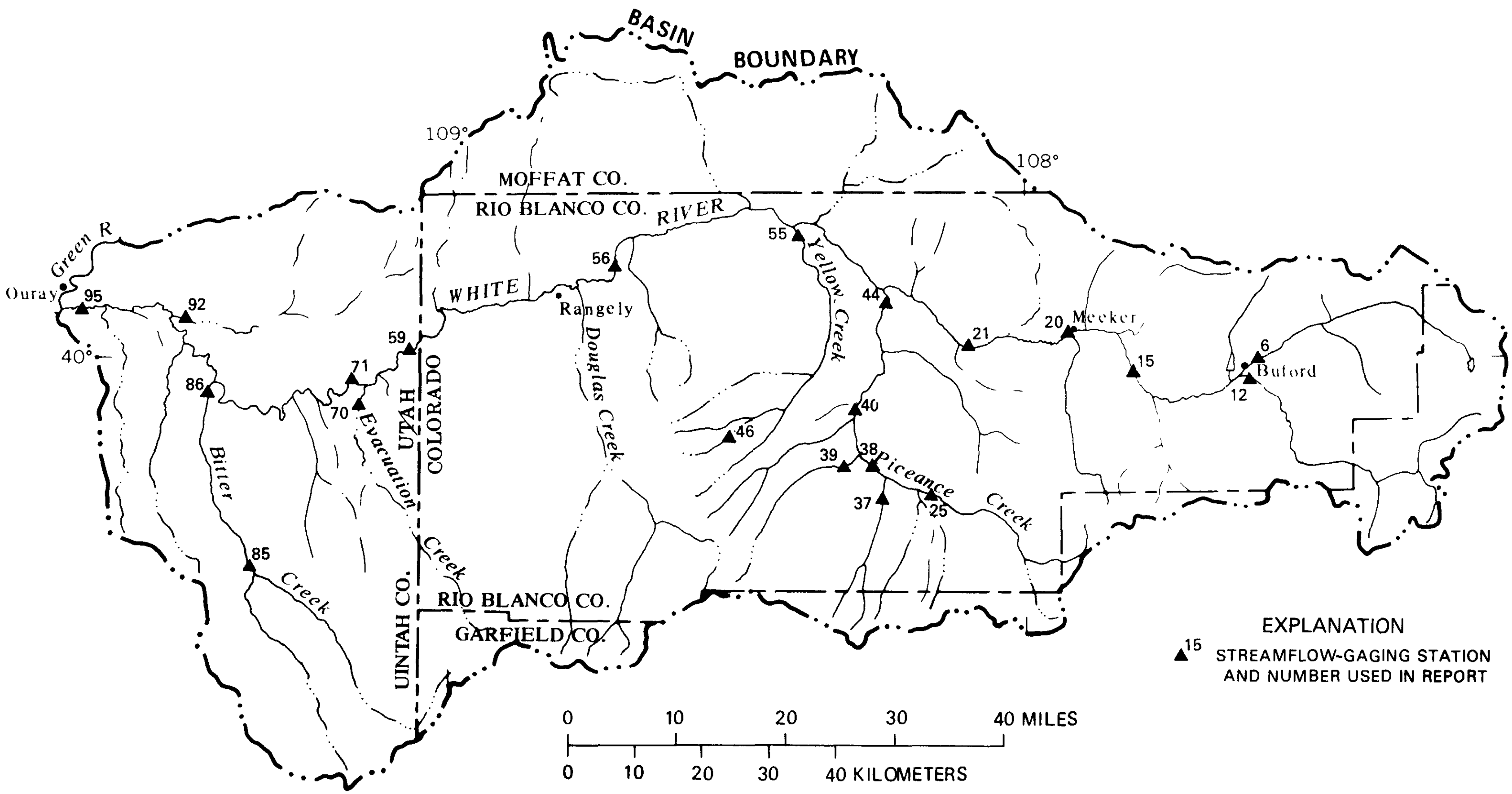


Figure 6.1.1-1.--Location of streamflow-gaging stations used to estimate daily dissolved-solids concentrations and monthly and annual loads.

Table 6.1.1-2.--*Monthly mean dissolved-solids loads and*

Station number used in report	Monthly mean dissolved-solids						
	October	November	December	January	February	March	April
6----	111	110	106	103	99	99	129
12----	57	51	48	46	29	49	65
15----	228	222	203	191	192	203	299
20----	347	350	344	364	347	360	476
21----	464	418	373	341	346	382	502
25----	11	16	14	13	13	16	29
37----	4.8	5.8	5.8	4.7	5.2	5.4	4.8
38----	21	36	41	35	35	38	46
39----	20	20	19	17	19	18	15
40----	46	60	54	48	55	63	55
44----	79	98	88	80	92	124	96
46----	.41	.30	.13	.07	.05	.07	.23
55----	8.1	9.5	7.6	6.5	14	17	14
56----	563	550	508	488	534	630	684
59----	532	545	527	548	630	728	895
70----	1.5	.36	.37	1.4	15	10	14
71----	597	583	526	515	593	816	880
85----	9.3	15	18	26	26	32	45
88----	27	25	22	23	26	27	29
92----	65	3.0	.0	.32	6.0	19	1.4
95----	553	577	534	533	740	1,090	862

total annual loads estimated from regression analysis

loads, in tons per day					
May	June	July	August	September	Total annual load (tons per year)
186	161	116	105	104	45,200
166	236	104	70	60	31,800
628	626	256	177	176	104,000
890	974	564	384	327	170,000
847	925	560	455	442	184,000
60	24	19	22	14	7,650
2.1	2.9	3.9	4.5	4.0	1,640
59	33	23	38	34	13,400
27	34	26	22	16	7,710
68	48	44	70	50	20,000
100	74	72	84	80	32,400
.95	.86	.66	.76	.64	157
12	8.9	8.3	9.2	7.3	3,700
1,130	1,140	666	534	518	242,000
1,130	1,300	664	442	417	254,000
20	4.8	7.0	4.5	3.3	2,510
1,390	1,290	664	551	545	272,000
41	28	16	7.5	4.4	8,150
37	40	26	26	26	10,200
.16	.04	20	494	5.5	19,000
1,350	1,360	753	510	482	284,000

DISSOLVED-SOLIDS LOADS ESTIMATED BY TWO METHODS

Dissolved-solids loads estimated from specific conductance and from discharge and time are very similar.

Dissolved-solids loads estimated from two methods were compared at 23 water-quality stations where the data needed for both methods had been measured. One method is to estimate daily dissolved-solids loads using daily streamflow as described in section 6.1.1. The second method is to estimate daily dissolved-solids loads using specific conductance as described below. Daily specific-conductance data generally are not available, and the more complicated model based on daily-discharge data commonly is used to estimate daily dissolved-solids loads. As shown in figure 6.1.2-1, which presents data at two representative water-quality stations, the loads computed by the two methods are very similar for most stations.

If daily specific-conductance data are available, daily dissolved-solids concentrations are computed easily from the nearly linear relation commonly expressed as (Delong, 1977):

$$C = E+(F \times K) \qquad \text{(eq. 6.1.2-1)}$$

where

C = daily dissolved-solids concentration, in milligrams per liter;
K = specific conductance, in micromhos per centimeter at 25°C; and
E and F = regression coefficients.

Monthly mean dissolved-solids loads are computed using daily dissolved-solids concentrations in equation 6.1.1-2.

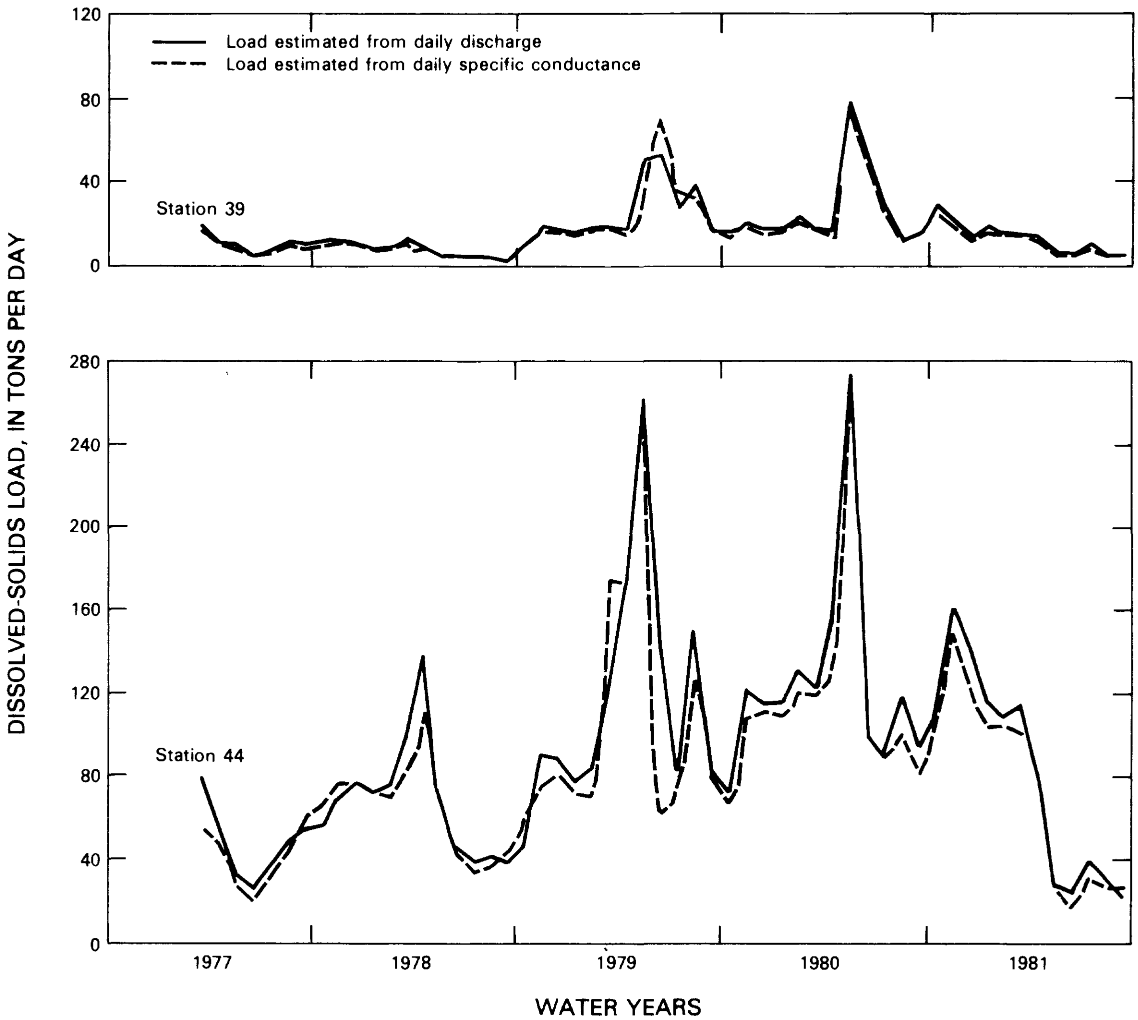


Figure 6.1.2-1.--Dissolved-solids loads at water-quality stations 39 and 44.

Of the 23 water-quality stations (figure 6.1.2-2) in the White River basin that were used in this analysis, there was a similar relation between dissolved-solids concentration and specific conductance values at 19 of the stations. Therefore, the data from these 19 stations were combined to develop one relation. The two stations on Bitter Creek, stations 85 and 88, were combined to develop one relation. Separate relations were determined for the two remaining stations: station 55, Yellow Creek near White River and station 58, Douglas Creek near Rangely, because their relations were found to differ significantly from any of the other stations. These four relations for the White River basin are shown in figure 6.1.2-3. Regression coefficients and the standard error of estimate for the four relations are listed in table 6.1.2-1.

Table 6.1.2-1.--*Coefficients for relations between dissolved-solids and specific conductance*

Group number	E	F	SE[1]
1------------------	-11	0.682	6.6
2------------------	378	.572	7.2
3------------------	-41	.808	3.4
4------------------	204	.927	13

[1]SE = Standard error of estimate, in percent of the mean.

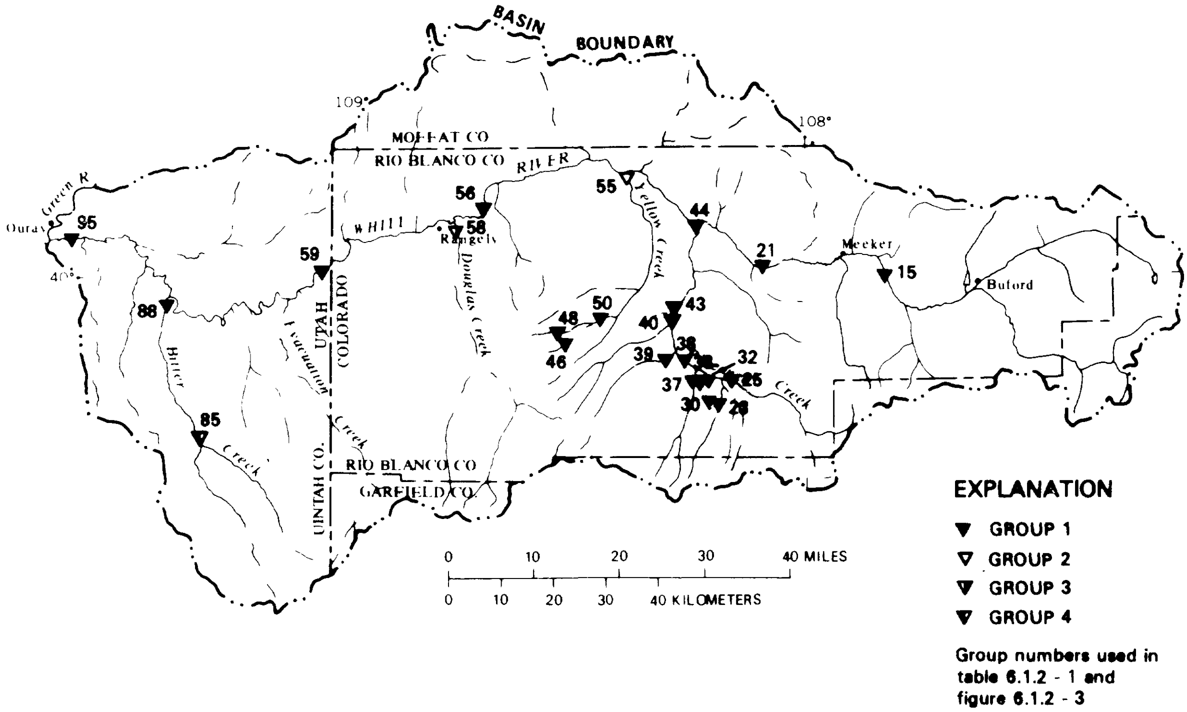


Figure 6.1.2-2.--Location of water-quality stations used to estimate dissolved-solids concentrations.

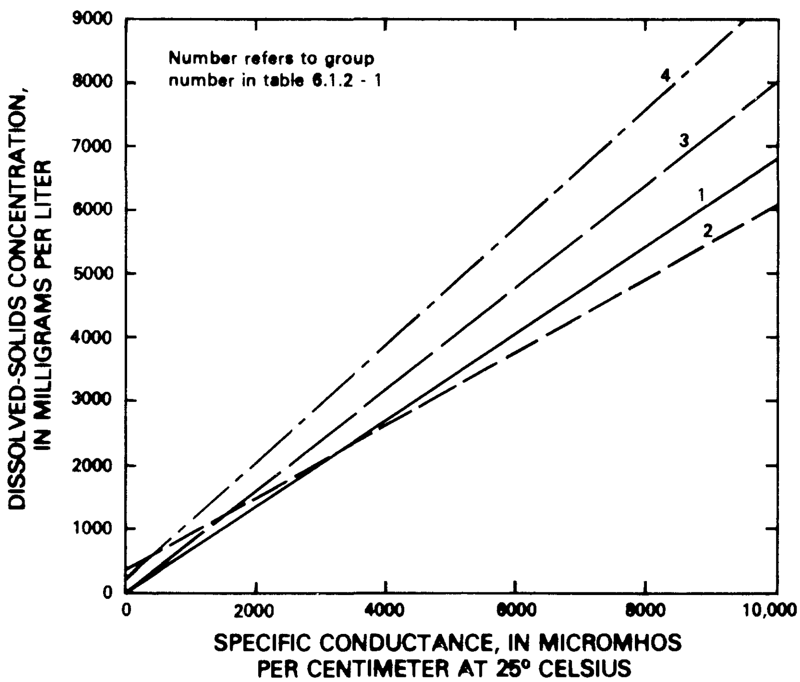


Figure 6.1.2-3.--Dissolved-solids and specific-conductance relations.

DEVELOPMENT COULD AFFECT DISSOLVED-SOLIDS LOADS AND CONCENTRATIONS

If oil shale is further developed in the White River basin, a 10-percent increase to a 14-percent decrease of the dissolved-solids load could result at the mouth of the White River near Ouray, Utah. This corresponds to a 5-percent increase to a 10-percent decrease of the dissolved-solids concentration.

Oil-shale developments require large quantities of water for their operation. Ground water commonly is pumped from subsurface mines and then used in mining operations, discharged to a stream, or pumped back into the ground. Surface water might be diverted for use in mining operations. Increases or decreases in streamflow will change the dissolved-solids load and concentration of the stream. Equation 6.1.3-1 was used to analyze changes in dissolved-solids loads and concentrations for hypothetical increases and decreases of streamflow:

$$C_{total} = (C_s \times Q_s + C_g \times Q_g)/(Q_s + Q_g) \qquad \text{(eq. 6.1.3-1)}$$

where

C_{total} = resulting dissolved-solids concentration in the stream, in milligrams per liter;
C_s = average annual dissolved-solids concentration in the stream, in milligrams per liter;
Q_s = mean annual discharge of the stream, in cubic feet per second;
C_g = average dissolved-solids concentration in the ground water, in milligrams per liter; and
Q_g = hypothetical discharge of the ground water, in cubic feet per second.

The effects of discharging ground water containing various dissolved-solids concentrations into Piceance Creek are shown in figure 6.1.3-1. The resulting dissolved-solids concentration of the stream is increased only if the dissolved-solids concentration of the ground water is greater than about 1,500 mg/L (milligrams per liter). The quantity of ground water discharged into the stream has little effect on the dissolved-solids concentration of the stream except when dissolved-solids concentrations in the ground water either are greater than 2,000 mg/L or are less than 750 mg/L.

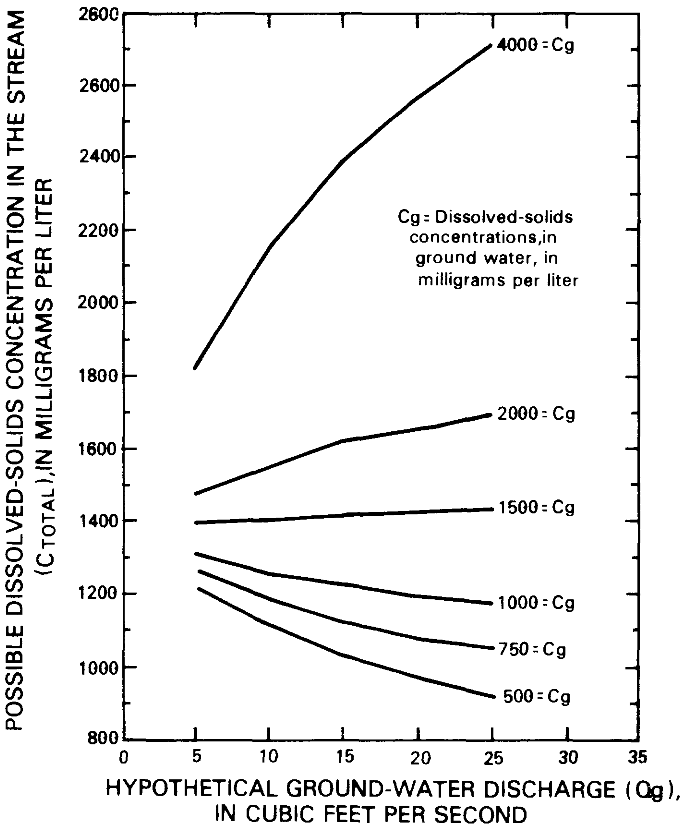


Figure 6.1.3-1.--Possible dissolved-solids concentrations in Piceance Creek at White River, Colo., that could result from the discharge of ground water containing variable dissolved-solids concentrations into the creek.

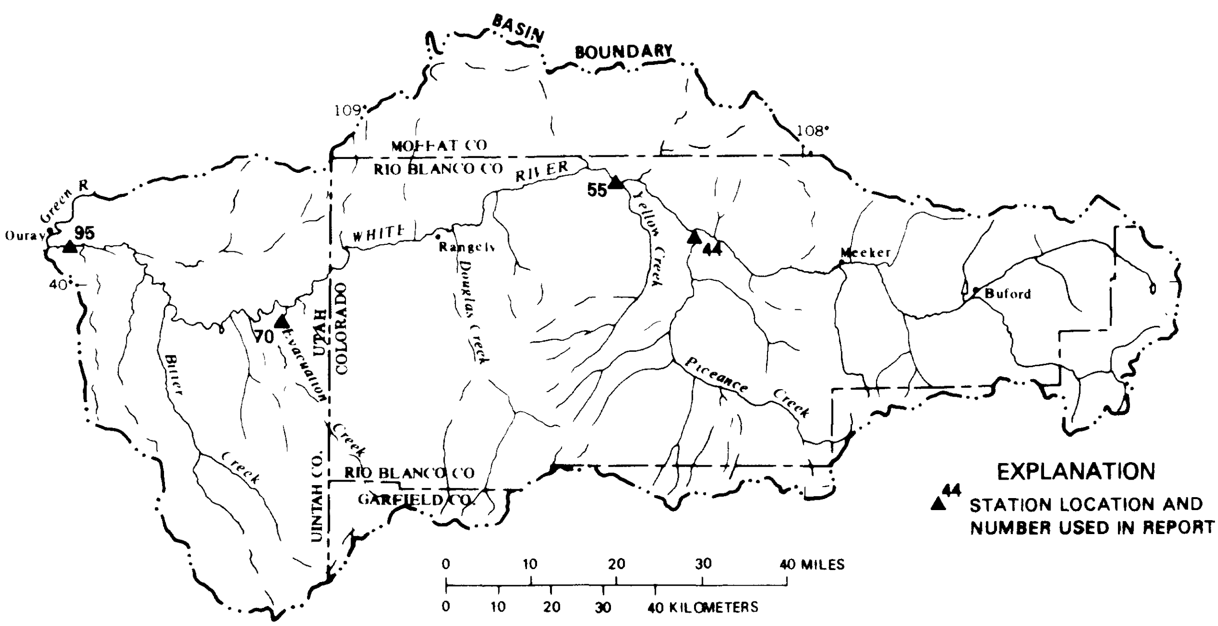


Figure 6.1.3.2.--Location of stations used in analysis of possible dissolved-solids changes in streamflow.

The mean annual discharge of Piceance Creek at White River (site 44 in figure 6.1.3-2) is 23.9 cubic feet per second. The mean annual discharge could approximately double if ground water were discharged into Piceance Creek at a rate of 25 cubic feet per second (Q_g). If the ground water has a dissolved-solids concentration of 1,000 mg/L ^{g}(Robson, 1981), the mean annual dissolved-solids load of 32,400 tons per year could increase 76 percent to 57,000 tons per year in Piceance Creek at White River. The mean annual dissolved-solids concentration in Piceance Creek at White River, 1,380 mg/L, could decrease 15 percent to 1,170 mg/L.

At Yellow Creek near White River (site 55 in figure 6.1.3-2), the mean annual discharge of 1.71 cubic feet per second could approximately double if ground water were discharged at a rate of 2 cubic feet per second (Q_g) into the stream. If the ground water has a dissolved-solids concentration of 1,000 mg/L, the mean annual dissolved-solids load of 3,700 tons per year could increase 50 percent to 5,550 tons per year in Yellow Creek near White River. The mean annual dissolved-solids concentration in Yellow Creek near White River, 2,200 mg/L, could decrease 30 percent to 1,540 mg/L. The relation of dissolved-solids concentration in ground water (C_g) and the resultant dissolved-solids concentration (C_{total}) in Yellow Creek near White River for a ground-water discharge (Q_g) of 2 cubic feet per second is shown in figure 6.1.3-3.

The mean annual discharge of Evacuation Creek near Watson (site 70 in figure 6.1.3-2), 1.59 cubic feet per second, could approximately double if ground water is discharged at a rate of 2 cubic feet per second (Q_g) into the stream. If the ground water has a dissolved-solids concentration of 1,000 mg/L, the mean annual dissolved-solids load of 2,510 tons per year could increase 80 percent to 4,520 tons per year in Evacuation Creek near Watson. The mean annual dissolved-solids concentration in Evacuation Creek near Watson, 2,270 mg/L could decrease 35 percent to 1,480 mg/L. The relation of dissolved-solids concentration in ground water (C_g) and the resultant dissolved-solids concentration (C_{total}) in Evacuation Creek near Watson for a ground-water discharge of 2 cubic feet per second is shown in figure 6.1.3-4.

The mean annual discharge at the mouth of the White River near Ouray, Utah (site 95 in figure 6.1.3-2), 644 cubic feet per second, could increase 5 percent to 676 cubic feet per second and the mean annual dissolved-solids load of 284,000 tons per year could increase 10 percent to 312,000 tons per year if simultaneous discharges of ground water to Piceance Creek, Yellow Creek, and Evacuation Creek occur as described. The mean annual dissolved-solids concentration, 447 mg/L, could increase 5 percent to 469 mg/L. A decrease in dissolved-solids loads of about 14 percent to 244,000 tons per year and a decrease in dissolved-solids concentrations of about 10 percent to 402 mg/L at the mouth of the White River could result if Piceance Creek, Yellow Creek, and Evacuation Creek were to cease flowing due to the diversion of surface water.

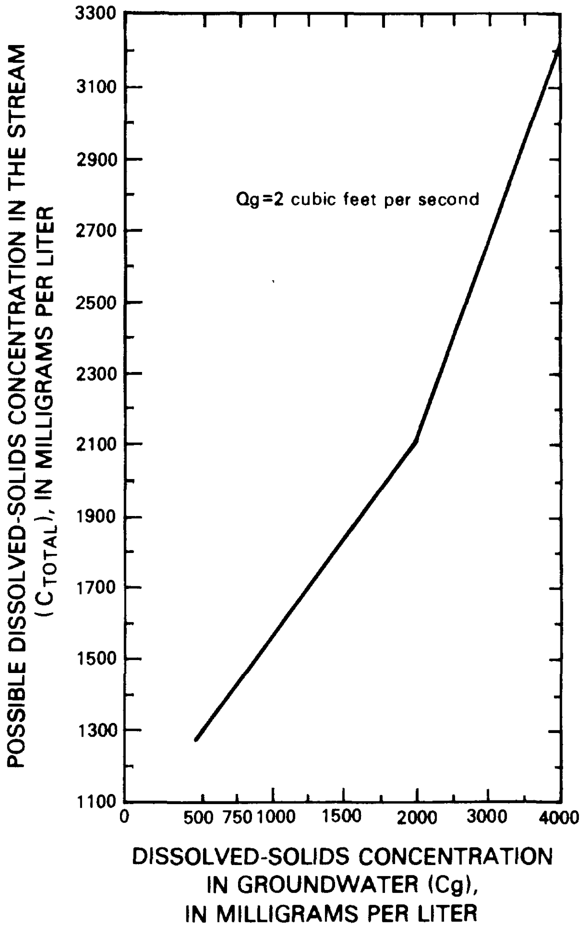


Figure 6.1.3-3.--Possible dissolved-solids concentrations in Yellow Creek near White River, Colo., that could result from the discharge of ground water containing variable dissolved-solids concentrations into the creek.

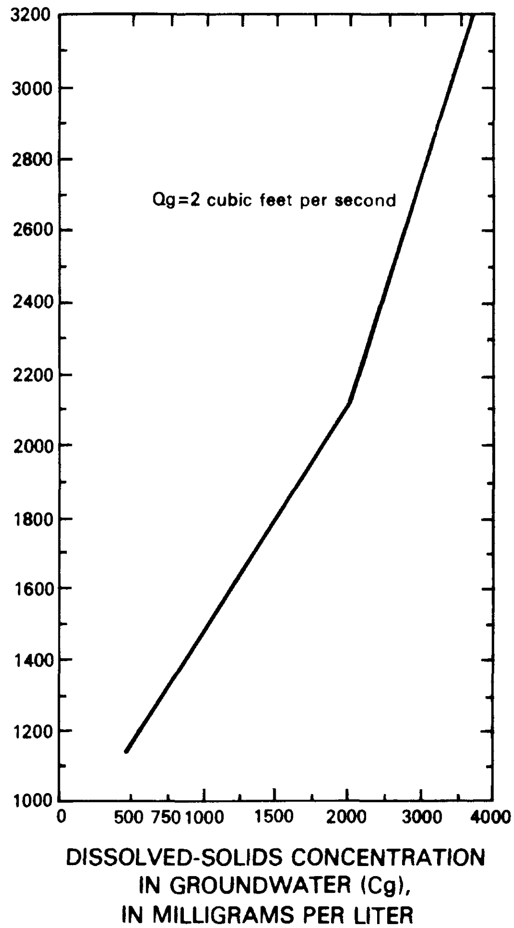


Figure 6.1.3-4.--Possible dissolved-solids concentrations in Evacuation Creek near Watson, Utah, that could result from the discharge of ground water containing variable dissolved-solids concentrations into the creek.

WATER TEMPERATURES ARE HARMONICALLY DISTRIBUTED

Stream temperatures can be estimated with equations developed from periodic stream-temperature data.

Stream temperatures follow a cyclic seasonal pattern with high temperatures in the summer and low temperatures in the winter. This seasonal pattern fits a harmonic curve because it approximates a mathematical sine function. The general form of the harmonic sine function is:

$$T = HM + A[\sin(b \times t + C)] \qquad \text{(eq. 6.2.1-1)}$$

where

T = stream temperature, in degrees Celsius, on day t;
HM = harmonic-mean temperature, in degrees Celsius;
A = amplitude, in degrees Celsius;
b = 0.0172 radians per day = $2\pi/365$ days; and
C = phase angle, in radians.

The harmonic-mean temperature is the average stream temperature for the harmonic curve. Amplitude is the maximum difference between the highest or lowest part of the curve and the harmonic-mean temperature. Phase angle is the time that the curve is offset from a normal sine curve. Values for these harmonic parameters for selected stations were determined by a regression analysis that fits a harmonic curve to the data.

Seasonal temperature patterns and the completed harmonic curves for station 21, White River below Meeker, and station 44, Piceance Creek at White River, are shown in figures 6.2.1-1 and 6.2.1-2. The harmonic-mean temperature (HM), amplitude (A), and phase angle (C) are labeled in the figures. The number of observations, harmonic-mean temperature, amplitude, phase angle, and standard error of estimate for 20 selected stations are listed in table 6.2.1-1.

The instantaneous daily stream temperatures used in the harmonic analysis generally were measured during the day. Temperatures measured during the daytime are biased toward the maximum daily value. Therefore, the harmonic parameters determined from these stream temperatures will be between those expected from daily mean temperatures and daily maximum temperatures.

The maximum annual stream temperature, in degrees Celsius (°C), can be calculated by adding the harmonic-mean (HM) plus the amplitude (A) (figs. 6.2.1-1 and 6.2.1-2). The minimum annual stream temperature is equal to the harmonic-mean (HM) minus the amplitude (A), but is never less than freezing, 0° Celsius.

Table 6.2.1-1.--*Harmonic parameters for periodic stream temperatures for selected stations*

[HM = Harmonic-mean temperature; A = Amplitude; C = Phase angle; SE = Standard error of estimate; and °C = degrees Celsius]

Station number used in report	Station name	Number of measurements	HM (°C)	A (°C)	C (radians)	SE (°C)
1	North Fork White River below Trappers Lake, Colo.	50	3.25	9.56	2.41	3.3
6	North Fork White River at Buford, Colo.	247	6.09	6.87	2.76	2.4
12	South Fork White River at Buford, Colo.	183	2.73	6.80	2.73	2.6
15	White River above Coal Creek, near Meeker, Colo.	324	6.88	7.16	2.72	2.4
20	White River at Meeker, Colo.	122	7.71	7.86	2.79	2.6
21	White River below Meeker, Colo.	373	8.09	8.53	2.80	2.7
25	Piceance Creek below Rio Blanco, Colo.	154	8.47	7.47	2.88	3.2
38	Piceance Creek above Hunter Creek, near Rio Blanco, Colo.	154	9.76	7.86	2.79	2.9
40	Piceance Creek below Ryan Gulch, near Rio Blanco, Colo.	297	8.97	8.38	2.82	3.2
44	Piceance Creek at White River, Colo.	208	9.50	9.96	2.94	3.9
50	Corral Gulch near Rangely, Colo.	117	11.2	5.17	2.90	2.8
55	Yellow Creek near White River, Colo.	82	11.0	11.2	2.91	4.8
56	White River above Rangely, Colo.	137	9.24	9.99	2.82	2.3
58	Douglas Creek at Rangely, Colo.	14	11.6	12.0	2.96	3.4
59	White River near Colorado-Utah State line, Utah	97	10.7	11.2	2.77	2.7
66	Evacuation Creek below Park Canyon, near Watson, Utah	39	10.6	12.6	2.69	4.0
70	Evacuation Creek near mouth, near Watson, Utah	137	13.3	11.4	2.70	4.9
71	White River near Watson, Utah	282	10.9	11.5	2.83	3.1
92	Coyote Wash near mouth, near Ouray, Utah	21	13.6	11.6	2.82	2.5
95	White River at mouth, near Ouray, Utah	206	10.9	12.2	2.83	2.8

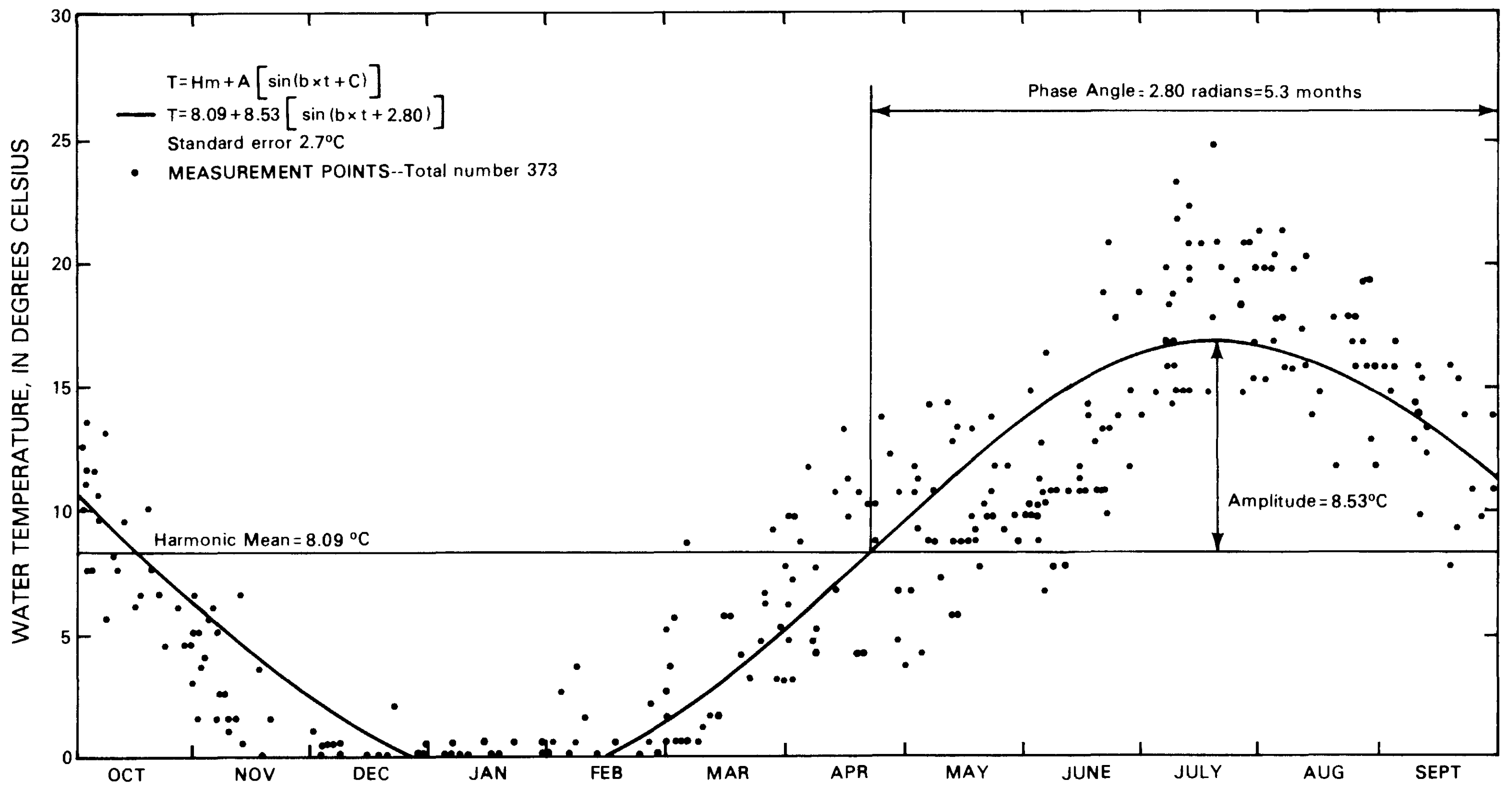


Figure 6.2.1-1.--Seasonal temperature patterns for period of record at station 21 White River below Meeker, Colo. (1962-81).

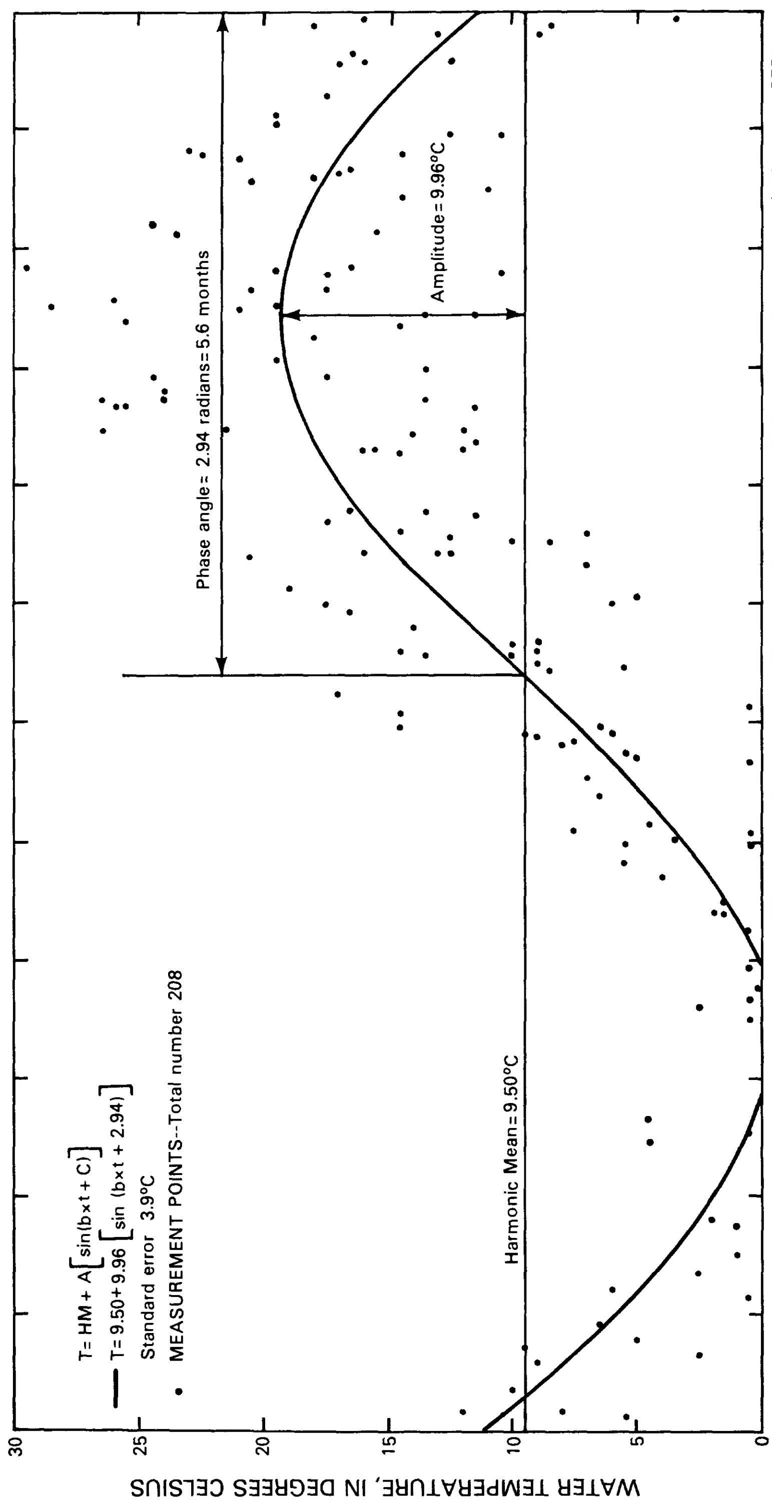


Figure 6.2.1-2.--Seasonal temperature patterns for period of record at station 44 Piceance Creek at White River, Colo. (1971-81).

6.2.2 Harmonic Characteristics versus Elevation

HARMONIC-TEMPERATURE CHARACTERISTICS CAN BE RELATED TO ELEVATION

The harmonic-mean temperature and amplitude for an annual temperature cycle decreases with an increase in elevation.

The harmonic-mean stream temperatures change with elevation. Stream temperatures increase in a downstream direction as elevation decreases. The harmonic temperature characteristics for a basin can be estimated using average basin elevation. Harmonic-mean temperature (*HM*) is related to average basin elevation (*X*) in the White River basin according to the equation (calculated from fig. 6.2.2-1):

$$HM = 22.8-(0.0018 \times X) \quad \text{(eq. 6.2.2-1)}$$

where *HM* = harmonic-mean temperature, in degrees Celsius;
22.8 and 0.0018 = regression coefficients; and
X = average basin elevation, in feet above sea level.

Amplitude (*A*) is related to average basin elevation according to the equation (calculated from fig. 6.2.2-1):

$$A = 18.0-(0.0011 \times X) \quad \text{(eq. 6.2.2-2)}$$

where *A* = amplitude, in degrees Celsius;
18.0 and 0.0011 = regression coefficients; and
X = average basin elevation, in feet above sea level.

Phase angle can be effectively estimated as the average value of phase angle ($\bar{C}$) for the basin. This is indicated by the similarity of the standard error of estimate of the regression line with the standard deviation about the mean (fig. 6.2.2-1).

Wentz and Steele's (1980) regression equation for estimating stream temperatures in the nearby Yampa River basin, northwestern Colorado,

$$HM = 20.8-(0.0022 \times X),$$

is similar to that calculated for the White River basin, $HM = 22.8-(0.0018 \times X)$.

An analysis of harmonic temperature characteristics for a basin may be useful in estimating changes resulting from man's activities even though there may be no predevelopment information near the development site. Harmonic temperature characteristics can be calculated from stream-temperature data collected downstream from the development. These characteristics can then be compared to predevelopment characteristics estimated from the average basin elevation of the site using the information in figure 6.2.2-1, which was analyzed using predevelopment data for the basin.

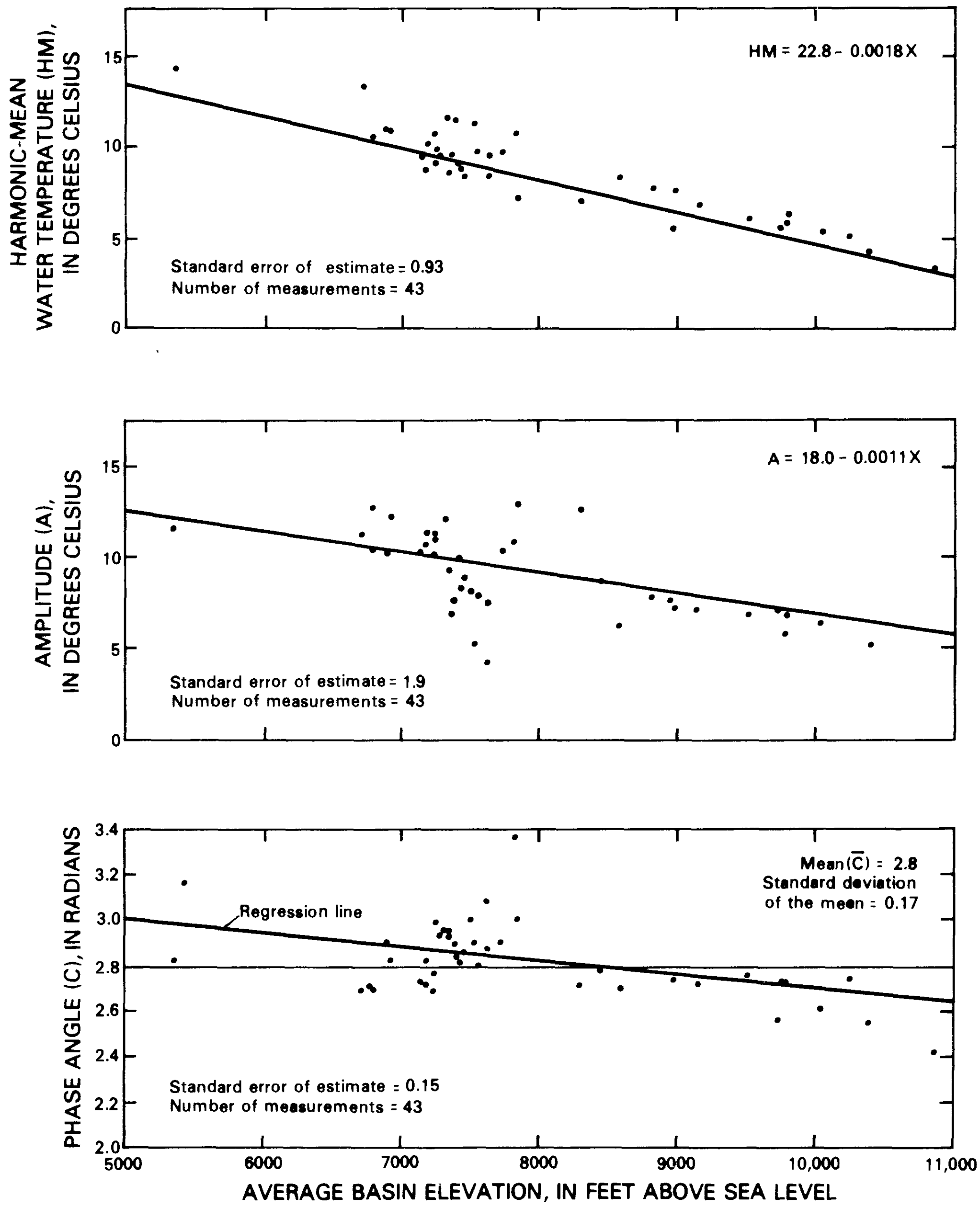


Figure 6.2.2-1.--Relations between stream-temperature harmonic-analysis coefficients and stream elevation.

6.2.3 Air-Temperature Relations

AIR TEMPERATURE CAN BE USED TO ESTIMATE WATER TEMPERATURE

A relation between air temperature and water temperature was found for 13 sites in the central part of the White River basin.

Water temperature is affected directly by air temperature. As air temperature fluctuates, the water temperature will change in the same manner after a short time lag. Therefore, the average daily water and air temperatures generally will increase and decrease proportionately from day to day. The relation between water temperature and air temperature can be expressed as:

$$WTEMP = A+(B \times ATEMP) \qquad \text{(eq 6.2.3-1)}$$

where

$WTEMP$ = water temperature, in degrees Celsius;
A and B = regression coefficients; and
$ATEMP$ = air temperature, in degrees Celsius.

Air-temperature data from the Meeker No. 2 weather station located in Meeker, Colo., were used for $ATEMP$ in the analysis. Air-temperature data were not available in the western or eastern parts of the White River basin and, therefore, only streams in the central part of the basin were analyzed.

Water-temperature data at 13 streamflow-gaging stations were analyzed. The regression coefficients (A and B) and the standard error of estimate (SE) for the 13 stations are listed in table 6.2.3-1. The relation of water temperature and air temperature for the 13 stations, three of which are located on the White River, seven in the Piceance Creek basin, and three in the Yellow Creek basin, is shown in figure 6.2.3-1.

Table 6.2.3-1.--*Water temperature versus air temperature, White River basin, Colorado*

Station number used in report	Station name	Regression coefficients A	Regression coefficients B	SE[1]
15	White River above Coal Creek, Colo.---------------	2.86	.601	25
20	White River at Meeker, Colo.----------------------	3.65	.570	30
21	White River below Meeker, Colo.----------------------	3.77	.642	27
25	Piceance Creek below Rio Blanco, Colo.----------	4.43	.538	23
27	Stewart Gulch above West Fork, Colo.-----------	6.29	.244	14
37	Willow Creek near Rio Blanco, Colo.----------	4.52	.476	23
38	Piceance Creek above Hunter Creek, Colo.---------------	4.98	.506	19
39	Black Sulphur Creek near Rio Blanco, Colo.----------	5.61	.428	20
40	Piceance Creek below Ryan Gulch, Colo.---------------	3.79	.667	21
44	Piceance Creek at White River, Colo.---------------	4.79	.701	29
48	Box Elder Gulch near Rangely, Colo.-------------	2.50	.658	19
51	Corral Gulch at 84 Ranch, Colo.----------------------	5.83	.509	31
55	Yellow Creek near White River, Colo.---------------	3.93	.731	29

[1]SE = Standard error of estimate, in percent of the mean.

White River upstream and downstream from streamflow-gaging station above Coal Creek, near Meeker, Colorado

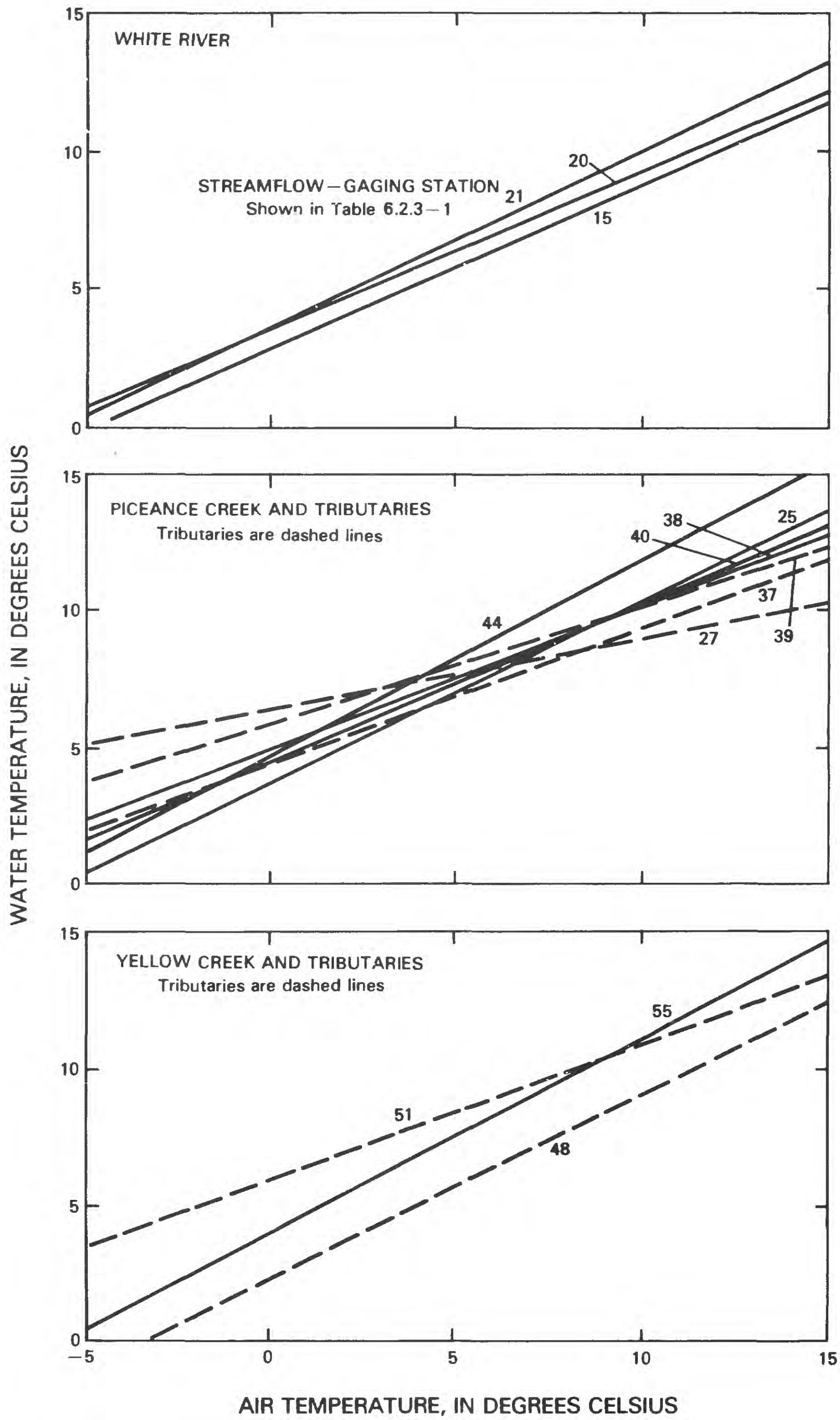


Figure 6.2.3-1.--Water temperature and air temperature relations at 13 streamflow-gaging stations in the central part of the White River basin, Colorado.

SUSPENDED-SEDIMENT MEASUREMENTS WERE MADE AT SEVEN STATIONS

The suspended-sediment discharge ranged from a minimum of 0.24 ton per day at a water discharge of 90 cubic feet per second at South Fork White River at Buford to a maximum sediment discharge of 130,000 tons per day for a water discharge of 1,150 cubic feet per second at White River above Rangely.

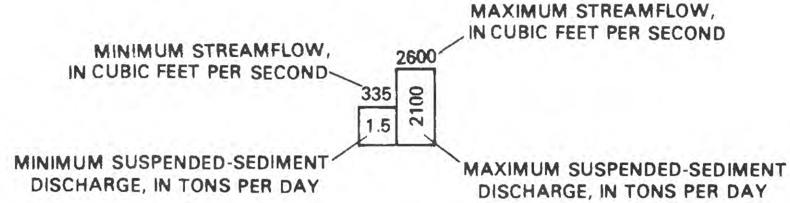
Suspended sediment is an important water-quality characteristic of flowing water. Suspended sediment consists of rock and soil particles that enter a stream either from hillslope erosion and entrainment or directly from the streambed. The sediment is transported in suspension by the turbulent components of flow. The minimum and maximum suspended-sediment discharges and the corresponding streamflow are shown in figure 6.3-1 for seven stations where suspended-sediment samples were collected.

Conditions that affect sediment discharge are geology, climate, topography, vegetative cover, and land use. The White River basin encompasses a variety of these conditions. For instance, the geology consists of resistant igneous rocks in the extreme upper reaches and loosely cemented sedimentary rocks in the middle and lower reaches. Loose-cemented sedimentary rock erodes faster and will contribute larger quantities of sediment to the river than resistant igneous rock. Vegetative cover varies from dense conifers and aspen in the eastern part of the basin to sparse semiarid flora in the western part. Vegetation holds the soil together and prevents it from eroding. Intense summer thunderstorms of short duration also will contribute to the sediment discharge by causing surface-runoff erosion.

Prolonged periods of large sediment concentration can have a harmful effect on the habitat of aquatic organisms. Suspended sediment can interfere with photosynthesis, bury benthic invertebrates by deposition, inhibit the respiration of gilled organisms, and could ultimately alter the aquatic ecosystem.

STATION NUMBER USED IN REPORT	STATION NAME
6	North Fork White River at Buford, Colo.
12	South Fork White River at Buford, Colo.
15	White River above Coal Creek, near Meeker, Colo.
21	White River below Meeker, Colo.
56	White River above Rangely, Colo.
59	White River near Colorado-Utah State line, Utah
95	White River at mouth, near Ouray, Utah

EXPLANATION



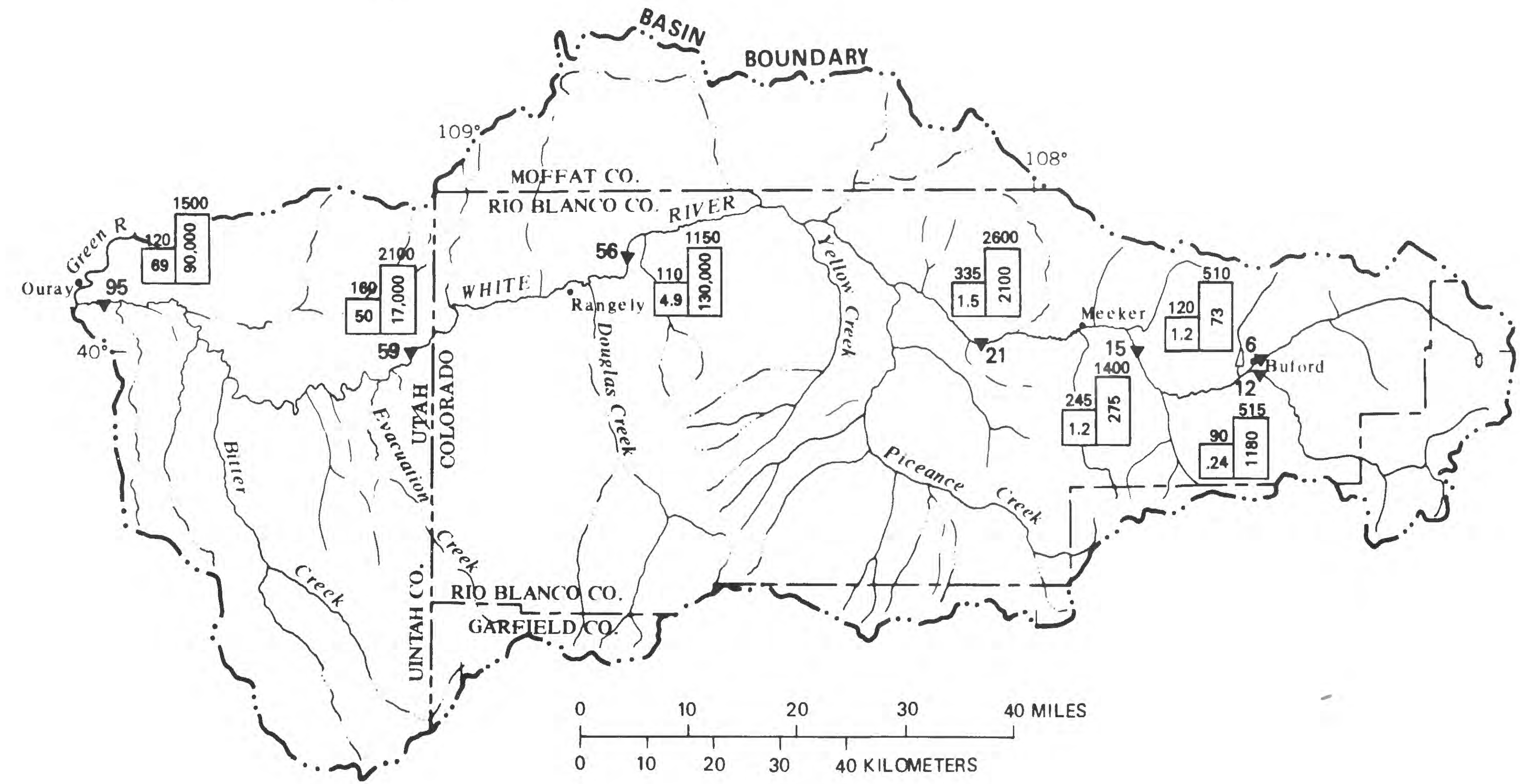


Figure 6.3-1.--Minimum and maximum suspended-sediment discharges at seven stations.

ANALYSIS OF LONG-TERM WATER-QUALITY DATA

Eight selected chemical constituents can be estimated from specific conductance and discharge.

Regression equations (table 6.4-1) were calculated for five stations on the White River that had water-quality records for more than 7 years (fig. 6.4-1). Major chemical constituents were regressed against specific conductance and against discharge. The chemical constituents used in the analysis were alkalinity, calcium, chloride, magnesium, potassium, sodium, and sulfate.

These regression equations can be used to estimate the seven chemical constituents when no chemical data are available but when either discharge or specific-conductance data are available. The regression equations were calculated using the Statistical Analysis System (SAS) General Linear Models (GLM) procedure (Barr and others, 1979). The GLM procedure computes the equations by the least-squares method in the form of $y = mx+b$, where m is the slope and b is the y intercept. The number of data pairs used to calculate the equations and the standard error of estimates (SE) also are included in table 6.4-1. The standard error of estimate is an indication of how well the regression equation predicts the constituent of interest; the smaller the standard error, the more accurate the prediction. The standard errors of estimate ranged from 6.3 to 95.1 percent.

Table 6.4-1.--*Regression equations of major ions versus specific conductance and discharge at selected stations*

[All constituents, in milligrams per liter;
N = number of data pairs used to compute regression equations;
K = specific conductance, in micromhos per centimeter at 25° Celsius; and
Q = water discharge, in cubic feet per second]

Regression equation			N	Standard error of estimate (SE), in percent of the mean
Station 15 White River above Coal Creek, near Meeker, Colo.				
Log alkalinity (as $CaCO_3$)	=	0.48 log K + 0.80	148	7.8
Log calcium	=	1.04 log K - 0.92	148	6.3
Log chloride	=	1.60 log K - 3.96	148	95.1
Log magnesium	=	0.88 log K - 1.27	148	6.6
Log potassium	=	0.20 log K - 0.48	148	18.3
Log sodium	=	1.05 log K - 2.11	148	16.6
Log sulfate	=	1.93 log K - 3.10	148	13.6
Log alkalinity (as $CaCO_3$)	=	-0.12 log Q + 2.34	148	8.3
Log calcium	=	-0.27 log Q + 2.42	148	8.2
Log chloride	=	-0.47 log Q + 1.31	148	93.3
Log magnesium	=	-0.24 log Q + 1.60	148	7.3
Log potassium	=	-0.05 log Q + 0.18	148	18.6
Log sodium	=	-0.29 log Q + 1.30	148	15.0
Log sulfate	=	-0.51 log Q + 3.14	148	16.8

Table 6.4-1.--*Regression equations of major ions versus specific conductance and discharge at selected stations*--Continued

Regression equation			N	Standard error of estimate (SE), in percent of the mean
Station 21 White River below Meeker, Colo.				
Log alkalinity (as $CaCO_3$)	=	0.56 log K + 0.58	194	38.8
Log calcium	=	0.80 log K - 0.39	194	7.8
Log chloride	=	1.86 log K - 3.69	194	22.5
Log magnesium	=	1.00 log K - 1.52	194	12.6
Log potassium	=	0.54 log K - 1.22	194	25.0
Log sodium	=	1.69 log K - 3.20	194	14.3
Log sulfate	=	1.49 log K - 2.04	194	13.9
Log alkalinity (as $CaCO_3$)	=	-0.19 log Q + 2.65	199	39.6
Log calcium	=	-0.32 log Q + 2.67	199	9.9
Log chloride	=	-0.79 log Q + 3.54	199	18.4
Log magnesium	=	-0.36 log Q + 2.23	199	18.3
Log potassium	=	-0.16 log Q + 0.70	199	27.0
Log sodium	=	-0.68 log Q + 3.27	199	17.9
Log sulfate	=	-0.58 log Q + 3.64	199	19.1
Station 56 White River above Rangely, Colo.				
Log alkalinity (as $CaCO_3$)	=	0.64 log K + 0.42	68	8.6
Log calcium	=	0.66 log K - 0.09	68	8.6
Log chloride	=	1.62 log K - 3.14	68	18.4
Log magnesium	=	1.02 log K - 1.55	68	8.4
Log potassium	=	0.74 log K - 1.82	68	23.7
Log sodium	=	1.61 log K - 2.87	68	11.9
Log sulfate	=	1.38 log K - 1.74	68	12.3
Log alkalinity (as $CaCO_3$)	=	-0.25 log Q + 2.92	66	12.8
Log calcium	=	-0.27 log Q + 2.55	66	11.9
Log chloride	=	-0.72 log Q + 3.44	66	21.1
Log magnesium	=	-0.38 log Q + 2.40	66	18.2
Log potassium	=	-0.18 log Q + 0.78	66	30.5
Log sodium	=	-0.60 log Q + 3.35	66	28.7
Log sulfate	=	-0.50 log Q + 3.52	66	25.4
Station 59 White River near Colorado-Utah State line, Utah				
Log alkalinity (as $CaCO_3$)	=	0.60 log K + 0.52	38	8.8
Log calcium	=	0.67 log K - 0.11	38	8.9
Log chloride	=	1.93 log K - 4.06	38	23.0
Log magnesium	=	0.99 log K - 1.44	38	10.0
Log potassium	=	0.63 log K - 1.50	38	19.9
Log sodium	=	1.58 log K - 2.78	38	12.2
Log sulfate	=	1.37 log K - 1.71	38	10.4
Log alkalinity (as $CaCO_3$)	=	-0.17 log Q + 2.71	39	12.1
Log calcium	=	-0.22 log Q + 2.42	39	10.4
Log chloride	=	-0.67 log Q + 3.26	39	22.6
Log magnesium	=	-0.31 log Q + 2.22	39	15.4
Log potassium	=	-0.21 log Q + 0.86	39	23.5
Log sodium	=	-0.49 log Q + 3.05	39	22.4
Log sulfate	=	-0.44 log Q + 3.37	39	18.7
Station 95 White River at mouth, near Ouray, Utah				
Log alkalinity (as $CaCO_3$)	=	0.52 log K + 0.77	114	14.4
Log calcium	=	0.65 log K - 0.08	114	10.7
Log chloride	=	1.67 log K - 3.31	114	18.0
Log magnesium	=	1.02 log K - 1.55	114	15.2
Log potassium	=	0.65 log K - 1.55	114	21.8
Log sodium	=	1.51 log K - 2.54	114	15.8
Log sulfate	=	1.37 log K - 1.72	114	9.9
Log alkalinity (as $CaCO_3$)	=	-0.15 log Q + 2.69	114	17.7
Log calcium	=	-0.21 log Q + 2.37	114	15.8
Log chloride	=	-0.59 log Q + 3.08	114	27.1
Log magnesium	=	-0.33 log Q + 2.27	114	23.1
Log potassium	=	-0.19 log Q + 0.85	114	24.9
Log sodium	=	-0.49 log Q + 3.15	114	28.8
Log sulfate	=	-0.43 log Q + 3.40	114	25.2

White River downstream from Colorado-Utah state line

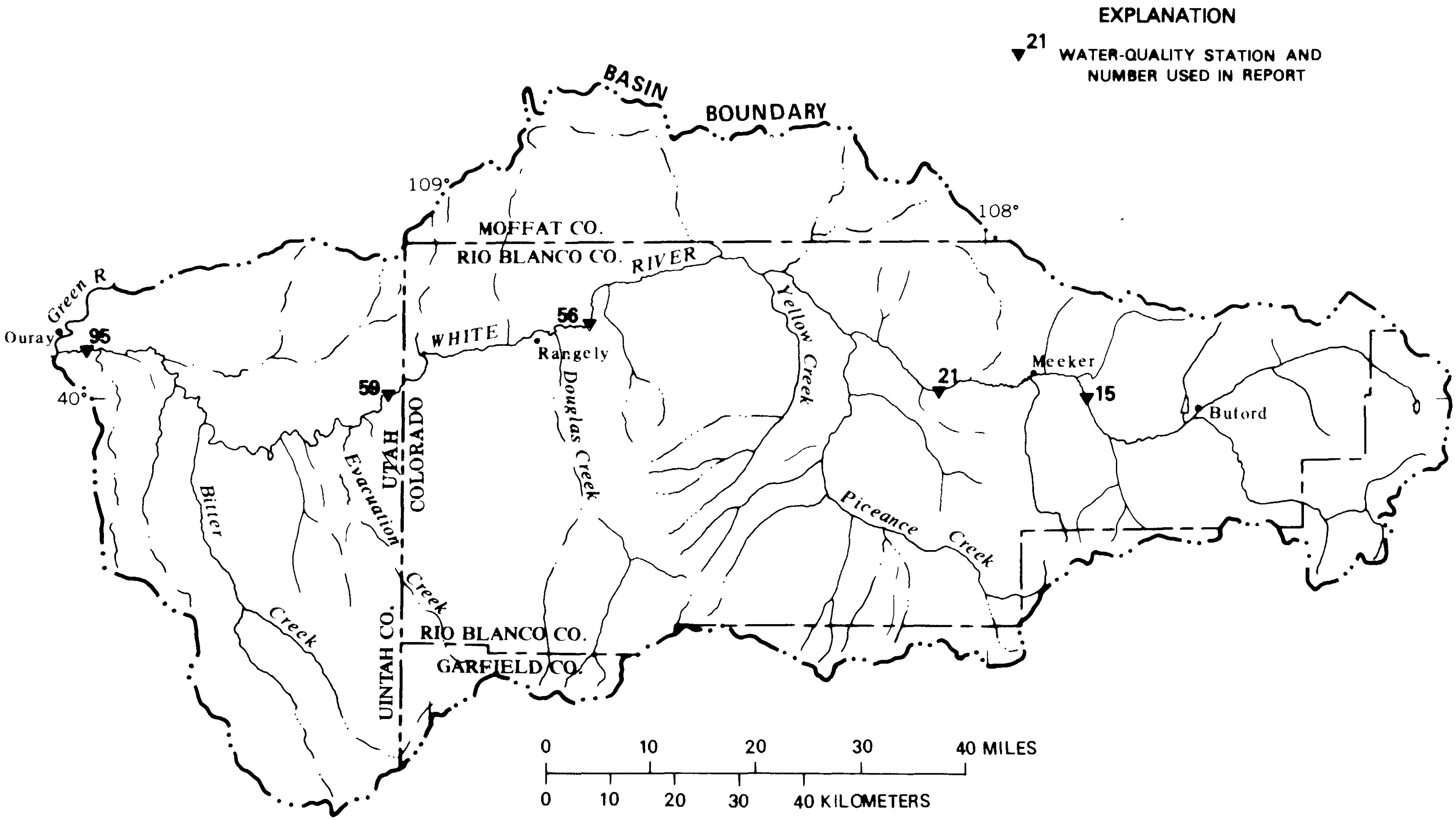


Figure 6.4-1.--Long-term water-quality stations on the White River.

BENTHIC INVERTEBRATES LIVE IN THE WHITE RIVER

Benthic invertebrates can be used to assess changes in the aquatic environment.

Benthic invertebrates are animals without backbones that live on or in the bed material of a stream. These animals include immature forms of insects such as mayflies, stoneflies, and caddisflies, and other benthic organisms such as snails, leeches, scuds, watermites, and aquatic worms.

Benthic invertebrates possess certain characteristics that make them useful for water-quality studies. They have relatively long aquatic-life stages, are relatively immobile, and are sensitive to changes in their environment; therefore, a change in population can indicate a change in water quality. The population of benthic invertebrates in a stream is useful in detecting past disturbances in the aquatic environment, which may not be detected by chemical sampling.

Biologic communities are a reflection of the chemical and physical properties of a stream. A stream with unpolluted water will support many invertebrate species in relatively equal abundance. Streams with degraded water quality will support fewer species, but each species will be more tolerant of extremes in aquatic conditions. Immature insects such as stoneflies, mayflies, and caddisflies usually are associated with water-quality conditions reflecting unpolluted water. Other organisms such as aquatic worms, midges, and certain snails usually are associated with deficient oxygen concentrations and organic enrichment.

The relative benthic-invertebrate composition at six stations on the White River (fig. 6.5-1) are listed in table 6.5-1. The 10-rock sampling technique was used to define invertebrate composition. At each station, 10 fist-sized rocks were examined, and the relative abundance of each insect order was determined. This is a qualitative technique and hence the results are reported as being absent, one, present, common, or abundant (Wentz, 1974). From a biological standpoint, the data indicate that the eastern part of the White River is an unpolluted stream. This is indicated by the abundance of caddisflies and the presence of mayflies. The appearance of two-winged flies indicates a slight deterioration of the White River downstream from the confluence of the North Fork White River and the South Fork White River.

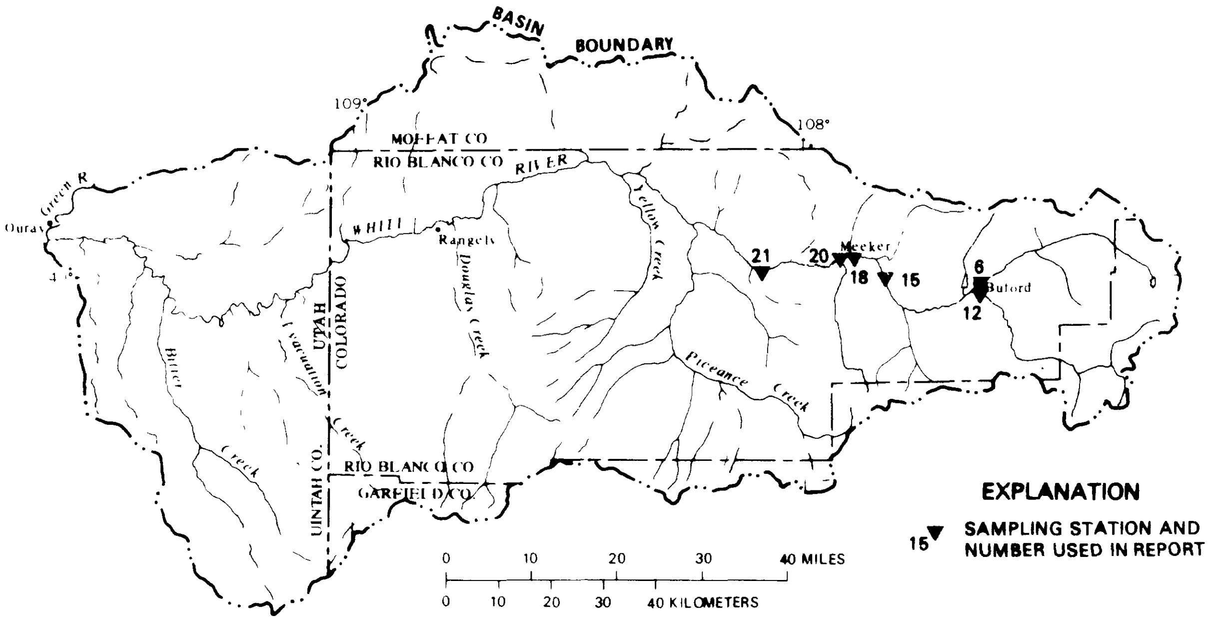


Figure 6.5-1.--Benthic-invertebrate sampling stations on the White River, Colo.

Table 6.5-1.--*Relative abundance of benthic invertebrates at six White River stations, White River basin, Colorado*

[A=absent; 1=one organism observed; P=present; C=common; C+=abundant]

Station number used in report	Station name	Beetles	Caddisflies	Mayflies	Stoneflies	Two-winged flies	Snails
6	North Fork White River at Buford, Colo.----------------------------	1	C+	P	A	A	A
12	South Fork White River at Buford, Colo.----------------------------	A	C+	P	A	A	P
15	White River above Coal Creek, near Meeker, Colo.----------------	A	C+	P	A	C	P
18	White River near Meeker, Colo.-----	A	C+	P	P	C	C
20	White River at Meeker, Colo.-------	A	C+	C	C	P	P
21	White River below Meeker, Colo.----	1	C	P	A	P	P

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7.0 REFERENCES CITED

Barr, A. J., and others, 1979, SAS User's Guide (1979 ed.): Raleigh, N. C. SAS Institute, Inc., 494 p.

Delong, L. L., 1977, An analysis of salinity in streams of the Green River basin, Wyoming: U.S. Geological Survey Water-Resources Investigations Report 77-103, 11 p.

Donnell, J. R., 1965, Geology and oil-shale resources of the Green River Formation: The Mountain Geologist, v. 2, no. 3, p. 95-100.

National Climatic Data Center, 1982a, Climatological data annual summary, Colorado: Asheville, N. C., v. 87, no. 13, p. 4-7.

_____1982b, Climatological data annual summary, Utah: Asheville, N. C., v. 87, no. 13.

Robson, S. G., and Saulnier, G. J., Jr., 1981, Hydrogeochemistry and simulated solute transport, Piceance basin, northwestern Colorado: U.S. Geological Survey Professional Paper 1196, p. 27, 37-41.

Wentz, D. A., 1974, Effect of mine drainage on the quality of streams in Colorado, 1971-72: Colorado Water Conservation Board Water-Resources Circular 21, 117 p.

Wentz, D. A., and Steele, T. D., 1980, Analysis of stream quality in the Yampa River basin, Colorado and Wyoming: U.S. Geological Survey Water-Resources Investigations Report 80-8, p. 16-21.

Summary of surface-water hydrologic monitoring stations

[* = data being collected during water year 1983; -- = no data available]

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years) Discharge	Chemical	Sediment	Biology
1	09302400	North Fork White River below Trappers Lake, Colo.	19.5	1956-65	--	--	--
2	09302420	North Fork White River above Ripple Creek, near Trappers Lake, Colo.	62.5	1965-73	--	--	--
3	09302450	Lost Creek near Buford, Colo.	21.5	1964-*	1981	--	1981
4	09302500	Marvine Creek near Buford, Colo.	59.7	1903-06, 1972-*	1975-81	1975	1981
5	09302800	North Fork White River near Buford, Colo.	220	1903-06, 1956-72	--	--	--
6	09303000	North Fork White River at Buford, Colo.	260	1910-15, 1919-20, 1951-*	1975-81	1975-78, 1981	1981
7	09303300	South Fork White River at Budges Resort, Colo.	52.3	1975-*	--	--	--
8	09303320	Wagonwheel Creek at Budges Resort, Colo.	7.36	1975-*	--	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
9	09303340	Patterson Creek near Budges Resort, Colo.	11.2	1976-*	--	--	--
10	09303400	South Fork White River near Budges Resort, Colo.	128	1976-*	1976-81	--	--
11	09303500	South Fork White River near Buford, Colo.	152	1903-06, 1910-15, 1942-47, 1967-*	1975-81	1975	1981
12	09304000	South Fork White River at Buford, Colo.	177	1919-20, 1951-*	1975-81	1977-78, 1981	1981
13	09304100	Big Beaver Creek near Buford, Colo.	34.1	1955-64	--	--	--
14	09304150	Miller Creek near Meeker, Colo.	57.6	1970-*	1981	--	1981
15	09304200	White River above Coal Creek, near Meeker, Colo.	648	1961-*	1970, 1973-81	1975, 1981	1981
16	09304300	Coal Creek near Meeker, Colo.	25.1	1957-68	--	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
17	09304480	Coal Creek below Little Beaver Creek, near Meeker, Colo.---------	--	1978-*	1978-*	--	1981
18	09304500	White River near Meeker, Colo.-----	755	1901-06, 1909-*	1947, 1971, 1973-77, 1981	--	1981
19	09304550	Curtis Creek near Meeker, Colo.----	--	1978-*	1978-*	--	1981
20	09304600	White River at Meeker, Colo.-------	808	1978-*	1978-*	--	--
21	09304800	White River below Meeker, Colo.----	1,024	1961-*	1974-*	1980-*	1974-81
22	09305000	White River at White River, Colo.--	--	1895	--	--	--
23	09305500	Piceance Creek at Rio Blanco, Colo.	--	1952-57	--	--	--
24	09306000	Piceance Creek near Rio Blanco, Colo.----------------------------	--	1940-43	--	--	--
25	09306007	Piceance Creek below Rio Blanco, Colo.----------------------------	177	1974-*	1974-*	1974-*	1974-76, 1978-81
26	09306015	Middle Fork Stewart Gulch near Rio Blanco, Colo.-----------------	24.0	1974-76, 1978-*	--	1974-76, 1978-*	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
27	09306022	Stewart Gulch above West Fork, near Rio Blanco, Colo.--------------	44.0	1974-*	1974-*	1974-*	1974-76, 1978-81
28	09306025	West Fork Stewart Gulch near Rio Blanco, Colo.-------------------	14.2	1974-76, 1978-*	1974-76, 1978-*	1974-76, 1978-*	1975, 1976
29	09306028	West Fork Stewart Gulch at mouth, near Rio Blanco, Colo.--------------	15.7	1974-*	1974-*	1974-*	--
30	09306033	Sorghum Gulch near Rio Blanco, Colo.-	1.22	1974-76, 1978-*	1974-76, 1978-*	1974-76	1975, 1976
31	09306036	Sorghum Gulch at mouth, near Rio Blanco, Colo.-----------------------	3.62	1974-*	1974-*	1974-82	--
32	09306039	Cottonwood Gulch near Rio Blanco, Colo.-------------------------------	1.20	1974-*	1974-*	1974-82	--
33	09306042	Piceance Creek tributary near Rio Blanco, Colo.-----------------------	1.06	1974-*	1974-*	1974-*	1980
34	09306045	Piceance Creek below Gardenhire Gulch, near Rio Blanco, Colo.-------	--	1980-82	--	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years) Discharge	Chemical	Sediment	Biology
35	09306050	Scandard Gulch near Rio Blanco, Colo.-	6.61	1974-76, 1978-*	1974-76, 1978-*	1974-76, 1978-81	1978-80
36	09306052	Scandard Gulch at mouth, near Rio Blanco, Colo.------------------------	7.97	1974-76, 1977-*	1974-76, 1977-*	1974-76, 1977-82	1977-80
37	09306058	Willow Creek near Rio Blanco, Colo.---	48.4	1974-*	1974-*	1974-*	1976, 1978-81
38	09306061	Piceance Creek above Hunter Creek, near Rio Blanco, Colo.---------------	309	1974-*	1974-*	1974-*	1975-81
39	09306175	Black Sulphur Creek near Rio Blanco, Colo.------------------------	103	1974-*	1975-*	1975-81	1975-81
40	09306200	Piceance Creek below Ryan Gulch, near Rio Blanco, Colo.---------------	506	1964-*	1970-*	1972-*	1976-81
41	09306202	Horse Draw near Rangely, Colo.--------	1.47	1977-*	1977-*	1977-81	--
42	09306203	Horse Draw at mouth, near Rangely, Colo.-----------------------	2.87	1977-*	1977-*	1977-81	--
43	09306210	Piceance Creek near White River, Colo.-------------------------------	515	1971-76	1971-76	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
44	09306222	Piceance Creek at White River, Colo.	630	1964-66, 1970-*	1971-*	1974-*	1974-82
45	09306230	Stake Springs Draw near Rangely, Colo.	26.1	1974-77	1974-77	1974-77	--
46	09306235	Corral Gulch below Water Gulch, near Rangely, Colo.	8.61	1974-*	1974-*	1974-*	1976, 1978-80
47	09306237	Dry Fork near Rangely, Colo.	2.74	1974-*	--	1974-*	--
48	09306240	Box Elder Gulch near Rangely, Colo.	9.21	1974-*	1974-*	1975-*	1975, 1976 1978, 1979
49	09306241	Box Elder Gulch tributary near Rangely, Colo.	2.39	1974-*	1974-*	1974-*	--
50	09306242	Corral Gulch near Rangely, Colo.	31.6	1974-*	1975-*	1975-*	1976, 1978-80
51	09306244	Corral Gulch at 84 Ranch, Colo.	37.8	1975-77	1975-77	1975-77	1976
52	09306246	Yellow Creek tributary near 84 Ranch, Colo.	5.53	1975-77	1976	--	1975

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
53	09306248	Duck Creek at Upper Station, near 84 Ranch, Colo.	39.1	1975-77	1976	--	--
54	09306250	Duck Creek near 84 Ranch, Colo.	50.0	1975-77	1976	1975-77	--
55	09306255	Yellow Creek near White River, Colo.	262	1972-82	1975-*	1975-*	1976, 1978 1979, 1980
56	09306300	White River above Rangely, Colo.	2,773	1972-82	1975-*	1975-*	1975-80
57	09306315	Gilliam Draw near Rangely, Colo.	13.6	1974-77	--	--	--
58	09306380	Douglas Creek at Rangely, Colo.	425	1977-78	1976, 1981	1976-77	1981
59	09306395	White River near Colorado-Utah State line, Utah	3,680	1976-*	1976-*	1976-*	1981
60	09306400	White River above Hells Hole Canyon, near Watson, Utah	3,700	1975-76	1974, 1975, 1980-82	1975, 1980, 1981	1974, 1975, 1981

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
61	09306405	Hell's Hole Canyon Creek at mouth, near Watson, Utah------------	24.5	1974-*	1975, 1979, 1980	1975, 1976, 1979	--
62	09306408	West Evacuation Creek near Dragon, Utah------------------------	15.7	1975, 1976, 1979, 1980	1975-77	1975, 1976, 1979	1975, 1976
63	09306409	East Evacuation Creek at mouth, near Dragon, Utah-------------------	--	--	--	--	--
64	09306410	Evacuation Creek above Missouri Creek, near Dragon, Utah------------	100	1974-*	1974-*	1975-78	1974-77
65	09306413	Missouri Creek at mouth, near Dragon, Utah------------------------	90.4	1975-77	1975-77	--	--
66	09306415	Evacuation Creek below Park Canyon, near Watson, Utah-----------	246	1975-76	1975-76	1975-76	--
67	09306417	Thimble Rock Canyon near Watson, Utah--------------------------------	1.70	1975	--	--	--
68	09306420	Evacuation Creek at Watson, Utah-----	259	1975-76	1974-77	1974-76	1974-77
69	09306425	Evacuation Creek tributary near Watson, Utah------------------------	12.4	1975	--	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
70	09306430	Evacuation Creek near mouth, near Watson, Utah	284	1951-54, 1974-*	1951-54, 1974-*	1974-*	1974-78
71	09306500	White River near Watson, Utah	4,020	1904-06, 1923-79	1965-79	1974-79	1974-79
72	09306600	White River above Southam Canyon, near Watson, Utah	4,030	1974-76	1974-76	1975	1974-75
73	09306605	Southam Canyon Wash near Watson, Utah	2.50	1976, 1979, 1980	1976, 1979, 1980	1976	--
74	09306610	Southam Canyon Wash at mouth, near Watson, Utah	8.30	1976, 1979, 1980	1976, 1979, 1980	1976	--
75	09306620	Asphalt Wash below Center Fork, near Watson, Utah	94.4	1976	1976	1976	--
76	09306625	Asphalt Wash near mouth, near Watson, Utah	97.5	1974-*	1976, 1979	1976, 1979	--
77	09306700	White River below Asphalt Wash, near Watson, Utah	4,130	1974-78, 1981-82	1974-78, 1981-82	1974-78, 1981-82	1974-78, 1981-82

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
78	09306720	White River above Bitter Creek, near Bonanza, Utah----------------	4,190	--	1974	--	1974
79	09306740	Bitter Creek above Dick Canyon, Utah------------------------------	11.7	1974-78	1974-78	1974-78	1974-78
80	09306745	Rat Hole Canyon above Bitter Creek, near Bonanza, Utah----------------	25.4	1974-77	1974-77	--	--
81	09306750	Bitter Creek above Pete Canyon, near Bonanza, Utah----------------	139	1974-77	1974-77	--	--
82	09306760	Sweetwater Canyon below South Canyon, near Watson, Utah---------	22.6	1974-78	1974-78	1974-78	1974-78
83	09306780	Sweetwater Canyon Creek near mouth, near Watson, Utah----------	124	1975-78	1975-78	1975-78	1975-77
84	09306790	Bitter Creek below Sweetwater Canyon, near Bonanza, Utah--------	315	1974-77	1974-77	--	--
85	09306800	Bitter Creek near Bonanza, Utah----	324	1971-*	1974-*	1975-78	1975-78
86	09306820	Bitter Creek above Buck Camp Canyon, near Bonanza, Utah--------	358	1974-77	1974-77	--	--

Summary of surface-water hydrologic monitoring stations--Continued

Station number used in report	U.S. Geological Survey Station number	Station name	Drainage area (square miles)	Type and period of record (water years)			
				Discharge	Chemical	Sediment	Biology
87	09306830	Bitter Creek below Buck Camp Canyon, near Bonanza, Utah--------	375	1974-77	--	--	--
88	09306850	Bitter Creek at mouth, near Bonanza, Utah---------------------	398	1974-*	1974	1975-78	1974-78
89	09306870	Sand Wash near Ouray, Utah---------	59.7	1974-*	1976-*	--	--
90	09306872	Sand Wash near mouth, near Ouray, Utah------------------------------	71.1	1976-*	1978	--	--
91	09306874	White River below Sand Wash, near Ouray, Utah----------------------	4,690	1974-77	1974-77	--	--
92	09306878	Coyote Wash near mouth, near Ouray, Utah------------------------------	228	1976-*	1977-*	1976-78, 1980	--
93	09306880	North Wash near Ouray, Utah--------	11	1980, 1981	1981	--	--
94	09306885	Cottonwood Wash at mouth, near Ouray, Utah----------------------	70.6	1976-*	1977-*	1978	--
95	09306900	White River at mouth, near Ouray, Utah------------------------------	5,120	1974-*	1974-*	1974-*	1974