Water Resources of the Upper Colorado River Basin—Technical Report

GEOLOGICAL SURVEY PROFESSIONAL PAPER 441

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March 3, 1849

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By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

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By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

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Introduction and summary of an appraisal of the water resources of the Upper Colorado River Basin, with special emphasis on surface water and its quality

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WATER RESOURCES OF THE UPPER COLORADO RIVER BASIN—TECHNICAL REPORT

INTRODUCTION AND SUMMARY

By W. V. Iorns, C. H. Hembree, and G. L. Oakland

ABSTRACT

This chapter contains an introduction and a summary.

The introduction gives background information on the area: geography, geology, physiography, climate, and stream regimen. Included is a table of hydrologic units, prepared by D. A. Phoenix, which separates the complex assortment of rocks according to generalized hydrologic properties.

The rest of the chapter summarizes the quantity and chemical quality of the surface water of the basin. There is a great deal of water which enters the basin annually as precipitation (92,739,000 acre-ft). Only a small part of this (2,257,500 acre-ft) is consumed by humans or is diverted out of the basin. The rest leaves the basin through outflow (12,733,100 acre-ft) or is lost by evaporation and plant transpiration (77,748,400 acre-ft).

The amount and chemical quality of the streamflow vary with time and place owing to both natural and human causes. To give a common base for comparing streamflow, an average was used which would have occurred if the level of upstream development existing in 1957 had existed throughout water years 1914–57.

Natural factors affect the streamflow and chemical quality: the amount of precipitation, the underlying soils, and the ground water. The human factor, however, greatly influences streamflow and chemical quality. Water quantity and quality are changed as the water is diverted for domestic, industrial, and agricultural uses. Domestic and industrial uses add 33,600 tons of dissolved solids annually to the streamflow; irrigation adds 3,446,700 tons. Water quality also depends on the proportion of individual constituents and the amount of suspended sediment.

INTRODUCTION

The first comprehensive study of the water resources of the Colorado River Basin was made by E. C. LaRue (1916). The introduction to the report was written by Nathan C. Grover, Chief Hydraulic Engineer, Water Resources Division, U.S. Geological Survey. Much of what Grover said about the Colorado River Basin is as timely today (1957) as it was in 1916:

> The region traversed by the Colorado and its tributaries is for many reasons of intense interest to the people of the United States. Here was the home of that forgotten people of which there is almost no record except the hieroglyphics on the rocks, the ruins of their irrigation systems, and the cliff dwellings by which they are most widely known; here were Spanish missions whose history extends back nearly to the days of Balboa and Cortez; here is the Grand Canyon, whose sublimity was first fully disclosed by Maj. Powell and his associates, who navigated it from end to end in 1869 and 1872; here are the greatest known natural bridges, so remote and inaccessible * * * here is the mighty river and its tributaries * * *. We are interested in its mysteries, its traditions, its history, and its possible future; in the fascination of its deserts, whose immensity awes us; in the grandeur of its mountains, from the highest peaks of the Rockies on the east to the beauties of the Uinta and Wasatch mountains on the west; in the wonders of its canyons, perhaps the most famous in the world; in the range of its climate, from its short and cold summer season in Wyoming, where frosts may occur in every month of the year, to the sub-tropical temperatures of the valleys of Arizona, where the growing season never ends.
>
> Its high valleys contain valuable forests and its mountains extensive deposits of minerals. At many points within its borders prosperous agricultural communities have been established * * *
>
> What is to be the future of this immense region? Doubtless its forests will be utilized, its mineral wealth will be exploited, its wonderful scenic beauties will be unfolded. Its greatest development must come, however, from its water resources, on which the development of its other resources must largely depend * * *

Water in the rivers, creeks, lakes, ponds, and surface-water and ground-water reservoirs of the Colorado River Basin constitutes the water resources of the region. This is a continuously renewing resource, and its visible occurrence in the streams and impoundments and its hidden movements underground are parts of the recurring succession of events known as the hydrologic cycle. The surface and ground waters in the Colorado River Basin have their origin in precipitation, derived mostly from water evaporated from the Pacific Ocean or the Gulf of Mexico. Some of the precipitation is returned to the atmosphere by evapotranspiration, some percolates downward to the ground-water reservoirs, and some flows directly into the surface-water bodies. Part if not most of the water that enters the ground-water reservoirs ultimately finds its way to the streams. Man takes water from the surface-water bodies and ground-water reservoirs and consumes part of it for his sustenance and livelihood. Eventually, water flowing in the streams, except the water that is consumed by natural process or man, flows out of the basin toward the ocean.

Water from the first moment of contact with the land surface as precipitation is subjected to various natural environmental factors that influence its physical behavior and chemical character. The most important of these factors are climate, topography, type of rocks and soils, and vegetation. In addition to natural factors, the activities of man have changed the natural physical behavior and chemical character of many of the streams in the basin.

PURPOSE AND SCOPE

Much of the water supply of the Colorado River Basin is already being used. Additional water developments are planned to meet the evergrowing demands of the region. As these developments may be limited by legal, physical, and economic factors, an appraisal of the water-supply situation is needed.

The U.S. Geological Survey has prepared this report on the surface-water resources of the Upper Colorado River Basin as part of an appraisal of the water resources of the entire Colorado River Basin. The surface-water resources of the region are described and the effects of environmental factors on these resources are explained on the basis of available data and water uses existing in 1957. The report does not contain forecasts of changes in water quantity and quality which may take place as a result of water-utilization projects constructed after 1957.

The area encompassed by the report is the drainage basin of the Colorado River above "Lee Ferry," Ariz. "Lee Ferry" is an arbitrary point dividing the Upper Colorado River Basin and the Lower Colorado River Basin and is defined by the Colorado River Compact as "a point in the main stem of the Colorado River one mile below the mouth of the Paria River." "Lee Ferry" should not be confused with Lees Ferry, a small community at an old ferry site on the Colorado River about 1 mile above the mouth of the Paria River, where a gaging station is located.

Studies for the report have included the following: The assembling of basic data on the water resources; identification of deficiencies in the data; collection of additional data to fill obvious gaps; and an analysis of the influence of natural environmental factors and the activities of man on the occurrence, quantity, and quality of the water resource. The influence of natural factors on water regimen is complex because the factors and their effects on water are interrelated. The effects of the activities of man are also complex and are not easily discriminated from the effects of natural factors. Nonetheless, so far as can be demonstrated or reasonably inferred from the basic water data, this report seeks to explain the current (1957) water situation of the basin and, in so doing, to discriminate between natural and human effects. Ultimately, additional hydrologic research and collection of essential basic data will be needed to identify, more precisely than has been possible in this study, the effects of the activities of man on the chemical quality of the streams.

LOCATION

The Upper Colorado River Basin (fig. 1) comprises about 109,500 square miles in western Colorado (38,670 sq mi), southwestern Wyoming (17,430 sq mi), eastern Utah (37,310 sq mi), northwestern New Mexico (9,580 sq mi), and northeastern Arizona (6,510 sq mi). The basin is within parts of two large physical divisions of the United States—the Rocky Mountain system and the Intermontane Plateau (Fenneman and Johnson, 1946). The basin extends from lat 35°34′ N. to 43°27′ N., a distance of about 550 miles, and from long 105°38′ W. to 112°19′ W., a distance of about 350 miles.

The boundary of the basin from "Lee Ferry," Ariz., northward follows the crests of the Paria, Aquarius, and Wasatch Plateaus and the Wasatch and Wyoming Ranges to the Continental Divide at the north end of the Wind River Range in Wyoming.

The basin boundary from "Lee Ferry" southward and eastward follows a divide that trends first southward and then eastward across the Kaibito Plateau, along the north and east rim of Black Mesa, and across the south end of the Chuska Mountains to the Continental Divide a few miles northeast of Gallup, N. Mex. From here northward, the east boundary of the basin follows the Continental Divide almost 1,000 miles to the north end of the Wind River Range.

STREAM SYSTEM

The Colorado River (fig. 1) rises near the extreme eastern part of the basin on the east slope of Mount Richthofen, a peak having an altitude of 13,000 feet on the Continental Divide, and flows generally southwestward to "Lee Ferry." The Green River, the largest tributary, rises in the Wind River Range at the north end of the basin and flows southward to its junction with the Colorado River about 60 miles south of the town of Green River, Utah. The San Juan River, the second largest tributary, rises on the west slope of the

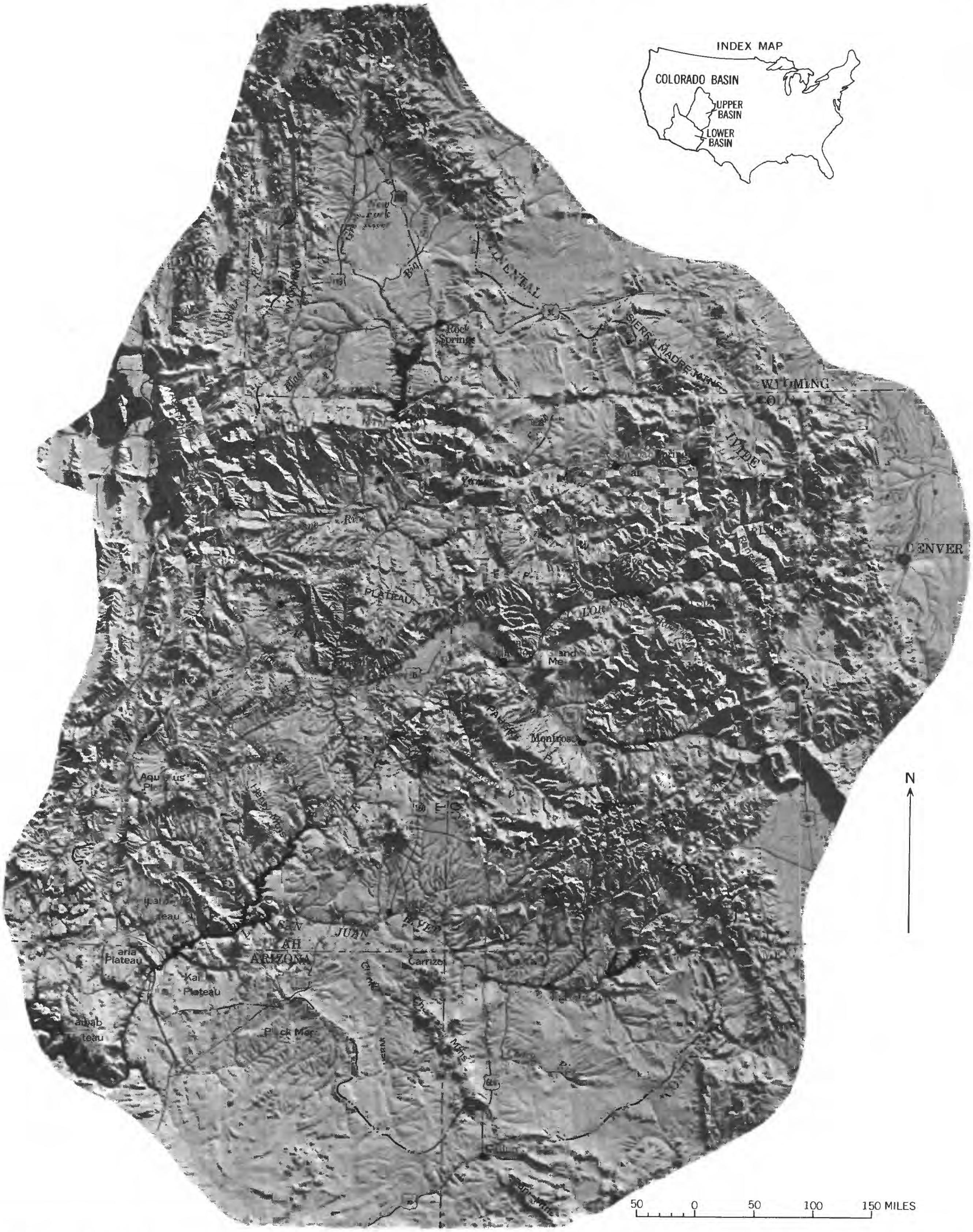


FIGURE 1.—Relief map of area including the Upper Colorado River Basin. Adapted from photograph by I. V. Goslin, Upper Colorado River Compact Commission.

Continental Divide in the southeastern part of the basin and flows westward to its junction with the Colorado about 75 miles west of Bluff, Utah.

The principal tributaries of the Colorado River above the Green River (in earlier years the river above the mouth of the Green River was called Grand River, but in 1921 Grand was changed to Colorado) are the Eagle River, Roaring Fork, Gunnison River, and the Dolores River. The principal tributaries of the Green River are New Fork River, Big Sandy Creek, Blacks Fork, Henrys Fork, and Yampa, White, Duchesne, Price, and San Rafael Rivers. The principal tributaries of the San Juan River are the Navajo, Los Pinos, Animas, and La Plata Rivers. Other tributaries that enter the Colorado River below the Green River are the Dirty Devil, Escalante, and Paria Rivers.

GEOLOGY

The geology in the Upper Colorado River Basin profoundly influences the occurrence, behavior, and chemical quality of the water resources. In the mountains, where most of the water supply originates, there is a close relation between ground water in the consolidated rocks and in the alluvium and water in the streams. In these mountain areas some of the rainfall and snowmelt enters ground-water reservoirs and ultimately reaches the streams through springs, seeps, or through the alluvium along the stream channels. As the streams rise and fall, water alternately moves from the streams into the alluvium along the stream channels and back to the streams. Thus, there is an almost continuous interchange between ground water and surface water. In the process the rocks react with the water and impart distinctive chemical characteristics to the water.

In the interior valleys and basins, ground water in the consolidated rocks has only a minor relation to the discharge and chemical quality of water in the streams, except locally where thermal springs from deep-seated sources discharge to the streams. For the most part, precipitation is insufficient to provide any appreciable ground-water recharge. Aquifers, whose recharge areas are in and along the mountains where precipitation is abundant, are buried beneath great thicknesses of impermeable strata in the interior valleys.

Although the consolidated rocks at or close to the surface in the interior of the basin do not contribute an appreciable amount of ground water to the streams, they do influence the chemical quality of streams. As in the mountains, the rocks react with the surface runoff from infrequent, but intense, rainfall and impart distinctive chemical characteristics to the water. Extensive deposits of river alluvium occur along some of the streams in the interior valleys, and interchange between the water in the streams and the alluvium results in a close relation between the chemical quality of water in the streams and that in the alluvium.

The rocks exposed in the basin range in age from Precambrian to Recent. Generally, the Precambrian rocks, which include the older plutonic and metamorphic rocks, form the basement upon which the sedimentary rocks rest, but in places, mostly in the mountains, the older rocks have been exposed through uplifting, folding, faulting, and erosion. More than 200 formational subdivisions of sedimentary rocks in the basin have been named. Some of these formations are thin and only crop out locally, but others are thousands of feet thick and crop out throughout large areas in the interior of the basin and along the flanks of the mountains. Volcanic rocks, mostly of Tertiary age, are widely distributed, but the area of these rocks, when compared to the total area of the basin, is rather small. The youngest deposits are the surficial debris from the weathering of older rocks. The surficial deposits, which have been transported from place to place by wind, glaciers, and streams, cover the consolidated rocks as a veneer in many places but may be a hundred or more feet thick in other places.

The rocks differ greatly in their lithologic and hydrologic properties. Some are composed of minerals that are resistant to rapid weathering, but others contain readily soluble minerals. Some are relatively permeable, whereas others are relatively impermeable. These properties vary widely, even in the same formation.

The complex assortment of rocks in the Upper Colorado River Basin has been classified into several subdivisions or units by D. A. Phoenix. (See table 1.) Each of the units conforms to the time-rock system of classification which separates the rocks according to generalized hydrologic properties. Some of the units include many formations, and others include only a few. The areal extent of the units is shown in plate 1.

The following summarizes the characteristics of the units and areas of occurrence, as described by Phoenix:

HYDROLOGIC UNIT 8, IGNEOUS AND METAMORPHIC ROCKS

The granitic and related metamorphic rocks of Precambrian age of unit 8 crop out in about 7 percent, or 7,900 square miles, of the basin, mostly in the mountains. The rocks are composed largely of several common rock-forming minerals, most of which are slow to react with water.

Most of the rocks of this group are granitic types associated with schist and gneiss. In some areas, chiefly in the Uinta Mountains, metamorphic rocks consist of shale, argillite, and quartzite. Highly foliated and metamorphosed rocks crop out in the Wind River Range, in the Uncompahgre Plateau, and in the Rocky Mountains.

HYDROLOGIC UNIT 7, IGNEOUS ROCKS

The rocks of unit 7 occur as lava flows, ash falls, laccoliths, volcanic necks, and diatremes and as dikes, sills, and larger discordant intrusive masses that transgress bedding in sedimentary or volcanic rocks. Rocks of this unit occur in small bodies in many localities and crop out in about 3 percent, or 3,500 square miles, of the basin.

The most notable of the intrusive bodies of igneous rocks are the laccoliths of the Henry, La Sal, Abajo, Carrizo, Ute, and La Plata Mountains. Irregular bodies of intrusive rock also occur in the Rocky Mountains. Many of the physical and chemical characteristics of these rocks are similar to those in unit 8.

Lava flows and basaltic rocks crop out in the San Juan Mountains, West Elk Mountains, Grand and Black Mesas, and the Aquarius Plateau in southern Utah. Dark-colored basalt flows, the most conspicuous rocks of this group, are associated with thick deposits of pale-gray to reddish-brown andesite, latite, dacite, and rhyolite and with deposits of tuff, agglomerate, and flow breccia.

HYDROLOGIC UNIT 6, PREDOMINANTLY MARINE ROCKS

The rocks of unit 6 consist of limestone, dolomite, quartzose sandstone, shale, and saline minerals. These rocks range in age from Cambrian to Permian and have been mapped and classified into about 35 formations. They crop out in about 6 percent, or 6,900 square miles, of the basin and mostly are extensively exposed in the White River Plateau; along the flanks of the Rocky, Uinta, and San Juan Mountains; and in a large area in southern Utah and northern Arizona.

In the mountainous areas—particularly in the White River Plateau and surrounding areas in western Colorado, in parts of the Uinta Mountains, and in parts of the Wyoming Range—these rocks are covered with talus, with partly decomposed rock, and with soil.

HYDROLOGIC UNIT 5, CONTINENTAL AND MARINE ROCKS

Unit 5 is composed of six formations. The Moenkopi and Chinle formations, included in the unit, also underlie virtually all the other rocks. The rocks crop out in many places in the Canyon Lands of southwestern Colorado, southeastern Utah, and northeastern Arizona. About 5 percent, or 5,300 square miles, of the basin is underlain by this unit.

The formations of the unit are characterized by differences in lithology: in places they are composed of thick deposits of silty mudstone and shale and near the middle, of thin lenticular beds of coarse-grained sandstone and conglomerate. Common minerals are anhydrite and gypsum. These soluble minerals appear as beds, seams, and interstitial fillings in the fine-grained sediments. Much of the exposed upper part is covered by a thin fluffy coating of bentonitic clay, which is susceptible to rapid erosion by surface runoff.

HYDROLOGIC UNIT 4, PREDOMINANTLY CONTINENTAL ROCKS

The rocks of unit 4 crop out in many places in the Canyon Lands and in southern Utah and southeastern Colorado. Many of the conspicuous hogbacks and ridges in the foothills of the San Juan and Rocky Mountains are formed by these rocks, which crop out in about 25 percent, or 27,000 square miles, of the basin.

Rocks of this group, from oldest to youngest, are divided into the Glen Canyon Group, San Rafael Group, and Burro Canyon, Dakota, and Morrison Formations. Other formations of related age and lithology are also included, but because of their restricted distribution are of less importance to the regional hydrology. Siltstone and mudstone interbedded with fine- to medium-grained quartzose sandstone, and locally with limestone, characterize the upper part. Massive quartzose sandstone composes most of the lower part.

HYDROLOGIC UNIT 3, MARINE AND CONTINENTAL ROCKS

The upper part of unit 3 contains a large number of intertonguing and overlapping formations of continental sandstone and marine shale. The lower part is mostly marine Mancos Shale and the Mesaverde Group and related formations.

These rocks crop out in about 23 percent, or more than 25,000 square miles, of the basin; their area of outcrop is almost equal to that of hydrologic unit 4. They crop out in and along the Book Cliffs, the Wasatch, Aquarius, and Kaiparowits Plateaus, the cliffs around Black Mesa, and large areas near the San Juan and Rocky Mountains and in the Green River basin in Wyoming and in the Uinta Basin. Many broad valleys underlain by the lower part of the unit have attracted settlers. Valleys in the vicinity of Price, Vernal, and Green River, Utah; Rock Springs, Wyo.; Grand Junction, Delta, and Montrose, Colo.; Farmington, N. Mex.; and many smaller towns are underlain by the Mancos Shale and related formations.

HYDROLOGIC UNIT 2, CONTINENTAL ROCKS

The oldest and most extensive formations of unit 2 are the Wasatch, Green River, Uinta, Bridger, and related formations of Tertiary (Eocene) age. The youngest rocks include the Browns Park (Miocene?),

TABLE 1.—*Geologic formations in the Upper Colorado River Basin*

Colorado	Wyoming	Utah	New Mexico	Arizona
HYDROLOGIC UNIT 1, UNCONSOLIDATED CONTINENTAL DEPOSITS				
All unconsolidated deposits including alluvial deposits, torrential wash, landslides, terrace deposits, mudflows, Wisconsin Till, glacial outwash, Durango Till, glacial outwash, Florida Gravel, Cerro Till, moraines.	All unconsolidated deposits including alluvial deposits, lake sediments, landslide deposits, windblown sand, glacial deposits.	All unconsolidated deposits including alluvial deposits, terrace and pediment gravels, landslides, mudflows, dunes, glacial till, moraines, outwash.	All unconsolidated deposits including alluvial deposits, bolson, pediment, windblown sand, high-level terrace deposits, landslides, spring, and morainal deposits.	All unconsolidated deposits including alluvial deposits, dunes, landslides, playas, and terrace deposits.
HYDROLOGIC UNIT 2, CONTINENTAL ROCKS				
Chuska Sandstone and other formations of related lithology				
		Sevier River Formation	Santa Fe Group	
Bridgetimber Gravel, North Park Formation.			Chuska Sandstone, alluvial and lacustrine deposits, basalt flows.	Chuska Sandstone, Bidahochi Formation.
Browns Park Formation, Creede Formation, Arikaree Sandstone.	Bishop Conglomerate, Browns Park Formation.	Bishop Conglomerate, Browns Park Formation, Brian Head Formation.		
Telluride Conglomerate, Blanco Basin Formation.				
Uinta Formation and other formations of related lithology				
		Duchesne River Formation		
Bridger Formation	Bridger Formation, Pass Peak Conglomerate, Fowkes Formation.	Bridger Formation		
Green River Formation	Green River Formation	Uinta Formation, Green River Formation, Currant Creek Formation.		
Wasatch Formation, Ohio Creek Conglomerate, Blanco Basin Formation, Fort Union Formation.	Wasatch Formation, Almy Formation, Fort Union Formation, also conglomerate along the southwest flank of the Wind River Mountains.	Wasatch Formation, Flagstaff Limestone.	San Jose Formation, Torrejon Formation, Puerco Formation, Nacimiento Formation.	
Animas Formation, Middle Park Formation.	Evanston Formation	North Horn Formation	Animas Formation	
HYDROLOGIC UNIT 3, MARINE AND CONTINENTAL ROCKS				
Mesaverde Formation and other formations of related lithology				
			Ojo Alamo Sandstone, McDermott Formation, Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, Lewis Shale.	
Lance Formation, McDermott Formation, Kirtland Shale, Fruitland Formation, Pictured Cliffs Sandstone, Lewis Shale, Williams Fork Formation, Iles Formation, Cliff House Sandstone, Menefee Formation, Point Lookout Sandstone, Mesaverde Formation and Group, Pierre Shale.	Lance Formation, Lewis Shale, Almond Formation, Mesaverde Formation, Adaville Formation, Ericson Sandstone, Steele Shale, Rock Springs Formation.	Mesaverde Formation and Group, Price River Formation, Blackhawk Formation, Star Point Sandstone, Kaiparowits Formation.	Cliff House Sandstone, Menefee Formation, Point Lookout Sandstone, Crevasse Canyon Formation, Gallup Sandstone.	Yale Point Sandstone, Wepo Formation and Toreva Formation in the Black Mesa Basin, Crevasse Canyon Formation, Gallup Sandstone.
Mancos Shale and other formations of related lithology				
Mancos Shale, Niobrara Formation.	Cody Shale, Hilliard Shale, Blair Formation, Baxter Shale.	Frontier Formation, Wahweap Sandstone, Tropic Shale, Mancos Shale.	Mancos Shale	Mancos Shale.
Benton Shale	Mowry Shale, Thermopolis Shale, Bear River Formation, Gannett Group.	Aspen Shale, Straight Cliffs Sandstone.		
HYDROLOGIC UNIT 4, PREDOMINANTLY CONTINENTAL ROCKS				
Dakota and Morrison Formations and other formations of related lithology				
Dakota Sandstone, Burro Canyon Formation.	Cloverly Formation	Dakota Sandstone, Burro Canyon Formation, Cedar Mountain Formation.	Dakota Sandstone	Dakota Sandstone.
	Beckwith Formation			
Morrison Formation	Morrison Formation	Morrison Formation	Morrison Formation	Morrison Formation.
San Rafael Group in the Colorado Plateau province of Arizona, Utah, Colorado, and New Mexico				
Summerville Formation, Wanekah Formation, Curtis Formation, Entrada Sandstone.	Stump Sandstone, Preuss Sandstone, Beckwith Formation.	Summerville Formation, Curtis Formation, Entrada Sandstone, Carmel Formation, Bluff Sandstone.	Cow Springs Sandstone (not part of the San Rafael Group). Bluff Sandstone, Summerville Formation, Todilto Limestone, Entrada Sandstone, Lukachukai Member of the Wingate Sandstone, Carmel Formation.	Morrison Formation and Cow Springs Sandstone (not part of the San Rafael Group). Summerville Formation, Bluff Sandstone, Entrada Sandstone, Carmel Formation.
Twin Creek Limestone	Twin Creek Limestone	Twin Creek Limestone		

TABLE 1.—*Geologic formations in the Upper Colorado River Basin*—Continued

Colorado	Wyoming	Utah	New Mexico	Arizona
Glen Canyon Group in the Colorado Plateau province of Arizona, Utah, Colorado, and New Mexico				
	Nugget Sandstone			
Navajo Sandstone		Navajo Sandstone		Navajo Sandstone.
Kayenta Formation		Kayenta Formation	Glen Canyon Group undivided	Kayenta Formation.
Dolores Formation		Wingate Sandstone		Wingate Sandstone, Moenave Formation.
HYDROLOGIC UNIT 5, CONTINENTAL AND MARINE ROCKS **Formations of Triassic age**				
	Ankareh Shale	Ankareh Shale		
Triassic rocks undivided (includes the Chinle and Moenkopi Formations in southwest Colorado).		Chinle Formation	Chinle and Moenkopi Formations.	Chinle and Moenkopi Formations.
	Thaynes Limestone, Woodside Formation, Dinwoody Formation.	Thaynes Limestone, Woodside Formation, Moenkopi Formation.		
Some Permian rocks undivided in the vicinity of La Plata, Placerville, Telluride, Norwood, north of Montrose.				
HYDROLOGIC UNIT 6, PREDOMINANTLY MARINE ROCKS **Formations of Permian and Pennsylvanian age**				
Cutler Formation, Park City Formation.	Phosphoria Formation	Cutler Formation, Park City Formation, Kaibab Limestone, Coconino Sandstone.	Cutler Formation, San Andres Limestone, Glorieta Sandstone, Yeso Formation, Abo Formation.	Cutler Formation, Kaibab Limestone, Toroweap Formation, Coconino Sandstone, Hermit Shale.
Weber Sandstone				
Maroon Formation	Wells Formation, Tensleep Sandstone.	Oquirrh Formation		Supai Formation.
Rico Formation		Rico Formation		Rico Formation (subsurface), Hermosa Formation (subsurface).
		Weber Sandstone		
Hermosa Formation, Eagle Valley Evaporite, Jacque Mountain Limestone, Minturn Formation, Belden Shale.		Hermosa Formation		Molas Formation (subsurface).
	Amsden Formation	Morgan Formation		
Formations of early Paleozoic, Devonian, and early Mississippian age				
Leadville Limestone	Brazer Limestone, Madison Limestone.	Brazer Limestone, Madison Limestone.		Leadville Limestone (subsurface).
Ouray Limestone, Elbert Formation, Chaffee Formation, Manitou Formation, Dotsero Formation, Ignacio Quartzite, Sawatch Quartzite.	Three Forks Shale, Jefferson Limestone, Darby Formation.	Devonian, Silurian, Ordovician, and Cambrian rocks undivided.		Ouray Limestone, Elbert Formation (subsurface).
HYDROLOGIC UNIT 7, IGNEOUS ROCKS **Extrusive igneous rocks**				
Basalt flows capping high plateaus.	Basalt flows	Basalt flows capping high plateaus.	Basalt flows	Flow rocks locally.
Intrusive igneous rocks				
Sills, laccoliths, plugs, and dikes chiefly in La Plata, Ute, San Juan Mountains.		Chiefly laccoliths in the Henry, Abajo, and La Sal Mountains.	Scattered diatremes, dikes	Scattered diatremes, dikes.
HYDROLOGIC UNIT 8, IGNEOUS AND METAMORPHIC ROCKS **Precambrian complex**				
Metamorphic and plutonic rocks including Uinta Mountain Group, Front Range Granite Group, Needle Mountains Group, Gunnison River Series.	Chiefly granite with minor amounts of metamorphic rocks.	Metamorphic and plutonic rocks.	Metamorphic and plutonic rocks.	
		Uinta Mountain Group		

Bishop (Oligocene or Miocene), Chuska (Pliocene?), and Bidahochi (Pliocene) Formations. The older rocks are predominantly lacustrine and fluviatile. They consist of marl, siltstone, and fine-grained sandstone interbedded with diatomite, limestone, evaporite, oil shale, and trona and related saline minerals. The younger rocks are principally lenticular deposits of coarse sand and conglomerate. In part, the younger rocks are lacustrine and fluviatile and, in part, glacial and fluvioglacial.

In Wyoming, Utah, and Colorado, the Green River and many of its tributaries flow for long distances over these rocks. In other parts of the Upper Colorado River Basin the rocks occur below altitudes of 7,000 feet in an arid to semiarid region, and direct runoff is not large. About 30 percent, or 34,000 square miles, of the basin is underlain by these rocks.

HYDROLOGIC UNIT 1, UNCONSOLIDATED CONTINENTAL DEPOSITS

Unit 1 consists of all unconsolidated material mantling the consolidated rocks. This material is classed as residuum and alluvium. Residuum consists of products of rock weathering that have accumulated faster than they can be removed by water and wind. Material of this type mantles hillsides and tops of mesas and plateaus. Alluvium consists of products of rock weathering and erosion that have been transported and deposited by water. Hunt (1956, p. 72) estimated that unconsolidated deposits cover bedrock in about 75 percent of the Henry Mountains region of southeastern Utah. This estimate probably applies to the entire Upper Colorado River Basin. Much of these deposits are very thin, but in some areas, especially in the valleys, they may be thick.

River and glacial alluvium, which cover an estimated 1,200 square miles, or less than 1 percent, of the basin, are shown on the hydrologic map (pl. 1). The deposits of residuum are not shown on the map but are estimated to cover about three-fourths of the basin, or 82,000 square miles.

PHYSIOGRAPHIC AND STRUCTURAL FEATURES

The plateaus and mountains that form the boundaries of the Upper Colorado River Basin and the highlands in the interior are a series of uplifted earth masses deeply dissected by erosion, by glaciation, and by weathering. Between the intersecting mountain ranges in the interior of the basin are plateaus, mesas, and broad basins, some gently rolling and others deeply carved by erosion.

Long before the earth movements that created the present mountains started, the area was the scene of alternate encroachment and retreat of great inland seas. The sedimentary material that accumulated and was not subsequently removed by erosion during the periods when the land stood above the seas is represented by the sedimentary rocks that underlie much of the basin. These rocks are thousands of feet thick and range in attitude from sharply tilted around the mountains to nearly horizontal in the interior. These events took place during the Paleozoic and Mesozoic Eras.

Earth movement that formed the present mountains began in the Mesozoic and continued into the Cenozoic Era. These movements formed the ancestral Rocky Mountains and started regional downwarps, which culminated in at least six large structural basins. These basins received thick deposits of sediment eroded from the highlands. During middle Cenozoic time streams began to downcut into the Cenozoic and older Paleozoic and Mesozoic rocks. Continuous erosion since middle Cenozoic time has produced the present topography.

The topography and stream system divide the area into three major drainage systems, referred to in this report as "divisions." The divisions are designated the Grand, the Green, and the San Juan. The Grand division is the drainage basin of the Colorado River above the Green River. The Green division is the drainage basin of the Green River. The San Juan division is the drainage basin of the Colorado River below the Green River and above "Lee Ferry," Ariz. (fig. 2).

CLIMATE

The climate of the Upper Colorado River Basin is due more to the influence of mountain ranges on the movement of air masses than to latitude. The high mountains are comparatively wet and cool, whereas the plateaus and lower mountains are dryer and are subject to wide ranges of temperature. The interior valleys at lower altitudes are hot and dry in the summer and cold in the winter.

Moist Pacific airmasses can move across the entire basin. Dry polar air from the north and moist tropical air from the south move into the basin at times, but rarely continue all the way across. Movement of both types of airmasses is obstructed and deflected by the encircling mountains so that their interactions and effects within the basin are weaker and more erratic than airmasses in most other parts of the United States.

The Pacific Ocean and the Gulf of Mexico, whose nearest coastlines are 600 and 1,000 miles, respectively, from the center of the basin, provide most of the moisture for precipitation. Airmasses moving in from these sources are pushed up to high altitudes and lose much of their moisture before they enter the basin.

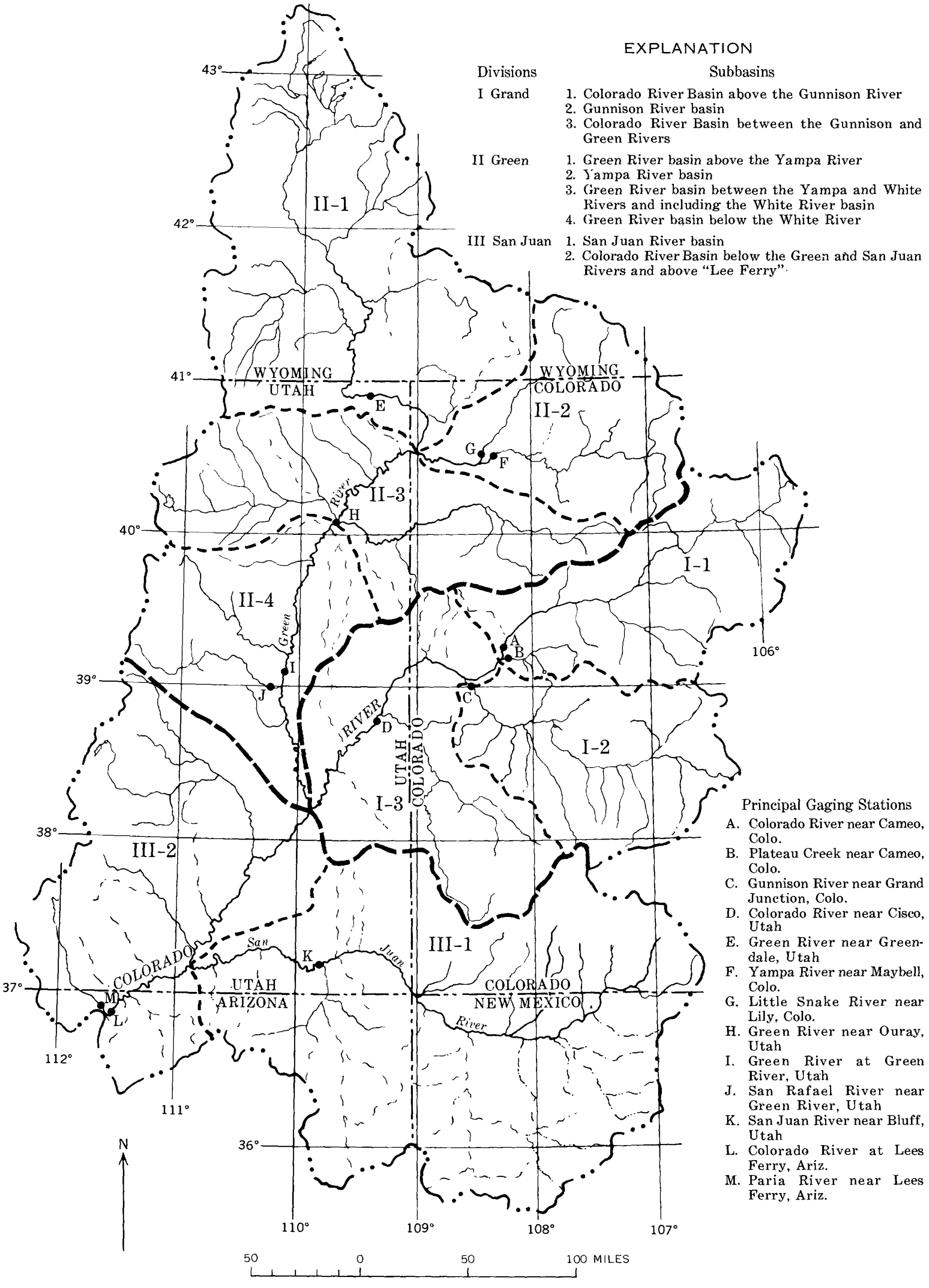


FIGURE 2.—Divisions and subbasins in the Upper Colorado River Basin.

Generally, from about October through April, airmasses from the Pacific Ocean dominate. During the late spring and summer a large part of the basin receives precipitation from moisture that originates in the Gulf of Mexico.

Figure 3 shows monthly precipitation and average monthly temperature at 11 weather stations in the upper basin. Except in the southern part, the monthly precipitation is greater in the winter than during the remainder of the year. The effects of altitude and latitude on the average annual temperature are noticeable.

The average annual precipitation ranges from less than 6 inches in the arid parts of the basin to more than 60 inches in parts of the Wind River Range and San Juan Mountains (pl. 1).

Table 2 gives the areal distribution of average annual precipitation (calendar years 1921–50) in the Upper Colorado River Basin. The average annual precipitation was 15.88 inches on the basis of precipitation computed from this tabulation is 15.97 inches. For water years 1914–57 the average annual precipitation at 46 stations for calendar years 1921–50 and water years 1914–57. Precipitation of 15.88 inches on 109,500 square miles is equivalent to 92,739,000 acre-feet of water.

Average annual lake evaporation generally ranges from 28 to 60 inches. The average annual evaporation from water surfaces in the basin is about 575,000 acre-feet (table 3).

POPULATION

The population of the Upper Colorado River Basin is about 335,600 (1960 census), which is only about 6½ people per square mile. Approximate distribution of the population is Colorado, 170,000; Wyoming, 33,100; Utah, 69,000; New Mexico, 59,000; and Arizona, 4,500.

TABLE 2.—*Areal distribution of precipitation in the Upper Colorado River Basin, calendar years 1921–50*

Precipitation range (inches)	Area	
	Square miles	Percent of total
60–70	46	0. 04
50–60	374	. 34
40–50	1, 815	1. 66
30–40	7, 271	6. 64
25–30	6, 906	6. 31
20–25	9, 071	8. 28
16–20	13, 911	12. 70
12–16	23, 634	21. 59
10–12	15, 201	13. 88
8–10	15, 417	14. 08
6–8	14, 126	12. 90
4–6	1, 728	1. 58
Total	109, 500	100 00

TABLE 3.—*Average annual evaporation, in acre-feet, from water surfaces in the Upper Colorado River Basin*

[After Meyers (1962)]

Principal reservoirs and regulated lakes	83, 000
Other lakes more than 500 acres	16, 000
Principal streams and canals	156, 000
Small ponds and reservoirs	217, 000
Small streams	103, 000
Total	575, 000

The five largest communities and their populations are Farmington, N. Mex., 23,786; Grand Junction, Colo., 18,694; Durango, Colo., 10,530; Rock Springs, Wyo., 10,371; and Price, Utah, 6,802. Rock Springs, Wyo., the only large community not on a major tributary of the Colorado River, is one of the few that does not depend on farming and ranching to support most of its population. Railroad, mining, and oil industries employ many of the people of Rock Springs. However, a shutdown of the mines has resulted in some decrease in population. The population of other towns in which people depend heavily on mining has decreased. On the other hand, some communities such as Farmington, N. Mex., have had large increases in population. Farming and stock raising, however, occupy people throughout the basin and contribute to a fairly stable economy and a uniform population growth.

ORGANIZATION OF THE REPORT

To facilitate the presentation of data and appraisal of the surface water resources of the Upper Colorado River Basin, a technical report and a basic-data report have been prepared.

This, the technical report, is composed of five chapters. The first chapter contains the introduction and summary; the second explains the techniques and criteria used in appraising the surface-water resources; and the third, fourth, and fifth discuss the surface-water resources of the Grand, Green, and San Juan divisions, respectively. In the last three chapters the divisions are further subdivided into subbasin units (fig. 2), so that the effects of climate, topography, geology, vegetation, and the activities of man on the surface-water resource may be identified locallly.

The basic-data report (Iorns and others, 1964) contains tables of duration of water discharge, monthly and annual summaries of chemical-quality and sediment data obtained at sites of continuous record, results of chemical-quality and sediment analyses at other sites, data on the chemical quality and other characteristics of ground water, a map showing location of surface- and ground-water sampling sites, and isohyetal maps of normal seasonal and annual precipitation.

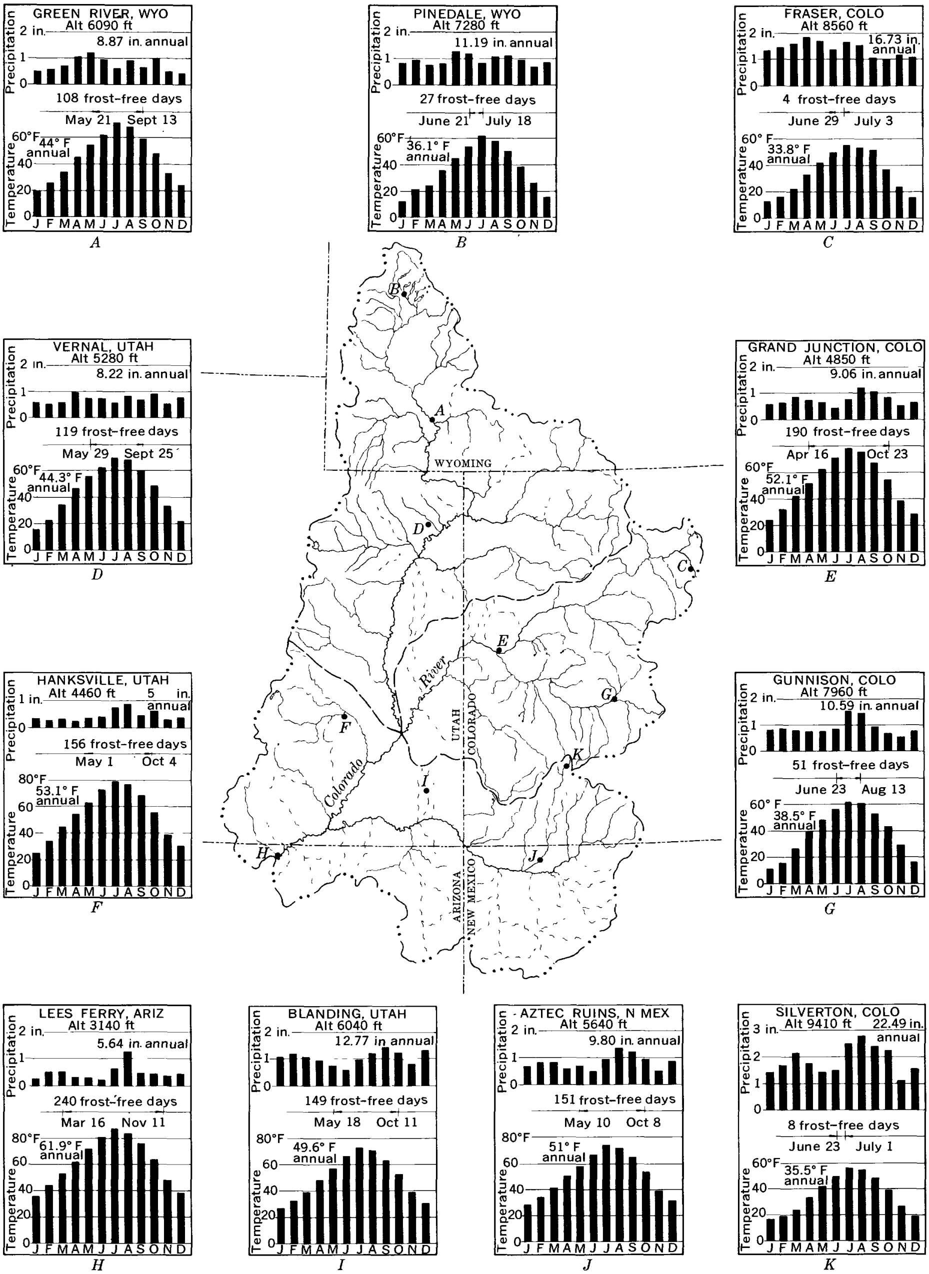


Figure 3.—Normal precipitation and temperature and frost-free seasons at representative stations n the Upper Colorado River Basin. Data from U.S. Weather Bureau normals (average calendar years, 1921–50).

PREVIOUS INVESTIGATIONS AND REPORTS

The water resources of the Upper Colorado River Basin, and plans for their development have been the subjects of several reports by the U.S. Geological Survey and the U.S. Bureau of Reclamation. Some of these reports discussed only parts of the Upper Colorado River Basin. Others dealt with much larger areas. All the reports, the first of which was published in 1916, were based on water-resources data available at the time of preparation. In addition, other Federal bureaus and State and other organizations have occasionally published reports relating to the water resources of the area. Notable among those pertaining to the Upper Colorado River Basin are the reports of the State Engineers of Colorado, Wyoming, Utah, New Mexico, and Arizona, and annual reports of the Upper Colorado River Commission.

The following reports relate principally to the surface waters of the basin and deserve special mention:

Colorado River and its Utilization, E. C. La Rue, 1916: U.S. Geol. Survey Water-Supply Paper 395.

Water Power and Flood Control of the Colorado River below Green River, Utah, E. C. La Rue, 1925: U.S. Geol. Survey Water-Supply Paper 556.

Upper Colorado River and its Utilization, Robert Follansbee, 1929: U.S. Geol. Survey Water-Supply Paper 617.

The Green River and its Utilization, Ralf R. Wooley, 1930: U.S. Geol. Survey Water-Supply Paper 618.

The Colorado River, U.S. Department of the Interior, 1946: U.S. 80th Cong., 1st sess., H. Doc. 419.

Final Report of the Engineering Advisory Committee to Upper Colorado River Basin Compact Commission, 1948: Upper Colorado River Basin Compact Comm.

The Colorado River, Ten Rivers in America's Future: Rept. of the President's Water Resources Policy Comm., 1950, v. 2.

Colorado River Storage Project, U.S. Bureau of Reclamation, 1954, 83d Cong., 2d sess., H. Doc. 364.

Water Utilization in the San Juan River Basin, by E. C. La Rue. This is an unpublished report, available for public inspection in the offices of the Geological Survey in Washington, D.C., and Denver, Colo.

In addition, chapters of this report cite other references which contain information on the surface-water resources.

ACKNOWLEDGMENTS

The precipitation maps were prepared by E. L. Peck, Hydrologist in charge, Water Supply Forecast Unit, and M. J. Brown, State Climatologist, both of U.S. Weather Bureau, Salt Lake City, Utah. J. S. Meyers prepared tables of precipitation for the 46 index stations. The vegetation maps were prepared by F. A. Branson.

D. A. Phoenix participated in the study and prepared a report on the geology, ground-water provinces, and occurrence and chemical quality of ground water. The hydrologic maps, ground-water data, and listing of formations in the eight hydrologic units given in this report were obtained from the report prepared by Phoenix.

The authors have benefited greatly from suggestions made by colleagues in the Geological Survey. An early draft of the report was reviewed by C. H. Hardison and B. R. Colby. A. M. Piper reviewed a later draft and L. B. Leopold, E. L. Hendricks, S. K. Jackson, T. G. McLaughlin, F. C. Ames, F. M. Bell, and W. D. E. Cardwell reviewed one or more chapters. The counsel and criticism of these colleagues have contributed greatly to the report.

For their work in compiling and computing data, the authors gratefully acknowledge the assistance of J. M. Knott, D. C. Hahl, Afton Wright, L. L. Stewart, M. E. Young, N. D. Thornton, P. A. Davies, Betty Owens, A. H. Beers, R. K. Glanzman, D. L. Haney, T. A. Pudlewski, I. B. Droz, T. A. Holt, G. M. Baxter, F. J. Sidlauskas, Jr., J. R. Brochu, L. B. Salazar, J. L. Bird, and E. K. Maurer.

SUMMARY

WATER UTILIZATION

The surface waters in the Upper Colorado River Basin are used for domestic, industrial, and municipal purposes, including the dilution of sewage and industrial wastes, irrigation, watering of livestock, production of hydroelectric power, preservation of fish and wildlife, and recreation. Water is also exported for use in adjoining basins. These uses of water by man have resulted in changes in the natural regimen of many of the streams in the basin.

The major use of water is for irrigation. In 1957 about 1,413,000 acres of land was irrigated (table 4). Most of the irrigated lands have been developed by private enterprise; however, Bureau of Reclamation projects furnish water for about 270,000 acres (including some previously irrigated lands on which supplemental water is supplied). In addition, the Bureau of Indian Affairs operates five projects totaling about 93,000 acres on Indian reservations (President's Water Resources Policy Comm., 1950, p. 365).

The average annual irrigation consumptive use of water has been estimated to be 1,769,100 acre-feet (Upper Colorado River Basin Compact Comm., 1948). Several times this amount is diverted from the streams, applied to the lands, and—except for the amount used consumptively—is returned to the streams.

Ninety-two storage reservoirs each having capacities greater than 1,000 acre-feet had been constructed in the basin by 1957. The combined capacity of these reservoirs, which were constructed to utilize more of the water supply, is about 1,635,000 acre-feet. Of the total capacity, about 738,000 acre-feet is primarily used to provide water for irrigation, domestic, and industrial uses within the Upper Colorado River Basin. The rest of the stored water is primarily for export or is used to supplement the water supply in the basin at times when transmountain diversions reduce the flow of the streams to the point that prior rights are affected.

An average of about 468,400 acre-feet of water was being exported annually in 42 transmountain canals and tunnels as of 1957. Part of this water was used in Colorado, east of the Continental Divide, and part was used in the Great Basin of Utah. One canal in Wyoming also diverts water across the Continental Divide from the Green River basin. An average of about 2,600 acre-feet is annually imported through one diversion into the Upper Colorado River Basin from the Great Basin. Figure 4 shows the increase in

Table 4.—*Summary data on utilization of surface water in the Upper Colorado River Basin, 1957*

Water use	Division			Total in basin
	Grand	Green	San Juan	
Storage reservoirs having usable capacities greater than 1,000 acre-ft:				
Number	33	41	18	92
Total usable capacity acre-ft	831, 600	575, 400	228, 160	1, 635, 160
Transmountain diversions:				
Number	17	20	7	[1]44
Exported (average annual) acre-ft	[2]453, 400	112, 200	2, 800	[2]568, 400
Imported (average annual) acre-ft	0	0	[3]102, 600	[3]102, 600
Irrigation:				
Irrigated acres	583, 200	590, 100	239, 700	1, 413, 000
Estimated consumptive use (average annual) acre-ft	739, 100	728, 900	301, 100	1, 769, 100
Domestic and industrial use:				
Population (1960)	130, 200	99, 400	106, 000	335, 600
Estimated consumptive use (average annual) acre-ft	8, 800	6, 700	7, 100	22, 600
Hydroelectric powerplants:				
Number	15	5	5	25
Installed capacity kw	47, 610	2, 730	5, 070	55, 410

[1] Of the 44 transmountain diversions, 42 exported water out of the basin, 1 imported water into the basin, and 1 transported water between divisions of the basin.

[2] Includes 100,000 acre-ft. diverted from the Grand to the San Juan division.

[3] Includes 100,000 acre-ft. imported from the Grand division and 2,600 acre-ft. imported from the Sevier River (Great Basin).

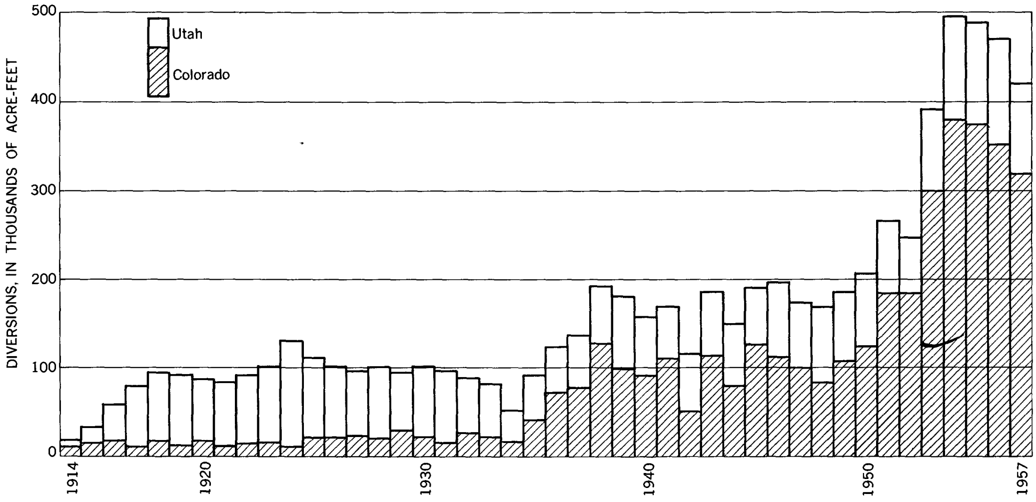


Figure 4.—Annual transmountain diversions in Colorado and Utah from the Upper Colorado River Basin, water years 1914–57.

transmountain diversions in Colorado and Utah since 1914.

Consumption of water by domestic and industrial uses is estimated to average about 22,600 acre-feet annually (1957). The total amount of water withdrawn for this purpose is several times the amount consumed.

In the basin, 25 hydroelectric powerplants have a total installed capacity of about 55,410 kilowatts. No data are available on the amount of water passed through the turbines in the production of hydroelectric power.

WATER SUPPLY

Streamflow in the Upper Colorado River Basin varies from day to day, month to month, and year to year. The annual hydrographs in figure 5 illustrate daily and monthly variations in discharge at four gaging stations, and figure 6 illustrates the yearly variations at the same stations for water years 1914–57.

Most of the water supply comes from the mountains where precipitation is abundant. During the winter the precipitation in the mountains is mostly snow, which in places accumulates to great depths. As temperatures rise in the late spring and early summer, the snow melts rapidly causing the streams to rise and then subside as the stored supply of snow is exhausted. Usually by late July, the perennial streams that flow from the mountains have subsided to a base flow, which generally prevails until the snowmelt period begins the following spring; then the cycle is repeated.

Precipitation in the mountains during the summer does not contribute much water to the streams; native vegetation consumes most of it.

Large areas in the interior of the basin, where precipitation is low, contribute little water to the streams. About 77 percent of the basin receives an average annual precipitation of less than 20 inches, and 42 percent receives less than 12 inches. Many of the tributary streams that drain the interior areas are dry most of the time, and water flows in them only after infrequent storms.

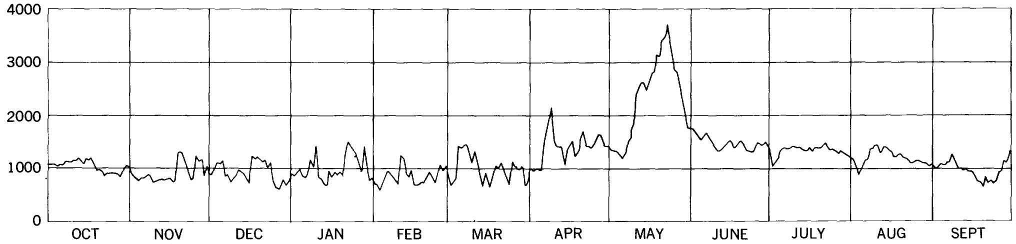
If records of streamflow had been obtained before and after the activities of man began in the basin, the magnitude of the change in stream regimen caused by man's use of water could be determined accurately; however, man's use of water in the basin was far advanced before collection of records began. Although precise determinations cannot be made, many useful appraisals of man's effect and the effects of natural environmental factors on the streams can be determined from available data.

For the appraisal, the streamflow records for the period October 1, 1913, to September 30, 1957, were adopted as being indicative of the long-term water supply. During this period water-use development increased, which decreased the flow of some streams. To have a common base for comparisons of streams, the level of development in 1957 was adopted for the report. This common base is useful for comparing streams that have different environments and for appraising the magnitude of changes in streamflow and chemical quality of water caused by the activities of man. Where upstream water use changed during the base period (1914–57), the streamflow records were adjusted to be representative of what would have occurred had the water-use developments existing in 1957 been in operation throughout the 1914–57 period.

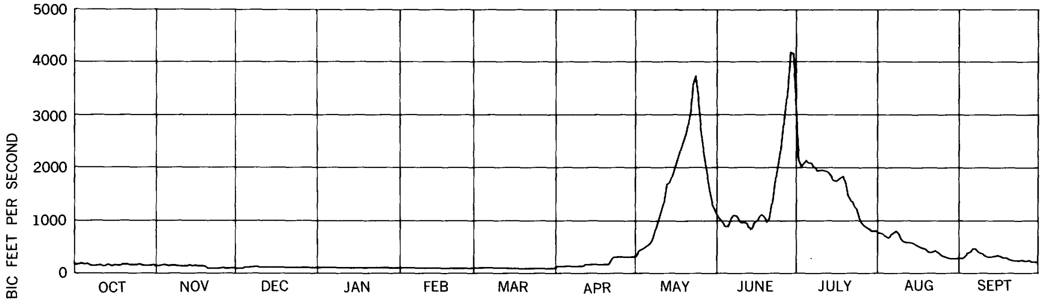
Flow-duration curves, which show the percentage of time that water discharges of various magnitude have been equaled or exceeded during the 44-year base period, were computed for many streams from the headwaters to "Lee Ferry." At sites where upstream water use had resulted in changes in stream discharge during the base period, the curves were adjusted to be representative of the level of upstream use in 1957. Flow-duration curves for four streams are shown in figure 7. The data for these and other curves for selected gaging stations are given in table 5. Similar flow-duration curves and tables were computed for many other sites. By arithmetically integrating the area under the flow-duration curves, the average water discharge for the period represented by the curve may be determined.

The shape and slope of the flow-duration curves for many streams were used to study and compare the effects of drainage environmental factors on stream behavior. The curves for snowmelt streams, when plotted on logarithmic-probability paper, tend to have a flat slope at the upper end and a fairly steep slope in the central part. The effects of dense vegetation tend to flatten, whereas the effects of sparse vegetation tend to steepen the top part of the curve. Flow-duration curves for streams draining areas underlain by permeable rocks tend to have a relatively flat slope because part of the precipitation infiltrates to ground-water reservoirs. These reservoirs maintain the flow during periods of low flow. If the drainage basin is underlain by relatively impermeable rocks, the lower part of the curve is steep.

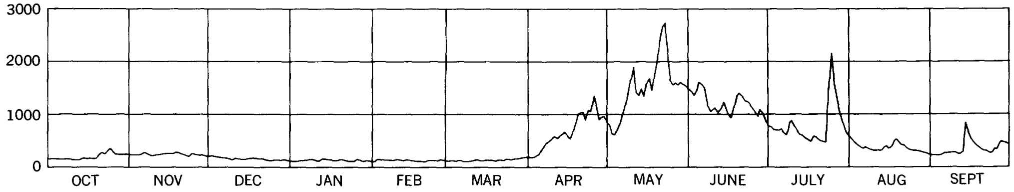
In the mountains, ground water and surface water are closely related. Here, precipitation is abundant, and where the formations are permeable, there is ample opportunity for recharge of ground-water reservoirs. Because most streams in the mountains are deeply incised, most ground-water reservoirs are effluent to the streams at all times and sustain them during periods of low flow. Ground-water contribution to the streams, expressed as a percentage of the total water discharge, is an indication of the relative premeability of the rocks underlying the drainage basin. For example, 11



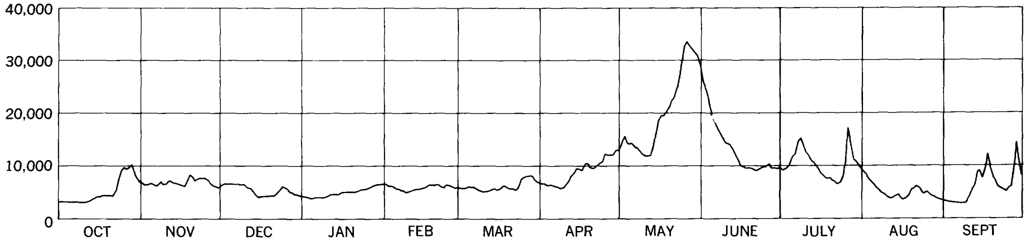
A. Colorado River at Glenwood Springs, Colo.



B. Green River at Warren Bridge, near Daniel, Wyo.

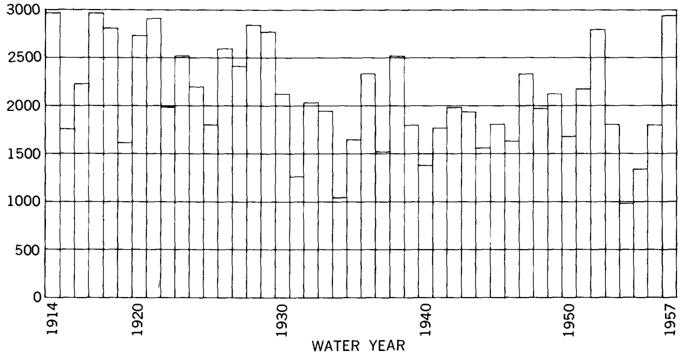


C. Animas River at Durango, Colo.

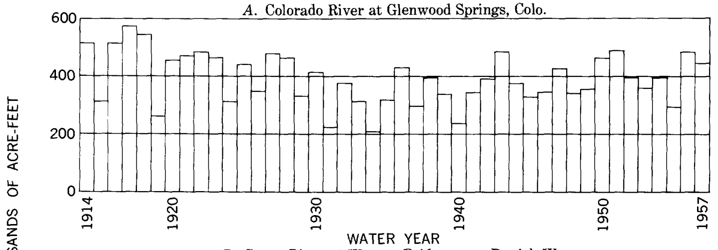


D. Colorado River at Lees Ferry, Ariz.

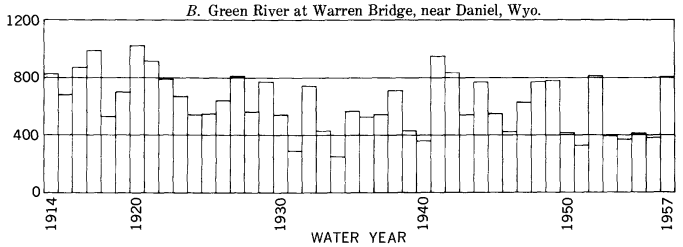
FIGURE 5.—Seasonal pattern of streamflow for selected streams in the Upper Colorado River Basin, 1954 water years.



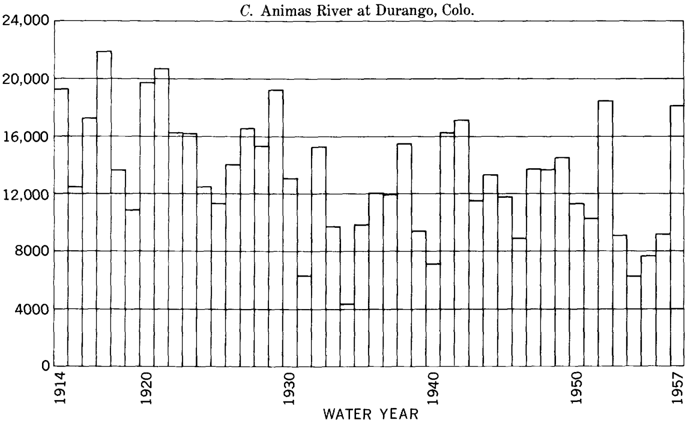
A. Colorado River at Glenwood Springs, Colo.



B. Green River at Warren Bridge, near Daniel, Wyo.

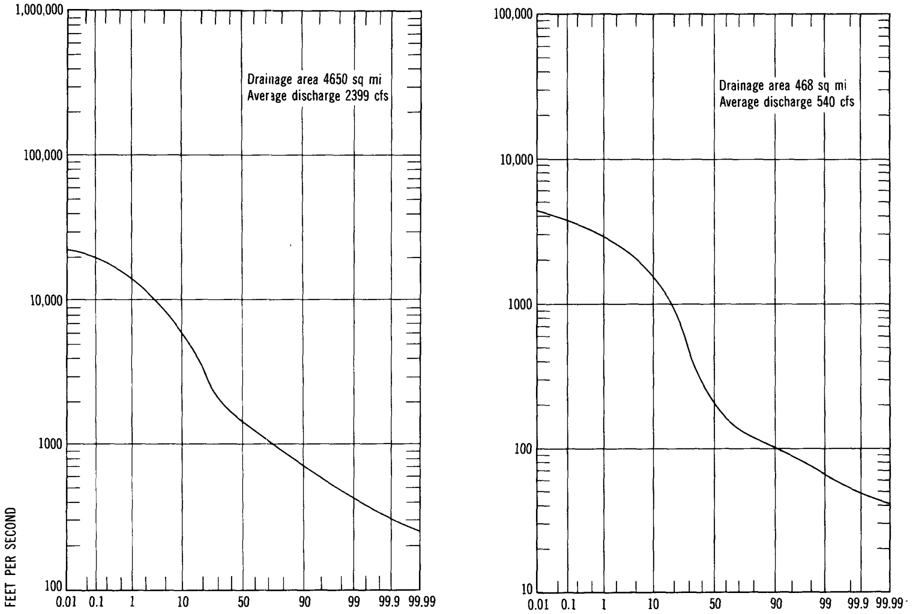


C. Animas River at Durango, Colo.



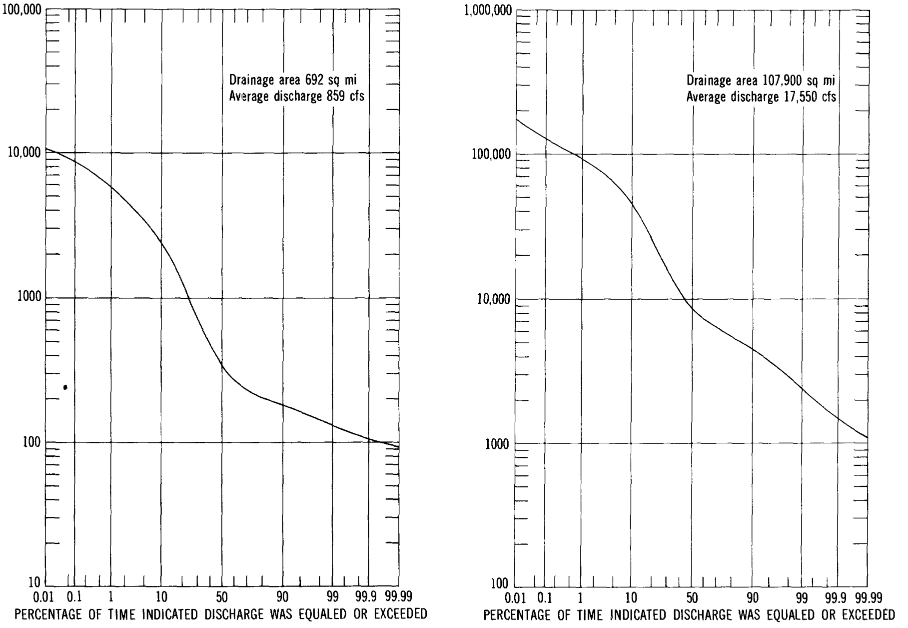
D. Colorado River at Lees Ferry, Ariz.

FIGURE 6.—Variability of annual discharges of selected streams in the Upper Colorado River Basin, water years 1914–57 adjusted to 1914 base.



A. Colorado River at Glenwood Springs, Colo.

B. Green River at Warren Bridge, near Daniel, Wyo.



C. Animas River at Durango, Colo.

D. Colorado River at Lees Ferry, Ariz.

FIGURE 7.—Flow-duration curves for selected streams in the Upper Colorado River Basin, water years 1914–57 adjusted to 1957 conditions.

TABLE 5.—*Flow-duration tables for selected gaging stations in the Upper Colorado River Basin*

[Data are for the water years 1914-57 adjusted to 1957 conditions]

Station No.	Streamflow station	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Mean discharge (cfs)	Mean annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
725	Colorado River at Glenwood Springs, Colo	22,470	20,400	18,760	15,100	11,260	8,960	7,219	5,189	3,220	2,005	1,637	1,417	1,224	1,034	868	695	507	390	308	2,399	1,738,000
955	Colorado River near Cameo, Colo	35,000	33,500	31,600	26,800	20,500	16,300	12,700	9,100	5,300	3,500	2,670	2,180	1,930	1,730	1,550	1,310	1,040	860	760	4,138	2,998,000
1050	Plateau Creek near Cameo, Colo	3,900	3,350	2,980	2,370	1,690	1,250	895	540	225	135	106	90	80	71	60	45	27	19	15	235	170,200
1475	Uncompahgre River at Colona, Colo	4,080	2,770	2,340	1,830	1,400	1,130	910	675	430	250	154	118	99	88	80	66	47	29	18	278	201,400
1525	Gunnison River near Grand Junction, Colo	32,000	27,900	25,100	20,000	15,200	12,000	9,400	6,400	3,240	1,790	1,310	1,100	970	860	760	630	390	220	155	2,601	1,884,000
1805	Colorado River near Cisco, Utah	62,270	59,540	55,710	47,950	38,090	30,970	25,250	18,760	11,020	6,060	4,200	3,540	3,180	2,820	2,520	2,160	1,580	975	746	7,639	5,534,000
1885	Green River at Warren Bridge near Daniel, Wyo	4,400	3,920	3,600	3,100	2,600	2,200	1,820	1,430	960	500	300	210	160	139	119	101	81	61	49	540	391,200
2345	Green River near Greendale, Utah	17,900	17,400	16,700	14,300	11,100	9,150	7,500	5,250	3,490	2,200	1,500	1,150	870	680	540	426	340	296	260	2,271	1,645,000
2395	Yampa River at Steamboat Springs, Colo	5,800	5,250	4,800	3,990	3,050	2,460	1,960	1,350	615	255	172	140	125	108	92	73	52	29	8.4	472	341,900
2510	Yampa River near Maybell, Colo	17,300	16,200	14,950	12,500	9,750	8,050	6,600	4,750	2,540	950	550	410	332	280	235	182	108	36	12	1,590	1,152,000
2600	Little Snake River near Lily, Colo	8,000	7,550	7,000	5,750	4,340	3,460	2,720	1,920	946	350	190	123	87	65	41	11	.1	0	0	622	450,600
2795	Duchesne River at Duchesne, Utah	3,830	3,460	3,150	2,520	1,800	1,373	1,025	632	317	234	200	180	166	151	137	113	79	50	30	323	234,000
3070	Green River near Ouray, Utah	63,000	55,500	49,700	39,800	30,200	24,900	20,000	15,400	9,600	5,450	3,750	2,850	2,380	2,060	1,750	1,420	990	580	370	6,223	4,508,000
3150	Green River at Green River, Utah	63,430	56,430	51,450	41,720	32,100	25,850	20,210	14,800	9,267	5,614	3,881	2,966	2,439	2,091	1,793	1,424	1,006	637	462	6,292	4,558,000
3285	San Rafael River near Green River, Utah	4,050	3,150	2,690	2,020	1,370	865	475	242	117	76	64	51	41	32	24	1.4	0	0	0	141	102,100
3565	San Juan River near Blanco, N. Mex	19,250	16,200	14,200	11,400	8,580	6,950	5,550	4,000	2,450	1,300	760	530	388	302	252	200	130	64	34	1,519	1,100,000
3615	Animas River at Durango, Colo	10,700	9,180	8,170	6,400	4,750	3,740	2,900	2,090	1,290	730	470	338	272	235	203	180	152	123	106	859	622,300
3795	San Juan River near Bluff, Utah	32,000	27,000	24,000	19,100	14,400	11,400	9,200	6,900	4,400	2,690	1,810	1,240	930	750	610	440	240	76	20	2,800	2,028,000
3800	Colorado River at Lees Ferry, Ariz	178,200	137,300	122,200	101,500	82,090	69,120	55,060	41,660	25,690	16,120	11,280	8,678	7,428	6,492	5,646	4,584	3,263	2,162	1,493	17,550	12,710,000
3820	Paria River at Lees Ferry, Ariz	7,500	3,400	1,800	570	190	97	60	38	27	22	18	14	11	6.8	4.9	3.8	2.9	2.3	1.9	31.9	23,110

percent of the water discharge of Homestake Creek near Red Cliff, Colo., is base flow contributed largely by ground water. This drainage basin is underlain by Precambrian rocks that are relatively impermeable but are broken by joints and faults through which water may enter and circulate. However, the intake rate, capacity of the openings, and rate of release to the stream system are small. A contrasting example is Gypsum Creek near Gypsum, Colo. Of the total water discharge at this station, about 66 percent is base flow, largely from ground water. The drainage basin of Gypsum Creek is underlain by rocks and Pennsylvanian and Permian age. They consist of conglomerate, sandstone, some limestone, and shale beds interbedded and interspersed with gypsum. These rocks weather deeply and are relatively permeable.

Yearly variations in stream discharge, except where modified by the activities of man, are principally the result of differences in annual precipitation. However, the geologic environment considerably modifies the annual variations in the discharge of some streams, principally through carryover storage in ground-water reservoirs. Coefficient of variation (ratio of standard deviation of annual discharges to the average discharge) is a statistical measure of the annual variability of streamflow. Perennial headwater streams, whose source of supply is principally snowmelt, have a relatively narrow range in coefficients of variation, from about 0.25 to about 0.38. However, in some drainage basins the coefficients greatly exceed this range because of low permeability and structure of the underlying rocks. Where the rocks are relatively permeable and extensive ground-water reservoirs are present, the coefficient is as low as 0.18. Where the rocks are relatively impermeable, the coefficient is as high as 0.60. Intermittent streams that flow only in response to infrequent thunderstorms have high coefficients, usually about 0.80.

By considering geographic location, character of underlying rocks, and the coefficients of variation of streams having a similar environment, one can estimate the variability of annual discharge for many streams that have relatively short periods of record.

WATER BUDGET

Table 6 gives an approximate water budget for the Upper Colorado River Basin. The budget is based on the assumption that no water moves from the basin by ground-water underflow. The irrigation consumptive use was compiled by the Upper Colorado River Basin Compact Commission (1948). The total average annual precipitation supply is 92,739,000 acre-feet, which is equivalent to an average annual precipitation over the basin of 15.88 inches. All the precipitation supply not accounted for by outflow from the basin, by transmountain diversions (less imported water), and by consumptive use due to the activities of man is considered to be evapotranspiration from the land surface and native vegetation.

TABLE 6.—*Water budget, Upper Colorado River Basin*

	Average annual (acre-ft)
Outflow from the basin	12, 733, 100
Transmountain diversions exporting water	468, 400
Transmountain diversion importing water	−2, 600
Irrigation consumptive use	1, 769, 100
Domestic and industrial consumptive use	22, 600
Evapotranspiration	[1] 77, 748, 400
Total	92, 739, 000

[1] Includes 575,000 acre-ft estimated evaporation from water surfaces.

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Water and dissolved-solids discharge and weighted-average concentration of dissolved solids at selected sites in the Upper Colorado River Basin are given in table 7. These data represent the long-term average that would have occurred if the water-use developments in 1957 had been in operation throughout water years 1914–57. Similar data at many other sites were also computed.

The water and dissolved-solids discharge at the sites listed in table 7 expressed as a percentage of the combined water and dissolved-solids discharge of Colorado and Paria Rivers at Lees Ferry, Ariz. (outflow from the Upper Colorado River Basin) are given in figure 8. The precision of the percentages varies, and the last figure of the values shown in figure 8 may not be trustworthy for some stations. Comparison of the percentages at the different sites shows that most of the water comes from the mountains and high plateaus, but most of the dissolved-solids content comes from the lower parts of the basin. Here, precipitation is low and relatively little water is contributed to the streams. The rocks exposed in the mountains are generally much more resistant to the solvent action of water than the rocks that underlie a large part of the lowlands.

The Grand division, though the smallest in drainage area of the three divisions, contributes more water and dissolved solids than either of the other two divisions. About 44 percent of the water and 48 percent of the dissolved solids at "Lee Ferry," Ariz. (combined water and dissolved solids of Colorado and Paria Rivers at Lees Ferry) come from the Grand division (26,500 sq mi), about 37 percent of the water and 33 percent of the dissolved solids come from the Green division (44,700 sq mi), and about 19 percent of the water and 19 percent of the dissolved solids come from the San

TABLE 7.—*Water and dissolved-solids discharge at selected stations in the Upper Colorado River Basin*

[Water and dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions except as indicated]

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per square mile (tons)	Average annual discharge (tons)
345	Colorado River at Hot Sulphur Springs, Colo	782	244	176, 800	76	50	23	18, 260
690	Eagle River at Gypsum, Colo	844	602	436, 100	303	492	213	179, 700
705C	Colorado River near Glenwood Springs, Colo	4, 486	2, 399	1, 738, 000	270	1, 750	142	639, 200
850	Roaring Fork at Glenwood Springs, Colo	1, 460	1, 353	980, 200	225	821	205	299, 900
955	Colorado River near Cameo, Colo	8, 060	4, 138	2, 998, 000	387	4, 320	196	1, 578, 000
1050	Plateau Creek near Cameo, Colo	604	235	170, 200	285	181	109	66, 110
1145	Gunnison River near Gunnison, Colo	1, 010	753	545, 500	126	256	93	93, 500
1280	Gunnison River below Gunnison Tunnel, Colo	3, 980	1, 303	944, 000	111	391	36	142, 800
1475	Uncompahgre River at Colona, Colo	437	278	201, 400	376	282	236	103, 000
1495	Uncompahgre River at Delta, Colo [1]	1, 110	286	207, 200	1, 610	1, 240	408	452, 910
1525	Gunnison River near Grand Junction, Colo	8, 020	2, 601	1, 884, 000	592	4, 160	189	1, 519, 000
1665	Dolores River at Dolores, Colo	556	492	356, 400	125	166	109	60, 630
1755	San Miguel River at Naturita, Colo	1, 080	351	254, 300	316	299	101	109, 200
1800	Dolores River near Cisco, Utah	4, 630	940	681, 000	496	1, 260	99	460, 200
1805	Colorado River near Cisco, Utah	24, 100	7, 639	5, 534, 000	547	11, 280	171	4, 120, 000
1885	Green River at Warren Bridge, near Daniel, Wyo	468	540	391, 200	151	220	172	80, 360
2010	New Fork River near Boulder, Wyo	552	401	290, 500	69	75	50	27, 390
2095	Green River near Fontenelle, Wyo	3, 970	1, 609	1, 166, 000	185	805	74	294, 000
2135	Big Sandy Creek near Farson, Wyo	320	86. 6	62, 740	47	11	13	4, 020
2160	Big Sandy Creek below Eden, Wyo	1, 610	48. 8	35, 350	1, 340	176	40	64, 280
2165	Green River at Green River, Wyo	7, 670	1, 802	1, 305, 000	284	1, 380	66	504, 000
2250	Blacks Fork near Green River, Wyo.[2]	3, 670	345	249, 900	537	500	50	182, 600
2345	Green River near Greendale, Utah	15, 100	2, 271	1, 645, 000	378	2, 320	56	847, 400
2395	Yampa River at Steamboat Springs, Colo	604	472	341, 900	74	94	57	34, 330
2425	Elk River near Trull, Colo	415	544	394, 100	47	69	61	25, 200
2510A	Yampa River at bridge on county road, near Maybell, Colo	3, 590	1, 590	1, 152, 000	140	599	61	218, 800
2570	Little Snake River near Dixon, Wyo	988	547	396, 300	91	135	50	49, 310
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	3, 355	622	450, 600	196	330	36	120, 500
2635A	Green River at Jensen, Utah	26, 100	4, 607	3, 338, 000	316	3, 930	55	1, 435, 000
2795	Duchesne River at Duchesne, Utah	660	323	234, 000	218	190	105	69, 400
2885	Strawberry River at Duchesne, Utah	1, 040	157	113, 700	396	168	59	61, 360
3020	Duchesne River near Randlett, Utah	3, 920	767	555, 700	608	1, 260	117	460, 200
3045	White River near Meeker, Colo	762	638	462, 200	244	420	201	153, 400
3065	White River near Watson, Utah	4, 020	764	553, 500	439	905	82	330, 600
3070	Green River near Ouray, Utah	35, 500	6, 223	4, 508, 000	392	6, 590	68	2, 407, 000
3145	Price River at Woodside, Utah	1, 500	116	84, 040	2, 110	662	161	241, 800
3150	Green River at Green River, Utah	40, 600	6, 292	4, 558, 000	427	7, 260	65	2, 652, 000
3285	San Rafael River near Green River, Utah	1, 690	141	102, 100	1, 370	521	113	190, 300
3300	Fremont River near Bicknell, Utah [3]	776	85. 8	62, 160	302	70	33	25, 570
3335	Dirty Devil River near Hite, Utah [4]	4, 360	102	73, 890	1, 960	541	45	197, 600
3350	Colorado River at Hite, Utah	76, 600	14, 167	10, 260, 000	527	20, 170	96	7, 367, 000
3395	Escalante River at mouth, near Escalante, Utah [5]	2, 010	85. 2	61, 720	300	69	13	25, 200
3425	San Juan River at Pagosa Springs, Colo	298	403	292, 000	73	79	97	28, 850
3565	San Juan River near Blanco, N. Mex	3, 560	1, 519	1, 100, 000	125	512	53	187, 000
3615	Animas River at Durango, Colo	692	859	622, 300	183	425	224	155, 200
3645	Animas River at Farmington, N. Mex	1, 360	971	703, 500	233	611	164	223, 200
3680	San Juan River at Shiprock, N. Mex	12, 900	2, 679	1, 941, 000	256	1, 850	52	675, 700
3795	San Juan River near Bluff, Utah	23, 000	2, 800	2, 028, 000	361	2, 730	43	997, 100
3800	Colorado River at Lees Ferry, Ariz	107, 900	17, 550	12, 710, 000	499	23, 660	80	8, 642, 030
3820	Paria River at Lees Ferry, Ariz	1, 570	31. 9	23, 110	1, 090	94	22	34, 300

[1] For water years 1939–57.

[2] For water years 1948–57.

[3] For water years 1938–43, 1947–57.

[4] For water years 1947–57.

[5] For water years 1951–55.

Juan division (38,300 sq mi). In the San Juan division, the San Juan River contributes about 16 percent of the water and about 11 percent of the dissolved solids at "Lee Ferry," Ariz. The weighted-average concentration of dissolved solids in the Colorado River at "Lee Ferry," Ariz. (12,733,100 acre-ft) is 501 ppm (parts per million) for water years 1914–57 adjusted to 1957 conditions.

In computing the dissolved-solids concentrations and discharges given in table 7, duration tables of dissolved-solids concentrations and discharges, similar to tables 8 and 9, were prepared. Four of the stations given in the tables are at or near the lower end of the divisions, and four are near the headwaters. In the computations for these tables the analyses of water samples, water discharge at the time of sampling, curves showing relation of dissolved-solids discharge to water discharge, and flow-duration curves of water discharge were used. The computed dissolved-solids concentrations and discharges are representative of conditions in 1957, and will probably continue to be representative until conditions change.

VARIATIONS IN CHEMICAL QUALITY

The chemical quality of water of the streams in the Upper Colorado River Basin varies from day to day and month to month. The concentration of dissolved solids varies nearly in inverse relation to streamflow; it is lowest during high flows and highest during low flows. The relation between water discharge and dissolved-solids concentration shown in figures 9 and 10 is representative of streams in the basin.

In the headwaters the range in concentration between high and low flows is relatively small, but in the downstream reaches of many streams the range is large.

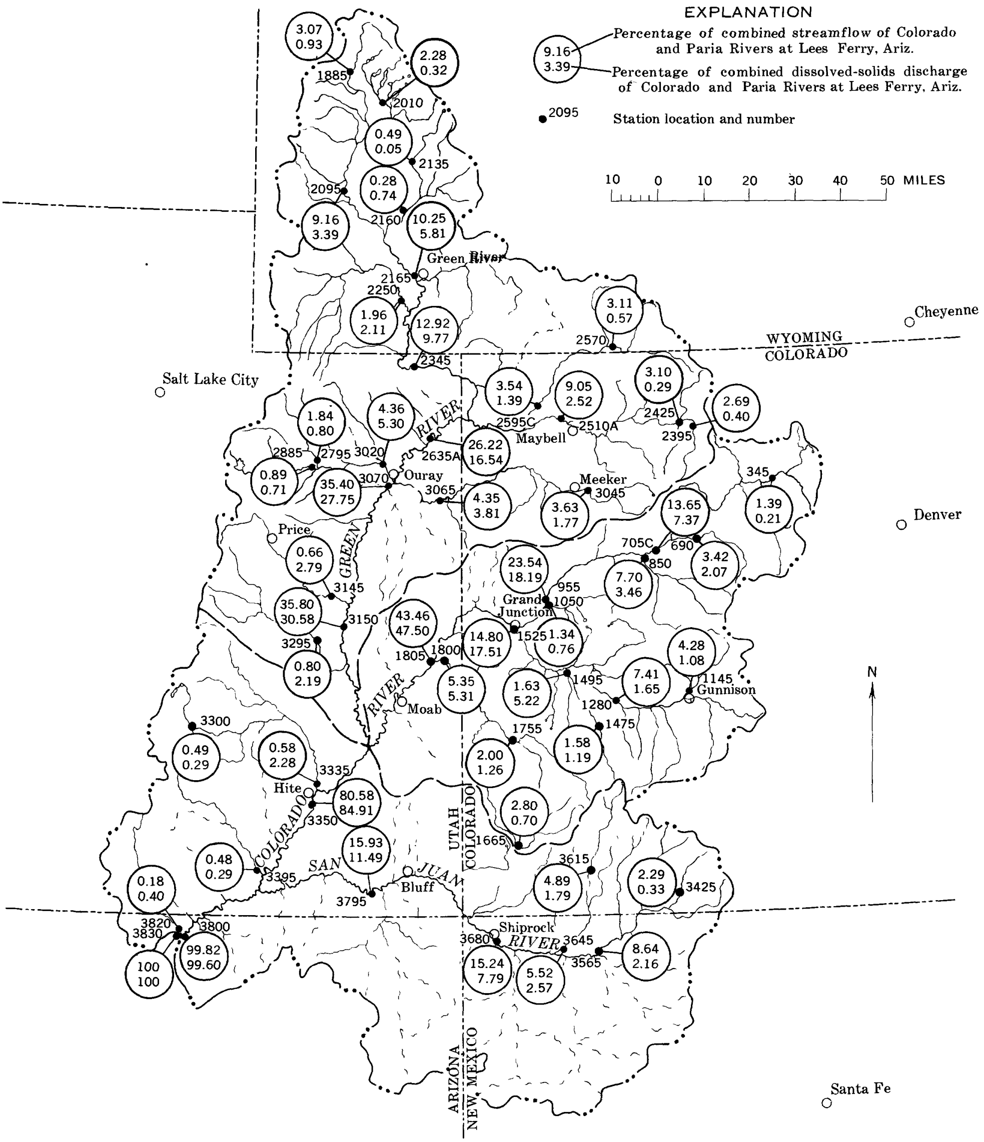


FIGURE 8.—Approximate dissolved-solids discharge and streamflow, expressed as percentages of the combined dissolved-solids discharge and combined streamflow of the Colorado and Paria Rivers at Lees Ferry, Ariz.

TABLE 8.—*Duration table of dissolved-solids concentration for eight stations in the Upper Colorado River Basin*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Chemical-quality station	Dissolved-solids concentration, in parts per million, that was equaled or exceeded for indicated percentage of time																			Weighted-average concentration (ppm)
		99.99	99.94	99.85	99.4	98	96	93	88	80	70	60	50	40	30	20	10	3	0.6	0.1	
1475	Uncompahgre River at Colona, Colo	170	180	185	195	212	230	258	300	388	500	580	600	620	640	645	660	680	700	700	376
1805	Colorado River near Cisco, Utah	238	239	240	241	248	258	273	309	415	660	895	1,030	1,130	1,240	1,350	1,470	1,680	1,810	1,850	547
2395	Yampa River at Steamboat Springs, Colo	38	38	38	39	40	41	44	51	76	127	155	171	180	188	197	204	211	218	220	74
2795	Duchesne River at Duchesne, Utah	132	132	132	133	134	137	141	157	220	273	301	319	332	348	360	381	400	408	415	218
3150	Green River at Green River, Utah	222	222	222	225	230	240	270	326	430	570	655	700	735	755	775	800	820	850	860	427
3565	San Juan River near Blanco, N. Mex	84	84	85	86	86	88	91	97	113	150	195	230	264	286	300	317	335	340	345	125
3795	San Juan River near Bluff, Utah	183	190	194	203	217	230	243	265	308	385	500	660	780	845	900	960	1,050	1,080	1,100	361
3800	Colorado River at Lees Ferry, Ariz	250	253	256	262	270	280	295	322	420	580	730	860	935	990	1,040	1,120	1,170	1,200	1,210	499

TABLE 9.—*Duration table of dissolved-solids discharge for eight stations in the Upper Colorado River Basin*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Chemical-quality station	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
1475	Uncompahgre River at Colona, Colo	1,870	1,350	1,170	964	801	702	634	547	450	338	241	191	166	152	139	118	86	55	34	282	236
1805	Colorado River near Cisco, Utah	40,010	38,420	36,100	31,200	25,510	21,570	18,610	15,650	12,350	10,800	10,150	9,840	9,700	9,440	9,190	8,570	7,170	4,760	3,730	11,280	171
2395	Yampa River at Steamboat Springs, Colo	595	539	493	420	329	272	233	186	126	87	72	65	61	55	49	40	30	17	5.0	94	57
2795	Duchesne River at Duchesne, Utah	1,360	1,230	1,120	905	651	508	390	268	188	172	163	155	149	142	133	116	85	55	34	190	105
3150	Green River at Green River, Utah	38,020	33,820	30,840	25,350	19,930	16,750	14,730	13,030	10,760	8,640	6,860	5,610	4,840	4,260	3,750	3,080	2,230	1,460	1,070	7,260	65
3565	San Juan River near Blanco, N. Mex	4,370	3,670	3,260	2,650	1,990	1,650	1,360	1,050	747	526	400	329	277	233	204	171	118	59	32	512	53
3795	San Juan River near Bluff, Utah	15,810	13,850	12,570	10,470	8,440	7,080	6,040	4,940	3,660	2,800	2,440	2,210	1,960	1,710	1,480	1,140	680	222	59	2,730	43
3800	Colorado River at Lees Ferry, Ariz	120,300	93,790	84,460	71,800	59,840	52,250	43,860	36,220	29,130	25,240	22,230	20,150	18,760	17,350	15,870	13,850	10,300	7,000	4,870	23,660	80

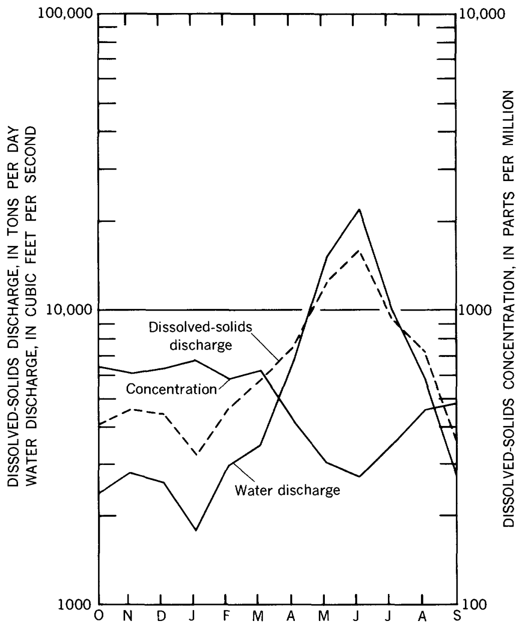


Figure 9.—Dissolved-solids concentration and discharge and water discharge, Green River near Ouray, Utah, 1951 water year.

Yampa River at Steamboat Springs, Colo., is representative of headwater streams, and Colorado River near Cisco, Utah, is representative of streams in downstream reaches.

A relation between coefficients of variation for weighted-average concentration of dissolved-solids and for water discharge is indicated by daily records at chemical-quality stations (fig. 11). In the Grand division a linear relation is indicated, whereas in the Green and San Juan divisions the relation, though probably linear, is not as clear. Linear equations (computed by the least-squares method) for each of the divisions are given in figure 11. Chapter B explains how these equations can be used to compute approximate long-term coefficients of variation of dissolved-solids concentration at sites where continuous records of chemical quality are of short duration or where chemical-quality data have been obtained only infrequently.

RELATION TO STREAMFLOW

The relations between streamflow and chemical composition of water at four stations near the lower ends of the three divisions are given in table 10 and figure 12. At these locations during high flows, calcium and bicarbonate are the predominate cations and anions, except in Colorado River near Cisco, Utah, where sulfate is slightly greater than bicarbonate. At median and low flows, sodium and sulfate become the predominate cations and anions, except in San Juan River near Bluff, Utah, where calcium is greater than sodium. In this classification of high, median, and low flows, a high flow is the discharge equaled or exceeded 10 percent of the time, a median flow is the discharge equaled or exceeded 50 percent of the time, and a low flow is the discharge equaled or exceeded 90 percent of the time. These flow rates are also indicated by the diagrams in figure 12. In table 10 the water discharges equaled and exceeded 12, 50, and 90 percent of the time are indicated.

In the headwaters the range in dissolved-solids concentrations is not as large as it is in the same streams at lower altitudes where the terrane is composed of sedimentary rocks and the climate is more arid. Fig-

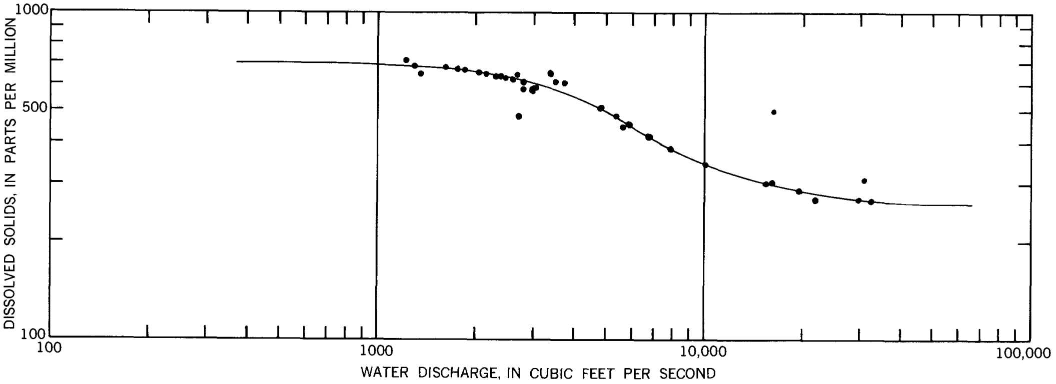


Figure 10.—Relation of concentration of dissolved solids to water discharge, Green River near Ouray, Utah. Curve is based on monthly average discharges and monthly weighted-average concentrations for periods of available data, water years 1951–52 and 1957.

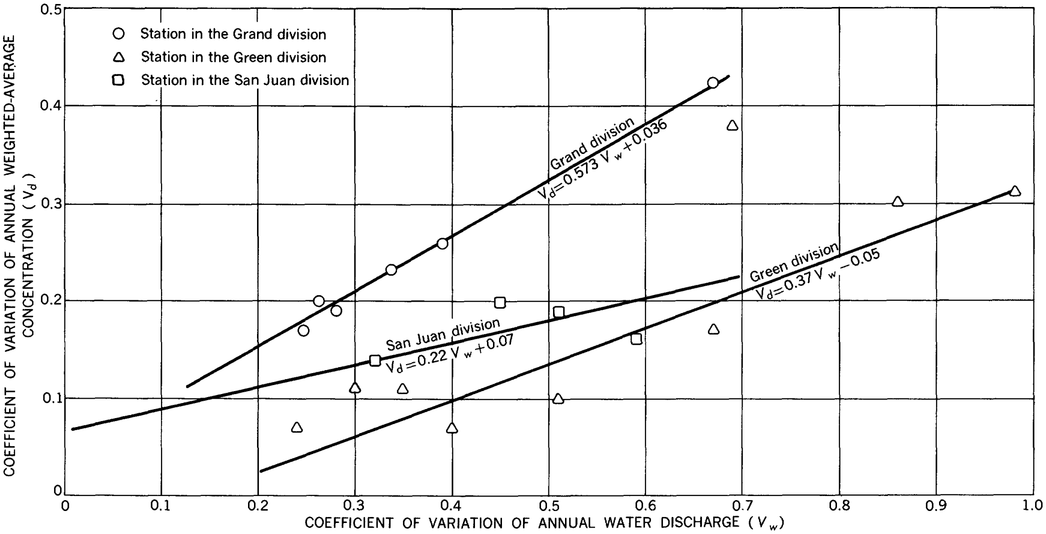


FIGURE 11.—Relation of the variability of dissolved-solids concentration to the variability of water discharge at daily chemical-quality stations, Upper Colorado River Basin.

ure 13 shows the relation of chemical composition and concentration of dissolved solids to water discharge for four typical headwater streams. Calcium is the predominate cation in all four streams for all flows, and bicarbonate is the predominate anion in all four streams during high flows but only in Yampa River at Steamboat Springs, Colo., and Duchesne River at Duchesne, Utah, for all flows. For median and low flows bicarbonate and sulfate are about equal in San Juan River near Blanco, N. Mex., whereas sulfate is predominate in Uncompahgre River at Colona, Colo. The difference in composition at median and low flows seems to be principally dependent on the type of soil and rocks that underlie the areas upstream from the stations.

RELATION TO GEOLOGY

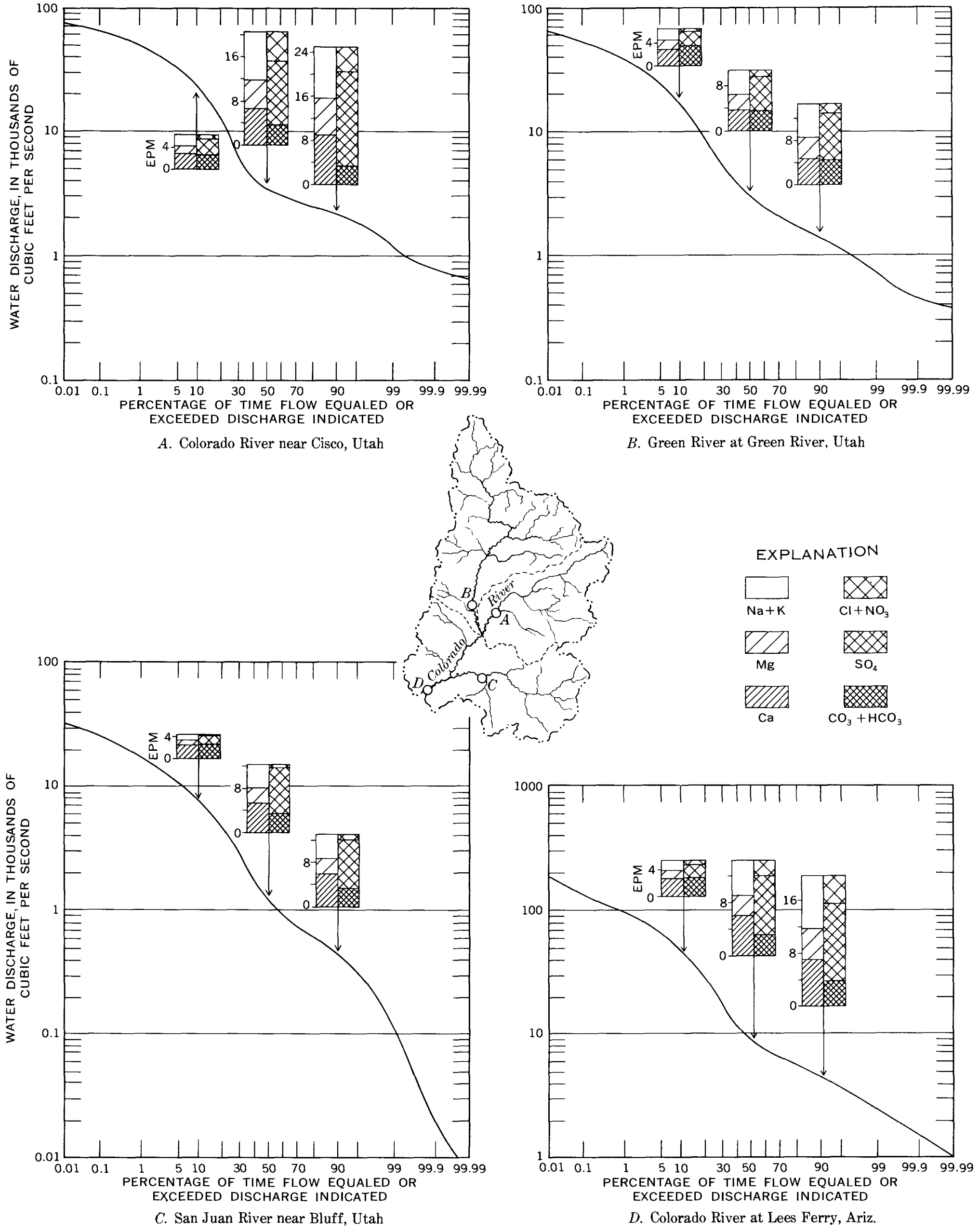
The dissolved-solids concentrations of the water and the proportions of the individual constituents in streams of the Upper Colorado River Basin differ greatly from place to place. These differences are the result of hydrologic and other environmental factors that prevail in each drainage basin. One of the major factors that determine the chemical quality of each stream is the type of rocks that underlie each drainage basin.

The headwaters of the Colorado, Green, and San Juan Rivers and their principal tributaries are underlain by rocks that are relatively resistant to the solvent action of water; these rocks are chiefly granite and associated metamorphic, volcanic, and the more indurated sedimentary rocks.

Igneous and metamorphic rocks are composed of similar minerals and therefore the waters of the streams that drain areas underlain by these rocks are similar in chemical composition and dissolved-solids concentration. The principal difference between the waters draining the areas underlain by the volcanic, granitic, and associated metamorphic rocks is that waters from the volcanic terranes usually have a slightly higher concentration of dissolved solids and silica.

The most dilute surface waters in the upper basin come from the high mountain areas that are underlain by igneous and associated metamorphic rocks. The water of the streams close to the divides may contain less than 20 ppm of dissolved solids. The weighted-average concentration of the dissolved solids in streams at any point in the mountains along the Continental Divide, in the higher parts of the San Juan Mountains, in the Uinta Mountains, and in some of the high plateaus never exceeds 100 ppm and seldom exceeds 50 ppm.

The waters of the mountain streams are a calcium bicarbonate type at all rates of streamflow, but the waters with concentrations of less than about 30 ppm may contain relatively large percentages of sodium and sulfate ions. The concentration of silica in the mountain streams ranges from about 6 to 15 ppm, except



A. Colorado River near Cisco, Utah

B. Green River at Green River, Utah

C. San Juan River near Bluff, Utah

D. Colorado River at Lees Ferry, Ariz.

FIGURE 12.—Relation of the chemical composition and concentration of dissolved solids to water discharge at stations on the three main streams in the Upper Colorado River Basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914-57 adjusted to 1957 conditions.

TABLE 10.—*Relation between water discharge and chemical quality of water*

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italic) except as indicated; data are for the water years 1914–57 adjusted to 1957 conditions]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (sum)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
Colorado River near Cisco, Utah																
62,270	39 *1.95*	6.8 *.56*	13 *.57*	2.2 *.06*	120 *1.97*	53 *1.10*	2.4 *.07*	0.04	238	0.32	40,010	126	27	18	378	0.5
59,540	39 *1.95*	6.9 *.57*	14 *.61*	2.2 *.06*	121 *1.98*	55 *1.14*	2.5 *.07*	.04	239	.33	38,420	126	27	19	380	.5
55,710	40 *2.00*	7.1 *.58*	15 *.65*	2.2 *.06*	122 *2.00*	57 *1.19*	2.5 *.07*	.04	240	.33	36,100	129	29	20	380	.6
47,950	41 *2.05*	7.5 *.62*	16 *.70*	2.2 *.06*	125 *2.05*	63 *1.31*	2.6 *.07*	.04	241	.33	31,200	134	31	20	380	.6
38,090	43 *2.15*	8.5 *.70*	18 *.78*	2.2 *.06*	128 *2.10*	73 *1.52*	3.0 *.08*	.05	248	.34	25,510	142	38	21	390	.7
30,970	45 *2.25*	9.3 *.76*	22 *.96*	2.2 *.06*	134 *2.20*	85 *1.77*	3.2 *.09*	.05	258	.35	21,570	150	40	24	403	.8
25,250	47 *2.35*	11 *.90*	25 *1.09*	2.3 *.06*	139 *2.28*	97 *2.02*	3.6 *.10*	.05	273	.37	18,610	162	48	25	435	.9
18,760 [1]	51 *2.54*	13 *1.07*	31 *1.35*	2.5 *.06*	146 *2.39*	121 *2.52*	4.5 *.13*	.05	309	.42	15,650	180	61	27	480	1.0
11,020	60 *2.99*	17 *1.40*	47 *2.04*	2.7 *.07*	160 *2.62*	176 *3.66*	6.6 *.19*	.05	415	.56	12,350	220	88	31	645	1.4
6,060	70 *3.49*	25 *2.06*	79 *3.44*	3.6 *.09*	178 *2.92*	281 *5.84*	11 *.31*	.08	660	.90	10,800	278	132	38	1,010	2.1
4,200	84 *4.19*	33 *2.71*	106 *4.61*	4.3 *.11*	194 *3.18*	389 *8.09*	15 *.42*	.09	895	1.22	10,150	345	186	40	1,300	2.5
3,540 [2]	97 *4.84*	37 *3.04*	123 *5.35*	4.9 *.13*	202 *3.31*	460 *9.57*	17 *.48*	.10	1,030	1.40	9,840	394	228	40	1,480	2.7
3,180	102 *5.09*	40 *3.29*	138 *6.00*	5.1 *.13*	211 *3.46*	506 *10.52*	19 *.54*	.11	1,130	1.54	9,700	419	246	41	1,600	2.9
2,820	109 *5.44*	46 *3.78*	160 *6.96*	5.6 *.14*	219 *3.59*	575 *11.96*	21 *.59*	.12	1,240	1.69	9,440	461	282	43	1,740	3.2
2,520	125 *6.24*	50 *4.11*	172 *7.48*	5.9 *.15*	230 *3.77*	650 *13.52*	24 *.68*	.14	1,350	1.84	9,190	518	329	42	1,850	3.3
2,160 [3]	142 *7.09*	60 *4.93*	190 *8.26*	6.7 *.17*	230 *3.77*	770 *16.02*	29 *.82*	.17	1,470	2.00	8,570	601	412	40	2,000	3.4
1,580	180 *8.98*	78 *6.41*	210 *9.14*	8.5 *.22*	230 *3.77*	975 *20.28*	35 *.99*	.22	1,680	2.28	7,170	770	581	37	2,280	3.3
975	220 *10.98*	85 *6.99*	215 *9.35*	10 *.26*	230 *3.77*	1,080 *22.46*	48 *1.35*	.27	1,810	2.46	4,760	898	710	34	2,400	3.1
746	235 *11.73*	90 *7.40*	220 *9.57*	12 *.31*	230 *3.77*	1,150 *23.92*	60 *1.69*	.28	1,850	2.52	3,780	956	768	63	2,450	3.1
7,639	66 *3.29*	21 *1.73*	62 *2.70*	3.2 *.08*	162 *2.66*	233 *4.85*	8.8 *.25*	.07	547	.74	11,280	251	118	35	806	1.7
Green River at Green River, Utah																
63,430	44 *2.20*	10 *.82*	19 *.83*	1.9 *.05*	160 *2.62*	52 *1.08*	8.5 *.24*	0.07	222	0.30	38,020	151	20	21	345	0.7
56,430	44 *2.20*	10 *.82*	19 *.83*	1.9 *.05*	160 *2.62*	52 *1.08*	8.6 *.24*	.07	222	.30	33,820	151	20	21	350	.7
51,450	44 *2.20*	10 *.82*	19 *.83*	2.0 *.05*	160 *2.62*	52 *1.08*	8.6 *.24*	.07	222	.30	30,840	151	20	21	350	.7
41,720	44 *2.20*	10 *.82*	20 *.87*	2.0 *.05*	160 *2.62*	54 *1.12*	8.6 *.24*	.07	225	.31	25,350	151	20	22	350	.7
32,100	45 *2.25*	10 *.82*	21 *.91*	2.2 *.06*	160 *2.62*	59 *1.23*	8.8 *.25*	.08	230	.31	19,980	154	22	23	355	.7
25,850	45 *2.25*	11 *.90*	23 *1.00*	2.3 *.06*	160 *2.62*	64 *1.33*	9.2 *.26*	.08	240	.33	16,750	158	26	24	375	.8
20,210	45 *2.25*	11 *.90*	25 *1.09*	2.4 *.06*	160 *2.62*	69 *1.44*	10 *.28*	.08	270	.37	14,730	158	26	25	410	.9
14,800 [1]	46 *2.30*	12 *.99*	29 *1.26*	2.6 *.07*	162 *2.66*	80 *1.66*	11 *.31*	.09	326	.44	13,030	164	32	27	475	1.0
9,267	50 *2.50*	14 *1.15*	37 *1.61*	2.8 *.07*	169 *2.77*	104 *2.16*	15 *.42*	.09	430	.58	10,760	182	44	30	615	1.2
5,614	57 *2.84*	20 *1.64*	56 *2.44*	3.1 *.08*	193 *3.17*	153 *3.18*	23 *.65*	.10	570	.78	8,640	224	66	35	780	1.6
3,881	65 *3.24*	26 *2.14*	75 *3.26*	3.4 *.09*	214 *3.51*	210 *4.37*	30 *.85*	.11	655	.89	6,860	269	94	37	890	2.0
2,966 [2]	71 *3.54*	31 *2.55*	86 *3.74*	3.6 *.09*	228 *3.74*	252 *5.24*	36 *1.02*	.11	700	.95	5,610	304	118	38	945	2.1
2,439	74 *3.69*	34 *2.79*	95 *4.13*	3.8 *.10*	230 *3.77*	280 *5.82*	39 *1.10*	.11	735	1.00	4,840	324	136	39	1,000	2.3
2,091	76 *3.79*	36 *2.96*	100 *4.35*	3.9 *.10*	232 *3.80*	300 *6.24*	43 *1.21*	.12	755	1.03	4,260	338	148	39	1,030	2.4
1,793	78 *3.89*	39 *3.21*	106 *4.61*	4.0 *.10*	234 *3.84*	322 *6.70*	46 *1.30*	.12	775	1.05	3,750	355	163	39	1,050	2.4
1,424 [3]	81 *4.04*	41 *3.37*	112 *4.87*	4.2 *.11*	236 *3.87*	345 *7.18*	50 *1.41*	.12	800	1.09	3,080	370	177	39	1,100	2.5
1,006	83 *4.14*	42 *3.45*	119 *5.18*	4.5 *.12*	238 *3.90*	360 *7.49*	54 *1.52*	.13	820	1.12	2,230	380	184	40	1,130	2.7
637	85 *4.24*	43 *3.53*	122 *5.31*	5.0 *.13*	240 *3.94*	370 *7.70*	57 *1.61*	.14	850	1.16	1,460	388	192	40	1,170	2.7
462	87 *4.34*	44 *3.62*	122 *5.31*	5.4 *.14*	240 *3.94*	370 *7.70*	58 *1.64*	.14	860	1.17	1,070	398	201	40	1,170	2.7
6,292	54 *2.69*	18 *1.48*	45 *1.96*	2.8 *.07*	181 *2.97*	130 *2.70*	19 *.54*	.09	427	.58	7,260	208	80	32	608	1.4

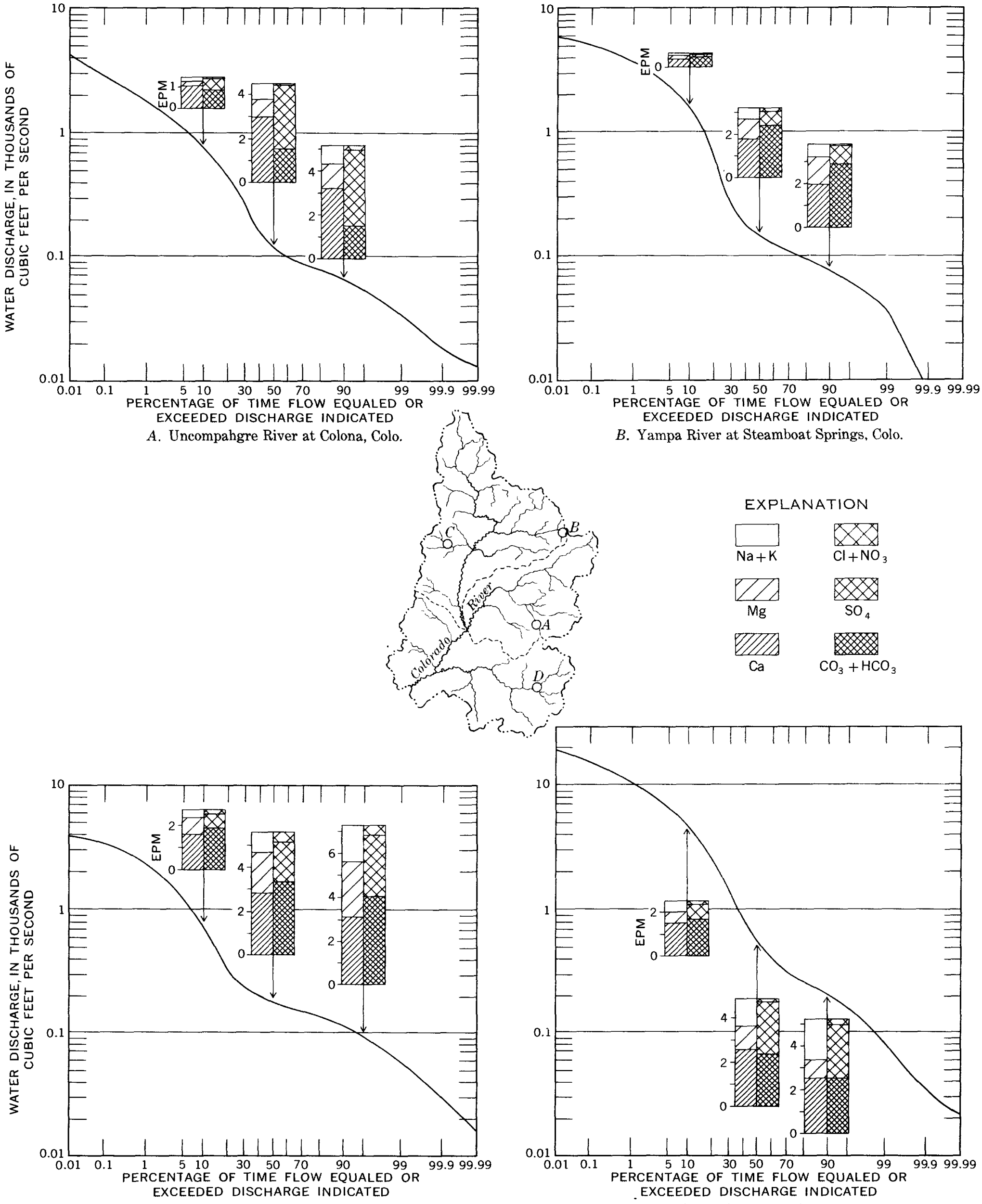
See footnotes at end of table.

TABLE 10.—*Relation between water discharge and chemical quality of water*—Continued

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italic) except as indicated; data are for the water years 1914–57 adjusted to 1957 conditions]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (sum)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
San Juan River near Bluff, Utah																
32,000	39 *1.95*	8.4 *.69*	14 *.61*	1.9 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	0.05	183	0.25	15,810	132	35	18	285	0.5
27,000	39 *1.95*	8.6 *.71*	14 *.61*	2.0 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	.05	190	.26	13,850	133	36	18	295	.5
24,000	39 *1.95*	8.6 *.71*	14 *.61*	2.0 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	.05	194	.26	12,570	133	36	18	305	.5
19,100	40 *2.00*	8.9 *.73*	14 *.61*	2.1 *.05*	118 *1.94*	64 *1.33*	3.8 *.11*	.05	203	.28	10,470	136	40	18	315	.5
14,400	41 *2.05*	9.2 *.76*	15 *.65*	2.2 *.06*	119 *1.95*	68 *1.41*	4.0 *.11*	.05	217	.30	8,440	140	43	18	340	.5
11,400	43 *2.15*	9.4 *.77*	16 *.70*	2.4 *.06*	120 *1.97*	74 *1.54*	4.2 *.12*	.05	230	.31	7,080	146	48	19	355	.6
9,200	44 *2.20*	9.8 *.81*	17 *.74*	2.5 *.06*	121 *1.98*	80 *1.66*	4.5 *.13*	.05	243	.33	6,040	150	52	19	375	.6
6,900[1]	46 *2.30*	10 *.82*	18 *.78*	2.6 *.07*	123 *2.02*	86 *1.79*	5.2 *.15*	.05	265	.36	4,940	156	55	20	410	.6
4,400	52 *2.59*	12 *.99*	22 *.96*	2.8 *.07*	130 *2.13*	112 *2.33*	6.6 *.19*	.06	308	.42	3,660	179	72	21	470	.7
2,690	64 *3.19*	14 *1.15*	33 *1.44*	3.1 *.08*	145 *2.38*	157 *3.27*	9.3 *.26*	.06	385	.52	2,800	217	98	25	590	1.0
1,810	76 *3.79*	17 *1.40*	48 *2.09*	3.4 *.09*	160 *2.62*	210 *4.37*	13 *.37*	.06	500	.68	2,440	260	128	28	750	1.3
1,240[2]	91 *4.54*	23 *1.89*	70 *3.04*	3.7 *.09*	174 *2.85*	305 *6.34*	17 *.48*	.07	660	.90	2,210	322	179	32	950	1.7
930	105 *5.24*	29 *2.38*	85 *3.70*	3.9 *.10*	182 *2.98*	375 *7.80*	22 *.62*	.08	780	1.06	1,960	381	232	32	1.100	1.9
750	113 *5.64*	33 *2.71*	94 *4.09*	4.0 *.10*	187 *3.07*	415 *8.63*	26 *.73*	.09	845	1.15	1,710	418	264	33	1,170	2.0
610	117 *5.84*	36 *2.96*	102 *4.44*	4.2 *.11*	191 *3.13*	445 *9.26*	29 *.82*	.10	900	1.22	1,480	440	284	33	1,250	2.1
440[3]	123 *6.14*	39 *3.21*	111 *4.83*	4.5 *.12*	197 *3.23*	480 *9.98*	33 *.93*	.11	960	1.31	1,140	468	306	34	1,330	2.2
240	125 *6.24*	40 *3.29*	122 *5.31*	5.1 *.13*	201 *3.30*	500 *10.40*	39 *1.10*	.12	1,050	1.43	680	476	312	35	1,450	2.4
76	128 *6.39*	42 *3.45*	130 *5.66*	6.4 *.16*	201 *3.30*	540 *11.23*	46 *1.30*	.12	1,080	1.47	222	492	327	36	1,480	2.6
20	130 *6.49*	43 *3.53*	135 *5.87*	8.2 *.21*	202 *3.31*	550 *11.44*	49 *1.38*	.12	1,100	1.50	59	501	336	36	1,500	2.6
2,800	58 *2.89*	14 *1.15*	31 *1.35*	2.8 *.07*	136 *2.23*	143 *2.97*	8.6 *.24*	.06	361	.49	2,730	202	90	25	539	.9
Colorado River at Lees Ferry, Arizona																
178,200	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	80 *1.66*	10 *.28*	0.09	250	0.34	120,300	168	46	22	405	0.7
137,300	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	80 *1.66*	11 *.31*	.09	253	.34	93,790	168	46	22	410	.7
122,200	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	81 *1.68*	11 *.31*	.09	256	.35	84,460	171	49	22	415	.7
101,500	47 *2.35*	13 *1.07*	23 *1.00*	3.5 *.09*	149 *2.44*	82 *1.71*	12 *.34*	.09	262	.36	71,800	171	49	22	425	.8
82,090	48 *2.40*	13 *1.07*	24 *1.04*	3.5 *.09*	150 *2.46*	83 *1.73*	13 *.37*	.09	270	.37	59,840	174	50	23	440	.8
69,120	49 *2.45*	13 *1.07*	26 *1.13*	3.5 *.09*	152 *2.49*	87 *1.81*	14 *.39*	.09	280	.38	52,250	176	52	24	460	.9
55,060	50 *2.50*	14 *1.15*	29 *1.26*	3.5 *.09*	154 *2.53*	95 *1.98*	16 *.45*	.09	295	.40	43,860	182	56	25	480	.9
41,660[1]	53 *2.64*	15 *1.23*	35 *1.52*	3.5 *.09*	158 *2.59*	115 *2.39*	20 *.56*	.09	322	.44	36,220	194	64	28	520	1.1
25,690	62 *3.09*	19 *1.56*	51 *2.22*	3.7 *.09*	170 *2.79*	160 *3.33*	31 *.87*	.09	420	.57	29,130	232	93	32	660	1.5
16,120	76 *3.79*	25 *2.06*	74 *3.22*	4.0 *.10*	184 *3.02*	235 *4.89*	48 *1.35*	.11	580	.79	25,240	292	142	35	890	1.9
11,280	90 *4.49*	31 *2.55*	100 *4.35*	4.8 *.12*	199 *3.26*	310 *6.45*	66 *1.86*	.14	730	.99	22,230	352	189	38	1,120	2.3
8,680[2]	103 *5.14*	37 *3.04*	122 *5.31*	5.3 *.14*	208 *3.41*	372 *7.74*	83 *2.34*	.16	860	1.17	20,150	409	238	39	1,300	2.6
7,430	112 *5.59*	40 *3.29*	135 *5.87*	5.8 *.15*	213 *3.49*	410 *8.53*	95 *2.68*	.18	935	1.27	18,760	444	270	39	1,400	2.8
6,490	118 *5.89*	44 *3.62*	145 *6.31*	6.2 *.16*	218 *3.58*	445 *9.26*	105 *2.96*	.19	990	1.35	17,350	476	296	39	1.470	2.9
5,650	125 *6.24*	48 *3.95*	150 *6.52*	6.6 *.17*	221 *3.62*	480 *9.98*	115 *3.24*	.20	1,040	1.41	15,870	510	328	39	1.550	2.9
4,580[3]	133 *6.64*	53 *4.36*	157 *6.83*	7.2 *.18*	226 *3.71*	510 *10.61*	130 *3.67*	.21	1,120	1.52	13,850	550	364	38	1,620	2.9
3,260	142 *7.09*	60 *4.93*	105 *7.18*	7.8 *.20*	230 *3.77*	550 *11.44*	145 *4.09*	.23	1,170	1.59	10,300	601	412	37	1,700	2.9
2,160	146 *7.29*	66 *5.43*	173 *7.53*	8.3 *.21*	230 *3.77*	590 *12.27*	151 *4.26*	.23	1,200	1.63	7,000	636	448	37	1,720	3.0
1,490	147 *7.34*	68 *5.59*	175 *7.61*	8.6 *.22*	230 *3.77*	600 *12.48*	156 *4.40*	.23	1,210	1.65	4,870	646	458	37	1,720	3.0
17,550	70 *3.49*	23 *1.89*	62 *2.70*	4.2 *.11*	174 *2.85*	198 *4.12*	41 *1.16*	.11	499	.68	23,660	269	126	33	772	1.6

[1] 12 percentile. [2] 50 percentile. [3] 90 percentile.



A. Uncompahgre River at Colona, Colo.

B. Yampa River at Steamboat Springs, Colo.

C. Duchesne River at Duchesne, Utah

D. San Juan River near Blanco, N. Mex.

Figure 13.—Relation of the chemical composition and concentration of dissolved solids to water discharge for streams in the headwaters of the Upper Colorado River Basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914-57 adjusted to 1957 conditions.

for streams that drain areas underlain by volcanic rocks, such as in the San Juan Mountains and on some of the high mesas where concentration of silica may at times exceed 40 ppm and usually averages more than 20 ppm.

The middle and lower reaches of the Colorado, Green, and San Juan Rivers and their principal tributaries are underlain chiefly by sedimentary rocks, which contain minerals that are more soluble than the minerals in rocks in the headwaters. For this reason and as a result of irrigation, the concentration of dissolved solids in the streams increases progressively downstream. Concurrently, the composition of the water changes from a calcium bicarbonate type to types that contain progressively greater percentages of magnesium, sodium, sulfate, and chloride. (See pl. 2). The diagrams in plate 2 show the chemical character of the streams during low flow, when the effect of geology on chemical quality is more pronounced than it is during high flow.

In general, the weighted-average concentration of dissolved-solids in streams near the mountains is less than 100 ppm; the weighted-average concentration in most main streams and their principal tributaries does not exceed about 500 ppm, except in their lower reaches; and the weighted-average concentration in only a few of the main streams and principal tributaries in their lower reaches exceeds 800 ppm. Figure 14 shows the approximate weighted-average concentration in streams at 50 sites for water years 1914–57 adjusted to 1957 conditions.

The principal natural factors affecting the dissolved-solids concentration and chemical composition of the surface water in any area seem to be the underlying rocks and soils developed therefrom and the amount of precipitation. The effect of any factor is, of course, modified by other factors, such as water use.

RELATION TO GROUND WATER

Ground-water inflow to the streams comes from ground-water reservoirs recharged by precipitation, from alluvium bordering the streams that is recharged intermittently by the stream, from thermal springs, and from ground-water return flow from irrigated lands. The quality of the ground water entering the streams greatly influences the quality of the water in the streams. During periods of low flow most of the stream water is ground-water inflow and is a mixture of all ground water entering the stream system.

Extensive ground-water reservoirs occur in the mountains where precipitation is abundant. Estimates of the amount of dissolved-solids contributed to some headwater streams by ground water are given in table 11. The estimates are based on the amount of water contributed to the streams from ground-water reservoirs and the dissolved-solids concentration of the streams during base flow. Comparison of the weighted-average concentration of dissolved solids in the ground water with the weighted-average concentration of dissolved solids in the stream shows that the ground water almost invariably has the higher concentration.

The chemical composition of water in the streams and of water in the flood plain alluvium nearby is commonly similar. Both the stream water and the water in the alluvium are usually mixtures of surface and ground water because of the interchange of water between the stream and the alluvium. The interchange may be due to the rise and fall of the stream or to the irrigation of lands along the river.

Generally, water in the alluvium contains more dissolved solids than that in the streams (pls. 2 and 3). In the middle and lower reaches of the principal streams and their tributaries, the ground-water contribution is mostly surface water that has entered the alluvium during high flow, or is return flow of irrigation. This ground water contains dissolved solids leached from the soluble minerals in the alluvium through which it has passed. Because of the concentrating effect of evapotranspiration and the solution of minerals by the water in its journey through the alluvium, the water that enters the streams from the alluvium usually has a higher dissolved-solids concentration than the water in the stream (fig. 15). Thus, the dissolved-solids concentration of the stream water is increased.

High concentrations of certain mineral constituents occur in water in the alluvium in local areas. In some arid areas water in the alluvium contains large amounts of calcium, magnesium, sodium, and sulfate. In these areas high concentrations of chloride, carbonate, and bicarbonate also may occur in the streams. In some local areas concentrations of nitrate in the ground water exceed 45 ppm. Along some of the northward-flowing tributaries in the Duchesne River basin, boron in the ground water exceeds 10 ppm. High concentrations of boron also occur in the ground water along the lower reaches of Willow Creek near Ouray, Utah.

Many thermal springs discharge along the streams. The flow of most springs is small in comparison with the flow of the streams into which they discharge; and though their concentration of dissolved solids may be high, the net effect on the quality of the stream water is small. Some springs, however discharge substantial quantities of water containing high concentrations of dissolved solids into streams and the effect on the quality of the stream water is marked. For example, computations based on the flow and dissolved-solids concentration of hot springs in the reach of the Colorado River

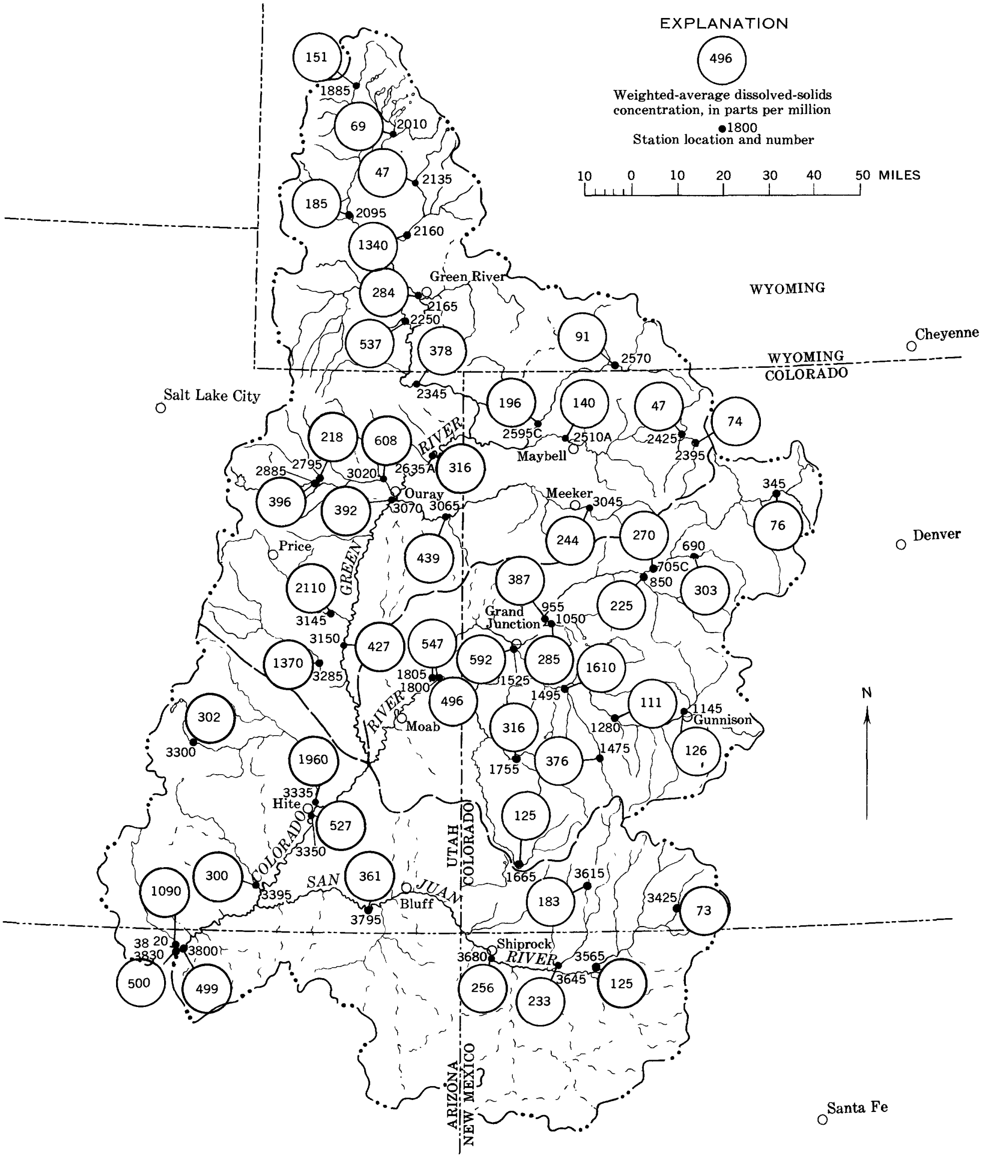


Figure 14.—Weighted-average concentration of dissolved solids at selected sites in the Upper Colorado River Basin, water years 1914–57 adjusted to 1957 conditions.

between Eagle River and the Shoshone powerplant, about 17 miles downstream, indicate that springs in this reach contribute about 182,600 tons of dissolved solids to the river annually, of which about 160,700 tons is sodium chloride. The annual water and dissolved solids contributed by all known thermal springs in the Upper Colorado River Basin is about 59,100 acre-feet and 541,600 tons, respectively. The amounts of water and

TABLE 11.—*Water and dissolved solids contributed by ground water to selected headwater streams in the Upper Colorado River Basin*

[Water and dissolved solids for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Station name	Stream water			Ground water		
		Discharge (acre-ft per yr)	Dissolved solids		Discharge (acre-ft per yr)	Dissolved solids	
			Tons per year	Weighted-average concentration (ppm)		Tons per year	Weighted-average concentration (ppm)
125	North Inlet at Grand Lake, Colo	56, 800	1, 240	16	4, 900	120	18
200	Willow Creek near Granby, Colo	50, 570	4, 380	65	9, 200	820	66
695	Gypsum Creek near Gypsum, Colo	26, 950	10, 230	279	17, 700	9, 410	391
1125	East River at Almont, Colo	243, 400	48, 580	147	56, 400	15, 700	206
1155	Tomichi Creek at Sargents, Colo	131, 100	31, 410	83	19, 000	2, 440	94
1855	Green River at Warren Bridge near Daniel, Wyo	391, 200	80, 360	151	105, 800	48, 000	187
2260	Henrys Fork near Lonetree, Wyo	31, 590	2, 500	59	7, 600	930	90
2665	Ashley Creek near Vernal, Utah	76, 790	5, 840	56	23, 300	2, 600	82
2790	Rock Creek near Mountain Home, Utah	136, 900	9, 130	49	49, 200	4, 800	72
3245	Cottonwood Creek near Orangeville, Utah	70, 200	22, 280	233	18, 300	7, 100	285
3400	San Juan River near Pagosa Springs, Colo	97, 800	10, 230	77	15, 400	2, 090	100
3610	Hermosa Creek near Hermosa, Colo	106, 500	31, 780	219	20, 400	11, 400	411

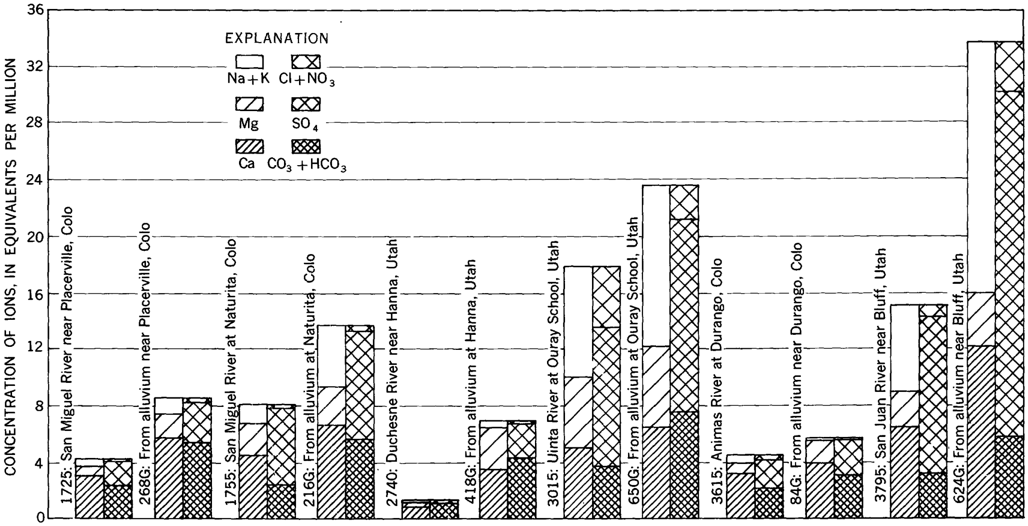


FIGURE 15.—Analyses of water from selected streams in the Upper Colorado River Basin and from the alluvium nearby.

dissolved solids contributed annually by thermal springs in the three divisions are as follows:

Division	*Water discharge (acre-feet)*	*Dissolved-solids discharge (tons)*
Grand	41, 000	482, 000
Green	15, 900	48, 600
San Juan	2, 200	11, 000
Total	59, 100	541, 600

EFFECT OF TRANSMOUNTAIN DIVERSIONS

At the end of the 1957 water year, an average of about 468,400 acre-feet of water and 37,500 tons of dissolved solids were being diverted annually out of the Upper Colorado River Basin in transmountain diversions. Of these, about 353,100 acre-feet of water and 17,800 tons of dissolved solids were being diverted from the Colorado River and its tributaries above the Gunnison River, and about 112,200 acre-feet of water and 19,300 tons of dissolved solids were being diverted from the Green division, mostly from the Strawberry and Duchesne River basins in Utah.

There may be relatively large changes in the weighted-average dissolved-solids concentration of streams whose flow is greatly depleted by transmountain diversions. For example, the transmoutain diversions from the Colorado River above Hot Sulphur Springs, Colo., have decreased the average annual water discharge from about 417,300 acre-feet in 1914 to about 176,800 acre-feet in 1957; have decreased dissolved-solids discharge from about 34,900 tons to about 18,260 tons; and have increased the weighted-average concentration from about 61 to 76 ppm. Similarly, the diversion of 102,100 acre-feet annually through Strawberry River and Duchesne River tunnels has increased the weighted-average concentration of the Duchesne River below the mouth of the Uinta River from about 533 to 608 ppm.

The net effect of all transmountain diversions on the weighted-average concentration of the Colorado River at "Lee Ferry," Ariz., however, is relatively small. The weighted-average concentration of the Colorado River at this point is about 501 ppm for the level of development in 1957. If there were no water exported out of the basin, the weighted-average concentration of the river would be 485 ppm, or 16 ppm less than that for the 1957 level of upstream development. Without transmountain diversions, the water and dissolved-solids discharge of the Colorado River at "Lee Ferry" would be about 13,201,500 acre-feet and 8,713,800 tons, respectively, if one assumes no change in stream losses. Transmountain diversion of water has increased the weighted-average concentration at "Lee Ferry" about 3.4 ppm for each 100,000 acre-feet of water diverted.

EFFECT OF THE ACTIVITIES OF MAN

Part of the water used for domestic and industrial purposes is consumed and part returns to the stream system. The water returned to streams contains dissolved solids that were added to the water during its use for domestic or industrial purposes. The effect of these uses is to decrease the amount of water that would flow down the streams under natural conditions and to increase the dissolved-solids concentration of the streams. This report presents data which show that about 100 tons of dissolved solids are added to the stream system annually by domestic and industrial uses of water for each 1,000 people in the basin.

Part of the water diverted from the streams for irrigation never returns to the stream system, but is used consumptively by evaporation from the surfaces of canals, ponded areas, and wetted ground and by transpiration of water by the crops and vegetation. In evapotranspiration only a small amount of dissolved solids is taken up and retained in the plants; most of the dissolved solids remains in the soil or in the soil solution. The dissolved solids contained in the consumed water must not be allowed to accumulate in the soil but must be flushed away; otherwise, salinity of the soil will be increased to a level that will diminish the productivity of the lands.

To maintain a favorable salt balance, some of the water applied in irrigation is used to flush, beyond the root zone, the dissolved solids that were contained in the consumed water. Part of this water may move over the ground surface and pick up additional soluble solids on its way back to the stream system. Another part of this water, together with water that seeps from the canals and laterals, moves downward through the soil and subsoil to the water table. This water, in addition to transporting its part of the dissolved solids from the consumed water, also leaches soluble minerals from the soils and rocks as it moves to and through the ground-water reservoir on its route back to the stream system.

The leaching is not confined to carrying away in solution the soluble salts that have been deposited by evapotranspiration of irrigation water or that were present in the soil before irrigation began. The leaching also picks up soluble solids that are constantly being made available by chemical weathering. In the irrigated areas, chemical weathering is greatly accelerated by moisture and by carbon dioxide from decaying vegetation.

Irrigation water in its journey through the irrigated areas picks up dissolved solids in addition to those contained in the water at points of diversion; accordingly, the return flow adds to the dissolved-solids loads already being carried by the streams. Because of the added dissolved solids and consumption of part of the diverted water, the dissolved-solids concentration of the return flows is much greater than that of the stream water; thus, the dissolved-solids concentrations of the streams are increased below the points of return flow. As irrigated lands are on terraces, benches, and flood plains, the surface runoff from the irrigated lands and water from the ground-water reservoirs under these lands are usually tributary to the same stream system from which the irrigation water is diverted.

The quantities of dissolved solids that are leached from the land by irrigation and the effect of these additional salts on the concentration of the streams to which the drainage water returns, differ greatly from place to place. In many of the headwater areas, such as the Fraser and New Fork River basins, the soils and rocks that underlie the irrigated lands are composed of relatively insoluble materials, and the amount of dissolved solids picked up by the leaching of irrigation water is relatively small (table 12). However, most of the irrigated land is in the arid and semiarid parts of the basin, where the soils and underlying rocks contain minerals that are relatively soluble. Large amounts of dissolved solids, contained in the return flow from the irrigated land in these areas, are contributed to the stream system. The dissolved-solids yield from irrigated lands, over and above the amount that would come from these lands naturally, generally ranges from 0.1 ton per acre per year in the headwater areas to 5.6 tons per acre per year in some of the interior valleys. The irrigated lands in the areas listed in table 12 comprise 41 percent of the total irrigated acreage. The amount of dissolved solids contributed by irrigation in any area depends principally on the amount of land irrigated, on the amount of water applied to the irrigated land, and on the types of soils and underlying rocks.

The data in this report show that the activities of man in the basin add about 3,480,300 tons of dissolved solids to the stream system annually (table 13). Of this amount, domestic and industrial uses of water, which consume about 22,600 acre-feet of water annually, are estimated to add about 33,600 tons of dissolved solids annually. Contribution by domestic and industrial uses is relatively small because of the sparse population and small amount of industrial development. Irrigation, which consumes about 1,769,100 acre-feet of water annually, probably contributes about 3,446,700 tons of dissolved solids to the stream system.

The average annual water and dissolved-solids discharges from the Upper Colorado River Basin for the water years 1914–57 adjusted to 1957 conditions, are about 12,733,100 acre-feet and 8,676,300 tons, respectively. If there were no activities of man, exclusive of transmountain diversions, the long-term weighted-average concentration of dissolved solids of the Colorado River at "Lee Ferry," Ariz., would be about 263 ppm. Thus, there is an increase of 238 ppm in dissolved-solids concentration (501 ppm minus 263 ppm) caused by domestic, industrial, and agricultural uses of water. This increase is equivalent to 13.3 ppm for each 100,000 acre-feet of water consumed, and is about four times that caused by the diversion of an equivalent amount of water from the basin.

TABLE 12.—*Yield rates of dissolved solids from irrigated lands in 21 areas that comprise about 41 percent of the irrigated lands in the Upper Colorado River Basin*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Area	Underlying formation	Average annual precipitation (inches)	Dissolved solids (tons per acre per yr)
Fraser River basin, Colorado	Precambrian rocks and North Park Formation.	16–25	0.1
Colorado River Basin below Granby and Willow Creek Reservoirs and above Hot Sulphur Springs, Colo., exclusive of Fraser River basin, Colorado.	Alluvium derived from Precambrian rocks, Tertiary volcanics, and Middle Park Formation.	14–16	1.0
Troublesome Creek basin, Colorado	North Park Formation	12–16	.5
Roaring Fork basin, Colorado	Permian rocks, Mancos Shale, and Mesaverde Formation.	18–25	3.0
Gunnison River basin below Gunnison tunnel and Uncompahgre River Valley below Colona, Colo.	Mostly Dakota Sandstone and Mancos Shale of Cretaceous age.	8–16	5.0
Colorado River Basin below Plateau Creek and Gunnison River and above Dolores River.	Mancos Shale	8–10	5.6
San Miguel River basin between Placerville and Naturita, Colo.	Dakota Sandstone and Morrison Formation	12–16	2.8
New Fork River basin above Boulder Creek, Wyo	Alluvium of glacial origin	12–16	.5
Fontenelle Creek basin, Wyoming	Mostly Wasatch and Green River Formations of Tertiary age.	10–16	1.3
Big Sandy Creek basin, Wyoming	Shallow alluvium underlain by Bridger Formation.	8–10	4.4
Blacks Fork basin above Muddy Creek, Wyoming	River alluvium underlain by Green River and Bridger Formations.	8–10	.9
Hams Fork above Frontier, Wyo	River alluvium underlain by Wasatch Formation.	12–16	.3
Yampa River basin between Morrison Creek and Steamboat Springs, Colorado.	Alluvium of glacial origin	25–30	.2
Elk River basin, Colorado	Mancos Shale	20–30	.4
Little Snake River basin above Dixon, Colo	River alluvium underlain by Fort Union, Lance, and Bridger Formations and Mancos Shale.	16–30	1.2
Ashley Creek basin, Utah	Alluvium underlain by Mancos Shale	8–12	2.1
Duchesne River basin above Duchesne, Utah	Uinta Formation	9–14	3.3
White River basin between Buford and Meeker, Colo	Permian rocks and Mancos Shale	19–28	4.8
San Rafael basin, Utah	Shales of Cretaceous age	8–10	3.2
La Plata River basin, Colorado	Alluvium underlain by Mesaverde Formation.	12–20	.5
La Plata River basin, New Mexico	Mesaverde Formation and Tertiary rocks	8–12	1.4

TABLE 13.—*Average annual dissolved-solids discharge and probable amounts from natural sources and the activities of man in the Upper Colorado River Basin*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Subbasins and divisions	Drainage area (sq mi)	Water discharge (acre-ft)	Acres irrigated	Dissolved-solids discharge				
				Total (tons)	Probable from natural sources		Probable from activities of man	
					Tons	Tons per sq mi	Tons	Tons per acre irrigated
Colorado River Basin above the Gunnison River	8,670	3,168,200	192,500	1,644,100	1,242,100	143	402,000	2.1
Gunnison River basin	8,020	1,884,000	269,400	1,519,000	542,000	68	977,000	3.6
Colorado River Basin between the Gunnison and Green Rivers	9,810	[1] 481,800	121,300	1,041,500	469,900	48	571,600	4.7
Total for Grand division	26,500	[1] 5,534,000	583,200	4,204,600	2,254,000	85	1,950,600	3.4
Green River basin above the Yampa River	17,000	[2] 1,645,000	258,400	967,100	646,600	38	320,500	1.2
Yampa River basin	8,000	[3] 1,602,600	73,700	405,800	343,400	43	62,400	0.8
Green River basin between the Yampa and White Rivers, including the White River basin	10,800	[4] 1,260,400	198,000	1,034,100	471,800	44	562,300	2.3
Green River basin below the White River	8,900	[5] 152,100	60,000	521,100	288,400	32	232,700	3.9
Total for Green division	44,700	[6] 4,660,100	590,100	2,928,100	1,750,200	39	1,177,900	2.0
San Juan River basin	24,900	[7] 2,028,000	206,400	[8] 1,073,000	[8] 784,900	32	288,100	1.4
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz	13,400	[9] 511,000	33,300	470,600	406,900	30	[10] 63,700	1.9
Total for San Juan division	38,300	2,539,000	239,700	1,543,600	1,191,800	31	351,800	1.5
Total for Upper Colorado River Basin	109,500	12,733,100	1,413,000	8,676,300	5,196,000	47	3,480,300	2.5

[1] Does not include runoff from 2,400 sq mi between Colorado River near Cisco, Utah, gaging station and the Green River.

[2] Does not include runoff from 1,900 sq mi in the subbasin between Green River near Greendale gaging station and the Yampa River.

[3] Does not include runoff from 800 sq mi in the subbasin between Yampa River near Maybell, Colo., and Little Snake River near Lily, Colo., gaging station and the Green River.

[4] Includes runoff from the two areas described in footnotes 2 and 3.

[5] Does not include runoff from 2,400 sq mi between Green River at Green River, Utah, and San Rafael River near Green River, Utah, gaging stations and the Colorado River.

[6] Includes runoff from the two areas described in footnotes 2 and 3 but not that described in 5.

[7] From San Juan River basin above gaging station near Bluff, Utah.

[8] Includes 17,000 tons of dissolved solids imported from the Dolores River.

[9] Includes contribution from San Juan River basin below the gaging station near Bluff, Utah, and from the areas described in footnotes 1 and 5.

[10] Includes 700 tons of dissolved solids imported in the Tropic and East Fork Canal.

FLUVIAL SEDIMENT

Water and suspended-sediment concentration and discharge at 42 sites in the Upper Colorado River Basin are given in table 14. Most of the data in the table represent the long-term average that would have occurred if the water-use developments as of 1957 had been in operation throughout water years 1914–57. The data for shorter periods are probably representative of the long-term average and 1957 conditions.

Figure 16 shows the water and suspended-sediment discharge at the sites listed in table 14, expressed as percentages of the combined water and suspended-sediment discharge of Colorado and Paria Rivers at Lees Ferry, Ariz. (outflow from the Upper Colorado River Basin). The precision of the percentages varies, and the last significant figure shown in the values presented in figure 16 may not be trustworthy for some of the stations. Of the combined sediment discharge of the Colorado and Paria Rivers (103,955,000 tons), about 20,495,000 tons (20 percent) comes from the Colorado River Basin above Green River, about 27,875,000 tons (27 percent) comes from the Green River basin, and about 55,585,000 tons (53 percent) comes from the remainder of the Upper Colorado River Basin below the mouth of the Green River. Of the amount from the basin below the Green River, about 39,840,000 tons, or 38 percent of the combined suspended-sediment of the Colorado and Paria Rivers, comes from the San Juan River basin.

Of the streams listed in table 14, the drainage basin of the San Juan River above the gaging station near Blanco, N. Mex., has the highest annual yield of suspended sediment per square mile of drainage area (2,607 tons). However, a greater annual yield was computed for the 2,332 square miles intervening above this station and below the stations on San Juan River at Rosa, N. Mex.; Los Pinos River near Bayfield, Colo.; and Spring Creek at La Boca, Colo. This computed yield is about 3,900 tons. The area involved is mostly underlain by shale, siltstone, sandstone, and conglomerate of Tertiary age.

From another intervening area, that between the stations on the Colorado River and Roaring Fork at Glenwood Springs, Colo., and the station on Colorado River near Cameo, Colo. (2,040 sq mi), about 8,475,000 tons of suspended sediment is contributed to the Colorado River annually. This amount of sediment is equivalent to a yield of about 4,200 tons per square mile per year. Most of the drainage area south of the river is underlain by the Wasatch Formation of Tertiary age. This formation also crops out in part of the area north of the river, where a large area of the

Green River Formation is also exposed. Other units exposed on the north side of the river are the Mesaverde Formation, Mancos Shale, Dakota Sandstone, Morrison Formation, and rocks of Permian and Mississippian ages. Most of the rocks are siltstone, sandstone, and shale and are relatively soft and erodible. The high sediment yield is caused by the erodible rocks, which occur at all altitudes in this area of rugged relief where precipitation is as much as 30 inches annually.

Similar rocks underlie large areas in the interior of the basin. If these interior areas were less arid, the

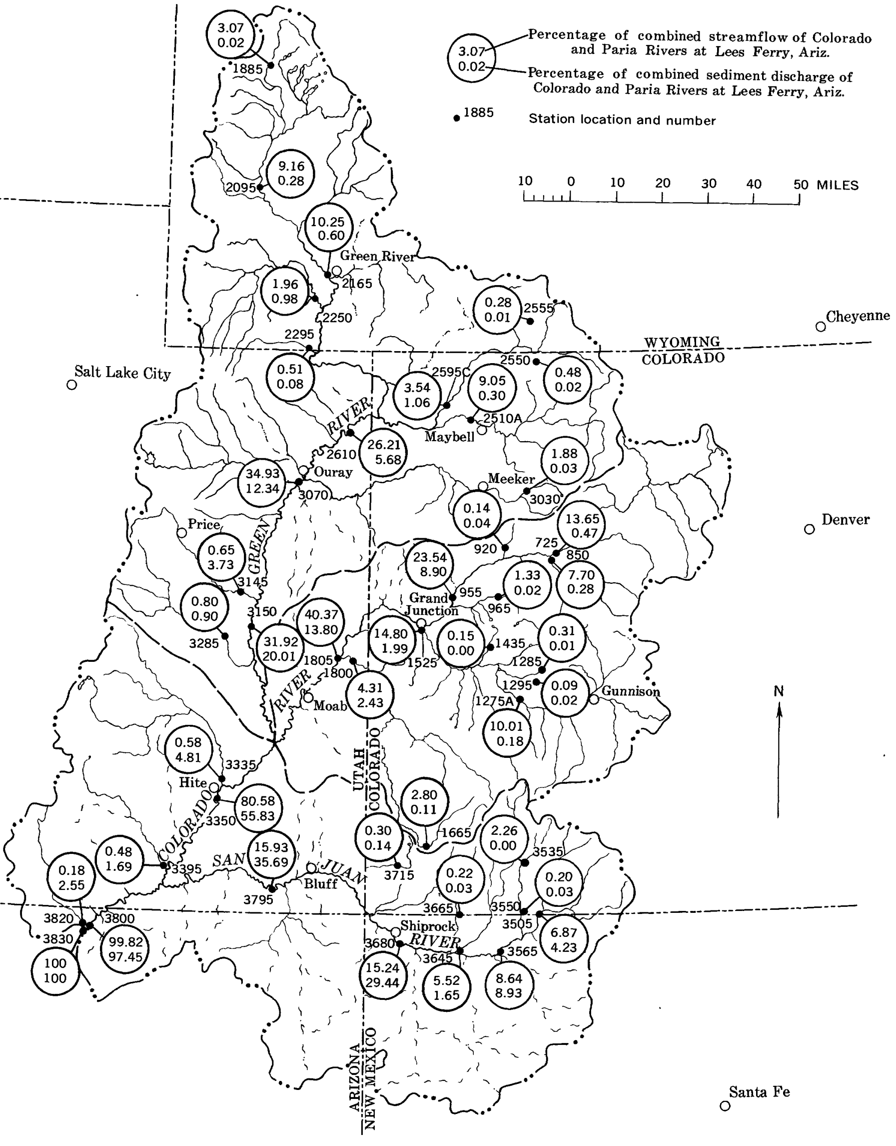


FIGURE 16.—Approximate water and suspended-sediment discharge expressed as percentages of the combined streamflow and combined suspended-sediment discharge of the Colorado and Paria Rivers at Lees Ferry, Ariz.

TABLE 14.—*Water and suspended-sediment discharge at gaging stations in the Upper Colorado River Basin*

[Discharges for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Station name	Average annual water discharge (acre-ft)	Suspended sediment		
			Weighted-average concentration (ppm)	Discharge	
				Tons per year	Tons per sq mi per year
725	Colorado River at Glenwood Springs, Colo	1, 738, 000	200	485, 800	107
850	Roaring Fork at Glenwood Springs, Colo	980, 200	220	287, 100	197
920	Rifle Creek near Rifle, Colo.[1]	17, 800	1, 800	43, 500	311
955	Colorado River near Cameo, Colo	2, 998, 000	2, 300	9, 248, 000	1, 150
965	Plateau Creek near Cameo, Colo	170, 200	180	19, 000	216
1275A	Gunnison River above Gunnison tunnel, Colo	1, 281, 000	105	183, 000	46
1285	Smith Fork near Crawford, Colo	39, 600	224	12, 000	287
1295	Iron Creek near Crawford, Colo.[2]	12, 200	986	16, 400	245
1435	Surface Creek near Cedaredge, Colo.[3]	19, 600	112	3, 000	70
1525	Gunnison River near Grand Junction, Colo	1, 884, 000	806	2, 067, 000	258
1665	Dolores River at Dolores, Colo	356, 400	245	119, 100	214
1800	Dolores River near Cisco, Utah [4]	549, 900	3, 370	2, 524, 000	545
1805	Colorado River near Cisco, Utah [5]	5, 141, 000	2, 050	14, 351, 000	595
1885	Green River at Warren Bridge, near Daniel, Wyo	391, 200	36	19, 000	41
2095	Green River near Fontenelle, Wyo	1, 166, 000	180	292, 000	74
2165	Green River at Green River, Wyo	1, 305, 000	350	625, 000	81
2250	Blacks Fork near Green River, Wyo.[6]	249, 900	3, 000	1, 020, 000	278
2295	Henrys Fork at Linwood, Utah	65, 800	960	85, 800	162
2510A	Yampa River at bridge on county road, near Maybell, Colo	1, 152, 000	196	308, 000	90
2550	Slater Fork near Slater, Colo	60, 800	212	17, 500	109
2555	Savery Creek at upper station, near Savery, Wyo	36, 800	146	7, 300	39
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	450, 600	1, 790	1, 099, 000	295
2610	Green River near Jensen, Utah	3, 333, 000	1, 300	5, 902, 000	226
3030	White River at Buford, Colo	239, 800	102	33, 200	131
3070	Green River near Ouray, Utah [7]	4, 448, 000	2, 120	12, 824, 000	361
3145	Price River at Woodside, Utah	84, 000	33, 900	3, 879, 000	2, 586
3150	Green River at Green River, Utah [5]	4, 067, 000	3, 760	20, 800, 000	512
3285	San Rafael River near Green River, Utah	102, 100	6, 700	931, 000	551
3335	Dirty Devil River near Hite, Utah [8]	73, 900	50, 200	5, 000, 000	1, 147
3350	Colorado River at Hite, Utah	10, 260, 000	4, 000	55, 960, 000	731
3395	Escalante River at mouth, near Escalante, Utah [9]	61, 700	20, 900	1, 757, 000	874
3505	San Juan at Rosa, N. Mex	875, 100	3, 800	4, 400, 000	2, 211
3535	Los Pinos River near Bayfield, Colo	287, 600	5	1, 800	6
3550	Spring Creek at La Boca, Colo	25, 600	940	32, 000	552
3565	San Juan River near Blanco, N. Mex	1, 100, 000	6, 400	9, 280, 000	2, 607
3645	Animas River at Farmington, N. Mex	703, 500	1, 800	1, 720, 000	1, 263
3665	La Plata River at Colorado-New Mexico State line	27, 900	740	28, 000	85
3680	San Juan River at Shiprock, N. Mex	1, 941, 000	11, 600	30, 600, 000	2, 372
3715	McElmo Creek near Cortez, Colo	38, 800	2, 600	141, 000	605
3795	San Juan River near Bluff, Utah	2, 028, 000	13, 500	37, 100, 000	1, 613
3800	Colorado River at Lees Ferry, Ariz	12, 710, 000	5, 800	101, 300, 000	939
3820	Paria River at Lees Ferry, Ariz	23, 100	84, 400	2, 655, 000	1, 691

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[1] For water years 1940–46, 1953–57.
[2] For water years 1948–52.
[3] For water years 1918–57.
[4] For water years 1952–57.
[5] For water years 1930–57.
[6] For water years 1948–57.
[7] For Dec. 1, 1950 to Sept. 30, 1955, and Nov. 1, 1955, to Sept. 30, 1957.
[8] For water years 1914–57.
[9] For water years 1951–55.

sediment yield to the Colorado River would be much higher.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

Concentration of dissolved minerals in water is a criteria used for judging the suitability of water for domestic use. The criteria sets specific maximum limits for concentration of total dissolved solids and concentration of specific constituents such as iron, manganese, chloride, fluoride, nitrate, and sulfate.

The waters of most perennial streams, near their headwaters, have less than the maximum specified concentrations of dissolved solids and are suitable for domestic use. After the streams leave the mountains, the waters of some streams become unsuitable for domestic use during periods of low flow, principally because of high concentrations of total dissolved-solids or high concentrations of one or more of the chloride, nitrate, and sulfate ions. Some streams, however, are not suitable for domestic use even during times of high flow.

On the basis of maximum total dissolved-solids concentration (limit 500 ppm), streams listed in table 7 whose waters have weighted-average concentrations of 500 ppm or more would be suitable for domestic use no more than 30 percent of the time.

Table 10 indicates that the total dissolved-solids limit is exceeded in Colorado River near Cisco, Utah, when the water discharge is less than about 9,000 cfs (cubic feet per second). Sulfate concentration also exceeds the limit (250 ppm) at about the same discharge.

Table 10 indicates that the total dissolved-solids limit is exceeded in Green River at Green River, Utah, when the water discharge is less than about 7,000 cfs. The sulfate concentration exceeds the limit for discharges less than about 3,000 cfs.

Table 10 indicates that the total dissolved solids in San Juan River near Bluff, Utah, exceeds the limit when the discharge is less than about 1,800 cfs. The sulfate limit is exceeded when discharge is less than about 1,500 cfs.

Table 10 indicates that the total dissolved solids in Colorado River at Lees Ferry, Ariz., exceeds the limit when discharge is less than about 21,500 cfs. The sulfate limit is exceeded when the discharge drops below about 15,000 cfs.

The waters of the perennial streams in their headwaters are usually soft but become progressively harder with increasing distance from the mountains. Beyond the mountains, softening of the surface waters would be desirable for most uses and almost mandatory for some uses.

The monthly weighted-average concentration of nitrate has been as much as 40 ppm in Colorado River near Cisco, Utah, and as much as 61 ppm in Dolores River near Cisco, Utah. Though nitrate is present in all streams, it is usually not in sufficient concentrations to constitute a hazard for domestic use except locally during low flows.

Some of the surface water, whose source is principally springs, such as Steamboat Springs, Colo., contains flouride in amounts sufficient to cause mottling of children's teeth if used continuously for drinking and cooking.

AGRICULTURAL USE

Agricultural use of water in the Upper Colorado River Basin includes among other uses watering livestock and irrigation. A high concentration of dissolved solids and of certain ions in the water may cause the water to be unsuitable for these purposes.

Sheep and cattle are the main livestock in the basin. They apparently have the ability to tolerate relatively high concentrations of dissolved solids in their drinking water, although low concentrations of certain constituents, such as selenium, are toxic. Most of the surface water is suitable for watering livestock.

Data indicating the suitability of water for irrigation at the 50 sites listed in table 7 and shown in figure 8 are given in table 15. Methods proposed by Wilcox, Blair, and Bower (1954, p. 259–266), U.S. Salinity Laboratory Staff (1954), and Eaton (1954) were used to compute the data. The classifications are based entirely on chemical analyses of water at high, medium, and low discharges. Not taken into account are minerals that may be present in the soils irrigated, irrigation practices, and other factors that may significantly change a water-usability classification based only on chemical analyses of applied water.

Terms in the box heads of table 15 are those proposed for the classification of water for irrigation in the cited references. In the classification of water discharges, high flows are those greater than the flow exceeded 20 percent of the time; low flows are those less than the flow exceeded 80 percent of the time; and medium flows are those greater than the flow exceeded 80 percent of the time but less than the flow exceeded 20 percent of the time.

Of the streams listed in table 15, residual sodium carbonate exceeded 1.25 equivalents per million only in Strawberry River at Duchesne, Utah. This concentration is considered to be the lower limit for waters marginal for irrigation. Mixing of Strawberry River water with Duchesne River water a short distance downstream should result in a water much lower in residual sodium carbonate. A few other streams investigated also exceeded the limit for residual sodium carbonate, but these were in areas where the water is not used for irrigation.

As indicated in the table, most sources of water supply serving irrigated lands range from C1–S1 to C3–S1. According to the U.S. Salinity Laboratory Staff (1954), waters in the C1 category can be used for irrigation of most crops on most soils with little likelihood that soil salinity will occur, and waters in the C3 category cannot be used on soils with restricted drainage. The S1 category implies that the water can be used for irrigation on almost all soils with little danger of the occurrence of harmful levels of exchangeable sodium. Water in the poorer quality categories, for the most part, occurs in the lower reaches of the streams below irrigated lands and in canyon areas where the water is not used for irrigation.

The degree of leaching required for good crop yields as computed for the sources of water supply that serve irrigated lands is generally low, and probably higher percentages of applied water actually pass through most irrigated soils than are indicated in table 15. Waters in downstream reaches of some streams have high required leaching percentages. These waters, for the most part, are in tributary streams below the points that water is diverted for irrigation. As the

TABLE 15.—*Suitability of surface water for irrigation in the Upper Colorado River Basin*

[Calcium *a*, to adjust water to 70 percent sodium; calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954) [1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
345	Colorado River at Hot Sulphur Springs, Colo.	10-56	53.6	Low	167	19	0.4	0.22	C1-S1	−1.29	1.66	0.30	1.2	157
		6-57	2,111	High	81	21	.3	.08		−.52	.67	.30	.7	105
		8-57	174	Medium	153	19	.4	.21		−1.09	1.43	.30	1.1	150
690	Eagle River at Gypsum, Colo.	1-49	192	Low	1,170	30	1.8	.00	C3-S1	−6.76	2.44	.24	19	0
		4-49	405	Medium	537	19	.7	.00	C2-S1	−3.89	1.95	.28	5.9	0
		6-49	2,829	High	213	14	.3	.00	C1-S1	−1.65	1.21	.30	1.4	0
705C	Colorado River near Glenwood Springs, Colo.	3-57	825	Low	808	42	2.3	.00	C3-S1	−3.16	2.06	.26	12	0
		6-57	14,020	High	238	16	.4	.00	C1-S1	−1.79	1.51	.30	1.3	5
		9-57	1,485	Medium	664	37	1.7	.00	C2-S1	−3.04	2.03	.27	9.0	0
850	Roaring Fork at Glenwood Springs, Colo.	9-15-54	610	Medium	654	9	.3	.00		−5.60	2.96	.28	5.4	0
		10-18-55	365	Low	794	21	1.0	.00	C3-S1	−5.92	3.11	.27	8.4	0
		6-3-58	8,250	High	171			.00	C1-S1	−1.50	1.11	.30	.8	0
955	Colorado River near Cameo, Colo.	10-55	1,476	Low	1,260	51	3.7	.00	C3-S1	−3.28	2.24	.23	23	0
		6-56	10,700	High	377	33	1.1	.00	C2-S1	−1.98	1.54	.29	4.1	0
		7-56	2,810	Medium	863	44	2.4	.00	C3-S1	−3.12	2.11	.26	13	0
1050	Plateau Creek near Cameo, Colo.	9-17-47	88	Medium	833	37	2.0	.38		−4.52	6.11	.29	7.0	440
		11-11-50	35	Low	936	38	2.3	.35		−4.94	6.70	.28	8.2	477
		5-7-58	1,490	High	303			.10	C2-S1	−2.62	2.89	.30	1.1	133
1145	Gunnison River near Gunnison, Colo.	10-8-45	342	Medium	271	7	.2	.00		−2.66	2.47	.30	1.3	26
		5-7-58	2,100	High	166			.00	C1-S1	−1.44	1.33	.30	.8	44
1280	Gunnison River below Gunnison tunnel, Colo.	10-30-57	570	Medium	256	13	.3	.00	C2-S1	−2.15	1.93	.30	1.1	19
		5-29-58	12,500	High	122			.00	C1-S1	−1.04	1.03	.30	.7	68
1475	Uncompahgre River at Colona, Colo.	5-28-58	2,150	High	273			.00	C2-S1	−2.32	1.63	.30	1.5	0
		8-7-58	193	Medium	781	16	.7	.00	C3-S1	−6.94	2.83	.28	8.2	0
1495	Uncompahgre River at Delta, Colo.	4-22-58	1,090	High	782	27	1.3	.00		−5.41	2.96	.28	7.8	0
		8-8-58	119	Medium	2,340	30	2.8	.00	C4-S1	−17.62	2.41	.15	49	0
1525	Gunnison River near Grand Junction, Colo.	9-56	341	Low	2,520	32	3.2	.00		−17.43	1.43	.12	60	0
		2-57	986	Medium	1,550	33	2.5	.00	C3-S1	−9.55	2.77	.23	24	0
		6-57	19,630	High	360	18	.5	.00	C2-S1	−2.70	2.07	.29	2.3	0
1665	Dolores River at Dolores, Colo.	5-16-41	4,080	High	234	12	.3	.00	C1-S1	−1.81	1.52	.30	.4	2
		11-15-56	25	Low	476	19	.7	.00	C2-S1	−3.40	1.34	.28	5.4	0
		4-8-57	100	Medium	421	19	.6	.00		−2.98	1.76	.29	4.1	0
1755	San Miguel River at Naturita, Colo.	10-24-57	287	Medium	702	16	.7	.00		−6.02	2.54	.28	7.2	0
		5-8-58	3,000	High	318			.00		−2.97	2.33	.30	1.3	0
		8-7-58	86		730	17	.7	.00		−6.12	2.27	.28	7.8	0
1800	Dolores River near Cisco, Utah	3-18-32	450	Medium		51	4.3	.00		−4.29	2.11	.20	35	0
		5-21-32	5,600	High		20	.6	.00		−2.68	2.22	.29	2.5	0
		10-22-32	86	Low		71	15	.00					100	
1805	Colorado River near Cisco, Utah.	9-56	1,369	Low	2,350	37	3.5	.00	C4-S1	−12.91	1.39	.13	58	0
		2-57	3,018	Medium	1,720	46	3.8	.00	C3-S1	−6.27	2.13	.20	33	0
		6-57	48,040	High	360	19	.6	.00	C2-S1	−2.58	2.02	.29	2.4	0
1885	Green River at Warren Bridge, near Daniel, Wyo.	10-3-39	246	Medium		4	.1	.00		−3.54	1.45	.29	2.7	0
		5-15-58	1,040	High	294			.00	C2-S1	−2.90	2.00	.30	1.4	0
2010	New Fork River near Boulder, Wyo.	8-26-39	130	Medium		14	.3	.00	C1-S1	−1.80	1.86	.30	.8	84
		5-15-58	525	High	103			.09		−.80	.97	.30	.8	110
2095	Green River near Fontenelle, Wyo.	5-14-58	3,970	High	317			.00	C2-S1	−2.68	2.48	.30	1.3	23
		8-4-58	1,080	Medium	326			.00		−2.59	2.55	.30	1.7	61
2135	Big Sandy Creek near Farson, Wyo.	1-7-57	5.0	Low	156	29	.6	.03	C1-S1	−.80	1.00	.30	1.2	117
		4-1-57	40	Medium	158	35	.8	.00		−.72	.85	.30	1.4	101
		7-1-57	835	High	65	29	.4	.00		−.35	.42	.30	.8	87
2160	Big Sandy Creek below Eden, Wyo.	11-18-57	35	Medium	3,130	50	6.1	.00	C4-S2	−10.69	.49	.05	84	0
		1-27-58	6	Low	3,560	42	5.3	.00					100	
		6-2-58	296	High	533	46	2.0	.00	C2-S1	−1.75	1.32	.28	5.4	0
2165	Green River at Green River, Wyo.	12-54	288	Low	927	32	1.7	.00	C3-S1	−5.58	3.75	.27	8.9	0
		3-57	928	Medium	731	34	1.7	.00	C2-S1	−4.07	2.91	.28	6.8	0
		6-57	8,007	High	326	18	.5	.00		−2.46	2.39	.30	1.8	54
2250	Blacks Fork near Green River, Wyo.	5-52	3,082	High	579	32	1.4	.00		−3.25	3.28	.29	4.8	75
		2-53	117	Medium	1,360	42	3.0	.00	C3-S1	−5.96	3.77	.24	19	0
		9-53	2.5	Low	2,070	60	6.5	.00	C3-S2	−3.23	2.33	.19	38	0
2345	Green River near Greendale, Utah.	12-56	416	Low	945	32	1.8	.00	C3-S1	−5.62	3.54	.27	9.8	0
		3-57	1,069	Medium	795	33	1.7	.00		−4.54	3.49	.28	7.4	0
		6-57	11,420	High	420	25	.9	.00	C2-S1	−2.79	2.55	.29	2.8	12
2395	Yampa River at Steamboat Springs, Colo.	6-3-50	2,210	High	67			.00	C1-S1	−.56	.48	.30	.5	51
		11-9-50	117	Medium	270			.00	C2-S1	−2.44	2.36	.30	1.4	51
		10-20-55	67	Low	308	16	.5	.00		−2.45	2.48	.30	1.6	77
2425	Elk River near Trull, Colo.	6-3-50	2,000	High	59			.03	C1-S1	−.42	.51	.30	.6	91
		10-20-55	50	Low	184	12	.2	.00		−1.36	1.33	.30	.9	63
		8-7-58	88	Medium	113			.00		−.89	.92	.30	.7	77
2510A	Yampa River at bridge on county road, near Maybell, Colo.	10-56	126	Low	629	41	1.9	.00	C2-S1	−2.62	3.14	.28	6.8	187
		3-57	467	Medium	549	35	1.5	.00		−2.82	2.71	.29	4.8	42
		6-57	11,430	High	173	16	.3	.00	C1-S1	−1.30	1.30	.30	1.0	70
2570	Little Snake River near Dixon, Wyo.	10-23-57	110	Medium	266	18	.5	.00	C2-S1	−2.11	2.28	.30	1.4	110
		5-20-58	4,400	High	109			.00	C1-S1	−.93	.92	.30	.6	68
		8-13-58	2.7	Low	460	32	1.2	.26	C2-S1	−2.67	3.55	.29	3.5	274
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo.	10-56	7.2	Low	1,320	64	5.6	.00	C3-S2	−1.13	3.28	.25	22	562
		6-57	3,632	High	205	21	.5	.10	C1-S1	−1.42	1.70	.30	1.3	136
		8-57	129	Medium	642	51	2.7	.25	C2-S1	−1.75	3.30	.28	7.8	428
2610	Green River near Jensen, Utah.	9-48	726	Low	900	39	2.2	.00	C3-S1	−4.17	3.04	.27	10	0
		2-57	1,838	Medium	980	37	2.2	.00		−5.16	3.63	.27	11	0
		6-57	32,180	High	420	24	.8	.00	C2-S1	−2.90	2.73	.29	2.7	28
2795	Duchesne River at Duchesne, Utah.	10-19-55	83	Low	607	19	.8	.00		−4.91	3.77	.29	4.1	0
		5-23-58	2,150	High	198			.00	C1-S1	−1.83	1.60	.30	.7	16
		8-22-58	121	Medium	779	24	1.2	.00	C3-S1	−5.79	3.82	.28	7.0	0
2885	Strawberry River at Duchesne, Utah.	9-29-48	38	Low	812	39	2.2	.83		−4.15	6.28	.29	8.0	566
		10-22-57	96	Medium	820	43	2.4	1.32		−3.52	6.24	.29	8.5	704
		5-23-58	1,000	High	459	21	.8	.23	C2-S1	−3.53	4.18	.30	2.5	222

TABLE 15.—*Suitability of surface water for irrigation in the Upper Colorado River Basin*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
3020	Duchesne River near Randlett, Utah.	1-51	425	Medium	1,100	37	2.3	.00	C3-S1	−5.84	4.07	.26	13	0
		10-56	70.3	Low	2,100	47	4.5	.00	C3-S2	−8.06	3.27	.18	40	0
		6-57	3,095	High	492	29	1.1	.00	C2-S1	−2.95	2.47	.29	3.9	0
3045	White River near Meeker, Colo.	5-8-58	1,860	High	367	--------	--------	.00		−2.56	2.10	.29	2.9	0
		8-4-58	361	Medium	446	--------	--------	.00		−3.98	2.66	.29	2.9	0
3065	White River near Watson, Utah.	9-56	217	Low	997	38	2.2	.00	C3-S1	−4.59	2.99	.26	13	0
		3-57	497	Medium	1,110	43	2.8	.00		−4.57	3.63	.26	14	0
		6-57	3,661	High	545	23	.9	.00	C2-S1	−3.53	3.32	.29	3.4	19
3070	Green River near Ouray, Utah.	9-52	2,787	Medium	870	38	2.1	.00	C3-S1	−4.37	3.19	.27	10	0
		1-57	1,350	Low	962	35	2.0	.00		−5.26	3.74	.27	11	0
		6-57	32,180	High	420	24	.8	.00	C2-S1	−2.90	2.73	.29	2.7	28
3145	Price River at Woodside, Utah.	9-56	8.33	Low	5,600	51	9.1	.00	C4-S3	--------	--------	--------	100	--------
		3-57	43.6	Medium	5,360	52	8.9	.00		--------	--------	--------	100	--------
		8-57	478	High	3,280	45	5.5	.00	C4-S2	−14.87	.35	.02	92	0
3150	Green River at Green River, Utah.	10-56	1,243	Low	1,040	42	2.6	.00	C3-S1	−4.50	2.99	.26	13	0
		3-57	3,846	Medium	980	44	2.7	.00		−3.80	2.96	.27	12	0
		6-57	31,440	High	393	25	.8	.00	C2-S1	−2.55	2.37	.29	2.6	26
3285	San Rafael River near Green River, Utah.	10-56	.85	Low	5,200	45	7.3	.00	C4-S3	--------	--------	--------	100	--------
		2-57	65.7	Medium	3,070	44	5.2	.00	C4-S2	−14.28	1.11	.07	78	0
		6-57	1,588	High	854	27	1.4	.00	C3-S1	−5.65	3.28	.27	8.3	0
3300	Fremont River near Bicknell, Utah.	8-31-49	78	Medium	500	15	.5	.00	C2-S1	−3.70	2.51	.29	3.7	0
		10-22-57	111	High	858	16	.7	.00	C3-S1	−7.33	2.90	.27	9.4	0
		5-23-58	45	Low	433	--------	--------	.00	C2-S1	−3.43	2.36	.29	3.2	0
3335	Dirty Devil River near Hite, Utah.	11-53	106	Medium	2,130	26	2.2	.00	C3-S1	−15.92	1.46	.15	50	0
		6-54	.12	Low	7,590	46	8.6	.00	C4-S3	--------	--------	--------	100	--------
		4-26-58	405	High	1,490	17	1.1	.00	C3-S1	−13.63	1.53	.22	27	0
3350	Colorado River at Hite, Utah	9-56	2,697	Low	1,620	38	3.0	.00		−8.11	2.26	.21	30	0
		3-57	6,774	Medium	1,360	44	3.2	.00		−5.30	2.64	.24	22	0
		6-57	80,100	High	407	24	.8	.00	C2-S1	−2.64	2.19	.29	2.9	0
3395	Escalante River at mouth, near Escalante, Utah.	7-51	17.1	Low	670	25	1.1	.00		−4.19	2.70	.28	7.0	0
		10-51	69.4	Medium	561	19	.7	.00		−4.27	2.80	.29	4.9	0
		5-52	158	High	379	17	.5	.00		−3.08	2.48	.29	2.5	0
3425	San Juan River at Pagosa Springs, Colo.	5-29-58	2,550	High	67	--------	--------	.04	C1-S1	−.38	.51	.30	.7	101
		8-8-58	68	Medium	185	32	.8	.00		−1.05	1.27	.30	1.5	122
3565	San Jnan River near Blanco, N. Mex.	6-52	7,241	High	136	16	.3	.00		−1.09	1.04	.30	.9	59
		3-53	609	Medium	459	26	1.0	.00	C2-S1	−3.05	2.21	.29	3.7	0
		1-54	177	Low	534	36	1.5	.00		−2.58	2.56	.29	12	63
3615	Animas River at Durango, Colo.	10-23-57	409	Medium	431	--------	--------	.00		−3.67	2.06	.29	3.4	0
		5-19-58	4,500	High	204	--------	--------	.00	C1-S1	−1.79	1.38	.30	1.0	0
3645	Animas River at Farmington, N. Mex.	10-56	87	Low	1,140	29	1.8	.00	C3-S1	−7.24	3.28	.26	14	0
		3-57	300	Medium	894	29	1.5	.00		−6.67	2.88	.27	10	0
		6-57	6,077	High	226	10	.2	.00	C1-S1	−1.87	1.32	.30	1.3	0
3680	San Juan River at Shiprock, N. Mex.	9-45	358	Low	978	42	2.6	.00	C3-S1	−4.15	2.54	.27	12	0
		7-57	8,869	High	318	31	.9	.00	C2-S1	−1.84	1.78	.29	2.4	54
		9-57	2,012	Medium	516	36	1.5	.00		−2.64	2.26	.29	4.3	0
3795	San Juan River near Bluff, Utah.	9-56	64.5	Low	1,470	45	3.4	.00	C3-S1	−5.66	1.88	.23	23	0
		3-57	1,150	Medium	996	32	1.8	.00		−5.88	2.63	.26	12	0
		6-57	13,220	High	318	21	.6	.00	C2-S1	−2.16	1.72	.29	2.0	0
3800	Colorado River at Lees Ferry, Ariz.	10-56	3,034	Low	1,830	38	3.1	.00	C3-S1	−9.44	2.10	.19	36	0
		3-57	8,108	Medium	1,340	42	2.9	.00		−5.73	2.88	.24	20	0
		6-57	94,860	High	452	21	.7	.00	C2-S1	−3.26	2.64	.29	3.1	0
3820	Paria River at Lees Ferry, Ariz.	7-15-48	4.2	Low	556	26	1.0	.00		−3.61	1.82	.28	5.4	0
		12-1-48	14	Medium	1,080	30	1.7	.00	C3-S1	−6.99	2.77	.26	13	0
		3-1-49	137	High	1,440	42	3.2	.00		−6.75	2.75	24	21	0

[1] For good yield.

flow of the tributaries is small compared to that of the main stream, the required leaching percentage of mainstream water is not materially increased by inflow from the tributaries.

The amounts of gypsum required (table 15) for good crop yields are based on the assumption that all calcium required to adjust the sodium percentage to 70, to offset bicarbonate precipitation, and to supply the calcium needs of the plants must come from the irrigation water. This may not be applicable to all irrigated lands in the Upper Colorado River Basin, as most soils are gypsiferous and the addition of gypsum is not necessary for good crop yields.

INDUSTRIAL USE

The water of headwater streams can be used in many industrial applications without treatment. Most of the water in the middle and lower reaches of the streams cannot be used for many industrial applications without treatment, and the water in the streams near most of the larger towns and cities would require extensive treatment. Most of the surface water could be used without treatment by mining industries and for certain phases of metal fabrication, where the tolerances of dissolved solids are high.

RECREATIONAL USE

Most streams are suitable for recreation. The few exceptions include tributary streams during periods of low flow or when suspended-sediment concentrations are exceedingly high. Specifically, the dissolved-solids concentrations in the lower reaches of Blacks Fork and the Duchesne, Price, San Rafael, and San Miguel Rivers and in several smaller streams are intermittently high enough to be objectionable for some recreational uses and to be detrimental to aquatic life.

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Hydrologic Techniques and Criteria Used in Appraising the Surface-Water Resources

By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

WATER RESOURCES OF THE UPPER COLORADO RIVER BASIN—TECHNICAL REPORT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 441-B

Summary of available data and explanation of techniques and criteria used in appraising the water resources of the Upper Colorado River Basin

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GLOSSARY

Acre-foot is a unit for measuring volume and is equal to the quantity of water or other material required to cover 1 acre to a depth of 1 foot or a volume of 43,560 cubic feet.

Average annual precipitation is an average of the yearly precipitation usually expressed in inches of water that falls or is computed to fall at a point or on an area during a specified number of calendar or water years.

Base flow is sustained or fair-weather streamflow. In most streams, base flow is composed largely of ground-water effluent.

Chemical-quality station is a particular site on a stream, canal, lake, or reservoir where water samples are collected on a systematic basis for chemical study.

Chemical quality of water is a term that embodies all the chemical and physical properties or attributes of water which are imparted to the water by the amounts and kinds of chemical constituents in colloidal suspension or dissolved in the water.

Coefficient of variation is the ratio of the standard deviation to the average of an array of data.

Concentration is a term used to describe the amounts of a material or substance in relation to the total mixture. In this report concentration is expressed in parts per million and in equivalents per million.

Consumptive use is the quantity of water discharged to the atmosphere or incorporated in the products of the process in connection with domestic use, vegetative growth, food processing, or an industrial process.

Cubic feet per second (cfs) is a unit expressing rates of discharge, and is equal to the discharge through a rectangular cross section, 1 foot wide and 1 foot deep, flowing at an average velocity of 1 foot per second.

Direct runoff is the water from rainfall or melting snow that enters the stream system rapidly either as overland flow or as subsurface flow that does not reach the zone of saturation and whose time spent underground is so brief that its rate of movement into the stream is almost as rapid as overland flow.

Dissolved solids are solids that originate mostly from rocks and are in solution. Some colloidal material is treated as if it were in solution in determining dissolved solids.

Dissolved-solids discharge is (1) the rate at which dry weight of dissolved solids passes a section of a stream or other conveyance channel or (2) the quantity of dissolved solids, measured by dry weight or by volume, that is discharged in a given time.

Dissolved-solids yield. *See* **Tons per square mile per year.**

Duration curve is a cumulative frequency curve that shows the percentage of time that specified water, dissolved-solids, or sediment discharges, or dissolved-solids concentration are equaled or exceeded. A duration curve of water discharge is called a flow-duration curve.

Equivalents per million (epm) is a unit for expressing the concentration of chemical constituents in terms of the electrically charged particles, or ions, in solution. One equivalent per million of a positively charged ion (cation) will react with 1 equivalent per million of a negatively charged ion (anion). Parts per million are converted to equivalents per million by multiplying the reciprocal of the combining weight of the ion. The reciprocals for the more common constituents (ions) are given in the following table:

Cations	*Factor*	*Anions*	*Factor*
Calcium (Ca^{++})	0. 0499	Carbonate (CO_3^{--})	0. 0333
Magnesium (Mg^{++})	. 0823	Bicarbonate (HCO_3^-)	. 0164
Sodium (Na^+)	. 0435	Sulfate (SO_4^{--})	. 0208
Potassium (K^+)	. 0256	Chloride (Cl^-)	. 0282
		Nitrate (NO_3^-)	. 0161

Evaporation is the process by which water is changed from the liquid or solid state into the vapor state.

Evapotranspiration is the process by which water is withdrawn from a land area by evaporation from water surfaces and moist soil and transpiration by plants.

Flow-duration curve *See* **Duration curve.**

Fluvial sediment is sediment that is transported by, suspended in, or deposited from water.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or water discharge are obtained. A streamflow gaging station is a gaging station on a stream.

Gallons per minute (gpm) is a unit expressing rates of discharge. One cubic foot per second is equal to 448.8 gpm or 646,272 gpd (gallons per day).

Hardness is a property of water which has generally been associated with the effects observed in the use of soap, or with the deposit left by some types of water when they are heated. Hardness, expressed in terms of an equivalent quantity of calcium carbonate ($CaCO_3$), is calculated from the equivalence of calcium and magnesium, or is determined by direct titration. Hardness caused by calcium and magnesium (and other ions if significant) equivalent to the carbonate and bicarbonate is called carbonate hardness; the hardness in excess of this quantity is called noncarbonate hardness.

Histogram is a graphical representation of yearly variability of annual water discharge by rectangles.

Hydrogen-ion concentration (pH) is the negative logarithm of the concentration of hydrogen ions. The pH is a measure of the activity of the hydrogen ions and thus is a numerical value or measure of the alkalinity or acidity of the water. Ordinarily, water having a pH of 7.0 is regarded as neutral; a pH lower than 7.0 indicates acidic properties; and a pH higher than 7.0 indicates alkalinity. However, a water that is acid, alkaline, or neutral according to the pH scale is not necessarily the same by another standard.

Hydrograph is a graph showing stage, flow, velocity, or other property of water with respect to time.

Index station is a precipitation or streamflow-gaging station, the data from which is used as an index in adjusting or computing the precipitation or streamflow at other stations.

Intermittent stream is one which flows part of the time, as after a rainstorm, or during part of the year.

Ion is an electrified particle formed when a neutral atom or group of atoms loses or gains one or more electrons. If electrons are lost, the particle is positively charged and is called a cation. If electrons are gained, the particle is negatively charged and is called an anion. When a molecule goes into solution, it breaks down into one or more cations and one or more anions. For example, a molecule of the mineral gypsum or calcium sulfate ($CaSO_4$) when dissolved in water dissociates into a calcium ion (Ca^{++}) and a sulfate ion (SO_4^{--}).

Irrigation is the controlled application of water to arable lands to supply water requirements not satisfied by rainfall.

Leaching percent is the ratio, expressed in percentage, of the amount of water that passes downward through the root zone of crops to the amount of water that is applied to the land surface.

Low, medium, and high flows are arbitrary designations based on the percentage of time a water discharge was equaled or exceeded. High flows are those greater than a discharge that was equaled or exceeded 20 percent of the time; low flows are those less than a discharge that was equaled or exceeded 80 percent of the time; and medium flows are those greater than a discharge equaled or exceeded 80 percent of the time but less than a discharge equaled or exceeded 20 percent of the time.

Parts per million (ppm) is a unit for expressing concentration of dissolved solids and sediment. A part per million of dissolved solids is a unit weight of dissolved solids in a million unit weights of a water-dissolved solids solution. A part per million of sediment is a unit weight of sediment in a million unit weights of water-sediment mixture.

Percent sodium is the ratio, expressed in percentage, of equivalents per million of sodium ions to the sum of equivalents per million of calcium, magnesium, sodium, and potassium ions.

Perennial stream is one which flows continuously from source to mouth during most years.

Precipitation is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon land or water surface. The term is also used to designate the quantity of water that is precipitated.

Probable deviation. An array of data that is normally distributed has a spread of values on each side of the mean within which 50 percent of the individual values fall. Such a spread is defined as one probable deviation above and one probable deviation below the mean. It is equal to 0.6745 times the standard deviation.

Rainfall is the quantity of water that falls as rain only. The term is not synonymous with precipitation.

Residual sodium carbonate (RSC) is the amount of carbonate plus bicarbonate, expressed in equivalents per million, that would remain in solution if all the calcium and magnesium were precipitated as carbonate.

$$\mathrm{RSC} = (\mathrm{CO_3} + \mathrm{HCO_3}) - (\mathrm{Ca} + \mathrm{Mg})$$

Return flow is the water returned to the stream system or source after being used. Return flow is generally equal to water use less consumptive use.

Runoff is that part of the precipitation that appears in surface streams. It is the same as streamflow unaffected by artificial diversions, storage, or other works of man in or on the stream channels or on the drainage area.

Sediment is fragmental material that originates mostly from rocks and is transported by, suspended in, or deposited from water or air, or is accumulated in beds by other natural agencies.

Sediment discharge is (1) the rate at which dry weight of sediment passes a section of a stream or (2) the quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

Sediment station is a particular site on a stream, canal, or other waterway where a record of sediment discharge is obtained.

Sediment yield. *See* **Tons per square mile per year.**

Sodium-adsorption-ratio (SAR) is related to the adsorption of sodium by the soil and is an index of the sodium, or alkali, hazard of the water. In the computation of SAR, concentrations of constituents are in equivalents per million.

$$\mathrm{SAR} = \frac{\mathrm{Na^+}}{\sqrt{\dfrac{\mathrm{Ca^{++}} + \mathrm{Mg^{++}}}{2}}}$$

Specific conductance is a measure of the capacity of a solution to conduct an electrical current and is expressed in micromhos per centimeter at 25°C. It is 1 million times the reciprocal of specific resistance at 25°C. Specific resistance is the resistance in ohms of a column of water 1 centimeter long and 1 square centimeter in cross section. Because the specific conductance is related to the number and specific chemical types of ions in solution, it can be used for approximating the salinity of the water. The following general relations are applicable:

$$\text{Specific conductance} \times (0.65 \pm 0.10) = \text{ppm dissolved solids}$$

$$\frac{\text{Specific conductance}}{100} = \frac{\text{total epm}}{2}$$

Standard deviation of an array of data that is normally distributed is:

$$S = \sqrt{\frac{\Sigma x^2}{n-1}}$$

where S is the standard deviation, x is the difference between the value of an individual item and the average of all the items in a sample, and n is the number of items in the sample.

Streamflow is the water discharge that occurs in a natural channel, whether or not the water discharge is affected by regulation or underflow.

Suspended sediment is sediment that is supported by the upward components of turbulent currents or by colloidal suspension if the sediment particles are very small.

Tons per day is a unit for expressing discharge and is commonly used in expressing the discharge of dissolved solids and sediment.

Tons per square mile per year is a unit for expressing the discharge of dissolved solids or sediment from an area. Sediment yield and dissolved-solids yield is usually given in tons per square mile per year.

Use (water) is the total quantity of water pumped, diverted, applied, or utilized for any purpose.

Variability index is the standard deviation of the logarithms of stream discharge (Lane and Lei, 1950). The index may be determined approximately from a flow-duration curve plotted on logarithmic probability paper by scaling vertically the number of log cycles between the points defined by the intersection of the flow-duration curve with the 16 and 84 percent lines and dividing this number by 2.

Water and dissolved-solids budget is an accounting of the water and dissolved-solids inflow to and outflow from a drainage area, including additions and losses in the drainage area.

Water discharge is the flow of a stream or canal, outflow from a basin, or flow of water from a pipe. Water discharge includes the sediment mixed with and solids dissolved in the water.

Water type is a term used to denote the predominate cations and anions in water. Whether certain cations (calcium, magnesium, sodium, and potassium) and certain anions (bicarbonate, sulfate, and chloride) predominate depends on the concentrations in equivalents per million and the relation of the concentration of the individual ions to each other. For example, if the concentration of sodium makes up most of the total cations and the concentration of bicarbonate makes up most of the total anions, the water is classified as a sodium bicarbonate type. However, if the second most abundant cation or anion is more than half the most abundant cation or anion, and the third most abundant cation or anion is more than half the second, they are included in the water-type classification in order of magnitude. Examples of these more complex water types would be calcium magnesium bicarbonate, calcium magnesium bicarbonate sulfate, and sodium magnesium calcium chloride sulfate.

Water year is the 12-month period October 1 through September 30 of the following calendar year. The water year is designated by the calendar year in which it ends.

Water years 1914–57 adjusted to 1957 conditions means that the data given are representative of what would have occurred if the upstream water developments existing in 1957 had been in operation throughout the water years 1914–57.

Water yield is the runoff from a drainage basin.

Weighted-average concentration is a discharge-weighted average that approximated the dissolved-solids concentration of water that would be found in a reservoir containing all the water passing a given station during a specified period after thorough mixing in the reservoir. The effects of evaporation, precipitation, or the addition or removal of dissolved constituents by plants or animals is not considered in this definition.

WATER RESOURCES OF THE UPPER COLORADO RIVER BASIN—TECHNICAL REPORT

HYDROLOGIC TECHNIQUES AND CRITERIA USED IN APPRAISING THE SURFACE-WATER RESOURCES

By W. V. IORNS, C. H. HEMBREE, and G. L. OAKLAND

ABSTRACT

This chapter of the report on the water resources of the Upper Colorado River Basin explains the techniques and criteria used in appraising the surface-water resources of the area.

The base used in evaluating streamflow, dissolved-solids discharge and concentration, and sediment yield is the average which would have occurred if the level of upstream development existing in 1957 had existed throughout water years 1914–57. The available basic data, which were adjusted to this base, are briefly discussed as are other data used in the appraisal such as climatic data, topographic and geologic maps, and maps of native vegetation and irrigated lands.

The methods used in computing and adjusting to the common base precipitation data, flow-duration curves, duration curves of dissolved-solids concentration and discharge, and sediment yield are described in some detail if the procedures have not been previously described in published hydrologic literature. Statistical methods for determining the variability of streamflow, dissolved-solids concentration, and sediment yield are explained. A method is given for computing the amount of water and dissolved solids contributed to stream systems by ground water. In addition, the method used to estimate the amount of dissolved solids added to the stream system by the activities of man is outlined. The criteria used in appraising the suitability of water for various users are also given.

INTRODUCTION

This chapter outlines the hydrologic techniques and criteria used in appraising the surface-water resources of the region. Brief discussions of precipitation maps, vegetation maps, and other data used in the appraisal are also included.

Many methodologies for solving hydrologic problems are given in the engineering and hydrologic literature. Published methodologies were applicable to some of the problems encountered in this study, but other problems could not be solved by the methods available. It was necessary, therefore, to develop methods of analysis, based on accepted hydrologic concepts, to answer some of the problems that were unique to this study. Some of the hydrologic techniques that have not been previously published are relatively new, having been developed prior to this study by one or more of the authors and others or by the authors during this study.

This chapter will not only assist the reader in understanding the methods used to determine the answers to specific problems discussed in other chapters of the report, but will also serve those who may wish to solve similar problems for streams and areas in the basin for which solutions are not included in this report.

BASE FOR APPRAISING THE SURFACE-WATER RESOURCES

The period beginning October 1, 1913, and ending September 30, 1957, was selected as a base period representative of long-term climatic conditions in the Upper Colorado River Basin. Previous studies by the Upper Colorado River Compact Commission (1948) and the U.S. Bureau of Reclamation (1954) used the periods 1914–45 and 1914–47, respectively. All three periods include years of high runoff and the extended drought period between 1930 and 1940. Consequently, the general water-supply picture portrayed by these two previous studies and the present one should be about the same. Precipitation is probably the best measure of climatic differences for the three study periods. Table 1 shows the average precipitation for groups of stations for the water years 1914–45 and 1914–47 in relation to the average for the water years 1914–57.

The average precipitation values for the water years 1914–45 and 1914–47 are consistently slightly higher than those for the water years 1914–57 in the Upper Colorado River Basin and its subdivisions. The minor difference in mean precipitation in various periods chosen for study does not affect the conclusions of the present investigation. Rather, it is clearly desirable

TABLE 1.—*Average precipitation for groups of stations in the Upper Colorado River Basin for water years 1914–45 and 1914–47 in relation to the average precipitation for water years 1914–57*

Station	Number of precipitation stations	Average annual precipitation expressed as percentage of 1914–57 precipitation	
		1914–45	1914–47
Colorado River Basin above Green River	17	101.64	101.15
Green River basin	16	100.48	100.06
San Juan basin	8	105.07	103.67
Colorado River Basin below Green and San Juan Rivers and above "Lee Ferry"	5	102.13	102.86
Colorado River Basin above "Lee Ferry"	46	101.03	101.35

to include years of record after 1947, during which much additional streamflow, chemical quality, and sediment data became available.

The native vegetative cover and water use existing in 1957 were selected as the environmental base for appraising the water resources of the basin. Changes in natural environmental factors and the activities of man during the water years 1914–57 have resulted in modifications in the streamflow, chemical quality of water, and sediment yield of some of the streams. Except in the irrigated areas, which constitute only a small percentage of the total area, little change has occurred during the water years 1914–57 in the hydrologic effect of the natural environmental factors such as topography, rocks, and soils. Although there may have been some changes in the native vegetative cover, the magnitude of the hydrologic effect of any such change on streamflow, chemical quality of water, and sediment yield was considered negligible.

The major expansion of irrigation took place before 1914. Between 1914 and 1957 irrigation increased, but the increase was small as compared with the amount of land being irrigated in 1914. For this study, it was assumed that the effect of irrigation on stream depletion remained about the same throughout the water years 1914–57.

In 1914 there were only a few reservoirs and diversions out of the basin. Between 1914 and 1957 the number of reservoirs increased, and the diversions increased greatly. Data on these water-use facilities, constructed since 1914, are generally sufficient to evaluate their effect on stream regimen and to adjust historical records of streamflow to be representative of 1957 conditions of upstream development.

In this report the term "water years 1914–57 adjusted to 1957 conditions," means that the data given are representative of what would have occurred if the upstream water-use developments existing in 1957 had been in operation thoroughout the water years 1914–57.

AVAILABLE DATA

STREAMFLOW

Collection of streamflow data in the Upper Colorado River Basin began in 1891, when a short period of record of the discharge of Green River at Green River, Wyo., was obtained by the State Engineer of Wyoming. Systematic streamflow measurements, however, did not begin until 1894, when the U.S. Geological Survey established gaging stations on Colorado and Gunnison Rivers at Grand Junction, Colo., Green River at Green River, Utah, and Price River at Wellington, Utah.

Stream gaging expanded slowly, and by 1911 records were being obtained at only 116 sites (fig. 17). From 1911 until the early 1930's the number of gaging stations decreased more than 50 percent. The adoption by Congress in 1929 of dollar-for-dollar cooperation with the States for stream gaging by the Geological Survey, the serious droughts of the early 1930's, and the need of the Bureau of Reclamation for more streamflow data gave impetus to the stream-gaging program. When the Upper Colorado River Compact was adopted by Congress in 1949, additional stations were established at the request of the Upper Colorado River Commission.

During 1894 to 1957 continuous records were obtained at 753 sites. At 93 of these, less than 1 year of record was obtained, but for one site, 62 years of continuous record is available. The following tabulation shows the number of sites for which records of the stated lengths, or longer, are available:

Number of sites	*Years of record*	*Number of sites*	*Years of record*
1	62	139	20
10	50	198	15
38	40	294	10
61	30	489	5
85	25	660	1

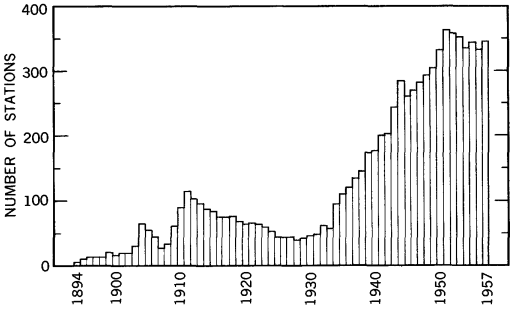

FIGURE 17.—Number of streamflow-gaging stations operated annually in the Upper Colorado River Basin, water years 1894–1957.

An inventory of streamflow records is included in the basic data report (Iorns and others, 1964, table 292).

CHEMICAL QUALITY

The first chemical analyses of surface water in the Upper Colorado River Basin by the Geological Survey were made in 1905 and 1906 to determine the quality of waters likely to be used for reclamation projects. Chemical-quality data were obtained by the Geological Survey at six stream-gaging sites in these years. In 1916 and 1917 the Utah State Agricultural College obtained and analyzed samples of water used for irrigation at 16 sites (Greaves and Hirst, 1918).

Systematic collection of chemical-quality data began in 1928 when chemical-quality stations were established on Colorado River near Cisco, Utah, and on Green River at Green River, Utah. The following year, a station was established on San Juan River near Bluff, Utah. Figure 18 shows the number of stations that have been operated annually.

By the end of the 1957 water year, daily records of chemical quality had been obtained at 41 sites. The records range in length from 7 months to 29 years and total about 340 station years of record. The following tabulation shows the number of sites for which records of the stated lengths, or longer, are available:

Number of sites	*Years of record*	*Number of sites*	*Years of record*
2	29	12	9
3	28	13	7
4	26	22	6
5	24	23	5
6	17	26	4
7	16	30	2
11	10	38	1

In addition to the daily records of chemical quality, chemical analyses are available for more than 850 miscellaneous sites. Most of these sites are at, or near, streamflow-gaging stations. From 1 to 100 determinations of water quality were obtained at each of these sites.

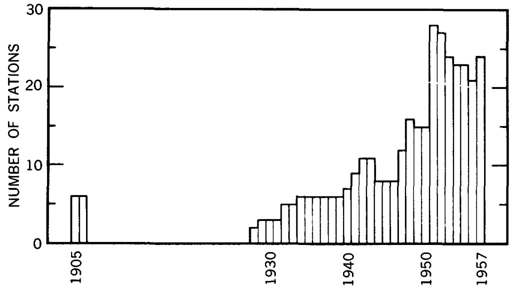

Figure 18.—Number of daily chemical-quality stations operated annually in the Upper Colorado River Basin, water years 1905–57.

An inventory of chemical-quality data is included in the basin data report (Iorns and others, 1964, table 292). The report also contains monthly and annual summaries of chemical-quality analyses for daily stations and analyses of water obtained at other sites.

SEDIMENT

Suspended-sediment data were obtained periodically at five sites in the Upper Colorado River Basin in 1905 and 1906. The periods during which data were obtained ranged from 6 to 14 months. No other suspended-sediment data were obtained unitl 1928, when daily data were obtained for 2 months on San Juan River near Bluff, Utah. Daily sampling began at this station the following year and has continued. A daily suspended-sediment station was established on Colorado River near Lees Ferry, Ariz., in the 1929 water year, and except for two short breaks the record has been continuous. Daily sampling of suspended sediment was begun on Colorado River near Cisco, Utah, and Green River at Green River, Utah, in 1930 and has been continuous. Between 1948 and 1951 the number of daily suspended-sediment stations was greatly increased (fig. 19).

By the end of the 1957 water year daily suspended-sediment data had been obtained at 21 sites. The records range in length from 1 year to more than 28 years and total about 192 station years of record. The following tabulation shows the number of sites for which records of the stated lengths, or longer, are available.

Number of sites	*Years of record*	*Number of sites*	*Years of record*
1		288	7
3		2713	6
4		1715	5
5		1016	3
6		917	2
7		821	1

In addition to the daily suspended-sediment data collected at the 21 stations, suspended-sediment samples have been collected at about 200 other sites. Particle-

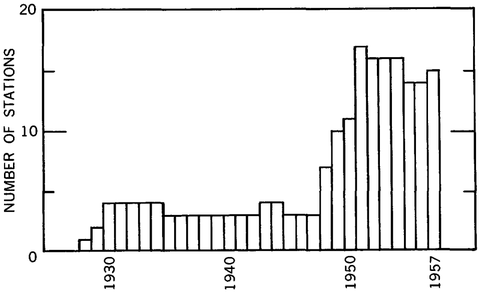

Figure 19.—Number of daily sediment stations operated annually in the Upper Colorado River Basin, water years 1928–57.

size analyses of many of the suspended-sediment samples have been made. An inventory of the suspended-sediment data collected in the Upper Colorado River Basin is included in the basic data report (Iorns and others, 1964, table 292). The basic data report also contains monthly and annual summaries of suspended-sediment discharge at the daily stations, measurements of the suspended-sediment discharge at the 200 other sites, and particle-size analyses.

CLIMATE

The U.S. Weather Bureau, in cooperation with the Survey, developed average (calendar years 1921–50) seasonal precipitation maps, October to April and May to September, and an average annual precipitation map for the Upper Colorado River Basin. The seasonal and annual maps, at a scale of 1:500,000, are contained in the basic data report (Iorns and others, 1964, pls. 2, 3, and 4). The maps are adjusted for topography, exposure to airmass movements, and other parameters. The techniques used in developing the maps are discussed by Peck and Brown (1962), and the base maps used were the latest Sectional Aeronautical Charts published by the U.S. Coast and Goedetic Survey.

The average annual precipitation maps (calendar years 1921–50) at scales of 1:750,000 are shown on maps for chapters C, D, and E of the report. These maps also show average annual lake evaporation from maps prepared by Kohler, Nordenson, and Baker (1959, pl. 2). Other data on precipitation, temperature, and frost-free seasons given in the report were obtained from publications of the U.S. Weather Bureau.

BASE MAP

The base map for the report was adapted from the Sectional Aeronautical Charts of the U.S. Coast and Geodetic Survey. Other maps, such as quadrangle maps, State maps, county maps, and 2-degree Army Map Series were also used in this study.

HYDROLOGIC MAP

The consolidated and unconsolidated rocks in the Upper Colorado River Basin have been studied and mapped for deposits of minerals, for resources of coal, gas, and oil, and to a much less degree for the water resources they influence and contain. Regional and State geologic maps of various parts of the Upper Colorado River Basin have been published (Burbank and others, 1935; Andrews and Hunt, 1948; Love and others, 1955; Dane and Bachman, 1957). On these maps more than 200 formational units have been distinguished; some are thin and crop out only locally, whereas others are thick and exposed over large areas. The rocks range in age from late Precambrian to Recent, and owing to folding, faulting, and weathering, the system of exposure is complex.

In an effort to simplify this complex assortment of rocks into a system for hydrologic study, the rock formations have been classified into eight units by D. A. Phoenix and are shown on hydrologic maps (pls. 1–3). Each of the groupings, besides conforming to the conventional time-rock system of classification, includes those formations having similar hydrologic properties, and each group is called a hydrologic unit. The formations in the eight hydrologic units are listed in a table and their general characteristics are described in chapter A. The classifications into hydrologic units, however, pertain more to geochemical properties and sediment production than to the effect of the rocks on the physical behavior of streams.

The names of specific rock formations shown on regional and State geologic maps have been used in discussing the hydrologic effects of geologic factors on streams. The hydrologic units, into which the different rock formations have been classified, may be determined by reference to the hydrologic map (pl. 1) and to table 1, in chapter A.

MAP OF NATIVE VEGETATION AND IRRIGATED LANDS

Native vegetation zones shown on the maps of native vegetation and irrigated lands in chapters C, D, and E were adapted from a map compiled by F. A. Branson, U.S. Geological Survey. The irrigated lands shown on these maps were compiled from maps in a report entitled "The Colorado River" (U.S. Dept. of the Interior, 1947).

COMPUTING AND ADJUSTING PRECIPITATION DATA

The average annual preciptiation for calendar years 1921–50 was determined for the Upper Colorado River Basin and subareas by planimetering the areas between the isohyetal lines on the precipitation maps. Average annual precipitation at 46 index stations, scattered over and adjacent to the basin, was also computed for water years 1914–57. On the assumption that the precipitation at the index stations, which are in valleys, is proportional to that occurring over the adjacent areas, the precipitation map data were adjusted to the index-station data to obtain areal precipitation data for desired periods of time.

The following tabulation demonstrates the adjustment of 1921–50 average annual precipitation data to the water years 1914–57 in the Grand division.

	1921–50 (inches)	*1914–57 (inches)*
17 index stations	15.95	15.86
Grand division	20.39	[1] 20.27

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[1] By proportion.

Index-station data are also used to compute average annual precipitation over drainage basins for comparison with annual runoff, as follows:

$$\text{Factor}=\frac{20.27}{15.86}=1.278$$

The factor is used with the average annual precipitation for the 17 index stations to obtain precipitation over the division for each water year. (See following tabulation.)

Year	*Average, 17 index stations (inches)*	*Factor*	*Average, Grand division (inches)*
1914	18.41	1.278	23.53
1915	14.27	1.278	18.24

Another use of index-station data is to compute average annual precipitation for periods of years for which runoff data are available. An example would be the computation of the average annual precipitation in the drainage basin above the streamflow-gaging station on Mill Creek near Moab, Utah, for water years 1951–57. The 1921–50 average annual precipitation as planimetered from the precipitation map is 16.70 inches. Of the 46 selected stations, the precipitation stations at Moah, Utah (Grand division), and Blanding, Utah (San Juan division), bracket the Mill Creek drainage basin. For these two stations the ratio of the 1951–57 average annual precipitation (8.90 in.) to the 1921–50 average (10.86 in.) is 0.82. Thus the average annual precipitation in the drainage basin for water years 1951–57 is computed as 16.70 times 0.82, or 13.69 inches.

The precipitation quantities obtained by the above procedures are subject to deficiencies inherent in the precipitation maps and are affected by possible variation between annual valley precipitation and annual area precipitation. The computed precipitation for individual years may differ from reality by an unknown and possibly significant amount, but computed values for long periods of time are probably close to reality.

COMPUTING AND ADJUSTING STREAMFLOW DATA

FLOW-DURATION CURVES

The flow-duration curve is a means of representing streamflow data and combines in one curve the flow characteristics of a stream throughout the range of discharge. As described by Searcy (1959), the flow-duration curve is a cumulative-frequency curve that shows the percentage of time specified discharges were equaled or exceeded during a period of time. It can be used to study and to compare the effects of environmental factors on the behavior of streams. A flow-duration curve that represents the long-term flow of a stream may be used to estimate long-term dissolved-solids and sediments yields and the distribution of future streamflow for waterpower, water supply, and pollution studies.

In the Upper Colorado River Basin about 8,400 station years of daily streamflow records had been obtained at more that 750 sites by the end of the 1957 water year. Historical flow-duration tables were prepared for stations at 174 of these sites by using an electronic computer to process about 4,000 station years of daily streamflow records. The historical flow-duration tables for the 174 stations are given in the basic data report (Iorns and others, 1964, tables 1–174). Flow-duration curves of the historical data and flow-duration curves adjusted to the 44-year base period and to 1957 conditions were prepared for this report.

Many writers have discussed the development and statistics of flow-duration curves, and the reader is referred to the hydrologic literature on this subject. The basic techniques used in this study for adjusting flow-duration curves or short periods to represent long-term conditions are described by Searcy (1959). The following discussion of flow-duration curves is limited to the special techniques developed for this study.

GENERAL CHARACTERISTICS

A large part of the annual runoff of most of the streams in the Upper Colorado River Basin is derived from snowmelt. During the winter snow accumulates in the high mountain ranges. As temperatures rise in the late spring and early summer, the accumulated snow melts. The streams rise to a peak, then subside to near a base or minimum flow, which generally prevails until the cycle is repeated the following spring.

This annual, cyclic hydrograph pattern results in a typical shape of flow-duration curve characteristic of snowmelt-type streams; that is, about 5 to 15 percent of the days will have sustained high flow during the melting period. This results in a flow-duration curve which has a flat slope at the upper end and a fairly steep slope in the central part. The lower end of the curve may be either relatively flat or steep, depending on ground-water conditions and natural regulation by lakes. Differences in topography, geology, and vegetative cover also cause some variations in individual curves, but in general, the curves tend to have the characteristics described.

The runoff in streams draining the areas of lower altitudes is intermittent and is mostly derived from infrequent thundershower-type storms. The shape of the flow-duration curves for these streams is entirely different from those for snowmelt-type streams. Generally, the curves for these streams are steep at the upper end and vertically intersect the bottom line of the logarthmic-plotting paper. The flow from this type of stream, which may be dry as much as 90 percent of the time, constitutes only a minor part of the runoff of the major streams in their downstream reaches.

ADJUSTING FLOW-DURATION CURVES TO BASE PERIOD

Flow-duration curves for short periods of record were adjusted to the base period, water years 1914-57. The index-station method (Searcy, 1959, p. 12-17) was used for adjusting most of short period flow-duration curves to the base period. In addition, three others were developed to adjust records to this base. These methods, which have been named "record-completion method," "monthly means method," and "substitute method," were used where applicable to fill out the periods of missing record.

The record-completion method was used where streamflow records were missing for part of a year. If the missing record consisted of periods when little streamflow fluctuation normally would occur, an average discharge was estimated by interpolation or correlation with index stations, and the estimated average was used for each day of missing record. If the missing record consisted of periods when streamflow fluctuation was likely, an estimated hydrograph based on index stations was prepared and daily discharges filled in from the hydrograph. The completed years of record were combined with other years of daily flow-duration data to fill out the base period. Generally, this method was used for years in which the streamflow record was mostly complete.

The monthly means method was used where 1 or more years of record were missing and reliable monthly estimates could be obtained by correlation with index stations. A flow-duration curve was prepared for the missing years of record using the estimated monthly means. The high and low extremities of this curve were drawn parallel to the flow-duration curve prepared from the historical flow-duration data. The two curves were then combined into one curve for the base period.

The substitute method was used for stations where historical flow-duration data were missing for a few years and satisfactory daily or monthly estimates were impossible, but where acceptable annual averages had been or could be estimated. The method consisted of substituting for years of missing record the historical flow-duration data for other years which had approximately the same average discharges. Flow-duration data for nearby stations and stations on the same stream were used as guides in selecting the substitute years. The method was used only where few years had to be substituted and not where the discharge for missing years was much more, or less, than any of those for which historical data were available.

ADJUSTING FLOW-DURATION CURVES TO 1957 CONDITIONS OF UPSTREAM DEVELOPMENT

A characteristic of the snowmelt streams in the Upper Colorado River Basin is that within any geographic area, over which the climate does not vary greatly, the runoff events occur at about the same time at all stations. The similarity in time of occurrence of runoff events is shown in the relation between annual hydrographs of daily discharge of the streams. It is also displayed in the relation of annual flow-duration curves for the streams: the percentage of time that flows of relative magnitude (high, medium, and low flows) occur is about the same.

As the source of water supply of the main-stem streams is principally the snow-fed tributaries, the time of occurrence of runoff events in the main-stem streams is also approximately the same as in the headwater streams. Annual hydrographs of the streams at successive downstream points are similar, although there is some time lag and flattening of peaks in a downstream direction. Annual flow-duration curves for these streams at successive downstream points, where not influenced by artificial factors, agree closely in the percentage of time that flows of relative magnitude occur.

Beginning at upstream gaging stations, the authors developed two flow-duration curves for the period of years corresponding to each level of upstream development. One curve was representative of streamflows which would have taken place had the water development project not been in existence and the other curve was representative of streamflows after development. These duration curves were computed by adjusting the historic records as described in the next four paragraphs.

An approximation of what the discharges at the gaging station for water years 1914–57 would have been had the upstream developments not been in existence was obtained by adjusting the historical record at the gaging station for the effect of the upstream changes. As upstream changes principally involved transmountain diversions and reservoir operations (effect of irrigation was assumed to be constant because total acres of irrigated land remained relatively constant), the historical record during each level of development was adjusted by adding to it the quantities diverted out of the basin or stored in the reservoirs (subtracted if water was released from the reservoir). Because data of diversions and reservoir changes were available only in monthly quantities, the reconstructed record could only be prepared in terms of monthly quantities.

From the reconstructed monthly record a flow-duration curve representative of conditions had the development not taken place was prepared for the period of each level of development and was compared with the historical flow-duration curve for the same period. The differences in discharge between the two curves at selected percentages were used as the adjustment due to the development. This adjustment was applied to the historical flow-duration curve for the station for the period before the upstream development became effective.

For some streams several levels of upstream development existed in the 44-year base period. For these streams the adjustments, beginning with the time the last development became effective, were cumulated and applied to the historical flow-duration curves for each earlier level of development. The adjusted curves were then combined with the latest curve, which required no adjustment, to obtain a final adjusted curve for the water years 1914–57. The curves were combined by giving weight to the number of years each curve was applicable and to the percentage of time shown by each curve for a given discharge.

Each tributary stream on which upstream developments took place was treated in a similar manner. The adjustments in cubic feet per second for each percentage point were cumulated in a downstream direction and applied to the historical flow-duration curves at downstream stations. Although the adjustment basically requires that the downstream flow-duration data be divided into as many periods as there were different levels of upstream development, there was little difference in results if adjustments based on the difference between the final adjusted curve and the historical curve at main-stem control points for the 44-year period were applied to other downstream 44-year historical flow-duration curves.

A summary of the adjustments for upstream developments which have appreciable effects on flow-duration curves at downstream points is given in table 2. The summary does not include adjustments for many small reservoirs and diversions whose effects, except locally, were negligible. It was not necessary to adjust for the diversion from the Dolores River to the San Juan basin or from the Strawberry Reservoir in Utah to the Great Basin because these were virtually in full operation throughout water years 1914–57.

Controls were maintained at all stages of computations by checking the average discharges computed from the flow-duration curves against average discharges computed from summarization of actual records. Within the limits of accuracy of plotting flow-duration curves and picking data from them, close

Table 2.—*Summary of adjustments, in cubic feet per second, to correct historical flow-duration curves to conditions of upstream development existing in 1957*

Percent of time that indicated adjustment in cfs was equaled or exceeded	Total adjustment, Colorado River at Hot Sulphur Springs, Colo.[1]	Jones Pass tunnel	Hoosier Pass tunnel	Williams Fork Reservoir	Green Mountain Reservoir	Columbine and Wurtz ditches	Total adjustment, Colorado River at Glenwood Springs, Colo.[2]	Roaring Fork at Glenwood Springs, Colo.[3]	Gunnison River at Grand Junction, Colo.[4]	Colorado River near Cisco, Utah[5]	Green River at Green River, Utah[6]	Colorado River at Hite, Utah[7]	San Juan River near Bluff, Utah[8]	Colorado River at Lees Ferry, Ariz.[9]
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.01	−5, 730	0	0	−390	−1, 380	−7. 0	−7, 527	−300	−3, 400	−11, 227	−570	−11, 797	−850	−12, 647
0.06	−5, 005	0	0	−350	−1, 440	−7. 0	−6, 802	−260	−1, 100	−8, 162	−570	−8, 732	−650	−9, 382
0.15	−4, 390	0	−10	−330	−1, 500	−7. 0	−6, 237	−250	−800	−7, 287	−550	−7, 837	−510	−8, 347
0.6	−3, 420	0	−10	−290	−1, 470	−7. 0	−5, 197	−250	−600	−6, 047	−480	−6, 527	−360	−6, 887
2.0	−2, 440	−9	−30	−190	−1, 260	−12. 7	−3, 942	−170	−400	−4, 512	−400	−4, 912	−220	−4, 132
4.0	−1, 900	−21	−40	−85	−980	−14. 1	−3, 040	−140	−350	−3, 530	−347	−3, 877	−184	−4, 062
7.0	−1, 488	−30	−35	−40	−670	−17. 6	−2, 281	−120	−250	−2, 651	−290	−2, 941	−150	−3, 091
12.0	−1, 000	−21	−22	+15	−320	−13. 4	−1, 361	−80	−200	−1, 641	−198	−1, 839	−120	−1, 959
20	−420	−13	−13	+12	−80	−5. 6	−520	−50	−160	−730	−83	−813	−70	−883
30	−178	−7	−5	+26	+143	−3. 7	−25	−15	−100	−140	−36	−176	−60	−236
40	−108	−2	−1	+22	+247	−0. 7	+157	−5	−50	+102	−19	+83	−30	+53
50	−68	−1	0	+15	+250	−0. 1	+197	−5	−50	+142	−14	+128	−10	+118
60	−44	0	0	+11	+217	0	+184	−5	−40	+139	−11	+128	−10	+118
70	−29	0	0	+8	+165	0	+144	−3	−40	+101	−9	+92	−5	+87
80	−19	0	0	+6	+106	0	+93	0	−40	+53	−7	+46	0	+46
90	−14	0	0	+6	+33	0	+25	0	−35	−10	−6	−16	+10	−6
97	−12	0	0	+11	−52	0	−53	0	0	−53	−4	−57	+10	−47
99.4	−9	0	+. 3	+6	−62	0	−65	0	+20	−45	−3	−48	+6	−42
99.9	−10	0	+. 4	−6	−51	0	−67	0	+33	−34	−3	−37	+4	−33
Weighted average	−332	−5. 4	−6. 5	0	0	−3. 1	−347	−26. 6	−95. 4	−469	−62. 0	−531	−42. 5	−573

[1] Includes adjustments for Berthoud Pass ditch, Moffat tunnel, Grand River ditch, Colorado Big-Thompson project, and Willow Creek Reservoir.

[2] Sum of adjustments in columns 2–7.

[3] Includes adjustments for Twin Lakes and Busk-Ivanhoe tunnels.

[4] Includes adjustments for Taylor Park Reservoir and Gunnison tunnel.

[5] Sum of columns 8–10.

[6] Adjustment for Duchesne tunnel only.

[7] Sum of columns 11 and 12.

[8] Adjustment for Vallecitos Reservoir and increase in water use on reservoir project lands.

[9] Sum of 13 and 14.

agreement was maintained between the two sets of data.

Tables in chapters C, D, and E, indicate the methods used to adjust the flow-duration curves to the 44-year base period, list the upstream developments that necessitated the adjustment to 1957 conditions, and rate the accuracy of the results.

RELATION OF GEOLOGY AND GROUND WATER TO STREAMFLOW

Flow-duration curves were used to assess the relation between geology and streamflow and the amount of ground water contributed to the stream systems.

Searcy (1959, p. 22) in his discussion of the shape of flow-duration curves said:

> As the shape of the flow-duration curve is determined by the hydrologic and geologic characteristics of the drainage area, the curve may be used to study the characteristics of a drainage basin or to compare the characteristics of one basin with those of another. A curve with a steep slope throughout denotes a highly variable stream whose flow is largely from direct runoff, whereas a curve with a flat slope reveals the presence of surface- or ground-water storage, which tends to equalize the flow. The slope of the lower end of the duration curve shows the characteristics of the perennial storage in the drainage basin; a flat slope at the lower end indicates a large amount of storage; and a steep slope indicates a negligible amount. Streams whose high flows come largely from snowmelt tend to have a flat slope at the upper end. The same is true for streams with large floodplain storage or those that drain swamp areas.

Later in his discussion of the effect of geology on low flows Searcy (1959, p. 24) stated:

> The flow-duration curve is a valuable medium for studying and comparing drainage basin characteristics, particularly the effect of basin geology on low flows. Except in basins with a highly permeable surface, the distribution of high flows is governed largely by the climate, the physiography, and the plant cover of the basin. The distribution of low flows is controlled chiefly by the geology of the basin. Thus, the lower end of the flow-duration curve is a valuable means for studying the effect of geology on the ground-water runoff to the stream. Where the stream drains a single formation, the position of the low-flow end of the curve is an index of the contribution to streamflow by the formation.

Lane and Lei (1950) introduced a method of measuring the slope of flow-duration curves that was used in this study. Their measure of slope is called the "variability index" and was defined as the standard deviation of the logarithms of stream discharge. On log probability paper, this index represents the fall (in terms of log cycles) of the duration curve in one standard deviation. It may be determined approximately by scaling vertically the number of log cycles between the 16-percent and 84-percent intersection points of the flow-duration curve and dividing this by 2.

The variability indexes for many streams were determined. For headwater snowmelt streams, the index values were found related to the relative permeability of exposed rocks in the drainage basins. The index values are high for basins underlain by impermeable rocks. In these basins the impermeable rocks offer little opportunity for infiltration of water to the ground-water reservoirs and subsequent release to the stream system during periods of low flow. On the other hand, the index values are low for basins underlain by relatively permeable rocks. In these basins the opportunity for ground-water recharge and discharge is great. There is, however, no means of assigning permeability values to rock formations except in generalized terms such as the following: Intrusive igneous rocks are relatively impermeable, and coarse-grained sandstones are relatively permeable. Where several rock formations are exposed in a drainage basin, any relative permeability classification would be exceedingly complex to formulate.

A method of using flow-duration curves to determine the amount of ground water contributed to streams was developed by the authors. The method is principally applicable to headwater streams of the snowmelt-type that are affected little by the activities of man and which have minimal regulation by natural lakes. In the following paragraphs, the method is described and results are compared with the results obtained from hydrographs.

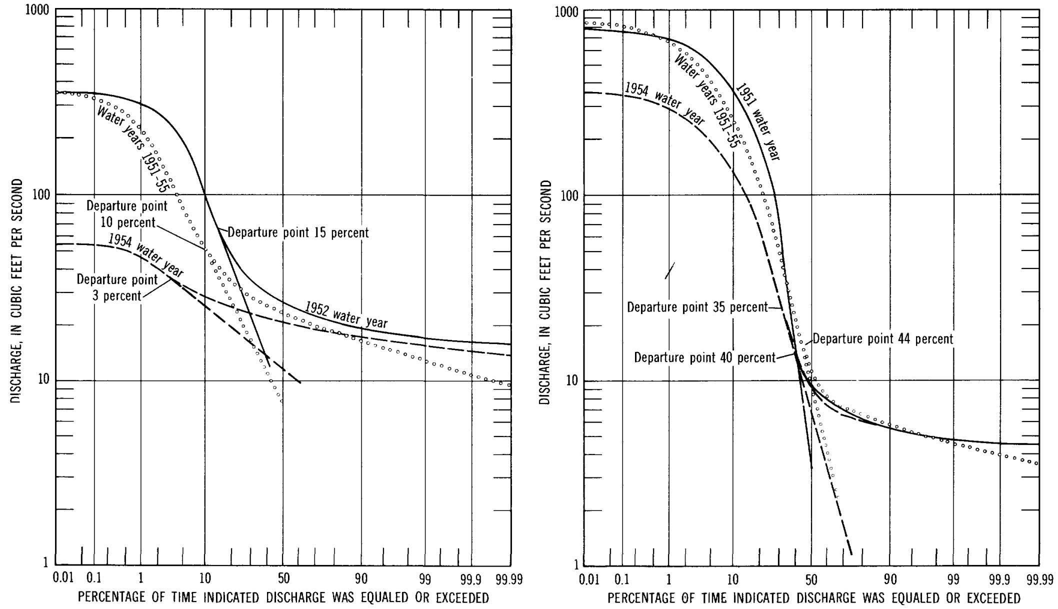
Two types of discharge occur in most streams in the mountainous areas of the Upper Colorado River Basin, direct runoff and base or sustained flow. Direct runoff is water from rainfall or melting snow that enters the stream system rapidly either as overland flow or as subsurface flow that does not reach the zone of saturation and whose time spent underground is so brief that its rate of movement into the stream system is almost as rapid as overland flow. The base or sustained flow of the streams is mostly water discharged from ground-water reservoirs. Natural lake and marsh storage may also contribute water to the base flow of some streams, but in this study, this contribution was considered negligible. Generally, the rate of contribution of ground water to the stream system in the mountains is a maximum immediately after the snowmelt period and gradually diminishes until the snow begins to melt the following spring. For most streams ground water continues to contribute to the stream system during the snowmelt period.

The average time that the flow in a snowmelt-type stream is controlled by ground water may be approximately determined from a flow-duration curve by drawing a line tangent to the steep part of the curve and noting the percentage point at which the lower part of the curve definitely departs from the straight line. (See fig. 20.) The flow represented by the part of the curve below this point consists principally of water discharged from ground-water storage. The streamflow that comes from ground-water storage can be computed by arithmetically integrating the area under the flow-duration curve between the departure point and 100 percent of time.

In the mountain areas the streams are deeply incised, and the slope of the ground-water table is toward the stream channels. Consequently, even during periods of high discharge (when flow is controlled by direct runoff) the ground-water reservoirs are effluent to the streams. In this study the average rate of ground-water discharge during the time that the streams are controlled by direct runoff was found to be approximately equal to the flow-duration-curve discharge that is equaled 70 percent of the time. By adding the ground-water increment of flow, for the percentage of time that the flow-duration-curve discharge is greater than the departure-point discharge, to that obtained by integrating the area under the flow-duration curve below the departure point, the amount of ground water contributed to the stream is obtained.

Flow-duration curves and tables for high and low water years and for a period of years for Gypsum Creek near Gypsum, Colo., and Homestake Creek near Red Cliff, Colo., are used as examples to illustrate the method. (See fig. 20 and table 3.) Figure 21 shows hydrographs for the respective annual flow-duration curves given in figure 20. On these hydrographs the estimated flow contributed by ground water is shown. Table 4 gives the comparative data of the amounts of water computed using the duration curve and hydrograph methods. Data are also given in the table for other water years computed in the same manner. In the determinations, data from the plotted flow-duration curves and hydrographs were used. No attempt was made to balance average annual discharges computed from the flow-duration table and from the actual record.

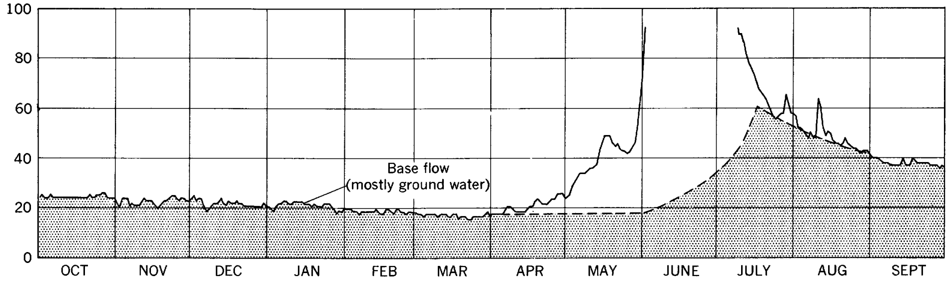
Gypsum and Homestake Creeks were used to illustrate the method of determining the amount of ground water contributed to streams because of their widely different stream behavior and difference in geology. The drainage basin of Gypsum Creek is underlain by the Eagle Valley Evaporite. This formation is composed of sandstone and shale containing much gypsum. Rocks of this formation weather to thick deposits of permeable material. The soil mantle in Gypsum Creek basin supports thick stands of vegetative cover. Such



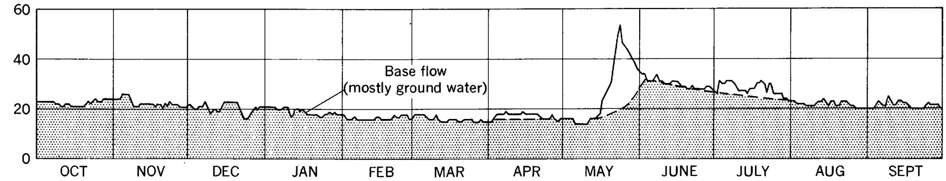
A. Gypsum Creek near Gypsum, Colo.

B. Homestake Creek near Red Cliff, Colo.

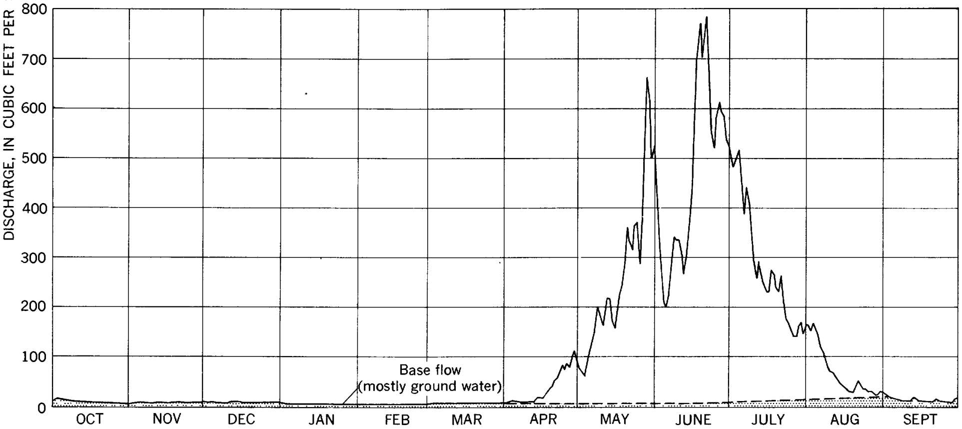
FIGURE 20.—Flow-duration curves for Gypsum and Homestake Creeks.



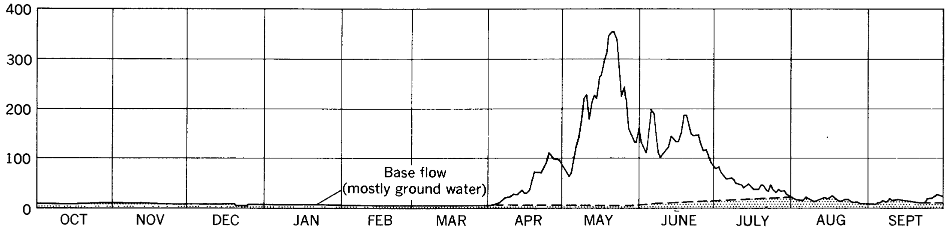
A. Gypsum Creek near Gypsum, Colo., 1952 water year



B. Gypsum Creek near Gypsum, Colo., 1954 water year



C. Homestake Creek near Red Cliff, Colo., 1951 water year



D. Homestake Creek near Red Cliff, Colo., 1954 water year

Figure 21.—Hydrographs of discharge and estimated ground water for Gypsum and Homestake Creeks.

TABLE 3.—*Computation of total discharge and ground-water discharge of Gypsum Creek near Gypsum and Homestake Creek near Red Cliff, Colo., by flow-duration tables*

Total discharge					Ground-water discharge				
Time limits (percent)	Time interval (percent)	Mean of interval (percent)	Discharge (cfs)	Increment of discharge (cfs)	Time limits (percent)	Time interval (percent)	Mean of interval (percent)	Discharge (cfs)	Increment of discharge (cfs)
GYPSUM CREEK NEAR GYPSUM, COLO.									
1952 water year									
0.00–0.02	0.02	0.01	350	0.07					
.02–0.10	.08	.06	350	.28					
.10–0.20	.10	.15	347	.35					
.20–1.00	.80	.6	320	2.55	0.00–15	15		22	3.30
1.00–3.00	2.0	2.0	275	5.50					
3.00–5.00	2.0	4.0	220	4.40					
5.00–9.00	4	7.0	150	6.00					
9 –15	6	12	80	4.80					
15 –25	10	20	47.5	4.75	15 –25	10	20	47.5	4.75
25 –35	10	30	35	3.50	25 –35	10	30	35	3.50
35 –45	10	40	29.5	2.95	35 –45	10	40	29.5	2.95
45 –55	10	50	26	2.60	45 –55	10	50	26	2.60
55 –65	10	60	24	2.40	55 –65	10	60	24	2.40
65 –75	10	70	22	2.20	65 –75	10	70	22	2.20
75 –85	10	80	20.7	2.07	75 –85	10	80	20.7	2.07
85 –95	10	90	19	1.90	85 –95	10	90	19	1.90
95 –99	4	97	18.7	.75	95 –99	4	97	18.7	.75
99 –99.8	.8	99.4	16.8	.13	99 –99.8	.8	99.4	16.8	.13
99.8 –100	.2	99.9	16.2	.03	9.8 –100	.2	99.9	16.2	.03
Totals	100.00			47.23		100.00			26.58
1954 water year									
0.00–0.02	0.02	0.01	54	.01					
.02–0.10	.08	.06	54	.04					
.10–0.20	.10	.15	54	.05					
.20–1.00	.80	.6	49	.39	0.00–3.00	3		19	0.57
1.00–3.00	2.0	2.0	41	.82					
3.00–5.00	2.0	4.0	34	.68	3.00–5.00	2.0	4.0	34	.68
5.00–9.00	4	7.0	30.5	1.22	5.00–9.00	4.0	7.0	30.5	1.22
9 –15	6	12	27.5	1.65	9 –15	6	12	27.5	1.65
15 –25	10	20	25.0	2.50	15 –25	10	20	25.0	2.50
25 –35	10	30	23.0	2.30	25 –35	10	30	23.0	2.30
35 –45	10	40	21.8	2.18	35 –45	10	40	21.8	2.18
45 –55	10	50	20.7	2.07	45 –55	10	50	20.7	2.07
55 –65	10	60	19.9	1.99	55 –65	10	60	19.9	1.99
65 –75	10	70	19.0	1.90	65 –75	10	70	19.0	1.90
75 –85	10	80	18.2	1.82	75 –85	10	80	18.2	1.82
85 –95	10	90	17.2	1.72	85 –95	10	90	17.2	1.72
95 –99	4	97	16.2	.65	95 –99	4	97	16.2	.65
99 –99.8	.8	99.4	15.3	.12	99 –99.8	.8	99.4	15.3	.12
99.8 –100	.2	99.9	14.5	.03	99.8 –100	.2	99.9	14.5	.03
Totals	100.00			22.14		100.00			21.40
Water years 1951–55									
0.00–0.02	0.02	0.01	350	0.07					
.02–0.10	.08	.06	335	.27					
.10–0.20	.10	.15	314	.31					
.20–1.00	.80	.6	257	2.06	0.00–10	10		20	2.00
1.00–3.00	2.0	2.0	162	3.24					
3.00–5.00	2.0	4.0	102	2.04					
5.00–9.00	4	7.0	66	2.64					
9 –15	6	12	46	2.76	10 –15	5	12.5	45.2	2.26
15 –25	10	20	34	3.40	15 –25	10	20	34.0	3.40
25 –35	10	30	27.3	2.73	25 –35	10	20	27.3	2.73
35 –45	10	40	25.2	2.52	35 –45	10	40	25.2	2.52
45 –55	10	50	23	2.30	45 –55	10	50	23.0	2.30
55 –65	10	60	21.4	2.14	55 –65	10	60	21.4	2.14
65 –75	10	70	20.0	2.00	65 –75	10	70	20.0	2.00
75 –85	10	80	18.3	1.83	75 –85	10	80	18.3	1.83
85 –95	10	90	16.4	1.64	85 –95	10	90	16.4	1.64
95 –99	4	97	14.2	.57	95 –99	4	97	14.2	.57
99 –99.8	.8	99.4	12.3	.10	99 –99.8	.8	99.4	12.3	.10
99.8 –100	.2	99.9	10.9	.02	99.8 –100	.2	99.9	10.9	.02
Totals	100.00			32.64		100.00			23.51

TABLE 3.—*Computation of total discharge and ground-water discharge of Gypsum Creek near Gypsum and Homestake Creek near Red Cliff, Colo., by flow-duration tables*—Continued

Total discharge					Ground-water discharge				
Time limits (percent)	Time interval (percent)	Mean of interval (percent)	Discharge (cfs)	Increment of discharge (cfs)	Time limits (percent)	Time interval (percent)	Mean of interval (percent)	Discharge (cfs)	Increment of discharge (cfs)
HOMESTAKE CREEK NEAR RED CLIFF, COLO.									
1951 water year									
0.00–0.02	0.02	0.01	780	0.16					
.02–0.10	.08	.06	760	.61					
.10–0.20	.10	.15	740	.74					
.20–1.00	.80	.6	715	5.72	0.00–40	40		7.0	2.80
1.00–3.00	2.0	2.0	640	12.80					
3.00–5.00	2.0	4.0	550	11.00					
5.00–9.00	4	7.0	445	17.80					
9 – 15	6	12	325	19.50					
15 – 25	10	20	190	19.00					
25 – 35	10	30	70	7.00					
35 – 45	10	40	15	1.50	40 – 45	5	42.5	13.7	.66
45 – 55	10	50	9.3	.93	45 – 55	10	50	9.3	.93
55 – 65	10	60	7.9	.79	55 – 65	10	60	7.9	.79
65 – 75	10	70	7.0	.70	65 – 75	10	70	7.0	.70
75 – 85	10	80	6.2	.62	75 – 85	10	80	6.2	.62
85 – 95	10	90	5.5	.55	85 – 95	10	90	5.5	.55
95 – 99	4	97	5.0	.20	95 – 99	4	97	5.0	.20
99 – 99.8	.8	99.4	4.7	.04	99 – 99.8	.8	99.4	4.7	.04
99.8 –100	.2	99.9	4.5	.01	99.8 –100	.2	99.9	4.5	.01
Totals	100.00			99.67		100.00			7.30
1954 water year									
0.00–0.02	0.02	0.01	354	0.07					
.02–0.10	.08	.06	350	.28					
.10–0.20	.10	.15	340	.34					
.20–1.00	.80	.6	310	2.48					
1.00–3.00	2.0	2.0	260	5.20	0.00– 35	35		6.5	2.28
3.00–5.00	2.0	4.0	215	4.30					
5.00–9.00	4	7.0	165	6.60					
9 – 15	6	12	118	7.08					
15 – 25	10	20	65	6.50					
25 – 35	10	30	26	2.60					
35 – 45	10	40	14	1.40	35 – 45	10	40	14	1.40
45 – 55	10	50	9.0	.90	45 – 55	10	50	9.0	.90
55 – 65	10	60	7.3	.73	55 – 65	10	60	7.3	.73
65 – 75	10	70	6.5	.65	65 – 75	10	70	6.5	.65
75 – 85	10	80	6.0	.60	75 – 85	10	80	6.0	.60
85 – 95	10	90	5.5	.55	85 – 95	10	90	5.5	.55
95 – 99	4	97	5.0	.20	95 – 99	4	97	5.0	.20
99 – 99.8	.8	99.4	4.8	.04	99 – 99.8	.8	99.4	4.8	.04
99.8 –100	.2	99.9	4.6	.01	99.8 –100	.2	99.9	4.6	.01
Totals	100.00			40.53		100.00			7.36
Water years 1951–55									
0.00–0.02	0.02	0.01	867	0.17					
.02–0.10	.08	.06	840	.67					
.10–0.20	.10	.15	810	.81					
.20–1.00	.80	.6	720	5.76					
1.00–3.00	2.0	2.0	580	11.60					
3.00–5.00	2.0	4.0	460	9.20	0.00– 44	44		7.2	3.17
5.00–9.00	4	7.0	335	13.40					
9 – 15	6	12	220	13.20					
15 – 25	10	20	115	11.50					
25 – 35	10	30	50	5.00					
35 – 45	10	40	21	2.10	44 – 45	1	44.5	16.7	.17
45 – 55	10	50	11.5	1.15	45 – 55	10	50	11.5	1.15
55 – 65	10	60	8.2	.82	55 – 65	10	60	8.2	.82
65 – 75	10	70	7.2	.72	65 – 75	10	70	7.2	.72
75 – 85	10	80	6.5	.65	75 – 85	10	80	6.5	.65
85 – 95	10	90	5.8	.58	85 – 95	10	90	5.8	.58
95 – 99	4	97	5.0	.20	95 – 99	4	97	5.0	.20
99 – 99.8	.8	99.4	4.4	.04	99 – 99.8	.8	99.4	4.4	.04
99.8 –100	.2	99.9	4.0	.01	99.8 –100	.2	99.9	4.0	.01
Totals	100.00			77.58		100.00			7.51

TABLE 4.—*Comparative data in computing ground-water contribution, in cubic feet per second, Gypsum Creek near Gypsum and Homestake Creek near Red Cliff, Colo.*

Water year	Average annual discharge		Average ground-water discharge	
	Actual record	Flow-duration curve	Hydrograph	Flow-duration curve
Gypsum Creek near Gypsum, Colo.				
1951	32.5	32.3	23.1	23.0
1952	47.7	47.2	26.9	26.6
1953	34.6	34.8	26.4	26.4
1954	21.9	22.1	20.6	21.4
1955	25.0	25.8	19.0	20.2
Average	32.3	32.4	23.2	23.5
1951-55 [1]	----------	32.6	----------	23.5
Homestake Creek near Red Cliff, Colo.				
1951	98.6	99.7	8.4	7.3
1952	102	101	8.7	8.1
1953	78.6	80.0	9.4	7.4
1954	41.8	40.5	8.6	7.4
1955	63.0	64.5	8.0	8.8
Average	76.8	77.1	8.6	7.8
1951-55 [1]	----------	77.6	----------	7.5

[1] Computed from flow-duration curve for water years 1951-55.

an environment is favorable to infiltration of precipitation, part of which would build up the ground-water table which, in turn, would maintain the stream during the low-flow periods.

In contrast to Gypsum Creek basin, the drainage basin of Homestake Creek is underlain mostly by granite and much of the land surface is bare rock. This rock is relatively impermeable, but apparently absorbs some moisture along joints and faults and discharges it downgradient to the stream. Ground-water storage capacity in such formations is not large; the openings in the rock will accept only a small amount of recharge; and because of restricted passageways, ground water would discharge to the stream at a relatively constant rate.

Ground-water contribution to streams computed by the flow-duration curve method, when expressed as a percentage of the total stream discharge, shows good correlation with variability indices (table 5 and fig. 22) computed by the method proposed by Lane and Lei (1950). Stream sites above and below irrigated lands are included. Chapters C, D, and E give additional data on the variability indices and percentages of ground-water contribution to the streams and discuss the geologic characteristics of the drainage areas.

STATISTICAL ANALYSIS OF ANNUAL FLOWS

The probability techniques described by Leopold (1959) in an analysis of streamflows for Colorado River at Lees Ferry, Ariz., were used to determine the variability of the annual discharges of streams and to estimate the probable future flow of streams. The effect of drainage-basin environmental factors were investigated by comparing the variability of annual discharges for streams. Variations in annual runoff are principally due to variations in precipitation, but other environmental factors also influence the magnitude of annual variations.

TABLE 5.—*Variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water to the stream system at selected sites in the Upper Colorado River Basin*

[Data are for the water years 1914-57 adjusted to 1957 conditions except as indicated]

Station No.	Station	Variability index of streamflow	Percent of average annual discharge contributed by ground water
125	North Inlet at Grand Lake, Colo	0.75	9
200	Willow Creek near Granby, Colo	.56	18
360	Williams River near Leal, Colo	.48	30
470	Blue River at Dillon, Colo	.47	31
520	Rock Creek near Dillon, Colo	.59	22
595	Pine Creek near State bridge, Colo	.54	20
645	Homestake Creek near Red Cliff, Colo	.74	11
695	Gypsum Creek near Gypsum, Colo	.19	66
780	Fryingpan Creek near Norrie, Colo	.59	24
825	Crystal River near Redstone, Colo	.52	23
965	Plateau Creek near Collbran, Colo	.55	16
975	Buzzard Creek near Collbran, Colo	.81	13
1125	East River at Almont, Colo	.53	23
1155	Tomichi Creek at Sargents, Colo	.34	42
1245	Lake Fort at Gateview, Colo	.52	24
1315	Muddy Creek at Bardine, Colo	.58	16
1475	Uncompahgre River at Colona, Colo	.43	31
1665	Dolores River at Dolores, Colo	.67	13
1725	San Miguel River at Placerville, Colo	.39	31
1855	Green River at Warren bridge near Daniel, Colo	.51	27
2030	East Fork near Big Sandy, Wyo	.72	11
2045	East Fork at Newfork, Wyo	.40	31
2055	North Piney Creek near Mason, Wyo	.48	29
2085	LaBarge Creek near Viola, Wyo	.28	52
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[1]	.35	43
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo	.56	19
2140	Little Sandy Creek near Elkhorn, Wyo	.56	21
2165	Green River at Green River, Wyo	.42	30
2185	Blacks Fork near Millburne, Wyo.[2]	.53	22
2230	Hams Fork near Elk Creek ranger station, Wyo	.58	17
2260	Henrys Fork near Lone Tree, Wyo	.52	24
2375	Yampa River near Oak Creek, Colo	.25	60
2410	Elk Creek at Clark, Colo	.58	19
2530	Little Sandy Creek near Slater, Colo	.67	12
2555	Savery Creek at upper station near Savery, Colo	.48	33
2665	Ashley Creek near Vernal, Utah	.40	30
2775	West Fork Duchesne River near Hanna, Utah	.36	32
2790	Rock Creek near Mountain Home, Utah	.42	36
2925	Yellowstone Creek near Altonah, Utah	.34	44
2995	Whiterocks River near Whiterocks, Utah	.40	30
3045	White River near Meeker, Colo	.26	57
3180	Huntington Creek near Huntington, Utah	.38	32
3245	Cottonwood Creek near Orangeville, Utah	.46	26
3265	Ferron Creek (upper station) near Ferron, Utah	.53	18
3400	San Juan River near Pagosa Springs, Colo	.64	16
3425	San Juan River at Pagosa Springs, Colo	.62	17
3460	Navajo River at Edith, Colo	.50	25
3495	Piedra River near Piedra, Colo	.61	17
3505	San Juan River at Rosa, Colo	.61	19
3575	Animas River at Howardsville, Colo	.58	20
3610	Hermosa Creek near Hermosa, Colo	.58	19
3615	Animas River at Durango, Colo	.46	28
3655	LaPlata River at Hesperus, Colo	.60	17
3795	San Juan River near Bluff, Utah	.51	26
3800	Colorado River at Lees Ferry, Ariz	.40	36

[1] Water years 1952-57.
[2] Water years 1940-57.

Not all the records of streamflow were long enough to make a reliable statistical analysis. However, a study of frequency data for the long-term records revealed two important characteristics. First, the distribution of the annual discharges of many streams for the water years 1914-57 was approximately normal. Second, the coefficients of variation (slope of the frequency curve

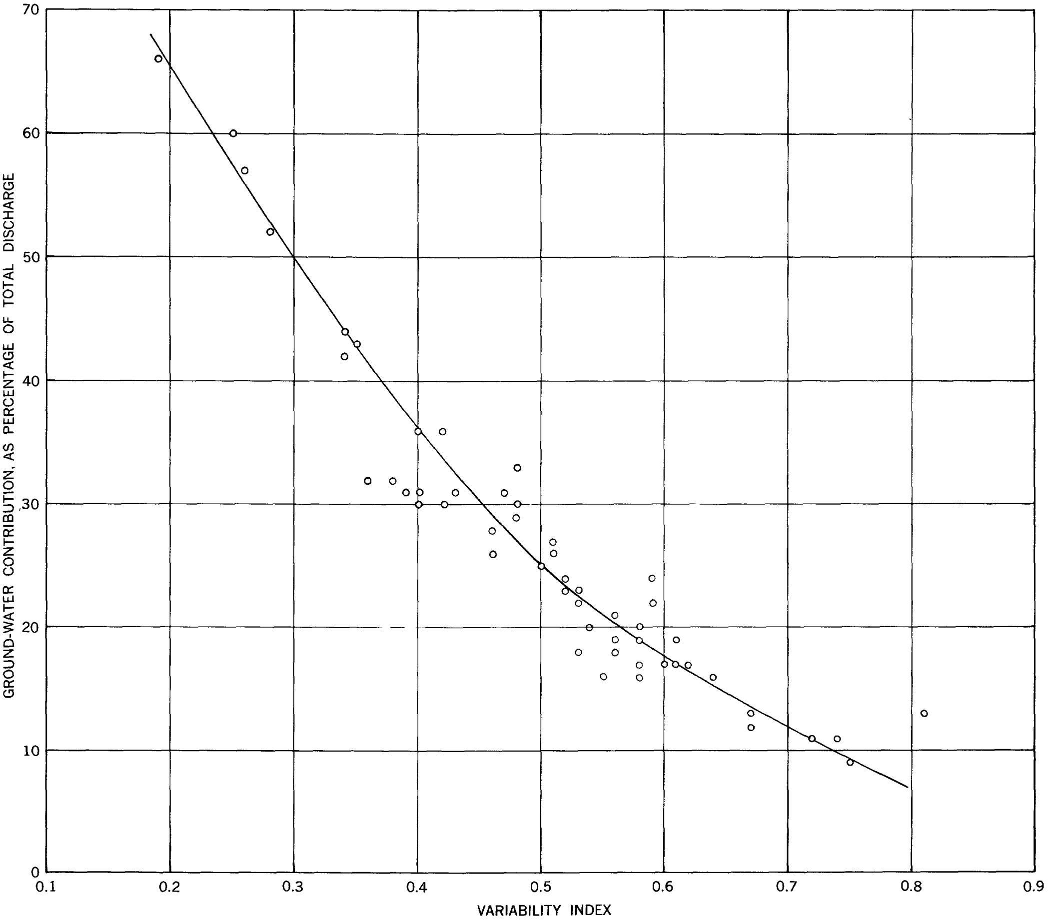


FIGURE 22.—Relation between the variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water for selected streams in the Upper Colorado River Basin, water years 1914–57 adjusted to 1957 conditions.

expressed as the ratio of the standard deviation of the average discharge) had geographic significance. These two characteristics provide a basis for probability statements about streams which have short streamflow records.

The standard deviation of an array of data that is normally distributed is computed by the formula

$$S=\sqrt{\frac{\Sigma x^2}{n-1}},$$

where S is the standard deviation, x is the difference between the value of an individual item and the average of all the items in a sample, and n is the number of items in the sample.

If the individual items are expressed as ratios of the average of all the items, x becomes the difference between the individual ratios and 1.00, and the computed standard deviation would also be in terms of a ratio to the average. Expressing annual-discharge data as a ratio to the average discharge eliminates most of the effect of size of drainage area and difference in annual runoff between basins. Normally distributed data expressed as ratios to the mean will plot on probability paper as a straight line passing through an abscissa value of 1.00 and an ordinate value of 50 percent. The line also passes through (1) an abscissa value of 1.00 plus the ratio of the standard deviation to the average discharge and an ordinate value of 84.1 percent, and (2) another abscissa value of 1.00 minus the ratio of the standard deviation to the average discharge and an ordinate value of 15.9 percent.

The probable deviation expressed as a ratio to the average discharge can be either determined from probability plotting at 25-percent or 75-percent abscissa values or computed by multiplying the ratio of the standard deviation to the average discharge (coefficient of variation) by the factor 0.6745. Deviations from the mean (1.00 ordinate value) can be scaled from a probability plotting or computed by multiplying the standard deviation by a factor for other probabilities. For example, the factor for the deviation at 10 percent and 90 percent is 1.282, at 5 percent and 95 percent is 1.645 and at 1 percent and 99 percent is 2.326.

The computed effect of persistence of hydrologic data (tendency for grouping of years of high runoff and years of low runoff) for streams in this area generally agreed with the variability of mean values of streamflow for records of various lengths derived by Leopold (1959, p. 8). The following tabulation shows average values used in this report to correct for the effect of persistence of hydrologic data:

Number of years included in mean	*Variability as ratio of variability of mean 1-year flows*	*Number of years included in mean*	*Variability as ratio of variability of mean 1-year flows*
1	1.00	10	.47
2	.82	20	.37
4	.66	44	.27

Most streams in the area are affected by changes in irrigation depletion, transmountain diversions, or reservoir regulation. In the statistical analysis of the variability of annual runoff of streams affected by these changes, the records of streamflow were adjusted to a fixed level of upstream development to eliminate the effect of changing conditions.

Annual irrigation depletions have been approximately constant as there has been little change in irrigated acreage. Irrigation depletion, therefore, has little effect on the variability values of annual runoff when expressed as the ratio of the standard deviation to the average discharge.

The annual discharges of streams, affected by transmountain diversions and reservoirs were adjusted to a 1914 base by adjusting for changes in diversions and reservoir storage after 1914. Coefficients of variation computed on this base can be used with the average discharge of streams for water years 1914–57 adjusted to 1957 conditions to determine the variability of runoff for the level of upstream development existing in 1957.

Streamflow data for Roaring Fork at Glenwood Springs, Colo., were used as an example to show adjustments to the 1914 base, the frequency distribution curve, the coefficient of variation, and frequency distribution for periods of different lengths. To adjust the streamflow record for the effect of changes in transmountain diversions, the annual quantities diverted by the Twin Lakes and Busk-Ivanhoe tunnels were added to the historical record of streamflow of Roaring Fork at Glenwood Springs (table 6). The discharges were then arranged in order of magnitude and converted to ratios of the average discharge for the 44-year period; the probability plotting position was computed from the formula

$$\text{Plotting positon} = 100 - \frac{100m}{n+1},$$

in which m is the order number and n is the number of years of record (table 7). The ratios and probability values were then plotted on probability plotting paper, and a straight line was drawn to conform to the points (fig. 23).

The standard deviation as a ratio to the average discharge is represented by a and a' at abscissa values of 84.1 percent and 15.9 percent on figure 23. The ratio value scaled from the graph is 0.27.

TABLE 6.—*Adjustment of streamflow records for Roaring Fork at Glenwood Springs, Colo., to 1914 base, in thousands of acre-feet*

Water year	Historical discharge	Adjustments		Discharge 1914 base [1]
		Twin Lakes tunnel	Busk-Ivanhoe tunnel	
1914	1,845	0	0	1,845
1915	748.5	0	0	748.5
1916	1,231	0	0	1,231
1917	1,463	0	0	1,463
1918	1,362	0	0	1,362
1919	913.9	0	0	913.9
1920	1,356	0	0	1,356
1921	1,285	0	0	1,285
1922	1,072	0	0	1,072
1923	1,236	0	0	1,236
1924	990.4	0	0	990.4
1925	978.5	0	1.61	980.1
1926	987.6	0	4.19	991.8
1927	1,170	0	5.76	1,176
1928	1,100	0	4.65	1,105
1929	1,206	0	6.64	1,213
1930	944.1	0	5.28	946.4
1931	547.9	0	2.96	550.9
1932	1,141	0	6.37	1,147
1933	948.6	0	5.20	953.8
1934	499.1	0	3.47	502.6
1935	899.2	18.02	5.01	922.2
1936	1,048	23.24	7.07	1,079
1937	789.1	31.92	5.35	826.4
1938	1,194	45.46	5.54	1,245
1939	767.1	37.06	5.32	809.5
1940	589.9	27.04	4.02	621.0
1941	861.6	36.09	3.81	901.5
1942	1,008	13.40	.82	1,022
1943	933.5	48.02	4.85	986.4
1944	884.4	37.73	2.10	924.2
1945	895.7	44.78	4.90	945.4
1946	798.3	39.32	4.64	842.3
1947	1,156	37.31	1.44	1,195
1948	1,087	25.03	1.00	1,113
1949	958.6	38.19	4.30	1,001
1950	798.0	34.88	3.41	836.3
1951	872.7	44.92	5.13	922.7
1952	1,239	51.36	6.34	1,297
1953	800.1	40.30	5.08	845.5
1954	477.9	27.47	3.20	508.6
1955	660.8	35.06	5.27	701.1
1956	717.4	36.44	4.40	758.2
1957	1,521	32.74	5.51	1,559
Average				1,021

[1] Quantities rounded to four significant figures.

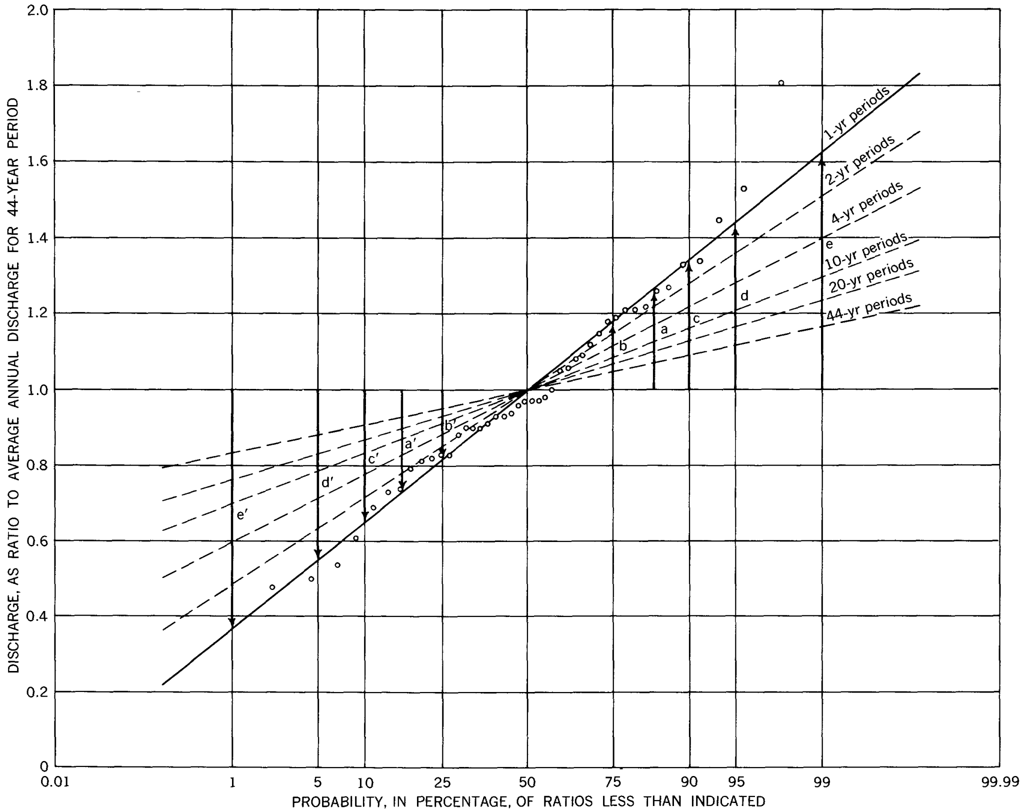


FIGURE 23.—Distribution of average flows for periods of various length, Roaring Fork at Glenwood Springs, Colo., water years 1914–57 adjusted to 1914 base.

The standard deviation may also be computed from the adjusted annual discharges in table 6 by the formula given on page 54. The average of all the discharges in the 44-year period is 1,021,000 acre-feet, and n is 44. The computed standard deviation is 273,000 acre-feet, which when expressed as a ratio to the average discharge is $\frac{273,000}{1,021,000}$, or 0.27.

In this report the coefficient of variation is defined as the ratio of the standard deviation to the average discharge, though in hydrologic literature it is sometimes expressed in percentage. This ratio, or coefficient of variation, is also a measure of the slope of the frequency curve when plotted on probability paper (ordinate a in fig. 23). The frequency curve for a highly variable stream would have a steep slope and a high coefficient of variation. A less variable stream would have a flatter slope and lower coefficient of variation.

The lengths of the ordinates b and b' in figure 23 at the 75 and 25 percentiles are equal to the ratio of one probable deviation to the average discharge. This length is plotted above and below the average (1.00). The ordinate distances c and c', d and d', and e and e' are the ratios of deviations to the average flow at the 10 and 90 percentiles, 5 and 95 percentiles, and 1 and 99 percentiles, respectively.

The frequency distribution for the 2-, 4-, 10-, 20-, and 44-year average discharges are also plotted in figure 23 as dashed lines. The slopes of these lines were obtained by multiplying the slope of the 1-year period line by the ratios in the tabulation on page 55. Ordinate values in terms of ratios to the average discharge at various percentiles may be scaled from the distribution graph or computed by multiplying the coefficient of variation by the appropriate factor.

The standard deviation and coefficient of variation were computed for many streams where streamflow records spanned the 44-year base period or where missing data could be estimated. Some records of shorter

TABLE 7.—*Computation of ratios of the average discharge and plotting position in probability analysis, Roaring Fork at Glenwood Springs, Colo.*

[Data are for the water years 1914-57 adjusted to 1914 base]

Order No.	Annual discharges in order of magnitude: Discharge (thousands of acre-ft)	Annual discharges in order of magnitude: Ratio of average discharge	Plotting position (probability, in percent)
1	1,845	1.81	97.8
2	1,559	1.53	95.6
3	1,463	1.45	93.4
4	1,362	1.34	91.1
5	1,356	1.33	89.0
6	1,297	1.27	86.8
7	1,285	1.26	84.6
8	1,245	1.22	82.3
9	1,236	1.21	80.1
10	1,231	1.21	77.9
11	1,213	1.19	75.7
12	1,195	1.18	73.5
13	1,176	1.15	71.2
14	1,147	1.12	68.9
15	1,113	1.09	66.7
16	1,105	1.08	64.4
17	1,079	1.06	62.2
18	1,072	1.05	60.0
19	1,022	1.00	57.8
20	1,001	.98	55.6
21	991.8	.97	53.4
22	990.4	.97	51.2
23	986.4	.97	48.9
24	980.1	.96	46.7
25	953.8	.94	44.5
26	946.4	.93	42.3
27	945.4	.93	40.1
28	924.2	.91	37.8
29	922.7	.90	35.6
30	922.2	.90	33.4
31	913.9	.90	31.2
32	901.5	.88	28.9
33	845.5	.83	26.6
34	842.3	.83	24.4
35	836.3	.82	22.2
36	826.4	.81	20.0
37	809.5	.79	17.8
38	758.2	.74	15.5
39	748.5	.73	13.3
40	701.1	.69	11.1
41	621.0	.61	8.9
42	550.9	.54	6.7
43	508.6	.50	4.4
44	502.6	.49	2.2
Average	1,021	1.00	

length were also used. The computed coefficients of variation were plotted on maps and the environmental factors examined to explain possible causes of differences in the coefficients for various drainage areas. By taking into consideration, climate, and other environmental factors, coefficients of variation can be estimated for many streams in the basin for which streamflow records are not long enough for a 44-year statistical analysis.

In addition to providing data on the variability of annual discharges in the 44-year period, the frequency data may be used to estimate how much future average streamflows for different periods of years are likely to deviate from the average observed in the 44-year period. For example, if the average discharge during water years 1914–57 and the coefficient of variation are known, or can be estimated, the probable difference between the average water discharge during the next 44-year period, or other selected periods of years, and the historical average can be computed for different selected confidence limits from the factors given in table 8 and the following equation:

$$\text{Range in deviation} = V_wQF,$$

where V_w is the coefficient of variation of annual discharge for the 44-year base period, Q is the average annual discharge for the 44-year base period, and F is the factor for means of periods of years for the selected confidence limits given in table 8.

TABLE 8.—*Factors for computing probable range in deviation of the average discharge for various periods of years and confidence limits from the average discharge in a 44-year period*

Confidence limits (percent)	Factors (F) for mean of periods of years indicated: 1	2	4	10	20	44
50	0.67	0.58	0.48	0.37	0.30	0.26
80	1.28	1.11	.91	.59	.58	.49
90	1.64	1.42	1.17	.89	.74	.63
98	2.33	2.01	1.66	1.26	1.05	.89

Incorporated in the factors in table 8 is the variability of the mean of the 44-year sample and the variability of the means for various periods of years. For example, the factor in the table for a confidence limit of 50 percent and a 10-year period is $0.6745\sqrt{(0.27)^2+(0.47)^2}$, or 0.37. The ratios 0.27 and 0.47 are from the tabulation for the 10-year and 44-year periods (p. 55).

Where the distribution of data is known to be approximately normal, the probable values of average flows for various periods in the future may be determined by computing the average discharge and standard deviation and by using the equation on page 54 with the factors given in table 8. For example, one may want to determine how much the average flow for Roaring Fork at Glenwood Springs for various periods of years might vary from the average observed during the water years 1914–57, adjusted to the 1914 base.

The standard deviation computed from the equation on page 54 and the data in table 6 is 273,000 acre-feet. By use of the equation for range in deviation for selected confidence limits and periods of years

$$\text{Range in deviation} = S_w\,F,$$

where S_w is the standard deviation for the 44-year period and F is the factor for means of periods of years for the selected confidence limits from table 8, the following estimates of future average discharges (assuming a 50-percent confidence limit) can be made:

1. There is a 50-percent chance that the average discharge for any future year will lie between 1,204,000 acre-feet (1,021,000+183,000) and 838,000 acre-feet (1,021,000—183,000), and there is a 25-percent chance, or one chance in four, that the average for any 1 year will be less than

838,000 acre-feet and the same chance that it will be more than 1,204,000 acre-feet.

2. There is a 50-percent chance that the average discharge for any future 2-year period will lie between 1,179,000 acre-feet (1,021,000+158,000) and 863,000 acre-feet (1,021,000—158,000), and there is a 25-percent chance that the average will be less than 863,000 acre-feet and the same chance that it will be more than 1,179,000 acre-feet.
3. There is a 50-percent chance that the average discharge for any future 10-year period will lie between 1,122,000 acre-feet (1,021,000+101,000) and 920,000 acre-feet (1,021,000−101,000), and there is a 25-percent chance that the average will be less than 920,000 acre-feet and the same chance that it will be more than 1,122,000 acre-feet.
4. There is a 50-percent chance that the average discharge for any future 44-year period will lie between 1,092,000 acre-feet (1,021,000+71,000) and 950,000 acre-feet (1,021,000−71,000), and there is a 25-percent chance that the average will be less than 950,000 acre-feet and the same chance that it will be more than 1,092,000 acre-feet.

COMPUTING CHEMICAL-QUALITY DATA

DURATION TABLES OF DISSOLVED SOLIDS

The concentration of dissolved solids of most streams in the Upper Colorado River Basin varies nearly in inverse relation to the discharge of the stream. Figure 24 shows a typical curve of this relation. The concentration is maximum during low-flow periods when the flow of the stream is predominately effluent ground water. At times of high discharge, the higher concentration of the ground-water inflow is diluted by the lower concentration of the surface runoff. For high mountain streams draining areas of metamorphic and granitic rocks in the Upper Colorado River Basin, the shape of this curve is rather flat, and the range between maximum and minimum concentration is small. For streams draining areas where highly concentrated ground water enters the stream, the curve has a pronounced reverse S-shape on log-log paper, and the range between maximum and minimum concentration is large (fig. 24).

Curves showing relation between the concentration of dissolved solids and the discharge of the stream at the time of sampling were prepared for many streams. Data obtained from these curves were combined with the flow-duration tables of streamflow for water years 1914–57 adjusted to 1957 conditions to obtain values for duration tables of dissolved-solids concentration and dissolved-solids discharge. (See table 9.) Footnotes to table 9 explain the computations. The sum of the increments in column 5 is the average water discharge, and the sum of the increments in column 8 is the average dissolved-solids discharge. Weighted-average concentration is computed by the following equation:

$$C_a=\frac{t}{0.0027\,q},$$

where

C_a=weighted-average concentration of dissolved solids,
t=tons per day of dissolved solids,
q=average water discharge in cubic feet per second, and
0.0027=a factor used for converting the product of concentration in parts per million and water discharge in cubic feet per second to tons per day. This factor is based on unit density of water and introduces no error of practical importance for water containing less than about 7,000 ppm of dissolved solids.

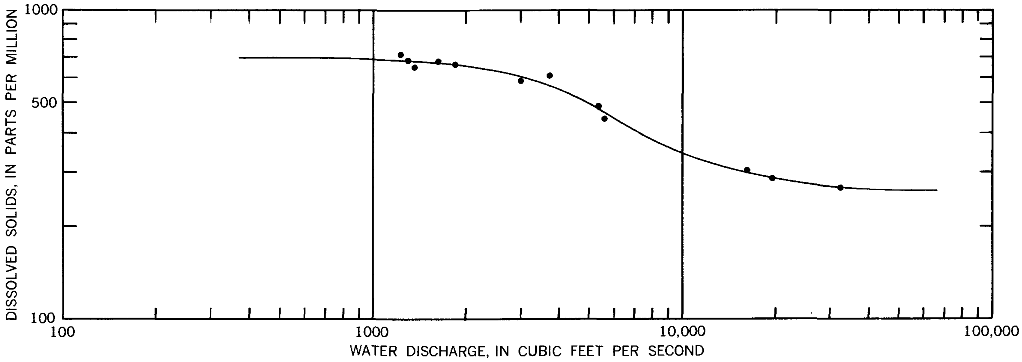


FIGURE 24.—Relation of weighted-average concentration of dissolved solids to water discharge, Green River near Ouray, Utah. Curve is based on monthly average discharges and monthly weighted-average concentrations for periods of available data, water years 1951–52 and 1957.

TABLE 9.—*Duration table of water discharge and dissolved-solids concentration and discharge of Green River near Ouray, Utah*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Duration table percentage			Water discharge		Dissolved solids concentration for mean of time interval (ppm)	Dissolved-solids discharge	
Time limits	Time interval	Mean of interval	Discharge for mean of interval (cfs)	Increment of discharge in time interval (cfs)		Discharge for mean of interval (tons per day)	Increment of discharge in time interval (tons per day)
1	2	3	4	5	6	7	8
0. 00– 0. 02	0. 02	0. 01	63, 000	13	261	44, 400	9
. 02– 0. 10	. 08	. 06	55, 500	44	262	39, 260	31
. 10– 0. 20	. 10	. 15	49, 700	50	263	35, 290	36
. 20– 1. 00	. 80	. 6	39, 800	318	266	28, 580	228
1. 00– 3. 00	2. 0	2. 0	30, 200	604	270	22, 020	440
3. 00– 5. 00	2. 0	4. 0	24, 900	498	277	18, 620	372
5. 00– 9. 00	4	7. 0	20, 000	800	286	15, 440	618
9– 15	6	12	15, 400	924	301	12, 520	751
15– 25	10	20	9, 600	960	353	9, 150	915
25– 35	10	30	5, 450	545	475	6, 990	699
35– 45	10	40	3, 750	375	568	5, 750	575
45– 55	10	50	2, 850	285	615	4, 730	473
55– 65	10	60	2, 380	238	642	4, 130	413
65– 75	10	70	2, 060	206	660	3, 670	367
75– 85	10	80	1, 750	175	678	3, 200	320
85– 95	10	90	1, 420	142	682	2, 610	261
95– 99	4	97	990	40	695	1, 860	75
99– 99. 8	. 8	99. 4	580	5	700	1, 100	9
99. 8 –100	. 2	99. 9	370	1	700	699	2
Totals				6, 223			6, 594

1. Limits of spread of time interval used in integrating area under duration curves by partial areas.
2. Spread of time interval.
3. Selected percentages on duration curves used in duration tables for this study.
4. Flow-duration table of water discharge for the water years 1914–57 adjusted to 1957 conditions.
5. Column 2 times column 4 divided by 100.
6. From fig. 24 for water discharges in column 4. This is duration table of dissolved-solids concentration.
7. Column 4 times column 6 times 0.0027. This is duration table of dissolved-solids discharge.
8. Column 2 times column 7 divided by 100.

Computations similar to those illustrated in table 9 were used to develop duration tables of dissolved-solids concentration and tables of dissolved-solids discharge for many streams. (See chapters C, D, and E.) Curves showing relation between dissolved-solids concentration and water discharge were based on data obtained during the latter part of the 44-year period; consequently, the computed dissolved-solids concentration and loads are representative of conditions existing in 1957.

DISSOLVED SOLIDS CONTRIBUTED TO STREAMS BY GROUND WATER

The amount of dissolved solids carried into snowmelt-type streams in ground water was computed. The computations are based on the method described on pages 48–53 for computing the amount of ground-water contribution to streams from ground-water reservoirs, and the dissolved-solids concentration of the streams during the times that the flow is maintained principally by ground water. Duration tables of dissolved-solids discharge are used for the computation. Table 10 gives an example of the procedures applied to the records for Green River near Ouray, Utah. About 3,779 tons per day or 1,380,000 tons per year is

TABLE 10.—*Computation of dissolved solids contributed to the stream system by ground water, Green River near Ouray, Utah*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Duration table percentage			Ground-water dissolved-solids discharge	
Time limits	Time interval	Mean of interval	Discharge for mean of interval (tons per day)	Increment of discharge in time interval (tons per day)
1	2	3	4	5
0. 00–35	35	----------	3, 670	1, 284
35–45	10	40	5, 750	575
45–55	10	50	4, 730	473
55–65	10	60	4, 130	413
65–75	10	70	3, 670	367
75–85	10	80	3, 200	320
85–95	10	90	2, 610	261
95–99	4	97	1, 860	75
99–99. 8	. 8	99. 4	1, 100	9
99. 8 –100	. 2	99. 9	699	2
Totals	100			3, 779

1. Limits of spread of time interval used in integrating area under duration curve by partial areas. The time limit for the first line is the spread from 0.00 percent to the point of departure percentage on the flow-duration curve. (See page 48.)
2. Spread of time interval.
3. Selected percentages on duration curve used in the duration tables for this study.
4. From duration table of dissolved-solids discharge for water years 1914–57 adjusted to 1957 conditions, except first line which is estimated to be the same as the dissolved-solids discharge equaled or exceeded 70 percent of the time.
5. Column 2 times column 4 divided by 100.

contributed to the stream system above the Ouray station by ground water. The Ouray record was used as an example because the same record was used to illustrate the computation of total water discharge and total dissolved-solids discharge. (See table 9.)

VARIABILITY OF DISSOLVED-SOLIDS CONCENTRATION

Continuous chemical-quality records were available at relatively few locations in the basin, and the length of these were for relatively short periods of time as compared with the 44-year base period. Annual variability is a parameter which may be ascertained even from relatively short records. Data on the annual variability of concentration of dissolved solids for the 44-year base period were developed.

For concurrent periods of daily chemical-quality and streamflow records in the different basin divisions, the coefficients of variation for annual weighted-average concentrations of dissolved solids and annual historical discharges were computed. Table 11 and figure 25 show the relation between the concentration and discharge coefficients in the Grand division. The plot shows that empirically there is a linear relation for major streams in this division. The empirical relation computed by the least-squares method is defined by the following equation:

$$V_d=0.573V_w+0.036,$$

where V_d is the coefficient of variation of annual weighted-average concentration of dissolved solids and V_w is the coefficient of variation of annual discharge.

TABLE 11.—*Variability of annual weighted-average concentration as related to variability of annual water discharge for stations in the Colorado River Basin above the Gunnison River*

Station No.	Station	Water years	Coefficient of variation	
			Streamflow (V_w)	Weighted-average concentration (V_d)
690	Eagle River at Gypsum, Colo	1948–57	0.28	0.19
705C	Colorado River near Glenwood Springs, Colo	1942–57	.26	.20
955	Colorado River near Cameo, Colo	1934–57	.25	.17
1525	Gunnison River near Grand Junction, Colo	1932–57	.39	.26
1800	Dolores River near Cisco, Utah	1948–57	.67	.42
1805	Colorado River near Cisco, Utah	1929–57	.34	.23

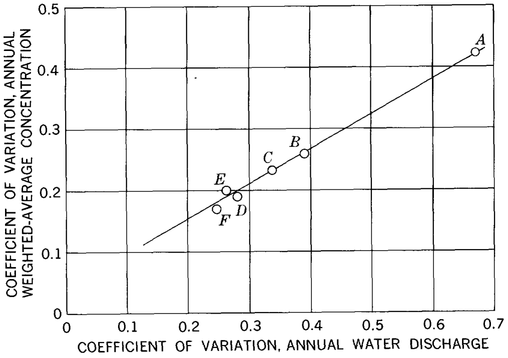


FIGURE 25.—Relation of the variability of dissolved-solids concentration to the variability of water discharge in the Grand divison. *A*, Dolores River near Cisco, Utah; *B*, Gunnison River near Grand Junction, Colo.; *C*, Colorado River near Cisco, Utah; *D*, Eagle River at Gypsum, Colo.; *E*, Colorado River near Glenwood Springs, Colo.; and *F*, Colorado River near Cameo, Colo.

This relation was derived from actual records. The relation is a means for developing statistical expressions of the variability of dissolved-solids concentrations for the 44-year base period for stations where continuous records of chemical quality were not available, but where infrequent chemical-quality data had been obtained. The coefficients of variation of annual water discharge were computed for a number of stations and are given in tables of the respective subbasin in which the stations are located. These coefficients were also plotted on maps. Coefficient values for other locations were interpolated from the maps. By use of computed or interpolated coefficients of variation of annual water discharge, and the empirical equation above, the coefficient of variation of weighted-average annual concentration of dissolved solids can be computed. As the coefficient of variation is the ratio of the standard deviation to the average concentration, the standard deviation in parts per million may be computed if the average concentration in parts per million is known or can be determined.

The foregoing may be illustrated by the example of an analysis of Roaring Fork at Glenwood Springs, Colo., where the coefficient of variation of water discharge is 0.27, and the weighted-average concentration is 225 ppm for water years 1914–57 adjusted to 1957 conditions. Substituting the coefficient of variation of water discharge in the equation

$$\begin{aligned}V_d&=0.573V_w+0.036\\&=(0.573)(0.27)+0.036\\&=0.19,\end{aligned}$$

and as

$$\begin{aligned}S_d&=V_d+C_a\\&=0.19\times225\\&=43\text{ ppm},\end{aligned}$$

wherein V_w is the coefficient of variation of annual water discharges, V_d is the coefficient of variation of annual weighted-average dissolved-solids concentrations, C_a is the weighted-average concentration of dissolved solids, and S_d is the standard deviation of annual weighted-average dissolved-solids concentrations.

If the weighted-average concentration of dissolved solids for periods of various length are assumed to have variances comparable to those of streamflow, the factors in table 8 can be used to compute probable values of concentration for various periods in the future. For example, if the level of development existing in 1957 were to exist during the next 44-year period, there is a 50-percent chance that the weighted-average concentration of dissolved solids of Roaring Fork at Glenwood Springs, Colo., will lie between 236 ppm (225 + 43 × 0.26) and 214 ppm (225 − 43 × 0.26) and there is a 25-percent chance that the weighted-average concentration of dissolved solids for the period will be less than 214 ppm.

EFFECT OF TRANSMOUNTAIN DIVERSIONS ON THE CHEMICAL QUALITY OF WATER OF STREAMS

Water diverted out of the Upper Colorado River Basin carries with it the minerals dissolved in the diverted water. The effect of a diversion on the master stream at a downstream point is to deplete the flow and to change the dissolved-solids discharge. Whether the diversion increases or decreases, the weighted-average concentration of the master stream at a downstream point depends on the relation of the weighted-average concentration of the diverted water to the original weighted-average concentration of the master stream at the downstream point. If the diverted water is the more dilute, the effect will be to increase the concentration of the master stream; and if less dilute, the effect will be to decrease the concentration of the master stream. If no changes in water loss are assumed to occur in the master stream channel, the relation between water discharges and weighted-average concentrations would be as follows:

$$C_c(Q_a+Q_b)=Q_aC_a+Q_bC_b$$

or

$$C_c=\frac{Q_aC_a+Q_bC_b}{Q_a+Q_b},$$

where

Q_a=average discharge of master stream at downstream point when water is being diverted,

C_a=weighted-average concentration of the water in the master stream when water is being diverted,

Q_b=average discharge of diversion,

C_b=weighted-average concentration of diverted water, and

C_c=weighted-average concentration of master stream at downstream point when no water is being diverted.

EFFECTS OF THE ACTIVITIES OF MAN ON DISSOLVED-SOLIDS DISCHARGE

GENERAL

The program for collecting data on chemical-quality of water in the Upper Colorado River Basin is not designed to identify the dissolved-solids loads contributed to the stream system by irrigation, mining, industry, and other sources. The data program is directed toward evaluating the chemical character of water and streamflow at various points in the stream system. Where the drainage area above a sampling site has little or no water-use development, the data are representative of natural conditions. Where the sampling site is below areas containing irrigated tracts of land, communities, industries, and other activities of man, the dissolved-solids load at the site is the total contribution from natural sources and the activities of man.

In the studies conducted specifically for the report, chemical-quality data were collected to help determine the effects of man; so, collection sites were both above and below areas containing irrigated tracts of land and communities. From analysis and correlation of these data and other available chemical-quality data with the geology, location of irrigated lands and communities, soil characteristics, and other factors, the general effects of the activities of man on the dissolved-solids loads of the streams can be identified. The results of the study can be further refined by additional data collection specifically designed to identify the effects of man's activities.

Part of the water used by communities and industries is consumed, and part is used to transport waste products for disposal, usually to the nearest stream channel. Although some of the wastes from these activities are treated for removal of organic matter and purification, the treatment does not remove the dissolved solids which have been added.

Partial analyses of samples of water supply and sewage for three communities in the Great Basin in Utah and two communities in the Upper Colorado River Basin are shown in table 12. The analyses by the Utah State Department of Public Health were furnished by L. M. Thatcher and C. K. Sudweeks (written commun., 1961). Population figures are those collected for the 1960 census.

Little data are available on the average annual amount of water used by the communities or the average annual sewage discharge except for Salt Lake City. The average daily use of water by Salt Lake City has been estimated to be 45 million gallons daily (U.S. Dept. of Health, Education, and Welfare, 1962), and the sewage discharge has been estimated to average 32 million gallons daily (U.S. Dept. of Health, Education, and Welfare, 1959). The average daily supply of

TABLE 12.—*Partial chemical analyses, in parts per million, of water supply and sewage for three communities in the Great Basin and two communities in the Upper Colorado River Basin, Utah*

	Salt Lake City (population 189,454		Murray (population 16,806)		Spanish Fork (population 6,472)		Vernal (population 3,655)		Duchesne (population 770)	
	Water supply [1]	Sewage [2]	Water supply [3]	Sewage [4]	Water supply [3]	Sewage [5]	Water supply [6]	Sewage [7]	Water supply [3]	Sewage [3]
Calcium (Ca)	51	138	46	75	105	93	14	50	97	66
Magnesium (Mg)	14	46	18	35	18	50	4	18	23	35
Sodium and potassium (Na+K)	10	445	4	162	63	230	1	34	30	114
Bicarbonate (HCO_3)	184	407	165	403	248	555	56	196	381	490
Sulfate (SO_4)	45	292	35	109	148	192	4	52	64	86
Chloride (Cl)	12	635	13	133	89	159	0	22	11	9
Total dissolved solids	240	1, 780	216	731	593	1, 006	67	322	435	599

[1] Weighted average of one sample each from five sources of supply, analyses U.S. Geol. Survey (Lohr and Love, 1954, p. 427 and 428).
[2] Average of two analyses by U.S. Geol. Survey, 1959 (written commun., 1961).
[3] One analysis by Utah State Dept. of Health (written commun., 1961).
[4] Average of five analyses by Utah State Dept. of Health (written commun., 1961).
[5] Average of six analyses by Utah State Dept. of Health (written commun., 1961).
[6] One analysis by U.S. Geol. Survey, 1958 (Iorns and others, 1964, table 223, p. 560).
[7] Average of two analyses by Utah State Dept. of Health (written commun., 1961).

water is about 240 gpd (gallons per day) per capita, and the average daily sewage discharge is about 170 gpd per capita.

Most of the difference between Salt Lake City's water supply and sewage discharge (70 gpd per capita) is probably water used in watering lawns and washing streets. The amount of water consumptively used in households and by industry is probably small. If the amount of water consumed in households and by industry is assumed to be negligible, and 170 gpd per capita is used for both the water supply and the sewage discharge, the increase attributable to domestic and industrial uses is about 400 tons per year per 1,000 people.

In Murray, Spanish Fork, and Vernal, Utah, industrial establishments are few or none. The sewage discharge for these small communities probably averages about 140 gpd per capita. If the water consumed in households and by industry is assumed to be negligible and the supply is 140 gpd per capita, the data in table 12 indicate the dissolved solids added per year by each 1,000 people are: Murray, 112 tons; Spanish Fork, 88 tons; and Vernal, 54 tons.

An important factor not taken into account in these determinations is the possibility that ground water infiltrates into the sewage disposal system. Ground-water infiltration may result in dilution or in increased dissolved-solids concentration. The latter alternative is probably partly the reason for the relatively high results obtained for Salt Lake City as compared with those obtained for the smaller communities. Also, Salt Lake City is highly industrialized, and its sewage probably includes wastes from at least one petroleum refinery.

Most communities in the Upper Colorado River Basin are comparable to Spanish Fork and Vernal, Utah, although some, which have a few industrial establishments, are comparable to Murray, Utah. A conservative figure of 100 tons per year per 1,000 people has been adopted for this report as the amount of dissolved solids added to the stream system by domestic and industrial uses of water.

Part of the water that is diverted for irrigation never returns to the streams or to ground-water storage. This part is consumed by evaporation in the irrigation canals and fields and by evapotranspiration. A relatively minor amount of water is retained within the plants themselves. The dissolved solids in the irrigation water remain either in the soil, in groundwater recharge, or in the return flow to the stream system. Except in areas where the ground water is not tributary to the stream system, the ground-water reservoirs reach a state of equilibrium, and any recharge from irrigation is rejected as part of the return flow to the stream system.

In addition to the increase of dissolved-solids concentration caused by the consumption of water by irrigation, the total salt load is increased by leaching of the irrigated land. The amount of dissolved solids added to the return flow by leaching depends largely on the amount and solubility of the minerals in the irrigated soils and in the underlying rocks, though other factors—such as irrigation practices, addition of chemical amendments, and fertilizers—may also contribute to the amount of dissolved solids in the return flow. All soils and rocks are soluble to some extent, and thus there will always be additions of dissolved solids to the return flow over and above the amount contained in the diverted water. The only exception will be those few areas where salts are actively increasing in the soil—a situation which finally eliminates possibility of continued irrigation farming.

COMPUTATION OF DISSOLVED SOLIDS ADDED TO THE STREAMS BY THE ACTIVITIES OF MAN

For many areas in the Upper Colorado River Basin, sufficient data were available to compute approximate amounts of dissolved solids that are added to the streams by the activities of man. The results of these computations were used to estimate the amounts of dissolved solids added to the streams in other areas where data were insufficient to compute the effect of the activities of man and the environmental factors such as geology, extent of irrigated lands, and density of population and industry are similar.

Computations were made for drainage basins above gaging stations where determination of long-term dissolved-solids discharge had been computed or for reaches along the main streams where determinations of dissolved solids entering and leaving the reach had been computed. These areas include about 41 percent of the lands under irrigation in the Upper Colorado River Basin—a sample representing a considerable part of the total. The increase in dissolved solids over and above that which can be accounted for in the inflow and natural contributions in these areas is considered to be the amount added to the stream system by the activties of man. Long-term water and dissolved-solids discharges adjusted to 1957 conditions are used, and any transmountain diversions in the areas were assumed to have been in place and in operation throughout water years 1914–57 at their 1957 level of development.

Two examples, which follow, illustrate the method of computation for areas with widely different environments—first, for the basin of the Fraser River, typical headwater stream in Colorado; and second, for the Grand Valley area, which is at an intermediate altitude along the Colorado River between the gaging stations near Cameo, Colo., and near Cisco, Utah.

In the first example, the Fraser River basin, measured inflow is known for the gaging stations on Fraser River near Winter Park (27.6 sq mi)and St. Louis Creek near Fraser (32.8 sq mi). Measured outflow is known for the station on Fraser River at Granby (285 sq mi). Intervening between the inflow stations and the outflow station are 194 square miles of mountainous watershed and 31 square miles (about 20,000 acres) of valley land. Of the valley land, 10,200 acres is irrigated from streams within the area; the remaining 9,800 acres is undeveloped. Table 13 is a summary budget of the water and dissolved solids contributed to and discharged from the intervening area.

The budget for the intervening area is estimated and involves the following considerations:

1. The one unmeasured item of the outflow budget, water consumed on irrigated land, is estimated on the basis of a consumptive use ranging from 0.7 to 1.0 foot. On 10,200 acres, therefore, aggregate consumption is from 7,000 to 10,200 acre-feet a year. This consumption represents net depletion of streamflow for conditions existing in 1957. Solids that were dissolved in the consumed water must, in the long run, be discharged from the area as part of the dissolved-solids load passing the gaging station at Granby.
2. Unmeasured natural inflow to Fraser River may be considered in two parts, ground-water contribution and direct runoff (surface water). The geology of the area indicates that the ground-water contribution to the Fraser River would mostly come from the valley fill underlying the 20,000 acres of valley land. Precipitation, which over the valley land averages about 20 inches annually, would be the principal source of ground-water recharge under natural conditions. Evapotranspiration at this altitude consumes about 12 to 15 inches of the annual precipitation. Of the remainder it is estimated that under natural conditions 3 to 5 inches recharged the ground-water reservoir and 2 to 3 inches was direct runoff. Accordingly from the 20,000 acres of valley land, the unmeasured ground-water inflow to Fraser River under natural conditions would be from about 5,000 to 8,400 acre-feet a year. Presumably, its natural dissolved-solids content would have ranged from 35 to 50 ppm, in accord with chemical analyses of water from adjacent streams during low flow (Fraser River near Winter Park, 38 ppm; St. Louis Creek near Fraser, 58 ppm; and Ranch Creek near Tabernash, 37 ppm).
3. The surface-water inflow is calculated to balance the inflow-outflow budget. So calculated, the amount ranges from 91,200 to 97,700 acre-feet a year, or on the average from 405 to 435 acre-feet a year per square mile of intervening area. The calculation agrees in magnitude with virgin yields per square mile from adjacent gaged drainage areas that have a similar hydrologic environment: Williams Fork above Williams Fork Reservoir, 490 acre-feet per square mile; and Willow Creek above Willow Creek Reservoir, 480 acre-feet per square mile. Concentration of dissolved solids in this unmeasured surface-water inflow under natural conditions should not differ greatly from the mean of weighted-average concentrations at the stations near Winter Park and near Fraser. A concentration of 36 ppm is assigned in the budget.

Effluent ground water and net depletion by irrigation are complimentary in the sense that if the estimate of one tends to be too large, that of the other

TABLE 13.—*Water and dissolved-solids budget, Fraser River basin and Grand Valley area*

[Data are for water years 1914–57 adjusted to 1957 conditions]

	Drainage area (sq mi)	Average annual discharge (acre-ft)	Dissolved solids		
			Weighted-average concentration (ppm)	Tons per year	Tons per square mile per year
FRASER RIVER BASIN, COLORADO					
Inflow:					
Fraser River near Winter Park	27.6	15,100	30	620	22.5
St. Louis Creek near Fraser	32.8	17,000	41	950	28.9
Unmeasured surface water	225	91,200–97,700	36	4,470–4,790	19.8–21.3
Unmeasured natural ground water	31	8,400–5,000	35–50	570–240	18.4–7.8
Total		131,700–134,800		6,600	23.2
Outflow:					
Consumed on irrigated land		7,100–10,200			
Fraser River at Granby	285	124,600	47	8,040	28.2
Total		131,700–134,800		8,040	
Increase from unbudgeted sources				1,440	[1] 90.6
GRAND VALLEY AREA					
Inflow:					
Colorado River near Cameo, Colo	8,060	2,998,000	387	1,578,000	196
Plateau Creek near Cameo, Colo	604	170,200	285	66,100	109
Gunnison River near Grand Junction, Colo	8,020	1,884,000	592	1,519,000	189
Dolores River near Cisco, Utah	4,630	681,000	496	460,200	100
Unmeasured natural runoff from drainage area north of Colorado River	2,216	22,100	900–1,470	27,000–44,200	12–20
Unmeasured natural runoff from drainage area south of Colorado River	554	17,700	200–350	4,800–8,400	9–15
Natural ground water		(2)		(2)	
Total		5,773,000		3,655,100–3,675,900	152–153
Outflow:					
Natural channel and riparian-vegetation losses		39,000			
Other depletions		200,000			
Colorado River near Cisco, Utah	24,100	5,534,000	547	4,120,000	171
Total		5,773,000		4,120,000	
Increase from unbudgeted sources				464,900–444,100	[3] 3,580

[1] Equivalent to 0.14 ton per acre of irrigated area.

(2) Nominal only.

[3] Minimum value per square mile of irrigated area. Equivalent to 5.6 tons per acre of irrigated land after deducting domestic and industrial contribution.

tends to be too small. In this particular subbasin budget, the volumes and dissolved-solids loads (tons per year) compensate one another algebraically.

The inflow items of the budget are so derived as to account for all the dissolved-solids load that should pass the measured-outflow station if there were no activities by man within the area. Yet the computed outflow load includes the effects of man's activities as of 1957. For the Fraser River basin, it exceeds the computed inflow load by 1,440 tons per year. This difference is due to man's activities, principally irrigation.

In the second example, that of the Grand Valley area, water and dissolved-solids inflow are recorded at the gaging stations on the Colorado River and Plateau Creek near Cameo, Colo., Gunnison River near Grand Junction, Colo., and Dolores River near Cisco, Utah (chap. C, table 14). Water and dissolved-solids outflow are recorded at the gaging station on Colorado River near Cisco, Utah (chap. C, table 14).

The area that intervenes between the inflow and outflow stations is 2,770 square miles—about 2,216 square miles north of the Colorado River and 554 square miles south of the river. Here, mean altitude and relief of the land surface are considerably less than in the Fraser River basin just described. Average yearly precipitation is from 8 to 10 inches on the lower part of the area. Of the intervening valley lands, about 78,700 acres (123 sq mi) is irrigated; 3,000 acres of this irrigated land is in the basin of the Little Dolores

River. Table 13 summarizes inflow and outflow of water and of dissolved solids.

In this second example the unmeasured natural runoff from the intervening areas north and south of the Colorado River is known to be relatively small and is estimated to average 10 and 32 acre-feet per square mile per year, respectively. Some of these average values are derived from inflow data in a report by the Upper Colorado River Basin Compact Commission (1948, p. 48), and others are determined from the characteristics of a few streams in other parts of the Colorado River Basin, under much the same hydrologic environment. In this runoff the dissolved-solids concentration is estimated to range from 900 to 1,470 ppm in the north-side area. This range is based on partial chemical analyses of storm runoff in eight stock ponds in Badger Wash (K. R. Melin, oral commun.,) and the specific conductance of Westwater Creek in the summer of 1958. In contrast, the dissolved-solids concentration in the south-side area is estimated to range from 200 to 350 ppm. This range is based on chemical analyses of Little Dolores River near the Colorado-Utah State line and of West Creek at Gateway, Colo. (Iorns and others, 1964, table 220).

The conclusion that there would be no appreciable ground-water inflow from the intervening area under natural conditions is compatible with topographic, geologic, and climatic characteristics. In such an area substantially all the precipitation, about 8 to 10 inches, either runs off or is returned to the atmosphere by evapotranspiration.

Among the outflow items is one designated as "other depletions." Depletions in this category include water lost as evapotranspiration by irrigated crops and underflow that bypasses the outflow station or adds to ground-water storage beneath the irrigated area. In the Grand Valley area a depletion of 200,000 acre-feet a year is compatible with an irrigated acreage of 78,700, a precipitation of 10 inches or less, and a consumptive use of 30 inches by irrigated crops. This value is somewhat larger than the value given by the Upper Colorado River Compact Commission; their estimate of consumptive use of water in the Grand Valley was 146,000 acre-feet a year. Available records indicate that virtually no underflow can bypass the outflow station at Cisco. Continuing accretion to ground-water storage is considered unlikely because irrigation in the Grand Valley has been practiced so long that ground-water storage and return flow to the river have probably reached a state of approximate equilibrium.

Of the increase from unbudgeted sources, less than 1 percent may conceivably be caused by domestic and industrial wastes. About 35,000 people live in the area—19,000 in Grand Junction and 16,000 on farms and in other communities. If the dissolved-solids contribution from domestic and industrial wastes were assumed to be 100 tons per year per 1,000 people, the aggregate from all the area would amount to about 3,500 tons annually. This estimate is probably large (see p. 62); even so, it is only about 0.8 percent of the total dissolved-solids increase derived in the budget.

For the Grand Valley area the unbudgeted increase in dissolved-solids load—at least 440,000 tons per year, or 5.6 tons per year per irrigated acre—may be attributed to irrigation.

In the preceding two inflow-outflow budgets, used as examples, the indicated yields of dissolved solids per unit of area range widely. In this connection it is noteworthy that a large yield per unit area requires not only a substantial quantity of available soluble material in the rocks, in their weathering products, and in the soils—but also sufficient percolating and flowing water to dissolve the soluble and transport it to a stream. Conversely, a small dissolved-solids yield per unit of area implies any one of three environmental conditions: (1) little soluble material exists or ever existed in the soil and rocks of the area, (2) precipitation and runoff are so great and so widely dispersed that all the soil and rocks long since have been thoroughly leached to a substantial depth below the land surface, even though solubles may be plentiful at greater depth, or (3) precipitation is so very little that, even though solubles may be plentiful, leaching and transport of salts to the stream are minimal. All three of these environments exist in the Upper Colorado River Basin. It is implicit in this situation that, to characterize any particular area, water and dissolved solids contributions must be considered jointly.

Water and dissolved-solids budgets were made for 19 other areas in the Upper Colorado River Basin and are given in chapters C, D, and E of this report. All these budgets were derived by methods discussed in the preceding two examples. In these budgets the excess of dissolved-solids outflow over dissolved-solids inflow is commonly derived as a range also. This range may be construed as defining probable minimum and maximum values for the effect of man's activities in the particular subbasin, because each inflow budget seeks to conservatively account for all natural accretions to the dissolved-solids at the outflow station, so far as those accretions are measured or can reasonably be inferred from existing data. Only the minimum values are carried forward into summaries at gaging stations, for the subbasins, and for the divisions in the Upper Colorado River Basin.

The results of the computations on the probable effect of irrigation in 21 areas are summarized in table 14, which includes data on average precipitation on the areas and information on the underlying formations. The effects of irrigation on the dissolved-solids load on the streams vary with major rock classes, as the rocks influence the relative quantities of soluble salts contained in the overlying soils.

TABLE 14.—*Yield rates of dissolved solids from irrigated lands in 21 areas that are about 41 percent of the irrigated lands in the Upper Colorado River Basin*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Area	Underlying formation	Average annual precipitation (inches)	Dissolved solids (tons per acre per yr)
Fraser River basin, Colorado	Precambrian rocks and North Park Formation.	16–25	0.1
Colorado River Basin below Granby and Willow Creek Reservoirs and above Hot Sulphur Springs, Colo., exclusive of Fraser River basin, Colorado.	Alluvium derived from Precambrian rocks, Tertiary volcanics, and Middle Park Formation.	14–16	1.0
Troublesome Creek basin, Colorado	North Park Formation	12–16	.5
Roaring Fork basin, Colorado	Permian rocks, Mancos Shale, and Mesaverde Formation.	18–25	3.0
Gunnison River basin below Gunnison tunnel and Uncompahgre River Valley below Colona, Colo.	Mostly Dakota Sandstone and Mancos Shale of Cretaceous age.	8–16	5.0
Colorado River Basin below Plateau Creek and Gunnison River and above Dolores River.	Mancos Shale	8–10	5.6
San Miguel River basin between Placerville and Naturita, Colo.	Dakota Sandstone and Morrison Formations	12–16	2.8
New Fork River basin above Boulder Creek, Wyo	Alluvium of glacial origin	12–16	.5
Fontenelle Creek basin, Wyoming	Mostly Wasatch and Green River Formation of Tertiary age.	10–16	1.3
Big Sandy Creek basin, Wyoming	Shallow alluvium underlain by Bridger Formation.	8–10	4.4
Blacks Fork basin above Muddy Creek, Wyo	River alluvium underlain by Green River and Bridger Formation.	8–10	.9
Hams Fork above Frontier, Wyo	River alluvium underlain by Wasatch Formation.	12–16	.3
Yampa River basin between Morrison Creek and Steamboat Springs, Colo.	Alluvium of glacial origin	25–30	.2
Elk River basin, Colorado	Mancos shale	20–30	.4
Little Snake River basin above Dixon, Colo	River alluvium underlain by Fort Union, Lance, and Bridger Formations and Mancos Shale.	16–30	1.2
Ashley Creek basin, Utah	Alluvium underlain by Mancos Shale	8–12	2.1
Duchesne River basin above Duchesne, Utah	Uinta Formation	9–14	3.3
White River basin between Buford and Meeker, Colo	Permian rocks and Mancos Shale	19–28	4.8
San Rafael basin, Utah	Shales of Cretaceous age	8–10	3.2
La Plata River basin, Colorado	Alluvium underlain by Mesaverde Formation	12–20	.5
La Plata River basin, New Mexico	Mesaverde Formation and Tertiary rocks	8–12	1.4

COMPUTING SEDIMENT DATA

Curves showing relation between the concentration of suspended sediment and the discharge of the stream at the time of sampling were prepared for many streams where samples had been collected on less than a daily basis. Figure 26 is an example of this relation. On the basis of data obtained from these curves and the flow-duration tables of streamflow for water years 1914–57 adjusted to 1957 conditions, duration tables of suspended-sediment discharge were computed. (See table 15.) As the curves showing relation between suspended-sediment concentration and water discharge were based on data obtained during the latter part of the 44-year period, the computed suspended-sediment discharges are representative of conditions existing in 1957. A more detailed explanation of this method of computing suspended-sediment discharge, is given by Miller (1951).

WATER-QUALITY CRITERIA

Water is commonly described as good or bad; these relative terms are meaningless unless the use for the water is known. For example, a high-percent-sodium water may be bad if it is used for irrigation, but acceptable if it is used for domestic purposes.

PROPERTIES AND CHARACTERISTICS OF WATER

PHYSICAL PROPERTIES

Water is used in each of its three physical states. Water as a gas is water vapor; as a liquid it is water, dew, or rain; and as a solid it is ice, snow, hail, or frost. Temperature determines the physical state of water and also its density. A unique characteristic of water is that it freezes at 32°F but has its greatest density at 39.2°F.

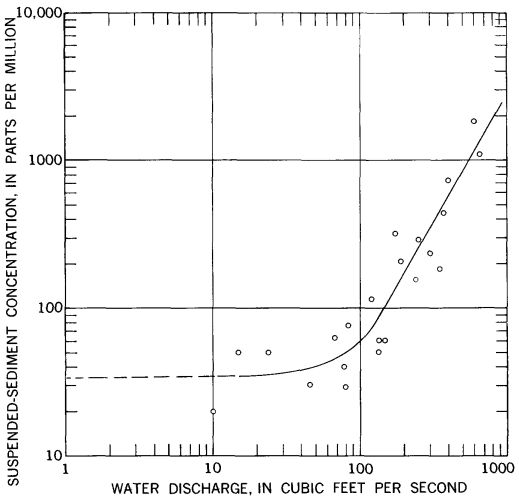


Figure 26.—Relation of concentration of suspended sediment to water discharge, Savery Creek at upper station near Savery, Wyo.

The rate of evaporation from a water surface is controlled by such factors as temperature of the air and water, differences in vapor pressure, humidity, solar radiation, wind movement, altitude or barometric pressure, and the chemical quality of the water. Surface tension is one of the fundamental properties of liquid surfaces and produces capillarity, which is of great importance in the movement of ground water.

Water in movement has the ability to suspend and transport sediment. The amount of sediment that can be transported by water depends upon the size, specific gravity, and shape of the sediment particles, the forces acting upon the particles, and the amount of water flowing.

CHEMICAL PROPERTIES AND CHARACTERISTICS

Water that falls to the earth as rain or snow is virtually devoid of dissolved constituents except for small amounts of dissolved gases, such as carbon dioxide. Natural waters in streams, lakes, oceans, and ground-water reservoirs contain dissolved mineral matter in variable amounts. These dissolved minerals are derived from the rocks and soils with which the water has been in contact. Differences in the dissolved-mineral composition and concentration of waters are due to differ-

Table 15.—*Duration table of water discharge and suspended-sediment discharge and concentration, Savery Creek at upper station near Savery, Wyo.*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Duration table percentage			Water discharge		Suspended-sediment concentration for mean of time interval (ppm)	Suspended-sediment discharge	
Time limits	Time interval	Mean of interval	Discharge for mean of interval (cfs)	Increment of discharge in time interval (cfs)		Discharge for mean of interval (tons per day)	Increment of discharge in time interval (tons per day)
1	2	3	4	5	6	7	8
0.00–0.02	0.01	0.02	515	0.1	900	1,250	0.2
.02–0.10	.06	.08	475	.4	780	1,000	.8
.10–0.20	.15	.10	440	.4	680	808	.8
.20–1.00	.6	.80	370	3.0	505	504	4.0
1.00–3.00	2.0	2.0	288	5.8	327	254	5.1
3.00–5.00	4.0	2.0	229	4.6	220	136	2.7
5.00–9.00	7.0	4	178	7.1	143	69	2.8
9–15	12	6	128	7.7	80	28	1.7
15–25	20	10	74	7.4	47	9.4	.9
25–35	30	10	38	3.8	38	3.9	.4
35–45	40	10	27	2.7	36	2.6	.3
45–55	50	10	22	2.2	35	2.1	.2
55–65	60	10	18	1.8	35	1.7	.2
65–75	70	10	15	1.5	35	1.4	.1
75–85	80	10	12	1.2	34	1.1	.1
85–95	90	10	9.3	.9	34	.9	.1
95–99	97	4	4.2	.2	34	.4	0
99–99.8	99.4	.8	.9	0	33	.1	0
99.8–100	99.9	.2	.5	0	33	.0	0
Totals	100.00	------------	------------	50.8	------------	------------	20.4

1. Limits of spread of time interval used in integrating area under duration curves by partial areas.
2. Spread of time interval.
3. Selected percentages on duration curves used in duration table for this study.
4. Flow-duration table of water discharge for water years 1914–57 adjusted to 1957 conditions.
5. Column 2 times column 4 divided by 100.
6. From fig. 26 for water discharges in column 4. This is duration table of suspended-sediment concentration.
7. Column 4 times column 6 times 0.0027. This is duration table of suspended-sediment discharge.
8. Column 2 times column 7 divided by 100.

ences in the mineral composition of the rocks and in the solubility of these minerals. The different types of rocks and soils and the solubility of the minerals therein affect the rate of leaching.

The mineral constituents that affect the value of water for most uses are silica, iron, manganese, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrate, and boron. Detailed discussions of these constituents are found in Clarke (1924), California Institute of Technology (1957), and Hem (1959).

Other chemical properties and characteristics of water that are of importance are temperature, dissolved-oxygen content, color, turbidity, hydrogen-ion concentration, acidity, alkalinity, specific conductance, hardness, sodium-adsorption-ratio, and corrosiveness. These terms are explained by Lohr and Love (1954 p. 2–13, 427, 428) and Hem (1959).

Water is classified as to type on the basis of predominate mineral constituents. Whether certain cations (calcium, magnesium, sodium, and potassium) and certain anions (bicarbonate, sulfate, and chloride) predominate depends on the concentrations in equivalents per million and the relation of the concentration of the individual ions to each other. For example, if the concentration of sodium makes up most of the total cations and the concentration of bicarbonate makes up most of the total anions, the water is classified as a sodium bicarbonate type. However, if the second most abundant cation or anion is more than half the most abundant cation or anion, and the third most abundant cation or anion is more than half the second, they are included in the water-type classification in order of magnitude. Examples of these more complex water types would be calcium magnesium bicarbonate, calcium magnesium bicarbonate sulfate, and sodium magnesium calcium chloride sulfate.

WATER-QUALITY CRITERIA FOR MAJOR USES

The chemical and physical properties of a water are often the factors that control its use. An ample supply of water is of little moment if the quality of water is such that it cannot be used for the purpose desired. For example, the ocean is an unlimited source of water, but the high concentration of dissolved solids in sea water prevents its use at the present time except for very limited purposes. The following discussion of the criteria that are used to appraise the suitability of water for various uses is by no means complete, and the reader is referred to the literature for more complete discussions of water-quality criteria. Only the dissolved constituents that are normally determined by the Geological Survey were used in the appraisal.

DOMESTIC USE

A water that is turbid, or noticeably colored, or has an unpleasant or unusual odor or taste should obviously not be used for domestic purposes if clarification is practicable or if a more acceptable supply is available. (U.S. Public Health Service, 1962.) Moreover, the water should be reasonably cool and noncorrosive, should not form deposits, and should be free of disease-causing organisms.

The U.S. Public Health Service (1962) has devised standards for the drinking water furnished by interstate carriers. This agency was empowered to set the standards under the provisions of the Interstate Quarantine Regulations, which were enacted in 1914. The standards are mandatory only for waters used for drinking and cooking on railroad cars, aircraft, vessels, and any other carriers engaged in interstate traffic. However, the American Water Works Association has adopted and has recommended these standards for all public water supplies. The standards for the chemical constituents usually considered to be most important are listed in the following tables. Water containing dissolved material in excess of the listed concentrations should not be used where more suitable supplies are, or can be made, available.

Substance	*Maximum concentrations (ppm)*
Iron	0.3
Manganese	.23
Chloride	250
Nitrate	45
Sulfate	250
Total dissolved solids	500

When fluoride is naturally present in drinking water, the concentration should not average more than indicated in the following table:

Annual average of maximum daily air temperatures	*Maximum concentration of fluoride (ppm)*
50.0–53.7	1.7
53.8–58.3	1.5
58.4–63.8	1.3
63.9–70.6	1.2
70.7–79.2	1.0
79.3–90.5	.8

Concentrations of chemical constituents that exceed certain limits may be very undesirable. Surface waters seldom contain as much as 1 ppm of dissolved iron; although in some regions, where the water is acid, large concentrations of iron may be in solution. Iron and manganese in solution may cause reddish-brown stains on porcelain or enameled ware and fixtures and on fabrics washed in the water. The effect of sulfates and especially magnesium sulfate on the digestive tract is well known, and concentrations of these salts high enough to produce cathartic effects should be avoided. The salty taste of water due to chloride can be detected by most people when the concentration of chloride exceeds 500 ppm.

Small quantities of fluoride in the water supply have been shown to lessen the incidence of dental caries. The American Dental Association recommends that water used for drinking by children should contain about 1.0 ppm of fluoride. However, when the fluoride content of the water supply exceeds about 2.00 ppm, the enamel of children's teeth may become irregularly stained or mottled (Dean, 1936).

In a report by the National Research Council, Maxcy (1950, p. 271) stated that nitrates in excess of 44 ppm may cause cyanosis in infants (blue babies). Nitrate in surface water is usually present in concentrations of less than 5 ppm, which is too low to adversely affect the value of the water for most purposes. In surface waters the aquatic vegetation is constantly utilizing nitrate by converting it to organic nitrogen in the plant cells by photosynthetic action. Thus, nitrates are seldom abundant in surface water. Nitrate may be present in ground water as a result of leaching of fertilizer or effluent from cesspools; and because photosynthetic action is not active beneath the ground, the nitrates in ground water will remain. Harmful amounts of nitrate are much more likely to be found in ground water than in surface water.

Hardness is the characteristic of water that is most often recognized by the difficulty of producing a lather or by the increased quantity of soap necessary to form a lather. Hard water is also objectionable because it causes the formation of scale in pipes, boilers, and other equipment. Hardness is caused principally by compounds of calcium and magnesium. Other constituents such as iron, aluminum, strontium, barium, zinc, and free acid also cause hardness, although these constituents are usually not in the water in sufficient quantity to be troublesome.

Hardness may be classified as follows:

Hardness (ppm)	*Rating*	*Usability*
<60	Soft	Suitable for many uses without further softening.
61–120	Moderately hard	Usable except in some industrial applications. Softening profitable for laundries.
121–180	Hard	Softening required by laundries and some other industries.
>180	Very hard	Softening desirable for most purposes.

INDUSTRIAL USE

The mineral constituents in water and the properties and characteristics of water determine whether the water can be used for specific industrial purposes. Water-quality tolerances for some industrial applications are given in table 16. The chemical analyses of waters, when compared with the data in table 16, indicate the suitability of the water for industrial purposes.

AGRICULTURAL USE

The successful use of water for irrigation depends on many factors such as climate, texture and internal drainage of the soil and subsoil, management of the soil or farming practices, crops, and the chemical quality of the water used for irrigation. The importance of individual ions depends on their effect on the structure of the soil, their physiological effect on the plants, and on how they combine with other ions after the water is applied to the land.

IMPORTANT MINERAL CONSTITUENTS

The following constituents are important in determining the suitability of water for irrigation:

Calcium.—The element calcium is essential for plant growth and, in addition, has a beneficial effect on the soil. Therefore, in reasonable concentration, calcium is a desirable constituent in irrigation water. If sufficient calcium ions are adsorbed on the soil colloids, the soil will be friable and will readily absorb and transmit water. High concentrations of calcium, however, as of any other ion, can be harmful to plants.

Magnesium.—In many respects magnesium is similar to calcium and is essential for plant growth. Water in which the concentration of magnesium is high is undesirable for irrigation because of the adverse effect of high concentrations on plants.

Sodium.—One of the essential plant nutrients is sodium. In irrigation, however, its importance as a plant nutrient is often outweighed by its undesirable effects on the soil. If the concentration of sodium in equivalents per million exceeds that of calcium plus magnesium, the sodium will tend to replace the calcium ions on the soil coloids. Such a soil becomes almost impermeable to water and drains with difficulty.

Potassium.—An essential plant nutrient is potassium, whose chemical reactions are similar to those of sodium. Concentrations of potassium in waters are usually so low as to have no effect on the classification of the waters for irrigation.

Carbonate and bicarbonate.—If calcium and magnesium are precipitated in the soil as carbonates, the percent sodium would obviously increase and an alkali soil would result. Therefore, the ratio of the concentration of carbonate and bicarbonate to calcium, magnesium, and sodium is sometimes a critical factor in the classi-

TABLE 16.—*Water-quality tolerances for industrial applications*

[Data adapted from Am. Water Works Assoc. (1950, tables 3, 4, p. 66–67). Allowable limits in parts per million except as indicated]

General: A, no corrosiveness; B, no slime formation; C, conformance to Federal drinking water standards necessary; D, NaCl, 275 ppm.

Industry	Turbidity	Color units	Color units $+O_2$ consumed	Dissolved oxygen (ml per l)	Odor	Hardness	Alkalinity (as $CaCO_3$)	pH	Total solids	Ca	Fe	Mn	Fe+Mn	Al_2O_3	SiO_2	Cu	F	CO_3	HCO_3	OH	$CaSO_4$	Na_2SO_4 to Na_2SO_4 ratio	General
Air conditioning [1]											0.5	0.5	0.5										A, B
Baking	10	10				(2)					.2	.2	.2										C
Boiler feed:																							
0–150 psi	20	80	100	2		75		8.0+	3,000–1,000					5	40			200	50	50		1:1	
150–250 do	10	40	50	.2		40		8.5+	2,500– 500					.5	20			100	30	40		2:1	
>250 do	5	5	10	0		8		9.0+	1,500– 100					.05	5			40	5	30		3:1	
Brewing: [3]																							
Light beer	10				Low		75	6.5–7.0	500	100–200	.1	.1	.1				1				100–200		C, D
Dark beer	10				do		150	7.0	1,000	200–500	.1	.1	.1				1				200–500		C, D
Canning:																							
Legumes	10				do	25–75					.2	.2	.2										C
General	10				do						.2	.2	.2				1						C
Carbonated beverages [4]	2	10	10		0	250	50		850		.2	.2	.3				.2						C
Confectionery					Low			(5)	100		.2	.2	.2										
Cooling [6]	50					50					.5	.5	.5										A, B
Food, general	10				Low						.2	.2	.2										C
Ice (raw water) [7]	1–5	5					30–50		300		.2	.2	.2		10								C
Laundering						50					.2	.2	.2										
Plastics, Clear, Uncolored	2	2							200		.02	.02	.02										
Paper and pulp: [8]																							
Groundwood	50	20				180					1.0	.5	1.0										A
Kraft pulp	25	15				100			300		.2	.1	.2										
Soda and sulfite	15	10				100			200		.1	.05	.1										
Light paper, HL-Grade	5	5				50			200		.1	.05	.1										B
Rayon (viscose) pulp:																							
Production	5	5				8	50		100		.05	.03	.05	8.0	25	5							
Manufacture	.3					55		7.8–8.3			.0	.0	.0										
Tanning [9]	20	10–100				50–135	135	8.0			.2	.2	.2										
Textiles:																							
General	5	20				20					.25	.25											
Dyeing [10]	5	5–20				20					.25	.25	.25										
Wool scouring [11]		70				20					1.0	1.0	1.0										
Cotton bandage [11]	5	5			Low	20					.2	.2	.2										

[1] Waters with algae and hydrogen sulfide odors are unsuitable for air conditioning.

[2] Some hardness desirable.

[3] Water for distilling must meet the same general requirements as for brewing (gin and spirits mashing water of light-beer quality; whiskey mashing water of dark-beer quality).

[4] Clear, odorless, sterile water for syrup and carbonization. Water consistent in character. Most high quality filtered municipal water not satisfactory for beverages.

[5] Hard candy requires pH of 7.0 or greater, as low value favors inversion of sucrose, causing sticky product.

[6] Control of corrosiveness is necessary as is also control of organisms, such as sulfur and iron bacteria, which tend to form slimes.

[7] $Ca(HCO_3)$ particularly troublesome. $Mg(HCO_3)$ tends to green tint. CO_2 assists to prevent cracking. Sulfates and chlorides of Ca, Mg, Na should each be less than 300 ppm (white butts).

[8] Uniformity of composition and temperature desirable. Iron objectionable as cellulose adsorbs iron from dilute solution. Manganese very objectionable, clogs pipelines and is oxidized to permanganates by chlorine, causing red tint.

[9] Excessive iron, manganese or turbidity creates spots and discoloration in tanning of hides and leather goods.

[10] Constant composition; residual alumina 0.5 ppm.

[11] Calcium, magnesium, iron, manganese, suspended matter, and soluble organic matter may be objectionable.

fication of an irrigation water. Residual sodium carbonate may be present if the carbonate is in excess of the combining weights of calcium and magnesium.

Sulfate and chloride.—Sulfate is an essential plant nutrient, whereas high concentrations of chloride are toxic to most land plants, especially fruit trees. Sulfate is about half as toxic as chloride.

Boron.—The presence of boron in irrigation water is critical because a very slight amount of boron is toxic to many plants. However, boron is one of the essential plant nutrients and some must be available to plants for proper growth. Limiting concentrations of boron for several classes of irrigation water for different crops (Scofield, 1936) are given in the following table.

Permissible limits of boron, in parts per million, for several classes of irrigation water

Classes of water		Crops		
Rating	Grade	Sensitive	Semi-tolerant	Tolerant
1	Excellent	0.33	0.67	1.00
2	Good	0.33-0.67	0.67-1.33	1.00-2.00
3	Permissible	.67-1.00	1.33-2.00	2.00-3.00
4	Doubtful	1.00-1.25	2.00-2.50	3.00-3.75
5	Unsuitable	1.25	2.50	3.75

SUITABILITY FOR IRRIGATION

Irrigation specialists have known for a long time that the chemical quality of the water is important in determining the economic feasibility of any irrigation project. Several methods of classifying water for irrigation have been developed, and all are based on the mineral content of the water. The different classifications are empirical in that they are based on field observation, experience, and research in plant tolerance and are predicated on the presumption that the soil to be irrigated is neither impermeable nor exceptionally porous, that the correct soil management practices are followed, and that, in general, average conditions prevail.

Wilcox developed a diagram that may be used to rate water for irrigation on the basis of specific conductance and percent sodium. Thorne and Thorne (1951, p. 10) modified the Wilcox diagram to include more classes of water and to define more clearly the probable effect of the water and the required irrigation practices, soils, and drainage.

The U.S. Salinity Laboratory Staff (1954) introduced the sodium-adsorption-ratio (SAR) as a method of predicting the sodium or alkali hazard in the use of irrigation water. SAR is calculated by dividing the sodium concentration by the square root of one-half the calcium and magnesium concentration (all concentrations are in equivalents per million). The interpretation of salinity and sodium hazards indicated by a diagram (fig. 27) devised by the U.S. Salinity Laboratory Staff is as follows:

Low-salinity water (C1) can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of extremely low permeability.

Medium-salinity water (C2) can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control.

High-salinity water (C3) cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required and plants with good salt tolerance should be selected.

Very high salinity water (C4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must be permeable, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and a very salt-tolerant crop should be selected.

The classification of irrigation waters with respect to SAR is based primarily on the effect of exchangeable sodium on the physical condition of the soil. Sodium-sensitive plants may, however, be injured as a result of

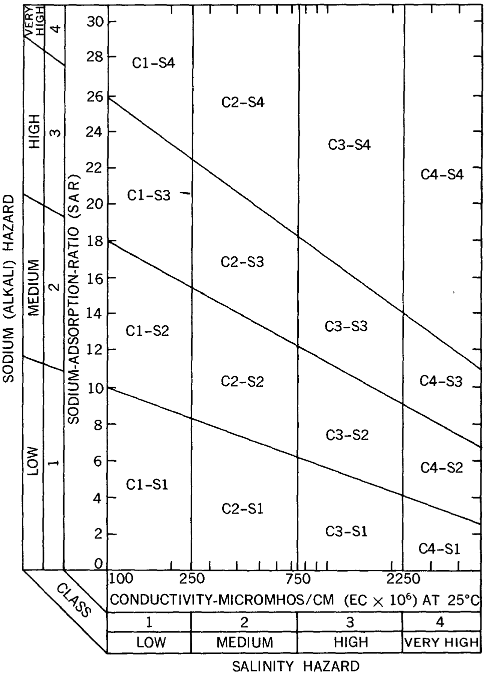


FIGURE 27.—Classification of irrigation waters by U.S. Salinity Laboratory Staff.

sodium accumulation in plant tissues when exchangeable sodium values are lower than those effective in causing deterioration of the physical conditions of the soil.

Low-sodium water (S1) can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. However, sodium-sensitive crops such as stone-fruit trees and avocados may accumulate injurious concentrations of sodium.

Medium-sodium water (S2) will present an appreciable sodium hazard in fine-textured soils having high cation-exchange-capacity, especially under low-leaching conditions, unless gypsum is present in the soil. This water may be used on coarse-textured or organic soils with good permeability.

High-sodium water (S3) may produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching, and organic-matter additions. Gypsiferous soils may not develop harmful levels of exchangeable sodium from such waters. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

Very high sodium water (S4) is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soils or use of gypsum or other amendments may make the use of these waters feasible.

When the content of bicarbonate and carbonate of an irrigation water exceeds that of calcium plus magnesium, residual sodium carbonate may form if the calcium and magnesium are precipitated as carbonates. Thus, the formation of residual sodium carbonate will accompany the increase in percent sodium. The residual sodium carbonate will cause the water to be alkaline, and the organic material of the soil will dissolve. The color of the soil will become a grayish black, a condition referred to as "black alkali." Wilcox, Blair, and Bower (1954, p. 265–266) studied the effects of residual sodium carbonate. The following tabulation summarizes their tentative conclusions:

Residual sodium carbonate (epm)	*Suitability for irrigation*
>2.5	Not suitable.
1.25–2.5	Marginal.
<1.25	Probably safe.

They point out that the amount of leaching will modify the permissible limit to some extent.

Leaching is required because the water applied to the land will be reduced in volume and the salts will become more concentrated by evaporation and plant uptake. Water, as it moves through the soil, will displace the antecedent water downward. Therefore, to keep salts from accumulating in the root zone of the soil, part of the applied irrigation water must be used to leach and transport the salts beyond the root zone. Obviously, the more saline the applied water, the more water necessary for required leaching.

The deleterious effects caused by using irrigation water of unsuitable quality can be partly offset by adding gypsum to (1) adjust the percent sodium below 70 (considered to be a maximum safe level), (2) offset carbonate precipitation with calcium and magnesium, and (3) supply calcium and magnesium taken by the plants in excess of sodium.

Eaton (1954) presented a method for estimating (1) the percentage of irrigation water that must move downward beyond the root zone and (2) the amount of gypsum required to reduce the percent sodium and residual sodium carbonate of an irrigation water to safe levels. The ratio of the amount of water that moves downward through the root zone to the amount of water that is applied to the land is the percentage of leaching. "Required leaching" is the percentage of leaching that is necessary to keep the root zone free of excessive accumulations of salts.

Eaton's formulas (1954) and explanation of symbols used in the formulas are as follows:

Sw—Salinity of irrigation waters expressed as milliequivalents per liter of chloride plus one-half the sulfate.

d and D—Tentative (d) and final (D) are percentages of applied irrigation water passed through the root zone as drainage.

Mss—Salinity of mean soil solution measured as chloride plus half the sulfate, milliequivalent per liter. The value 40 is taken as a Mss concentration that is expected to produce reasonable yields; and the value 20, to produce good yields of crops of intermediate salt tolerance grown in a semiarid climate, such as that at Riverside, Calif.

Required leaching for good yield—tentative

$$d=\frac{Sw\times 100}{(2\times Mss)-Sw}$$

or

$$d=\frac{Sw\times 100}{(2\times 20)-Sw}$$

Calcium requirements—calcium in milliequivalents per liter:

a. To adjust water to 70 percent sodium:

$$(\text{Na}\times 0.429)-(\text{Ca}+\text{Mg})=\text{Ca}$$

(retain plus or minus sign)

b. To offset HCO_3 precipitation:

$$\frac{\text{HCO}_3\times(100-d)}{100}=\text{Ca}$$

c. To supply calcium plus magnesium taken by plants in excess of sodium:

$$\frac{0.30\times(100-d)}{100}=\text{Ca}$$

$$\text{"Total Ca"}=a+b+c$$

Multiply "total Ca" by 234 to get pounds of gypsum per acre-foot of irrigation water.

Required leaching for good yield—final

$$\frac{(Sw+\tfrac{1}{2}\text{ "total Ca"})\times 100}{(2\times Mss)-(Sw+\tfrac{1}{2}\text{ "total Ca"})}=D$$

Eaton (1954) defined a reasonable yield as the production level of crops; that is, between 70 and 80 percent of yields obtained in a semiarid climate on nonsaline soil; he defined a good yield as 85 to 90 percent.

By use of the previously described methods and chemical analyses of water for high, medium, and low discharges, the suitability of the water for irrigation at many sites in the Upper Colorado River Basin was investigated and the results tabulated in tables in the report. The data indicate the chemical suitability of water for irrigation where average conditions prevail with respect to soil, irrigation and drainage practices, climate, and type of crops. Deviations in these variables may permit the use of a water of poor quality or cause a water of good quality to be unsafe for irrigation. Successful irrigation with marginal waters is possible in many places having soil and water amendments and good management practices.

The amounts of required gypsum computed by Eaton's formulas are based on obtaining good yields and on the assumption that all calcium to adjust the percent sodium to 70, to offset bicarbonate precipitation, and to supply the calcium needs of the plants must come from the irrigation water. This may not be applicable to all irrigated lands in the Upper Colorado River Basin as generally the soils are gypsiferous, and the addition of gypsum would not be necessary until the natural gypsum was depleted.

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Surface-Water Resources of the Grand Division

By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

WATER RESOURCES OF THE UPPER COLORADO RIVER BASIN—TECHNICAL REPORT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 441-C

Analysis and appraisal of the water resources of the Grand division of the Upper Colorado River Basin, with special emphasis on surface water and its quality

U.S. DEPARTMENT OF THE INTERIOR
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SURFACE-WATER RESOURCES OF THE GRAND DIVISION

By W. V. IORNS, C. H. HEMBREE, and G. L. OAKLAND

ABSTRACT

This chapter presents the results of an appraisal of the surface-water resources of the Grand division, which includes the 26,500 square miles of the drainage area of the Colorado River above the Green River. Water uses existing in 1957 are reported, and interpretations are made of stream behavior, chemical quality of water, and sediment yield on the basis of the average that would have occurred if the 1957 level of upstream development had existed throughout water years 1914–57. The appraisal will be useful in planning additional development of surface-water supplies and evaluating changes in streamflow, chemical quality of water, and sediment yield that may result from water-development projects constructed after 1957.

An average of about 28,648,300 acre-feet of water was annually precipitated in water years 1914–57. Had the developments in 1957 prevailed throughout the 44-year period, the average annual consumption of water for irrigation would have been about 739,100 acre-feet. An average of about 8,800 acre-feet would have been annually consumed for domestic and industrial uses, about 453,400 acre-feet would have been diverted annually out of the division, and an average of about 5,534,000 acre-feet would have been annually discharged in the Colorado River. Evapotranspiration probably accounted for the remaining 21,913,000 acre-feet on the assumption that there was no ground-water outflow.

About 34,800 tons of dissolved solids in 453,400 acre-feet of water was annually carried out of the division by the transmountain diversions existing in 1957. These transmountain diversions have caused an increase of about 39 parts per million in the weighted-average concentration of the Colorado River below the mouth of the Dolores River.

The dissolved-solids discharge from the Grand division in the Colorado River was computed to average about 4,204,600 tons annually for water years 1914–57 adjusted to 1957 conditions. About 2,254,000 tons of this amount comes from natural sources; about 482,000 tons of this total comes from thermal springs.

Activities of man, other than the diversion of water out of the area, consume water and result in the addition of dissolved solids—about 1,950,600 tons annually—to the stream system. Exclusive of the effect of transmountain diversions, the weighted-average concentration of dissolved solids of the Colorado River below the mouth of the Dolores River is estimated to have been increased about 291 parts per million as a result of the activities of man. The major part of this increase is attributed to irrigation.

Domestic, industrial, and irrigation uses of water in the division have caused about five times as much increase in concentration of dissolved solids of the Colorado River below the Dolores River for each acre-foot of water consumed as the transmoutain diversions have caused for each acre-foot of water exported.

The average annual suspended-sediment discharge from the division totals about 20,495,000 tons and from each subbasin is as follows: 9,269,000 tons from the Colorado River Basin above the Gunnison River; 2,067,000 tons from the Gunnison River basin; and 9,159,000 tons from the Colorado River Basin between the Gunnison and Green Rivers.

Most of the surface water in the headwaters is suitable for domestic and industrial use. However, the waters of many streams in the central and western parts of the division are not suitable for domestic use because of high concentrations of sodium, magnesium, sulfate, chloride, and nitrate. The waters of practically all the streams are suitable for irrigation.

INTRODUCTION

PURPOSE AND SCOPE

This chapter presents an appraisal of the surface-water resources of the Grand division. The following items are considered: The present utilization of the surface-waters supplies, the flow characteristics of the streams and the effect of environmental factors on streamflow, the chemical-quality characteristics of the streams and the influence of environmental factors on the quality of water, and the sediment yield of the streams.

The basic data, hydrologic techniques, and criteria used in this appraisal are discussed and explained in chapter B, which also contains a glossary of the technical terms used.

LOCATION AND SUBBASINS

The Grand division of the Upper Colorado River Basin is the area drained by the Colorado River above the mouth of the Green River (chap. A, fig. 2). The division includes parts of western Colorado and eastern Utah and has an area of 26,500 square miles.

To facilitate presentation of data and the analysis of the effects of natural environmental factors and the activities of man on the hydrology of the streams of the division, it was divided into three subbasins, as follows:

1. The subbasin of the Colorado River above the Gunnison River is the area (8,670 sq mi) drained by the Colorado River above a point just below the mouth of Plateau Creek. Gaging stations on Colorado River and on Plateau Creek near Cameo, Colo., measure the outflow from the subbasin. These gaging stations are 3.4 and 1.1 miles, respectively, upstream from the mouth of Plateau Creek.
2. The Gunnison River subbasin is the area (8,020 sq mi) above the gaging station on Gunnison River near Grand Junction, Colo. This gaging station is 2 miles upstream from the mouth of the Gunnison River.
3. The subbasin of the Colorado River between the Gunnison and Green Rivers is the remaining area (9,810 sq mi) in the division. Computations of outflow from the subbasin are based on records for the gaging station on Colorado River near Cisco, Utah. The station is 97 miles above the Green River. There is some tributary inflow between the gaging station and the Green River.

HYDROLOGIC ENVIRONMENT

PHYSIOGRAPHY AND STREAM NET

The plateaus and mountains that form the boundaries of the Grand division (fig. 28), in a clockwise direction from the mouth of the Green River, are the East Tavaputs and White River Plateaus and the Park Range on the north; the Snowy and Sawatch Ranges on the east; and the San Juan, La Plata, and Abajo Mountains on the south. Other important topographic features include the Gore Range, Elk Mountains, Grand Mesa, Battlement Mesa, Book Cliffs, Uncompahgre Plateau, and La Sal Mountains. Some of these features form the natural boundaries between the subbasins in the division.

The western part of the area is essentially a dissected plateau, and the eastern part is a series of uplifted mountain masses, weathered and deeply dissected by agents of erosion, such as water and glaciers. The streams in the eastern part of the division flow in deep canyons or in V-shaped valleys between the mountain masses. Most of the flatland is restricted to relatively narrow flood plains and terraces along the main streams.

In much of the west half the relief is not so great as in the east half. In places, the streams flow through wide valleys bordered by extensive areas of relatively level land, such as the Grand Valley and the Uncompahgre River valley. However, in other places the streams flow in deep, narrow canyons cut below benches and table lands. All the division is at an altitude of more than 3,880 feet, and many of the mountain peaks exceed an altitude of 13,000 feet.

The drainage pattern is the result of the action of many forces during a long period of geologic history. Some streams follow ancient synclinal valleys, and other streams in parts of their courses follow strike valleys, where softer rocks are exposed along the fringes of uplifts. Some streams are antecedent in parts of their courses; that is they were able to maintain their courses across an uplift by downcutting while the uplift was taking place. Others have maintained a course superimposed from a drainage pattern that was established on rocks overlying those now exposed. In general, the main stem of the Colorado River follows a southwesterly route across the division near the north boundary. The major part of the area is drained by tributaries flowing generally northwestward to their junction with the main stem.

Long before the start of the earth movements that created the Rocky Mountains, the area was the scene of alternate encroachment and retreat of great inland or epicontinental seas. When the area was above sea level, erosion was active. When the area was covered by the great seas, erosion ceased but was still active on the surrounding emerged land. Streams drained the surrounding land and carried the products of erosion into the sea. Thus, during each submergence, great thicknesses of sediments of all sizes and types and beds of chemical precipitates, such as calcium carbonate, were built up. The sedimentary material that accumulated and that was not subsequently removed by erosion during the periods when the land was above sea level is represented by the sedimentary rocks that now underlie much of the area. These rocks, in total, are thousands of feet thick and range in attitude from the sharply tilted strata around the mountains to the flatter lying beds of some of the younger rocks in the intermontane basins.

The earth movements that culminated in formation of the Rocky Mountains and the erosion that accompanied and followed these movements were instrumental in determining the present topography and the structure of the rocks on which it is formed. In the latter part of the Tertiary period, which ended about a million years ago, the mountains were eroded, and part of the eroded material was deposited in basins between the mountains.

The exposed rocks in the Grand division range in age from late Precambrian to Recent. The pattern of exposures is complex because of the net effect of uplift, folding, faulting, weathering and erosion. The outcrop

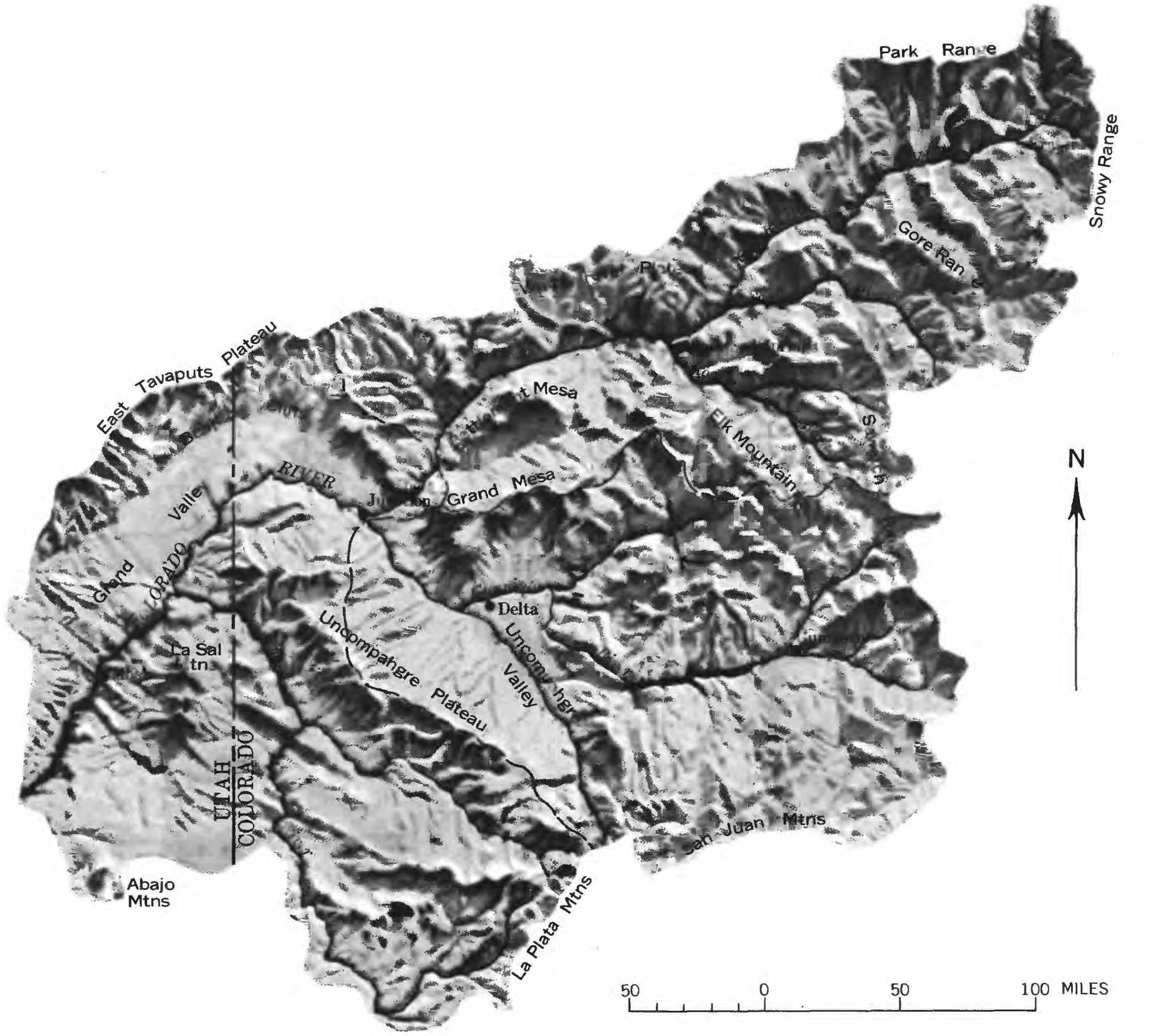


FIGURE 28.—Relief map of the Grand division of the Upper Colorado River Basin. Adapted from photograph by I. V. Goslin, Upper Colorado River Compact Commission.

areas of rock formations in the division, classified into eight units having similar hydrologic properties, are shown in plate 1. The formations and their characteristics are discussed in chapter A.

SOILS

The unconsolidated material mantling the consolidated rocks is principally residuum and river alluvium. Residuum consists of products of rock weathering that have accumulated faster than they can be removed by water and wind. Material of this type mantles hillsides and the tops of mesas and plateaus. It ranges in thickness from a few inches to several tens of feet. As it is near its source, it retains many of the geochemical characteristics of the parent rock. Where the climate is favorable to the growth of vegetation, mature soils have developed on the residuum. In the drier parts of the division, where the climate is not favorable for the growth of vegetation, the mantle for the most part is relatively thin, and the soils are poorly developed. This condition is due in part to the slowness of weathering where precipitation and underground moisture are low and in part to the susceptibility of barren ground to erosion.

River alluvium consists of the products of erosion that have been transported and deposited by streams. It underlies the flood plains and the adjacent terraces along the streams. Generally, it consists of water-worked mixtures of silt, sand, and gravel. Its composition and texture differ from place to place in accordance with (1) the age of the material, (2) the distance and mode of transportation, and (3) the type of rocks from which it was derived. The soils developed on it vary widely in depth and maturity.

In the headwater areas, the river alluvium is derived principally from rocks that are resistant to the solvent action of water. In downstream areas, it is derived principally from shale and siltstone and contains the relatively soluble salts generally associated with these rocks. In the vicinity of Montrose and Grand Junction, the river alluvium consists principally of water-reworked Mancos Shale. It is generally underlain by the Mancos Shale, by the Dakota Sandstone, or by the Morrison Formation, but locally gravel intervenes between the bedrock and the fine sediment.

Most of irrigated lands are on river alluvium, but some are on residuum. Plate 1 shows the areas of river alluvium. As the residuum is closely associated with the parent rocks, its areas of occurrence and type of material are indicated by the outcrop areas in plate 1.

CLIMATE

EFFECT OF TOPOGRAPHY AND ALTITUDE

The high mountain ranges that rim the Grand division on the north, east, and most of the south act as partial barriers to approaching moist airmasses. The west side is lower, and Pacific airmasses enter the area from that direction. The western part of the south side is also relatively low; thus airmasses from the Gulf of Mexico are permitted to enter the western part. The high mountain ranges and mesas trending north to south and east to west take their toll of moisture from the airmasses that move across the area. The effect of the topography on the distribution of precipitation can be seen by comparison of figure 28 and plate 4.

Temperatures and rates of evaporation are also related to altitude. Valley temperatures and evaporation rates generally decrease from west to east as the altitude increases.

PRECIPITATION

Precipitation during the period October through April is more effective in producing runoff than precipitation in the summer months. Precipitation patterns for the two periods are different. During October to April, airmasses from the Pacific Ocean move across the Grand division. Most of the precipitation during this period, particularly in the high mountains, occurs as snow, which sometimes accumulates to a great depth along the high divides.

Precipitation during the summer usually occurs as thundershowers. In the western part, where the mountains along the south boundary are not high enough to block the movement of airmasses from the Gulf of Mexico, summer storms of high intensity occur occasionally and produce flash floods.

The monthly distribution of precipitation at representative precipitation stations is shown in figure 29. The distribution of average annual precipitation is shown in plate 4. This map, which is adjusted for topography, exposure to airmass movements, and climatic factors, is based on precipitation data observed during calendar years 1921–50. The average annual precipitation for this period, as planimetered from the map, is 20.39 inches and ranges from less than 8 inches in the western part to more than 50 inches on the high mesas and in the mountains. The following tabulation shows the areal distribution of precipitation over the 26,500 square miles of drainage area:

Precipitation range (inches)	*Area (sq mi)*	*Precipitation range (inches)*	*Area (sq mi)*
50–60	32	16–20	4,971
40–50	606	12–16	5,414
30–40	3,362	10–12	1,983
25–30	3,304	8–12	1,592
20–25	4,178	6–8	1,058

In computing precipitation data applicable to the base period adopted for this study and for other periods, 17 index-precipitation stations in or adjacent to the division were selected (tables 1 and 2; pl. 4). As explained in chapter B (pp. 44–45), precipitation records at the index stations were used to compute average precipitation for various water years and periods of water years. The average annual precipitation for the 44-year base period thus computed was 20.27 inches. On the 26,500 square miles of drainage area, this precipitation would be equivalent to 28,648,300 acre-feet of water per year.

The year of highest precipitation was 1927, when the average precipitation computed by the index-station method was 26.98 inches; the year of lowest precipitation was 1931, when the precipitation was 14.97 inches. The precipitation in these two years was, respectively, about 33 percent more than and 26 percent less than the 44-year annual average. As shown by the annual quantities in table 2, the precipitation was generally greater than average from 1914 to 1929, less than average from 1930 to 1940, greater than average from 1942 to 1949, and less than average from 1950 to 1956.

TEMPERATURE AND EVAPORATION

Figure 29 shows the effect of altitude on average monthly temperatures and length of frost-free season. Between Moab, Utah, and Fraser, Colo., the altitude

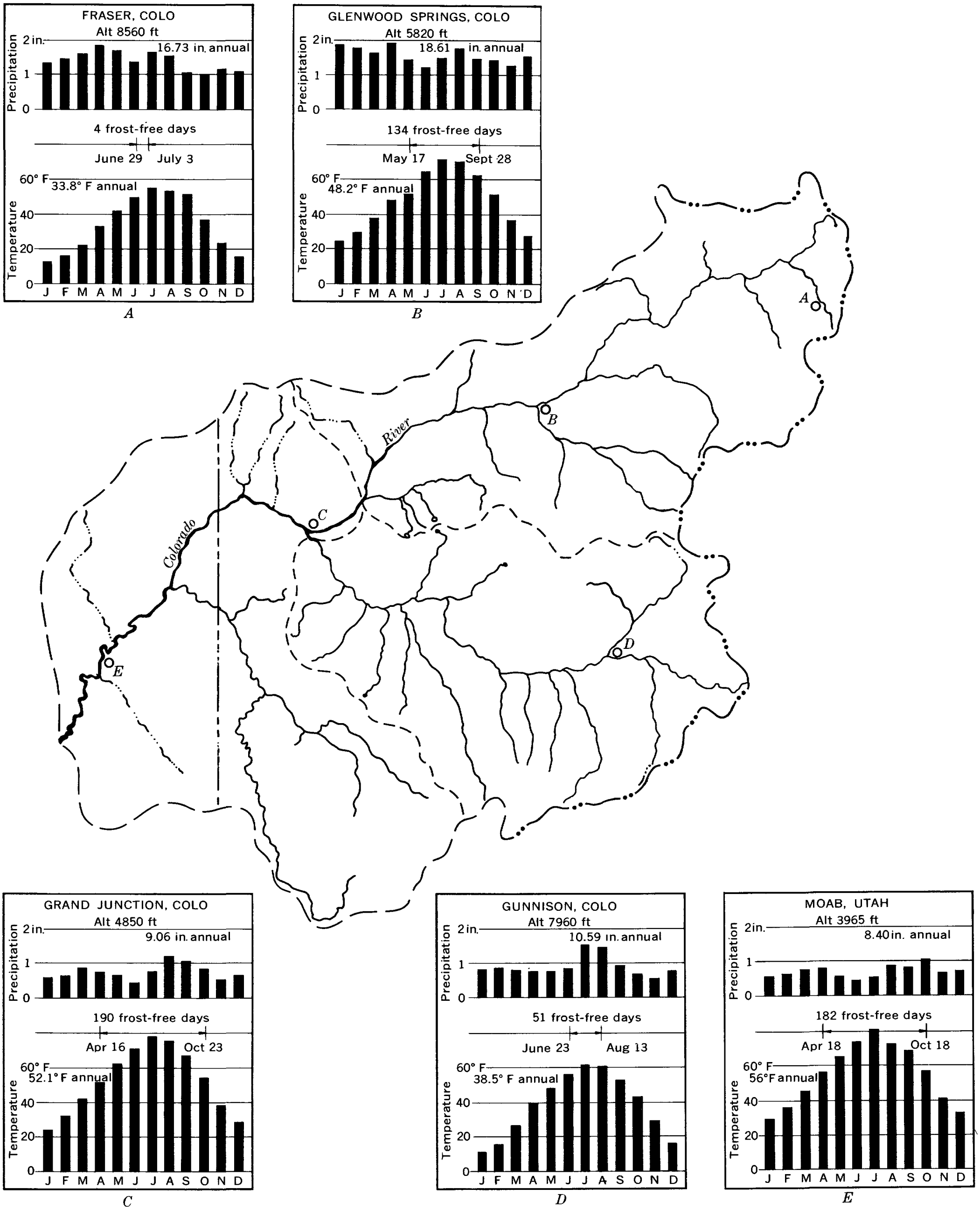


FIGURE 29.—Normal precipitation and temperature and frost-free seasons at representative stations in the Grand division. Data from U.S. Weather Bureau normals (average for 1921–50 calendar years).

increases 4,600 feet and the average annual temperature decreases about 22°F. while the frost-free season decreases from 182 days to 4 days.

Isopleths of average annual lake evaporation, from a map by Kohler and others (1959, pl. 2), are shown on plate 4. The isopleths are generalized and do not take into account large variations in topography and exposure which may influence evaporation considerably at specific locations.

The annual amounts of evaporation from water surfaces in the 17 Western States have been estimated by Meyers (1962). The following tabulation gives his estimates of average annual evaporation from water surfaces in the Grand division:

	Annual evaporation (acre-ft)
Principal reservoirs and regulated lakes	35, 000
Principal streams and canals	40, 000
Small ponds and reservoirs	113, 000
Small streams	28, 000
Total	216, 000

VEGETATION

Native species of vegetation, except in cultivated areas, are about the same as existed before settlement. Grazing and lumbering have partially removed the native grasses and trees in some areas, but other grasses, shrubs, or woody species have taken their place, partly as a result of reforestation and range-improvement programs. Only a small percentage of the total basin area is cultivated.

The native species, which developed through many thousands of years of evolution, are adapted to the conditions of cold, heat, wetness, dryness, and soil type of the areas in which they grow. Many grow only within narrow ranges of climate, topography, and type of soil. The most important plant communities in the Upper Colorado River Basin are the alpine meadows, subalpine forests, montane forests, mountain brush, pinyon-juniper, big sagebush, shadscale, blackbrush, greasewood, saltbrush, summer-cypress, and grasslands. F. A. Branson has described the species in the plant communities as follows:

Alpine meadows

The alpine meadows are at altitudes higher than the timberline, usually at more than 12,000 feet. The species usually found in the alpine meadows are sedges (*Carex* spp.), bluegrasses (*Poa* spp.), spike trisetum (*Trisetum spicatum*), alpine timothy (*Phleum alpinum*), willows (*Salix* spp.), bistort (*Polygonum bistorta*), bluebells (*Mertensia alpina*), gentian (*Gentiana frigida*), and clovers (*Trifolium* spp.).

Subalpine forests

The subalpine forests are at altitudes lower than the alpine meadows. At higher altitudes in the subalpine forest, which is sometimes called the spruce-fir forest, the dominant trees are Englemann spruce (*Picea englemanni*) and subalpine fir. At lower altitudes in the subalpine forest are three species that occupy large areas. These species are lodgepole pine (*Pinus contorta latifolia*), Douglas-fir (*Pseudotsuga taxifolia*), and quaking aspen (*Populus tremuloides*). Plants commonly found in the subalpine forest are pinegrass (*Calamagrostis rubescens*), elk sedge (*Carex geyeri*), arnica (*Arnica cordifolia*), and huckleberry (*Vaccinium scoparium* and *V. membranaceum*). Much of the subalpine forest has dense stands of trees and little undergrowth.

Streambank and meadow communities in the subalpine forest consist of woody plants such as willows, cottonwoods (chiefly *Populus angustifolia*), aspen, birches (*Betula fontinalis* and *B. glandulosa*), and dogwood (*Cornus stolonifera*). Some of the important herbaceous species are tufted hair-grass (*Deschampsia cacspitosa*), bluejoint (*Calamagrostis canadensis*), sedges, and rushes (*Juncus* spp.).

Montane forests

The montane forests are characterized by the presence of ponderosa pine (*Pinus ponderosa*). Ponderosa pine forms open stands and usually has an abundance of understory plants. Some of the important plants are mountain muhly (*Muhlenbergia montana*), Arizona fescue (*Festuca arizonica*), Idaho fescue (*Festuca idahoensis*), slender wheatgrass (*Agropyron trachycanlum*), and oatgrasses (*Danthonia intermedia* and *D. unispicata*). Common shrubs are big sagebrush (*Artemisia tridentata*), serviceberry (*Amelanchier alnifolia*), snowberries (*Symphoricarpos* spp.), mountain-mahogany (*Cercocarpus montana*), and bitterbrush (*Purshia tridentata*).

Streambank and meadow communities in the montane forest consist of a number of woody plants such as willows, cottonwoods (chiefly *Populus angustifolia*), aspen, birches (*Beutla fontinalis* and *B. glandulosa*), and dogwood (*Cornus stolonifera*). Some of the important herbaceous species are tufted hair-grass (*Deschampsia caespitosa*), bluejoint (*Calamagrostis canadensis*), sedges, and rushes.

In the mountain areas of Colorado the zonation between the subalpine and montane forests is well defined. In Utah the zonation between these two types is not well defined. Because of this poor definition, the two types have been grouped in Utah as subalpine forest.

Mountain brush

At lower altitudes mountain brush is sometimes termed chaparral and includes shrub types that commonly occur as a transition between coniferous forest and other vegetation types. Common shrubs of this type are oaks (chiefly *Quercus gambelli*), mountain-mahogany, serviceberry, snowbrush (*Ceanothus velutinus*), bitterbrush, cliffrose (*Cowania mexicana*), chokecherry (*Prunus virginiana*), snowberry, and rose (*Rosa* spp.). Other plants commonly found in this zone are big sagebrush, bluebunch wheatgrass (*Agropyron spicatum*), needle-and-thread (*Sipta comata*), junegrass (*Koeleria cristata*), and annual bromes (*Bromus* spp.).

Pinyon-juniper

Occurring in low mountain areas, pinyon-juniper types are not usually abundant at altitudes higher than 6,000 feet or lower than 4,000 feet. The most common junipers are Utah juniper (*Juniperus osteospera*), Rocky Mountain juniper (*J. scopulorum*), and one-seed juniper (*J. mono-sperma*). Colorado pinyon (*Pinus edulis*) is the most common pine in this zone. Understory species include bitterbrush, big sagebrush, mountain-mahogany, and cliffrose (*Cowania stansburiana*). Some herbaceous species present are blue grama (*Bouteloua gracilis*), galleta (*Hilaria jamesi*), bluebunch wheatgrass, western wheatgrass (*Agropyron smithi*), Indian-ricegrass (*Oryzopsis hymenoides*), Russian-thistle (*Salsola Kali*), and cheatgrass (*Bromus tectorum*).

Big sagebrush

Occurring in extensive zones, sagebrush is not as restricted by altitude as are the other communities and is found at altitudes of up to 10,000 feet. Sagebrush is found on well-drained, commonly sandy soils that are not usually saline. Many woody and herbaceous species are associated with sagebrush. Some of these shrubs are rabbitbrush (*Chrysothamnus* spp.), horsebrush (*Tetradymia nuttalli* and *T. canescens*), winterfat (*Eurotia lanata*), and snakeweed (*Gutierrezia sarothrae*). Understory grasses are galleta, blue grama, western wheatgrass, bluebunch wheatgrass, and squirreltail (*Sitanion hystrix*).

Shadscale

Limited to soils that are slightly saline and relatively impermeable, shadscale (*Atriplex confertifolia*) grows in some places in nearly pure stands but is commonly mixed with other shrubs such as sagebrush, horsebrush, and spiny hopsage (*Grayia spinosa*). Nuttall saltbrush (Atriplex nuttalli) commonly occurs locally as pure stands within this zone.

Blackbrush

Blackbrush grows in a zone characterized by sandy usually nonalkaline soils at lower altitudes. Plants associated with blackbrush (*Coleogyne ramosissima*) are fourwing saltbush (*Atriplex canescens*), Mormon tea (*Ephedra* spp.), yucca (*Yucca* spp.), snakeweed, and galleta.

Greasewood

Growing on terraces above permanent streams and along intermittent stream channels at lower altitudes greasewood is a phreatophyte which is very salt tolerant and deep rooted and which usually indicates the presence of ground water. It usually grows as nearly pure stands but is in some places associated with shadscale, sagebrush, and rabbitbrush. Herbaceous phreatophytes commonly associated with greasewood are saltgrass (*Distichlis stricta*) and alkali sacaton (*Sporobolus airoides*).

Saltbush (Nuttall)

Saltbush grows in nearly pure stands on soils that have very low infiltration rates and that are usually heavy textured and commonly saline. Greasewood and sagebrush are commonly associated with saltbush in small channel bottoms. Winterfat and black sage (*Artemisia nova*) are also mixed with nuttall saltbush in a few places or form alternate pure stands.

Summer-cypress

Summer-cypress grows in scattered stands at lower altitudes in the northern part of the division on dry, heavy soils that are usually saline. Other plants commonly found growing with summer-cypress (*Kochia americana*) are bud sage (*Artemisia spinescens*), winterfat, and widely scattered plants of sandberg bluegrass (*Poa secunda*), Indian ricegrass, and scarlet globemallow (*Sphaeralcea coccinea*).

Grasslands

Grasslands and grasslands mixed with shrubs cover extensive areas. At the higher altitudes, grasses mixed with shrubs occur as small scattered "islands." The most common grasses are western wheatgrass, bluebunch, wheatgrass, squirreltail, and needlegrass (*Stipa* spp.). In the lower altitudes the most abundant grasses are blue grama and galleta.

All the plant communities occur in the Grand division except saltbush and summer-cypress (pl. 5). Vegetation that is typical of some of the zones in this division is shown in figures 30–32.

COLORADO RIVER BASIN ABOVE THE GUNNISON RIVER

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Sixteen reservoirs that have storage capacities greater than 1,000 acre-feet have been constructed in the Colorado River Basin above the Gunnison River (table 3, pl. 4). The combined usable storage capacity of these reservoirs in 1957 was 659,430 acre-feet. Many small reservoirs and stock ponds are scattered over the subbasin. The Shadow Mountain, Lake Granby, and Willow Creek Reservoirs are a part of the Colorado-Big Thompson project and were constructed primarily for the exportation of water out of the Colorado River Basin. The Williams Fork and Ivanhoe Reservoirs were constructed to store water for use in the Colorado River Basin when transmountain diversions

FIGURE 30.—Alpine meadows and subalpine forest zones in the headwaters of the Blue River. (Photograph by D. A. Phoenix.)

FIGURE 31.—Subalpine forest near Gore Pass, Colo. The vegetation is quaking aspen and mixed conifers, including lodgepole pine, and a small island of grassland in foreground. (Photograph by F. A. Branson.)

reduced downstream flows below irrigation requirements. The Green Mountain Reservoir also serves the same purpose and, in addition, provides storage for hydroelectric-power production. The remaining reservoirs provide storage for irrigation water. All reservoirs store water from the drainage basin in which they are located except Harvey Gap Reservoir, which stores water from East Fork Rifle Creek.

TRANSMOUNTAIN DIVERSIONS

The diversion of water out of the subbasin began in 1880, when the Ewing ditch was constructed to divert water from the headwaters of the Eagle River to the Arkansas River basin for placer mining. As the need for irrigation and municipal water east of the Conti-

FIGURE 32.—Big sagebrush 1 mile northwest of Kremmling, Colo. The low-growing shrub in the background is winterfat. (Photograph by F. A. Branson.)

nental Divide grew, other transmountain diversion ditches and diversion tunnels were constructed. Thirteen transmountain ditches and tunnels were in operation by 1957.

The average annual diversion for the four water years 1954–57 was 353,000 acre-feet. The annual transmountain diversions from the subbasin during the 1914–57 period are listed in table 4. Water diverted through the East and West Hoosier ditches, which were operated in water years 1935–40 and then abandoned, has been included in the data for Hoosier Pass tunnel. Diversion through the Fremont Pass ditch was discontinued after 1943.

Figure 33 shows the rate of increase of transmountain diversions and the annual variations through the years. In years of both high and low runoff some of the diversions are less than average, owing to lack of need and to a deficiency in supply, respectively.

IRRIGATION

The major use of water is for the irrigation of crops. In the Colorado River Basin above the Gunnison River in 1949 the U.S. Bureau of the Census (1953) reported 192,500 acres of irrigated land, which was about the same amount irrigated in 1957. The amount and distribution of irrigated land in the tributary basins along river reaches and above gaging stations are shown in table 5 and plate 5.

Irrigated lands above Glenwood Springs are mostly on narrow valley bottoms along the streams at altitudes ranging from 6,500 feet near Dotsero to 8,500 feet near Fraser. Because of the short growing season and low temperature, the principal crop is native grasses for livestock feed. Water is generally plentiful during most of the irrigation season and is applied at rates

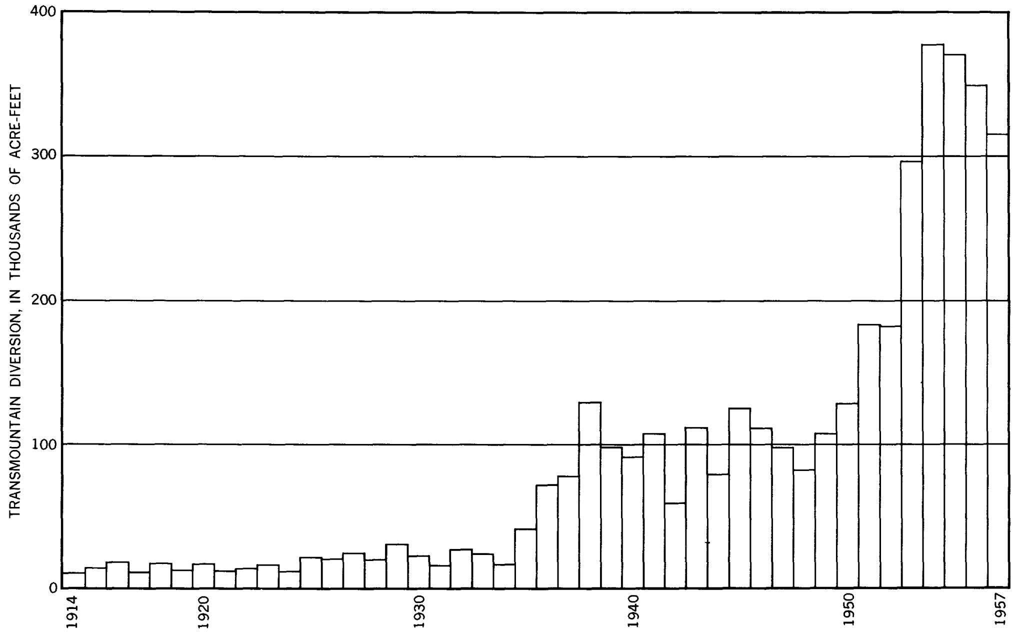


FIGURE 33.—Transmountain diversions from the Colorado River Basin above the Gunnison River, water years 1914–57.

of as much as 5 to 8 acre-feet per acre annually. A large part of the applied water returns to the streams.

Between Glenwood Springs and Cameo the irrigated lands are mostly on benches at altitudes of about 5,000 feet. The climate in this area is favorable for growing fruit, vegetables, alfalfa, and sugar beets. Most of the irrigation water is obtained from tributary streams, and the supply in the latter part of the season is deficient for about half of the lands irrigated. Irrigation water is applied at rates of 3 to 5 acre-feet per acre annually. About half to two-thirds of the applied water returns to the streams. In the Plateau Creek basin the climate and irrigation practices are similar to those between Glenwood Springs and Cameo. The Upper Colorado River Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water in the subbasin due to irrigation was 190-300 acre-feet. In the Commission's study it was estimated that 179,800 acres of land was irrigated and that 20,300 acres of land received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The 1960 population was about 26,200, which is an average of about three persons per square mile. The five largest communities and their population are Glenwood Springs, 3,637; Rifle, 2,135; Climax, 1,609; Aspen, 1,101; and Dillon, 814 (Bureau of the Census). Principal means of livelihood are farming, ranching, mining, and the tourist trade.

Most communities receive their water supplies from springs or mountain streams. Most of the larger communities have sewage-treatment plants or lagoons or individual family septic tanks. However, some sewage is discharged directly into the streams. Detailed data are not available on the domestic uses of water for supply or waste dilution, but the per capita use of water is estimated to be about 200 gpd (gallons per day). This would be equivalent to about 6,000 acre-feet per year for domestic use. The consumptive use of water for domestic and industrial purposes is estimated to average about 60 gpd per capita, or about 1,800 acre-feet annually.

Production of hydroelectric power is the major industrial use of water. Eight hydroelectric powerplants have an installed capacity of 37,400 kilowatts. The largest two are the Green Mountain plant on the Blue River (21,600 kilowatts) and the Shoshone plant on the Colorado River above Glenwood Springs (14,400 kilowatts). Other industries using water are mines and smelters, sugar factories, dairies, food-processing plants, and a few small industries. All the industries are relatively small and their use of water is negligible.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Melting of snow that accumulates in the mountains provides most of the water supply. Rising temperatures in the late spring and early summer rapidly melt the snow and cause the streams to peak and then subside as the stored supply of snow is exhausted. Usually by late July the streams have subsided to near a base flow, which generally prevails until the cycle is repeated the following spring. Relatively little runoff is produced by the local thundershowers, which occur during the summer months.

The seasonal pattern of the rise and fall of the headwater streams, being principally dependent on temperature, is practically the same throughout the area (fig. 34). The rise and fall of main-stem streams closely follows the pattern of the headwater streams (fig. 35). There is, however, a progressive lag in the downstream direction.

FLOW-DURATION CURVES

Historical flow-duration data were prepared for streams at 40 selected sites in the Colorado River Basin above the Gunnison River. For all but two of these sites, curves representative of the 44-year base period, adjusted to 1957 conditions, were developed. The historical and adjusted curves reduced to table form are given in table 6. In addition, flow-duration curves were synthesized for two sites for which historical flow-duration curves were not prepared. The usefulness of these curves in hydrologic studies, their characteristics, and the methods used to adjust flow-duration curves for short periods of record to the 44-year base period and for changes in upstream water developments are explained in chapter B (pp. 45–48).

Records of streamflow at only four of the selected sites in the subbasin were complete for the 44-year base period. At a few sites, more than 34 years of record was available, but at some sites as little as 5 years of record had been obtained. During the base period many changes in upstream water developments considerably affected some of the streamflow records. Methods used in adjusting the historical flow-duration curves are given in table 7, and the upstream water developments—in which changes occurred—are outlined. The table also gives the author's accuracy ratings of the adjusted long-term curves. Computations and data necessary to show the details of the adjustments are too voluminous for inclusion in the report.

The flow-duration curves for the headwater streams have a typical shape and are similar to each other (fig. 36). The curves generally have a steep slope and are flat at the upper end. Differences in topography, rocks, soils, and vegetative cover in the drainage basins cause the curves to vary slightly.

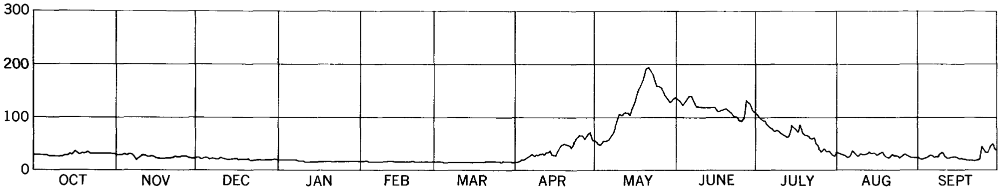
The flow-duration curves for the Colorado River at three gaging stations are shown in figure 37*A–C*. These curves are generally similar in shape; however, those for the downstream stations are slightly modified by intervening water-use developments. In figure 37*D* the curves for the Colorado River at the three stations are shown, the water discharge being expressed as a ratio to the average flow. Expressing the discharge as a ratio eliminates most of the effects of differences in size of drainage area and amount of runoff. The modifying effect of storage releases is apparent near the middle of the curves for the two downstream stations. The flatter slope of the lower end of the flow-duration curves for the downstream stations is caused by return flow from the irrigation of intervening lands.

The variability indices (Lane and Lei, 1950) and percentages of ground-water contribution to stream systems (see chap. B, pp. 48–53) were computed for selected streams (table 8). In general, the relation between the two parameters is inverse (fig. 38). The average curve in figure 38 is based on data for selected streams in this subbasin and other subbasins in the Upper Colorado River Basin.

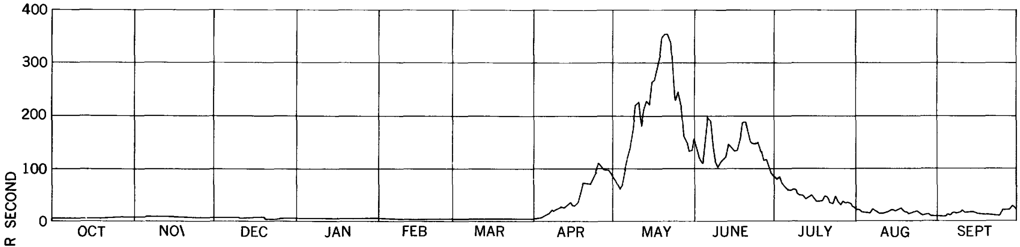
North Inlet and Homestake Creek, two of the streams listed in table 8, flow in basins underlain entirely by Precambrian rocks and have the highest variability indices and lowest percentage of ground-water contribution. These rocks are impermeable but are broken by faults and joints through which water may enter and circulate. The ground-water storage capacity in rocks of this type is relatively small.

The drainage basins of Rock and Fryingpan Creeks and the Williams River also are principally underlain by Precambrian rocks, but the basins contain extensive deposits of glacial outwash. These deposits are permeable and provide considerable ground-water storage. These streams have a relatively low variability index and a relatively high percentage of ground-water contribution.

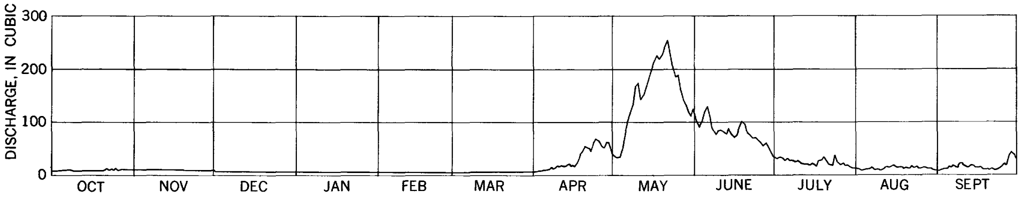
The Buzzard Creek basin is underlain by the Wasatch Formation, which consists of sandy clays and sandstones. The formation, as a whole, is relatively impermeable, and streams draining areas underlain by rocks of this type could be expected to have a high variability index and a low percentage of ground-water contribution.



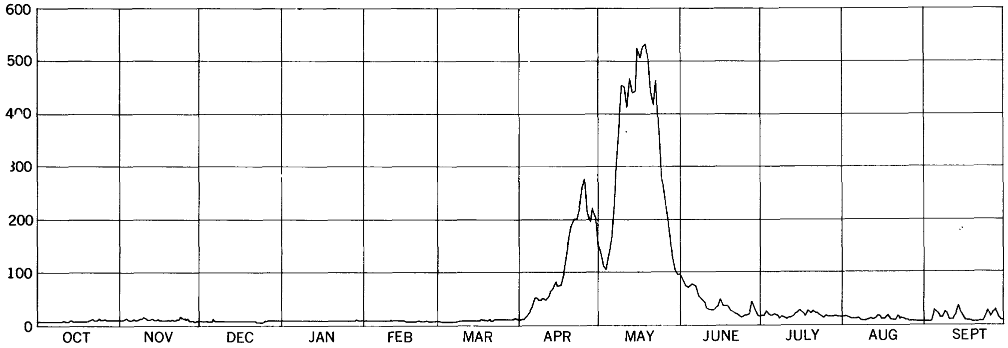
A. Williams River near Leal, Colo.



B. Homestake Creek near Red Cliff, Colo.

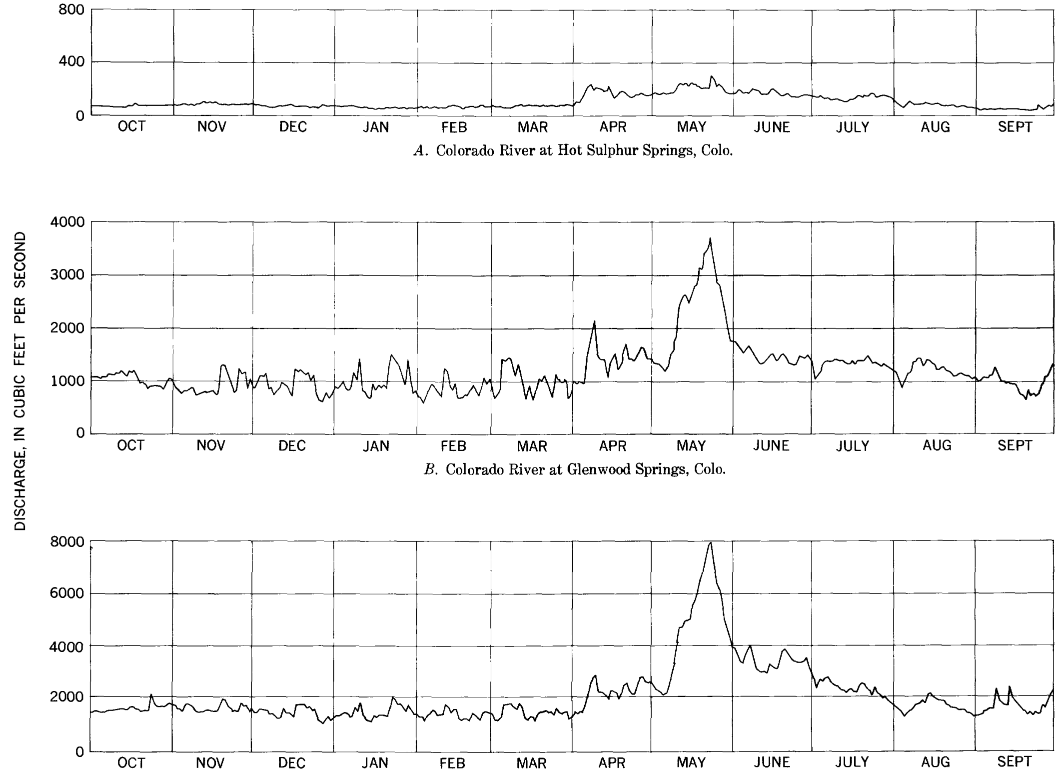


C. Hunter Creek near Aspen, Colo.



D. Plateau Creek near Collbran, Colo.

Figure 34.—Seasonal pattern of runoff of headwater streams in the Colorado River Basin above the Gunnison River, 1954 water year.



A. Colorado River at Hot Sulphur Springs, Colo.

B. Colorado River at Glenwood Springs, Colo.

C. Colorado River near Cameo, Colo.

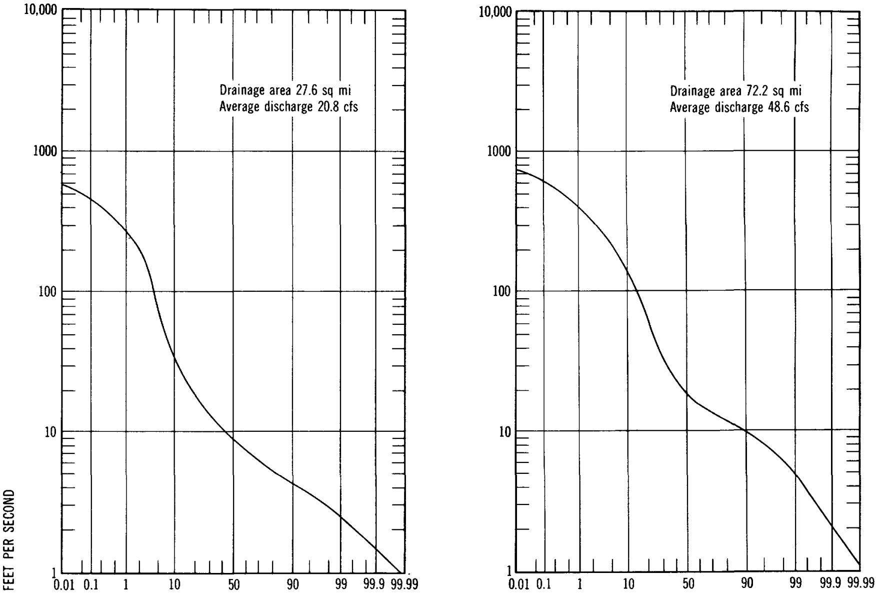
FIGURE 35.—Seasonal pattern of runoff of the Colorado River above the Gunnison River, 1954 water year.

The drainage basin of Gypsum Creek, which has the lowest variability index and highest percentage of ground-water contribution of the streams listed in table 8, is underlain by the Eagle Valley Evaporite. This formation consists of conglomerates and sandstones and some limestone and shale beds containing much gypsum. Rocks of this formation weather to thick deposits of permeable residuum. The rocks and weathered mantle provide opportunity for ground-water recharge and a relatively high storage capacity. Streams draining areas underlain by this type of formation could be expected to have a low variability index and a high percentage of ground-water contribution.

The drainage basins of the rest of the streams listed in table 8 contain more than one type of formation, some of which are steeply tilted and incised by streams. As some of the rocks are permeable and some are impermeable, the combination would tend to cause streams draining such areas to have a variability index and percentage of ground-water contribution in the intermediate range.

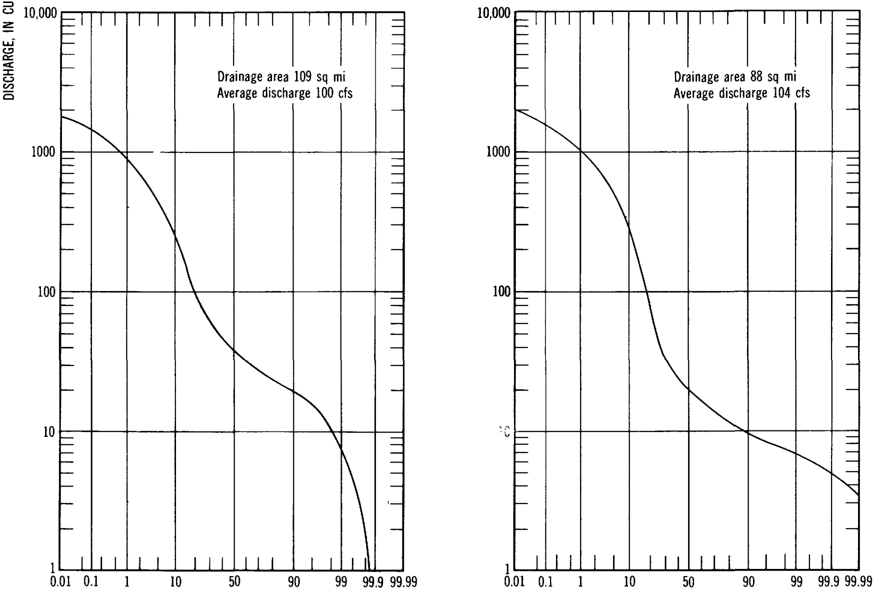
The effect of environmental factors, particularly geology, on the shape of the flow-duration curves and the variability index can be further illustrated by comparing Homestake Creek near Red Cliff, Colo., with Gypsum Creek near Gypsum, Colo. These streams are both in the Eagle River basin. The drainage basins of these streams have about the same average annual precipitation and directional exposure and altitude. Figure 39 shows flow-duration curves for these two stations plotted as ratios of the average discharge of the streams.

As previously noted, the Gypsum Creek basin is underlain by relatively permeable rocks. With favora-



A. Fraser River near Winter Park, Colo.

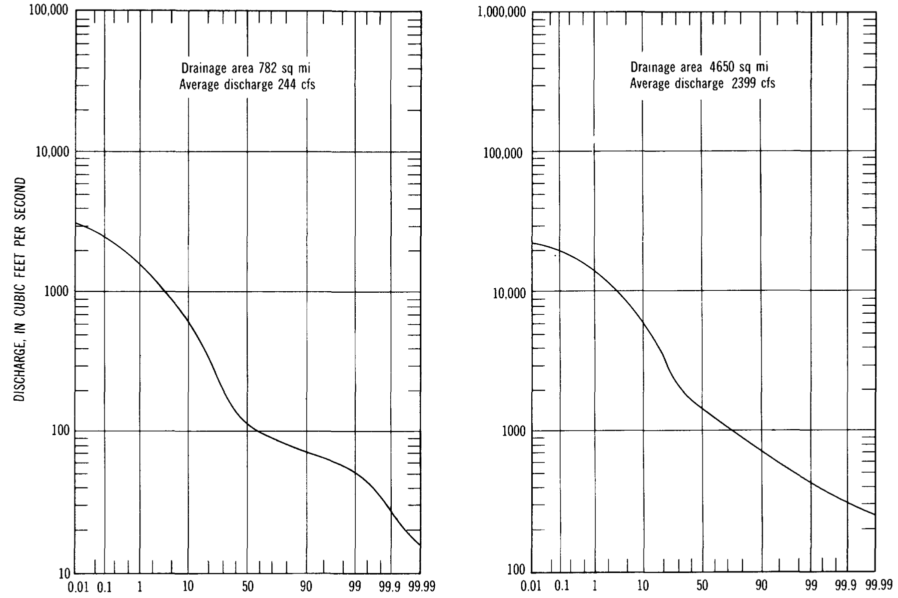
B. Eagle River at Red Cliff, Colo.



C. Roaring Fork at Aspen, Colo.

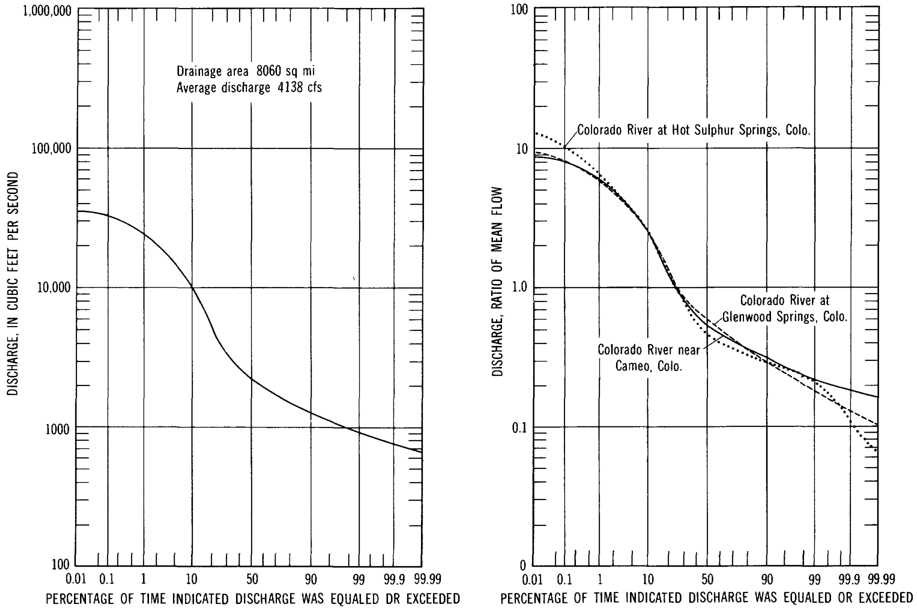
D. Plateau Creek near Collbran, Colo.

Figure 36.—Flow-duration curves of headwater streams in the Colorado River Basin above the Gunnison River, water years 1914–57 adjusted to 1957 conditions.



A. Colorado River at Hot Sulphur Springs, Colo.

B. Colorado River at Glenwood Springs, Colo.



C. Colorado River near Cameo, Colo.

D. Comparison of flow-duration curves for three main-stem Colorado River stations.

Figure 37.—Flow-duration curves of the Colorado River main-stem stations above the Gunnison River, water years 1914–57 adjusted to 1957 conditions.

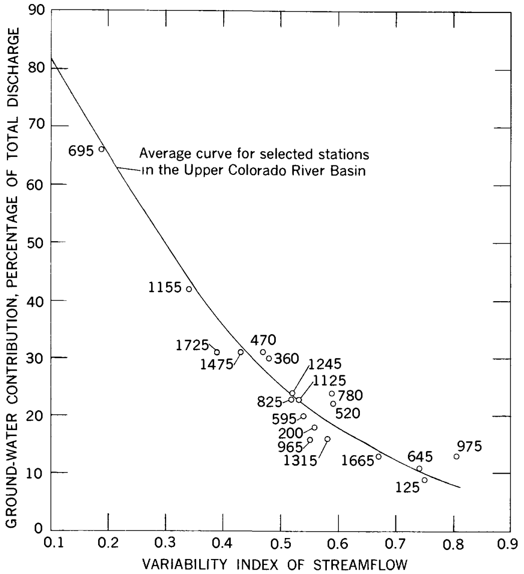


Figure 38.—Relation between the variability index of streamflow and the percentage of average annual discharge estimated to be contributed by ground water for selected stations in the Grand division, water years 1914–57 adjusted to 1957 conditions.

ble moisture, these rocks weather deeply and produce a relatively permeable soil mantle with good vegetative cover. The environment is favorable to infiltration of precipitation, part of which would build up the ground-water body, which in turn would maintain the stream during low-flow periods. The result is a relatively flat flow-duration curve, a low variability index, and high sustained flow.

The Homestake Creek drainage basin is underlain by relatively impermeable granite, much of which is exposed as bare rock. Glacial terrace deposits in the basin are relatively thin and overlie steeply sloping bedrock. This combination of environmental factors is reflected in a relatively high variability index.

VARIABILITY OF ANNUAL RUNOFF

The variations in annual discharge of streams in the subbasin are illustrated by the histograms for three selected stations (fig. 40). The quantities of water illustrated by the histograms were adjusted to the 1914 base. (See chap. B, pp. 53–60.) Changes in upstream use between 1914 and 1957 were considered in the adjustment. Tables 9 and 10 show the historical record and the adjustments applied for Fraser River near Winter Park, Colo., and Colorado River at Glenwood Springs, Colo. Similar data for Roaring Fork near Glenwood Springs, Colo., are given in tables 6 and 7, chapter B.

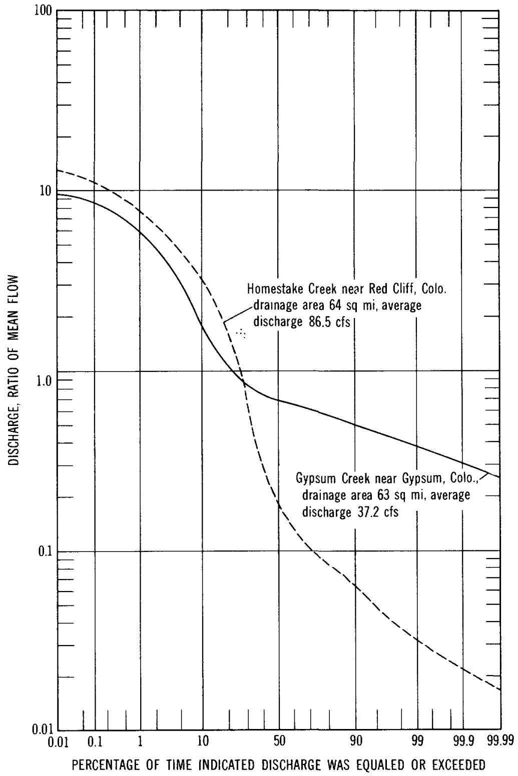
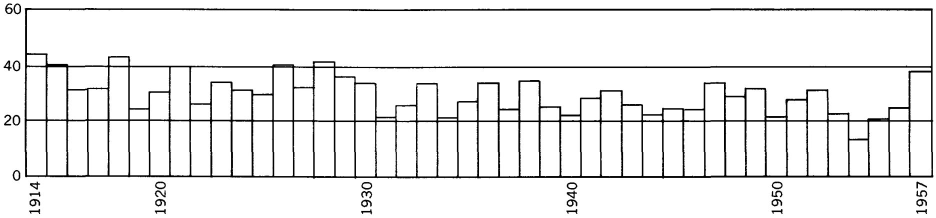
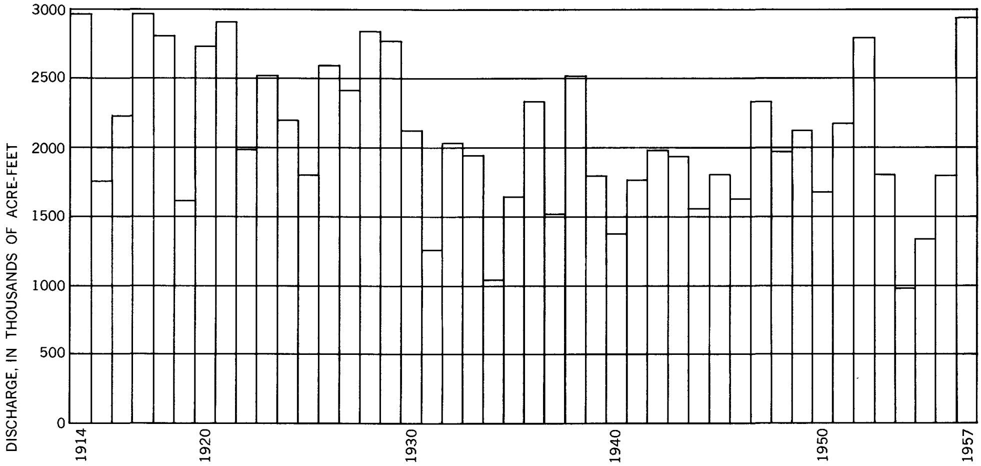


Figure 39.—Effect of environmental factors on flow-duration curves. Comparison of flow-duration curves for Homestake Creek near Red Cliff and Gypsum Creek near Gypsum, Colo., water years 1914–57 adjusted to 1957 conditions.

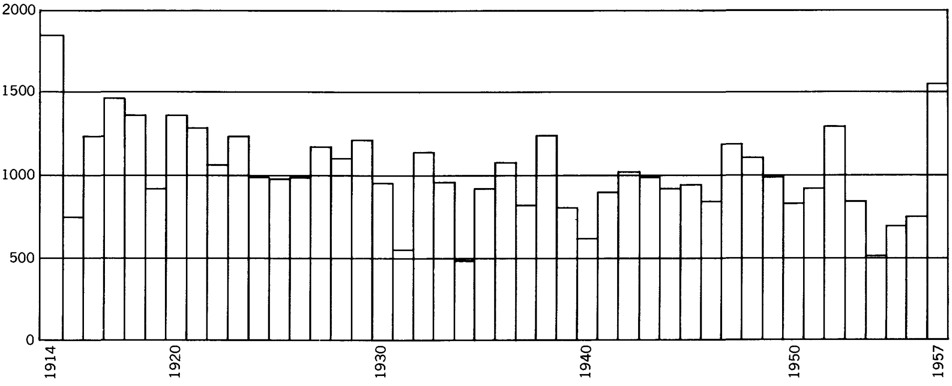
The standard deviation and coefficient of variation of annual discharges were computed for these three stations and other stations in the subbasin to investigate the effect of different environmental factors on the variability of annual discharges and to provide a basis for estimating probable future flows of streams in the area. (See chap. B, pp. 57–58.) The standard deviation and coefficient of variation for the streams are given in table 11. The coefficients are also plotted in plate 4. All the coefficients of variation in the table are considered to be applicable to natural conditions, but some are not applicable to present conditions be-



A. Fraser River near Winter Park, Colo.



B. Colorado River at Glenwood Springs, Colo.



C. Roaring Fork at Glenwood Springs, Colo.

FIGURE 40.—Variability of annual discharges of selected streams in the Colorado River Basin above the Gunnison River, water years 1914–57 adjusted to 1914 base.

cause the magnitude of changes in upstream developments during the period of record was large in relation to the total runoff. Coefficients that are not considered applicable to present conditions or for estimating probable future flows are indicated in the table.

The coefficients for south-side streams in the eastern part of the subbasin are approximately the same, probably owing to the similarity of climate in the different drainage areas and the relatively impermeable underlying rocks, which do not provide enough ground-water storage to sustain the streams in years of low precipitation. At downstream points along the main stream the coefficients are slightly reduced, possibly because of ground-water storage in the river alluvium.

The coefficient for Rifle Creek indicates a well-sustained flow even in years of low precipitation. The sustained flow comes mostly from East Rifle Creek. This stream crosses steeply tilted rocks bordering the White River Plateau. Though most of the headwater area is underlain by rocks of Pennsylvania age, older rocks of Mississippian age are exposed in the canyon upstream from the gaging station on East Rifle Creek. Springs discharging about 30 to 35 cfs issue from limestone beds in the Mississippian rocks about 2 miles above the gaging station (M. R. Collings, oral commun., 1962). The limestone strata are probably recharged at higher altitudes where precipitation is heavy, either where the limestone is exposed or through permeable beds in the Pennsylvania rocks.

Toward the western part of the basin, the coefficient of variation increases. The increase in variability reflects the effect of runoff from infrequent but intense summer storms, which are more common in this area.

The probable amounts (50-percent chance) by which average discharges for various periods in the future may differ from the long-term average discharge of some of the streams listed in table 11 are given in table 12. These determinations employ the probability techniques described by Leopold (1959) in an analysis of streamflows for Colorado River at Lees Ferry, Ariz. In chapter B (pp. 53–58) the statistical analysis of annual discharges is outlined, and an equation and table of factors are given for computing the most likely deviations in estimating average future streamflow for various periods of years and confidence limits. In table 12 the average discharges are those for water years 1914–57 adjusted to 1957 conditions (table 6), the coefficients of variation used are those given in table 11, and the factors used are those given for the 50-percent confidence band in table 8, chapter B. The quantities given in table 12 have been rounded to two significant figures. Similar determinations of probable errors in estimating the average annual flows for other periods of years and confidence bands may be made by using the other factors in table 8, chapter B.

PRECIPITATION-RUNOFF RELATION

The overall effect of environmental factors on runoff may also be investigated by comparing total precipitation with water yield. The measured runoff from a drainage area is the residual water left from precipitation in excess of that required to satisfy natural and man-caused water consumption. Evaporation from water surfaces, soil, and vegetation and transpiration by native vegetation make up the major part of natural consumptive use. This is commonly referred to as "nature's take" and is sometimes called "water loss," even though much of it serves a beneficial purpose in promoting growth of trees and forage to protect the soil from erosion.

The precipitation, runoff, and natural consumptive use of water were computed for six small drainage basins (table 13). Among these six, only the basin of the Eagle River below Gypsum includes any appreciable irrigated land. The natural consumptive use for four of the areas shows that the combined effect of environmental factors on natural consumptive use is practically the same. This fact suggests that the natural consumptive use over much of the subbasin is about 15 inches annually. The Homestake and Gypsum Creek basins have lower and higher natural consumptive use, respectively, than the four others and are considerably different from each other, probably due to differences in vegetation and in permeability of the underlying formations and residual mantle. The impervious surface, steep slopes, thin soil, and sparse vegetation in the Homestake Creek basin permit rapid runoff and minimum water loss. In contrast, the relatively deep and permeable soil and heavier cover of vegetation in the Gypsum Creek basin permit greater infiltration of precipitation and greater evapotranspiration.

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at five stations in the Colorado River Basin above the Gunnison River. Monthly and annual weighted-average chemical analyses for these stations are given in the basic data report (Iorns and others, 1964, tables 175–179). In addition to the daily data at the five stations, samples of stream water have been obtained for chemical analysis at many other sites in the subbasin. The dissolved-solids discharge for the daily stations and that computed for some of the sites where fewer samples were collected have been computed (table 14).

Duration tables of dissolved-solids concentration and discharge for the stations listed in table 14 are given in tables 15 and 16. The analyses of water samples, water discharge at the time of sampling, curves showing relation of dissolved-solids concentration to water discharge, and flow-duration curves of water discharge were used in the computations for these tables. The methods used to compute the data are described in chapter B (pp. 58–59).

By combining the average annual dissolved-solids and water discharges of Plateau Creek and Colorado River near Cameo, Colo., the average annual dissolved-solids discharge and water discharge from the subbasin were computed. Using these average annual quantities as a base, the percentage contribution of dissolved solids and water from other parts of the area were computed (fig. 41).

The data from figure 41 show that about 37 percent of the water but only about 15 percent of the dissolved solids come from the drainage basin above the Eagle River. Muddy Creek, a tributary above the Eagle River, contributes less than 2 percent of the water but at least 2 percent of the dissolved solids. The Eagle River contributes about 15 percent of the water and about 12 percent of the dissolved solids, whereas Roaring Fork, which contributes more than 30 percent of the water, contributes only about 18 percent of the dissolved solids.

Of the combined dissolved-solids discharges of Colorado River and Plateau Creek near Cameo, Colo., more than 10 percent is added to the Colorado River between the Eagle River and the chemical-quality station near Glenwood Springs (station 705C). The increase in flow in this reach is only about 0.2 percent of the combined flow of Colorado River and Plateau Creek near Cameo, Colo. The cause of the relatively large increase in dissolved solids in this reach is discussed on pages 102–103.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in dissolved-solids concentrations of headwater streams in this subbasin is illustrated by the data for Eagle River at Gypsum, Colo. (fig. 42). The seasonal pattern of dissolved-solids concentration of this stream is typical of snowmelt streams. The concentrations are lowest in the months of maximum water discharge—May, June, and July—and highest in the months of low flow when the streams are maintained largely by ground water. Water year 1954 was a year of relatively low runoff, and 1957 was a year of relatively high runoff. The seasonal range from maximum to minimum concentration at this station is much greater than that in many streams in this subbasin. The greater seasonal range is largely due to environmental factors in which geology plays a predominant part. The drainage basin of the Eagle River is mostly underlain by limestones, shales, and siltstones of Pennsylvanian and Permian ages. Limestones, shales, and siltstones generally contain soluble minerals. Generally, streams draining areas underlain by rocks of this type have a greater range in concentration of dissolved solids than streams draining areas underlain by less soluble rocks, such as granitic and metamorphic rocks.

Figure 43 shows distribution curves of the variability of the monthly weighted-average concentration of dissolved solids. The procedures used in this analysis are the same as those explained for the statistical analyses of streamflows in chapter B (pp. 53–58). As shown by the slopes of the monthly distribution curves, the months from November to March were the least variable, July and August were the most variable, and June, April, May, October, and September were less variable than July and August. The variability of annual weighted-average concentrations for Eagle River at Gypsum, Colo., for the period of record is also shown in figure 43.

The activities of man may considerably modify the natural seasonal variations in chemical quality of water in streams. A comparison of the seasonal variations in dissolved-solids concentration for Colorado River at Hot Sulphur Springs, Colo., for the 1949 and 1954 water years (fig. 44) reveals the effects of one modification by man. The change in pattern of seasonal variation at this station was caused principally by diversion of water containing relatively low dissolved-solids content from the basin through Colorado-Big Thompson project, beginning in 1950. However, the effect of the project on the seasonal pattern of dissolved-solids concentration diminishes downstream because of additional water and dissolved-solids contributed by tributary areas. About 80 miles downstream at Dotsero, the times of occurrence of high and low concentrations also follow the pattern of snowmelt streams.

The variability of annual dissolved-solids concentration (chap. B, pp. 60–61) is less than the variability of streamflow, as indicated by the relation between the coefficients of variation of annual weighted-average concentration of dissolved solids and annual water discharge for concurrent periods at three sites where records of streamflow and chemical quality of water have been obtained (table 17).

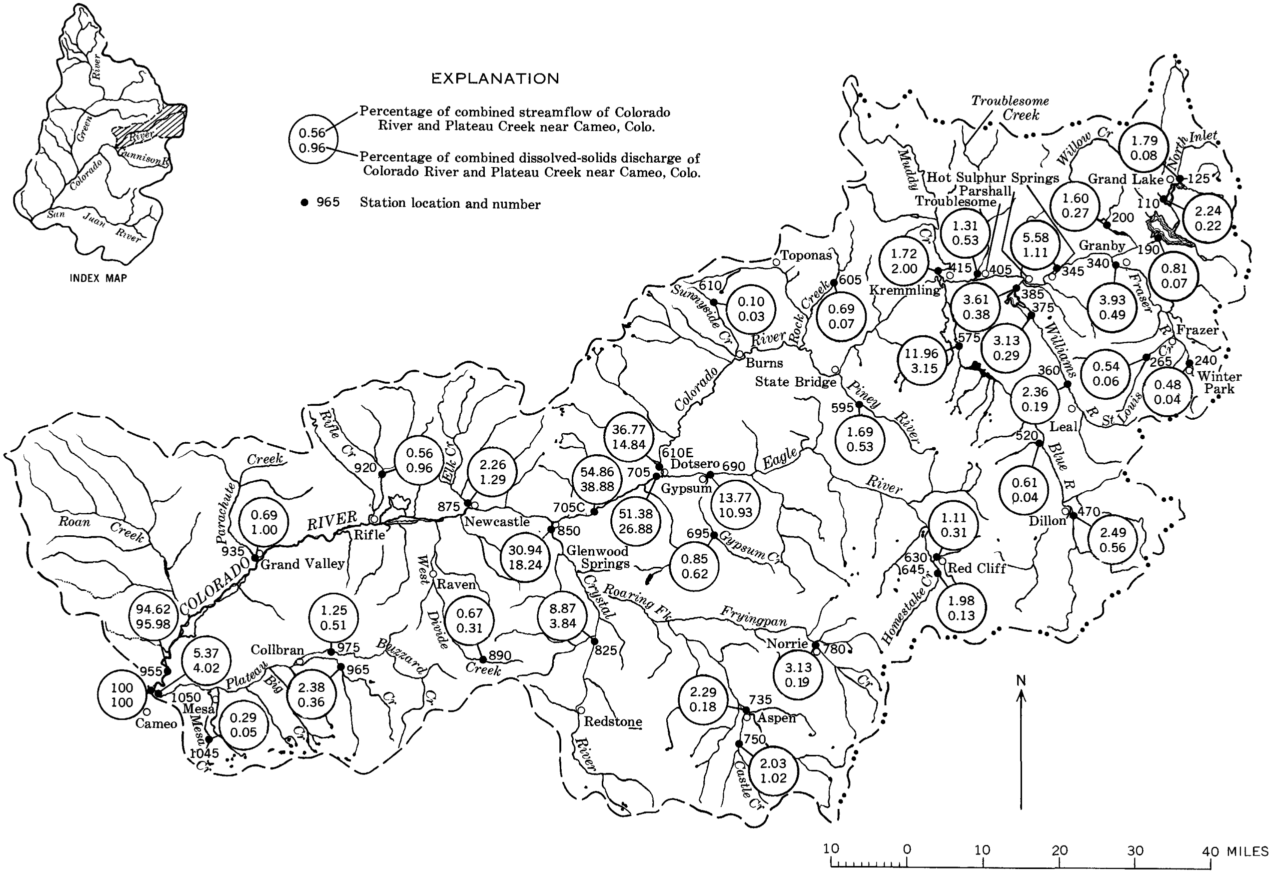


FIGURE 41.—Approximate dissolved-solids discharge and streamflow expressed as percentages of the combined dissolved-solids discharge and combined streamflow of Colorado River and Plateau Creek near Cameo, Colo.

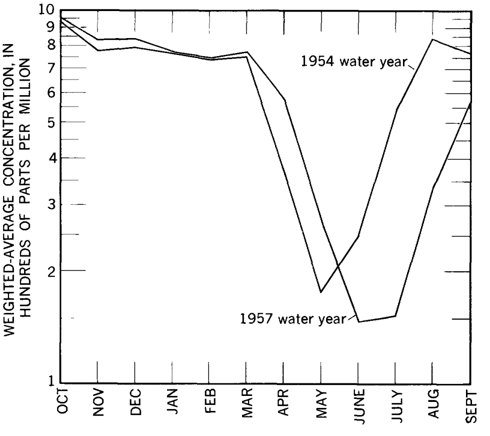


FIGURE 42.—Weighted-average concentration of dissolved solids at Eagle River at Gypsum, Colo., for the 1954 and 1957 water years.

In figure 45 the relation between the coefficients of variation for the three stations and others in the Grand division are shown. The equation of the line of relation (computed by the least-squares method) is

$$V_d=0.573V_w+0.036,$$

where

V_d=coefficient of variation of annual weighted-average concentration of dissolved solids, and

V_w=coefficient of variation of annual discharge.

As described in chapter B, the relation between the variability of water discharge and that of concentration of dissolved solids can be used to compute values of weighted-average concentration at other sites within probability limits for various periods in the future. Table 18 gives computed values of coefficients of varia-

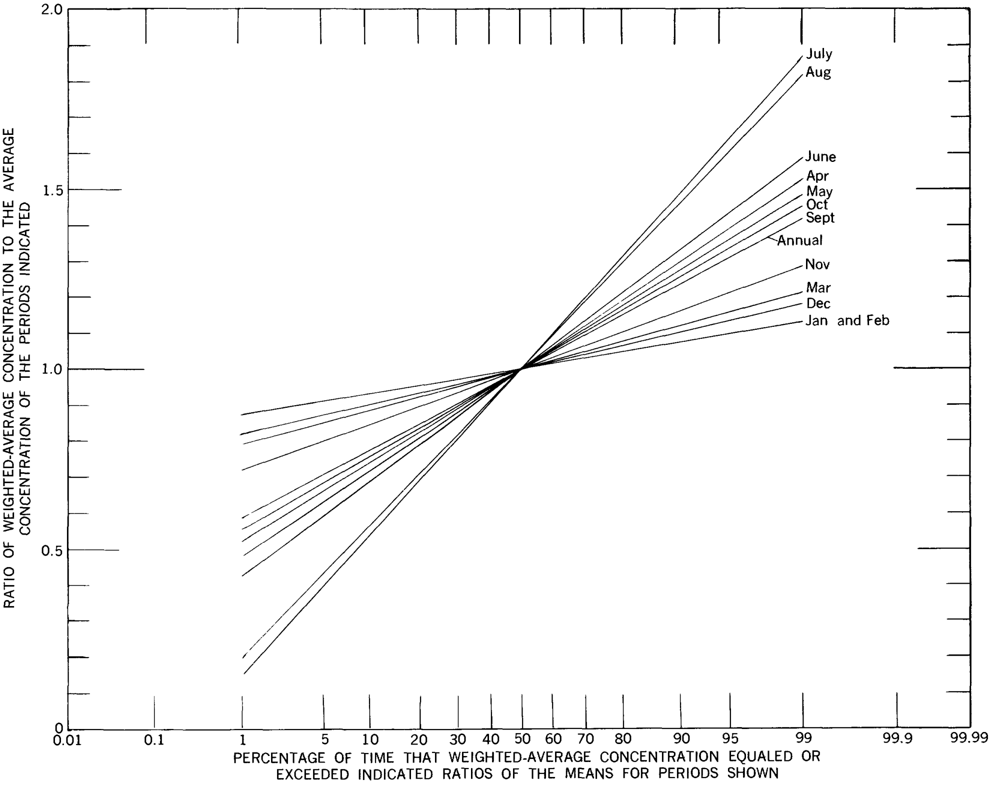


FIGURE 43.—Variability of the monthly and annual weighted-average concentration of dissolved solids at Eagle River at Gypsum, Colo., water years 1948–57.

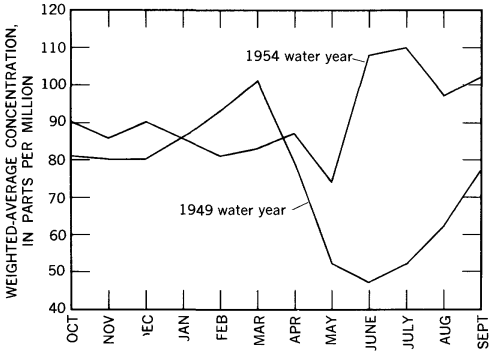


Figure 44.—Dissolved-solids concentration at Colorado River at Hot Sulphur Springs, Colo., for the 1949 and 1954 water years. Storage in Granby Reservoir began in September 1949.

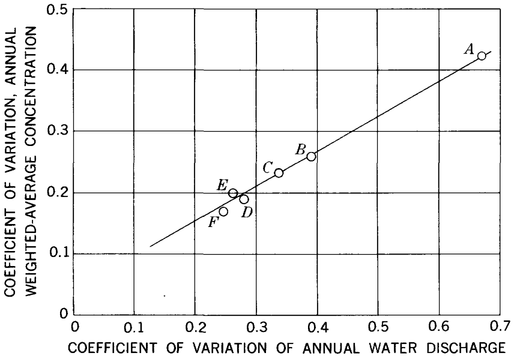


Figure 45.—Relation of the variability of dissolved-solids concentration to the variability of water discharge in the Grand division. *A*, Dolores River near Cisco, Utah; *B*, Gunnison River near Grand Junction, Colo.; *C*, Colorado River near Cisco, Utah; *D*, Eagle River at Gypsum, Colo.; *E*, Colorado River near Glenwood Springs, Colo.; *F*, Colorado River near Cameo, Colo.

tion and standard deviations of weighted-average concentrations of dissolved solids for selected stations. With these data and the factors in table 8, chapter B, probable deviations of dissolved-solids concentration for various periods in the future from the 1914–57 average, adjusted to 1957 conditions, can be computed.

RELATION TO STREAMFLOW

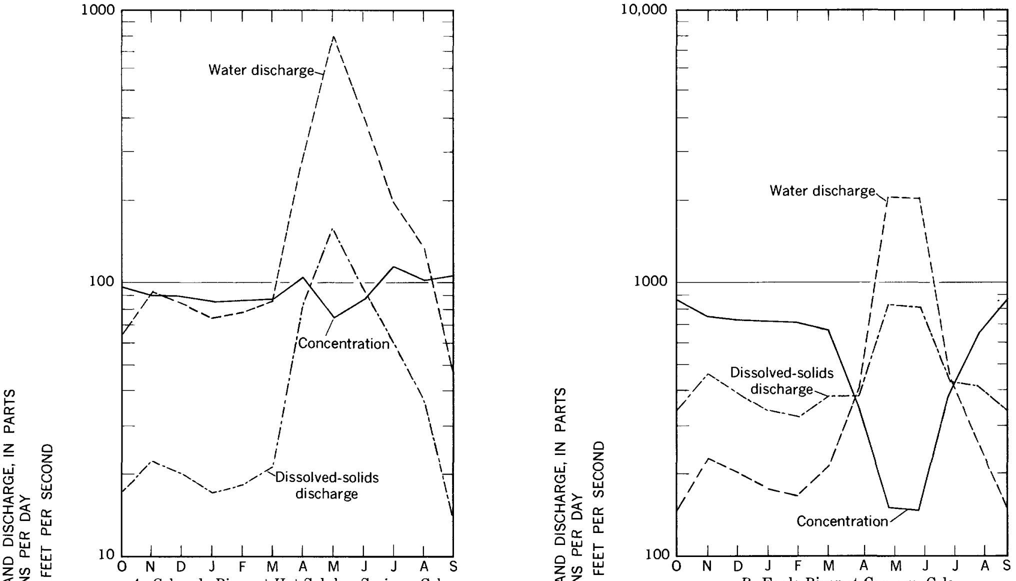
The patterns of relation between streamflow and dissolved solids for the level of upstream development existing in 1956 at four daily stations are shown in figure 46. The graphs for Colorado River at Hot Sulphur Springs, Colo., illustrate an abnormal relation caused by upstream developments. Although there are also developments above the other stations, the magnitude of their effect on the relation between streamflow and dissolved solids is not sufficient to alter the natural pattern generally exhibited by snowmelt streams.

Before the 1950 water year, the flow of Colorado River at Hot Sulphur Springs, Colo., showed an inverse relation between dissolved-solids concentration and water discharge for all ranges of discharge (fig. 47). Beginning with the 1950 water year, about 60 percent of the runoff upstream from Hot Sulphur Springs has been stored or diverted to the east side of the mountains through the Alva B. Adams Tunnel of the complex Colorado-Big Thompson project. This storage and regulation has changed the relation between concentration and water discharge at Hot Sulphur Springs, especially for water discharges of less than 500 cfs (cubic feet per second). For most water discharges, the concentration of dissolved solids has increased.

The effect of this substantial change in upstream water use on the chemical quality of water at Hot Sulphur Springs is further illustrated in figure 48. The weighted-average concentration of dissolved solids in the river at this site from April 1947 to September 1949 was 53 ppm (parts per million), or 0.07 ton per acre-foot of water. For the water years 1942–49 (water years 1942–46 estimated), the weighted-average concentration was computed to have been 60 ppm. For the water years 1950–57, however, the weighted-average concentration at Hot Sulphur Springs was 74 ppm, which is about one-fourth larger than for the water years 1942–49.

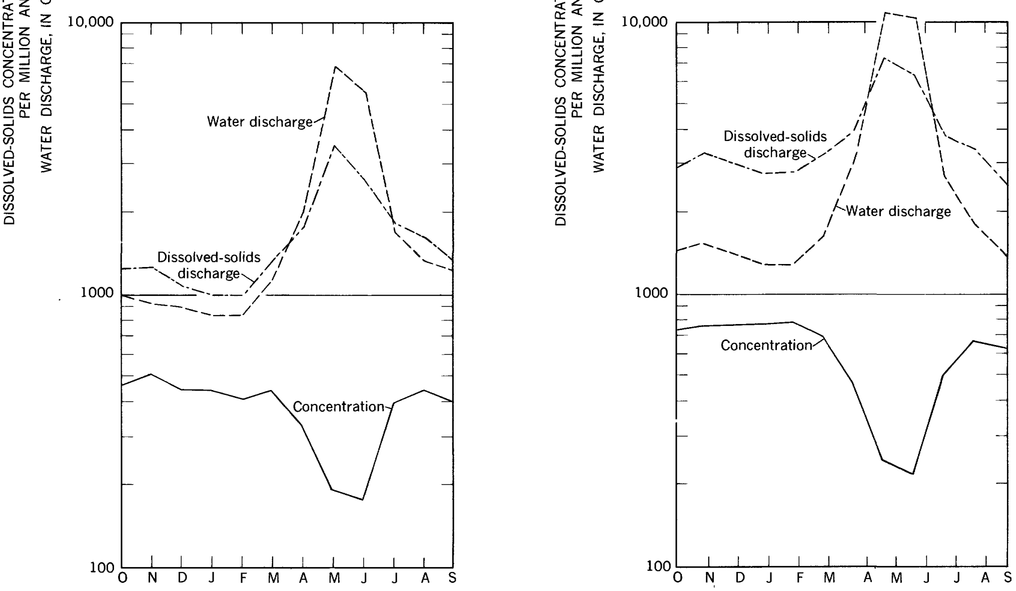
Most of the irrigated lands upstream from Hot Sulphur Springs are below points of diversion or storage for the Colorado-Big Thompson project. Therefore, the total quantity of dissolved solids added to the river by return flow from irrigation probably was not affected by the project. However, the diversion of the more dilute water, as previously discussed, has apparently resulted in an increase in the weighted-average concentration of dissolved solids in the river below the project.

Figure 49 shows two flow-duration curves for Colorado River at Hot Sulphur Springs, Colo., for water years 1914–57. The upper curve was developed from historical streamflow data. The lower curve represents what the long-term curve would have been if the level of upstream development existing in 1957 had existed throughout water years 1914–57. Figure 50 shows duration curves of dissolved-solids discharge for the same streamflow conditions. The upper curve was based partly on actual records of dissolved-solids discharge and partly on historical records of streamflow and the relation between dissolved-solids concentration and stream discharge prior to the Colorado-



A. Colorado River at Hot Sulphur Springs, Colo.

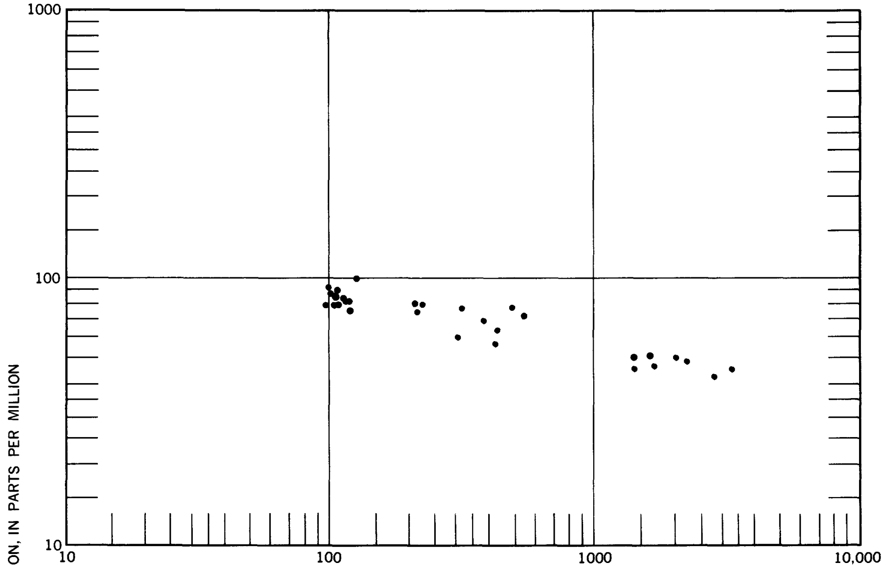
B. Eagle River at Gypsum, Colo.



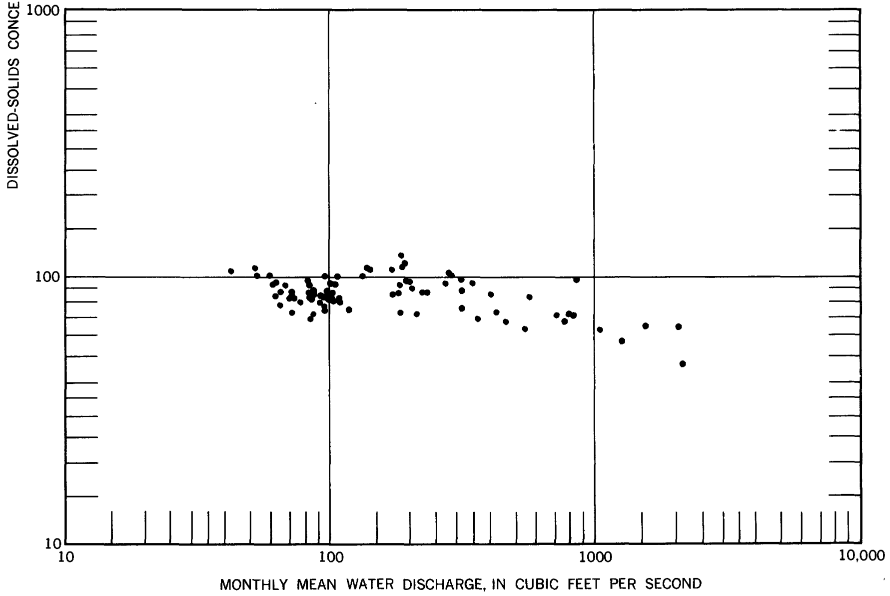
C. Colorado River near Glenwood Springs, Colo.

D. Colorado River near Cameo, Colo.

FIGURE 46.—Dissolved-solids concentration and discharge and water discharge at four daily stations in the Colorado River Basin above the Gunnison River, 1956 water year.



A. April 1947 to September 1949



B. October 1949 to September 1957

Figure 47.—Relation of dissolved-solids concentration to water discharge, Colorado River at Hot Sulphur Springs, Colo.

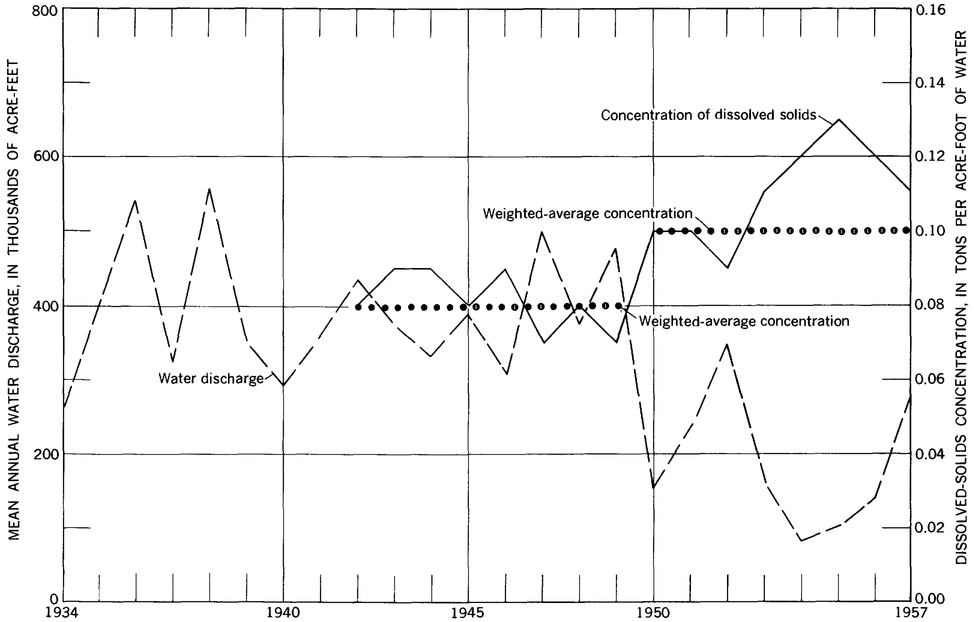


Figure 48.—Effect of the Colorado-Big Thompson project on the dissolved-solids concentration at Colorado River at Hot Sulphur Springs, Colo. Storage in Granby Reservoir began in September 1949.

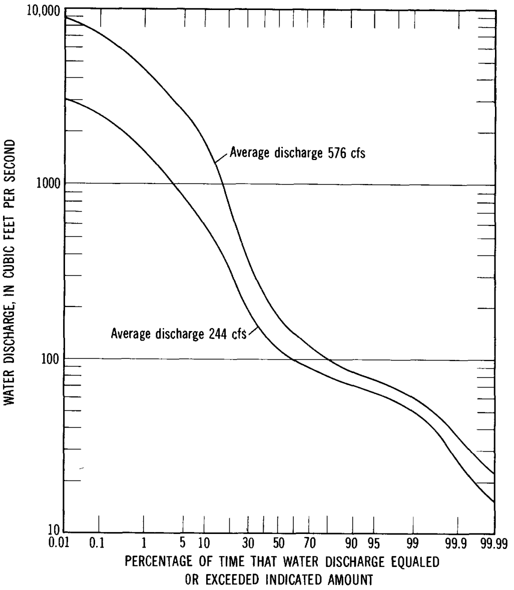


Figure 49.—Historical flow-duration curve for water years 1914–57 (upper curve) and flow-duration curve for water years 1914–57 adjusted to 1957 conditions (lower curve) for Colorado River at Hot Sulphur Springs, Colo. Difference between the two curves is due to the effect of increasing upstream developments.

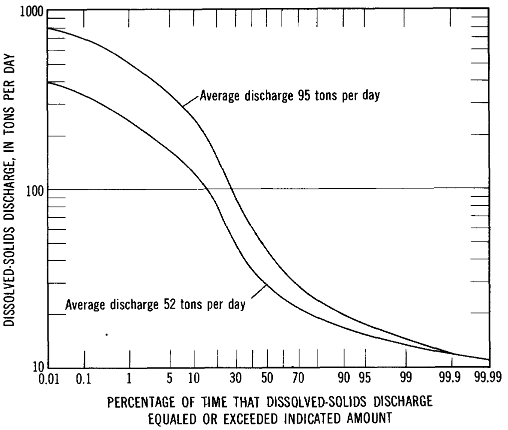


Figure 50.—Historical duration curve of dissolved-solids discharge for water years 1914–57 (upper curve) and duration curve of dissolved-solids discharge for water years 1914–57 adjusted to 1957 conditions (lower curve) for Colorado River at Hot Sulphur Springs, Colo. Difference between the two curves is due principally to increasing transportation of water out of the basin.

Big Thompson project. The lower curve was based on the flow-duration curve for water years 1914–57, adjusted to 1957 conditions, and the relation between dissolved-solids concentration and water discharge for water years 1950–57. The lower curve in tabular form is given in table 16.

The difference between the historical and the adjusted curves in figures 49 and 50, though an approximate measure of conditions before and after construction, illustrates an effect of transmountain diversions.

The relations between streamflow and chemical composition of water at four of the five daily chemical-quality stations in the subbasin are given in table 19 and illustrated in figure 51. The data in the table are based on tables of monthly and annual summaries of chemical analyses in the basic data report (Iorns and others, 1964, tables 175 and 177–179). The mean monthly discharges, in cubic feet per second, were plotted against the monthly weighted-average concentrations of the different constituents, in parts per million, and curves averaging the plotted points were drawn. Water discharges for which values were picked from the curves are the same as those shown in the flow-duration tables for the stations. Duration tables of dissolved-solids constituents may be prepared by using the values in tables 6, 15, 16, and 19. In table 19 the water discharges equaled and exceeded 12, 50, and 90 percent of the time are indicated.

RELATION TO GEOLOGY

The headwaters of the Colorado River and its principal tributaries above the Gunnison River are underlain by rocks that are relatively resistant to the solvent action of water. These rocks are predominantly granite and associated metamorphic rocks. Other rocks that underlie large areas in the headwaters are volcanic rocks of Tertiary and Quaternary ages and sedimentary rocks of Tertiary age, which were derived mostly from the older igneous and metamorphic rocks.

Because these metamorphic, granitic, and volcanic rocks are composed mostly of minerals of similar composition, surface waters from the areas that are underlain by them are similar in chemical composition and differ chiefly in the total amount of dissolved solids. The most dilute waters are from the high mountain areas that are underlain by granitic and metamorphic rocks. Water from these areas of high precipitation may contain less than 20 ppm of dissolved solids. The weighted-average concentration at any point in the headwaters does not exceed 100 ppm and seldom exceeds 50 ppm (table 14).

The waters of the streams in the headwaters are of the calcium bicarbonate type (see glossary, chap. B, for method of classification of water type), but the more dilute waters may contain substantial percentages of sodium and sulfate ions. The concentration of silica ranges from about 6 to 15 ppm and averages about 12 ppm, except for the streams that drain areas underlain by volcanic rocks, which contain siliceous minerals that are more soluble than those found in granitic rocks. The concentration of silica for streams that drain areas underlain by volcanic rocks may exceed 40 ppm, at times, and averages about 25 ppm.

The middle and lower reaches of the principal tributaries are underlain mostly by sedimentary rocks such as limestone, sandstone, siltstone, and shale. These rocks contain minerals that are more readily soluble than those in the rocks that underlie the headwaters. Consequently, the dissolved-solids concentrations of the streams increase progressively downstream.

Downstream from the headwaters, in the upper parts of areas underlain by sedimentary rocks, the waters are mostly of the calcium bicarbonate type. However, at downstream points the water contains progressively larger proportions of magnesium, sodium, sulfate, and chloride.

Broad zones of weighted-average concentration of dissolved solids have been delineated. Within these zones, weighted-average concentrations in the surface waters are between certain limits (fig. 52). These zones indicate that most surface waters have a weighted-average concentration of dissolved solids of less than 300 ppm, and almost none have a weighted-average concentration greater than 800 ppm.

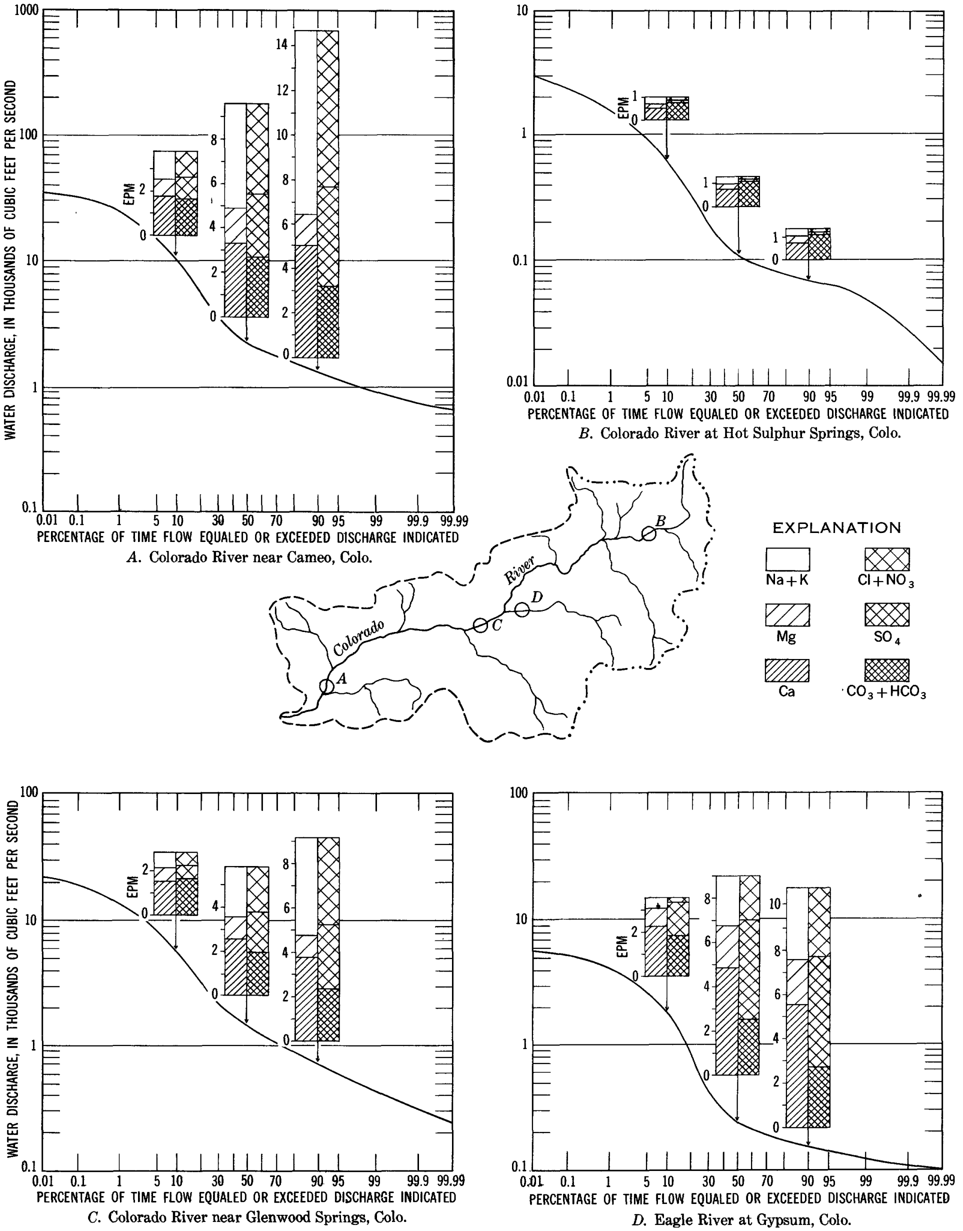
The diagrams shown in plate 2 show the geochemical character and ionic concentration of surface waters at many sites. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flow. The significance of the size and shape of the diagrams is given in the explanation on plate 2.

The principal environmental factor affecting the dissolved-solids concentration and chemical composition of the stream waters in any area seems to be the types of rocks that underlie each area. The effect of this factor is, of course, modified by the other factors. Comparisons of the zones shown in figure 52 with the different rock units and the precipitation map shown in plate 1 reveal the similarity between the distribution of the different zonal patterns of concentration and the areal distribution of the underlying rocks and of precipitation.

RELATION TO GROUND WATER

Chemical analyses of ground water are given in the basic data report (Iorns and others, 1964, table 227). These data are insufficient to permit a detailed appraisal of the effect of ground water on the surface water in the subbasin, but some of the relationships between the quality of water in the ground-water reservoirs and in the streams can be pointed out.

Ground-water flow to the streams comes from ground-water reservoirs recharged by precipitation, from alluvium bordering the streams that is recharged



A. Colorado River near Cameo, Colo.

B. Colorado River at Hot Sulphur Springs, Colo.

C. Colorado River near Glenwood Springs, Colo.

D. Eagle River at Gypsum, Colo.

FIGURE 51.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Colorado River Basin above the Gunnison River. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th centiles of the flow-duration curve for each location. The flow-duration curves are for water years 1914–57 adjusted to 1957 conditions.

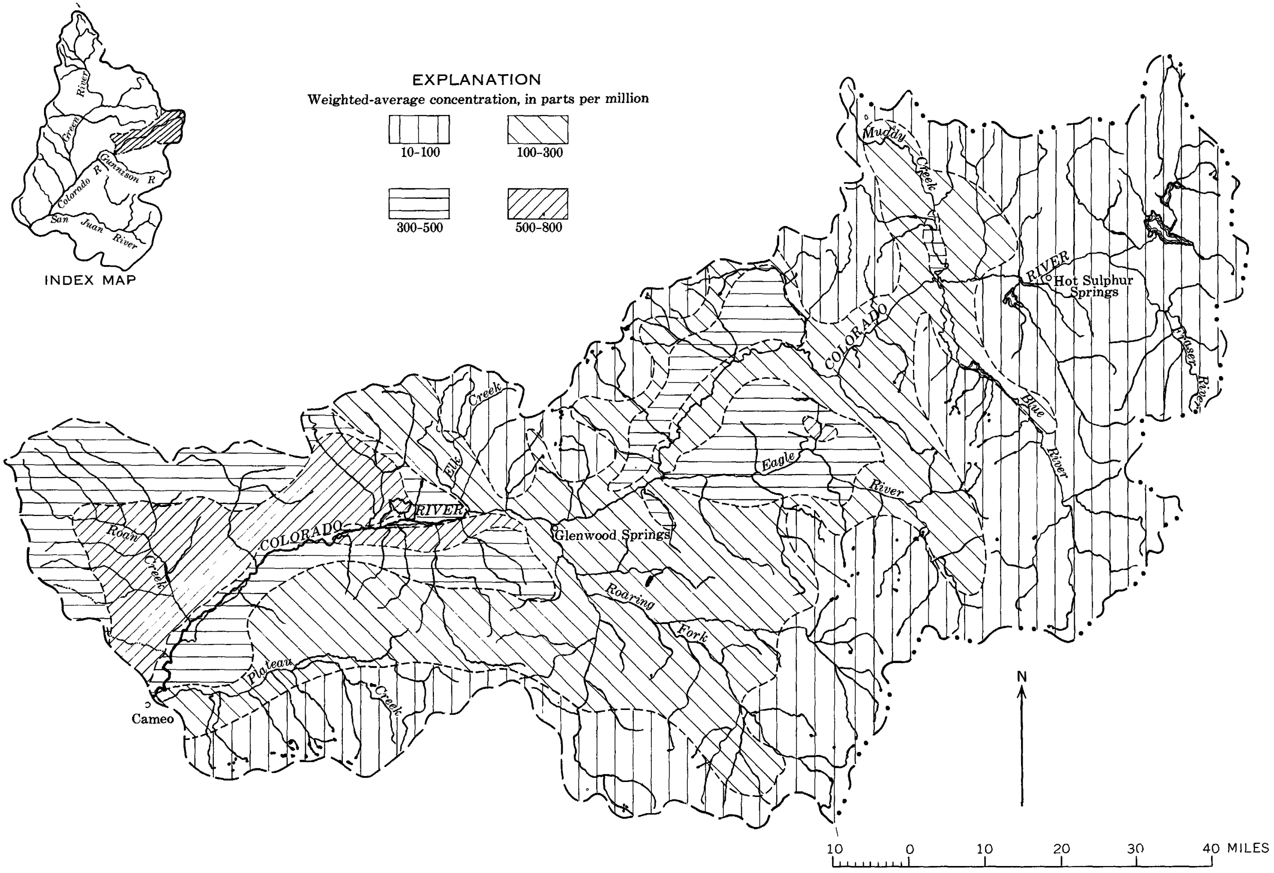


FIGURE 52.—Approximate weighted-average concentrations of dissolved solids in streams in the Colorado River Basin above the Gunnison River.

from the streams, from thermal springs, and from ground-water return flow from irrigated lands. The chemical quality of the ground water entering the streams from these sources greatly influences the chemical quality of the water in the streams. During periods of low flow, most of the stream water is effluent ground water and thus is a mixture of all ground water entering the stream system above the point of observation.

Extensive ground-water reservoirs are present in the mountainous areas where precipitation is abundant. Quantitative estimates of the amount of dissolved solids carried into selected headwater streams by water discharged from these reservoirs are given in table 20. These figures are based on the amount of water estimated to be contributed to the streams from ground-water reservoirs and the dissolved-solids concentration of the water in the streams during the times that the flow is maintained principally by ground water. (See chap. B, p. 59.) Comparison of the weighted-average concentration of dissolved solids in the ground water with the weighted-average concentration of dissolved solids in the stream shows that the ground water almost invariably has a higher concentration than the surface water.

A close similarity commonly exists between the chemical composition of water in flood-plain alluvium and that of the water in the stream. Both the river water and the water in the alluvium are a mixture of surface and ground water because of the interchange of water between the stream and the alluvium. The interchange may be due to the rise and fall of the stream or to the application of water to irrigated lands along the river. The chemical quality for low flow shown in figure 51 is probably representative of a mixture of all the ground water that enters the streams above each station.

Water from a well dug 18 feet into alluvium along the Colorado River below the Fraser River had a dissolved-solids concentration of 253 ppm. Both the ground water and the surface water in the immediate vicinity are of the calcium bicarbonate type. The concentration of the water in the alluvium is greater than the concentration of the water of the Colorado and Fraser Rivers nearby. Also, the water from the well had a higher percent sodium and greater percentage of sulfate than the surface water. Any water that flows into the Colorado River from the alluvium near this well would cause an increase in the concentration of the river water at all times of the year.

Water from a shallow well in alluvium on the north side of the Colorado River east of Kremmling has a chemical composition similar to that of Troublesome Creek near its mouth (fig. 53). The concentration of the ground water at the well is only slightly higher than that of Troublesome Creek during low flows.

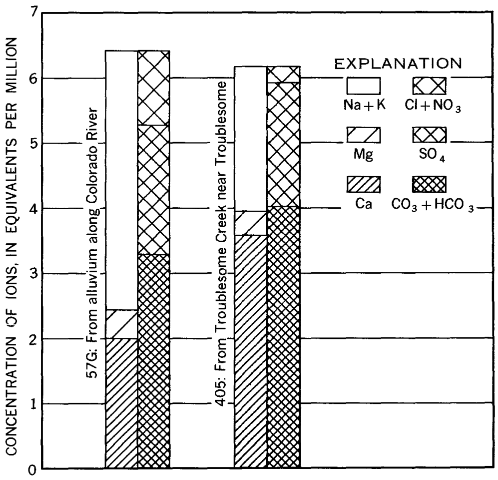


FIGURE 53.—Analyses of water from Troublesome Creek near Troublesome, Colo., and from alluvium nearby.

Analyses of water from a spring and from a well at Gore Pass Ranch in the valley of Pass Creek, a tributary of Muddy Creek, illustrate the differences in the chemical character of ground water that may exist within one small area. The water from the spring, which rises out of alluvium that overlies shale of Cretaceous age, had a dissolved-solids concentration of 290 ppm and is of the calcium bicarbonate type. The water from the well, which is reportedly drilled in alluvium overlying the shale, had a concentration of 848 ppm and is of the calcium sulfate bicarbonate type. Apparently the chemical quality of the water in the well is affected by the shale, whereas the spring water is affected sparingly, if at all, by that rock. In chemical composition and concentration the spring water closely resembles water from a well that penetrates the granite complex to the south and along the east side of the Gore Range.

In the subbasin many thermal springs, some of which have substantial concentrations of saline minerals, add their waters to the streams. Six thermal springs at Hot Sulphur Springs, Colo., have dissolved-solids concentrations of about 1,600 to 1,700 ppm (George and others, 1920). The water of the springs is of the sodium bicarbonate type. One spring is reported to discharge 75 gpm (gallons per minute) and another, 10 gpm. Though data are not available on the discharge of the other springs, the total discharge of all the springs probably does not exceed 100 gpm.

At this rate, the springs would discharge less than 400 tons of dissolved solids to the Colorado River annually.

In the Blue River basin near Dillon, Colo., four thermal springs discharge about 8 gpm of water having a dissolved-solids concentration of 1,300 to 1,800 ppm (George and others, 1920). These springs add about 27 tons of dissolved solids annually to the Blue River.

Two thermal springs below Dotsero, which discharge a total of about 1 cfs, have an average concentration of dissolved solids of about 10,700 ppm of which 88 percent is sodium chloride. At Glenwood Springs nine thermal springs discharge about 5 cfs. The average dissolved-solids concentration of these springs is about 20,200 ppm, of which about 87 percent is sodium chloride (Iorns and others, 1964, table 227). These 11 springs discharge about 91,300 tons per year of sodium chloride. In addition to these springs, there is evidence that other thermal springs rise in the bed of the river.

The dissolved-solids discharges of the Colorado River at the stream-gaging station near Dotsero, Colo., and at the chemical-quality station near Glenwood Springs (at Shoshone powerplant 6 miles upstream from Glenwood Springs) have been computed (table 14). As shown by the dissolved-solids discharge at the two sites, the increase in dissolved solids in the river reach is about 197,200 tons per year, most of which must be contributed by thermal springs rising in or near the bed of the stream. The amount of the contribution from the thermal springs may be approximately computed.

Between the gaging stations near Dotsero and at Glenwood Springs, Colo., the average increase in discharge is 152 cfs (table 14). On the basis of drainage area, about half the increase in surface flow would be tributary to the river above the quality station near Glenwood Springs. Chemical analyses of streams that enter the Colorado River in the reach indicate that the concentration of dissolved solids in the surface inflow would probably be less than 200 ppm. If we assume that the increase in streamflow between the gaging station near Dotsero and the quality station near Glenwood Springs is 76 cfs, that the concentration of the surface inflow is 200 ppm, and that the concentration of the ground-water inflow is 10,700 ppm (average of the two springs below Dotsero), then the ground-water discharge would be about 17 cfs. On the other hand, if we assume that the concentration of the ground-water inflow is 20,200 ppm (average of nine springs at Glenwood Springs), the ground-water discharge would be about 9 cfs. Either rate of ground-water discharge, with its respective dissolved-solids concentration, gives about 182,600 tons per year of dissolved solids as the amount contributed by ground water to the river between the stations near Dotsero and near Glenwood Springs. On the basis of percentage of sodium chloride at the two groups of springs, 160,700 tons per year of the dissolved-solids contribution is sodium chloride.

The water discharge of Colorado River at Glenwood Springs, Colo. (drainage area 4,560 sq mi), was used in computing the dissolved-solids discharge at the quality station near Glenwood Springs (drainage area 4,486 sq mi, table 14). The small amount of inflow between the two stations would have little effect on the computation of dissolved-solids discharge in table 14 or the preceding determinations.

Thermal springs below the quality station near Glenwood Springs also discharge large quantities of dissolved solids, mostly sodium chloride, into the Colorado River. Between the daily quality stations near Glenwood Springs and near Cameo, exclusive of the Roaring Fork basin, an average of 639,200 tons per year of dissolved solids are added to the stream (table 14). About 252,000 tons per year of this increase is sodium chloride. This determination was based on the average tons of sodium chloride transported past the station on Colorado River near Cameo, Colo., less the sodium chloride contributed by Colorado River near Glenwood Springs, Colo., and Roaring Fork at Glenwood Springs, Colo. Chemical analyses of water from the tributary streams in the reach indicate that most of the sodium chloride must come from ground-water inflow, most of which is probably from thermal springs.

In the Roaring Fork basin, thermal springs occur on Conundrum Creek, Fryingpan Creek, and Crystal River (George and others, 1920; Stearns and others, 1937). The springs on Conundrum Creek (about 18 miles south of Aspen, Colo.) have a dissolved-solids concentration of about 2,300 ppm and a discharge of less than 500 gpm. Those on Fryingpan Creek (below Norrie, Colo.) have a dissolved-solids concentration of about 2,200 ppm, and the discharge, though unknown, is reported to be large. The springs on the Crystal River, about 4 miles north of Redstone, Colo. (Avalanche Springs), have dissolved-solids concentrations ranging approximately from 2,000 to 3,100 ppm and range in discharge from 1 to 100 gpm. The weighted-average concentration of dissolved solids of the Avalanche Springs is about 2,700 ppm, and the total discharge is estimated to be less than 300 gpm. Assuming that the discharge of the springs on Fryingpan Creek is 500 gpm, the total dissolved-solids discharge of all the thermal springs in the Roaring Fork basin would be about 6,700 tons annually.

Four thermal springs in the Plateau Creek basin near Mesa, Colo., discharge from 1 to 50 gpm (George and others, 1920). The weighted-average dissolved-solids concentration of these springs is about 2,500 ppm, and the total discharge is 58 gpm. At these rates, the springs discharge about 320 tons of dissolved solids annually.

The combined discharge of all the known thermal springs in the subbasin (including those rising in the bed of the Colorado River) probably does not exceed 50 cfs, but the dissolved-solids discharge of the springs may be as much as 476,000 tons annually. This dissolved-solids discharge is about 30 percent of the combined dissolved-solids discharge of Colorado River and Plateau Creek near Cameo, Colo.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

The weighted-average concentration of dissolved solids in water diverted through the Alva B. Adams Tunnel near Grand Lake, Colo., was computed to be 35 ppm. An average of about 250,000 acre-feet of water annually was diverted or stored for diversion by this tunnel and appurtenant works in the water years 1954–57. This amount would normally be a part of the flow of Colorado River at Hot Sulphur Springs, Colo. Under conditions existing in the 1957 water year, the weighted-average concentration at Colorado River at Hot Sulphur Springs, Colo., was computed to be 76 ppm and the average annual discharge, 176,800 acre-feet (table 14). If the water now diverted through the tunnel still flowed past Hot Sulphur Springs, the weighted-average concentration in the water would be 62 ppm. (See chap. B, p. 61.) Records of the chemical quality of Colorado River at Hot Sulphur Springs, Colo., show that 62 ppm is about the same as computed for the short period the station was in operation before storage and diversion began.

Table 21 gives the estimated average annual amounts of water diverted out of the basin for the level of development existing upstream in 1957 and the weighted-average concentration of dissolved solids in the diverted water. With these data and those in table 14, the effect of the transmountain diversions on the quality of water for other streams and locations may be computed. For example, under conditions existing in 1957, about 353,100 acre-feet of water having a weighted-average concentration of 37 ppm was being diverted from this subbasin annually. The dissolved solids in the diverted water would amount to about 17,800 tons annually. The average annual discharge of Colorado River near Cameo, Colo., is 2,998,000 acre-feet, and weighted-average concentration is 387 ppm for water years 1914–57 adjusted to 1957 conditions. If there were no transmountain diversions, the average annual discharge would be about 3,351,100 acre-feet, and the weighted-average concentration would be about 350 ppm, or 37 ppm less than under 1957 conditions.

The average annual discharge of Colorado River and Plateau Creek near Cameo, Colo., is 3,168,200 acre-feet, and the weighted-average concentration is 382 ppm for water years 1914–57 adjusted to 1957 conditions. If there were no transmountain diversions, the combined average annual discharge of the two streams would be about 3,521,300 acre-feet, and the weighted-average concentration would be about 347 ppm, or 35 ppm less than under 1957 conditions.

EFFECT OF THE ACTIVITIES OF MAN

Sufficient data are available for several areas in the subbasin to provide a fairly reliable basis for computing the amounts of dissolved solids contributed to the streams as a result of the activities of man. In chapter B (pp. 61–66) the general procedures for making the determinations are discussed. In that discussion the dissolved-solids contributions to the Fraser River were used as an example. The following paragraphs briefly outline the data and computations for three other areas. Table 22 gives a budget of the water and dissolved solids contributed to and discharged from the area below Lake Granby and Willow Creek Reservoirs and above Hot Sulphur Springs.

Consumptive use on 5,500 acres of irrigated land in the intervening area is taken as 1.0 acre-foot per acre, according to relative altitude and mean temperature. Of the intervening area (50 sq mi) about 12 square miles (7,600 acres) is valley land, and about 38 square miles is mountainous. It is estimated that under natural conditions, the 7,600 acres of valley land would receive an average yearly ground-water recharge of about 4 inches, which would be effluent to the stream system. The estimated range of dissolved-solids concentration of this ground-water inflow is based on chemical analyses of water from a well on the north side of the Colorado River near the mouth of the Fraser River (253 ppm), of Fraser River at Granby at times of low flow (100 ppm), and of Colorado River at Hot Sulphur Springs at times of low flow (108 ppm).

The unmeasured surface-water inflow from the 32 square miles of mountainous terrain is the amount required to balance the inflow-outflow budget (16,000 acre-feet). Part of this area is underlain by rocks similar to the drainage area above Granby Dam, and part is underlain by rocks similar to the drainage area above the Willow Creek Reservoir. The weighted-average concentrations of dissolved solids in runoff from these two areas are 35 and 65 ppm, respectively. Accordingly, it is presumed that the weighted-average concentration of the intervening runoff would probably be in the same range.

Substantially all the indicated increase in dissolved solids within the intervening area—5,600 to 6,800 tons per year—is presumed to be the effect of irrigation. The smaller figure is equivalent to 1.0 ton per acre per year.

The second of the areas is the Troublesome Creek basin (table 22). In this budget, inflow is measured from 126 square miles and estimated for an intervening 52 square miles above the outflow station. Total unmeasured inflow of surface and ground water from the 52 square miles is the amount necessary to balance the outflow budget and estimated to be three-fourths surface water (4,800 acre-ft) and one-fourth effluent ground water (1,600 acre-ft). This proportion is based on the average annual precipitation in the area (about 14 in.), the nature of the underlying rocks and soils, and general topographic features. Because the rocks that underlie the intervening area are about the same as those above the two inflow stations, the dissolved-solids concentration of the unmeasured surface water would range somewhere between the weighted-averages for the two inflow stations. The natural concentration of the effluent ground water would probably range from about 75 to 120 ppm, as indicated by analyses of water from streams in the area during low flow (Troublesome Creek near Pearmont, 77 ppm, and East Fork Troublesome Creek near Troublesome, 112 ppm).

Water consumed on the intervening irrigated land is presumed to average 0.7 foot over the 8,000 acres of valley land involved. This relatively small consumption is compatible with the climatic environment and altitude of the irrigated lands—about 9,000 feet above sea level.

Substantially all the indicated increase in dissolved solids—not less than about 3,700 tons per year—is inferred to be an effect of irrigation. This increase is equivalent to about 0.5 ton per year per acre of irrigated land.

The third area is the Roaring Fork basin (table 23). In this area, four stations determine inflow from 486 square miles (see table 14); the intervening ungaged area, above the outflow station at Glenwood Springs, is 974 square miles. Being so extensive, this intervening area will be first considered according to the nature of underlying rocks and second, according to distribution of valley lands.

Granitic and Precambrian rocks underlie the drainage basins above the two inflow stations—Roaring Fork near Aspen and Fryingpan Creek at Norrie— and an equally extensive area within the ungaged intervening area. Being similar in mean altitude and other environmental features, the gaged and ungaged areas underlain by granitic and Precambrian rocks are presumed to yield water and dissolved solids in equal yearly amounts (171,700 acre-ft of water and 6,100 tons of dissolved solids, each).

Of the remaining intervening area, which is underlain by diverse rocks of sedimentary and volcanic origin, about 144 square miles is valley land and 918 square miles is mountainous terrain of which 282 square miles is above the gaging stations on Castle Creek near Aspen and Crystal River near Redstone. Valley lands in the vicinity of Aspen (about 50 sq mi) at altitudes generally more than 7,500 feet receive an annual precipitation of about 25 inches of which 7 inches is estimated to become ground-water recharge effluent to the stream system. In the lower part of the basin in the vicinity of Carbondale, at an altitude of about 6,000 feet, about 94 square miles of valley land receives an annual precipitation of about 18 inches of which about 4¼ inches a year is estimated to become effluent ground water. Thus, natural ground-water inflow from valley lands underlain mostly by sedimentary rocks would total about 40,000 acre-feet annually. Chemical analyses of water from two wells in the area showed dissolved-solids concentrations of 404 and 744 ppm. The dissolved-solids concentration of Roaring Fork at Glenwood Springs at low flow is about 500 ppm and that for Sopris Creek at low flow is about 450 ppm. However, the water in the wells may be more dilute than under natural conditions because of the application of large amounts of irrigation water; and the waters in the streams at times of low flow may not be indicative of natural ground water effluent from the valley lands because of dilution by water from headwater streams. For these reasons, a probable range in weighted-average concentration of dissolved solids of natural ground water from 400 to 900 ppm is used, though the higher limit is about 150 ppm greater than the maximum indicated by available data.

Water consumed on irrigated land is estimated at 1.1 feet per year from 31,400 irrigated acres, or 34,540 acre-feet yearly.

Unmeasured surface-water inflow from the mountainous part of the intervening area that is underlain by sedimentary and volcanic rocks is the amount which, with all other inflow items, will balance the outflow budget. The amount is 285,110 acre-feet a year. The dissolved-solids concentration of this last inflow item is taken as 160 ppm—that is, equal to the concentration of Castle Creek and the Crystal River after adjustment for thermal-spring water received by these two streams.

Excluding a nominal amount probably due to pickup of domestic and industrial wastes, the indicated increase in dissolved solids within the intervening area is considered an effect of irrigation. Per irrigated acre, this increase would be at least 3.0 tons per year.

The activities of man in other parts of the subbasin not included in the tabulations are estimated to result in a contribution of 297,100 tons of dissolved solids annually. This estimate is based on the indicated rates of dissolved-solids yield per acre of irrigated land for the areas in the preceding tabulations and for other areas in the Upper Colorado River Basin, the geologic character of the formations underlying irrigated lands, and chemical analyses of water at miscellaneous sites in the subbasin. It was assumed in the estimate that the distribution of population and industry were approximately proportional to the distribution of irrigated lands. Table 24 summarizes, at gaging stations and for the subbasin, data on dissolved solids contributed by natural sources and as a result of the activities of man. About 402,000 tons of the 1,644,100 tons of dissolved solids discharged annually from the subbasin are contributed as a result of the activities of man. The natural dissolved-solids discharge from the subbasin averages about 1,242,100 tons annually.

Had there been no activities of man, the weighted-average concentration of dissolved solids in the water flowing out of the basin would have been about 272 ppm, as compared to a weighted average of 382 ppm for water years 1914–57 adjusted to 1957 conditions. This figure is based on annual consumptive use of 1,800 acre-feet of the water withdrawn for domestic and industrial purposes and 190,300 acre-feet of the water used in irrigation.

The increase in dissolved solids due to irrigation may be approximately determined. If 100 tons per year per 1,000 people is assumed as the rate of contribution resulting from domestic and industrial water uses in the basin, the annual contribution would amount to about 2,620 tons of dissolved solids. This would leave a balance of about 399,600 tons per year as resulting from irrigation.

FLUVIAL SEDIMENT

Sediment records obtained by the U.S. Forest Service on two small tributaries of St. Louis Creek in the Fraser Experimental Forest in 1950–52 (Raymond Price, written commun., 1960) give some indication of the sediment contributed from forested lands. The concentration of suspended sediment in these streams indicated that the sediment transported by streams that drain similar areas would be about 36 tons per square mile per year. The drainage basin of St. Louis Creek is underlain by Precambrian rocks, such as schist and gneiss, and by glacial debris derived from these rocks.

Only one suspended-sediment station has been operated in the Colorado River Basin above the Gunnison River. This station, Colorado River near Kremmling, Colo., was operated for intermittent periods in 1905 and 1906. Because of the changes that have occurred upstream from this station since that time, this record is not as useful for indicating the probable sediment load under present conditions. However, if the Colorado River carried sediment in about the same concentration at the end of 1957 as it did in 1905–06, an average of about 186,000 tons per year would be transported past the station.

The sediment transported by the Colorado River at the Kremmling station, with the conditions of upstream development that existed in 1957, is at least 40,000 to 50,000 tons a year less than in 1905–06. Lake Granby and the Willow Creek, Williams Fork, and Green Mountain Reservoirs now trap the sediment that is removed from about 1,330 square miles of drainage area above the Kremmling station.

Estimates of the suspended-sediment discharge for other streams where suspended-sediment samples have been collected are given in table 25. (See chap B. p. 66.) A relatively large part of the sediment transported past the station near Cameo, Colo., comes from the drainage area between that station and the Roaring Fork. This area contributes an average of about 4,710 tons per year per square mile of drainage area.

Most of the sediment transported in suspension in the streams above the Gunnison River is smaller than 0.062 mm, or below sand size. Large amounts of sediment are probably transported by these streams on or close to the bed because the beds of the streams are composed of coarse material. No quantitative estimate can be made of the amount transported in this manner because of the lack of sediment data.

SUITABILITY OF WATER FOR VARIOUS USES

The following appraisals, based on chemical-quality criteria (see chap. B, pp. 66–73) indicate the general suitability of stream waters in the subbasin for domestic, agricultural, and industrial purposes. Pathological organisms which would require treatment of the water to make it bacteriologically safe for some uses, are not considered in the appraisal. The chemical analyses in the basic data report (Iorns and others, 1964) were used in appraising the suitability of water for various uses.

DOMESTIC USE

Generally, all streams in the subbasin in their headwater areas, where most of the water supply is produced, are of good quality and satisfactory for domestic use. Downstream, the quality of water in the streams is not as good as in the headwaters. The water in the main stem of the river above Glenwood Springs, Colo., even during periods of low flow is satisfactory for domestic uses, but at the gaging station near Cameo the concentrations of sulfate, chloride, and total dissolved solids at times exceed the maximum limits used in this appraisal.

Concentrations of dissolved solids in Muddy Creek in its lower reaches, the Eagle River as far upstream as Wolcott, and the Roaring Fork and Plateau Creek in their lower reaches also exceed the criteria for domestic use at times in periods of low flow. In addition, many of the smaller tributaries of these streams and of the main stem of the river between Glenwood Springs and Cameo are not satisfactory for domestic use in their lower reaches during periods of low flow. However, in any part of the subbasin, water satisfactory for domestic use is obtainable within a relatively short distance of the point of need. Table 26 shows the general suitability of water for domestic use in different parts of the subbasin.

Nitrate is present in most stream waters but usually in concentrations of less than 5 ppm. The waters in the streams range from soft to very hard.

AGRICULTURAL USE

Large quantities of water are used for irrigation in the subbasin. Water is also used for livestock, mostly sheep and cattle. Most livestock have the ability to tolerate relatively high concentrations of dissolved solids in their drinking water, although even small concentrations of certain constituents, such as selenium, are toxic. Most, if not all, of the surface water in the subbasin is suitable for livestock watering.

The suitability of surface water for irrigation varies from place to place. In table 27 the waters of the streams at many sites, for conditions of upstream development existing in 1957, are appraised as to their suitability for irrigation use. The criteria and methods used in the appraisal are given in chapter B (pp. 69–73). Chemical analyses for high, medium, and low flows in the basic data report (Iorns and others, 1964) were used for the appraisal. High flows are those greater than the flow exceeded 20 percent of the time; low flows are those less than the flow exceeded 80 percent of the time; and medium flows are those greater than the flow exceeded 20 percent of the time. The range of discharge for low, medium, and high flows for most of the sampling sites was determined from table 6.

One to three determinations of residual sodium carbonate were made for almost 100 sampling sites on streams in this subbasin. These determinations show that most of the surface waters contain no residual sodium carbonate or extremely small amounts. The greatest amount determined was 0.69 epm (equivalents per million) for Divide Creek at mouth, near Silt, Colo. This amount is considerably less than 1.25 epm, the upper limit for water considered generally safe for irrigation.

Surface waters in the subbasin range from C1–S1 to C4–S2 according to the criteria given in chapter B and to interpretation of plots of the relation of specific conductance to computed sodium-adsorption-ratio (SAR), as shown in figure 27, chapter B. Most of the water in this subbasin would be classified as C2–S1 or better. The U.S. Salinity Laboratory Staff (1954) states that C2–S1 waters can be used successfully for irrigation if a moderate amount of leaching occurs (usually less than 10 percent). Waters in this or a better category can be used on almost all soils with little danger of the accumulation of exchangeable sodium in harmful amounts.

Computations of the "required leaching" by Eaton's formulas (1954) show that for most of the surface water in the subbasin the required leaching for good yields would be less than 10 percent, except for the low flows of some streams. The greatest "required leaching" computed was 54 percent and was for a low flow of Roan Creek at De Beque. Even for low flows, a required leaching of more than 30 percent was computed for only a few sampling sites. These sites are at the mouths of Muddy, Rifle, and Roan Creeks.

Adverse effects of using irrigation water that has certain undesirable chemical properties can be partly offset by adding calcium sulfate (gypsum) to the fields or to the irrigation water. Computations show that most of the surface water above the Gunnison River needs less than 100 pounds of gypsum per acre-foot of applied water (table 27). Amounts of gypsum shown in table 27 are based on the assumption that all the calcium required to maintain a percent sodium of less than 70 to offset bicarbonate precipitation, or to supply calcium for plant assimilation, would have to come from the irrigation water. This assumption would, of course, not be applicable for most of the soils along the Colorado River and its tributaries above the Gunnison River. Most of the soils contain available calcium sufficient for plant uptake, and the addition of gypsum would not be necessary.

In summation, most of the surface waters of the Colorado River Basin above the Gunnison River can be used successfully for irrigation on most soils and for most crops if a moderate amount of leaching occurs. If the soils are such that the required leaching can take place, there is little danger of developing a saline soil or harmful levels of exchangeable sodium.

INDUSTRIAL USE

The surface water of the subbasin can be used in many industrial applications without further treatment. Comparisons of the chemical analyses of surface waters in the basic data report (Iorns and others, 1964) with the water-quality tolerances for many industrial uses given in chapter B (table 16) indicate that the waters will meet the requirements of most uses, especially if the water receives a minor amount of treatment.

Turbidity in water is due to suspended matter, such as clay, silt, sand, and organic material. The turbidity of many of the streams above the Gunnison River is usually low, but at times during the spring runoff and after storms the water from some of the streams would need to be clarified by filtering or by holding in settling basins before use. Some industries, such as those producing carbonated beverages or rayon, have very low tolerances for turbidity.

Industrial requirements for hardness in water vary greatly. The tolerance may be as low as 8 ppm, or even lower, for some boiler-feed water and as much as 200 ppm for water used in carbonated beverages, in brewing, and in distilling. Most industries, however, require a soft to moderately hard water. The water of many of the streams above the Gunnison River is soft to moderately hard and could be used for many industries without further softening.

Dissolved-solids concentration, pH, and concentrations of iron, manganese, and silica are important factors in the suitability of a water for industrial use. The dissolved-solids concentrations of most of the streams above the Gunnison River do not exceed maximum tolerances for most industries. Those industries that have low tolerances for total dissolved solids could be located near, or obtain water from, the headwaters of most of the streams. The pH of surface water in the drainage basin above the Gunnison River ranges from about 6.7 to 8.3. However, most of the waters have a pH of 7.5 to 8, which is within the tolerance range for pH of most industries. Water-quality tolerances of iron and manganese in water for industrial use are very low. The water from many of the streams in this subbasin would require treatment to remove these constituents before the water would be suitable for many industrial uses, such as most textile manufacturing.

Water-quality tolerances for many mining and metal-fabrication industries are rather broad. Most of the surface waters in the subbasin would be satisfactory for these uses without further treatment.

RECREATIONAL USE

Use of water for recreation is expanding rapidly. The streams and lakes in the subbasin are mostly ideal for this purpose. The surface waters offer unlimited opportunities for trout fishing, and private and public lands that border the streams and lakes are rapidly becoming a national playground. Boating and swimming in the many natural and manmade lakes attest to the suitability of these surface waters for recreational uses.

GUNNISON RIVER BASIN

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Ten reservoirs that have storage capacities greater than 1,000 acre-feet are in operation in the Gunnison River basin (table 3). The combined usable storage capacity of these reservoirs (1957) is 130,120 acre-feet, and all are used to store water for irrigation. Many small reservoirs, lakes, and stock ponds are scattered over the basin.

Most of the 10 reservoirs store water from the drainage basins in which they are located. However, Gould Reservoir receives part of its supply from Crystal Creek, and Fruitgrowers Reservoir receives its water supply from Surface and Currant Creeks.

TRANSMOUNTAIN DIVERSIONS

Three transmountain diversions export water out of the basin into the Arkansas and Rio Grande basins east of the Continental Divide. Table 28 lists the annual quantities exported by two of the diversions for the water years 1914–57. No records are available for the Tarbell ditch, which began diverting water in 1913. The average annual diversion by the Larkspur and Taber ditches for the 4 water years 1954–57 was 303 acre-feet.

Water is imported into the Surface Creek drainage basin from Leon Lake (Plateau Creek basin) and into the Uncompahgre River basin from Mineral Creek (San Juan basin). These diversions are small, and no records are available on the amount imported.

IRRIGATION

The major use of water in the Gunnison River basin is for irrigation. The U.S. Bureau of the Census (1953) reported 269,400 acres of irrigated land in 1949. Of this amount, 103,700 acres is in the Uncompahgre River and Roubideau Creek basins. Since 1949, the increase in irrigated acreage has been small; most of it has resulted from reclamation of land by drainage. The distribution of the irrigated lands is shown in plate 5 and summarized in table 5.

Most of the irrigated lands above the North Fork are at high altitudes, and the growing season is short. Along the North Fork and in the Uncompahgre River basin, the climate is favorable for growing fruit, vegetables, alfalfa, and sugar beets. Much of the irrigated land, particularly that irrigated from tributary streams, does not have a full water supply. Taylor Park Reservoir, completed by the U.S. Bureau of Reclamation in 1937, supplements the available supply from natural flow for a large area in the Uncompahgre

River valley. Water is diverted to this valley from the Gunnison River through the Gunnison tunnel which was completed in 1914. (See pl. 5.)

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water in the subbasin due to irrigation practices was 348,200 acre-feet. The Commission estimated that 251,800 acres of land was irrigated and that 32,900 acres of land received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The population (1960) of the Gunnison River basin was about 38,000, a little less than five persons per square mile. The five largest communities and their populations are Montrose, 5,044; Delta, 3,832; Gunnison, 3,477; Cedaredge, 1,152; and Paonia, 1,083.

Montrose is the only community that has a sewage-treatment plant. Most sewage wastes go directly into adjacent streams, but, because streamflows are relatively large and amounts of waste are small, pollution problems are not acute.

There are no hydroelectric plants and no major industrial plants in the basin. There are, however, a few mines in the headwater areas and a sugar refinery at Montrose. Domestic and industrial consumptive uses of water in the subbasin are estimated to be about 2,600 acre-feet per year.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Flow behavior of headwater streams in the Gunnison River basin is similar to that of headwater streams in the Colorado River Basin above the Gunnison River because the environmental factors in the two subbasins are similar. Summer thunderstorms increase in frequency and intensity toward the western part of the subbasin and cause sudden increases in runoff of short duration in some streams.

Seasonal patterns of runoff are shown by the hydrographs for streams at three sites for the 1954 water year (fig. 54). The hydrograph for East River at Almont, Colo., shows the pattern of runoff characteristic of a stream whose water is derived principally from melting snow and is only slightly affected by the activities of man. The hydrograph for Uncompahgre River at Colona, Colo., shows the effect of depletion by diversions for irrigation. Summer thundershowers cause brief increases in flow at the Colona station. The hydrograph for Gunnison River near Grand Junction, Colo., shows the outflow from the basin. Increases in runoff from storms during the July–October period are very apparent.

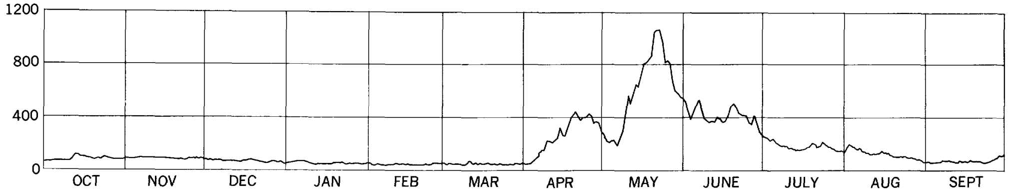
FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 19 selected sites. Using the methods described in chapter B (pp. 46–48), flow-duration curves for streams at 15 sites were developed and adjusted to the 44-year base period and conditions of upstream development existing in 1957. Adjustment to 1957 conditions of water use consisted principally of adjusting streamflow records at main-stem stations for the effect of Taylor Park Reservoir and the effect of increasing diversions through the Gunnison tunnel. The historical flow-duration curves and adjusted curves reduced to table form are given in table 6. The pattern of flow in the Gunnison River below the Gunnison tunnel was affected after 1914 by diversions through the tunnel and after the 1937 water year by regulation of Taylor Park Reservoir. For this reason, three historical flow-duration curves are given for Gunnison River below Gunnison tunnel in table 6. In table 7 the methods used in adjusting the historical flow-duration curves and the upstream developments in which changes occurred are shown. The table also gives the authors' accuracy rating of the adjusted long-term curves.

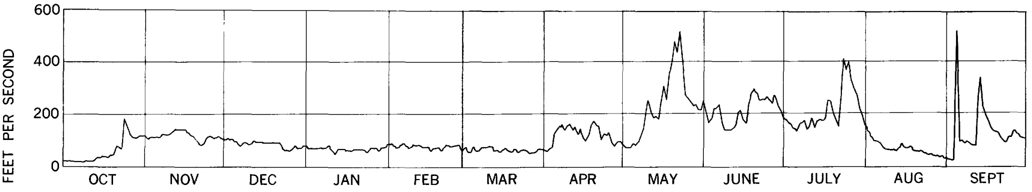
Flow-duration curves for streams at three sites, with discharges as ratios of the average discharges, are shown in figure 55. The influence of the summer thunderstorms in the western part of the basin probably explains why the upper part of the curve for Uncompahgre River at Colona, Colo., is steeper than the upper part of the curve for East River, whose major source of water is snowmelt. Summer storms and irrigation return flow, both of which affect the flow patterns of Uncompahgre River at Colona, Colo., and Gunnison River near Grand Junction, Colo., cause the middle and lower parts of the curves for these two stations to be similar.

Variability indices of the flow-duration curves and percentages of average annual discharge estimated to be contributed to the stream system by ground water for selected streams in the subbasin are given in table 8. (See fig. 38 and chap. B, pp. 48–53.) The percentage value of ground-water contribution for Smith Fork could not be computed because of the effect of irrigation.

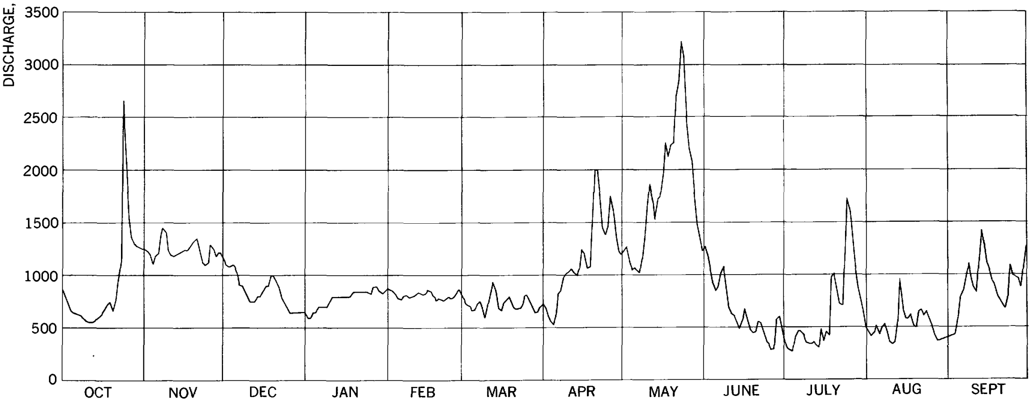
The headwaters of Tomichi Creek, which has the lowest variability index and highest percentage of ground-water contribution, are mostly underlain by extrusive igneous rocks. Fractures in these rocks allow precipitation to infiltrate into ground-water storage, which, in turn, maintains the stream during low-flow periods. The drainage basin of Uncompahgre River above Colona, Colo., which has the next lowest index value, also contains large areas of extrusive igneous rocks, such as tuff and breccia, in its headwaters.



A. East River at Almont, Colo.



B. Uncompahgre River at Colona, Colo.



C. Gunnison River near Grand Junction, Colo.

FIGURE 54.—Seasonal pattern of runoff in the Gunnison River basin, 1954 water year.

Because the permeability of these rocks is probably great, water can infiltrate to ground-water storage. Ground-water return flow from irrigation of lands upstream from the gaging station also contributes to the stream during low flow. The Lake Fork drainage basin also is underlain by extrusive igneous rocks that are highly altered, rich in clay, and consequently less permeable than those in the Tomichi Creek and Uncompahgre River basins.

The East River and Smith Fork drainage basins are mostly underlain by the Mancos Shale and the Mesaverde Formation, and the Muddy Creek drainage basin is mostly underlain by the Wasatch Formation. These sedimentary rocks are relatively impermeable, and runoff from these basins is rapid. Thus, flow-duration curves have steep slopes, and index values are high. These rocks afford relatively little opportunity for ground-water storage.

VARIABILITY OF ANNUAL RUNOFF

The variations in annual water discharges of three streams for the water years 1914–57, unadjusted, are shown in figure 56. The annual water discharges of East River at Almont, Colo., for the water years 1923–34 and of Gunnison River near Grand Junction, Colo., for the water years 1914–16 were estimated.

The histogram for East River is approximately representative of natural flow. The histogram for the Uncompahgre River does not represent natural flow, but the consumptive use of water above the station was probably constant throughout the period. The flow of Gunnison River near Grand Junction, Colo., is affected by irrigation consumptive use, in which some increase occurred during the 1914–57 period.

The standard deviation and coefficient of variation of annual discharges at five streamflow stations in the Gunnison River basin are given in table 11. The coefficients of variation are also shown in plate 4. The coefficients of all the streams except Gunnison River near Grand Junction, Colo., are remarkably close to the same value. The coefficient of variation of Uncompahgre River at Colona, Colo., might be expected to be slightly higher because of more frequent summer storms in the western part of the basin, but this is not the case. Permeable volcanic rocks in the headwaters of this stream may be the principal reason why the coefficient is lower than might be expected.

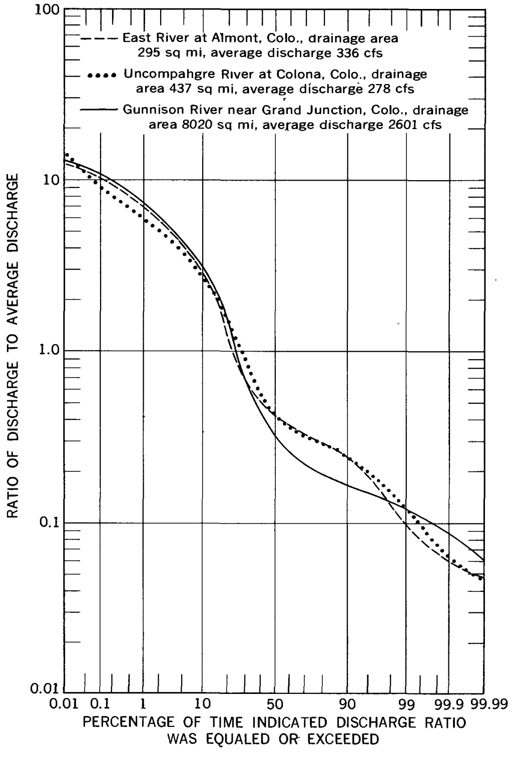


FIGURE 55.—Flow-duration curves of streams in the Gunnison River basin, water years 1914–57 adjusted to 1957 conditions.

The coefficient of variation of Gunnison River near Grand Junction, Colo., is higher than those of the headwater streams. The higher coefficient is probably due mainly to the cumulative effect of infrequent summer storms over a large area in the lower part of the basin, but it may be due in part to the effect of irrigation. If irrigation consumptive use were greater in years of low runoff and less in years of high runoff, the range in discharge between years of low and high runoff would be greater. On the other hand, the ground-water reservoir under the irrigated lands may serve to maintain a higher discharge in low-runoff years than would occur without irrigation.

PRECIPITATION-RUNOFF RELATION

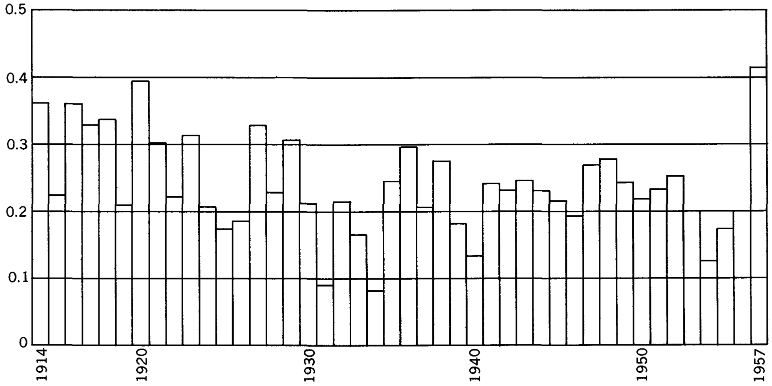
Precipitation, water yield, and natural consumptive use for four drainage areas in the subbasin are given in table 13. The water yield from the East River and Smith Fork basins is high because the basins are underlain by relatively impermeable rocks. Much of the headwater area of the Taylor River is underlain by rocks of the Precambrian complex and is an area of high runoff and low consumptive use. However, Taylor Park and the valley downstream contain extensive deposits of Quaternary alluvium, which is highly permeable and supports a heavy growth of vegetation. Consumptive use by this vegetation is appreciable. The extrusive volcanic rocks and extensive talus slopes at the edges of Grand Mesa in the headwaters of Kahnah Creek readily absorb precipitation. The talus slopes support a heavy growth of vegetation which consumes much of the precipitation.

CHEMICAL QUALITY OF WATER

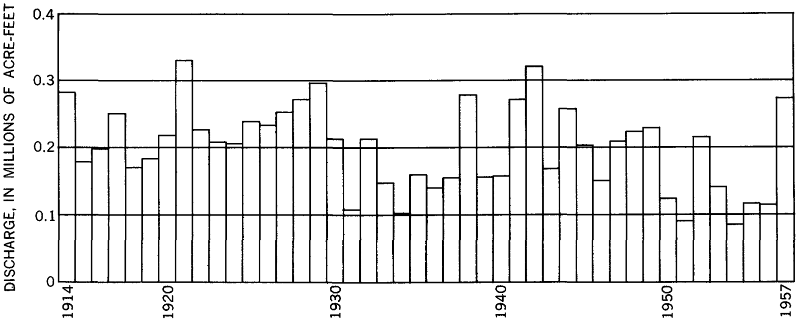
DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at only one station in the Gunnison River basin. Monthly and annual weighted-average chemical analyses for this site are given in the basic data report (Iorns and others, 1964, table 181). In addition to the daily data at this station, chemical analyses of streams at other sites have been obtained.

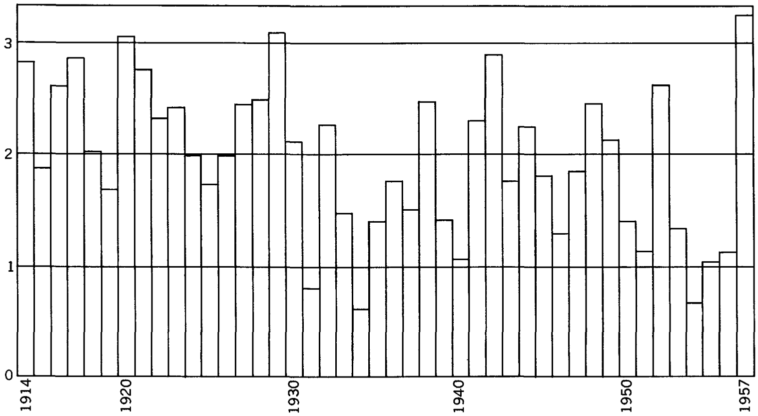
The chemical analyses of water at 16 sites, the daily record for Gunnison River near Grand Junction, Colo., and flow-duration tables were used to compute duration tables (tables 15 and 16) of dissolved-solids concentration and discharge. (See chap. B, pp. 58–59, for description of computation method.) Water and dissolved-solids discharge for the 17 stations is summarized in table 14. The computed dissolved-solids discharges for the 17 sites show that the average annual yield of dissolved solids from the Gunnison River basin ranges from about 21 tons per square mile in the areas that



A. East River at Almont, Colo.



B. Uncompahgre River near Colona, Colo.



C. Gunnison River near Grand Junction, Colo.

Figure 56.—Variability of annual discharges of selected streams in the Gunnison River basin, water years 1914–57.

are underlain by volcanic rocks on the north side of the San Juan Mountains to more than 400 tons per square mile for the Uncompahgre River basin above Delta.

Percentages of contribution of dissolved solids and water discharges from different parts of the basin, based on the dissolved-solids and water discharges of Gunnison River near Grand Junction, Colo., were computed from the data in table 14 (fig. 57).

The average annual discharge of the Gunnison River above the Gunnison tunnel (Gunnison River below Gunnison tunnel, Colo., 944,000 acre-ft, and Gunnison tunnel diversion, 337,000 acre-ft) is equivalent to about 68 percent of the outflow from the basin. This water contains an average of about 193,600 tons of dissolved solids per year (weighted-average concentration of dissolved solids, 111 ppm), which is only about 13 percent of the average annual discharge of dissolved solids of Gunnison River near Grand Junction, Colo. The drainage area above the Gunnison tunnel is about 50 percent of the total drainage area in the subbasin.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in the concentration of dissolved solids in all streams investigated in the Gunnison River basin, except immediately below the Taylor Park Reservoir, follows the normal pattern of snowmelt streams; the concentrations are highest during periods of low flow and lowest during periods of high flow. Mixing of water in Taylor Park Reservoir causes the concentration in the released water, at all times, to approximate the weighted-average concentration in the inflow to the reservoir. Above the Gunnison tunnel the seasonal range between minimum and maximum concentration is not great. The maximum concentration in streams in this area is usually less than twice the minimum concentration. The chemical composition of the

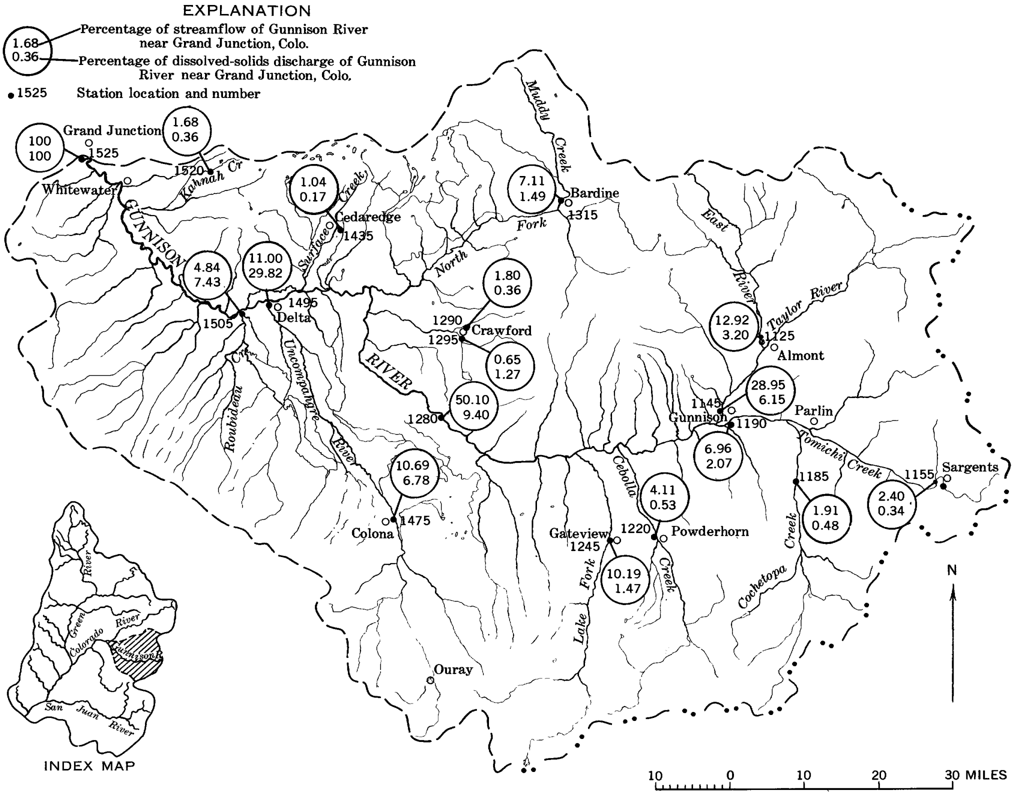


FIGURE 57.—Approximate dissolved-solids discharge and streamflow expressed as percentages of the dissolved-solids discharge and streamflow of Gunnison River near Grand Junction, Colo.

water in these headwater streams also does not change much between high and low flow.

Below the Gunnison tunnel, many streams have a much higher range in concentration during the year, particularly in their downstream reaches. For example, the maximum concentration at Gunnison River near Grand Junction, Colo., is more than 11 times the minimum concentration. The chemical composition of the water passing this station also changes considerably between high and low flow.

The coefficient of variation of yearly weighted-average concentration of dissolved solids for Gunnison River near Grand Junction, Colo., based on the period of historical chemical-quality record (water years (1932–57), is 0.26. For the same period, the coefficient of variation of annual water discharge is 0.39. Adjustment to water years 1914–57 increases both coefficients by 0.01. The relation between the coefficients of variation at this station is shown with others in the Grand division in figure 45. In table 18, coefficients of variation and standard deviations of weighted-average concentrations for selected stations, computed by the equation of relation shown on page 94, are given.

RELATION TO STREAMFLOW

The relation between water discharge and chemical composition of water of Gunnison River near Grand Junction, Colo., is given in table 19. The relation between chemical quality of water and streamflow at three other stations in the basin are also shown in figure 58. The chemical composition of Gunnison River below Gunnison tunnel, Colorado, is fairly representative of the streams above this station where the range in concentration is small between low and high discharges. Duration tables of dissolved-solids constituents may be prepared from the values in tables 6, 15, 16, and 19.

Chemical-quality records obtained for Gunnison River near Whitewater, Colo., in 1905 and the more recent records obtained a short distance downstream near Grand Junction indicate that a pronounced change in the relation between water discharge and dissolved-solids concentration has occurred during the intervening years (fig. 59). The solid curve plotted on figure 59 is based principally on the average relation between concentration and water discharges for water years 1950–57 at the gaging station on Gunnison River near Grand Junction, Colo.

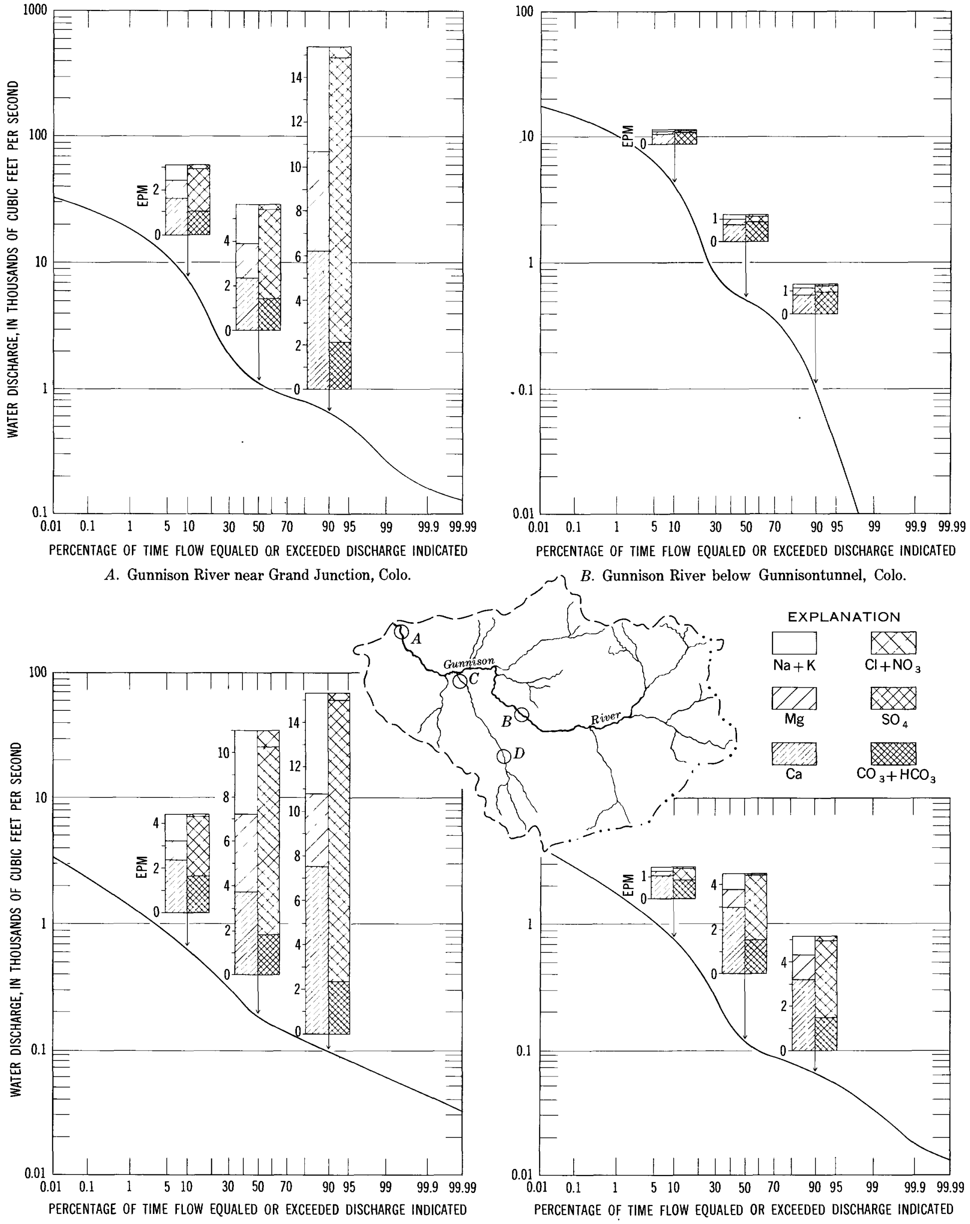
RELATION TO GEOLOGY

Except for two streams, the chemical type of water in the headwater streams does not vary greatly, regardless of the underlying rocks. The two exceptions are Tomichi Creek and the Uncompahgre River above Dallas Creek. The waters of Tomichi Creek are of the calcium bicarbonate type but contain large percentages of silica. The Tertiary volcanics underlying a large part of the Tomichi Creek basin are the most likely source of the silica. The waters of the Uncompahgre River above Dallas Creek are of the calcium sulfate type. Tertiary volcanic rocks underlying most of the drainage basin of the Uncompahgre above Dallas Creek have been faulted and highly altered. In such rocks, soluble sulfate and carbonate minerals are common.

In the rest of the subbasin, waters of the streams in their headwaters are of the calcium bicarbonate type with the concentration of dissolved solids differing measurably according to the type of underlying rock. For example, the concentration of dissolved solids in East River, whose basin is underlain largely by the Mancos Shale and the Mesaverde Formation of Late Cretaceous age, is about twice that of the Taylor River above the Taylor Park Reservoir, whose basin is underlain by igneous and metamorphic rocks of Precambrian age. At their junction during periods of low flow, the concentrations of dissolved solids in the East and Taylor River are about 150 and 77 ppm, respectively. The headwaters of Smith Fork and of Muddy Creek near Bardine, Colo., also are underlain by Cretaceous rocks and have concentrations during low flow of less than 300 ppm. It is most likely that in these areas of high precipitation much of the readily soluble minerals near the surface have been rather thoroughly leached from the Cretaceous rocks.

The interior of the subbasin below Cimarron Creek is mostly underlain by the Mancos Shale, the Mesaverde Formation, and the Dakota Sandstone of Cretaceous age. The waters of the streams as they pass through this area change from the calcium bicarbonate type to the calcium sodium magnesium sulfate type and increase greatly in dissolved-solids concentration. The average annual precipitation over this area is less than 12 inches, and consequently there is relatively little natural runoff. Most of the change in the quality of water in the streams is probably caused by irrigation. The irrigated lands are situated on alluvial material derived from the underlying parent rocks, which are mostly of marine origin. Because of the low precipitation, there has been little opportunity for leaching, and these deposits still retain much of the soluble mineral matter common in the parent rocks.

The quality of the water of the Gunnison River at its mouth is the result of all the upstream environmental factors that affect the water as it passes over and through the ground. Likewise, the quality of water of the streams in the drainage system at any point is the result of all the environmental factors above that point. This is illustrated by figure 60, in which zones of



A. Gunnison River near Grand Junction, Colo.

B. Gunnison River below Gunnisontunnel, Colo.

C. Uncompahgre River at Delta, Colo.

D. Uncompahgre River at Colona, Colo.

Figure 58.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Gunnison River basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for water years 1914–57 adjusted to 1957 conditions.

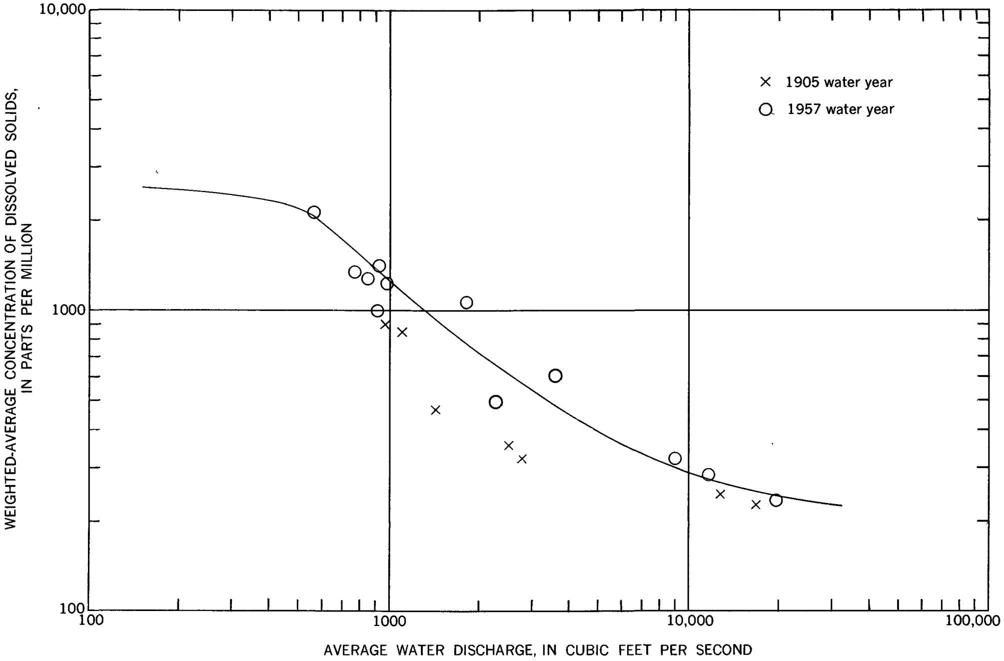


FIGURE 59.—Relation of concentration of dissolved solids to water discharge, Gunnison River near Grand Junction, Colo. Plotted points are monthly average discharges and monthly weighted-average concentrations.

weighted-average concentration of dissolved solids in streamflows are delineated. The general effect of rock types and irrigation on the concentration of dissolved solids in the streams can be observed by comparison of the zones shown on figure 60 with the different rock types in plate 1 and the location of irrigated lands in plate 5.

The diagrams in plate 2 show the geochemical character and ionic concentrations of surface water at many sites in the subbasin. These diagrams show the chemical character of the streams during low flow when the effect of geology on chemical quality is the most pronounced. The significance of the size and shape of the diagrams is given in the explanation in plate 2.

RELATION TO GROUND WATER

Extensive ground-water reservoirs are present in the mountainous areas where precipitation is abundant. Table 20 shows the water and dissolved solids contributed to some selected streams from the ground-water reservoirs in headwater areas. The concentration of dissolved solids of the ground-water contribution is greater than the weighted-average concentration in the streams in the four examples for this subbasin given in table 20. The same relation probably exists for all headwater streams in the basin.

The chemical composition of water in the alluvium along the Gunnison River in the vicinity of Gunnison, Colo., is similar to that of water in the river during low flow (fig. 61). Water in the alluvium contains more dissolved solids and proportionately more bicarbonate than water in the river.

Ground water from the alluvium of Tomichi Creek at Gunnison, Colo., contains almost twice as much dissolved material as the water of the creek even during low flows (fig. 62). The ground water contains much more sulfate than the surface water, which is of the calcium bicarbonate type.

An analysis of water from a spring issuing from the volcanic rocks that blanket the area between Gunnison and Cimarron shows that the chemical character of the surface water and the ground water associated with these rocks is almost identical (fig. 63). The principal difference between the two is that ground water usually contains more silica.

Water from a well in the Mancos Shale at Ridgway had a dissolved-solids concentration of about 4,200 ppm and was of the sodium calcium sulfate type.

During low flow, water from the river near this well contained less than one-eighth as much dissolved solids and was of the calcium sulfate type. Obviously, any ground water that reaches the river from the Mancos Shale in this area will cause an increase in the concentration of dissolved solids in the stream.

Water from two wells in terrace alluvium along the Uncompahgre River near the mouth of Cow Creek had concentrations of about 600 and 1,200 ppm. The water from these wells contains more dissolved solids than the water from either Cow Creek or the Uncompahgre River, during low flows (fig. 64). The water from the Uncompahgre River is of the calcium sulfate type, but that from Cow Creek is of the calcium bicarbonate type. The Cow Creek basin is underlain by volcanic rocks of Tertiary age and glacial outwash derived from them.

Two wells in the alluvium along the Gunnison River near Delta produce a calcium sodium magnesium sulfate water that has a concentration of 2,500 to 3,000 ppm. The water from these two wells is very similar to the water from irrigation drains near Delta and from Uncompahgre River at Delta, Colo., during the low flows of the irrigation season (fig. 65). Water from these two wells, dug 15 feet and 20 feet into alluvium, contained almost 70 ppm of nitrate. The water from another well nearby, 96 feet deep and also in alluvium, contained 220 ppm of nitrate.

The water of Gunnison River near Grand Junction, Colo., during the period from September to February,

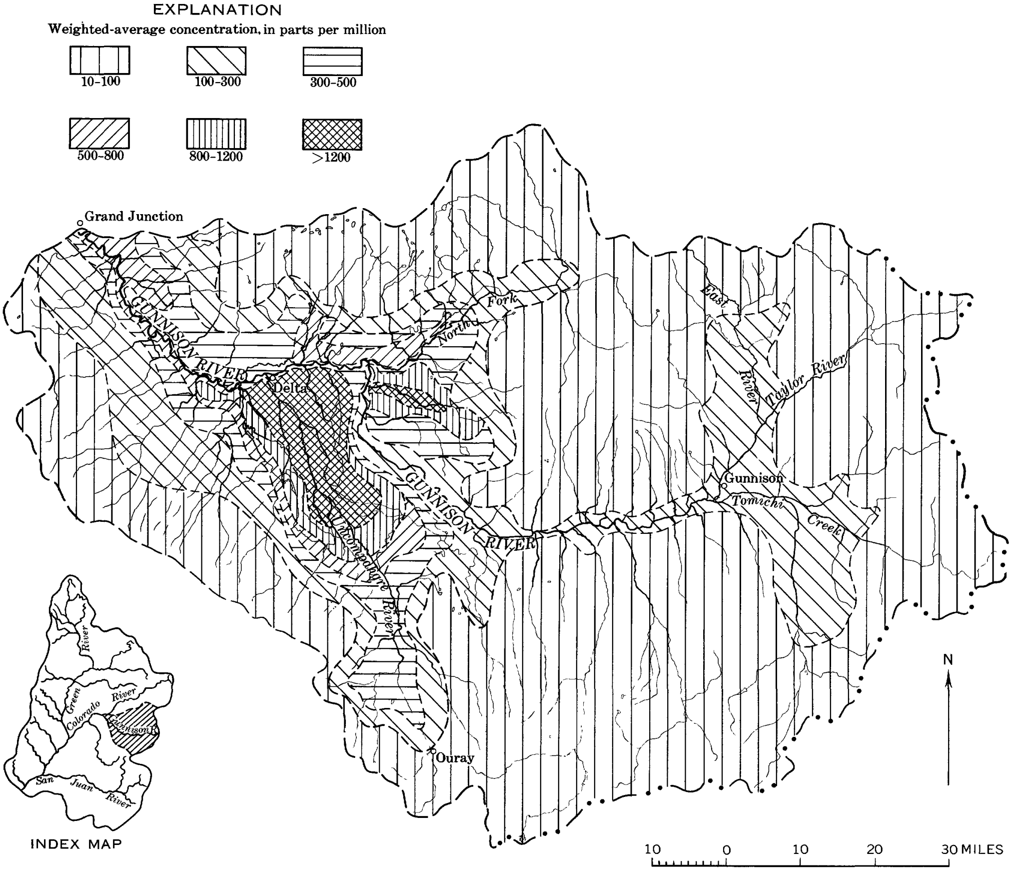


FIGURE 60.—Approximate weighted-average concentrations of dissolved solids in streams in the Gunnison River basin.

has a concentration of more than 10 ppm of nitrate. Part of the nitrate in the river water probably comes from ground water that seeps into the stream from the alluvium upstream.

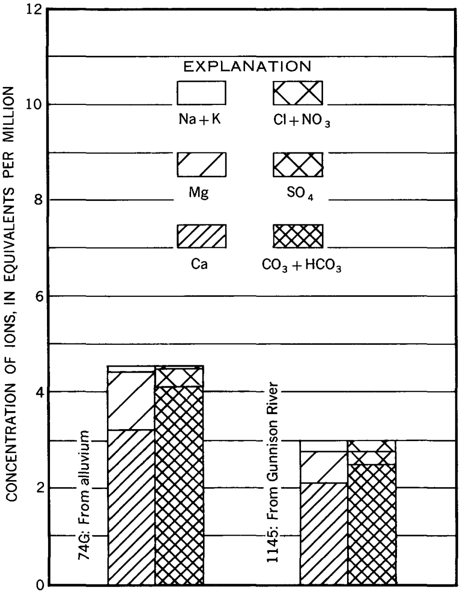


FIGURE 61.—Analyses of water from Gunnison River near Gunnison, Colo., and from alluvium nearby.

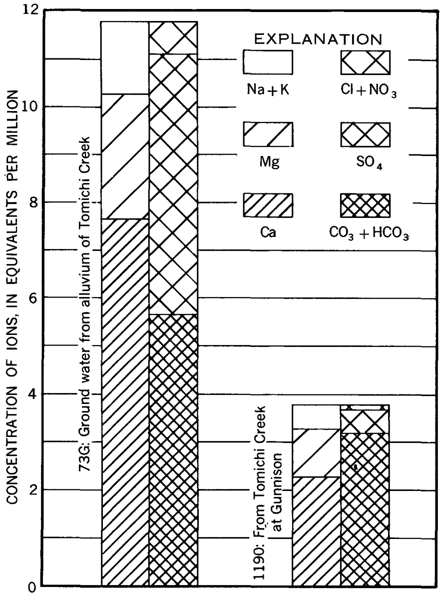


FIGURE 62.—Analyses of water from Tomichi Creek at Gunnison Colo., and from alluvium nearby.

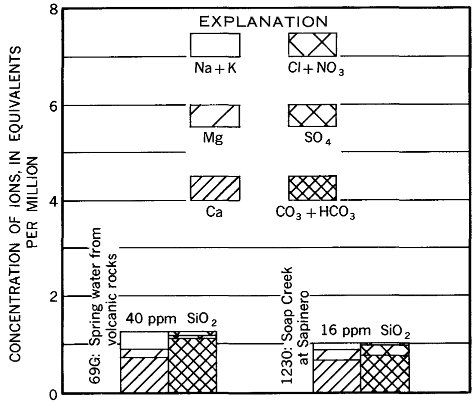


FIGURE 63.—Analyses of water associated with volcanic rocks of Tertiary age.

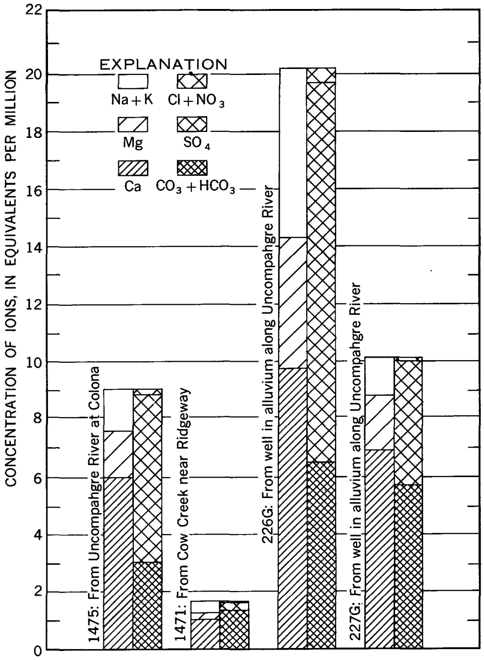


FIGURE 64.—Analyses of water from the Uncompahgre River and Cow Creek and from alluvium nearby.

Comparison of analyses of water from the streams and from the alluvium nearby indicates that ground water entering the streams will almost invariably cause an increase in the dissolved-solids concentration of the streams. The effect of the inflowing ground water during high flows is small because of the relatively small proportion of ground water entering the streams at these times. As the flow in the streams decreases, the proportion of inflowing ground water and its effect on the quality of the water in the streams increase. (See fig. 58.)

Several thermal springs issue along the East River and its tributaries in the vicinity of Crested Butte, Colo. (George and others, 1920). Jarvis Springs discharge about 25 gpm of calcium magnesium bicarbonate sulfate water. One spring (20 gpm) has a dissolved-solids concentration of about 800 ppm and the other spring (5 gpm), about 400 ppm. Two groups of springs on Cement Creek have dissolved-solids concentrations ranging from 500 to 700 ppm. The combined discharge of these springs is estimated to be about 1,840 gpm (Stearns and others, 1937). These springs are of the calcium sodium magnesium bicarbonate type. Of the 15,700 tons of dissolved solids estimated to be contributed to the East River annually in ground water (table 20), about 2,500 tons is contributed by the springs discussed in this paragraph.

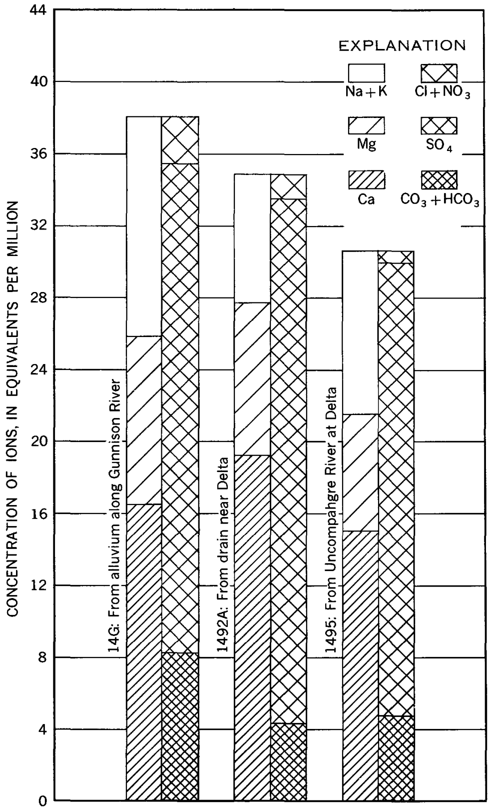


FIGURE 65.—Analyses of water from a well, a drain, and Uncompahgre River at Delta, Colo.

Waunita Hot Springs along Hot Springs Creek, a tributary of Tomichi Creek, is a sodium sulfate bicarbonate water having a dissolved-solids concentration of about 600 ppm (George and others, 1920). The discharge of the springs in this group has been estimated to be about 1,000 gpm (Stearns and others, 1937).

A group of thermal springs discharging into Cebolla Creek near Powderhorn, Colo., yield water ranging in dissolved-solids concentration from about 1,600 to 2,600 ppm (George and others, 1920). Individual springs discharge 1 to 15 gpm. The weighted-average concentration of dissolved solids in the springs is estimated to be about 2,300 ppm, and the total contribution to the creek from the spring area is estimated to be about 100 gpm (Stearns and others, 1937).

Near Lake City, Colo., two small thermal springs discharge into Lake Fork. One spring, discharging about 1 gpm, has a dissolved-solids concentration of 1,700 ppm; the other, which discharges about 5 gpm, has a dissolved-solids concentration of 200 ppm (George and others, 1920).

A small thermal spring discharges about 0.5 gpm near the mouth of Cimarron Creek. The dissolved-solids concentration of this spring is about 2,600 ppm (George and others, 1920).

Several thermal springs yielding sodium bicarbonate water rise along the North Fork. One spring about 19 miles east of Somerset, Colo., has a discharge of about 3 gpm. A group of springs near Hotchkiss have an average dissolved-solids concentration of about 4,300 ppm (George and others, 1920) and are of the sodium bicarbonate chloride type. The total discharge of three of the springs is reported to be 17 gpm; that from all the springs in the group is probably about 25 gpm.

Cold Sulphur Spring near Austin, Colo., yields a sodium chloride bicarbonate water having a dissolved-solids concentration of about 11,900 ppm. Alkali Spring, located nearby, yields the same type of water but has a concentration of about 16,000 ppm. The discharge of Cold Sulphur Spring is about 15 gpm, and the discharge of Alkali Spring is 3 gpm (George and others, 1920).

Park Springs, in the headwaters of the Uncompahgre River near Ironton, Colo., have a dissolved-solids concentration of about 1,000 ppm (George and others, 1920). Data are not available on the discharge of the springs, but the discharge probably does not exceed 50 gpm. Downstream at Ouray are numerous hot springs. These springs are of the calcium sulfate type. The dissolved-solids concentration of the group ranges from about 1,000 to about 1,700 ppm (George and others, 1920), and the combined discharge is about 200 gpm (Stearns and others, 1937). Farther downstream near Ridgway, two springs discharging 20 and 15 gpm have dissolved-solids concentrations of 2,500 ppm and 700 ppm, respectively. The water of the larger spring is of the sodium calcium sulfate type.

There may be a few other small thermal springs in the Gunnison River basin in addition to those listed. The combined discharge of the reported thermal springs is only slightly more than 7 cfs, and the dissolved-solids discharge is about 6,000 tons annually.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

Three small transmountain diversions from the Gunnison River basin were in existence at the end of the 1957 water year. The effect of these small diversions on the quality of the water leaving the Gunnison River basin is negligible. With an average diversion of about 300 acre-feet annually and a weighted-average concentration of 60 ppm, about 25 tons of dissolved solids is taken out of the basin annually in the transmountain diversions.

EFFECT OF THE ACTIVITIES OF MAN

In the Gunnison River basin, as in the Colorado River basin above the Gunnison River, the activities of man have caused an increase in the dissolved-solids discharge of the streams. That much of this increase is caused by irrigation is indicated by the high concentrations of dissolved solids in ground water in the alluvium and in the return flow in the drains in the irrigated areas of the lower part of the Uncompahgre River valley. The irrigation water in the Uncompahgre valley is a mixture of water from the Gunnison tunnel and the Uncompahgre River. On the basis of the average annual discharge of the Gunnison tunnel and of the river at the Colona gaging station, about 63 percent of the irrigation water comes from the Gunnison River through the tunnel (111 ppm) and about 37 percent comes from the Uncompahgre River (376 ppm). The weighted-average concentration of the irrigation water therefore would be about 209 ppm. The average dissolved-solids concentration of the drains in the Uncompahgre River valley is about 2,300 ppm (Iorns and others, 1964, table 219). These concentrations are used in the following tabulation, which indicates amounts of dissolved solids leached per acre per year from the soil and underlying material with irrigation application rates of 4 and 5 acre-feet per acre and consumptive use rates of 1.5, 2.0, and 2.5 acre-feet per acre:

Applied in irrigation (acre-ft per acre)	*Consumptive use (acre-ft per acre)*	*Return flow (acre-ft per acre)*	*Leached from lands (tons per acre)*
4	1.5	2.5	6.7
4	2.0	2.0	5.2
4	2.5	1.5	3.6
5	1.5	3.5	9.5
5	2.0	3.0	8.0
5	2.5	2.5	5.4

This tabulation illustrates the wide range in dissolved-solids yield from irrigated lands—a range that may be expected with different rates of applied water and consumptive use. It does not, however, take into account other natural sources of dissolved solids that may be included in the return flow.

Because of the large amount of water that bypasses the Uncompahgre River at Delta gaging station, a water and dissolved-solids budget cannot be computed for the Uncompahgre River valley. However, an approximate budget can be prepared for that part of the Gunnison River basin below the Gunnison tunnel and the gaging stations on the Uncompahgre River at Colona and Roubideau Creek near Delta and above the gaging station on the Gunnison River near Grand Junction. Table 22 gives the budget of water and dissolved solids for the area.

Records for Roubideau Creek near Delta indicate the average annual base flow (mostly ground water) of this stream (drainage area, 165 sq mi) to be about 5,000 acre-feet (30 acre-ft per sq mi). Applying this rate to the 673 square miles of drainage area between the gaging stations on the Uncompahgre River at Colona and at Delta indicates that about 20,000 acre-feet of ground water would be contributed to the Uncompahgre River under natural conditions. This unmeasured natural ground-water inflow is estimated to have a weighted-average concentration of dissolved solids between 1,300 and 2,300 ppm. The estimated concentration range is based on chemical analyses of water of wells and streams in the area during times of low flow (Iorns and others, 1964, tables 219 and 227).

The unmeasured natural surface-water contribution of 50,000 acre-feet in the Uncompahgre River valley is based principally on the direct runoff from Roubideau Creek near Delta (30,000 acre-ft less base flow) and on the relation of the ungaged drainage area west of the Uncompahgre River to that of Roubideau Creek. Because of the similarity between the Roubideau Creek basin and the ungaged area, the weighted-average concentration of dissolved solids in the unmeasured surface water (200 to 350 ppm) is based on chemical analyses of water of Roubideau Creek near Delta and other streams draining the Uncompahgre Plateau.

Measured natural inflow, mostly above irrigated lands, of tributaries to the Gunnison River in the area below Gunnison tunnel, Uncompahgre River at Delta, and Roubideau Creek at mouth is about 483,000 acre-feet (Smith Fork, 34,000; Iron Creek, 12,000; North Fork Gunnison River, 317,000; Current Creek, 5,000; Surface Creek, 3,000; Tongue Creek, 50,000; and Kahnah Creek, 32,000). Chemical analyses for many streams in the area indicate that, under natural conditions, the weighted-average concentration would be between 130 and 150 ppm (Iorns and others, 1964, table 219).

The unmeasured natural inflow from the area described in the preceding paragraph is the quantity of water needed to balance the inflow-outflow budget after allowing for 70 acre-feet estimated to be contributed annually by thermal springs. As this water comes from drainages similar to those listed in the preceding paragraph, the concentration of dissolved solids is estimated to be the same.

In the area above the Gunnison tunnel about 74,000 acres are irrigated. Data are not sufficient in this area to determine the amount of dissolved solids coming from natural sources. However, the rates of dissolved-solids yield from irrigated lands would be similar to irrigated lands in the Colorado River Basin above Hot Sulphur Springs and the Troublesome Creek basin—that is would range from 0.1 ton per acre per year to 1.0 ton per acre per year. On the basis of similarity of environments, irrigated lands in the Gunnison River basin above Tomichi Creek would probably yield about 0.7 ton per acre per year of dissolved solids, those in the Tomichi Creek basin about 0.5 ton per acre per year, and those in the basin below Tomichi Creek and above the Gunnison tunnel about 0.25 ton per acre per year. Application of these rates indicates that at least 36,000 tons annually of dissolved solids are added to the Gunnison River above the Gunnison tunnel by the activities of man.

In the Uncompahgre River basin above the gaging station at Colona, Colo., about 18,500 acres is irrigated. These lands are mostly on alluvium derived from the more resistant rocks in the headwaters of the Uncompahgre River, but the alluvium is underlain by the Mancos Shale, the Dakota Sandstone, and the Morrison Formation. On the basis of dissolved-solids yields from irrigated lands in areas of similar rocks and precipitation in other parts of the Upper Colorado River Basin, it is estimated that about 45,000 tons of dissolved solids annually are contributed to the stream system above the Colona station as a result of the activities of man.

As indicated by the preceding discussion of three areas in the Gunnison River basin, about 977,000 tons of dissolved solids (895,700 + 36,000 + 45,000) is added to the Gunnison River by the activities of man, and 542,000 tons (1,519,000 − 977,000 tons) comes from natural sources. In proportion to area, the amount resulting from man's activities is 3.6 tons per acre irrigated, and the amount from natural sources is 68 tons per square mile of drainage area. If there had been no activities of man in the basin, the weighted-average concentration of dissolved solids in the Gunnison River near Grand Junction, Colo., would have been about 178 ppm as compared to a weighted-average concentration of 592 ppm for water years 1914–57 adjusted to 1957 conditions. In the computation of the change in concentration, 2,600 acre-feet of water was considered to be consumptively used annually for domestic and industrial purposes, and 348,200 acre-feet was considered to be the annual amount of water consumptively used in irrigation.

Of the total amount of dissolved-solids discharge estimated to be caused by the activities of man in the subbasin, 3,800 tons is estimated to be due to domestic and industrial use of water and 973,200 tons, to irrigation. The estimate of 3,800 tons is based on 100 tons per year per 1,000 people as the rate of contribution resulting from domestic and industrial use of water.

FLUVIAL SEDIMENT

Suspended-sediment data were obtained at Gunnison River near Grand Junction, Colo (near Whitewater), in 1905. However, so many changes have occurred in the upstream environment since 1905 that these data are not representative of the stream under conditions that existed in the 1957 water year. Suspended-sediment data obtained in later years by the Bureau of Reclamation have been used to estimate the suspended-sediment discharge of the Gunnison River at this station.

Suspended-sediment samples have been collected at many other sites by the Bureau of Reclamation and at three sites by the Forest Service. The records collected by the Bureau of Reclamation have been used in conjunction with flow-duration curves to estimate the probable sediment discharge at several stations (table 25). Most of the sediment apparently comes from areas underlain by rocks of Cretaceous age.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The basis for appraising the suitability of stream waters in this subbasin is the same as that for the subbasin of the Colorado River above the Gunnison River. (See chap. B, pp. 66–73.)

In the headwater areas the waters of all tributaries to the Gunnison River are suitable for domestic use, so far as chemical quality is concerned, except for that in some of the headwater streams of the Uncompahgre River, where the concentrations of sulfate may exceed recommended limits. Most of the waters of the headwater streams are moderately hard to hard.

Above Smith Fork the water of the main stem of the Gunnison River also is chemically suitable for domestic use, but that in the lower reaches of many tributaries between Cimarron and Smith Fork is not satisfactory. The principal cause of unsuitability is high sulfate concentrations, but some streams have higher concentrations of iron, magnesium, chloride, and fluoride than are desirable for domestic use.

The waters of the Gunnison River below Smith Fork and most of the waters of the Uncompahgre River are not satisfactory for domestic use, except at times of high discharge. The same applies to the water of Smith Fork below its headquarters, the lower reaches of most tributaries of the Gunnison River below Smith Fork, and the lower reaches of most tributaries of the Uncompahgre River.

The fact that some of the stream waters do not meet the criteria adopted in this report for domestic uses does not mean that they cannot be used if necessary.

AGRICULTURAL USE

The principal use of surface water in the Gunnison River basin is for irrigation. Table 27 gives the classification of low, medium, and high flows of selected streams as to their suitability for irrigation. All the terms used in the table are self-explanatory or are explained on page 107 and in chapter B (pp. 69–73).

The determinations of residual sodium carbonate for the streams in table 27 indicate that residual sodium carbonate is either nonexistent or much less than 1.25 epm. This limit is considered the maximum permissible for irrigation waters, though some marginal waters are permissible.

The surface waters in the Gunnison River basin range from C1–S1 to C4–S4; most of the water that is used for irrigation is C3–S1 or better. The water in the poorer categories is mostly downstream from irrigated lands and is affected by return flow. According to the U.S. Salinity Laboratory Staff (1954), waters in the C3 category cannot be used on soils having restricted drainage. The S1 category implies that the water can be used on almost all soils with little danger of development of harmful levels of exchangeable sodium.

INDUSTRIAL USE

The water of most of the headwater streams in the Gunnison River basin can be used for many industries without treatment. Most of the water in streams near the centers of population would require extensive treatment. The water of Gunnison River near Grand Junction could be used for only a few industries without treatment.

Most of the surface water in the Gunnison River basin could be used without treatment by mining industries and for certain phases of metal fabrication where quality tolerances are liberal.

RECREATIONAL USE

Most of the streams and lakes in the headwaters of the Gunnison River basin are ideal for recreation. The use of the surface water for this purpose is expanding rapidly and will probably continue to do so as the population continues to increase.

COLORADO RIVER BASIN BETWEEN THE GUNNISON AND GREEN RIVERS

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Seven reservoirs that have storage capacities greater than 1,000 acre-feet were in operation in the Colorado River Basin between the Gunnison and Green Rivers in 1957 (table 3; pl. 4). These reservoirs have a total usable capacity of 42,050 acre-feet. In addition, there were a number of smaller reservoirs and stock ponds. Lake Hope and Trout Lake provide storage for hydroelectric-power production; the other reservoirs store irrigation water.

TRANSMOUNTAIN DIVERSIONS

About 100,000 acre-feet of water is diverted annually from Lost Canyon Creek and the Dolores River to irrigate approximately 37,000 acres in the San Juan basin (U.S. Dept of the Interior, 1947, p. 128). These diversions were in operation before 1914. A small amount of water is diverted from the headwaters of the San Miguel River to the Uncompahgre River drainage basin, but no records of the amount diverted are available.

IRRIGATION

About 121,300 acres is irrigated in the Colorado River Basin between the Gunnison and Green Rivers (table 5). Of this amount, about 75,700 acres is in the Grand Valley. About 3,000 acres of the cultivated land in the Grand Valley is irrigated with water diverted from the Gunnison River; all the rest, except for a few hundred acres, is irrigated with water diverted from the Colorado River. Of the 37,100 acres irrigated in the Dolores River basin, about 25,600 acres is in the San Miguel River basin.

The climate is favorable for growing a wide variety of crops, except in the headwater areas. Lands irrigated in Grand Valley have an adequate water supply, but the water supply is deficient for much of the land in the rest of the subbasin.

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water in the Grand Valley by irrigation practices was 146,000 acre-feet. The Commission estimated that in the valley 75,700 acres of land was irrigated and 12,600 acres received water incidental to irrigation practices. In the rest of the subbasin, the Commission estimated the consumptive use to be 54,600 acre-feet on 45,625 acres of irrigated land and 4,670 acres that received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The 1960 population was about 66,000, most of which is concentrated in and around Grand Junction, Colo. The five largest communities and their populations are Grand Junction, Colo., 18,694; Moab, Utah, 4,682; Fruita, Colo., 1,830; Uravan, Colo., 1,005; and Naturita, Colo., 979. Grand Junction, Fruita, and Naturita obtain their water supply from surface streams, and Uravan and Moab use well water. Ground water on the north side of the Colorado River in the vicinity of Grand Junction is generally not satisfactory for domestic use, and most small communities in this area obtain their domestic water from the Grand Junction or Fruita water-supply systems. Some small communities and most rural inhabitants in this area depend on hauled water for domestic use. Of the five largest communities, only Grand Junction and Moab have sewage-treatment plants.

The major industrial plants in the basin are uranium mills at Grand Junction, Uravan, and Vancorum, Colo., and Moab, Utah, and a gilsonite-processing plant at Grand Junction. At Grand Junction there is also a flour mill, a fruit-packing plant, and a cannery. Each of these installations uses water, but the consumptive use is negligible. The consumptive use of water for domestic and industrial uses is estimated to be about 4,400 acre-feet per year.

The following tabulation shows the hydroelectric-power installations in the subbasin:

Location of powerplant	*Installed capacity (kw)*
Colorado River at Palisades, Colo	3, 000
Gunnison River at Grand Junction, Colo	1, 400
Lake and Howard Forks near Ames, Colo	3, 600
San Miguel River near Ames, Colo	1, 200
Bridal Veil Creek near Telluride, Colo	800
San Miguel River at Uravan, Colo	160
Mill Creek at Moab, Utah	50
Total	10, 210

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Most of this subbasin is at a low altitude compared to the other two subbasins of the Grand division. Little or no snow accumulates during the winter months except in the mountainous headwaters of the Dolores and San Miguel Rivers and in the LaSal Mountains. Streams, except those draining mountainous areas, are intermittent and carry water only after infrequent summer storms. Most of these are thunderstorms, are of short duration, and cover only a small area. However, some are of high intensity and cause flash floods.

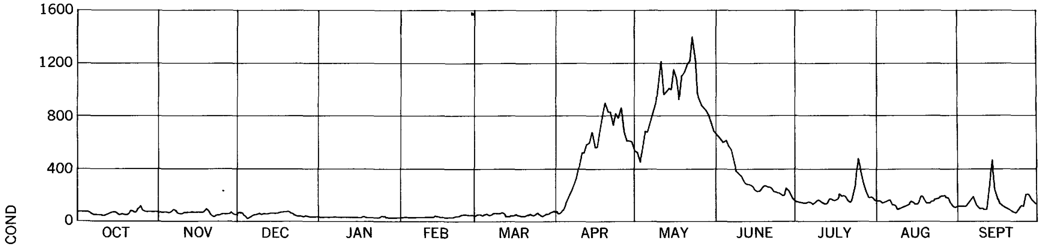
The pattern of seasonal runoff from the headwaters of the Dolores River, the principal tributary in the subbasin, is shown in figure 66. The hydrographs for Colorado River near Cameo, Colo. (fig. 35), and that for Gunnison River near Grand Junction, Colo. (fig. 54), show the pattern of inflow into the subbasin from these two major streams. The hydrograph for Colorado River near Cisco, Utah (fig. 66), shows the pattern of outflow from the subbasin and the Grand division.

FLOW-DURATION CURVES

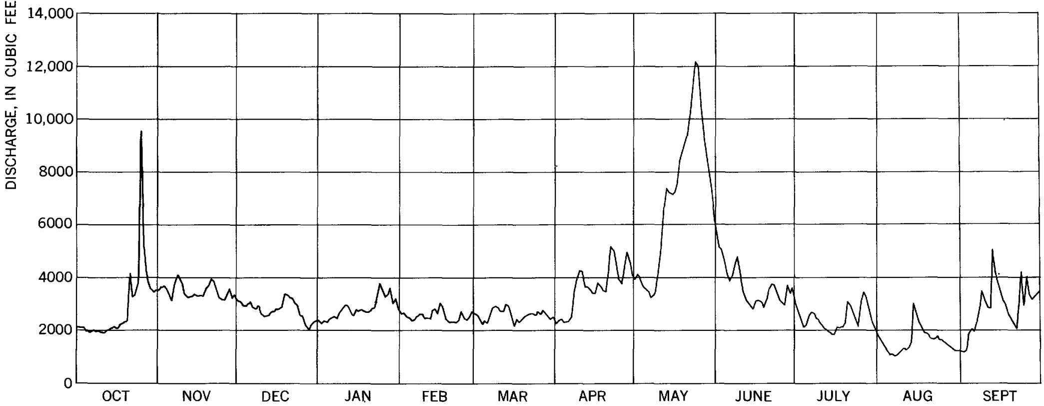
Historical flow-duration data were developed for streams at nine sites in the subbasin. Flow-duration curves representative of the 44-year base period adjusted to 1957 conditions were developed for all but two of these sites. The historical and adjusted curves reduced to table form are given in table 6. In the adjustment of historical data for Colorado River near Cisco, Utah, to 1957 conditions, adjustments were made for increasing amounts of transmountain diversions and reservoir regulation. Similar adjustments of historical data for stations in the Dolores basin were not necessary because practically no change in developments occurred after 1914. In table 7 are outlined the methods used in adjusting the historical flow-duration curves to 1957 conditions and the upstream water development in which changes occurred. The adjustment methods are explained in chapter B (pp. 46–48). The table also gives the authors' accuracy rating of the adjusted long-term curves.

The variability indices of the flow-duration curves and percent of average annual discharge estimated to be contributed to the stream system by ground water for two streams in the subbasin are given in table 8. (See fig. 38 and chap. B, pp. 48–53.) An indeterminate but negligible amount of the water attributed to ground water may be from natural lakes or from upstream reservoirs.

The drainage basin above the gaging station on Dolores River at Dolores, Colo., from higher to lower altitudes, is underlain principally by the Rico Formation, the Dakota Sandstone, the Morrison Formation,



A. Dolores River at Dolores, Colo.



B. Colorado River near Cisco, Utah

FIGURE 66.—Seasonal pattern of runoff in the Colorado River Basin between the Gunnison and Green Rivers, 1954 water year.

and the Mancos Shale. The drainage basin above the gaging station on San Miguel River at Placerville, Colo., from higher to lower altitudes is underlain principally by Tertiary volcanics, the Mancos Shale, the Dakota Sandstone, and the Morrison Formation. As indicated by the variability indices and percentage of groundwater contribution, the Tertiary volcanics underlying the major water-producing areas of the San Miguel River are apparently much more permeable than the Rico Formation, which underlies the major water-producing area of the Dolores River.

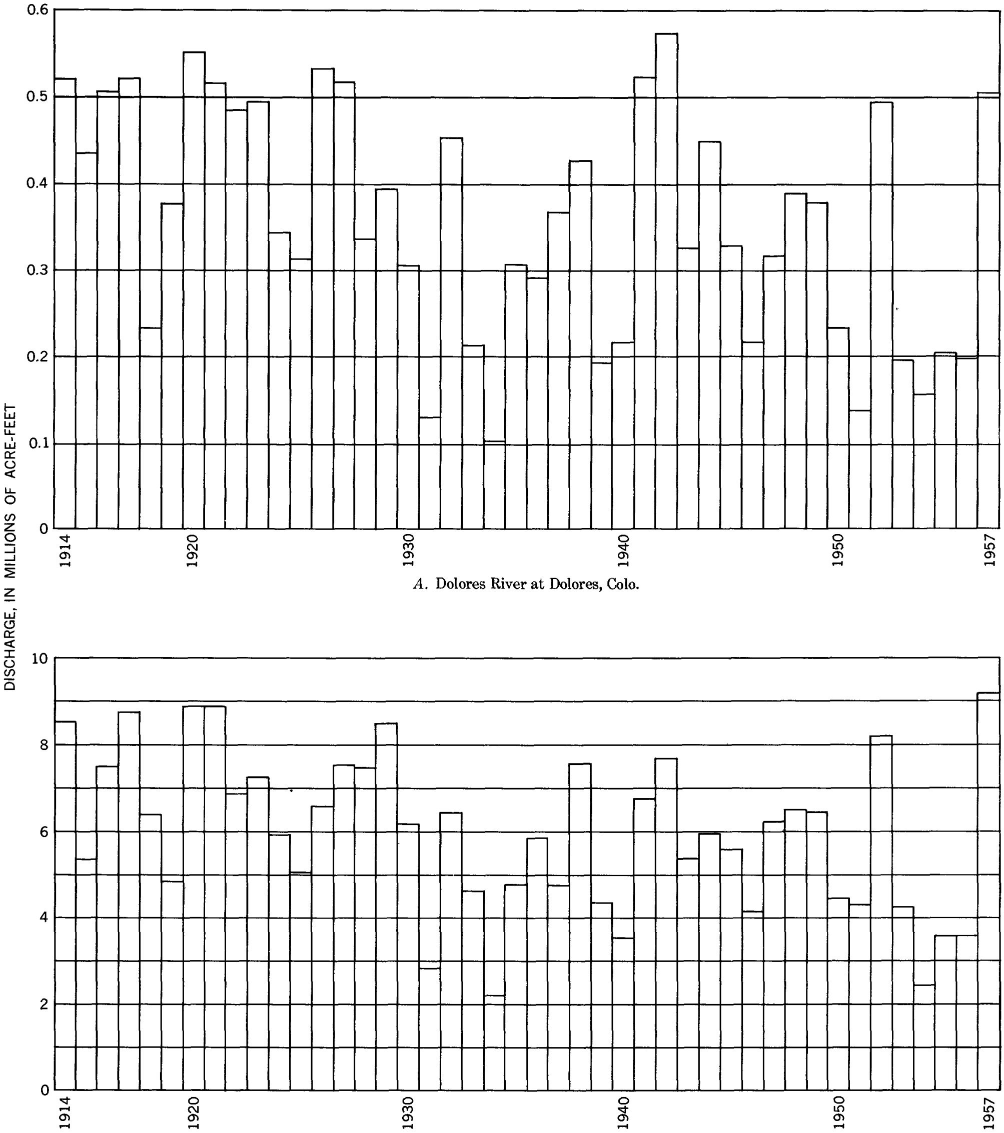
VARIABILITY OF ANNUAL RUNOFF

The streamflow record for Dolores River at Dolores, Colo., is representative of runoff from the mountainous areas in the subbasin (fig. 67). The record for this station was extended to the base period by estimating the discharge for the water years 1914–21. Only about 3,500 acres is irrigated above the station, and probably little change occurred between 1914 and 1957 in the amount of land irrigated.

The outflow from the Grand division is represented by the record for Colorado River near Cisco, Utah. Additional inflow from the 2,400 square miles of drainage area between this gaging station and the Green River is approximately offset by channel losses. Discharge records were not collected for water years 1918–22 but have been estimated by the Upper Colorado River Compact Commission and are published in Water-Supply Paper 1313 (U.S. Geol. Survey, 1954, p. 248). The annual discharges for this station (fig. 67) were adjusted to the 1914 base. (See chap. B, p. 55.) The adjustments take into consideration changes in upstream use between 1914 and 1957. Table 10 gives the historical record and the adjustments.

The standard deviation and coefficient of variation of annual discharge for Dolores River at Dolores, Colo., Colorado River near Cisco, Utah, and three other streams were computed and are given in table 11. The coefficients are also plotted in plate 4. The values given in the table for the shorter periods of record at some of the stations are believed to be near the average for the long-term base period.

Differences in topography and climate are the major factors causing the variability of annual runoff of tributary streams in this subbasin to be generally greater than the variability of annual runoff in the other two subbasins of the Grand division. Intense summer storms are common in this subbasin. The cumulative effect of infrequent summer storms over large areas is illustrated by the downstream increase in co-



A. Dolores River at Dolores, Colo.

B. Colorado River near Cisco, Utah

FIGURE 67.—Variability of annual discharges in the Colorado River Basin between the Gunnison and Green Rivers, water years 1914–57.

efficients of variation for the Dolores River and its principal tributary, the San Miguel River.

Streamflow records for such streams as Courthouse Wash and Hatch Wash in Utah are too short to use for the computations of coefficients of variation for each stream alone. However, by use of the station-year method and the short records for Courthouse Wash near Moab, Hatch Wash near La Sal, Salaratus Wash at Green River, Browns Wash near Green River, White Canyon near Hite, and North Wash near Hite, all in Utah, the approximate variability of these and similar streams can be computed. A computed coefficient of variation of 0.76 is probably representative of the average variability of streams draining the lower areas in the western part of the subbasin.

PRECIPITATION-RUNOFF RELATION

Precipitation, water yield, and natural consumptive use for two drainage basins in the subbasin are shown in table 13.

The headwaters area of the drainage basin above the gaging station on Dolores River at Dolores, Colo., is underlain by the Rico Formation. Consumptive use by the trees and other vegetation which grow densely on the favorable soils derived from this formation is probably responsible for the low runoff from this wet part of the subbasin.

The average annual precipitation in the Mill Creek drainage basin is about equal to the natural consumptive use in most areas investigated in the Grand division. As "nature's take" must first be satisfied from the available moisture, the water yield from the Mill Creek basin and similar basins is small.

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at three sites in the Colorado River Basin between the Gunnison and Green Rivers. The records obtained at two of the sites—Dolores River at Gateway, Colo. (1948–52), and near Cisco, Utah (1952–57)—are almost equivalent. Monthly and annual weighted-average chemical analyses of water at these sites are given in the basic data report (Iorns and others, 1964, tables 184 to 186). In addition, chemical analyses of streams have been obtained at many other sites.

Daily chemical-quality data obtained at the three sites and chemical analyses of streams at six other sites were used with flow-duration tables to compute duration tables of dissolved-solids discharge and concentration (tables 15 and 16). (See chap. B, pp. 58–59, for description of computation method.) Water and dissolved-solids discharges for the nine sites are summarized in table 14. The range of average annual dissolved-solids discharge per square mile of drainage area for the streams is large. For example, the average annual yield per square mile of drainage area ranged from 21 tons for Lost Canyon Creek to 171 tons for Colorado River near Cisco, Utah.

In the reach between the Cameo and Cisco gaging stations about 496,700 tons of dissolved solids are added annually to the Colorado River, exclusive of the amount contributed by Plateau Creek and the Gunnison and Dolores Rivers (table 29). This is the computed long-term average contribution for conditions existing in 1957. The yearly contribution of dissolved solids in this reach for water years 1934–57 is shown in table 30.

A mass diagram of the dissolved-solids contribution in the reach is shown in figure 68. The average rate of dissolved-solids contribution in the 24-year period is 745,000 tons per year (solid line). As indicated by the trends of the general slope (dashed lines) of the mass diagram, the average annual rate in the early years was about 860,000 tons, followed by an extended period having an average rate of about 745,000 tons. The trend in the most recent years was about 490,000 tons, which is about the same as the computed long-term average adjusted to 1957 conditions (table 29).

About 77 percent of the dissolved-solids discharge of Colorado River near Cisco, Utah, comes from the other two subbasins in the Grand division, 12 percent is added in the reach above the Dolores River, and 11 percent is contributed by the Dolores River (fig. 69).

The relation between water discharge and dissolved-solids discharge of Colorado River near Cisco, Utah, changed little during the period that chemical-quality data have been obtained at the gaging station (fig. 70). In years of low runoff, 1931 and 1954, the dissolved-solids discharge did not decrease as much as the water discharge. In years of intermediate and high runoff, the proportionality was fairly constant.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in the chemical quality of the streams, particularly in their downstream reaches, is large. This variation is illustrated by the graphs in figures 71 and 72 for Dolores and Colorado Rivers near Cisco, Utah.

Coefficients of variation of the annual weighted-average concentration of dissolved solids were computed for the periods of available record at two stations in this subbasin where daily chemical-quality records have been obtained. These coefficients and the coefficients of variation of the annual water discharge for the same periods are given in table 17.

The relation between the coefficients of variation of water discharge and concentration at these stations is shown with others in the Grand division in figure 45.

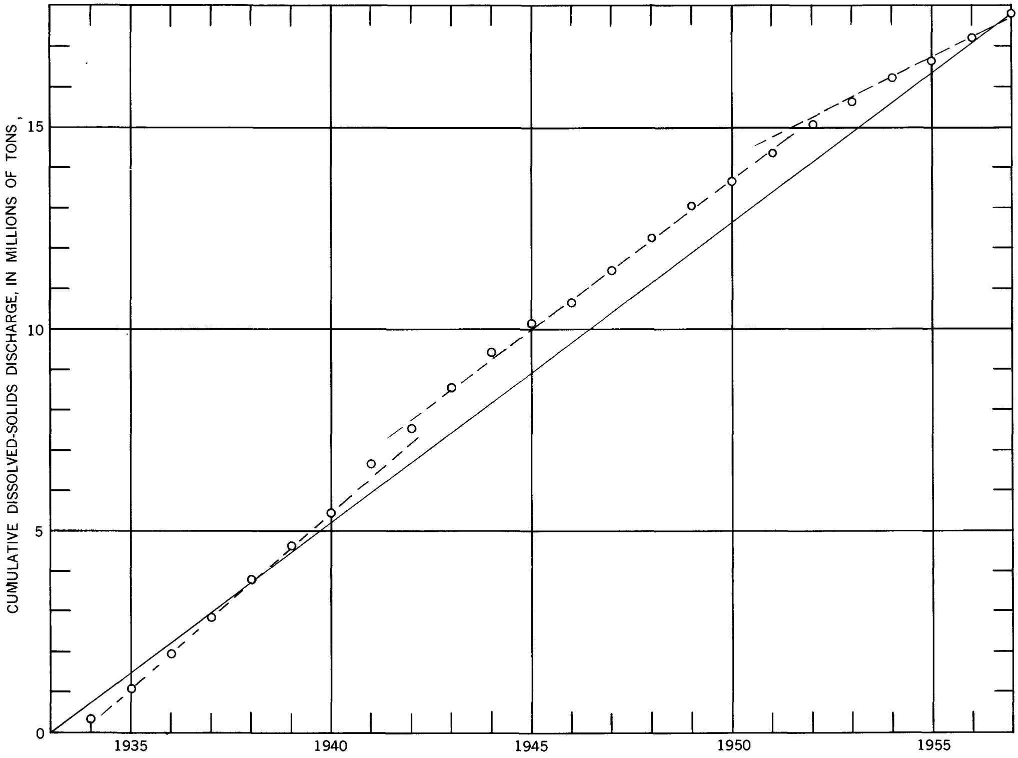


FIGURE 68.—Mass diagram of contribution of dissolved-solids to the Colorado River between the gaging stations on Colorado River near Cameo, Colo., and Colorado River near Cisco, Utah, water years 1934–57. Solid line indicates average rate for 24-year period; dashed lines indicate trends for periods of years.

In table 18, coefficients of variation and standard deviations of weighted-average concentration for selected stations in the subbasin, computed by the equation of relation shown on page 94, are given.

RELATION TO STREAMFLOW

The range in the dissolved-solids concentration of the Dolores River and its principal tributary, the San Miguel River, near their headwaters is not great between high and low flows (fig. 73). Downstream, the range in concentration between high and low flows increases in both streams, and the chemical type of water changes (fig. 73). The chemical quality of water of Colorado River near Cisco, Utah, also varies greatly between high and low discharges (fig. 73).

The relation between the chemical composition of water and streamflow at this station and the two daily stations operated on the Dolores River are shown in table 19. Duration tables of dissolved solids constituents may be prepared from the values in these tables and in tables 6, 15, and 16 and 19.

RELATION TO GEOLOGY

The type of rocks underlying this subbasin greatly influences the chemical quality of the streams. The chemical character and ionic concentration of surface waters at many sites in the subbasin at times of low flow are shown by the diagrams in plate 2. The significance of the size and shape of the diagrams is given in the explanation in plate 2.

It has already been explained (p. 124) that large amounts of dissolved solids are added to the Colorado River in the Grand Valley. The residuum and Mancos Shale which underlie most of this valley are the primary source of the dissolved solids added to the river. Figure 74 shows an example of the chemical composition of water contributed to the river from the area underlain by these rocks.

Rocks of the Glen Canyon Group of Triassic and Jurassic age underlie most of the drainage basin of the Little Dolores River, which is the only stream of consequence draining the north end of the Uncompahgre

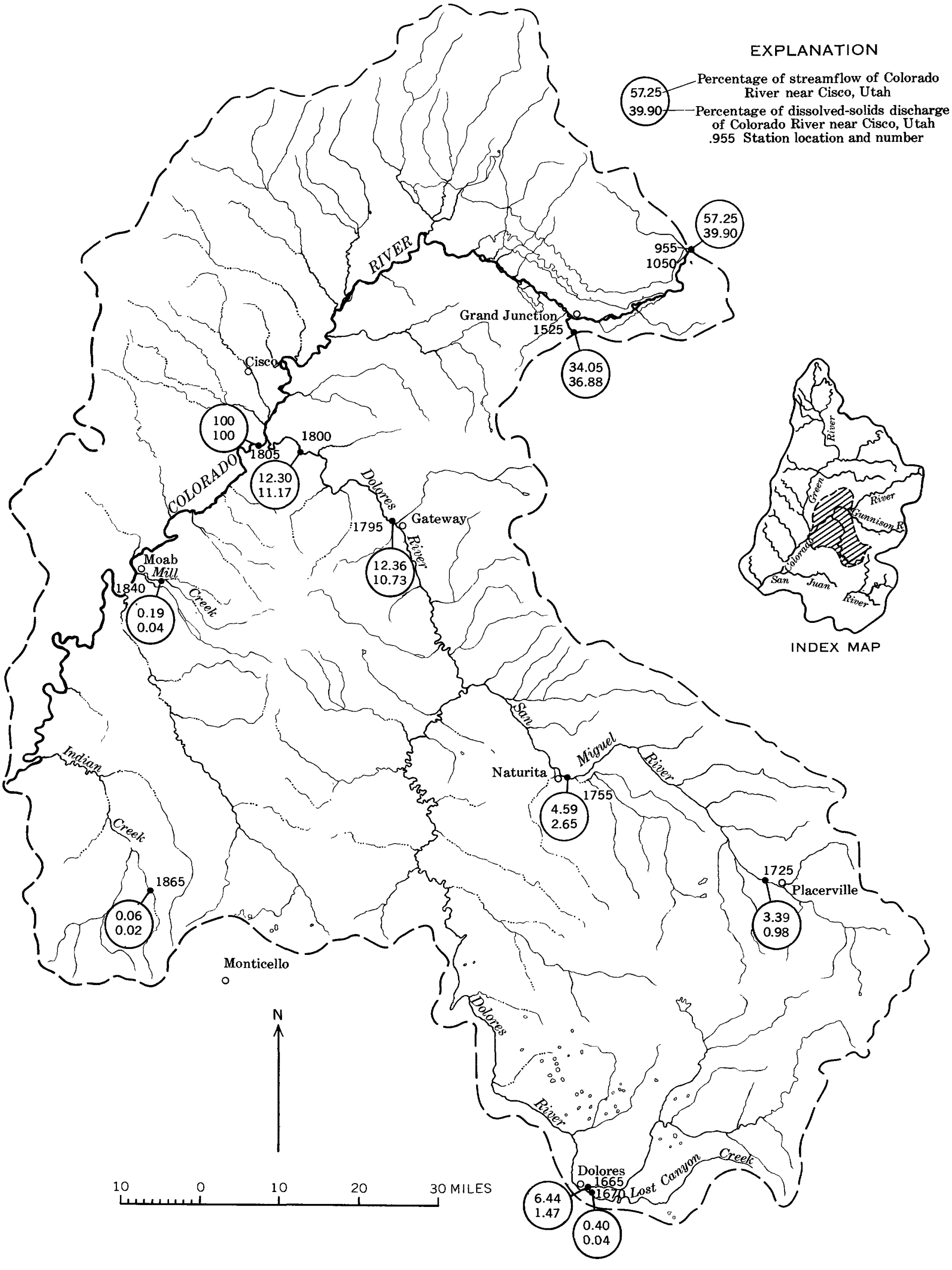


FIGURE 69.—Approximate dissolved-solids discharge and streamflow expressed as percentages of the dissolved-solids discharge and streamflow of Colorado River near Cisco, Utah.

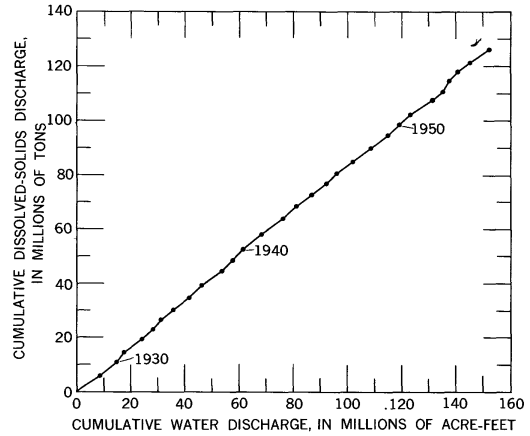


Figure 70.—Cumulative dissolved-solids discharge and water discharge for Colorado River near Cisco, Utah, water years 1929–57.

Plateau. In its lower reaches the river has eroded through these rocks and into igneous rocks of Precambrian age. Springs and seeps in the rocks of Triassic age are the source of most of the flow in the Little Dolores River at times of low flow. At these times, the water is of the calcium magnesium sulfate bicarbonate chloride type. At times of higher flows (above about 2 cfs) the water is of the calcium bicarbonate type. The source of most of the higher flows is runoff from the areas underlain by rocks of the Glen Canyon Group, which are mostly sandstones containing relatively insoluble minerals.

The Dolores River basin, which is about 62 percent of the drainage area between the Gunnison River and Colorado River near Cisco, Utah, is underlain predominantly by sedimentary rocks of Cretaceous age. In the headwaters of the Dolores River above Dolores, on the south flank of the San Miguel Mountains, rocks of Cretaceous age underlie the divides, and rocks of Permian, Triassic, and Jurassic ages underlie the valleys and the valley sides.

The water of Dolores River below Rico, Colo., which is downstream from a canyon cut by the Dolores River through the Rico Mountains, is of the calcium bicarbonate type during high flows and of the calcium sulfate bicarbonate type during low flows. The quality of the water is apparently influenced mostly by the limestone and gypsiferous limestone of the Rico Formation. At the station below Rico, the dissolved-solids concentration of the river water usually does not exceed 300 ppm. The water of West Fork Dolores River near Stoner, Colo., is similar in concentration and type to that of Dolores River below Rico, Colo. At Dolores, Colo., the water of the Dolores River is of the calcium bicarbonate type except when the streamflow is very low. At these times, the water may contain more equivalents per million of sulfate than of carbonate. The dissolved-solids concentration of Dolores River at Dolores, Colo., ranges from about 100 to 300 ppm for 90 percent of the time (table 15).

The drainage basins of the tributaries entering the Dolores River from the east between Dolores and Bedrock are underlain by rocks that contain readily soluble minerals. The predominant rocks are the Mancos Shale, the Dakota Sandstone, and the Morrison

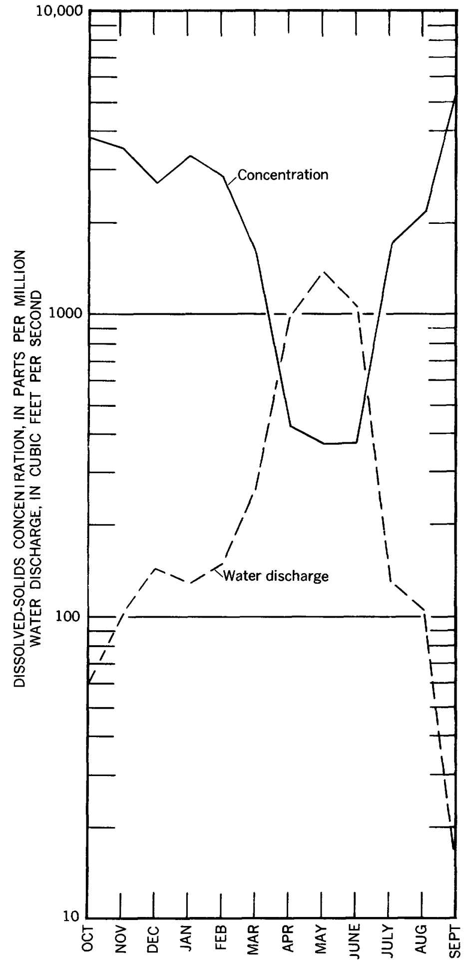


Figure 71.—Dissolved-solids concentration and water discharge of Dolores River near Cisco, Utah, 1956 water year.

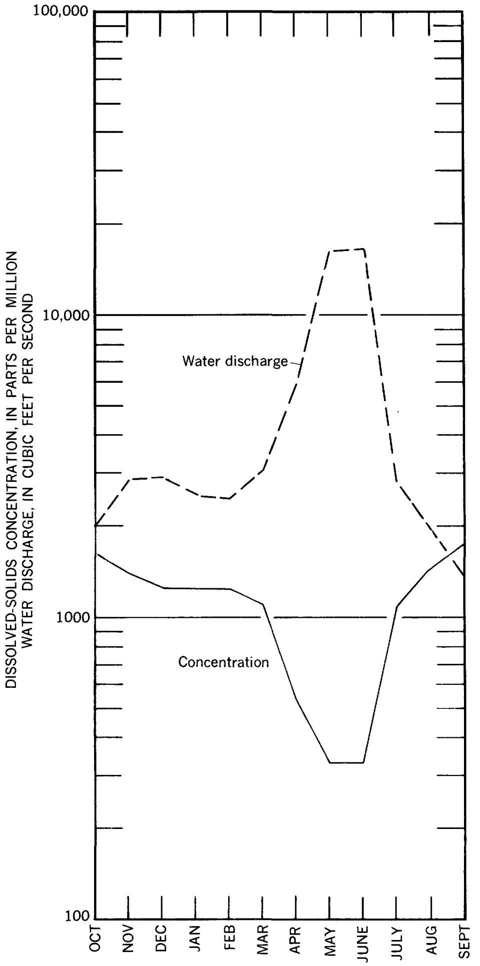


FIGURE 72.—Dissolved-solids concentration and water discharge of Colorado River near Cisco, Utah, 1956 water year.

Formation. Disappointment Creek, one of the tributaries underlain almost entirely by the Mancos Shale, contributes water that is of the calcium sulfate type except at very low flows, when the water is of the sodium sulfate type. The dissolved-solids concentration of Dissappointment Creek ranges from about 600 ppm to more than 6,000 ppm.

At low flow, the concentration of the water of Dolores River at Bedrock, Colo., at times exceeds 1,200 ppm, and the water is of the sodium chloride type. The sodium chloride most likely comes from the reach where the Dolores River cuts across the west end of the Gypsum Valley anticline or from Gypsum Creek, which drains the breached Gypsum Valley anticline. The Paradox Member of the Hermosa Formation is exposed in the Gypsum Valley. Great thicknesses of salt (sodium chloride) occur in the Paradox Member.

The Paradox Member is also exposed in, or underlies the alluvial fill in the Paradox Valley. Water from a well drilled 500 feet into the Paradox Member along the Dolores River contained 80,200 ppm of dissolved solids. Sodium and chloride were the predominant ions in this well water.

The San Miguel River rises in the west end of San Juan Mountains. In the extreme headwaters, the underlying rocks are mostly volcanic rocks of Tertiary age. The remainder of the drainage basin is predominantly underlain by the Dakota Sandstone, the Morrison Formation, and the Mancos Shale. These rocks, particularly the Mancos Shale and Morrison Formation, contain minerals that dissolve readily in water.

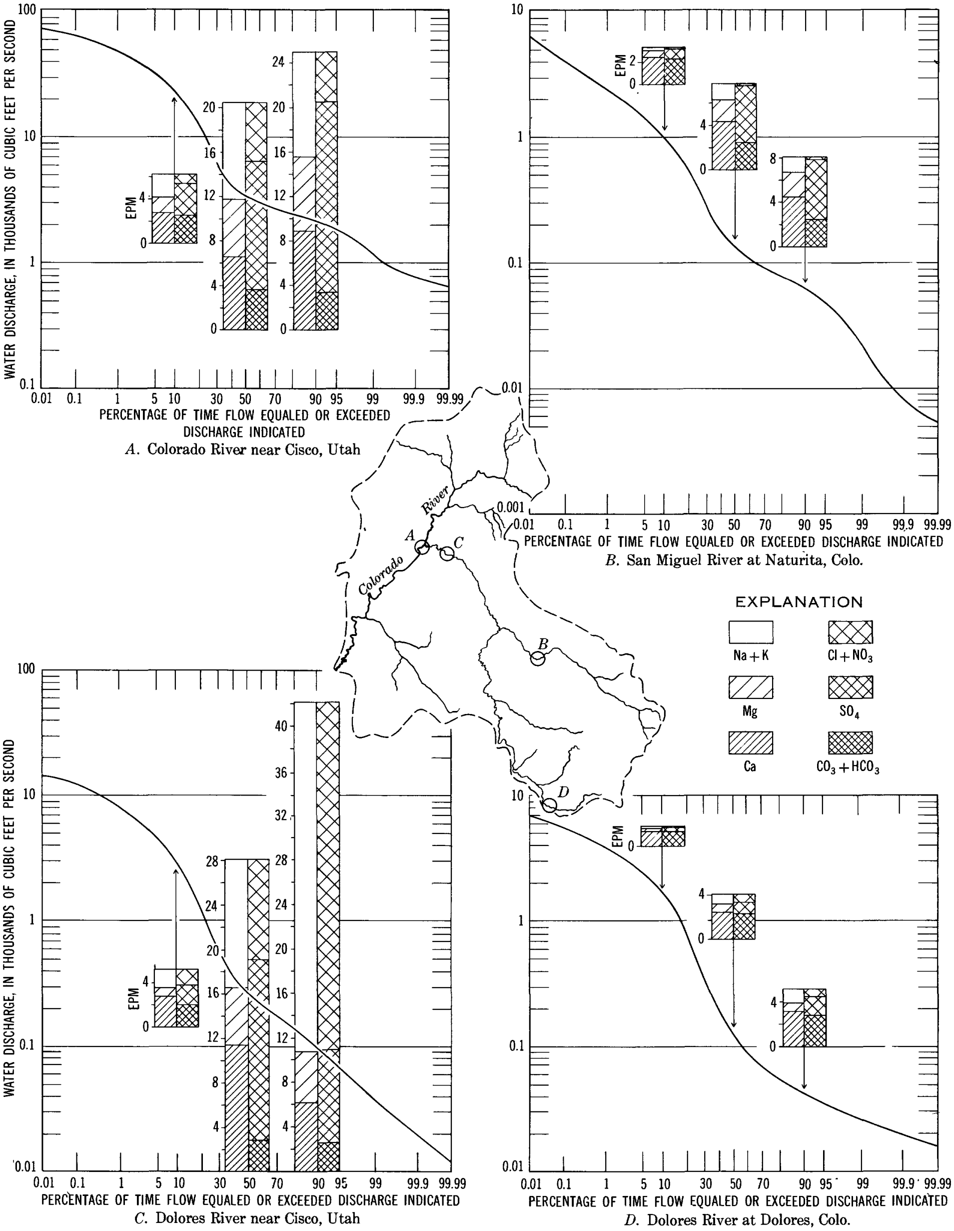
At times of high flows, when the runoff comes mostly from areas underlain by volcanic rocks, the water is of the calcium bicarbonate sulfate type. At times of low flow the water is of the calcium sulfate bicarbonate type. This change is probably caused by the greater influence of the Morrison Formation and Mancos Shale on the low flows as compared to their influence on high flows.

The waters of streams that rise on the Uncompahgre Plateau and enter the Dolores River between the San Miguel River and the mouth of the Dolores River are of the calcium bicarbonate type, and the concentration is usually less than 300 ppm. This area is underlain mostly by the Dakota Sandstone and rocks of the Glen Canyon Group, which are mostly sandstones.

Salt Creek, which flows into the Dolores River upstream from Gateway, drains the Sinbad Valley. This valley, which is a breached anticline, is underlain by the salt beds of the Paradox Member. The water of Salt Creek at the mouth had a specific conductance of 37,000 micromhos in March 1952 and a specific conductance of 44,400 micromhos in September 1951. In September 1951 the water contained 28,800 ppm of sodium chloride.

The dissolved-solids concentration of the water of Dolores River near Cisco, Utah, ranges from about 200 to 6,000 ppm. The concentration is more than 1,000 ppm for 60 percent of the time (table 15). At low flow, the quality of the water at this station is strongly influenced by water from the Gypsum, Paradox, and Sinbad Valleys and is of the sodium chloride type.

Many small tributaries flow into the Colorado River between the Dolores and Green Rivers. The drainage



A. Colorado River near Cisco, Utah

B. San Miguel River at Naturita, Colo.

C. Dolores River near Cisco, Utah

D. Dolores River at Dolores, Colo.

Figure 73.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Colorado River Basin between the Gunnison and Green Rivers. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th centiles of the flow-duration curve for each location. The flow-duration curves are for water years 1914–57 adjusted to 1957 conditions.

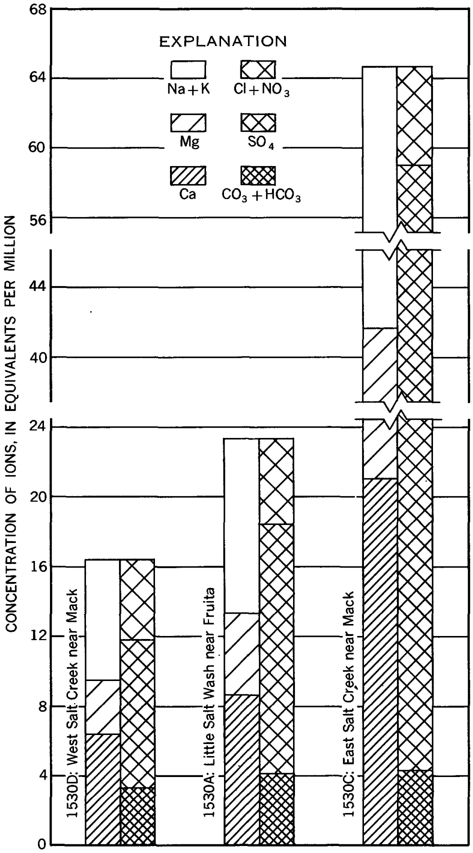


FIGURE 74.—Analyses of water from streams in the Grand Valley irrigation project.

basins of these tributaries are underlain mostly by sedimentary rocks of the Mesozoic Era. All the tributaries are intermittent, except for a few streams that head in the La Sal and Abajo Mountains east of the Colorado River. The dissolved-solids concentration of some of these streams is relatively high, but their flow is so small in comparison to the flow of the Colorado River that the quality of the Colorado River is only slightly affected. Many of the streams have high concentrations of sodium chloride.

Zones of approximate weighted-average concentration are shown in figure 75. Comparison of these zones with the different rock types shown in plate 1 and the irrigated areas (pl. 5) gives an indication of the effect of the rock types and irrigation on the quality of water. Analyses of a few samples of water from the Colorado River collected immediately above the Green River indicate that the weighted-average concentration of the river water at this point is about the same as at the Cisco station.

RELATION TO GROUND WATER

The headwaters of the Dolores and San Miguel Rivers are the only two areas in this subbasin in which the precipitation is sufficient for appreciable recharge to ground-water reservoirs. Quantities of dissolved solids estimated to be contributed by ground water to these two streams in their headwaters are given in table 20. Volcanic rocks underlying the headwaters of the San Miguel River apparently contain less soluble minerals than the Rico Formation underlying the headwaters of the Dolores River, as is indicated by the greater weighted-average concentration of ground water from the headwaters of the Dolores River. The large area of outcrop of the Mancos Shale in the higher areas of the San Miguel River basin is probably why the weighted-average concentration of San Miguel River near Placerville, Colo., is greater than that of Dolores River at Dolores, Colo.

Ground-water inflow to the Colorado River between the Gunnison and Dolores Rivers was probably negligible before irrigation began. The average annual precipitation is less than 10 inches over the valley area, and it exceeds 20 inches in only a small part of the highlands. The small tributaries that head in the highlands north of the river and flow across the valley are mostly dry washes and provide little water to maintain a ground-water reservoir in the residuum and alluvial mantle that covers the Mancos Shale underlying the valley. South of the river, the few tributaries that drain the Uncompahgre uplift are deeply incised in the rocks of the Glen Canyon Group. The fact that little ground water is contributed to these streams, even where they have eroded down to the Precambrian rocks, indicates that very little ground water is discharged to the Colorado River from the south.

As a result of irrigation, an extensive ground-water reservoir has been created beneath the irrigated lands in the Grand Valley. This reservoir is effluent to the Colorado River by seepage and drains. As this ground water has high concentrations of dissolved solids, it has a deteriorating effect on the quality of the water in the river. Analyses of samples of irrigation water, drainage water, and ground water have been made by the U.S. Salinity Laboratory at Riverside, Calif. These samples were collected during a soil survey of the Grand Junction area (Knobel and others, 1955). The analyses of these samples show the great differences

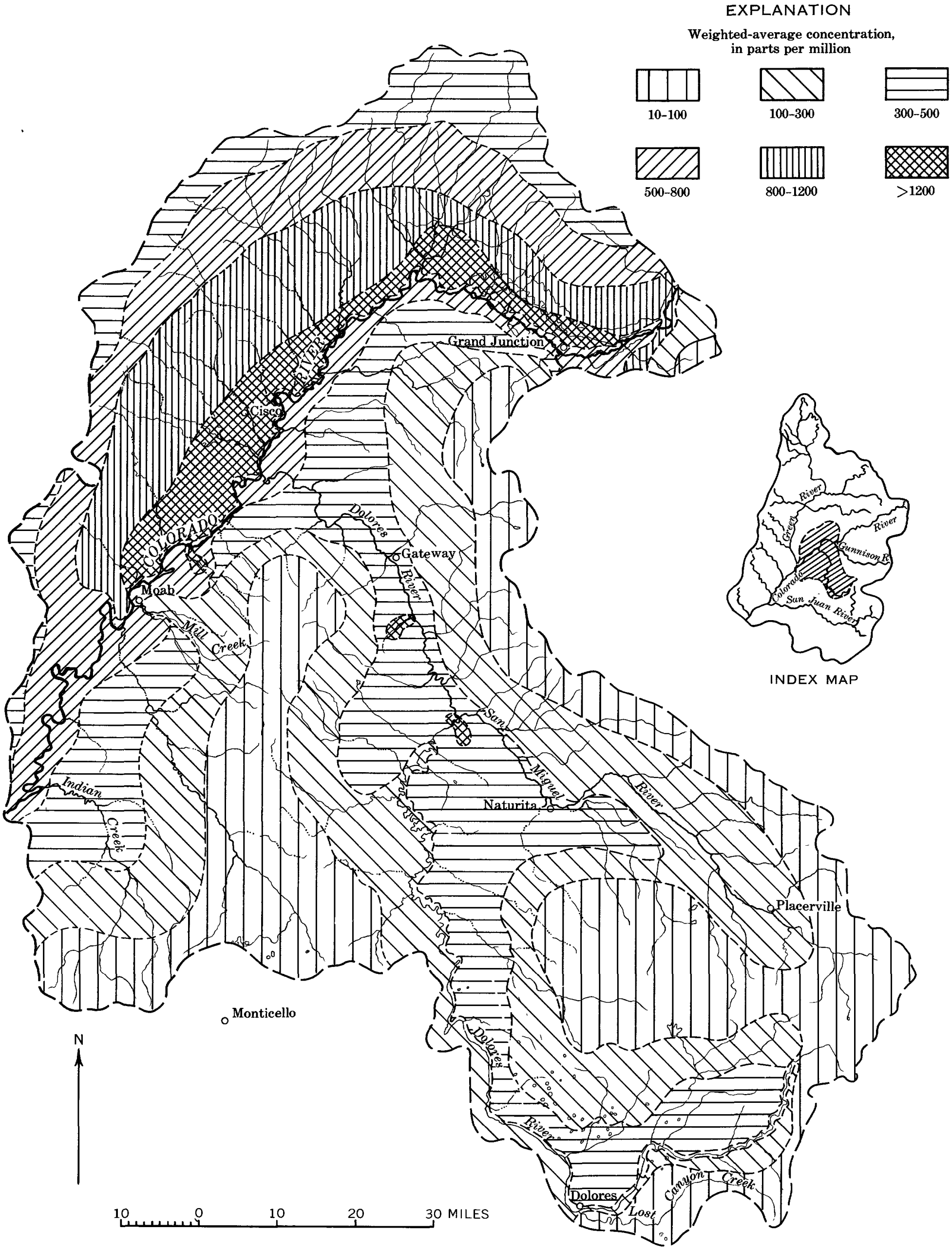


FIGURE 75.—Approximate weighted-average concentrations of dissolved solids in streams in the Colorado River Basin between the Gunnison and Green Rivers.

between the quality of the water before it is applied to the land and after it reaches the water table (fig. 76).

Water from two shallow wells in the alluvium along the Dolores River—one at Gladel, Colo., and one downstream at Bedrock—are similar in chemical type to the water in the river (fig. 77). Water from the well at Gladel contains more dissolved solids than water from the river at low flows. Water from the well at Bedrock contains slightly more dissolved solids than does the water from the well at Gladel. That the water in the well at Bedrock is more dilute than the water in the river is believed to be due to dilution from a nearby canal, which diverts water from upper West Paradox Creek.

Between Bedrock and Uravan, above and below the Paradox Valley, the concentration of the Dolores River on August 11, 1958, increased from 1,260 to 35,600 ppm, and most of the increase was in sodium chloride (fig. 78). The increase in dissolved solids in the river on this day was equivalent to about 160,000 tons per year. Apparently, most of the increased content of dissolved solids in the river was added by effluent ground water from the alluvium that fills the Paradox Valley, as there was no surface inflow to the river.

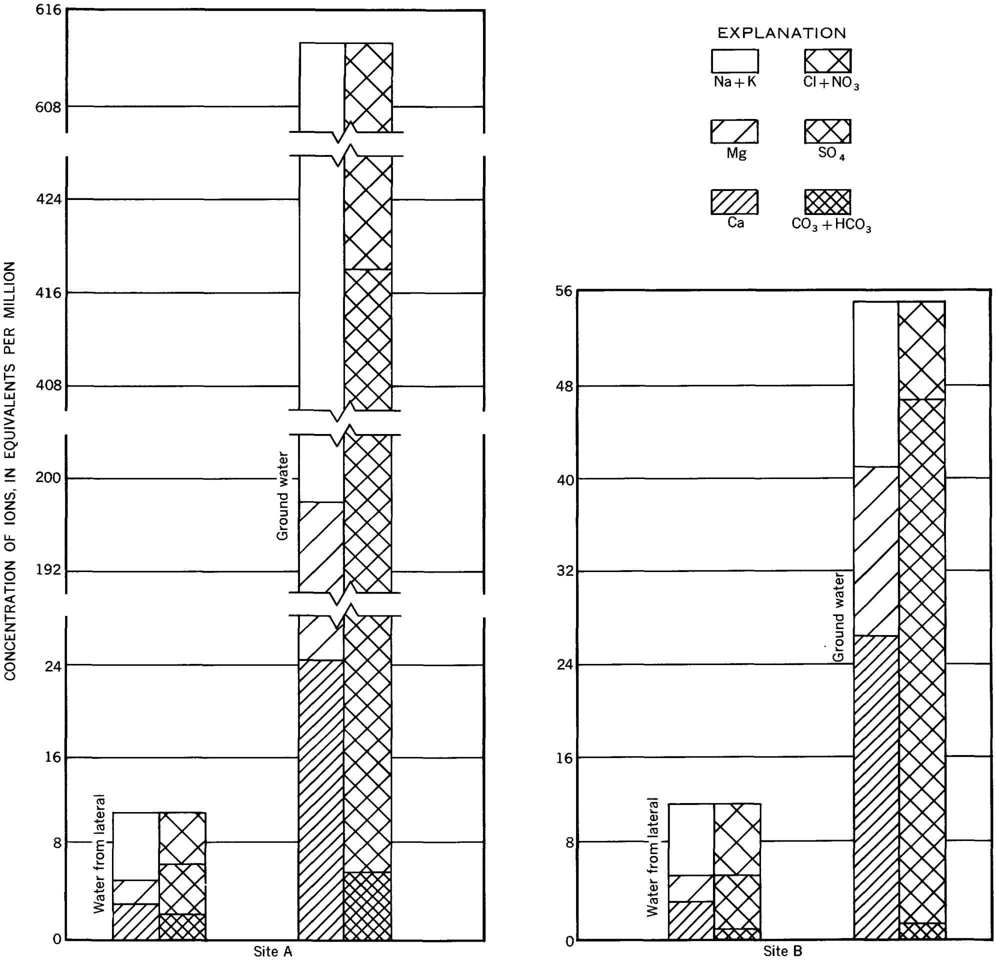


FIGURE 76.—Analyses of water from irrigation laterals and from wells nearby in the Grand Valley irrigation project near Grand Junction, Colo.

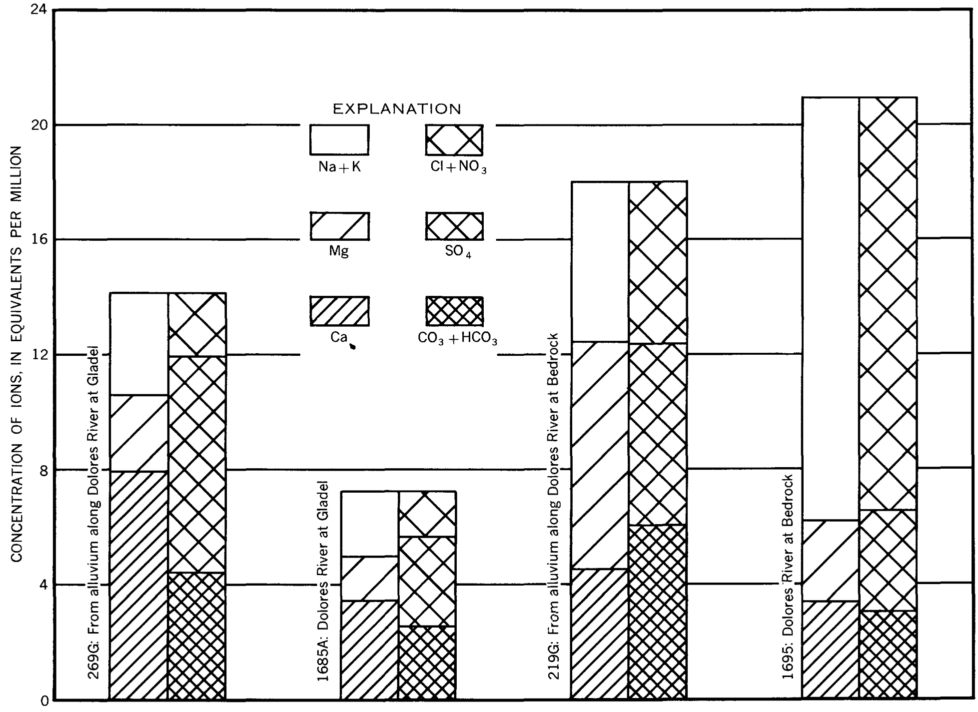


FIGURE 77.—Analyses of water from the Dolores River and from alluvium nearby.

Analyses of water in West Paradox Creek at times of discharge indicate very little sodium chloride in surface runoff from the Paradox Valley.

Ground water in the alluvium along the San Miguel River is generally of the calcium bicarbonate sulfate type in the upper reaches and of the calcium sulfate bicarbonate type in the lower reaches. At times of low flows, the water of the San Miguel River is of the same type as the ground water in the nearby alluvium. A similar relation exists between the water in West Creek at Gateway and the alluvium along West Creek (fig. 79). The water in the alluvium along the streams generally has a greater concentration of dissolved solids than the water in the streams.

Ground water that reaches the Colorado River by way of the streams that enter from the right bank between the Dolores and Green Rivers contains as little as 200 ppm and as much as 2,500 ppm of dissolved solids. **Ground water from the Entrada and Wingate** Sandstones and from the alluvium that overlies these formations is consistently low in dissolved solids. **Ground water associated with the Salt Wash Sandstone Member of the Morrison Formation usually contains** about 1,500 ppm. Some ground water comes from the Paradox Member of the Hermosa Formation west of the river in this reach, and this water usually contains more than 2,000 ppm of dissolved solids, most of which is calcium sulfate. Water from the Salt Wash Sandstone member of the Morrison Formation and the Wingate and Entrada Sandstones may be of either the sodium sulfate or the sodium bicarbonate type.

Between the Dolores and Green Rivers, ground water in the area east of the Colorado River is similar in quality to that entering from the right bank, except ground water associated with the Paradox Member. Water from the Paradox Member east of the river is of the sodium chloride type and contains as much as 15,000 ppm of dissolved solids at shallow depth. Water from a deep well in the Paradox Member along the Colorado River below the mouth of Cane Creek is of the sodium chloride type and contains more than 300,000 ppm of dissolved solids, more than 4,500 ppm of which is borate.

Two thermal springs in the headwater area of the San Miguel River basin have a combined discharge of less than 5 gpm (Iorns and others, 1964, table 227) and an average concentration of about 3,300 ppm. The waters of the springs are of the sodium sulfate bicarbonate chloride type. Two thermal springs in the headwaters of the Dolores River have a reported combined discharge of about 50 gpm (Stearns and others, 1937). On the assumption that the average concentration of all the springs is 3,300 ppm they would add only about 400 tons of dissolved solids to the streams annually.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

About 100,000 acre-feet of water having a weighted-average concentration of dissolved solids of 125 ppm is diverted annually from the Dolores River to irrigate land in the San Juan River basin (U.S. Dept. of the Interior, 1947, p. 128). This diversion, which is made below the streamflow station at Dolores, Colo., adversely affects the quality of the water downstream in the Dolores and Colorado Rivers. The effect of the diversion on the quality of water of the two streams is to increase the weighted-average concentration and to decrease the dissolved-solids discharge by 17,000 tons.

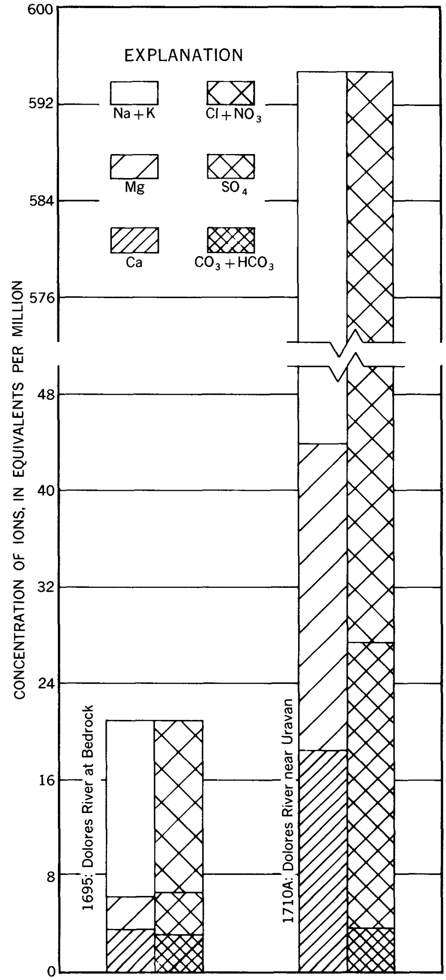


FIGURE 78.—Analyses of water from the Dolores River above and below Paradox Valley.

If the 100,000 acre-feet per year of water had not been diverted, the weighted-average concentration in Dolores River near Cisco, Utah, for the water years 1914–57 would have been about 48 ppm less. Similarly, the weighted-average concentration in Colorado River near Cisco, Utah, would have been about 7 ppm less.

About 453,400 acre-feet of water is diverted annually from the Colorado River Basin above the gaging station on Colorado River near Cisco, Utah. If this water had not been diverted, the weighted-average concentration in Colorado River near Cisco, Utah, for the water years 1914–57 would have been decreased by about 37 ppm. Existing transmountain diversions out of the division have caused an average increase of about 8 ppm at the Cisco gaging station for each 100,000 acre-feet per year diverted.

EFFECT OF THE ACTIVITIES OF MAN

About 78,700 acres is irrigated in this subbasin between Plateau Creek and the Dolores River. Other factors that affect the quality of water of this area are several small industries and a population of about 35,000.

Most of the irrigated lands are in the Grand Valley, which is underlain by the Mancos Shale and other rocks of Cretaceous age. These rocks are, in general, of the same type as those beneath most of the irrigated lands in the Uncompahgre River basin. According to the findings of a soil survey in the Grand Valley (Knobel and others, 1955, p. 30–31), the soils:

> have a high content of lime carbonate, gypsum, and salts of sodium, potassium, magnesium, and calcium. In many places irrigation has brought about a concentration of salts toxic to plants * * * Many of the soils having favorable physical characteristics have become more productive through the years of cultivation. This results from incorporation of organic matter by the growing of legumes and the application of moderate to large amounts of barnyard manure * * * Some soils of the area have limited agricultural suitability, or are entirely unsuited to irrigation farming. Large areas of alluvial soils have limited agricultural use because restricted internal drainage causes water logging and accumulation of strong concentration of salts.

An average of about 496,700 tons of dissolved solids are added annually to the Colorado River between Plateau Creek and the Dolores River, exclusive of the Gunnison River. (See p. 126.) Of this amount, about 52,600 tons comes from natural sources and about

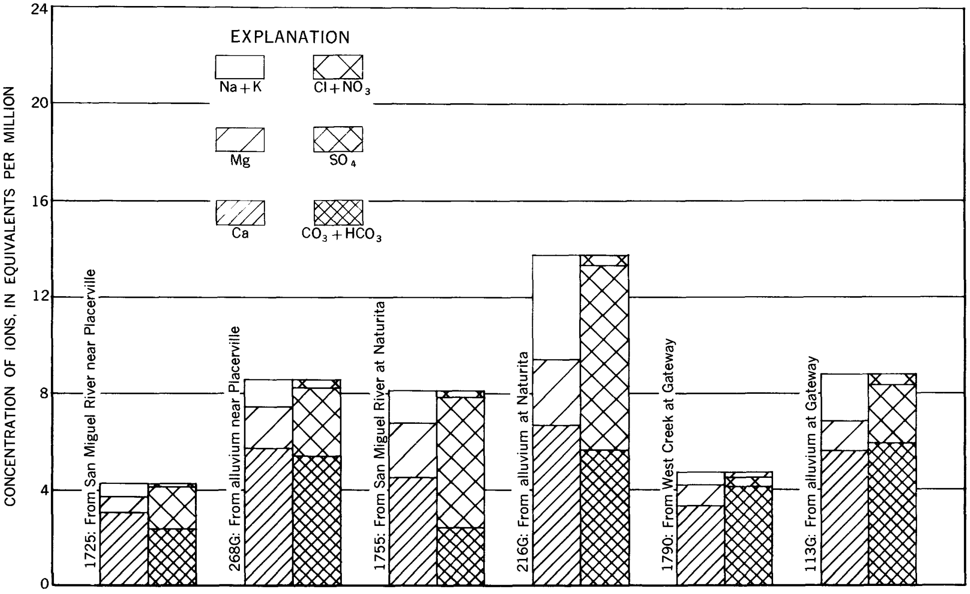


FIGURE 79.—Analyses of water from the San Miguel River and West Creek and from alluvium nearby.

444,100 tons is contributed as a result of the activities of man. (See chap. B, p. 61.) If 100 tons per year per 1,000 people is used as the rate of contribution of dissolved solids to the stream system as a result of domestic and industrial uses, the contribution from these sources would amount to 3,500 tons annually. The balance of 440,600 tons may be attributed principally to irrigation—5.6 tons per year per acre of irrigated land.

In the Dolores River basin, from which an average of about 460,200 tons of dissolved solids are added annually to the Colorado River, most of the irrigated lands are underlain by rocks of Cretaceous age, predominantly the Dakota Sandstone. In the part of this basin drained by the San Miguel River between the gaging stations near Placerville, Colo., and at Naturita, Colo., about 15,000 acres of land underlain by the Dakota Sandstone is irrigated. Table 22 gives an approximate budget of water and dissolved solids for the area.

The unmeasured inflow is estimated to be 96,700 acre-feet—that is, the difference between the measured inflow (San Miguel River near Placerville) and the measured outflow (San Miguel River at Naturita) plus 30,000 acre-feet estimated to be used consumptively on 15,000 irrigated acres.

Part of the 96,700 acre-feet of unmeasured inflow is surface water and part is ground water recharged by precipitation on the valley lands. Under natural conditions, about 2 inches of the average annual precipitation of 12–16 inches is estimated to enter the groundwater reservoir under about 25,000 acres of valley lands and ultimately to reach the streams. The natural ground-water inflow (about 4,200 acre-ft) is estimated to have a weighted-average dissolved-solids concentration of 400–600 ppm. The estimated concentration in the unmeasured natural ground-water inflow is based on chemical analyses of water from streams in the area during low flow—San Miguel River at Naturita (525 ppm), Tabeguache Creek near Uravan (358 ppm), and Rock Creek near Uranium (662 ppm). (See table 14 and Iorns and others, 1964, table 220.)

The unmeasured surface-water inflow of 92,500 acre-feet is the total unmeasured inflow (96,700 acre-ft) minus unmeasured natural ground-water inflow (4,200 acre-ft). Environmental factors, such as the type of rocks underlying the part of the basin from which the unmeasured surface water comes, are about the same as those above San Miguel River near Placerville. Therefore, the dissolved-solids concentration of the unmeasured surface water is estimated to be about 150 to 160 ppm.

The minimum computed increase in dissolved solids in table 22, if attributed entirely to irrigation, is equivalent to about 2.8 tons per year per acre of irrigated land.

For the rest of the Dolores River basin, about 71,300 tons of dissolved solids are estimated to be contributed annually to the streams as a result of the activities of man. This estimate is based on the indicated rate of dissolved-solids yield per acre determined for the 15,000 acres of irrigated land underlain by the Dakota Sandstone along the San Miguel River, data on other areas in the Upper Colorado River Basin where yield rates could be identified (see chap. B, table 14), the characteristics of rocks underlying irrigated lands, and chemical analyses of water at miscellaneous sites.

The disolved-solids contribution to the Colorado River from the 2,400 square miles of drainage area between the Dolores and Green Rivers is estimated to average 84,600 tons annually. This estimate was obtained by prorating, on the basis of drainage area, the dissolved-solids increase between the downstream chemical-quality stations in this subbasin and the Green division, and the upstream chemical-quality stations in the San Juan division. About 14,300 tons of the 84,600 tons is estimated to be contributed annually as a result of the activities of man.

Of the total dissolved solids contributed to the stream system (1,041,500 tons annually), about 469,900 tons comes from natural sources and about 571,600 tons is contributed as a result of the activities of man. Per unit of area, that from natural sources is 48 tons per square mile drained, and that caused by man is 4.7 tons per acre irrigated. On the basis of a population of 66,000, 6,600 tons of the contribution of dissolved solids due to the activities of man is estimated as caused by domestic and industrial uses of water and 565,000 tons as a result of irrigation.

In the other two subbasins of the Grand division and the part of this subbasin above the gaging station on Colorado River near Cisco, Utah, consumptive use of water by irrigation is about 732,500 acre-feet annually. Domestic and industrial uses of water are estimated to consume about 8,600 acre-feet annually. The activities of man are estimated to contribute an average of about 1,936,300 tons of dissolved solids to the river annually above the Cisco station. If there were no activities of man in the basin (exclusive of transmountain diversions), the weighted-average concentration of dissolved solids in Colorado River near Cisco, Utah, would be about 256 ppm as compared to a weighted-average concentration of about 547 ppm for water years 1914–57 adjusted to 1957 conditions.

Existing consumptive uses of water for domestic, industrial, and irrigation purposes in the Grand division above the Cisco gaging station have caused an average increase of about 39 ppm at the Cisco gaging station for each 100,000 acre-feet of water consumed. Domestic, industrial, and irrigation uses of water in the division have caused about five times as great an increase in dissolved-solids concentration at the Cisco station, for each acre-foot of water consumed, as the transmountain diversions have caused for each acre-foot of water transported out of the division.

FLUVIAL SEDIMENT

The collection of daily suspended-sediment data for Colorado and Dolores Rivers near Cisco, Utah, began in the 1930 and 1951 water years, respectively. Suspended-sediment discharges have been obtained at a few other sites, such as Dolores River at Dolores, Colo. The annual suspended-sediment discharges for the two daily stations are given in table 31. Suspended-sediment data collected at other sites are contained in the basic data report (Iorns and others, 1964, tables 232, 233, and 255).

The suspended-sediment discharge at the two stations near Cisco and the computed sediment discharge in Dolores River at Dolores, Colo., are given in table 25. Of the 14,351,000 tons of suspended sediment discharged annually by Colorado River near Cisco, Utah, about 3,015,000 tons originates in this subbasin. About 84 percent of the 3,015,000 tons is contributed by the Dolores River.

The suspended-sediment contribution to the Colorado River from the 2,400 square miles of drainage area between the Dolores and the Green Rivers is estimated to average 6,144,000 tons annually. This estimate was obtained by prorating, on the basis of drainage area, the suspended-sediment increase between the downstream suspended-sediment stations in this subbasin and in the Green division, and the upstream suspended-sediment stations in the San Juan division. The computed yield from the 5,850 square miles of intervening drainage area is 2,560 tons per square mile per year.

A statistical analysis of the annual suspended-sediment discharge shows that the variability of the suspended-sediment discharge for Colorado River near Cisco, Utah, is greater than the variability of either water discharge or dissolved-solids discharge at this station. The coefficient of variation of suspended-sediment discharge is 0.64. The coefficients for streamflow and dissolved-solids concentration are 0.31 and 0.22, respectively.

During the time in which the sediment station has been operated on Colorado River near Cisco, Utah, significant changes have taken place with time in the relation of sediment discharge to water discharge. After the 1942 water year, the annual suspended-sediment concentration of Colorado River near Cisco was generally less than in the the preceding years of record (table 31). The reasons for these changes are unknown, but they may be associated with variations in the intensity of summer storms or with periods of below-normal and above-normal precipitation.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classification of the surface waters in the Colorado River Basin between the Gunnison and Green Rivers is based on the water-quality criteria for major uses. (See chap. B, pp. 66–73.)

The waters of all the streams that enter the Colorado River between the Gunnison River and the Dolores River, except the Little Dolores River, contain at times more than 1,000 ppm of dissolved solids. The waters of these streams also contain more than 250 ppm of sulfate, which is the maximum permitted by the accepted standards for domestic use. A few of the streams also contain more than the allowable 125 ppm of magnesium. Only the water of the Little Dolores River, except during extremely low flows, is considered suitable for domestic purposes. All the stream waters are hard, and softening would be desirable for most purposes.

The waters of the Dolores River and tributaries above Disappointment Creek are suitable for domestic use. Between Disappointment Creek and the San Miguel River, the waters of the Dolores River and tributaries do not meet the criteria for domestic purposes used in this appraisal, except during the high flow in the spring. All these waters are moderately hard to hard.

The waters of the San Miguel River and its tributaries, except near their mouths during times of low flow, are suitable for domestic use. At low flows the waters of these streams contain more than the permissible amounts of sulfate. All the waters are hard to very hard.

Below the San Miguel River, the concentration of dissolved minerals in the water of the Dolores River and all tributaries from the west exceeds the maximum acceptable limits for domestic use. Tributaries that enter the Dolores River from the east between the San Miguel River and Gateway contain less than the maximum acceptable concentration of constituents adopted for this appraisal. The waters of the tributaries from the east and west sides are moderately hard to very hard.

Between the Dolores and Green Rivers, almost all the waters at the mouths of tributaries of the Colorado River contain more sulfate than is permissible according to the adopted domestic-use standards. The waters are hard to very hard. The dissolved solids in the Colorado River in this reach exceed the maximum of accepted standards except during high flow in the spring, and the water is not satisfactory for domestic purposes for about 9 months of the year.

The monthly weighted-average concentration of nitrate in Dolores and Colorado Rivers near Cisco, Utah, has been as much as 61 ppm and 40 ppm, respectively. Samples of ground water and water in drains in the Grand Valley collected in November 1960 contained as much as 84 ppm of nitrate. These high nitrate concentrations indicate that the use of some of these waters for domestic purposes, especially for preparing babies' formulas, might have serious consequences.

AGRICULTURAL USE

Table 27 gives the classification of selected streams as to their suitability for irrigation use at low, medium, and high flows. The chemical analysis on which the classification is based are in the basic data report (Iorns and others, 1964). The terms used in the table are self-explanatory or are explained on page 107 and in chapter B, pp. 69–73.

The waters of the streams at the sites listed in table 27 all contain less than 1.25 epm of residual sodium carbonate and are thus permissible for use in irrigation insofar as this measure of usability is concerned.

The surface waters in this subbasin range from the C1–S1 to the C4–S4 category, and most of the waters that are presently used for irrigation are classified as C3–S1 or better, acording to the method of classification of the U.S. Salinity Laboratory Staff (1954).

The waters of many of the streams at the sites listed in the table should not be used for irrigation, and some of the waters should be used only on soils that have exceptionally good drainage. Many of the waters of the streams have a high sodium-absorption-ratio and a high required leaching percentage.

INDUSTRIAL USE

Most of the waters in this subbasin would require treatment for most industrial applications. A few of the streams in the headwaters could be used for some industries without treamtent. (See chap. B, table 17, and the basic data report (Iorns and others, 1964).)

SUMMARY

The eastern part of the Grand division is a series of uplifted mountain masses deeply dissected as a result of erosional processes including weathering and glaciation. In the western part, essentially a dissected plateau, the streams flow in wide valleys or in deep narrow canyons cut below benches and tablelands. All the division is above an altitude of about 3,880 feet, and many of the mountain peaks rise above 13,000 feet. The Colorado River flows southwestward across the division near its north boundary.

The exposed rocks range in age from late Precambrian to Recent. The pattern of exposures is complex, owing to uplift, folding, faulting, and weathering. Hard rocks, mainly igneous and metamorphic, form the ridges and mountain cores, and softer rocks, such as siltstones and shales, underlie the valleys and lowlands. The unconsolidated deposits mantling the consolidated rocks are principally residuum developed from the underlying parent rock and river alluvium derived mostly from nearby sources.

The climate is governed largely by topography and altitude. The precipitation ranges from less than 8 inches in the western part to more than 50 inches on the high mesas and in the mountains. The precipitation on about three-fifths of the division is less than 20 inches. The annual average precipitation over the division is 20.27 inches (water years 1914–57).

Runoff varies with the seasons. Snow that accumulates in the mountains provides most of the water supply. As the snow melts in the late spring and early summer, the flow in the perennial streams rises to a peak and then subsides as the supply of snow is exhausted. Relatively little runoff occurs from local thunderstorms, which occur infrequently during the summer.

Flow-duration curves, which show the percentage of time during which specified rates of flow were equaled or exceeded, were adjusted to be representative of the streamflows that would have occurred if the level of development in 1957 had existed throughout water years 1914–57. The average discharges of the streams for the 44-year base period were computed from these curves.

Differences in the shape of flow-duration curves are the result of differences in drainage-basin characteristics. For snowmelt streams, which predominate, the relative permeability of the rocks underlying the drainage basins of the streams is apparently the major cause of variation in the slope of the flow-duration curves. The relative permeability of the rocks is reflected also in the percentage of average annual discharge contributed to the stream systems from groundwater reservoirs. For example, ground-water contribution to Gypsum and Homestake Creeks is computed to be 66 percent and 11 percent of the average annual discharge of the streams, respectively. The Gypsum Creek drainage basin is underlain by relatively permeable rocks and Homestake Creek drainage basin by relatively impermeable rocks. The average annual precipitation and the directional exposure and altitude are about the same for both drainage basins.

A statistical analysis for selected gaging stations indicates that the annual discharges of many streams for the base period (1914–57) are normally distributed and that the coefficients of variation (ratio of standard deviation to the average discharge) have geographic significance. These two characteristics provide a basis for estimating the probabilities of streamflow for a year or a group of years in streams for which the record is short. The coefficients of variation of the perennial streams investigated ranged from 0.18 to 0.59 and, on the average, increased from 0.27 in the eastern part to 0.39 in the western part. For intermittent streams in the western part, the coefficient was estimated to be about 0.76.

Table 32 shows an approximate water budget for the division. The total supply from precipitation is 28,648,300 acre-feet, which is equivalent to an annual average precipitation of 20.27 inches. All the precipitation not accounted for in outflow, transmountain diversions, and consumptive use due to the activities of man is considered to be evapotranspiration loss from land and water surfaces and native vegetation. This loss accounts for 76.5 percent of the precipitation, or 15.5 inches of water over the drainage basin.

Data on water utilization and storage reservoirs are summarized in table 33. The major use of water is for irrigation.

The differences in the chemical quality of the streams result from the differences in hydrologic and other environmental factors prevailing in the drainage basins. The major environmental factors that determine the chemical quality of each stream are precipitation, type of rock and soils that underlie each drainage basin, and the activities of man.

Most of the streams are of the snowmelt type and have the normal pattern of change in the dissolved-solids concentration. The concentrations are lowest in the months of maximum water discharge and highest in the months of low flow when the streams are maintained largely by ground water.

A statistical analysis of the variations in the concentration of dissolved solids for six stations indicates a linear relation between the coefficients of variation of yearly weighted-average concentration and the coefficients of variation of yearly water discharge. The variability of weighted-average concentration is about 60 percent of that of streamflow. This relation provides a means of developing statistical expressions of the variability of dissolved-solids concentration for many locations where chemical-quality stations have not been operated.

The range in concentraton of dissolved solids between high and low discharges is generally small in headwater streams but increases downstream. The range in concentration is especially large downstream from areas that contribute relatively large amounts of dissolved solids.

Most headwater streams do not change in chemical type from high to low flows, the water generally being of the calcium bicarbonate type at all flows. In their downstream reaches, the waters of most of the streams are of the calcium bicarbonate type during high flow and of the sodium sulfate type during low flow.

The mountainous headwaters of the Colorado and Gunnison Rivers are mostly underlain by granitic and associated metamorphic rocks of Precambrian age and volcanic rocks of Tertiary age that are resistant to the solvent action of water. The weighted-average concentration of dissolved solids of the headwater streams draining areas underlain by the Precambrian rocks is as low as 20 ppm and seldom exceeds 50 ppm. The concentration of silica in runoff from headwater areas underlain by the Tertiary volcanics may, however, average as much as 25 ppm.

The western part of the division is underlain principally by sedimentary rocks. Such rocks also underlie the central part at lower altitudes and in some places, the eastern part at lower altitudes. Many of these sedimentary rocks are of marine origin and contain substantial amounts of readily soluble minerals. Tributary streams draining areas underlain by marine sediments have relatively large concentrations of sodium, magnesium, sulfate, and chloride.

Sedimentary rocks, including those of marine origin, are also exposed in some of the headwater areas. Streams draining such areas have substantially higher concentrations of dissolved solids than streams draining nearby areas that are underlain by igneous and metamorphic rocks and that receive comparable precipitation.

The dissolved-solids concentration of most streams increases downstream. Most streams in the headwater areas, which are the source of most of the water supply, have weighted-average concentrations of less than 100 ppm. Downstream, the long-term weighted-average concentration of the Colorado River increases from 76 ppm at Hot Sulphur Springs, Colo., to 270 ppm at the station near Glenwood Springs, Colo., 387 ppm at the station near Cameo, Colo., and 547 ppm at the station near Cisco, Utah. The principal natural causes for the increase are the relatively high dissolved-solids concentration of the runoff from downstream areas underlain by sedimentary rocks, pickup by the streams as they flow over formations containing soluble minerals, and natural ground-water discharge, particularly from thermal springs. Among the principal activities of man that cause the concentration to increase are the consumptive use of water, the discharge of domestic and industrial wastes to the streams, and the leaching of soluble minerals from the soils and underlying rocks by irrigation water.

Ground-water contribution to the streams affects the chemical quality of the water in the streams, especially during periods of low flow when the streams are sustained largely by ground water. During periods of high flow, the relatively concentrated ground-water contribution to the streams is diluted by surface runoff.

In some areas water is interchanged between the streams and the adjacent flood-plain alluvium as a result of the rise and fall of the streams. The concentration of dissolved solids in the streams is usually much less than that of the ground water in the alluvium. The movement of ground water from the alluvium to the stream increases the concentration of dissolved solids in the stream.

Thermal springs having high concentrations but small discharge as compared to the receiving streams add appreciable quantities of dissolved solids to some of the streams. About 482,000 tons of dissolved solids are added to the streams annually by thermal springs. The combined annual water discharge of the springs is only about 41,000 acre-feet.

Water diverted out of the Grand division carries with it the dissolved minerals in the diverted water. The effect of the exportation on the master stream at downstream points is to deplete the flow, to decrease the dissolved-solids load, and to increase the dissolved-solids concentration. About 17,800 tons of dissolved solids is annually carried out of the Colorado River Basin above the Gunnison River in the 353,100 acre-feet of water diverted across the Continental Divide and about 25 tons is annually carried out of the Gunnison River basin in 300 acre-feet of water. The 100,000 acre-feet diverted annually from the Dolores River basin to the San Juan River basin carries with it about 17,000 tons of dissolved solids. The effect of the transmountain diversions on the Colorado River below the Dolores River has been an increase in the weighted-average concentration of about 37 ppm. This increase is equivalent to about 8 ppm for each 100,000 acre-feet of water exported.

Domestic, industrial, and irrigation use of water results in the consumption of about 748,000 acre-feet of water annually (table 33) and in the addition of about 1,950,600 tons of dissolved solids annually to the stream system (table 34). These activities of man (exclusive of transmountain diversions) have caused an increase of about 291 ppm in the weighted-average concentration of the Colorado River below the Dolores

River. This increase is equivalent to an average increase of about 39 ppm for each 100,000 acre-feet of water consumed or about five times the effect caused by the exportation of an equivalent amount of water. The major part of the increase in dissolved-solids concentration is attributed to irrigation.

About 20,495,000 tons of suspended sediment is discharged from the Grand division annually (table 34). Of this amount, about 45 percent comes from the Colorado River Basin above the Gunnison River, about 10 percent comes from the Gunnison River basin, and about 45 percent comes from the rest of the division below the Gunnison River.

Determinations of suspended-sediment discharge of streams were made at 3 sites on the Colorado River and at 10 sites on tributaries. Of the 13 areas above the sites, the drainage basin of the Gunnison River above the Gunnison tunnel, with a yield of 46 tons per square mile per year, had the lowest rate of yield. Colorado River near Cameo, Colo., had the highest rate—1,150 tons per year per square mile. Most of the suspended sediment transported past this station comes from the drainage area between the Cameo station and Roaring Fork. This area contributes an average of about 4,150 tons per year per square mile of drainage area.

Chemical-quality data indicate that the concentrations of dissolved solids in many streams are below the maximum accepted limits for domestic use, particularly in headwater streams. The concentrations in the lower reaches of some of these streams exceed the limits for domestic use. In the central and western parts of the basin, the waters of many streams do not meet the standards for domestic use because of high concentrations of sodium, magnesium, sulfate, or chloride. Below some of the irrigated areas the concentrations of nitrate also are relatively high. The monthly weighted-average concentration of nitrate in Dolores and Colorado Rivers near Cisco, Utah, has been as much as 61 ppm and 40 ppm, respectively. Samples of ground water and water in drains in Grand Valley collected in November 1960 contained a maximum of 84 ppm of nitrate. These high nitrate concentrations may cause methemoglobinemia ("blue baby disease") in infants if the water is used in preparing their formulas. Most surface waters in the division range from moderately hard to hard.

The waters of practically all streams in the Grand division are suitable for agricultural use. Exceptions to this are the return flows from some irrigated lands and low flows in the lower reaches of the Dolores River and some of its tributaries.

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TABLES 1–34

TABLE 1.—*Average monthly and annual precipitation, in inches, at 17 index-precipitation stations in the Grand division*

[Data are for water years 1914–57]

Station name	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Spicer, Colo	1.10	0.98	1.04	0.89	0.90	1.13	1.26	1.19	0.90	1.21	1.37	1.05	13.02
Estes Park, Colo	1.23	.93	.78	.57	.87	1.27	2.27	2.15	1.57	2.63	2.02	1.26	17.55
Fraser, Colo	1.29	1.17	1.34	1.63	1.57	1.72	2.07	1.85	1.33	1.97	1.71	1.17	18.82
Idaho Springs, Colo	1.00	.67	.50	.34	.50	.89	2.01	1.92	1.42	2.57	2.20	1.10	15.12
Dillon, Colo	1.36	1.16	1.32	1.33	1.39	1.92	2.16	1.68	1.06	1.85	1.80	1.26	18.29
Leadville, Colo	1.22	1.08	1.16	1.29	1.39	1.62	1.81	1.48	1.21	3.34	2.45	1.42	19.47
Shoshone, Colo	1.44	1.21	1.48	1.64	1.54	1.45	1.89	1.42	1.20	1.32	1.80	1.39	17.78
Collbran, Colo	1.38	1.04	1.07	1.22	1.08	1.44	1.64	1.42	.80	1.17	1.62	1.36	15.24
Grand Junction, Colo	.83	.59	.65	.68	.59	.80	.78	.72	.42	.68	1.21	.91	8.86
Cedaredge, Colo	1.14	.73	.82	.94	.89	.91	1.23	1.15	.75	.96	1.30	1.12	11.94
Paonia, Colo	1.49	1.20	1.34	1.42	1.27	1.35	1.70	1.36	.76	.99	1.35	1.24	15.47
Montrose, Colo	.90	.62	.64	.61	.48	.71	1.00	.98	.51	.84	1.35	.98	9.62
Gunnison, Colo	.66	.58	.73	.92	.81	.73	.74	.90	.72	1.69	1.43	.88	10.79
Pitkin, Colo	1.02	.93	1.23	1.40	1.29	1.41	1.38	1.30	1.01	2.18	1.95	1.30	16.40
Ames, Colo	2.17	1.40	1.77	1.93	2.04	2.54	2.58	2.05	1.26	2.64	2.99	2.20	25.57
Rico, Colo	2.01	1.54	2.12	2.61	2.25	2.54	2.12	1.66	1.21	2.77	2.90	2.62	26.35
Moab, Utah	1.04	.65	.86	.78	.64	.76	.88	.71	.45	.84	.88	.83	9.32
Averages	1.25	.97	1.11	1.19	1.15	1.36	1.62	1.41	.98	1.74	1.78	1.30	15.86

TABLE 2.—*Annual precipitation, in inches, at 17 index-precipitation stations and weighted-average precipitation in the Grand division, water years 1914–57*

Water year	Index stations																		Grand division weighted average
	Spicer	Estes Park	Fraser	Idaho Springs	Dillon	Lead-ville	Sho-shone	Coll-bran	Grand Junction	Cedar-edge	Paonia	Mont-rose	Gun-nison	Pitkin	Ames	Rico	Moab	Aver-age	
1914	10.79	20.28	17.08	19.68	15.58	18.59	23.07	21.74	9.74	17.93	23.37	13.60	12.64	19.83	31.19	25.78	12.05	18.41	23.53
1915	11.28	24.40	16.30	13.85	12.76	12.81	13.90	13.56	8.75	13.87	17.05	9.47	9.05	12.68	23.82	18.33	10.71	14.27	18.24
1916	11.46	15.32	22.78	12.13	15.82	16.64	18.35	16.24	8.88	10.49	18.35	11.33	12.58	18.03	30.81	23.22	15.42	16.34	20.88
1917	11.53	23.63	23.32	14.46	19.00	15.98	18.31	20.00	8.59	14.18	18.63	11.28	8.64	18.27	23.77	19.13	12.66	16.55	21.15
1918	9.80	20.15	23.88	18.23	16.23	16.79	15.78	15.08	6.67	10.20	16.30	7.86	9.88	20.86	19.97	26.11	13.67	15.73	20.10
1919	6.59	15.36	16.14	12.98	11.81	24.39	14.45	14.97	7.22	10.88	14.17	9.83	12.08	19.69	26.89	26.17	6.41	14.71	18.80
1920	13.30	21.26	23.73	14.66	16.58	23.91	15.03	15.81	10.35	12.49	22.45	10.77	13.01	21.71	25.74	30.98	8.00	17.63	22.53
1921	10.35	22.71	25.97	19.17	20.56	25.94	20.41	19.88	11.13	14.82	18.05	11.49	10.53	19.32	29.07	26.49	10.50	18.61	23.78
1922	5.81	14.16	19.00	14.44	14.85	20.31	13.66	16.00	7.39	12.17	16.84	7.20	6.36	14.63	22.65	27.98	7.91	14.20	18.15
1923	11.23	29.88	23.62	19.37	21.63	27.41	18.63	17.40	8.70	7.85	16.62	8.41	13.54	20.18	27.74	29.06	6.52	18.10	23.13
1924	8.86	19.52	16.91	11.02	13.38	15.49	12.31	15.35	9.10	9.42	13.84	9.83	8.45	9.15	21.87	18.21	9.13	13.05	16.68
1925	15.07	15.47	22.12	16.40	20.65	22.93	15.50	17.52	9.73	12.47	16.99	10.62	9.54	15.20	24.05	29.14	11.94	16.78	21.44
1926	11.88	21.72	21.63	19.25	24.40	19.25	14.48	15.89	9.79	12.97	15.14	9.76	10.97	15.55	27.18	30.91	10.90	17.16	21.93
1927	13.64	18.61	25.64	14.69	23.68	28.53	19.01	23.15	14.49	19.60	22.54	14.23	13.88	20.32	34.62	35.70	16.64	21.11	26.98
1928	11.38	17.95	21.66	11.56	21.12	18.33	13.74	14.16	8.17	10.49	15.09	8.89	11.23	15.96	19.17	19.89	7.21	14.47	18.49
1929	14.11	17.05	17.77	15.61	17.02	24.36	14.76	19.01	15.01	16.20	21.45	13.06	15.81	22.87	27.61	32.19	15.14	18.77	23.99
1930	11.06	11.05	26.23	13.71	18.59	20.96	14.24	16.02	8.99	12.60	16.39	8.49	9.48	12.32	24.64	25.61	11.16	15.38	19.66
1931	13.26	12.64	17.33	12.80	13.15	15.04	13.90	15.35	8.34	8.90	11.88	6.68	6.54	8.99	13.21	16.72	4.30	11.71	14.97
1932	12.91	13.16	20.06	11.59	15.57	23.48	14.58	17.40	9.31	11.88	14.76	9.06	9.86	12.84	22.43	29.72	9.63	15.19	19.41
1933	14.25	11.83	22.14	16.51	21.63	17.10	15.09	13.05	6.26	10.34	14.79	7.37	10.07	12.81	17.80	22.08	6.70	14.11	18.03
1934	9.66	12.22	15.63	17.01	19.52	23.31	11.40	12.03	7.77	9.65	11.19	9.34	7.22	11.97	13.85	21.34	8.17	13.02	16.64
1935	12.15	16.76	15.16	13.43	20.36	20.77	26.31	13.98	7.66	9.65	10.94	7.31	13.73	13.91	20.89	28.16	8.67	15.28	19.53
1936	10.65	18.97	20.45	12.50	29.22	29.36	20.68	12.92	8.08	8.90	12.23	6.64	11.57	17.71	21.75	25.18	7.29	16.12	20.60
1937	13.14	17.98	11.24	13.18	14.16	24.04	20.65	14.63	6.94	10.74	12.40	6.43	10.06	17.64	25.62	27.03	9.51	15.02	19.20
1938	16.46	21.68	19.40	20.18	20.70	28.82	22.35	16.31	10.75	15.31	15.99	13.37	11.42	16.85	33.05	30.40	7.70	18.87	24.12
1939	11.38	12.22	13.12	7.01	16.69	16.69	15.66	10.70	8.20	10.39	12.09	7.71	9.66	10.58	22.56	23.15	10.46	12.84	16.41
1940	14.16	16.48	17.35	14.18	17.67	17.71	16.09	13.60	8.54	12.86	13.32	6.99	9.85	10.90	22.87	27.26	10.93	14.75	18.85
1941	15.20	17.86	16.68	13.69	17.49	16.68	20.83	19.36	14.59	16.41	15.73	17.09	11.75	15.69	36.09	39.61	13.79	18.74	23.95
1942	11.72	18.13	16.08	17.34	18.70	17.60	19.34	17.91	9.22	13.75	16.14	10.40	7.96	18.01	29.69	29.59	11.88	16.67	21.30
1943	17.21	18.12	18.73	15.68	19.48	24.67	21.69	15.22	7.23	12.32	17.97	10.04	12.41	17.59	31.51	32.21	7.15	17.60	22.49
1944	12.06	14.65	10.87	16.90	13.57	12.06	17.03	10.93	6.47	12.08	13.69	9.00	6.76	12.61	28.00	28.26	7.73	13.69	17.50
1945	17.63	21.53	19.62	16.01	23.39	19.69	21.04	12.41	8.30	9.60	16.80	8.94	9.47	17.01	25.73	24.89	7.94	16.47	21.05
1946	12.41	24.99	13.40	16.17	17.91	15.26	16.28	11.96	6.61	11.08	14.81	8.84	10.07	18.09	28.95	23.92	6.49	15.13	19.34
1947	13.99	29.67	20.05	21.46	23.27	21.61	20.62	13.81	8.19	13.33	15.93	11.33	12.52	21.10	32.40	32.77	9.25	18.90	24.15
1948	16.12	15.79	15.08	14.41	16.51	15.84	17.64	16.78	11.20	13.40	17.24	12.72	11.92	18.70	28.44	28.82	10.30	16.52	21.11
1949	22.02	21.40	17.49	24.20	20.51	18.16	17.22	16.21	10.41	10.62	16.40	8.48	11.52	19.00	27.31	33.46	9.31	17.86	22.83
1950	13.20	10.97	12.88	11.74	14.65	13.64	14.91	11.02	6.74	8.25	14.24	7.33	5.91	13.50	22.70	20.71	8.45	12.40	15.85
1951	15.40	15.97	16.19	14.84	20.18	16.80	17.87	9.34	5.63	7.81	10.38	4.42	10.28	15.10	18.96	19.59	5.21	13.17	16.83
1952	17.39	12.84	20.53	13.94	19.90	20.14	26.43	13.75	8.14	12.87	17.14	10.40	14.83	20.55	33.01	25.83	9.92	17.51	22.38
1953	9.45	13.43	14.46	13.39	18.08	13.29	18.18	12.66	7.27	9.51	11.07	8.80	10.65	16.65	25.72	21.55	5.54	13.51	17.27
1954	15.94	9.76	12.83	9.80	13.20	12.94	16.51	12.70	9.48	10.68	10.63	9.93	10.63	15.25	24.59	25.63	7.70	13.42	17.15
1955	15.54	12.80	17.50	13.63	17.77	13.70	17.61	13.46	9.09	11.51	11.24	8.60	12.07	15.30	23.41	20.86	6.52	14.15	18.08
1956	15.10	14.02	20.19	10.85	18.02	14.30	19.67	9.55	3.76	8.07	9.16	5.90	12.90	13.75	22.09	18.58	3.39	12.90	16.49
1957	16.67	17.86	29.62	21.78	19.71	21.44	27.05	21.55	13.06	16.95	19.06	13.97	15.25	23.15	31.41	37.23	10.09	20.93	26.75
44-year averages	13.02	17.55	18.82	15.12	18.29	19.47	17.78	15.24	8.86	11.94	15.47	9.62	10.79	16.40	25.57	26.35	9.32	15.86	20.27

TABLE 3.—*Irrigation and power reservoirs in the subbasins in the Grand division*

[Source of data: U.S. Dept. of the Interior (1947)]

Reservoir	Location	Usable capacity (acre-ft)	Reservoir	Location	Usable capacity (acre-ft)
Colorado River Basin above the Gunnison River					
Shadow Mountain	Colorado River	1,800	Missouri Heights	Cattle Creek (Roaring Fork)	2,800
Lake Granby	do	465,600	Harvey Gap	Unnamed Creek	4,800
Willow Creek	Willow Creek	9,060	Leon Lake	Leon Creek (Plateau Creek)	3,000
Williams Fork	Williams River	7,180	Big Creek No. 1	Big Creek (Plateau Creek)	2,700
Troublesome	Troublesome Creek	1,070	Bonham	do	1,800
Barber	Red Dirt Creek (Muddy Creek)	4,500	Atkinson	do	1,500
Green Mountain	Blue River	146,900	Cottonwood Lake	Cottonwook Creek	2,800
Robinson Lake	East Fork Eagle River	2,520			
Ivanhoe	Ivanhoe Creek (Roaring Fork)	1,400	Total		659,430
Gunnison River basin					
Taylor Park	Taylor River	106,200	Eggleston Lake	Kiser Creek (Tongue Creek)	2,700
Gould (Onion Valley)	Iron Creek (Smith Fork)	6,420	Trickel Park Lake	Surface Creek (Tongue Creek)	3,200
Overland	Cow Creek (Muddy Creek)	2,600	Cedar Mesa	do	1,000
Island Lake	Ward Creek (Tongue Creek)	1,100	Fruitgrowers	Tongue Creek	4,500
Deep Ward Lake	do	1,400			
Baron Lake	Kiser Creek (Tongue Creek)	1,000	Total		130,120
Colorado River Basin between the Gunnison and Green Rivers					
Groundhog	Groundhog Creek (West Fork Dolores River).	21,700	Gurley	Beaver Creek (San Miguel River)	8,800
			Lone Cone	Naturita Creek (San Miguel River)	1,800
Buckeye	West Paradox Creek (Dolores River)	3,000	Valley City	Thompson Wash (Salt Valley Wash)	1,750
Lake Hope	Lake Fork (San Miguel River)	2,300			
Trout Lake	do	2,700	Total		42,050

TABLE 4.—*Transmountain diversion, in acre-feet, from the Colorado River and tributaries above the Gunnison River, water years 1914–57*

Water year	Stream and diversion														Total
	Colorado River			Fraser River		Williams River	Blue River			Eagle River			Roaring Fork		
	Grand River ditch	Eureka ditch	Alva B. Adams Tunnel	Berthoud Pass ditch	Moffat tunnel	Jones Pass tunnel	Hoosier Pass tunnel	Boreas Pass ditch	Fremont Pass ditch	Columbine ditch	Ewing ditch	Wurtz ditch	Twin Lakes tunnel	Busk-Ivanhoe tunnel	
1914	7,610	----------	----------	476	----------	----------	----------	[1] 200	----------	----------	2,360	----------	----------	----------	10,650
1915	12,210	----------	----------	650	----------	----------	----------	[1] 200	----------	----------	1,590	----------	----------	----------	14,650
1916	14,520	----------	----------	832	----------	----------	----------	[1] 200	----------	----------	2,410	----------	----------	----------	17,960
1917	7,590	----------	----------	504	----------	----------	----------	[1] 200	----------	----------	2,460	----------	----------	----------	10,750
1918	14,370	----------	----------	868	----------	----------	----------	[1] 200	----------	----------	2,210	----------	----------	----------	17,650
1919	10,130	----------	----------	476	----------	----------	----------	[1] 200	----------	----------	1,820	----------	----------	----------	12,630
1920	15,170	----------	----------	0	----------	----------	----------	[1] 200	----------	----------	1,740	----------	----------	----------	17,110
1921	9,210	----------	----------	100	----------	----------	----------	[1] 200	----------	----------	1,790	----------	----------	----------	11,300
1922	12,450	----------	----------	576	----------	----------	----------	[1] 200	----------	----------	1,660	----------	----------	----------	14,890
1923	12,550	----------	----------	1,370	----------	----------	----------	[1] 200	----------	----------	1,890	----------	----------	----------	16,010
1924	7,510	----------	----------	1,160	----------	----------	----------	[1] 200	----------	----------	2,330	----------	----------	----------	11,200
1925	16,720	----------	----------	1,050	----------	----------	----------	[1] 200	----------	----------	2,320	----------	----------	1,610	21,900
1926	14,500	----------	----------	452	----------	----------	----------	[1] 200	----------	----------	1,610	----------	----------	4,190	20,950
1927	16,490	----------	----------	420	----------	----------	----------	[1] 200	----------	----------	1,700	----------	----------	5,760	24,570
1928	13,530	----------	----------	422	----------	----------	----------	[1] 200	----------	----------	1,810	----------	----------	4,650	20,613
1929	19,900	----------	----------	1,210	----------	----------	----------	[1] 200	1,110	----------	1,100	----------	----------	6,640	30,165
1930	13,700	----------	----------	1,030	----------	----------	----------	[1] 200	1,220	----------	612	----------	----------	5,280	22,041
1931	10,590	----------	----------	312	----------	----------	----------	[1] 200	1,030	246	443	----------	----------	2,960	15,781
1932	13,850	----------	----------	768	----------	----------	----------	[1] 200	2,490	1,290	809	716	----------	6,370	26,488
1933	12,190	----------	----------	555	----------	----------	----------	289	1,820	1,230	550	1,680	----------	5,200	23,513
1934	7,690	----------	----------	649	----------	----------	----------	73	1,800	1,160	303	1,370	----------	3,470	16,520
1935	11,280	----------	----------	545	----------	----------	309	215	1,630	1,240	185	2,900	18,020	5,010	41,333
1936	19,030	----------	----------	720	12,140	----------	655	430	1,900	1,780	540	3,740	24,240	7,070	72,248
1937	13,640	----------	----------	0	21,630	----------	295	149	1,110	1,280	375	1,750	31,920	5,350	77,502
1938	25,210	----------	----------	777	43,180	----------	652	275	1,650	1,780	1,400	2,580	45,460	5,540	128,540
1939	18,630	----------	----------	892	30,860	----------	481	31	1,100	1,270	936	1,470	37,060	5,320	98,054
1940	17,220	36	----------	572	29,390	9,560	101	171	635	1,110	173	992	27,040	4,020	91,025
1941	19,190	76	----------	609	36,290	8,190	0	0	589	1,320	376	2,010	36,090	3,810	108,550
1942	20,150	0	----------	261	11,320	1,600	0	0	0	0	0	2,090	13,400	823	49,644
1943	17,530	133	----------	555	32,490	4,060	0	0	362	1,160	0	2,560	48,020	4,850	111,720
1944	16,650	85	----------	430	16,390	3,860	0	0	0	134	0	1,800	37,730	2,100	79,179
1945	23,300	186	----------	1,040	36,600	11,050	0	0	0	1,090	609	2,020	44,780	4,900	125,575
1946	18,820	152	----------	397	32,620	11,000	0	0	0	1,250	1,030	2,210	39,320	4,640	111,439
1947	24,820	175	4,610	166	23,600	2,070	0	0	0	0	1,340	2,880	37,310	1,440	98,411
1948	17,730	102	9,240	561	24,260	2,050	0	0	0	0	146	2,330	25,030	1,000	82,449
1949	17,190	91	17,480	327	24,660	1,890	0	0	0	0	1,340	2,690	38,190	4,300	108,158
1950	16,160	77	26,270	490	29,560	9,090	0	69	0	1,270	783	1,990	34,880	3,410	124,049
1951	24,970	124	56,310	716	33,800	11,140	0	176	0	1,740	1,420	2,940	44,920	5,130	183,386
1952	21,380	103	56,020	730	31,230	6,810	2,380	13	0	1,020	1,820	2,950	51,360	6,340	182,156
1953	19,750	26	180,000	594	35,070	7,420	4,840	273	0	1,040	1,140	2,010	40,300	5,080	297,543
1954	12,740	27	302,100	217	19,540	5,480	3,550	136	0	844	498	905	27,470	3,200	376,707
1955	16,150	125	256,600	458	37,020	10,300	6,450	268	0	1,160	415	1,350	35,060	5,270	370,626
1956	20,470	52	210,700	396	53,430	8,880	9,290	260	0	1,390	1,100	2,590	36,440	4,400	349,398
1957	16,060	124	195,200	568	48,180	4,540	7,110	475	0	1,110	1,360	2,640	32,740	5,510	315,617

[1] Estimated on basis of water years 1933–40 and 1950–57.

TABLE 5.—*Irrigated acreage in the subbasins in the Grand division*

[Source of data: U.S. Bur. of the Census (1953), U.S. Dept. of the Interior (1947), and Upper Colorado River Compact Comm. (1948)]

Location	*Irrigated acreage*
Colorado River Basin above the Gunnison River	
Source	0
Intervening area	3, 500
Fraser River tributary area	10, 200
Intervening area	2, 000
Total area, Colorado River at Hot Sulphur Springs	15, 700
Intervening area	1, 500
Williams River tributary area	3, 500
Intervening area	500
Troublesome Creek tributary area	8, 000
Blue River tributary area	10, 900
Muddy Creek tributary area	10, 200
Total area, Colorado River near Kremmling	50, 300
Intervening area	17, 500
Eagle River tributary area	15, 400
Intervening area	500
Total area, Colorado River at Glenwood Springs	83, 700
Roaring Fork tributary area	31, 400
Intervening area	48, 300
Total area, Colorado River near Cameo	163, 400
Plateau Creek tributary area	29, 100
Total in subbasin	192, 500
Gunnison River Basin	
Taylor River at Almont	0
East River at Almont tributary area	5, 700
Intervening area	17, 300
Total area, Gunnison River at Gunnison	23, 000
Tomichi Creek tributary area	27, 400
Intervening area	8, 000
Cebolla Creek tributary area	4, 000
Intervening area	2, 000
Lake Fork tributary area	2, 000
Intervening area	8, 000
Total area, Gunnison River at Gunnison tunnel	74, 400
Smith Fork tributary area	18, 400
North Fork tributary area	25, 500
Intervening area	37, 900
Uncompahgre River (including Roubideau Creek) tributary area	103, 700
Intervening area	9, 500
Total area, Gunnison River near Grand Junction	269, 400
Colorado River Basin between the Gunnison and Green Rivers	
Grand Valley:	
North of Colorado River	65, 700
South of Colorado River and above Gunnison River	7, 000
South of Colorado River and below Gunnison River	3, 000
Total tributary area above Colorado-Utah State line	75, 700
Intervening area	3, 000
Dolores River tributary area	37, 100
Intervening area	5, 500
Total in subbasin	121, 300

TABLE 6.—*Flow-duration table for stations in the subbasins in the Grand division*

[Italicized figures are for water years 1914–57 adjusted to 1957 conditions; figures opposite indicated water years are historical flow-duration data]

Station No.	Station name	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Average discharge (cfs)	Average annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Colorado River Basin above the Gunnison River, Colo.																					
110	Colorado River near Grand Lake	*1,770*	*1,510*	*1,320*	*980*	*660*	*485*	*355*	*235*	*132*	*71*	*45*	*32*	*25*	*20*	*17*	*14*	*9.1*	*2.4*	*1.0*	*97.8*	*70,850*
	1905–9, 1911–18, 1934–57	1,900	1,570	1,370	1,030	700	505	360	235	125	62	40	30	24	20	17	14	11	4.8	2.3	98.0	71,000
125	North Inlet at Grand Lake	*1,050*	*980*	*910*	*750*	*565*	*430*	*315*	*210*	*120*	*60*	*29*	*16*	*10*	*7.4*	*5.6*	*4.1*	*3.0*	*2.3*	*1.8*	*78.4*	*56,800*
	1948–55	900	840	770	625	455	345	250	160	83	36	18	11	7.7	6.1	4.9	3.9	3.0	2.3	1.8	59.6	43,180
200	Willow Creek near Granby	*1,060*	*940*	*870*	*725*	*545*	*415*	*300*	*186*	*78*	*34*	*20*	*16*	*14*	*12*	*10*	*9.0*	*7.6*	*6.8*	*6.4*	*69.8*	*50,570*
	1935–53	900	795	725	610	480	378	285	180	72	32	19	15	13	12	10	8.9	7.7	6.9	6.4	64.5	46,730
240	Fraser River near Winter Park	*570*	*480*	*420*	*310*	*200*	*105*	*50*	*29*	*19*	*13*	*10*	*8.7*	*7.4*	*6.3*	*5.2*	*4.2*	*3.2*	*2.2*	*1.4*	*20.8*	*15,070*
	1911–57	620	500	435	320	232	178	123	68	34	20	14	11	9.0	7.7	6.5	5.1	3.8	2.9	2.4	31.6	22,890
265	St.Louis Creek near Fraser	*370*	*335*	*305*	*260*	*180*	*123*	*68*	*36*	*21*	*15*	*12*	*12*	*11*	*9.7*	*8.4*	*6.7*	*5.0*	*4.2*	*3.9*	*23.5*	*17,020*
	1935–37	380	340	312	264	207	170	128	84	49	27	19	15	12	10	8.8	7.7	6.6	4.7	3.3	35.6	25,790
340	Fraser River at Granby	*1,860*	*1,720*	*1,580*	*1,330*	*1,060*	*820*	*645*	*470*	*220*	*130*	*70*	*55*	*50*	*46*	*42*	*36*	*26*	*17*	*7.2*	*172*	*124,600*
	1938–55 [1]	1,377	1,330	1,280	1,170	995	835	695	520	284	163	95	68	57	48	44	39	32	26	22	189	136,900
345	Colorado River at Hot Sulphur Springs	*3,050*	*2,620*	*2,310*	*1,770*	*1,250*	*980*	*762*	*550*	*340*	*202*	*140*	*113*	*99*	*90*	*81*	*71*	*60*	*46*	*27*	*244*	*176,800*
	1905–9, 1911–24, 1926–28, 1930–57	8,600	7,450	6,650	5,450	4,020	3,120	2,400	1,580	780	400	258	182	146	122	103	87	74	56	37	603	436,800
360	Williams River near Leal	*1,380*	*1,230*	*1,100*	*900*	*670*	*500*	*350*	*245*	*144*	*71*	*50*	*38*	*31*	*26*	*23*	*20*	*18*	*17*	*16*	*103*	*74,620*
	1934–57	1,500	1,315	1,190	940	685	515	355	220	119	60	43	34	28	24	21	19	17	16	15	97.1	70,350
375	Williams River near Parshall	*2,000*	*1,650*	*1,440*	*1,115*	*820*	*635*	*480*	*315*	*175*	*95*	*72*	*59*	*51*	*44*	*37*	*32*	*26*	*19*	*13*	*137*	*99,250*
	1905–24, 1934–57	1,920	1,630	1,450	1,190	895	700	520	345	180	105	77	61	52	46	40	34	27	20	13	147	106,500
385	Williams River below Williams Fork Reservoir [2]	*1,890*	*1,530*	*1,310*	*980*	*745*	*640*	*505*	*375*	*212*	*134*	*104*	*82*	*69*	*58*	*48*	*42*	*41*	*28*	*9.0*	*158*	*114,500*
	1949–54	1,530	1,370	1,240	1,000	760	610	510	305	155	110	87	73	63	56	50	45	40	23	7	142	102,870
405	Troublesome Creek near Troublesome	*840*	*750*	*680*	*550*	*390*	*290*	*198*	*112*	*57*	*36*	*30*	*25*	*23*	*22*	*19*	*14*	*6.0*	*2.6*	*1.6*	*57.1*	*41,370*
	1905, 1922–24, 1938–56	760	680	620	500	360	265	180	103	53	34	27	24	22	20	17	13	5.2	2.4	1.5	51.9	37,600
415	Muddy Creek at Kremmling [3]	*1,100*	*1,000*	*910*	*720*	*540*	*420*	*350*	*200*	*100*	*47*	*26*	*18*	*12*	*9.0*	*6.0*	*3.3*	*1.5*	*0.7*	*0.5*	*75.1*	*54,410*
470	Blue River at Dillon	*1,170*	*1,030*	*930*	*770*	*590*	*470*	*365*	*263*	*167*	*95*	*62*	*46*	*37*	*30*	*26*	*22*	*17*	*12*	*8.8*	*109*	*78,970*
	1911–57	1,180	1,040	940	795	620	502	402	298	183	99	63	46	37	30	26	22	17	12	8.8	116	84,040
520	Rock Creek near Dillon	*202*	*188*	*178*	*159*	*134*	*114*	*94*	*72*	*47*	*25*	*15*	*9.5*	*6.5*	*5.2*	*4.5*	*3.7*	*3.2*	*2.8*	*2.5*	*26.5*	*19,200*
	1943–56	208	197	185	160	130	110	89	64	39	19	11	7.1	5.5	4.7	4.1	3.5	3.0	2.7	2.4	23.5	17,020
535	Blue River above Green Mountain Reservoir	*4,900*	*4,350*	*3,980*	*3,220*	*2,420*	*1,900*	*1,480*	*1,080*	*700*	*430*	*268*	*192*	*154*	*129*	*109*	*92*	*79*	*71*	*65*	*456*	*330,400*
	1944–57	4,300	4,000	3,730	3,250	2,580	2,120	1,620	1,110	665	397	240	172	142	121	104	90	77	68	64	456	330,400
575	Blue River below Green Mountain Reservoir	*4,470*	*3,690*	*3,160*	*2,280*	*1,560*	*1,250*	*1,070*	*950*	*738*	*635*	*540*	*457*	*382*	*302*	*221*	*130*	*33*	*16*	*12*	*523*	*378,900*
	1946–57	3,400	3,130	2,890	2,450	1,890	1,620	1,380	1,040	765	610	505	420	340	265	195	130	35	12	8.0	538	389,800
580	Colorado River near Kremmling	*12,500*	*10,500*	*9,100*	*6,900*	*4,500*	*3,450*	*2,850*	*2,250*	*1,650*	*1,200*	*950*	*800*	*670*	*550*	*425*	*300*	*165*	*99*	*69*	*1,145*	*829,500*
	1914–18	20,000	18,900	17,800	15,500	12,200	9,500	7,180	4,850	2,800	1,500	990	760	600	480	405	330	280	215	190	1,973	1,429,000
595	Piney River near State Bridge	*1,220*	*1,130*	*980*	*710*	*485*	*390*	*300*	*205*	*100*	*41*	*24*	*20*	*17*	*15*	*13*	*10*	*7.0*	*3.4*	*1.6*	*74.0*	*53,610*
	1945–57	1,090	960	860	695	520	410	315	214	100	36	23	18	16	14	13	10	6.2	3.2	2.2	74.7	54,120
605	Rock Creek near Toponas	*420*	*390*	*362*	*304*	*220*	*166*	*123*	*76*	*34*	*15*	*10*	*8.6*	*7.9*	*7.2*	*6.6*	*5.8*	*4.4*	*2.6*	*1.8*	*30.1*	*21,810*
	1953–57	420	390	370	317	238	170	115	63	27	12	8.2	7.4	6.9	6.5	6.0	5.2	3.8	2.8	2.4	27.9	20,210
610	Sunnyside Creek near Burns	*68*	*62*	*57*	*44*	*39*	*22*	*16*	*10*	*4.7*	*2.4*	*1.9*	*1.6*	*1.5*	*1.2*	*1.0*	*0.8*	*0.4*	*0.2*	*0.1*	*4.5*	*3,260*
	1953–57	68	63	58	46	31	22	15	8.7	3.7	2.1	1.6	1.3	1.1	1.0	0.8	0.6	0.4	0.3	0.2	3.9	2,830
610E	Colorado River above Eagle River near Dotsero [4]	*14,050*	*12,600*	*11,500*	*9,210*	*6,930*	*5,600*	*4,270*	*3,180*	*2,120*	*1,530*	*1,260*	*1,080*	*910*	*770*	*637*	*492*	*371*	*301*	*260*	*1,608*	*1,165,000*
630	Eagle River at Red Cliff	*740*	*640*	*565*	*445*	*320*	*245*	*175*	*112*	*60*	*33*	*23*	*18*	*15*	*14*	*12*	*9.7*	*7.0*	*3.9*	*2.1*	*48.6*	*35,210*
	1911–25, 1945–57	950	790	700	550	410	300	210	135	71	36	24	19	16	15	13	11	8.4	5.7	1.2	57.4	41,580
645	Homestake Creek near Red Cliff	*1,140*	*1,020*	*920*	*750*	*570*	*460*	*357*	*258*	*143*	*64*	*26*	*16*	*11*	*8.5*	*7.0*	*5.3*	*3.4*	*2.4*	*1.8*	*86.5*	*62,670*
	1911–18, 1945–57	1,240	1,110	1,010	820	630	510	398	265	142	61	28	18	13	9.5	7.4	5.7	4.1	1.5	0.8	92.0	66,650
695	Gypsum Creek near Gypsum	*360*	*337*	*310*	*250*	*180*	*130*	*91*	*59*	*39*	*30*	*27*	*25*	*23*	*22*	*20*	*18*	*15*	*13*	*11*	*37.2*	*26,950*
	1951–55	360	337	308	240	150	100	67	45	35	28	25	23	21	20	18	17	15	13	11	32.3	23,400

700	Eagle River below																					
	Gypsum	*5,950*	*5,600*	*5,200*	*4,590*	*3,570*	*2,900*	*2,280*	*1,520*	*880*	*460*	*320*	*260*	*230*	*210*	*193*	*173*	*144*	*124*	*110*	*639*	*462,900*
	1947–57	6,000	5,780	5,470	4,700	3,650	2,960	2,250	1,400	795	405	282	233	212	197	182	164	142	124	110	609	441,200
705	Colorado River near																					
	Dotsero	*20,000*	*18,200*	*16,700*	*13,800*	*10,500*	*8,500*	*6,550*	*4,700*	*3,000*	*1,990*	*1,580*	*1,340*	*1.140*	*980*	*830*	*665*	*515*	*425*	*370*	*2,247*	*1,628,000*
	1943–57	18,400	17,100	15,900	13,500	10,750	9,100	7,350	5,000	2,960	1,700	1,330	1,160	1,020	910	820	700	570	490	425	2,220	1,608,000
725	Colorado River at																					
	Glenwood Springs	*22,470*	*20,400*	*18,760*	*15,100*	*11,260*	*8,960*	*7,219*	*5,189*	*3,220*	*2,005*	*1,637*	*1,417*	*1,224*	*1,034*	*868*	*695*	*507*	*390*	*308*	*2,399*	*1,738,000*
	1900–57	30,000	27,400	25,000	20,700	15,700	12,500	9,800	6,840	3,800	2,130	1,490	1,220	1,030	890	770	675	560	460	360	2,812	2,037,000
735	Roaring Fork at Aspen	*1,780*	*1,570*	*1,390*	*1,050*	*710*	*510*	*365*	*220*	*103*	*65*	*49*	*39*	*33*	*28*	*24*	*20*	*14*	*6.0*	*0.8*	*100*	*72,450*
	1911–21, 1932–57	2,300	1,990	1,770	1,360	930	680	470	287	136	70	49	39	32	27	23	19	13	5.0	1.0	123	89,110
750	Castle Creek near																					
	Aspen	*980*	*795*	*695*	*555*	*430*	*353*	*290*	*220*	*140*	*81*	*50*	*37*	*31*	*28*	*25*	*23*	*19*	*16*	*13*	*88.8*	*64,330*
	1912–19	980	840	760	620	490	403	330	255	160	96	66	50	40	35	32	28	26	24	24	105	76,070
780	Fryingpan Creek at																					
	Norrie	*1,500*	*1,310*	*1,190*	*1,000*	*825*	*690*	*555*	*385*	*195*	*99*	*65*	*45*	*32*	*25*	*21*	*18*	*15*	*13*	*11*	*137*	*99,250*
	1911–16, 1949–57	1,600	1,420	1,300	1,100	860	710	540	350	180	87	58	41	30	24	21	18	15	13	12	132	95,630
825	Crystal River near																					
	Redstone	*4,050*	*3,670*	*3,400*	*2,870*	*2,280*	*1,900*	*1,520*	*1,060*	*560*	*290*	*170*	*122*	*102*	*88*	*77*	*66*	*53*	*34*	*20*	*388*	*281,100*
	1936–57	4,200	3,600	3,230	2,680	2,130	1,830	1,490	1,035	530	250	140	105	90	80	71	63	54	34	21	364	263,700
850	Roaring Fork at																					
	Glenwood Springs	*17,400*	*14,700*	*12,900*	*9,900*	*7,350*	*5,900*	*4,550*	*3,100*	*1,870*	*1,075*	*720*	*595*	*515*	*450*	*400*	*350*	*305*	*270*	*240*	*1,353*	*980,200*
	1906–9, 1911–57	19,000	14,900	13,000	10,125	7,660	6,250	4,900	3,400	2,000	1,150	760	600	520	455	400	356	310	270	238	1,427	1,033,800
875	Elk Creek at New																					
	Castle	*1,600*	*1,400*	*1,300*	*1,080*	*830*	*690*	*480*	*260*	*66*	*38*	*31*	*28*	*24*	*19*	*13*	*5.1*	*2.1*	*1.4*	*1.0*	*99.0*	*71,720*
	1923–24, 1955–57	1,600	1,500	1,410	1,200	920	690	480	260	62	34	29	25	22	17	11	4.0	2.0	1.5	1.3	100	72,450
890	West Divide Creek																					
	below Willow Creek,																					
	near Raven	*648*	*560*	*498*	*368*	*235*	*176*	*135*	*95*	*40*	*7.7*	*3.9*	*2.7*	*1.8*	*1.3*	*0.9*	*0.5*	*0.1*	*0.0*	*0.0*	*29.2*	*21,150*
	1939–47	560	490	442	335	222	170	130	92	38	7.6	3.5	2.4	1.7	1.3	0.9	0.5	0.1	0.0	0.0	27.8	20,140
920	Rifle Creek near Rifle	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
	1940-46, 1953–57	340	263	205	128	73	56	48	42	37	34	30	23	13	8.7	7.3	5.9	4.7	3.8	3.2	24.6	17,820
935	Parachute Creek at																					
	Grand Valley	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
	1922–27, 1949–54	840	740	660	490	280	163	85	46	26	18	15	13	11	8.9	5.0	1.3	0.4	0.1	0.0	30.3	21,950
955	Colorado River near																					
	Cameo	*35,000*	*33,500*	*31,600*	*26,800*	*20,500*	*16,300*	*12,700*	*9,100*	*5,300*	*3,500*	*2,670*	*2,180*	*1,930*	*1,730*	*1,550*	*1,310*	*1,040*	*860*	*760*	*4,138*	*2,998,000*
	1934–57	35,000	33,000	31,000	26,700	21,300	17,200	13,500	9,470	5,300	2,980	2,180	1,880	1,700	1,550	1,410	1,240	1,070	920	800	4,032	2,921,000
965	Plateau Creek near																					
	Collbran	*2,020*	*1,820*	*1,640*	*1,360*	*940*	*675*	*455*	*243*	*100*	*38*	*27*	*22*	*18*	*15*	*13*	*10*	*7.9*	*6.5*	*5.3*	*104*	*75,340*
	1922–57	2,000	1,690	1,490	1,150	830	620	425	225	90	35	25	20	17	14	12	9.7	7.7	6.3	5.0	94.6	68,530
975	Buzzard Creek near																					
	Collbran	*1,100*	*940*	*835*	*660*	*484*	*365*	*259*	*143*	*54*	*22*	*15*	*9.5*	*6.3*	*4.2*	*2.6*	*1.3*	*0.6*	*0.3*	*0.2*	*54.6*	*39,560*
	1922–57	1,080	890	780	610	440	325	227	128	48	21	14	8.3	5.6	3.7	2.3	1.1	0.6	0.3	0.2	49.2	35,640
995	Big Creek at upper																					
	station, near Collbran	*570*	*500*	*455*	*350*	*220*	*160*	*118*	*78*	*54*	*38*	*27*	*18*	*11*	*7.5*	*5.3*	*4.5*	*3.8*	*3.3*	*3.0*	*37.6*	*27,240*
	1946–56	370	310	270	210	155	122	95	67	45	26	13	8.1	6.0	5.0	4.6	4.3	3.9	3.6	3.3	27.0	19,560
1045	Mesa Creek near Mesa	*111*	*88*	*75*	*54*	*40*	*33*	*29*	*24*	*20*	*16*	*12*	*9.3*	*7.7*	*6.5*	*5.5*	*4.5*	*3.0*	*1.0*	*0.5*	*12.9*	*9,350*
	1941–57	94	77	64	47	36	31	27	23	19	15	10	8.0	6.7	5.8	5.2	4.3	2.5	1.1	0.7	11.8	8,550
1050	Plateau Creek near																					
	Cameo	*3,900*	*3,350*	*2,980*	*2,370*	*1,690*	*1,250*	*895*	*540*	*225*	*135*	*106*	*90*	*80*	*71*	*60*	*45*	*27*	*19*	*15*	*235*	*170,200*
	1937–57	3,500	2,950	2,600	2,000	1,450	1,060	740	430	195	121	97	82	72	63	54	40	23	19	17	201	145,600

Gunnison River basin, Colorado

1100	Taylor River at Almont	*3,250*	*2,640*	*2,330*	*1,840*	*1,410*	*1,170*	*980*	*780*	*585*	*425*	*280*	*175*	*133*	*103*	*81*	*63*	*50*	*42*	*35*	*344*	*249,200*
	1911–57	3,500	2,970	2,620	2,100	1,600	1,270	1,000	760	520	360	255	188	150	126	105	77	50	40	34	346	250,700
1125	East River at Almont	*4,300*	*3,720*	*3,330*	*2,680*	*2,030*	*1,610*	*1,250*	*905*	*510*	*235*	*148*	*108*	*87*	*74*	*65*	*56*	*47*	*37*	*29*	*336*	*243,400*
	1911–22, 1935–57	4,500	3,820	3,470	2,800	2,130	1,680	1,320	970	550	257	152	109	86	73	63	55	46	34	24	355	257,200
1145	Gunnison River near																					
	Gunnison	*10,000*	*8,100*	*6,800*	*4,980*	*3,780*	*3,040*	*2,420*	*1,740*	*1,150*	*760*	*525*	*345*	*248*	*200*	*170*	*145*	*125*	*110*	*96*	*753*	*545,500*
	1911–28	12,000	10,000	8,500	6,100	4,650	3,800	3,050	2,200	1,340	700	490	375	300	260	230	200	175	152	139	888	643,300
	1945–57	9,000	7,500	6,600	5,150	3,700	2,850	2,150	1,500	990	780	580	350	240	195	172	152	130	115	103	714	517,300
1155	Tomichi Creek at																					
	Sargents	*680*	*600*	*540*	*450*	*348*	*275*	*210*	*138*	*76*	*43*	*35*	*30*	*28*	*25*	*22*	*20*	*16*	*14*	*13*	*62.5*	*45,280*
	1917–22, 1938–57	780	725	680	550	385	290	220	142	78	44	34	30	27	25	22	19	16	13	11	65.3	47,310
1185	Cochetopa Creek near																					
	Parlin	*440*	*397*	*370*	*316*	*252*	*202*	*154*	*105*	*62*	*43*	*33*	*28*	*24*	*22*	*19*	*14*	*9.2*	*7.4*	*6.5*	*49.8*	*36,080*
	1941–48	480	420	393	347	287	234	179	118	76	52	39	32	26	22	19	16	9.7	8.1	7.1	56.9	41,220
1190	Tomichi Creek at																					
	Gunnison	*1,730*	*1,520*	*1,370*	*1,130*	*890*	*710*	*570*	*400*	*230*	*153*	*118*	*100*	*87*	*76*	*67*	*56*	*34*	*25*	*20*	*181*	*131,100*
	1938–57	1,910	1,730	1,590	1,250	920	725	570	388	230	147	110	90	78	70	62	52	34	22	16	178	129,000
1220	Cebolla Creek at																					
	Powderhorn	*1,500*	*1,230*	*1,070*	*800*	*560*	*420*	*310*	*200*	*130*	*91*	*71*	*58*	*52*	*47*	*42*	*35*	*30*	*27*	*25*	*107*	*77,520*
	1938–55	1,300	1,140	1,030	800	560	405	290	185	117	85	67	56	50	45	40	35	30	27	24	102	73,890
1245	Lake Fork at Gateview	*2,730*	*2,540*	*2,370*	*1,970*	*1,500*	*1,200*	*950*	*675*	*410*	*235*	*135*	*95*	*72*	*60*	*52*	*43*	*37*	*34*	*31*	*265*	*192,000*
	1938–57	2,500	2,380	2,240	1,980	1,560	1,230	920	610	365	210	124	86	64	54	48	43	37	33	29	251	181,800
1280	Gunnison River below																					
	Gunnison tunnel	*17,000*	*15,300*	*13,900*	*11,300*	*8,500*	*6,800*	*5,250*	*3,400*	*1,640*	*785*	*585*	*500*	*433*	*350*	*235*	*95*	*17*	*5.0*	*0.0*	*1,303*	*944,000*
	1905–14	16,400	15,300	14,500	12,800	10,800	9,200	7,600	5,480	3,490	2,080	1,300	920	710	580	495	445	395	365	348	2,188	1,585,000
	1915–37	19,700	16,900	15,200	12,700	9,550	7,500	5,800	4,100	1,940	1,050	710	560	475	415	350	92	19	4.0	1.0	1,515	1,098,000
	1938–57	16,500	14,800	13,400	11,000	8,150	6,400	4,850	3,100	1,520	660	500	450	410	338	225	102	29	4.0	0.2	1,209	875,900

See footnotes at end of table.

TABLE 6.—*Flow-duration table for stations in the subbasins in the Grand division*—Continued

[Italicized figures are for water years 1914–57 adjusted to 1957 conditions; figures opposite indicated water years are historical flow-duration data]

Station No.	Station name	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Average discharge (cfs)	Average annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
Gnnnison River basin, Colorado—Continued																						
1285	Smith Fork near Crawford	*860*	*670*	*570*	*435*	*340*	*278*	*220*	*140*	*65*	*42*	*31*	*23*	*15*	*10*	*7.6*	*6.4*	*5.2*	*4.4*	*4.0*	*54.6*	*39,560*
	1936–57	860	670	525	390	305	243	180	115	57	27	17	12	9.6	7.8	6.9	6.0	5.1	4.4	4.0	44.0	31,880
1290	Smith Fork at Crawford	*1,225*	*790*	*595*	*410*	*318*	*255*	*200*	*133*	*54*	*27*	*18*	*14*	*11*	*8.8*	*6.6*	*4.5*	*2.8*	*1.9*	*1.6*	*46.8*	*33,900*
	1955–57	1,225	1,060	930	685	415	280	175	87	40	16	11	8.0	6.3	5.0	4.1	3.2	2.5	2.2	2.0	42.9	31,080
1295	Iron Creek near Crawford																					
	1948–52	117	98	88	72	55	46	39	30	23	18	15	13	11	9.6	8.4	7.0	5.4	3.7	2.9	16.9	12,240
1315	Muddy Creek at Bardine	*4,500*	*3,900*	*3,400*	*2,500*	*1,500*	*1,020*	*690*	*440*	*220*	*100*	*60*	*42*	*33*	*27*	*23*	*19*	*15*	*10*	*7.0*	*185*	*134,000*
	1950–55	2,700	2,400	2,130	1,570	1,000	740	520	300	125	44	30	26	24	22	20	18	15	12	10	122	88,380
1435	Surface Creek at Cedaredge																					
	1918–57	650	500	420	294	189	130	92	65	40	23	14	8.0	5.0	3.4	2.4	1.7	0.9	0.5	0.2	27.0	19,560
1475	Uncompahgre River at Colona	*4,080*	*2,770*	*2,340*	*1,830*	*1,400*	*1,130*	*910*	*675*	*430*	*250*	*154*	*118*	*99*	*88*	*80*	*66*	*47*	*29*	*18*	*278*	*201,400*
	1913–57	4,080	2,770	2,300	1,790	1,380	1,110	900	670	425	250	158	119	100	88	80	66	47	29	18	276	200,000
1495	Uncompahgre River at Delta																					
	1939–57	3,270	2,520	2,140	1,580	1,130	890	705	535	405	306	236	185	158	137	119	98	74	55	42	286	207,200
1505	Roubideau Creek at mouth, near Delta																					
	1940–54	1,900	1,660	1,490	1,160	790	550	360	210	135	102	83	69	60	52	45	38	30	24	20	126	91,280
1520	Kahnah Creek near Whitewater	*1,300*	*1,000*	*820*	*545*	*315*	*220*	*143*	*85*	*44*	*32*	*23*	*16*	*13*	*11*	*9.4*	*8.4*	*7.6*	*6.8*	*6.1*	*43.8*	*31,730*
	1918–21, 1923–57	1,300	970	790	520	310	205	134	72	43	30	21	16	12	10	9.1	8.3	7.4	6.8	6.0	41.1	29,780
1525	Gunnison River near Grand Junction	*32,000*	*27,900*	*25,100*	*20,000*	*15,200*	*12,000*	*9,400*	*6,400*	*3,240*	*1,790*	*1,310*	*1,100*	*970*	*860*	*760*	*630*	*390*	*220*	*155*	*2,601*	*1,884,000*
	1897–99, 1902–06, 1917–57	35,200	29,300	25,500	20,200	15,500	12,200	9,550	6,600	3,550	1,800	1,320	1,100	980	880	800	650	410	205	125	2,676	1,939,000
Colorado River Basin between the Gunnison and Green Rivers																						
1665	Dolores River at Dolores, Colo	*7,000*	*5,850*	*5,150*	*4,150*	*3,150*	*2,570*	*2,020*	*1,420*	*750*	*330*	*200*	*127*	*87*	*67*	*53*	*42*	*32*	*24*	*19*	*492*	*356,400*
	1896–1903, 1912, 1922–57	6,300	5,300	4,700	3,800	2,920	2,350	1,820	1,270	650	300	180	115	81	63	49	39	28	20	16	444	321,700
1670	Lost Canyon Creek at Dolores, Colo	*1,050*	*850*	*740*	*565*	*390*	*272*	*158*	*51*	*13*	*3.6*	*1.2*	*0.4*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*30.5*	*22,100*
	1942–48	830	710	620	465	310	210	130	51	13	3.6	1.2	0.5	0	0	0	0	0	0	0	25.7	18,620
1725	San Miguel River near Placerville, Colo	*2,710*	*2,280*	*2,020*	*1,610*	*1,230*	*1,010*	*820*	*610*	*415*	*257*	*158*	*113*	*93*	*80*	*70*	*62*	*54*	*47*	*41*	*259*	*187,600*
	1911–12, 1931–34, 1943–57	2,300	1,980	1,780	1,460	1,130	930	750	545	355	213	133	100	83	73	66	59	52	44	37	230	166,600
1755	San Miguel River at Naturita, Colo	*6,400*	*4,250*	*3,500*	*2,700*	*2,000*	*1,530*	*1,200*	*880*	*540*	*290*	*172*	*135*	*108*	*92*	*78*	*63*	*40*	*16*	*8.2*	*351*	*254,300*
	1918–29, 1941–57	6,400	4,400	3,620	2,800	2,080	1,610	1,270	930	565	320	180	135	110	93	80	67	44	12	7.1	368	266,600
1795	Dolores River at Gateway, Colo	*15,000*	*12,900*	*11,500*	*8,900*	*6,600*	*5,100*	*3,900*	*2,580*	*1,250*	*550*	*360*	*260*	*200*	*163*	*132*	*96*	*58*	*30*	*19*	*944*	*683,900*
	1937–54	15,000	14,000	12,900	10,200	7,300	5,400	3,750	2,290	1,220	545	328	240	198	164	140	108	72	42	29	938	679,500
1800	Dolores River near Cisco, Utah	*14,000*	*12,700*	*11,500*	*9,100*	*6,500*	*5,000*	*3,770*	*2,550*	*1,250*	*565*	*355*	*265*	*210*	*177*	*142*	*96*	*57*	*32*	*20*	*940*	*681,000*
	1952–57	12,200	10,900	10,200	8,600	6,380	4,700	3,100	1,780	890	370	240	189	155	128	105	74	32	13	6.9	759	549,900
1805	Colorado River near Cisco, Utah	*62,270*	*59,540*	*55,710*	*47,950*	*38,090*	*30,970*	*25,250*	*18,760*	*11,020*	*6,060*	*4,200*	*3,540*	*3,180*	*2,820*	*2,520*	*2,160*	*1,580*	*975*	*746*	*7,639*	*5,534,000*
	1916–17, 1923–57	74,000	65,200	60,000	51,000	40,500	33,300	26,700	19,200	11,000	5,900	4,050	3,400	3,040	2,760	2,500	2,150	1,570	995	765	7,783	5,638,000
1840	Mill Creek near Moab, Utah																					
	1950–57	410	140	110	90	70	47	31	22	16	13	11	10	9.2	8.6	8.0	7.2	6.4	5.8	5.3	14.3	10,360
1865	Indian Creek above Cottonwood Creek, near Monticello, Utah																					
	1950–57	98	90	83	66	43	29	18	10	5.0	2.6	1.7	1.3	1.0	0.9	0.7	0.4	0.2	0.1	0.1	4.83	3,500

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[1] Based on monthly means; includes Moffat tunnel diversion.

[2] Computed on basis of monthly means.

[3] Computed on basis of Troublesome Creek near Troublesome, Colo.

[4] No streamflow record. Duration data computed by subtracting Gypsum duration-table discharges from Colorado River near Dotsero duration-table discharges at common percentage points.

TABLE 7.—*Methods and accuracy of adjusting flow-duration data for stations in the subbasins in the Grand division to base period and 1957 conditions*

Years of record: Number of years of available historical flow-duration data during water years 1914–57.
Base period adjustment method: Used in adjusting historical data to base period: I, index-station method; C, record-completion method; M, monthly means method; S, substitute method.
Index station number: Number of index station used in adjusting flow-duration curve to base period or correlation station used in estimating data for missing periods of record.
Upstream water developments: Transmountain diversions and reservoirs in which changes occurred in base period requiring adjustment in historical data to 1957 conditions.
Accuracy rating in percent: Authors' rating of accuracy of adjusted flow-duration curve for water years 1914–57 to 1957 conditions. The accuracy rating indicates that the final developed flow-duration curve throughout its range is believed to be correct within the percentage indicated.

Station No.	Index station No.	Years of record	Base period adjustment method	Upstream water developments	Accuracy rating in percent
Colorado River Basin above the Gunnison River					
110	345	29	I	Grand River ditch	10
125	[1] 110	8	I		10
200	2395	19	I		10
240		44		Berthoud Pass ditch and Moffat tunnel.	10
265	[2] 360	23	I	Diversion to Moffat tunnel	15
340	195	18	I	Includes adjustments for 240 and 265.	10
345	240, 2395	42	C	Includes those for 340 and Grand River ditch, Colorado-Big Thompson project, and Willow Creek Reservoir.	10
360	375, 470	24	M	Jones Pass tunnel	10
375	470, 360	35	M	do	10
385	375	6	M	Williams Fork Reservoir and Jones Pass tunnel.	15+
405	2395, 375	22	S		15
415	405		S		15+
470		44		Hoosier Pass tunnel	10
520	[2] 360	14	I		10
535	470	14	I		10
575	535, 470	22	I	Hoosier Pass tunnel, Green Mountain Reservoir.	15+
580	345, 725	5	I	Includes those for 345, 385, and 575.	15+
595	470	13	I		15
605	2395	5	I		15
610	2395	5	I		15
630	470	25	I	Columbine and Wurtz ditches	10
645	470	18	I		10
695	[2] 700	5	I		15
700	[1] 850	11	I	Columbine and Wurtz ditches	10
705	725	15	I	Includes those for 345, 385, 575, and 700.	15
725		44		do	10
735	850	34	I	Twin Lakes tunnel	10
750	[2] 735	6	I		15
780	850	10	I	Busk-Ivanhoe tunnel	15
825	850	22	I		10
850		44		Twin Lakes and Busk-Ivanhoe tunnels.	10
875	3045	5	I		15+
890	975, 965, 1050	9	S		15+
955	725, 850	24	I	Includes those for 725 and 850	10
965	850	36	I		10
975	1050	36	S		15
995	965, 1050	11	M		15+
1045	[2] 1050	17	I		15+
1050	(3)	21	S		15
Gunnison River basin					
1100		44		Taylor Park Reservoir	10
1125	[4] 1100	32	I		10
1145	1100, 1125	28	M	Taylor Park Reservoir	10
1155	[2] 1125	26	I		10
1185	[1] 1220	8	I		15
1190	[1] 1155	20	I		15
1220	1475	18	I		15
1245	1475	20	I		10
1280		44		Taylor Park Reservoir and Gunnison tunnel.	10
1285	[1] 975	22	I		15+
1290	[1] 1285	3	I		15+
1315	[1] 965	6	I		15
1475		44			5
1520		39	S		10
1525		41	S	Taylor Park Reservoir and Gunnison tunnel.	10
Colorado River Basin between the Gunnison and Green Rivers					
1665	3655, 3630, 3610, 3615	34	S		10
1670	1665, 3655	7	I		15+
1725	1475	19	I		10
1755	1475	29	I		15
1795	[1] 1665, [1] 1755, 1800	18	I		15+
1800	[1] 1795	5	I		15+
1805	(5)	37	S	Includes adjustments for station 955, table 7, and for station 1525, table 32.	10

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[1] Flow-duration curve and data for index station that had been adjusted to base period and 1957 conditions were used.

[2] Flow-duration curve and data for index station that had been adjusted to base period were used.

[3] Annual estimates of discharge by Upper Colorado River Compact Commission (1948) were used.

[4] After 1937 adjusted for effect of Taylor Park Reservoir.

[5] Monthly and annual estimates of discharge by Upper Colorado River Compact Commission were used.

TABLE 8.—*Variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water at selected stations in the subbasins in the Grand division, Colorado*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Station name	Variability index	Ground water (percent)
	Colorado River Basin above the Gunnison River		
975	Buzzard Creek near Collbran	0. 81	13
125	North Inlet at Grand Lake	. 75	9
645	Homestake Creek near Red Cliff	. 74	11
520	Rock Creek near Dillon	. 59	22
780	Fryingpan Creek at Norrie	. 59	24
200	Willow Creek near Granby	. 56	18
965	Plateau Creek near Collbran	. 55	16
595	Piney River near State Bridge	. 54	21
825	Crystal River near Redstone	. 52	23
360	Williams River near Leal	. 48	30
470	Blue River at Dillon	. 47	31
695	Gypsum Creek near Gypsum	. 19	66
	Gunnison River basin		
1155	Tomichi Creek at Sargents	0. 34	42
1475	Uncompahgre River at Colona	. 43	31
1245	Lake Fork at Gateview	. 52	24
1125	East River at Almont	. 53	23
1285	Smith Fork near Crawford	. 56	--------
1315	Muddy Creek at Bardine	. 58	16
	Colorado River Basin between the Gunnison and Green Rivers		
1665	Dolores River at Dolores	0. 67	13
1725	San Miguel River near Placerville	. 39	31

TABLE 9.—*Adjustment of streamflow records for water years 1914–57 for Fraser River near Winter Park, Colo., to 1914 base, in acre-feet*

Water year	Historical discharge	Berthoud Pass ditch	Moffat tunnel diversions	Discharge (1914 base)
1914	44, 130	476	0	44, 610
1915	40, 170	650	0	40, 820
1916	30, 820	832	0	31, 650
1917	31, 400	504	0	31, 900
1918	43, 370	868	0	44, 250
1919	23, 780	476	0	24, 260
1920	30, 320	0	0	30, 320
1921	39, 370	100	0	39, 470
1922	25, 240	576	0	25, 820
1923	32, 700	1, 370	0	34, 070
1924	30, 320	1, 160	0	31, 480
1925	28, 440	1, 050	0	29, 490
1926	39, 240	452	0	39, 690
1927	31, 490	420	0	31, 910
1928	40, 810	422	0	41, 230
1929	35, 140	1, 210	0	36, 350
1930	32, 380	1, 030	0	33, 410
1931	21, 140	312	0	21, 450
1932	25, 130	768	0	25, 900
1933	33, 120	555	0	33, 680
1934	20, 640	649	0	21, 290
1935	26, 430	545	0	26, 980
1936	20, 680	720	12, 150	33, 550
1937	12, 880	0	11, 280	24, 160
1938	11, 650	777	22, 300	34, 730
1939	9, 660	892	14, 970	25, 520
1940	6, 300	572	15, 240	22, 110
1941	7, 570	609	20, 150	28, 330
1942	24, 370	261	6, 180	30, 810
1943	7, 140	555	18, 500	26, 200
1944	12, 720	430	9, 170	22, 320
1945	6, 610	1, 040	17, 470	25, 120
1946	6, 760	397	17, 370	24, 530
1947	21, 870	166	12, 020	34, 060
1948	15, 170	561	13, 480	29, 210
1949	21, 840	327	9, 950	32, 120
1950	7, 390	490	13, 650	21, 530
1951	11, 530	716	15, 100	27, 350
1952	14, 870	730	15, 570	31, 170
1953	6, 360	594	15, 330	22, 280
1954	4, 290	217	8, 910	13, 420
1955	5, 010	458	15, 620	21, 090
1956	7, 120	396	17, 500	25, 020
1957	31, 640	568	5, 680	37, 890

TABLE 10.—*Adjustment of streamflow records for water years 1914–57 for two stations in the Colorado River Basin to 1914 base, in thousands of acre-feet*

Transmountain diversions: Total adjustment for 12 diversions for Colorado River at Glenwood Springs, Colo., and for 16 diversions for Colorado River near Cisco, Utah.

Storage reservoirs: Net adjustment for 5 reservoirs for Colorado River at Glenwood Springs, Colo., and for 6 reservoirs for Colorado River near Cisco, Utah.

Water year	Historical discharge	Trans-mountain diversions	Storage reservoirs	Discharge (1914 base)	Water year	Historical discharge	Trans-mountain diversions	Storage reservoirs	Discharge (1914 base)
725. Colorado River at Glenwood Springs, Colo.									
1914	2,949	11	0	2,960	1936	2,283	41	0	2,324
1915	1,735	15	0	1,750	1937	1,463	40	0	1,503
1916	2,208	18	0	2,226	1938	2,433	78	0	2,511
1917	2,948	11	0	2,959	1939	1,728	56	+2	1,786
1918	2,778	18	0	2,796	1940	1,309	60	−2	1,367
1919	1,596	13	0	1,609	1941	1,690	69	4	1,763
1920	2,708	17	0	2,725	1942	1,946	35	60	1,981
1921	2,887	11	0	2,898	1943	1,777	59	107	1,943
1922	1,971	15	0	1,986	1944	1,510	39	−17	1,532
1923	2,494	16	0	2,510	1945	1,717	76	25	1,818
1924	2,177	11	0	2,188	1946	1,556	67	3	1,626
1925	1,771	20	0	1,791	1947	2,261	60	19	2,340
1926	2,572	17	0	2,589	1948	1,939	56	−28	1,967
1927	2,387	19	0	2,406	1949	2,048	66	17	2,131
1928	2,815	16	0	2,831	1950	1,476	86	102	1,664
1929	2,735	24	0	2,759	1951	1,848	133	190	2,171
1930	2,110	17	0	2,127	1952	2,441	124	223	2,788
1931	1,244	13	0	1,257	1953	1,589	252	−38	1,803
1932	2,009	20	0	2,029	1954	886	346	−254	978
1933	1,920	18	0	1,938	1955	1,026	330	−12	1,344
1934	1,030	13	0	1,043	1956	1,469	309	14	1,792
1935	1,621	18	0	1,639	1957	2,409	277	258	2,944
1805. Colorado River near Cisco, Utah									
1914	8,527	11	0	8,538	1936	5,766	73	0	5,839
1915	5,348	15	0	5,363	1937	4,664	78	0	4,742
1916	7,504	18	0	7,522	1938	7,422	129	45	7,596
1917	8,769	11	0	8,780	1939	4,252	98	−5	4,345
1918	6,396	18	0	6,414	1940	3,463	91	−30	3,525
1919	4,874	13	0	4,887	1941	6,576	109	63	6,748
1920	8,900	17	0	8,917	1942	7,706	50	−7	7,749
1921	8,896	12	0	8,908	1943	5,137	112	135	5,384
1922	6,880	15	0	6,895	1944	5,903	79	−28	5,954
1923	7,273	16	0	7,289	1945	5,407	126	57	5,590
1924	5,932	11	0	5,943	1946	4,062	112	−12	4,162
1925	5,025	22	0	5,047	1947	6,051	99	58	6,208
1926	6,601	21	0	6,622	1948	6,554	83	−77	6,560
1927	7,547	25	0	7,572	1949	6,287	109	29	6,425
1928	7,492	21	0	7,513	1950	4,236	124	72	4,432
1929	8,511	30	0	8,541	1951	3,921	184	201	4,306
1930	6,097	22	0	6,119	1952	7,707	183	255	8,145
1931	2,865	16	0	2,881	1953	4,037	298	−67	4,268
1932	6,687	27	0	6,714	1954	2,329	377	−266	2,440
1933	4,631	24	0	4,655	1955	3,241	371	−15	3,597
1934	2,220	17	0	2,237	1956	3,604	350	−2	3,952
1935	4,681	42	0	4,723	1957	8,486	316	342	9,144

TABLE 11.—*Average discharge, standard deviation, and coefficient of variation for selected stations in the subbasins in the Grand division*

[To convert to acre-feet per year multiply average discharge by 724.46]

Station No.	Station name	Period of record	Average discharge (cfs)	Standard deviation (cfs)	Coefficient of variation
	Colorado River Basin above the Gunnison River, Colo.				
240	Fraser River near Winter Park	1914–57 [1]	41.1	11.5	[2] 0.28
345	Colorado River at Hot Sulphur Springs	1914–57 [1]	676	189	[2] .28
405	Troublesome Creek near Troublesome	1922–57 [3]	52.1	17.0	.33
470	Blue River at Dillon	1914–57 [1]	116	31.3	.27
700	Eagle River below Gypsum	1947–57 [4]	615	166	.27
725	Colorado River at Glenwood Springs	1914–57 [1]	2,858	743	.26
850	Roaring Fork at Glenwood Springs	1914–57 [1]	1,410	377	.27
920	Rifle Creek near Rifle	1940–46; 1953–57 [3]	24.6	4.4	.18
935	Parachute Creek at Grand Valley	1922–27; 1949–54 [3]	30.3	20.0	.66
955	Colorado River near Cameo	1934–57 [5]	4,274	1,064	.25
965	Plateau Creek near Collbran	1922–57 [3]	94.5	42	.44
975	Buzzard Creek near Collbran	1922–57 [3]	49.3	29	.59
1050	Plateau Creek near Cameo	1936–57 [3]	198	82.3	.42
	Gunnison River basin, Colorado				
1125	East River at Almont	1914–57	[6] 336	104	0.31
1275A	Gunnison River near Gunnison tunnel	1914–57	[7] 1,759	545	.31
1325	North Fork Gunnison River near Somerset	1934–57	[6] 446	144	.32
1475	Uncompahgre River at Colona	1914–57	[6] 278	86	.31
1525	Gunnison River near Grand Junction	1914–57	[6] 2,600	1,040	.40
	Colorado River Basin between the Gunnison and Green Rivers				
1665	Dolores River at Dolores, Colo	1937–57	492	187	0.38
1725	San Miguel River near Placerville, Colo	1931–34; 1943–58	228	75.2	.33
1755	San Miguel River at Naturita, Colo	1918–58	374	158	.42
1795	Dolores River at Gateway, Colo	1937–57 [8]	917	542	.59
1805	Colorado River near Cisco, Utah	1914–57 [9]	8,257	2,533	.31

[1] Record adjusted to 1914 base.
[2] Not applicable to 1957 conditions of upstream development.
[3] Historical record.
[4] Record adjusted to 1947 base.
[5] Record adjusted to 1934 base.
[6] Historical discharge.
[7] Includes Gunnison tunnel diversion.
[8] Dolores River at Gateway, Colo., water years 1937–54, and Dolores River near Cisco, Utah, water years 1955–57.
[9] Historical record, plus transmountain diversions, plus the effect of increases in storage reservoirs.

TABLE 12.—*Probable error in estimating (50-percent chance) future average discharges of some streams in the Colorado River Basin above the Gunnison River, Colo., for various periods of years*

[Average discharge for water years 1914–57 adjusted to 1957 conditions]

Station No.	Station name	Coefficient of variation	Average discharge (acre-ft)	Probable variations (acre-ft) from 44-year average discharge			
				1-year	2-year	10-year	44-year
405	Troublesome Creek near Troublesome	0.33	41,000	9,100	7,900	5,100	3,600
470	Blue River at Dillon	.27	79,000	14,000	12,000	7,900	5,500
700	Eagle River below Gypsum	.27	460,000	84,000	72,000	46,000	32,000
725	Colorado River at Glenwood Springs	.26	1,700,000	300,000	260,000	170,000	120,000
850	Roaring Fork at Glenwood Springs	.27	980,000	160,000	140,000	91,000	64,000
955	Colorado River near Cameo	.25	3,000,000	500,000	430,000	280,000	200,000
965	Plateau Creek near Collbran	.44	75,000	22,000	19,000	12,000	8,600
975	Buzzard Creek near Collbran	.59	39,000	16,000	14,000	8,600	6,100

TABLE 13.—*Precipitation, runoff, and natural consumptive use, in inches, in selected drainage areas in the subbasins in the Grand division*

Station No.	Station name	Drainage area (sq mi)	Average altitude of drainage basin (feet)	Runoff	Precipitation	Natural consumptive use
	Colorado River Basin above the Gunnison River, Colo.					
	[Runoff computed from average discharge for water years 1914–57, adjusted to 1957 conditions, plus transbasin diversions and plus estimated irrigation consumptive use. Precipitation planimetered from precipitation map (fig. 4) and adjusted to water years 1914–57 by multiplying by 0.994]					
110	Colorado River near Grand Lake	103	10, 200	15. 8	30. 8	15. 0
595	Piney River near State Bridge	82. 6	9, 600	10. 4	25. 3	14. 9
630	Eagle River at Red Cliff	72. 2	10, 700	10. 4	26. 6	16. 2
645	Homestake Creek near Red Cliff	58. 9	10, 900	20. 0	29. 7	9. 7
695	Gypsum Creek near Gypsum	63	9, 680	8. 7	26. 9	18. 2
700	Eagle River below Gypsum	957	9, 400	9. 6	24. 6	15. 0
	Gunnison River basin, Colorado					
	[Runoff computed from average discharge for water years 1914–57, adjusted to 1957 conditions, plus estimated irrigation consumptive use. Precipitation planimetered from precipitation map (fig. 4) and adjusted to water years 1914–57 by multiplying by 0.994]					
1100	Taylor River at Almont	440	10, 600	9. 4	27. 1	17. 7
1125	East River at Almont	295	10, 200	15. 3	27. 0	11. 7
1285	Smith Fork near Crawford	42	9, 300	18. 8	28. 1	9. 3
1520	Kahnah Creek near Whitewater	55	----------	9. 8	28. 2	18. 4
	Colorado River Basin between the Gunnison and Green Rivers					
1665	Dolores River at Dolores, Colo	556	9, 680	[1] 12. 2	[2] 32. 3	20. 1
1840	Mill Creek near Moab, Utah	76	8, 050	[3] 2. 6	[4] 13. 7	11. 1

[1] Computed from average discharge for the water years 1914–57 adjusted to 1957 conditions, plus irrigation consumptive use.

[2] Planimetered from precipitation map (fig. 4) and adjusted to water years 1914–57 by multiplying by 0.994.

[3] Average discharge for water years 1951–57.

[4] Planimetered from precipitation map (fig. 4) and adjusted to water years 1951–57 by multiplying by 0.82. (See chap. B, p. 45.)

TABLE 14.—*Water and dissolved-solids discharges of streams in the subbasins in the Grand division*

[Water and dissolved-solids discharges for the water years 1914–57 adjusted to 1957 conditions except as indicated]

Station No.	Station name	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per square mile (tons)	Average annual discharge (tons)
	Colorado River Basin above the Gunnison River, Colo.							
110	Colorado River near Grand Lake	103	97. 8	70, 850	38	10	35	3, 650
125	North Inlet at Grand Lake	46. 6	78. 4	56, 800	16	3. 4	27	1, 240
190	Colorado River below Lake Granby	311	35. 4	25, 650	35	3. 3	--------	1, 210
200	Willow Creek near Granby	105	69. 8	50, 570	65	12	42	4, 380
240	Fraser River near Winter Park	27. 6	20. 8	15, 070	30	1. 7	22	621
265	St. Louis Creek near Fraser	32. 8	23. 5	17, 020	41	2. 6	29	950
340	Fraser River at Granby	285	172	124, 600	47	22	28	8, 040
345	Colorado River at Hot Sulphur Springs	782	244	176, 800	76	50	23	18, 260
360	Williams River near Leal	89. 5	103	74, 620	30	8. 4	34	3, 070
375	Williams River near Parshall	186	137	99, 250	35	13	26	4, 750
385	Williams River below Williams Fork Reservoir	234	158	114, 500	40	17	26	6, 210
405	Troublesome Creek near Troublesome	178	57. 1	41, 370	156	24	49	8, 770
415	Muddy Creek at Kremmling	275	75. 1	54, 410	444	90	119	32, 870
470	Blue River at Dillon	129	109	78, 970	85	25	71	9, 130
520	Rock Creek near Dillon	15. 8	26. 5	19, 200	22	1. 6	37	584
575	Blue River below Green Mountain Reservoir	623	523	378, 900	101	142	83	51, 870
595	Piney River near State Bridge	82. 6	74. 0	53, 610	120	24	106	8, 770
605	Rock Creek near Toponas	48	30. 1	21, 810	41	3. 3	25	1, 210
610	Sunnyside Creek near Burns	10	4. 5	3, 260	100	1. 2	44	438

TABLE 14.—*Water and dissolved-solids discharges of streams in the subbasins in the Grand division*—Continued

[Water and dissolved-solids discharges for the water years 1914–57 adjusted to 1957 conditions except as indicated]

Station No.	Station name	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per square mile (tons)	Average annual discharge (tons)
	Colorado River Basin above the Gunnison River, Colo—Continued							
610E	Colorado River above Eagle River, near Dotsero	3,420	1,608	1,165,000	154	668	71	244,000
630	Eagle River at Red Cliff	72.2	48.6	35,210	107	14	71	5,110
645	Homestake Creek near Red Cliff	58.9	86.5	62,670	25	5.8	36	2,120
690	Eagle River at Gypsum	844	602	436,100	303	492	213	179,700
695	Gypsum Creek near Gypsum	63	37.2	26,950	279	28	162	10,230
705	Colorado River near Dotsero	4,390	2,247	1,628,000	199	1,210	101	442,000
705C	Colorado River near Glenwood Springs	4,486	2,399	1,738,000	270	1,750	142	639,200
735	Roaring Fork at Aspen	109	100	72,450	30	8.1	27	2,960
750	Castle Creek near Aspen	62	88.8	64,330	192	46.	271	16,800
780	Fryingpan Creek at Norrie	89.5	137	99,250	23	8.5	35	3,100
825	Crystal River near Redstone	225	388	281,100	165	173	281	63,190
850	Roaring Fork at Glenwood Springs	1,460	1,353	980,200	225	821	205	299,900
875	Elk Creek at Newcastle	177	99.0	71,720	217	58	120	21,180
890	West Divide Creek below Willow Creek, near Raven	32.7	29.2	21,150	178	14	156	5,110
920	Rifle Creek near Rifle [1]	140	24.6	17,820	647	43	112	15,710
935	Parachute Creek at Grand Valley [2]	200	30.3	21,950	550	45	82	16,440
955	Colorado River near Cameo	8,060	4,138	2,998,000	387	4,320	196	1,578,000
965	Plateau Creek near Collbran	88	104	75,340	57	16	66	5,840
975	Buzzard Creek near Collbran	139	54.6	39,560	156	23	60	8,400
1045	Mesa Creek near Mesa	7	12.9	9,350	60	2.1	110	767
1050	Plateau Creek near Cameo	604	235	170,200	285	181	109	66,110
	Gunnison River basin, Colorado							
1125	East River at Almont	295	336	243,400	147	133	165	48,580
1145	Gunnison River near Gunnison	1,010	753	545,500	126	256	93	93,500
1155	Tomichi Creek at Sargents	155	62.5	45,280	83	14	33	5,110
1185	Cochetopa Creek near Parlin	346	49.8	36,080	149	20	21	7,300
1190	Tomichi Creek at Gunnison	1,020	181	131,100	176	86	31	31,410
1220	Cebolla Creek at Powderhorn	334	107	77,520	76	22	24	8,040
1245	Lake Fork at Gateview	338	265	192,000	85	61	66	22,280
1280	Gunnison River below Gunnison tunnel	3,980	1,303	944,000	111	390	36	142,400
1290	Smith Fork at Crawford	63	46.8	33,900	119	15	87	5,480
1295	Iron Creek near Crawford [3]	67	16.9	12,240	1,160	53	289	19,360
1315	Muddy Creek at Bardine	246	185	134,000	124	62	92	22,650
1435	Surface Creek at Cedaredge [4]	43	27.0	19,560	95	6.9	59	2,520
1475	Uncompaghre River at Colona	437	278	201,400	376	282	236	103,000
1495	Uncompahgre River at Delta [5]	1,110	286	207,200	1,610	1,240	408	452,910
1505	Roubideau Creek at mouth, near Delta [6]	245	126	91,280	908	309	461	112,900
1520	Kahnah Creek near Whitewater	55	43.8	31,730	127	15	100	5,480
1525	Gunnison River near Grand Junction	8,020	2,601	1,884,000	592	4,160	189	1,519,000
	Colorado River Basin between the Gunnison and Green Rivers							
1665	Dolores River at Dolores, Colo	556	492	356,400	125	166	109	60,630
1670	Lost Canyon Creek at Dolores, Colo	81	30.5	22,100	57	4.7	21	1,720
1725	San Miguel River near Placerville, Colo	308	259	187,600	157	110	130	40,180
1755	San Miguel River at Naturita, Colo	1,080	351	254,300	316	299	101	109,200
1795	Dolores River at Gateway, Colo	4,350	944	683,900	475	1,210	102	442,000
1800	Dolores River near Cisco, Utah	4,630	940	681,000	496	1,260	99	460,200
1805	Colorado River near Cisco, Utah	24,100	7,639	5,634,000	547	11,280	171	4,120,000
1840	Mill Creek near Moab, Utah [7]	76	14.3	10,360	129	5.0	24	1,830
1865	Indian Creek above Cottonwood Creek, near Monticello, Utah [7]	30	4.8	3,480	184	2.4	29	877

[1] For water years 1940–46, 1953–57.
[2] For water years 1922–27, 1949–54.
[3] For water years 1948–52.
[4] For water years 1918–57.
[5] For water years 1939–57.
[6] For water years 1940–54.
[7] For water years 1950–57.

TABLE 15.—*Duration table of dissolved-solids concentration for selected stations in the subbasins in the Grand division*

[Table based on measured or partly estimated streamflow for the water years 1914–57 adjusted to 1957 conditions and on applicable chemical-quality records]

Station No.	Station name	Dissolved-solids concentration, in parts per million, that was equaled or exceeded for indicated percentage of time																			Weighted-average concentration (ppm)
		99.99	99.94	99.85	99.4	98	96	93	88	80	70	60	50	40	30	20	10	3	0.6	0.1	
	Colorado River Basin above the Gunnison River, Colo.																				
110	Colorado River near Grand Lake	30	31	31	31	32	33	34	36	40	46	48	50	50	50	51	52	52	52	52	38
125	North Inlet at Grand Lake	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	16
190	Colorado River below Lake Granby	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	35
200	Willow Creek near Granby	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	65
240	Fraser River near Winter Park	23	23	24	24	26	28	32	34	36	37	37	38	38	38	38	39	39	40	40	30
265	St. Louis Creek near Fraser	24	24	25	25	27	30	37	45	50	52	53	53	53	54	54	55	56	56	56	41
340	Fraser River at Granby	23	24	25	26	28	32	35	40	54	65	78	82	84	85	86	88	91	96	100	47
345	Colorado River at Hot Sulphur Springs	60	60	60	62	64	65	67	70	80	86	86	88	89	91	91	92	96	106	108	76
360	Williams River near Leal	20	20	20	21	22	23	25	27	31	38	43	45	47	48	49	49	50	50	50	30
375	Williams River near Parshall	20	20	20	20	21	22	23	26	33	43	49	54	59	63	70	75	80	86	91	35
385	Williams River below Williams Fork Reservoir	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	40
405	Troublesome Creek near Troublesome	74	75	75	76	77	79	88	110	163	220	250	284	305	310	340	395	445	460	460	156
415	Muddy Creek at mouth, near Kremmling	160	162	165	174	190	212	235	345	555	900	1,280	1,470	1,600	1,670	1,710	1,720	1,720	1,720	1,720	444
470	Blue River at Dillon	78	78	78	79	79	80	81	82	85	89	94	98	102	106	109	112	120	135	150	85
520	Rock Creek near Dillon	21	21	21	21	21	21	22	22	22	23	24	24	25	25	25	26	26	26	26	22
575	Blue River below Green Mountain Reservoir	77	79	80	84	89	92	94	96	99	100	103	105	107	111	116	124	149	163	169	101
595	Piney River near State Bridge	68	70	72	78	86	92	100	112	140	178	195	200	204	208	210	214	225	240	250	120
605	Rock Creek near Toponas	26	26	26	27	27	28	28	30	44	70	80	83	84	86	87	88	91	96	98	41
610	Sunnyside Creek near Burns	79	80	82	84	86	92	96	102	112	122	128	130	130	137	139	142	156	170	190	100
610E	Colorado River above Eagle River, near Dotsero	104	105	107	109	113	117	123	130	142	156	168	181	197	214	235	260	290	310	320	154
630	Eagle River at Red Cliff	69	71	72	76	81	85	90	99	112	127	133	140	144	148	149	152	159	169	177	107
645	Homestake Creek near Red Cliff	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	25
690	Eagle River at Gypsum	117	118	119	120	124	130	143	177	261	420	550	640	700	750	800	860	980	1,060	1,110	303
695	Gypsum Creek near Gypsum	110	110	111	114	122	132	149	180	235	310	350	385	420	440	490	540	640	710	790	279
705	Colorado River near Dotsero	108	109	109	110	113	117	125	140	175	219	252	280	315	350	390	442	495	540	555	199
705C	Colorado River near Glenwood Springs	138	139	140	143	150	158	168	193	247	334	371	391	404	439	490	560	645	690	700	270
735	Roaring Fork at Aspen	20	20	20	20	21	22	23	27	36	41	44	45	46	47	48	48	50	52	54	30
750	Castle Creek near Aspen	101	104	105	109	115	120	130	147	187	248	296	315	325	330	335	340	345	350	354	192
780	Fryingpan Creek at Norrie	16	16	16	16	17	17	18	19	22	28	33	39	45	50	53	56	59	62	64	23
825	Crystal River near Redstone	91	92	93	94	98	100	106	120	165	225	292	343	370	389	400	415	435	460	480	165
850	Roaring Fork at Glenwood Springs	100	101	102	104	107	112	120	145	201	295	380	430	465	493	510	530	540	550	560	225
875	Elk Creek at New Castle	148	148	148	148	149	150	155	174	270	370	435	470	510	570	640	735	780	800	805	217
890	West Divide Creek below Willow Creek, near Raven	158	159	160	162	167	170	171	175	184	204	212	218	221	227	230	230	230	------	------	178
920	Rifle Creek near Rifle[1]	404	407	410	425	465	500	525	550	575	595	625	705	890	1,070	1,170	1,280	1,370	1,390	1,400	647
935	Parachute Creek at Grand Valley[2]	340	340	343	350	370	410	480	570	680	760	815	850	900	960	1,120	1,400	1,420	1,420	------	550
955	Colorado River near Cameo	179	180	181	183	189	194	209	245	345	455	550	625	680	735	780	865	950	965	970	387
965	Plateau Creek near Collbran	38	38	38	39	39	39	40	43	58	127	142	147	150	152	154	157	159	160	160	57
975	Buzzard Creek near Collbran	128	128	129	130	131	134	137	146	176	225	250	285	320	360	403	445	450	450	450	156
1045	Mesa Creek near Mesa	44	45	46	47	49	51	52	54	57	61	66	68	70	72	72	74	76	82	85	60
1050	Plateau Creek near Cameo	122	126	129	136	149	163	183	235	390	478	510	528	540	555	570	590	620	630	639	285

See footnotes at end of table.

TABLE 15.—*Duration table of dissolved-solids concentration for selected stations in the subbasins in the Grand division*—Continued

[Table based on measured or partly estimated streamflow for the water years 1914–57 adjusted to 1957 conditions and on applicable chemical-quality records]

Station No.	Station name	Dissolved-solids concentration, in parts per million, that was equaled or exceeded for indicated percentage of time																			Weighted-average concentration (ppm)
		99.99	99.94	99.85	99.4	98	96	93	88	80	70	60	50	40	30	20	10	3	0.6	0.1	
	Gunnison River basin, Colorado																				
1125	East River at Almont	109	111	113	116	120	127	130	137	150	171	189	200	204	207	209	210	212	218	220	147
1145	Gunnison River near Gunnison	100	100	102	104	105	106	107	111	120	138	156	170	175	177	178	179	180	180	180	126
1155	Tomichi Creek at Sargents	66	67	68	70	72	73	76	80	84	90	92	94	95	96	97	98	100	102	103	83
1185	Cochetopa Creek near Parlin	110	111	112	113	117	121	128	142	162	175	180	182	185	188	190	192	196	199	200	149
1190	Tomichi Creek at Gunnison	128	130	132	138	142	149	155	165	181	193	201	209	212	219	223	230	250	261	274	176
1220	Cebolla Creek at Powderhorn	61	62	62	63	64	66	67	71	76	82	86	92	94	96	99	102	104	106	107	76
1245	Lake Fork at Gateview	70	70	70	71	73	75	77	80	84	92	104	110	115	117	118	119	120	120	120	85
1280	Gunnison River below Gunnison tunnel	82	82	82	84	85	86	87	90	113	165	178	180	183	186	192	200	200	200	200	111
1290	Smith Fork at Crawford	55	56	58	62	66	70	76	92	155	210	237	249	259	265	270	275	278	280	280	119
1295	Iron Creek near Crawford [3]	420	432	440	470	535	615	710	905	1,130	1,310	1,420	1,500	1,590	1,650	1,700	1,750	1,820	1,900	1,920	1,160
1315	Muddy Creek at Bardine	101	102	104	105	107	110	113	117	127	145	165	186	199	205	212	218	221	229	229	124
1435	Surface Creek at Cedaredge [4]	60	61	62	64	71	77	83	90	104	123	140	154	163	169	171	175	179	179	179	95
1475	Uncompahgre River at Colona	170	180	185	195	212	230	258	300	388	500	580	600	620	640	645	660	680	700	700	376
1495	Uncompahgre River at Delta [5]	401	515	589	750	950	1,120	1,320	1,520	1,690	1,810	1,900	1,990	2,010	2,050	2,100	2,110	2,150	2,190	2,200	1,610
1505	Roubideau Creek at mouth, near Delta [6]	170	176	180	195	238	300	420	660	1,000	1,280	1,500	1,680	1,790	1,880	1,960	2,040	2,110	2,180	2,200	908
1520	Kahnah Creek near Whitewater	64	64	68	76	97	113	127	139	148	152	155	160	161	162	165	166	168	169	170	127
1525	Gunnison River near Grand Junction	225	229	231	241	258	274	297	349	510	780	1,000	1,170	1,300	1,450	1,610	1,900	2,340	2,500	2,580	592
	Colorado River Basin between the Gunnison and Green Rivers																				
1665	Dolores River at Dolores, Colo	90	90	91	92	95	97	100	107	125	165	205	238	260	272	282	295	303	313	320	125
1670	Lost Canyon Creek at Dolores, Colo	44	44	45	46	47	49	52	71	140	205	230	230	----	----	----	----	----	----	----	57
1725	San Miguel River near Placerville, Colo	110	112	113	116	119	121	125	132	148	175	208	227	235	240	246	250	251	255	258	157
1755	San Miguel River at Naturita, Colo	177	190	198	208	220	235	250	274	325	410	465	485	500	508	520	525	540	560	565	316
1795	Dolores River at Gateway, Colo	200	201	202	204	209	220	236	272	378	700	1,030	1,420	1,800	2,110	2,460	2,950	3,450	3,800	3,900	475
1800	Dolores River near Cisco, Utah	197	198	198	199	200	208	220	255	406	740	1,090	1,450	1,800	2,110	2,580	3,490	4,700	5,900	6,200	496
1805	Colorado River near Cisco, Utah	238	239	240	241	248	258	273	309	415	660	895	1,030	1,130	1,240	1,350	1,470	1,680	1,810	1,850	547
1840	Mill Creek near Moab, Utah [7]	106	115	116	118	120	122	126	128	130	132	133	134	135	136	136	137	138	139	140	129
1865	Indian Creek above Cottonwood Creek, near Monticello, Utah [7]	155	157	158	161	168	174	182	192	206	219	227	230	233	234	238	242	248	250	250	184

[1] For water years 1940–46, 1953–57.
[2] For water years 1922–27, 1949–54.
[3] For water years 1948–52.
[4] For water years 1918–57.
[5] For water years 1939–57.
[6] For water years 1940–54.
[7] For water years 1950–57.

TABLE 16.—*Duration table of dissolved-solids discharge for selected stations in the subbasins in the Grand division*

[Dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Station name	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Colorado River Basin above the Gunnison River, Colo.																					
110	Colorado River near Grand Lake	143	126	110	82	57	43	33	23	14	8.8	5.8	4.3	3.4	2.7	2.3	2.0	1.3	0.3	0.1	10	35
125	North Inlet at Grand Lake	45	42	39	32	24	19	14	9.1	5.2	2.6	1.3	.7	.4	.3	.2	.2	.1	.1	.1	3.4	27
200	Willow Creek near Granby	186	165	153	127	96	73	53	33	14	6.0	3.5	2.8	2.5	2.1	1.8	1.6	1.3	1.2	1.1	12	42
240	Fraser River near Winter Park	35	30	27	20	14	7.9	4.3	2.7	1.8	1.3	1.0	.9	.8	.6	.5	.4	.3	.2	.2	1.7	--------
265	St. Louis Creek near Fraser	24	22	21	18	13	10	6.8	4.4	2.8	2.1	1.7	1.7	1.6	1.4	1.2	1.0	.8	.6	.6	2.6	--------
340	Fraser River at Granby	116	111	107	93	80	71	61	51	32	23	15	12	11	11	9.8	8.6	6.4	4.4	1.9	22	--------
345	Colorado River at Hot Sulfur Springs	494	424	374	296	216	172	138	104	73	50	35	28	24	21	19	17	16	13	7.9	50	--------
360	Williams River near Leal	75	66	59	51	40	31	24	18	12	7.3	5.8	4.6	3.9	3.4	3.0	2.6	2.4	2.3	2.2	8.4	34
375	Williams River near Parshall	108	89	78	60	46	38	30	22	16	11	9.5	8.6	8.1	7.5	7.0	6.5	5.6	4.4	3.2	13	26
385	Williams River below Williams Fork Reservoir	204	165	141	106	80	69	55	40	23	14	11	8.9	7.5	6.3	5.2	4.5	4.4	3.0	1.0	17	26
405	Troublesome Creek near Troublesome	168	152	138	113	81	62	47	33	25	21	20	19	19	18	17	15	7.2	3.2	2.0	24	49
415	Muddy Creek at mouth, near Kremmling	475	437	405	338	277	240	222	186	150	114	90	71	52	41	28	15	7.0	3.3	2.3	90	119
470	Blue River at Dillon	246	217	196	164	126	102	80	58	38	23	16	12	10	8.6	7.7	6.7	5.5	4.4	3.6	25	71
520	Rock Creek near Dillon	11	11	10	9.0	7.6	6.5	5.6	4.3	2.8	1.6	1.0	.6	.4	.4	.3	.3	.2	.2	.2	1.6	37
575	Blue River below Green Mountain Reservoir	929	787	683	517	375	311	272	246	197	171	150	130	110	91	69	44	13	7.0	5.5	142	83
595	Piney River near State Bridge	224	214	191	150	113	97	81	62	38	20	13	11	9.4	8.4	7.4	6.4	4.3	2.2	1.1	24	106
605	Rock Creek near Toponas	29	27	25	22	16	13	9.3	6.2	4.0	2.8	2.2	1.9	1.8	1.7	1.6	1.4	1.1	.7	.5	3.3	25
610	Sunnyside Creek near Burns	15	13	13	10	9.1	5.5	4.1	2.8	1.4	.8	.6	.6	.5	.4	.4	.3	.2	.1	.1	1.2	44
610E	Colorado River above Eagle River, near Dotsero	3,950	3,570	3,320	2,710	2,110	1,770	1,420	1,120	813	644	572	528	484	445	404	345	290	252	225	668	--------
630	Eagle River at Red Cliff	138	123	110	91	70	56	43	30	18	11	8.3	6.8	5.8	5.6	4.8	4.0	3.0	1.8	1.0	14	71
645	Homestake Creek near Red Cliff	77	69	62	51	38	31	24	17	9.6	4.3	1.8	1.1	.7	.6	.5	.4	.2	.2	.1	5.8	36
690	Eagle River at Gypsum	1,770	1,680	1,570	1,410	1,140	972	846	698	593	488	435	406	391	381	374	360	341	318	297	492	213
695	Gypsum Creek near Gypsum	107	100	93	77	59	46	37	29	25	25	26	26	26	26	26	26	26	25	23	28	162
705	Colorado River near Dotsero	5,830	5,360	4,910	4,100	3,200	2,680	2,210	1,780	1,420	1,180	1,080	1,010	970	926	874	794	688	620	554	1,210	--------
705C	Colorado River near Glenwood Springs	8,370	7,660	7,090	5,830	4,560	3,820	3,270	2,700	2,150	1,810	1,640	1,500	1,340	1,230	1,150	1,050	883	727	582	1,750	--------
735	Roaring Fork at Aspen	96	85	75	57	40	30	23	16	10	7.2	5.8	4.7	4.1	3.6	3.1	2.6	1.9	.8	.1	8.1	27
750	Castle Creek near Aspen	267	223	197	163	134	114	102	87	71	54	40	31	27	25	23	21	18	15	12	46	271
780	Fryingan Creek at Norrie	65	57	51	43	38	32	27	20	12	7.5	5.8	4.7	3.9	3.4	3.0	2.7	2.4	2.2	1.9	8.5	35
825	Crystal River near Redstone	995	912	854	728	603	513	435	343	249	176	134	113	102	92	83	74	62	42	26	173	281
850	Roaring Fork at Glenwood Springs	4,700	4,010	3,550	2,780	2,120	1,780	1,470	1,210	1,010	856	739	691	647	599	551	501	445	401	363	821	205
875	Elk Creek at New Castle	639	559	519	432	334	279	201	122	48	38	36	36	33	29	22	10	4.4	3.0	2.2	58	120
890	West Divide Creek below Willow Creek, near Raven	276	240	215	161	106	81	62	45	20	4.2	2.2	1.6	1.1	.8	.6	.3	.1	0	0	14	156
920	Rifle Creek near Rifle[1]	371	289	227	147	92	76	68	62	57	55	51	44	31	25	23	20	17	14	12	43	112
935	Parachute Creek at Grand Valley[2]	771	679	611	463	280	180	110	71	48	37	33	30	27	23	15	4.9	1.5	.4	0	45	82
955	Colorado River near Cameo	16,920	16,280	15,440	13,240	10,460	8,540	7,170	6,020	4,940	4,300	3,960	3,680	3,540	3,430	3,260	3,060	2,670	2,240	1,990	4,320	--------
965	Plateau Creek near Collbran	207	187	168	143	99	71	49	28	16	13	10	8.7	7.3	6.2	5.4	4.2	3.4	2.8	2.3	16	66
975	Buzzard Creek near Collbran	380	325	291	232	171	132	96	56	26	13	10	7.3	5.4	4.1	2.8	1.6	.7	.4	.2	23	60
1045	Mesa Creek near Mesa	13	11	9.2	6.9	5.3	4.5	4.1	3.5	3.1	2.6	2.1	1.7	1.5	1.3	1.1	.9	.6	.2	.1	2.1	110
1050	Plateau Creek near Cameo	1,280	1,140	1,040	870	678	550	442	343	237	174	146	128	117	106	92	72	45	32	26	181	109

See footnotes at end of table.

TABLE 16.—*Duration table of dissolved-solids discharge for selected stations in the subbasins in the Grand division*—Continued

[Dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Station name	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
Gunnison River basin, Colorado																						
1125	East River at Almont	1,270	1,110	1,020	839	658	552	439	335	207	108	76	58	48	41	37	32	27	22	17	133	165
1145	Gunnison River near Gunnison.	2,700	2,190	1,870	1,400	1,070	870	699	522	373	283	221	158	117	96	82	70	61	53	47	256	93
1155	Tomichi Creek at Sargents	121	109	99	85	68	54	43	30	17	10	8.7	7.6	7.2	6.5	5.8	5.3	4.3	3.9	3.6	14	33
1185	Cochetopa Creek near Parlin	131	119	112	96	80	66	53	40	27	20	16	14	12	11	9.7	7.3	4.9	4.0	3.5	20	21
1190	Tomichi Creek at Gunnison	598	534	488	421	341	286	239	178	112	80	64	56	50	45	40	35	23	18	15	86	31
1220	Cebolla Creek at Powderhorn.	247	206	179	136	97	75	56	38	27	20	16	14	13	12	11	9.6	8.4	7.7	7.2	22	24
1245	Lake Fork at Gateview	516	480	448	378	296	243	198	146	93	58	38	28	22	19	17	14	12	11	10	61	66
1280	Gunnison River below Gunnison tunnel.	3,760	3,390	3,080	2,560	1,950	1,580	1,230	826	500	350	281	243	214	176	122	51	9.2	2.7	0	390	36
1290	Smith Fork at Crawford	182	119	93	69	57	48	41	33	23	15	12	9.4	7.7	6.3	4.8	3.3	2.1	1.4	1.2	15	87
1295	Iron Creek near Crawford [3]	133	114	105	91	79	76	75	73	70	64	58	53	47	43	39	33	27	19	15	53	289
1315	Muddy Creek at Bardine	1,230	1,070	955	709	433	303	211	139	75	39	27	21	18	15	13	11	9.0	6.2	4.3	62	92
1435	Surface Creek at Cedaredge [4]	105	82	70	51	36	27	21	16	11	7.6	5.3	3.3	2.2	1.6	1.1	.8	.4	.2	.1	6.9	59
1475	Uncompahgre River at Colona.	1,870	1,350	1,170	964	801	702	634	547	450	338	241	191	166	152	139	118	86	55	34	282	236
1495	Uncompahgre River at Delta.[5]	3,540	2,800	2,470	1,960	1,890	2,380	2,510	2,200	1,850	1,500	1,210	994	857	758	675	558	430	325	249	1,240	408
1505	Roubideau Creek at mouth, near Delta.[6]	872	789	724	611	508	446	408	374	365	353	336	313	290	264	238	209	171	141	119	309	461
1520	Kahnah Creek near Whitewater.	225	173	151	112	83	67	49	32	18	13	9.6	6.9	5.7	4.8	4.2	3.8	3.4	3.1	2.8	15	100
1525	Gunnison River near Grand Junction.	19,440	17,250	15,660	13,010	10,590	8,880	7,540	6,030	4,460	3,770	3,540	3,480	3,400	3,370	3,300	3,230	2,460	1,490	1,080	4,160	189
Colorado River Basin between the Gunnison and Green Rivers																						
1665	Dolores River at Dolores, Colo.	1,700	1,420	1,270	1,030	808	673	545	410	253	147	111	82	61	49	40	33	26	20	16	166	109
1670	Lost Canyon Creek at Dolores, Colo.	125	101	90	70	49	36	22	9.8	4.9	2.0	.7	.2	0	0	0	0	0	0	0	4.7	21
1725	San Miguel River near Placerville, Colo.	805	689	616	504	395	330	277	217	166	121	89	69	59	52	46	42	37	32	29	110	130
1755	San Miguel River at Naturita, Colo.	3,060	2,180	1,870	1,520	1,190	971	810	651	474	321	216	177	146	126	110	89	58	24	13	299	101
1795	Dolores River at Gateway, Colo.	8,100	7,000	6,270	4,900	3,720	3,030	2,490	1,890	1,280	1,040	1,000	997	972	929	877	765	540	308	200	1,210	102
1800	Dolores River near Cisco, Utah.	7,450	6,790	6,150	4,890	3,510	2,810	2,240	1,760	1,370	1,130	1,040	1,040	1,020	1,010	989	905	723	510	335	1,260	99
1805	Colorado River near Cisco, Utah.	40,010	38,420	36,100	31,200	25,510	21,570	18,610	15,650	12,350	10,800	10,150	9,840	9,700	9,440	9,190	8,570	7,170	4,760	3,730	11,280	171
1840	Mill Creek near Moab, Utah.[7]	117	43	34	29	23	15	11	7.6	5.6	4.6	4.0	3.6	3.4	3.2	2.9	2.7	2.4	2.2	2.0	5.0	24
1865	Indian Creek above Cottonwood Creek, near Monticello, Utah.[7]	41	38	35	29	20	14	8.8	5.2	2.8	1.5	1.0	.8	.6	.6	.4	.3	.1	.1	.1	2.4	29

[1] For water years 1940–46, 1953–57.
[2] For water years 1922–27, 1949–54.
[3] For water years 1948–52.
[4] For water years 1918–57.
[5] For water years 1939–57.
[6] For water years 1940–54.
[7] For water years 1950–57.

TABLE 17.—*Variability of annual weighted-average concentration of dissolved solids as related to variability of annual water discharge for selected daily stations in the Grand division*

Station No.	Station name	Water years	Coefficient of variation	
			Water discharge	Weighted-average concentration
	Colorado River Basin above the Gunnison River, Colo.			
690	Eagle River at Gypsum	1948–57	0.28	0.19
705C	Colorado River near Glenwood Springs	1942–57	.26	.20
955	Colorado River near Cameo	1934–57	.25	.17
	Colorado River Basin below the Gunnison River, Utah			
1800	Dolores River near Cisco, Utah [1]	1948–57	0.67	0.47
1805	Colorado River near Cisco, Utah	1929–57	.34	.23

[1] Combined record of stations at Gateway, Colo., and near Cisco, Utah.

TABLE 18.—*Variability of annual weighted-average concentration of dissolved solids for selected stations in the subbasins in the Grand division*

[Data are for the water years 1914–57 adjusted to 1957 conditions; dissolved-solids weighted-average concentration from table 15]

Station No.	Station name	Streamflow coefficient of variation	Dissolved solids		
			Computed coefficient of variation	Weighted-average concentration (ppm)	Computed standard deviation (ppm)
	Colorado River Basin above the Gunnison River, Colo.				
110	Colorado River near Grand Lake	[1] 0.27	0.19	38	7.2
360	Williams River near Leal	[1] .27	.19	30	5.7
470	Blue River at Dillon	[2] .27	.19	85	16
605	Rock Creek near Toponas	[1] .33	.22	41	9.0
610E	Colorado River above Eagle River at Dotsero	[1] .27	.19	154	29
630	Eagle River at Red Cliff	[1] .27	.19	107	20
645	Homestake Creek near Red Cliff	[1] .27	.19	25	4.8
690	Eagle River at Gypsum	[3] .27	.19	303	58
705C	Colorado River near Glenwood Springs	[4] .26	.18	270	49
750	Castle Creek near Aspen	[1] .27	.19	192	36
780	Fryingpan Creek at Norrie	[1] .27	.19	23	4.4
850	Roaring Fork at Glenwood Springs	[2] .27	.19	225	43
955	Colorado River at Cameo	[2] .25	.18	387	70
	Gunnison River basin, Colorado				
1125	East River at Almont	[2] 0.31	0.21	147	31
1145	Gunnison River near Gunnison	[1] .31	.21	126	26
1185	Cochetopa Creek near Parlin	[1] .31	.21	149	31
1245	Lake Fork at Gateview	[1] .31	.21	85	18
1315	Muddy Creek at Bardine	[1] .32	.22	124	27
1475	Uncompahgre River at Colona	[2] .31	.21	376	79
1525	Gunnison River near Grand Junction	[2] .40	.23	592	136
	Colorado River Basin between the Gunnison and Green River [Streamflow coefficient of variation from table 12]				
1665	Dolores River at Dolores, Colo	0.38	0.25	125	31
1725	San Miguel River near Placerville, Colo	.33	.23	157	36
1775	San Miguel River at Naturita, Colo	.42	.28	316	88
1800	Dolores River near Cisco, Utah	.59	.37	496	183
1805	Colorado River near Cisco, Utah	.31	.21	547	115

[1] Interpreted from figure 4.

[2] From table 11.

[3] Coefficient of variation assumed to be the same as that for Eagle River below Gypsum, Colo. (station 700, table 11).

[4] Coefficient of variation assumed to be the same as that for Colorado River at Glenwood Springs, Colo. (station 725, table 11).

TABLE 19.—*Relation between water discharge and chemical quality of water for selected stations in the subbasins in the Grand division*

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italicized) except as indicated; data are for the water years 1914–57 adjusted to 1957 conditions]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
COLORADO RIVER BASIN ABOVE THE GUNNISON RIVER																
345. Colorado River at Hot Sulphur Springs, Colo.																
3,050	11 *.55*	2.2 *.18*	4.0 *.17*	1.3 *.03*	47 *.77*	5.6 *.12*	0.9 *.03*		60	0.08	494	36		18	88	0.3
2,620	11 *.55*	2.2 *.18*	4.0 *.17*	1.3 *.03*	47 *.77*	5.6 *.12*	.9 *.03*		60	.08	424	36		18	88	.3
2,310	11 *.55*	2.2 *.18*	4.0 *.17*	1.3 *.03*	47 *.77*	5.7 *.12*	.9 *.03*		60	.08	374	36		18	88	.3
1,770	11 *.55*	2.2 *.18*	4.0 *.17*	1.3 *.03*	47 *.77*	5.7 *.12*	.9 *.03*		62	.08	296	36		18	90	.3
1,250	11 *.55*	2.2 *.18*	4.1 *.18*	1.3 *.03*	48 *.79*	5.7 *.12*	1.0 *.03*		64	.09	216	36		19	94	.3
980	11 *.55*	2.2 *.18*	4.1 *.18*	1.3 *.03*	48 *.79*	5.8 *.12*	1.0 *.03*		65	.09	172	36		19	96	.3
762	12 *.60*	2.3 *.19*	4.1 *.18*	1.3 *.03*	50 *.82*	5.8 *.12*	1.0 *.03*		67	.09	138	40		18	99	.3
550 [1]	13 *.65*	2.4 *.20*	4.3 *.19*	1.3 *.03*	54 *.89*	5.8 *.12*	1.1 *.03*		70	.10	104	42		18	103	.3
340	15 *.75*	2.7 *.22*	5.0 *.22*	1.4 *.04*	64 *1.05*	5.9 *.12*	1.1 *.03*		80	.11	73	48		18	120	.3
202	16 *.80*	3.1 *.25*	5.9 *.26*	1.6 *.04*	72 *1.18*	6.0 *.12*	1.3 *.04*		91	.12	50	52		19	137	.4
140	17 *.85*	3.3 *.27*	6.4 *.28*	1.6 *.04*	75 *1.23*	6.0 *.12*	1.3 *.04*		92	.13	35	56		19	138	.4
113 [2]	17 *.85*	3.3 *.27*	6.4 *.28*	1.6 *.04*	75 *1.23*	6.0 *.12*	1.3 *.04*		91	.12	28	56		19	137	.4
99	17 *.85*	3.3 *.27*	6.4 *.28*	1.6 *.04*	75 *1.23*	6.1 *.13*	1.4 *.04*		89	.12	24	56		19	135	.4
90	17 *.85*	3.3 *.27*	6.4 *.28*	1.6 *.04*	76 *1.25*	6.1 *.13*	1.4 *.04*		86	.12	21	56		19	130	.4
81	17 *.85*	3.3 *.27*	6.4 *.28*	1.6 *.04*	76 *1.25*	6.1 *.13*	1.4 *.04*		86	.12	19	56		19	130	.4
71 [3]	17 *.85*	3.3 *.27*	6.5 *.28*	1.6 *.04*	76 *1.25*	6.1 *.13*	1.4 *.04*		88	.12	17	56		19	133	.4
60	17 *.85*	3.3 *.27*	6.5 *.28*	1.6 *.04*	76 *1.25*	6.2 *.13*	1.4 *.04*		96	.13	16	56		19	145	.4
46	17 *.85*	3.3 *.27*	65. *.28*	1.6 *.04*	76 *1.25*	6.2 *.13*	1.4 *.04*		106	.14	13	56		19	161	.4
27	17 *.85*	3.4 *.28*	6.6 *.29*	1.6 *.04*	76 *1.25*	6.3 *.13*	1.5 *.04*		108	.15	7.9	56		20	167	.4
244	14 *.70*	2.7 *.22*	5.0 *.22*	1.4 *.04*	60 *.98*	5.9 *.12*	1.1 *.03*		76	.10	50	43		19	113	.3
690. Eagle River at Gypsum, Colo.																
5,590	28 *1.40*	4.8 *.39*	4.6 *.20*	0.9 *.02*	76 *1.25*	29 *.60*	5.6 *.16*		117	0.16	1,770	90	27	10	194	0.2
5,260	28 *1.40*	4.8 *.39*	4.6 *.20*	.9 *.02*	76 *1.25*	29 *.60*	5.8 *.16*		118	.16	1,680	90	27	10	195	.2
4,890	28 *1.40*	4.8 *.39*	4.7 *.20*	1.0 *.03*	76 *1.25*	29 *.60*	5.9 *.17*		119	.16	1,570	90	27	10	198	.2
4,340	28 *1.40*	4.9 *.40*	4.8 *.21*	1.0 *.03*	76 *1.25*	29 *.60*	6.2 *.17*		120	.16	1,410	90	28	10	200	.2
3,390	28 *1.40*	5.0 *.41*	5.5 *.24*	1.0 *.03*	77 *1.26*	31 *.64*	7.0 *.20*		124	.17	1,140	90	28	12	206	.3
2,770	29 *1.45*	5.2 *.43*	6.4 *.28*	1.0 *.03*	78 *1.28*	34 *.71*	7.8 *.22*		130	.18	972	94	30	13	214	.3
2,190	30 *1.50*	5.6 *.46*	7.7 *.33*	1.1 *.03*	80 *1.31*	39 *.81*	9.2 *.26*		143	.19	846	98	32	14	235	.3
1,460 [1]	35 *1.75*	6.7 *.55*	11 *.48*	1.3 *.03*	86 *1.41*	52 *1.08*	13 *.37*		177	.24	698	115	44	17	294	.4
841	47 *2.35*	9.3 *.76*	18 *.78*	1.7 *.04*	100 *1.64*	82 *1.71*	24 *.68*		261	.35	593	156	74	20	420	.6
430	75 *3.74*	15 *1.23*	35 *1.52*	2.5 *.06*	133 *2.18*	144 *3.00*	51 *1.44*		420	.57	488	248	140	23	665	1.0
293	98 *4.89*	19 *1.56*	52 *2.26*	3.2 *.08*	158 *2.59*	197 *4.10*	78 *2.20*		550	.75	435	322	193	26	860	1.3
235 [2]	115 *5.74*	21 *1.73*	65 *2.83*	3.7 *.09*	174 *2.85*	232 *4.83*	99 *2.79*		640	.87	406	374	231	27	1,000	1.5
207	127 *6.34*	23 *1.89*	74 *3.22*	4.0 *.10*	180 *2.95*	258 *5.37*	113 *3.19*		700	.95	391	412	264	28	1,090	1.6
188	133 *6.64*	25 *2.06*	80 *3.48*	4.3 *.11*	185 *3.03*	274 *5.70*	122 *3.44*		750	1.02	381	435	284	28	1,150	1.7
173	138 *6.89*	26 *2.14*	86 *3.74*	4.5 *.12*	188 *3.08*	290 *6.03*	130 *3.67*		800	1.09	374	452	298	29	1,200	1.8
155 [3]	145 *7.24*	28 *2.30*	93 *4.05*	4.7 *.12*	192 *3.15*	310 *6.45*	140 *3.95*		860	1.17	360	477	320	30	1,270	1.9
129	154 *7.68*	30 *2.47*	104 *4.52*	5.2 *.13*	194 *3.18*	348 *7.24*	157 *4.43*		980	1.33	341	508	348	31	1,400	2.0
111	159 *7.93*	32 *2.63*	114 *4.96*	5.4 *.14*	193 *3.17*	377 *7.84*	168 *4.74*		1,060	1.44	318	528	370	32	1,490	2.2
99	167 *8.33*	39 *3.21*	124 *5.39*	6.1 *.16*	206 *3.38*	413 *8.59*	185 *5.22*		1,110	1.51	297	577	408	32	1,540	2.2
602	56 *2.79*	11 *.90*	25 *1.09*	1.9 *.05*	108 *1.77*	100 *2.08*	36 *1.02*		303	.41	492	184	96	23	476	.8

See footnotes at end of table.

TABLE 19.—*Relation between water discharge and chemical quality of water for selected stations in the subbasins in the Grand division*—Con.

[Chemical-quality data and weighted averages arei n parts per million and equivalents per million (italicized) except as indicated; data are for the water years 1914-57 adj usted to 1957 conditions]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
COLORADO RIVER BASIN ABOVE THE GUNNISON RIVER—Continued																
705 C. Colorado River near Glenwood Springs, Colo.																
22,470	23 *1.15*	4.9 *.40*	8.0 *.35*	1.1 *.03*	82 *1.34*	22 *.46*	5.6 *.16*	0.02	138	0.19	8,370	78	10	18	220	0.4
20,400	23 *1.15*	5.0 *.41*	8.0 *.35*	1.2 *.03*	82 *1.34*	22 *.46*	6.0 *.17*	.02	139	.19	7,660	78	11	18	221	.4
18,760	24 *1.20*	5.0 *.41*	8.1 *.35*	1.3 *.03*	82 *1.34*	22 *.46*	6.3 *.18*	.02	140	.19	7,090	80	14	18	222	.4
15,100	24 *1.20*	5.0 *.41*	9.0 *.39*	1.3 *.03*	82 *1.34*	24 *.50*	7.6 *.21*	.03	143	.19	5,830	80	14	19	227	.4
11,260	26 *1.30*	5.2 *.43*	10 *.44*	1.3 *.03*	85 *1.39*	27 *.56*	9.4 *.27*	.03	150	.20	4,560	86	17	20	242	.5
8,960	28 *1.40*	5.5 *.45*	12 *.52*	1.4 *.04*	87 *1.43*	32 *.67*	12 *.34*	.03	158	.21	3,820	92	21	22	258	.5
7,219	30 *1.50*	6.0 *.49*	14 *.61*	1.5 *.04*	91 *1.49*	35 *.73*	15 *.42*	.03	168	.23	3,270	100	25	23	276	.6
5,189 [1]	33 *1.65*	6.6 *.54*	18 *.78*	1.7 *.04*	98 *1.61*	43 *.89*	21 *.59*	.03	193	.26	2,700	110	29	26	319	.7
3,220	40 *2.00*	8.0 *.66*	27 *1.17*	1.9 *.05*	108 *1.77*	57 *1.19*	33 *.93*	.04	247	.34	2,150	133	44	30	408	1.0
2,005	48 *2.40*	9.8 *.81*	40 *1.74*	2.2 *.06*	120 *1.97*	77 *1.60*	54 *1.52*	.04	334	.45	1,810	160	62	35	550	1.4
1,637	52 *2.59*	11 *.90*	47 *2.04*	2.3 *.06*	125 *2.05*	87 *1.81*	65 *1.83*	.04	371	.50	1,640	174	72	36	618	1.5
1,417 [2]	56 *2.79*	11 *.90*	53 *2.31*	2.4 *.06*	129 *2.12*	94 *1.96*	74 *2.09*	.04	391	.53	1,500	184	78	38	650	1.7
1,224	60 *2.99*	12 *.99*	61 *2.65*	2.5 *.06*	130 *2.13*	99 *2.06*	89 *2.51*	.04	404	.55	1,340	199	92	40	670	1.9
1,034	63 *3.14*	13 *1.07*	69 *3.00*	2.6 *.07*	139 *2.28*	111 *2.31*	97 *2.74*	.04	439	.60	1,230	210	96	41	730	2.1
868	67 *3.34*	14 *1.15*	78 *3.39*	2.7 *.07*	141 *2.31*	120 *2.50*	110 *3.10*	.05	490	.67	1,150	224	109	43	819	2.3
695 [3]	73 *3.64*	15 *1.23*	93 *4.05*	2.8 *.07*	149 *2.44*	132 *2.75*	130 *3.67*	.05	560	.76	1,050	244	122	45	928	2.6
507	79 *3.94*	16 *1.32*	116 *5.05*	3.0 *.08*	161 *2.64*	151 *3.14*	163 *4.60*	.05	645	.88	883	263	131	49	1,070	3.1
390	86 *4.29*	18 *1.48*	135 *5.87*	3.1 *.08*	172 *2.82*	165 *3.43*	194 *5.47*	.05	690	.94	727	288	148	50	1,150	3.5
308	92 *4.59*	19 *1.56*	151 *6.57*	3.2 *.08*	179 *2.94*	179 *3.72*	218 *6.15*	.05	700	.95	582	308	160	51	1,170	3.7
2,399	41 *2.05*	8.4 *.69*	32 *1.39*	1.9 *.05*	108 *1.77*	61 *1.27*	42 *1.18*	.04	270	.37	1,750	137	48	33	445	1.2
955. Colorado River near Cameo, Colo.																
35,000	35 *1.75*	6.8 *.56*	13 *.57*	1.8 *.05*	113 *1.85*	29 *.60*	16 *.45*	0.02	179	0.24	16,920	116	23	19	300	0.5
33,500	35 *1.75*	6.8 *.56*	13 *.57*	1.8 *.05*	113 *1.85*	29 *.60*	16 *.45*	.02	180	.24	16,280	116	23	19	300	.5
31,600	35 *1.75*	6.8 *.56*	13 *.57*	1.8 *.05*	113 *1.85*	29 *.60*	17 *.48*	.02	181	.25	15,440	116	23	19	302	.5
26,800	36 *1.80*	6.9 *.57*	15 *.65*	1.9 *.05*	113 *1.85*	30 *.62*	18 *.51*	.02	183	.25	13,240	118	26	21	305	.6
20,500	36 *1.80*	7.0 *.58*	17 *.74*	2.0 *.05*	113 *1.85*	34 *.71*	22 *.62*	.02	189	.26	10,460	119	26	23	317	.7
16,300	37 *1.85*	7.2 *.59*	20 *.87*	2.1 *.05*	114 *1.87*	37 *.77*	25 *.70*	.02	194	.26	8,540	122	28	26	326	.8
12,700	39 *1.95*	7.7 *.63*	24 *1.04*	2.2 *.06*	114 *1.87*	43 *.89*	30 *.85*	.03	209	28	7,170	129	36	28	350	.9
9,100 [1]	42 *2.10*	8.5 *.70*	31 *1.35*	2.5 *.06*	120 *1.97*	54 *1.12*	41 *1.16*	.03	245	.33	6,020	140	42	32	405	1:1
5,300	50 *2.50*	11 *.90*	50 *2.18*	3.2 *.08*	134 *2.20*	79 *1.64*	68 *1.92*	.04	345	.47	4,940	170	60	39	576	1.7
3,500	61 *3.04*	13 *1.07*	74 *3.22*	3.6 *.09*	150 *2.46*	107 *2.23*	100 *2.82*	.04	455	.62	4,300	206	82	43	758	2.2
2,670	69 *3.44*	16 *1.32*	94 *4.09*	4.0 *.10*	160 *2.62*	133 *2.77*	128 *3.61*	.05	550	.75	3,960	238	107	46	910	2.7
2,180 [2]	75 *3.74*	18 *1.48*	113 *4.92*	4.3 *.11*	168 *2.76*	151 *3.14*	152 *4.29*	.06	625	.85	3,680	261	123	48	1,030	3.0
1,930	79 *3.94*	19 *1.56*	125 *5.44*	4.5 *.12*	171 *2.80*	163 *3.39*	168 *4.74*	.06	680	.92	3,540	275	135	49	1,140	3.3
1,730	82 *4.09*	21 *1.73*	137 *5.96*	4.6 *.12*	176 *2.89*	174 *3.62*	185 *5.22*	.07	735	1.00	3,430	291	146	50	1,220	3.5
1,550	86 *4.29*	22 *1.81*	148 *6.44*	4.8 *.12*	180 *2.95*	185 *3.85*	204 *5.75*	.07	780	1.06	3,260	305	158	51	1,300	3.7
1,310 [3]	90 *4.49*	24 *1.97*	170 *7.40*	5.0 *.13*	187 *3.07*	200 *4.16*	230 *6.49*	.08	865	1.18	3,060	323	170	53	1,420	4.1
1,040	96 *4.79*	27 *2.22*	202 *8.79*	5.3 *.14*	196 *3.21*	225 *4.68*	277 *7.81*	.09	950	1.29	2,670	350	190	55	1,560	4.7
860	99 *4.94*	28 *2.30*	220 *9.57*	5.5 *.14*	207 *3.39*	230 *4.78*	315 *8.88*	.10	965	1.31	2,240	362	192	56	1,580	5.0
760	102 *5.09*	30 *2.47*	248 *10.79*	5.6 *.14*	210 *3.44*	255 *5.30*	343 *9.67*	.11	970	1.32	1,990	378	206	58	1,600	5.5
4,138	54 *2.69*	12 *.99*	61 *2.65*	3.1 *.08*	137 *2.25*	87 *1.81*	81 *2.28*	.04	387	.53	4,320	184	72	41	642	2.0

See footnotes at end of table.

TABLE 19.—*Relation between water discharge and chemical quality of water for selected stations in the subbasins in the Grand division*—Con.

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italicized) except as indicated; data are for the water years 1914-57 adjusted to 1957 conditions]

GUNNISON RIVER BASIN

1525. Gunnison River near Grand Junction, Colo.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
32,000	47 *2.35*	9.4 *.77*	12 *.52*	2.7 *.07*	130 *2.13*	70 *1.46*	3.0 *.08*	0.07	225	0.31	19,440	156	50	14	350	0.4
27,900	47 *2.35*	9.4 *.77*	12 *.52*	2.7 *.07*	130 *2.13*	70 *1.46*	3.0 *.08*	.07	229	.31	17,250	156	50	14	354	.4
25,100	49 *2.45*	9.6 *.79*	12 *.52*	2.7 *.07*	131 *2.15*	71 *1.48*	3.1 *.09*	.08	231	.31	15,650	162	54	14	357	.4
20,000	50 *2.50*	9.8 *.81*	13 *.57*	2.7 *.07*	131 *2.15*	76 *1.58*	3.2 *.09*	.08	241	.33	13,010	166	58	14	370	.4
15,200	52 *2.59*	10 *.82*	14 *.61*	2.7 *.07*	131 *2.15*	85 *1.77*	3.4 *.10*	.08	258	.35	10,590	170	63	15	394	.5
12,000	53 *2.64*	11 *.90*	15 *.65*	2.7 *.07*	132 *2.16*	94 *1.96*	3.7 *.10*	.08	274	.37	8,880	177	69	15	420	.5
9,400	55 *2.74*	12 *.99*	19 *.83*	2.7 *.07*	132 *2.16*	115 *2.39*	4.3 *.12*	.09	297	.40	7,540	186	78	18	448	.6
6,400 [1]	58 *2.89*	13 *1.07*	26 *1.13*	2.7 *.07*	136 *2.23*	132 *2.75*	4.8 *.14*	.10	349	.47	6,030	198	86	22	520	.8
3,240	66 *3.29*	20 *1.64*	43 *1.87*	3.0 *.08*	142 *2.33*	210 *4.37*	7.2 *.20*	.14	510	.69	4,460	246	130	27	730	1.2
1,790	95 *4.74*	35 *2.88*	73 *3.18*	3.8 *.10*	166 *2.72*	380 *7.90*	10 *.28*	.16	780	1.06	3,770	381	245	29	1,070	1.6
1,310	116 *5.79*	47 *3.86*	98 *4.26*	4.6 *.12*	184 *3.02*	518 *10.77*	14 *.39*	.17	1,000	1.36	3,540	482	332	30	1,320	1.9
1,100 [2]	133 *6.64*	51 *4.19*	112 *4.87*	5.2 *.13*	194 *3.18*	600 *12.48*	16 *.45*	.17	1,170	1.59	3,480	542	382	31	1,500	2.1
970	150 *7.48*	56 *4.60*	127 *5.52*	5.6 *.14*	201 *3.30*	670 *13.94*	17 *.48*	.18	1,300	1.77	3,400	604	439	31	1,630	2.2
860	167 *8.33*	61 *5.01*	140 *6.09*	6.0 *.15*	209 *3.43*	738 *15.35*	19 *.54*	.18	1,450	1.97	3,370	667	496	31	1,800	2.4
760	183 *9.13*	66 *5.43*	153 *6.66*	6.4 *.16*	219 *3.59*	824 *17.14*	22 *.62*	.18	1,610	2.19	3,300	728	548	31	1,940	2.5
630 [3]	205 *10.23*	73 *6.00*	175 *7.61*	7.1 *.18*	228 *3.74*	940 *19.55*	25 *.70*	.18	1,900	2.58	3,230	812	624	32	2,200	2.7
390	262 *13.07*	91 *7.48*	226 *9.83*	8.7 *.22*	236 *3.87*	1,230 *25.58*	33 *.93*	.18	2,340	3.18	2,460	1,030	834	32	2,600	3.1
220	297 *14.82*	104 *8.55*	268 *11.66*	10 *.26*	240 *3.94*	1,450 *30.16*	44 *1.24*	.19	2,500	3.40	1,490	1,170	972	33	2,760	3.4
155	320 *15.97*	115 *9.45*	280 *12.18*	12 *.31*	251 *4.12*	1,540 *32.03*	50 *1.41*	.19	2,580	3.41	1,080	1,270	1,060	32	2,840	3.4
2,601	81 *4.04*	24 *1.97*	50 *2.18*	3.5 *.09*	152 *2.49*	269 *5.60*	8.0 *.23*	.12	592	.81	4,160	300	176	26	798	1.3

COLORADO RIVER BASIN BETWEEN THE GUNNISON AND GREEN RIVERS

1795. Dolores River at Gateway, Colo.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
15,000	42 *2.10*	8.4 *.69*	13 *.57*	3.7 *.09*	124 *2.03*	50 *1.04*	16 *.45*		200	0.27	8,100	140	38	17	350	0.5
12,900	42 *2.10*	8.4 *.69*	13 *.57*	3.7 *.09*	124 *2.03*	50 *1.04*	16 *.45*		201	.27	7,000	140	38	17	350	.5
11,500	42 *2.10*	8.4 *.69*	13 *.57*	3.7 *.09*	124 *2.03*	51 *1.06*	16 *.45*		202	.27	6,270	140	38	17	351	.5
8,900	43 *2.15*	8.4 *.69*	13 *.57*	3.7 *.09*	124 *2.03*	52 *1.08*	17 *.48*		204	.28	4,900	142	40	16	355	.5
6,600	43 *2.15*	8.4 *.69*	14 *.61*	3.7 *.09*	124 *2.03*	53 *1.10*	18 *.51*		209	.28	3,720	142	40	17	360	.5
5,100	43 *2.15*	8.6 *.71*	16 *.70*	3.7 *.09*	125 *2.05*	56 *1.16*	20 *.56*		220	.30	3,030	143	40	19	372	.6
3,900	44 *2.20*	9.0 *.74*	21 *.91*	3.8 *.10*	126 *2.07*	59 *1.23*	25 *.70*		236	.32	2,490	147	44	23	390	.8
2,580 [1]	44 *2.20*	10 *.82*	32 *1.39*	4.0 *.10*	127 *2.08*	66 *1.37*	39 *1.10*		272	.37	1,890	151	47	31	445	1.1
1,250	49 *2.45*	14 *1.15*	70 *3.04*	5.4 *.14*	130 *2.13*	86 *1.79*	100 *2.82*		378	.51	1,280	180	74	45	628	2.3
550	62 *3.09*	23 *1.89*	185 *8.05*	9.9 *.25*	152 *2.49*	160 *3.33*	265 *7.47*		700	.95	1,040	249	124	61	1,170	5.1
360	78 *3.89*	32 *2.63*	310 *13.48*	15 *.38*	171 *2.80*	234 *4.87*	450 *12.69*		1,030	1.40	1,000	326	186	66	1,740	7.5
260 [2]	94 *4.69*	40 *3.29*	430 *18.70*	19 *.49*	180 *2.95*	285 *5.93*	638 *17.99*		1,420	1.93	997	399	252	69	2,400	9.4
200	103 *5.14*	47 *3.86*	530 *23.06*	23 *.59*	181 *2.97*	328 *6.82*	800 *22.56*		1,800	2.45	972	450	302	71	3,040	11
163	112 *5.59*	52 *4.27*	620 *26.97*	26 *.67*	183 *3.00*	360 *7.49*	940 *26.51*		2,110	2.87	929	493	343	72	3,550	12
132	119 *5.94*	58 *4.77*	720 *31.32*	30 *.77*	184 *3.02*	391 *8.13*	1,100 *31.02*		2,460	3.35	877	586	384	73	4,160	14
96 [3]	127 *6.34*	64 *5.26*	860 *37.41*	35 *.90*	185 *3.03*	440 *9.15*	1,320 *37.22*		2,950	4.01	765	580	428	75	5,000	16
58	133 *6.64*	70 *5.75*	1,050 *45.68*	41 *1.05*	186 *3.05*	498 *10.36*	1,620 *45.68*		3,450	4.69	540	620	467	77	5,890	18
30	133 *6.64*	73 *6.00*	1,170 *50.90*	44 *1.13*	187 *3.07*	521 *10.84*	1,800 *50.76*		3,800	5.17	308	632	478	79	6,400	20
19	133 *6.64*	74 *6.08*	1,230 *53.50*	44 *1.13*	188 *3.08*	521 *10.84*	1,900 *53.58*		3,900	5.30	200	636	482	79	6,650	21
944	53 *2.64*	15 *1.23*	101 *4.39*	6.8 *.17*	134 *2.20*	101 *2.10*	147 *4.15*		475	.65	1,210	194	84	52	798	3.2

See footnotes at end of table.

TABLE 19.—*Relation between water discharge and chemical quality of water for selected stations in the subbasins in the Grand division*—Con.

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italicized) except as indicated; data are for the water years 1914–57 adjusted to 1957 conditions]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO^{3})	Sulfate (SO^{4})	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180°C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos per cm at 25°C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-foot	Tons per day	Calcium, magnesium	Noncarbonate			
COLORADO RIVER BASIN BETWEEN THE GUNNISON AND GREEN RIVERS—Continued																
1800. Dolores River near Cisco, Utah																
14,000	46 *2.30*	3.9 *.32*	10 *.44*	1.6 *.04*	110 *1.80*	30 *.62*	25 *.70*	0.03	197	0.27	7,450	131	41	14	338	0.4
12,700	46 *2.30*	4.0 *.33*	11 *.48*	1.6 *.04*	112 *1.84*	31 *.64*	27 *.76*	.03	198	.27	6,790	132	40	15	339	.4
11,500	47 *2.35*	4.2 *.35*	11 *.48*	1.6 *.04*	113 *1.85*	33 *.69*	28 *.79*	.03	198	.27	6,150	135	42	15	339	.4
9,100	47 *2.35*	4.8 *.39*	13 *.57*	1.8 *.05*	114 *1.87*	36 *.75*	30 *.85*	.04	199	.27	4,890	137	44	17	340	.5
6,500	48 *2.40*	5.6 *.46*	16 *.70*	2.1 *.05*	116 *1.90*	40 *.83*	34 *.96*	.04	200	.27	3,510	143	48	19	345	.6
5,000	51 *2.54*	6.7 *.55*	21 *.91*	2.4 *.06*	116 *1.90*	48 *1.00*	40 *1.13*	.04	208	.28	2,810	154	60	22	357	.7
3,770	53 *2.64*	7.8 *.64*	25 *1.09*	2.7 *.07*	117 *1.92*	56 *1.16*	47 *1.33*	.04	220	.30	2,240	164	68	25	380	.9
2,550 [1]	55 *2.74*	9.5 *.78*	34 *1.48*	3.3 *.08*	118 *1.94*	68 *1.41*	61 *1.72*	.04	255	.35	1,760	176	79	29	430	1.1
1,250	60 *2.99*	14 *1.15*	63 *2.74*	4.8 *.12*	125 *2.05*	102 *2.12*	100 *2.82*	.04	406	.55	1,370	207	104	39	680	1.9
565	70 *3.49*	23 *1.89*	128 *5.57*	7.8 *.20*	138 *2.26*	176 *3.66*	183 *5.16*	.05	740	1.01	1,130	269	156	50	1,200	3.4
355	79 *3.94*	30 *2.47*	203 *8.83*	10 *.26*	150 *2.46*	253 *5.26*	274 *7.73*	.07	1,090	1.48	1,040	320	198	57	1,780	4.9
265 [2]	88 *4.39*	35 *2.88*	269 *11.70*	13 *.33*	156 *2.56*	313 *6.51*	363 *10.24*	.08	1,450	1.97	1,040	364	236	61	2,330	6.1
210	99 *4.94*	41 *3.37*	334 *14.53*	16 *.41*	157 *2.57*	366 *7.61*	466 *13.14*	.10	1,800	2.45	1,020	416	287	62	2,920	7.1
177	111 *5.54*	47 *3.86*	397 *17.27*	19 *.49*	155 *2.54*	401 *8.34*	576 *16.24*	.11	2,110	2.87	1,010	470	343	64	3,500	8.0
142	128 *6.39*	54 *4.44*	492 *21.40*	23 *.59*	154 *2.53*	462 *9.61*	732 *20.64*	.14	2,580	3.51	989	542	415	65	4,320	9.2
96 [3]	160 *7.98*	69 *5.67*	679 *29.54*	34 *.87*	154 *2.53*	592 *12.31*	1,050 *29.61*	.16	3,490	4.75	905	682	556	67	5,600	11
57	218 *10.88*	96 *7.89*	971 *42.24*	49 *1.25*	153 *2.51*	821 *17.08*	1,520 *42.86*	.22	4,700	6.39	723	938	813	68	7,500	14
32	292 *14.57*	128 *10.52*	1,300 *56.55*	67 *1.72*	157 *2.57*	1,210 *25.17*	2,040 *57.53*	.28	5,900	8.02	510	1,250	1,130	68	9,100	16
20	375 *18.71*	164 *13.48*	1,560 *67.86*	80 *2.05*	157 *2.57*	1,660 *34.53*	2,300 *64.86*	.32	6,200	8.43	335	1,610	1,480	66	9,500	17
940	61 *3.04*	14 *1.15*	80 *3.48*	5.2 *.13*	124 *2.03*	109 *2.27*	124 *3.50*	.05	496	.67	1,260	210	108	45	830	2.4
1805. Colorado River near Cisco, Utah																
62,270	39 *1.95*	6.8 *.56*	13 *.57*	2.2 *.06*	120 *1.97*	53 *1.10*	2.4 *.07*	0.04	238	0.32	40,010	126	27	18	378	0.5
59,540	39 *1.95*	6.9 *.57*	14 *.61*	2.2 *.06*	121 *1.98*	55 *1.14*	2.5 *.07*	.04	239	.33	38,420	126	27	19	380	.5
55,710	40 *2.00*	7.1 *.58*	15 *.65*	2.2 *.06*	122 *2.00*	57 *1.19*	2.5 *.07*	.04	240	.33	36,100	129	29	20	380	.6
47,950	41 *2.05*	7.5 *.62*	16 *.70*	2.2 *.06*	125 *2.05*	63 *1.31*	2.6 *.07*	.04	241	.33	31,200	134	31	20	380	.6
38,090	43 *2.15*	8.5 *.70*	18 *.78*	2.2 *.06*	128 *2.10*	73 *1.52*	3.0 *.08*	.05	248	.34	25,510	142	38	21	390	.7
30,970	45 *2.25*	9.3 *.76*	22 *.96*	2.2 *.06*	134 *2.20*	85 *1.77*	3.2 *.09*	.05	258	.35	21,570	150	40	24	403	.8
25,250	47 *2.35*	11 *.90*	25 *1.09*	2.3 *.06*	139 *2.28*	97 *2.02*	3.6 *.10*	.05	273	.37	18,610	162	48	25	435	.9
18,760 [1]	51 *2.54*	13 *1.07*	31 *1.35*	2.5 *.06*	146 *2.39*	121 *2.52*	4.5 *.13*	.05	309	.42	15,650	180	61	27	480	1.0
11,020	60 *2.99*	17 *1.40*	47 *2.04*	2.7 *.07*	160 *2.62*	176 *3.66*	6.6 *.19*	.06	415	.56	12,350	220	88	31	645	1.4
6,060	70 *3.49*	25 *2.06*	79 *3.44*	3.6 *.09*	178 *2.92*	281 *5.84*	11 *.31*	.08	660	.90	10,800	278	132	38	1,010	2.1
4,200	84 *4.19*	33 *2.71*	106 *4.61*	4.3 *.11*	194 *3.18*	389 *8.09*	15 *.42*	.09	895	1.22	10,150	345	186	40	1,300	2.5
3,540 [2]	97 *4.84*	37 *3.04*	123 *5.35*	4.9 *.13*	202 *3.31*	460 *9.57*	17 *.48*	.10	1,030	1.40	9,840	394	228	40	1,480	2.7
3,180	102 *5.09*	40 *3.29*	138 *6.00*	5.1 *.13*	211 *3.46*	506 *10.52*	19 *.54*	.11	1,130	1.54	9,700	419	246	41	1,600	2.9
2,820	109 *5.44*	46 *3.78*	160 *6.96*	5.6 *.14*	219 *3.59*	575 *11.96*	21 *.59*	.12	1,240	1.69	9,440	461	282	43	1,740	3.2
2,520	125 *6.24*	50 *4.11*	172 *7.48*	5.9 *.15*	230 *3.77*	650 *13.52*	24 *.68*	.14	1,350	1.84	9,190	518	329	42	1,850	3.3
2,160 [3]	142 *7.09*	60 *4.93*	190 *8.26*	6.7 *.17*	230 *3.77*	770 *16.02*	29 *.82*	.17	1,470	2.00	8,570	601	412	40	2,000	3.4
1,580	180 *8.98*	78 *6.41*	210 *9.14*	8.5 *.22*	230 *3.77*	975 *20.28*	35 *.99*	.22	1,680	2.28	7,170	770	581	37	2,280	3.3
975	220 *10.98*	85 *6.99*	215 *9.35*	10 *.26*	230 *3.77*	1,080 *22.46*	48 *1.35*	.27	1,810	2.46	4,760	898	710	34	2,400	3.1
746	235 *11.73*	90 *7.40*	220 *9.57*	12 *.31*	230 *3.77*	1,150 *23.92*	60 *1.69*	.28	1,850	2.52	3,730	956	768	33	2,450	3.1
7,639	66 *3.29*	21 *1.73*	62 *2.70*	3.2 *.08*	162 *2.66*	233 *4.85*	8.8 *.25*	.07	547	.74	11,280	251	118	35	806	1.7

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[1] 12 percentile. [2] 50 percentile. [3] 90 percentile.

TABLE 20.—*Water and dissolved solids contributed by ground water to selected streams in the subbasins in the Grand division*

[Data are for the water years 1914–57 adjusted to 1957 conditions; weighted-average concentration of dissolved solids of streams from table 14]

Station No.	Station name	Weighted-average concentration of dissolved-solids (ppm)	Ground water		
			Discharge (acre-ft per yr)	Dissolved solids	
				Tons per year	Weighted-average concentration (ppm)
	Colorado River Basin above the Gnnnison River, Colo.				
125	North Inlet at Grand Lake	16	4, 900	120	18
200	Willow Creek near Granby	65	9, 200	820	66
360	Williams River near Leal	30	22, 200	1, 360	45
470	Blue River at Dillon	85	24, 300	3, 430	104
595	Piney River near State Bridge	120	11, 200	3, 170	208
695	Gypsum Creek near Gypsum	279	17, 700	9, 410	391
780	Fryingpan Creek at Norrie	23	24, 100	1, 410	43
825	Crystal River near Redstone	165	65, 200	33, 800	381
965	Plateau Creek near Collbran	57	12, 000	2, 450	150
975	Buzzard Creek near Gypsum	156	5, 000	1, 970	290
	Gunnison River basin, Colorado				
1125	East River at Almont	147	56, 400	15, 700	206
1155	Tomichi Creek at Sargents	83	19, 000	2, 440	94
1245	Lake Fork at Gateway	85	45, 100	7, 110	114
1315	Muddy Creek at Bardine	124	21, 800	5, 830	200
	Colorado River Basin between the Gunnison and Green Rivers, Colo.				
1665	Dolores River at Dolores	125	47, 600	17, 500	270
1725	San Miguel River near Placerville	157	58, 300	19, 000	240

TABLE 21.—*Weighted-average concentration of dissolved solids of transmountain diversions in the Colorado River Basin above the Gunnison River*

[Data are for the water years 1914–57 adjusted to 1957 conditions; annual diversions based on average annual diversion for water years 1954–57]

Station No.	Diversion and location	Annual diversions (acre-ft)	Weighted-average concentration (ppm)	Station No.	Diversion and location	Annual diversions (acre-ft)	Weighted-average concentration (ppm)
100	Grand River ditch at LaPoudre Pass	16,400	30	615	Columbine ditch near Fremont Pass	1,100	50
120	Eureka ditch near Flattop Mountain	80	20	620	Ewing ditch near Tennessee Pass	840	50
125A	Alva B. Adams Tunnel at west portal, at Grand Lake.	241,200	35	625	Wurtz ditch near Tennessee Pass	1,900	25
215	Berthoud Pass ditch, at Berthoud Pass.	400	30	730	Twin Lakes tunnel at east portal near Twin Lakes.	32,900	60
225	Moffat water tunnel at East Portal	39,500	30	775	Busk-Ivanhoe tunnel at east portal near Malta.	4,600	60
350	Jones Pass tunnel at east portal near Jones Pass.	7,300	30				
420	Hoosier Pass tunnel	6,600	50	Average			37
460	Boreas Pass ditch at Boreas Pass	280	40	Total		353,100	

TABLE 22.—*Water and dissolved-solids budgets in the Grand division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
Colorado River Basin below Granby and Willow Creek Reservoirs and above Hot Sulphur Springs, exclusive of Fraser River basin			
Inflow:			
Release from Lake Granby	25, 600	35	1, 200
Release from Willow Creek Reservoir	13, 600	65	1, 200
Fraser River at Granby, Colo	124, 600	47	8, 000
Unmeasured surface water	16, 000	35–65	800–1, 400
Unmeasured natural ground water	2, 500	100–253	300–900
Total	182, 300	------------	11, 500–12, 700
Outflow:			
Consumed on irrigated land	5, 500	------------	----------------
Colorado River at Hot Sulphur Springs, Colo	176, 800	76	18, 300
Total	182, 300	------------	18, 300
Increase from other sources	------------	------------	6, 800–5, 600
Troublesome Creek basin, Colorado			
Inflow:			
Troublesome Creek near Pearmont	20, 800	60	1, 700
East Fork Troublesome Creek near Troublesome	19, 800	92	2, 500
Unmeasured surface water	4, 800	60–92	400–600
Unmeasured natural ground water	1, 600	75–120	200–300
Total	47, 000	------------	4, 800–5, 100
Outflow:			
Consumed on irrigated land	5, 600	------------	----------------
Troublesome Creek near Troublesome	41, 400	156	8, 800
Total	47, 000	------------	8, 800
Increase from other sources	------------	------------	4, 000–3, 700

TABLE 22.—*Water and dissolved-solids budgets in the Grand division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions]

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
Lower Gunnison River basin			
Inflow:			
Gunnison River above Gunnison tunnel	1, 281, 000	111	277, 100
Uncompahgre River at Colona, Colo	201, 400	376	103, 000
Roubideau Creek near Delta, Colo	30, 000	350	14, 300
Unmeasured natural ground-water inflow in Uncompahgre River valley	20, 000	1, 300–2, 300	35, 400–62, 600
Unmeasured natural surface-water inflow in Uncompahgre River valley	50, 000	200–350	13, 600–23, 800
Measured natural inflow to the Gunnison River	483, 000	130–150	85, 400–98, 500
Unmeasured natural inflow to the Gunnison River	211, 930	130–150	37, 500–43, 300
Thermal springs	70	7, 800	700
Total	2, 277, 400		567, 000–623, 300
Outflow:			
Consumed in the area	[1] 393, 400		
Gunnison River near Grand Junction, Colo	1, 884, 000		1, 519, 000
Total	2, 277, 400		1, 519, 000
Increase from other sources			[2] 952,000–895,700
San Miguel River basin between Placerville and Naturita, Colo.			
Inflow:			
San Miguel River near Placerville	187, 600	157	40, 200
Unmeasured surface water	92, 500	150–160	16, 900–23, 700
Unmeasured natural ground water	4, 200	400–600	2, 300–3, 400
Total	284, 300		59, 400–67, 300
Outflow:			
Consumed by irrigation	30, 000		
San Miguel River at Naturita	254, 300	316	109, 200
Total	284, 300		109, 200
Increase from other sources			49, 800–41, 900

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[1] Includes channel and other losses as well as irrigation consumptive use.
[2] Equivalent to 5.1 tons per acre per year on 176,500 acres of irrigated land.

TABLE 23.—*Water and dissolved-solids budget, Roaring Fork basin, Colorado*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

	Drainage area (sq mi)	Average annual discharge (acre-ft)	Dissolved solids	
			Weighted-average concentration (ppm)	Tons per year
Inflow:				
Roaring Fork near Aspen	109	72, 450	30	3, 000
Fryingpan Creek at Norrie	90	99, 250	23	3, 100
Unmeasured surface and ground water from area underlain by granitic and Precambrian rocks	199	171, 700	26	6, 100
Castle Creek near Aspen	62	64, 330	192	16, 800
Crystal River near Redstone	220	281, 100	165	63, 200
Unmeasured surface water	780	285, 110	160	62, 100
Unmeasured natural ground water	--------	40, 000	400–900	21, 800–49, 000
Thermal springs below Norrie	--------	800	2, 200	2, 400
Total	1, 460	1, 014, 740	----------	178, 500–205, 700
Outflow:				
Consumed on irrigated land	--------	34, 540	----------	----------------
Roaring Fork at Glenwood Springs	1, 460	980, 200	225	299, 900
Total	1, 460	1, 014, 740	----------	299, 900
Increase from other sources	--------	----------	----------	121, 400–94, 200

TABLE 24.—*Average annual dissolved-solids discharge and probable amounts from natural sources and the activities of man in the Colorado River Basin above the Gunnison River, Colo.*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Gaging station or subbasin	Drainage area (sq mi)	Acres irrigated	Dissolved-solids discharge				
			Total (tons)	Natural		Man-caused	
				Tons	Tons per square mile	Tons	Tons per acre irrigated
Colorado River at Hot Sulphur Springs	[1] 337	15, 700	18, 300	11, 300	34	7, 000	0. 45
Colorado River near Glenwood Springs	4, 486	83, 700	639, 200	516, 200	115	123, 000	1. 5
Roaring Fork at Glenwood Springs	1, 460	31, 400	299, 900	205, 700	141	94, 200	3. 0
Colorado River near Cameo	8, 060	163, 400	1, 578, 000	1, 214, 000	150	364, 000	2. 2
Plateau Creek near Cameo	604	29, 100	66, 100	28, 100	47	38, 000	1. 3
Colorado River Basin above Gunnison River	8, 670	192, 500	1, 644, 100	1, 242, 100	143	402, 000	2. 1

[1] Exclusive of area above Granby and Willow Creek Reservoirs.

TABLE 25.—*Suspended-sediment discharge at selected stations in the subbasins in the Grand division*

[Data are for the water years 1914–57 adjusted to 1957 conditions, except as indicated. Asterisk indicates that data for subbasins are estimated]

Station No.	Station name	Average water discharge (cfs)	Suspended sediment		
			Weighted-average concentration (ppm)	Discharge	
				Tons per year	Tons per sq mi per yr
	Colorado River Basin above the Gunnison River, Colo.*				
725	Colorado River at Glenwood Springs	2, 399	200	485, 800	107
850	Roaring Fork at Glenwood Springs	1, 353	220	287, 100	197
920	Rifle Creek near Rifle [1]	24. 6	1, 800	43, 500	311
955	Colorado River near Cameo	4, 138	2, 270	9, 248, 000	1, 150
965	Plateau Creek near Collbran	104	180	19, 000	216
	Gunnison River basin, Colorado*				
1275A	Gunnison River above Gunnison tunnel	1, 767	105	183, 000	46
1285	Smith Fork near Crawford	54. 6	224	12, 000	287
1295	Iron Creek near Crawford [2]	16. 9	986	16, 400	245
1435	Surface Creek at Cedaredge [3]	27. 0	112	3, 000	70
1525	Gunnison River near Grand Junction	2, 601	806	2, 067, 000	258
	Colorado River Basin between the Gunnison and Green Rivers				
1665	Dolores River at Dolores, Colo	492	245	119, 100	214
1800	Dolores River near Cisco, Utah [4]	759	3, 370	2, 524, 000	545
1805	Colorado River near Cisco, Utah [5]	7, 097	2, 050	14, 351, 000	595

[1] For water years 1940–46, 1953–57.
[2] For water years 1948–52.
[3] For water years 1918–57.
[4] For water years 1952–57.
[5] For water years 1930–57.

TABLE 26.—*Suitability of surface waters for domestic use in the Colorado River Basin above the Gunnison River*

[—indicates that maximum concentration observed in streams is less than the maximum limit accepted for domestic use; + indicates that maximum concentration observed is greater than accepted limit for domestic use]

Location or area	Rating in relation to accepted maximum chemical concentrations						Rating in relation to hardness
	Fe+Mn	Mg	Cl	Fl	SO_4	Total dissolved solids	
Above Colorado River at Hot Sulphur Springs.	—	—	—	—	—	—	Soft to moderately hard.
Williams and Blue River basins	—	—	—	—	—	—	Do.
Troublesome Creek basin	—	—	—	—	—	—	Soft to very hard.
Muddy Creek at mouth	—	+	—	—	+	+	Moderately hard to very hard.
Main stem and tributaries between Kremmling and Dotsero.	—	—	—	—	—	—	Do.
Eagle River above Eagle	—	—	—	—	—	—	Soft to hard.
Eagle River and most tributaries below Eagle.	—	—	—	—	+	+	Very hard.
Main stem and tributaries between Dotsero and Glenwood Springs.	—	—	—	—	—	—	Hard to very hard.
Roaring Fork basin	—	—	—	—	—	—	Soft to hard.
Tributaries between Roaring Fork and Cameo except Canyon Creek and streams that drain Battlement Mesa.	—	+	—	—	+	+	Hard to very hard.
Main stem between Roaring Fork and Cameo, Canyon Creek, and streams that drain Battlement Mesa.	—	—	—	—	—	—	Do.
Plateau Creek basin	—	—	—	—	—	—	Soft to very hard.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*

[Calcium *a*, to adjust water to 70 percent sodium; calcium *b*, to offset bicarbonate precipitation; calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Colorado River Basin above the Gunnison River, Colo.														
110	Colorado River near Grand Lake.	10-29-57	44	Medium	70	14	0.2	0.02	C1-S1	−0.53	0.59	0.30	0.6	84
		6-10-58	437	High	51	----	----	.01		−.36	.41	.30	.5	82
125	North Inlet at Grand Lake	10-28-57	32	Medium	19	34	.2	.06		−.08	.16	.30	.6	89
		6-17-58	238	High	15	----	----	.02		−.06	.12	.30	.6	84
130	Alva B. Adams Tunnel at east portal, near Estes Park.	7- 2-58	379	----	21	----	----	.04		−.10	.20	.30	.6	94
190	Colorado River below Lake Granby.	10-24-57	20	----	58	17	.2	.08		−.39	.51	.30	.6	98
		6-14-58	75	----	70	----	----	.00		−.54	.59	.30	.6	82
210	Willow Creek below Willow Creek Reservoir.	6- 9-58	36	----	228	30	.8	.11		−1.38	1.77	.30	1.8	161
		8-12-58	16	----	95	----	----	.04		−.73	.84	.30	.7	96
210A	Colorado River at bridge on U.S. Highway 40, near Granby.	11-10-50	43	----	128	----	----	.22		−.84	1.23	.30	1.1	161
		6-28-56	121	----	161	15	.3	.00		−1.46	1.54	.30	.8	89
225	Moffat water tunnel at East Portal.	6-26-58	117	----	38	----	----	.00		−.36	.34	.30	.4	66
265	St. Louis Creek near Fraser	6- 6-58	254	High	47	----	----	.00		−.39	.39	.30	.5	70
		8-14-58	15	Medium	77	----	----	.04		−.64	.72	.30	.6	89
270A	Fraser River at Fraser	6-28-56	82	----	76	16	.2	.00		−.70	.66	.30	.6	61
340	Fraser River at Granby	6- 9-58	960	High	49	----	----	.05		−.31	.43	.30	.7	98
		8- 5-58	35	Low	171	----	----	.14		−1.49	1.72	.30	.8	124
345	Colorado River at Hot Sulphur Springs.	10- -56	[2] 53.6	Low	167	19	.4	.22		−1.29	1.66	.30	1.2	157
		6- -57	[2] 2,111	High	81	21	.3	.08		−.52	.67	.30	.7	105
		8- -57	[2] 174	Medium	153	19	.4	.21		−1.09	1.43	.30	1.1	150
360	Williams River near Leal	8- 9-58	52	Medium	70	----	----	.02		−.60	.66	.30	.6	84
375	Williams River near Parshall	10-20-55	[2] 12	Low	145	10	.2	.00		−1.32	1.34	.30	.7	75
		6-11-58	687	High	48	----	----	.00		−.37	.39	.30	.6	75
		8- 9-58	46	Medium	133	----	----	.07		−1.18	1.31	.30	.7	101
390	Troublesome Creek near Pearmont.	6-11-58	84	----	71	----	----	.00		−.55	.59	.30	.7	80
		8-10-58	14	----	98	----	----	.04		−.78	.90	.30	.7	98
400	East Fork Troublesome Creek near Troublesome.	6-11-58	65	----	128	----	----	.08		−.90	1.12	.30	1.0	122
405	Troublesome Creek near Troublesome.	10-20-55	[2] 6.5	Low	572	33	1.4	.07	C2-S1	−3.08	3.91	.29	4.6	262
		6- 5-58	125	High	63	----	----	.00	C1-S1	−.43	.49	.30	.7	84
		8- 6-58	30	Medium	433	38	1.5	.37	C2-S1	−2.16	3.22	.29	3.8	316
405A	Colorado River above Muddy Creek, at Kremmling.	9-18-47	[3] 229	----	151	----	----	.00	C1-S1	−1.37	1.30	.30	.9	54
410	Muddy Creek near Kremmling	6-11-58	143	High	138	----	----	.00		−1.16	1.12	.30	.7	61
		8-11-58	3.5	Low	515	15	.5	.00	C2-S1	−4.58	3.91	.29	2.3	0
411	Antelope Creek near Kremmling	6-11-58	3.6	Low	215	----	----	.12	C1-S1	−1.57	1.87	.30	1.2	140
415	Muddy Creek at Kremmling	10-20-55	[3] 5	Low	2,040	21	1.7	.00	C3-S1	−17.41	2.04	.18	41	0
		10-22-57	52	Medium	1,010	20	1.1	.00		−8.15	2.70	.26	12	0
		6-11-58	216	High	519	15	.5	.00	C2-S1	−4.29	1.99	.29	4.5	0
460	Boreas Pass ditch at Boreas Pass	6-25-58	1.5	----	53	----	----	.00	C1-S1	−.49	.43	.30	.4	56
470	Blue River at Dillon	3-17-47	[2] 24	Low	224	----	----	.00		−2.29	1.00	.29	1.8	0
		5-28-50	[2] 246	High	140	----	----	.00		−1.32	.81	.30	.7	0
		11-10-50	[2] 29	Medium	152	----	----	.00		−1.38	1.07	.30	.7	0
480	Snake River at Dillon	10-21-57	11	Low	160	16	.3	.00		−1.25	1.22	.30	.8	63
		6-14-58	211	High	84	----	----	.00		−.69	.44	.30	.5	12
485A	Tenmile Creek above West Tenmile Creek, near Frisco.	6-13-58	116	High	159	----	----	.00		−1.33	.55	.30	1.1	0
505	Tenmile Creek at Dillon	10-25-57	41	Medium	267	8	.2	.00	C2-S1	−2.25	.86	.29	2.1	0
		6-14-58	430	High	105	----	----	.00	C1-S1	−.91	.59	.30	.4	0
520	Rock Creek near Dillon	6-12-58	73	High	26	11	.1	.00		−.23	.23	.30	.4	70
575	Blue River below Green Mountain Reservoir.	8-10-58	464	----	122	----	----	.00		−1.01	.77	.30	.5	14
575A	Blue River near Kremmling	10-20-55	[3] 100	----	176	7	0.1	0.00		−1.41	.94	.30	.9	0
580B	Sheephorn Creek near Radium	10-22-57	12	Low	558	15	.5	.00	C2-S1	−4.34	2.72	.29	2.7	0
		5-28-58	208	High	190	----	----	.00	C1-S1	−1.81	1.65	.30	.6	33
595	Piney River near State Bridge	10-23-57	25	Medium	299	4	.1	.00	C2-S1	−2.94	2.45	.30	1.6	0
		5-27-58	790	High	133	----	----	.00	C1-S1	−1.33	1.21	.30	.5	42
		8- 5-58	10	Low	347	----	----	.00	C2-S1	−3.43	2.42	.29	1.7	0
605	Rock Creek near Toponas	6-16-58	50	High	58	----	----	.08	C1-S1	−.41	.56	.30	.7	105
605A	Egeria Creek above Toponas Creek, near Toponas.	10-22-57	10	----	407	9	.3	.00	C2-S1	−3.73	3.24	.30	1.2	0
		6-16-58	2.7	----	486	----	----	.00		−4.66	3.67	.29	2.2	0
605B	Rock Creek at McCoy	8- 5-58	7.5	Low	435	22	.8	.00		−3.27	3.51	.30	2.3	126
610	Sunnyside Creek near Burns	4-24-58	4.3	Medium	239	----	----	.03	C1-S1	−2.14	2.30	.30	1.0	108
610A	Cabin Creek at Burns	8- 5-58	18	----	834	----	----	.00	C3-S1	−9.34	3.56	.27	8.8	0
610B	Derby Creek near Burns	4-24-58	58	----	187	----	----	.00	C1-S1	−1.65	1.73	.30	.9	89
		8- 5-58	10	----	416	----	----	.00	C2-S1	−3.83	3.83	.30	1.6	70
610C	Sweetwater Creek near Sweetwater.	10-22-57	52	----	462	1	.0	.00		−4.73	2.61	.29	2.9	0
		4-23-58	48	----	419	----	----	.00		−4.16	2.54	.29	2.6	0
610E	Colorado River above Eagle River, at Dotsero.	3-16-47	[3] 373	Low	459	26	.9	.00		−2.92	1.94	.28	5.2	0
		9-15-54	[3] 591	Medium	484	----	----	.00		−2.65	2.03	.29	4.9	0
625A	Eagle River near Tennessee Pass.	5- 8-44	----	----	61	----	----	.00	C1-S1	−.48	.43	.30	.5	58
630	Eagle River at Red Cliff	10-23-57	23	Medium	224	5	.1	.00		−2.20	2.01	.30	.6	26
		5-30-58	365	High	121	----	----	.00		−1.11	1.06	.30	.7	58
		8-13-58	14	Low	252	----	----	.00	C2-S1	−2.51	2.30	.30	.7	21
650A	Eagle River near Minturn	10-23-55	----	----	301	6	1.5	.00		−2.74	1.31	.29	2.4	0

See footnotes at end of table.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
	Colorado River Basin above the Gunnison River, Colo.—Continued													
651	Cross Creek near Minturn	9-18-47	[3] 3.0	Low	151			0.00	C1-S1	−0.90	0.38	0.30	1.3	0
665	Gore Creek near Minturn	5-29-58	1,190	High	94			.00		−.87	.87	.30	.6	70
		8- 6-58	58	Medium	280			.00	C2-S1	−2.80	2.16	.30	1.1	0
670C	Lake Creek at Edwards	9-17-47			310			.00		−3.15	1.58	.29	1.9	0
670D	Eagle River at Wolcott	5- 8-44			314			.00		−2.08	1.27	.29	2.9	0
		9-17-47			667	33	1.4	.00		−3.15	1.80	.27	8.5	0
		11-10-50	[3] 50		1,280	53	3.9	.00	C3-S1	−3.09	2.00	.22	26	0
670E	Alkali Creek at bridge on State Highway 131, near Wolcott.	10-23-57	2.4		1,170	22	1.2	.00		−7.88	3.45	.27	11	0
		4-24-58	5.4		827	21	1.1	.00		−6.62	3.94	.28	7.5	0
675	Eagle River at Eagle	3-17-47	[3] 82	Low	969	38	2.1	.00		−4.49	2.07	.25	16	0
		5-28-50	[3] 1,770	High	255			.00	C2-S1	−1.78	1.35	.29	2.0	0
		11-10-50	[3] 250	Medium	1,090	42	2.6	.00	C3-S1	−4.38	2.28	.24	19	0
680	Brush Creek near Eagle	8-12-58	27		441			.00	C2-S1	−4.39	2.25	.29	3.2	0
685	Brush Creek at Eagle	5-11-48			609	16	.6	.00		−5.32	2.50	.28	6.6	0
		11-10-50	[3] 24		1,170	13	.8	.00	C3-S1	−11.07	3.11	.25	16	0
690	Eagle River at Gypsum	1- -49	[2] 192	Low	1,170	30	1.8	.00		−6.76	2.44	.24	19	0
		4- -49	[2] 405	Medium	537	19	.7	.00	C2-S1	−3.89	1.95	.28	5.9	0
		6- -49	[2] 2,829	High	213	14	.3	.00	C1-S1	−1.65	1.21	.30	1.4	0
695	Gypsum Creek near Gypsum	10-24-57	31	Medium	436	2	.1	.00	C2-S1	−4.42	2.19	.29	3.0	0
		6- 2-58	139	High	220	4	.1	.00	C1-S1	−2.17	1.44	.30	1.1	0
695A	Gypsum Creek at Gypsum	9-17-47	[3] 20	Medium	733	5	.2	.00	C2-S1	−7.75	3.60	.28	6.0	0
		5-28-50	[3] 3	Low	1,630	2	.1	.00	C3-S1	−20.38	3.57	.22	26	0
700A	Eagle River at Dotsero	3-16-47	[3] 165	Low	987	24	1.3	.00		−7.02	2.39	.26	15	0
705	Colorado River near Dotsero	3-16-47	[2] 538	Low	621	28	1.2	.00	C2-S1	−3.91	2.13	.28	7.7	0
		5-31-58	11,700	High	174			.00	C1-S1	−1.35	1.20	.30	.8	35
		8-12-58	876	Medium	542	27	1.1	.00	C2-S1	−3.41	2.07	.28	5.9	0
705B	Wagon Gulch near Glenwood Springs.	5-28-50	[3] .5	Low	400			.01		−4.20	4.27	.30	.7	87
705C	Colorado River near Glenwood Springs.	3- -57	[2] 825	Low	808	42	2.3	.00	C3-S1	−3.16	2.06	.26	12	0
		6- -57	[2] 14,020	High	238	16	.4	.00	C1-S1	−1.79	1.51	.30	1.3	5
		9- -57	[2] 1,485	Medium	664	37	1.7	.00	C2-S1	−3.04	2.03	.27	9.0	0
735	Roaring Fork at Aspen	10-19-55	[2] 19	Low	83	14	.2	.01	C1-S1	−.61	.67	.30	.6	84
		6-12-56	[2] 294	High	40			.00		−.28	.30	.30	.5	75
745	Hunter Creek at Aspen	10-20-55	[3] 5.8	Low	77	12	.2	.00		−.60	.64	.30	.6	80
750A	Castle Creek at Aspen	10-20-55	[3] 50	Medium	460	2	.1	.00	C2-S1	−4.66	2.02	.29	3.6	0
		6-12-56	[3] 300	High	206			.00	C1-S1	−1.81	1.04	.30	1.2	0
765	Maroon Creek at lower station, near Aspen.	10-20-55	[3] 50	Low	507	1	.0	.00	C2-S1	−5.17	1.73	.29	4.7	0
		6-12-56	[3] 250	High	207			.00	C1-S1	−1.84	1.20	.30	1.1	0
765A	Woody Creek at Woody Creek	10-18-55			476	8	.3	.00	C2-S1	−4.64	4.26	.30	1.2	0
		6-11-56			129			.00	C1-S1	−1.13	1.02	.30	.6	44
770	Snowmass Creek at Snowmass	10-18-55	[3] 70	Low	761	6	.3	.00	C3-S1	−7.75	3.60	.28	6.4	0
		6- 1-58	286	High	275			.00	C2-S1	−2.63	1.84	.30	1.3	0
775	Busk-Ivanhoe tunnel at east portal, near Malta.	7- 1-58			81			.00	C1-S1	−.69	.70	.30	.5	73
780	Fryingpan Creek at Norrie	10-19-55	[2] 22	Medium	60	20	.2	.00		−.43	.44	.30	.6	73
		6- 1-58	[2] 679	High	27			.08		−.15	.30	.30	.7	105
785	North Fork Fryingpan Creek near Norrie.	10-19-55	[2] 2.7	Low	42	20	.2	.01		−.29	.33	.30	.5	80
		6-11-56	[2] 255	High	21			.00		−.13	.15	.30	.4	75
795	Lime Creek at Thomasville	10-19-55	[2] 10	Low	364	2	.1	.00	C2-S1	−3.79	2.62	.30	1.6	0
		6-11-56	[2] 140	High	115			.00	C1-S1	−.95	.95	.30	.7	70
800	Fryingpan Creek at Thomasville.	10-19-55	[2] 35	Low	159			.00		−1.34	1.17	.30	.7	30
		6-12-56	[2] 885	High	42			.00		−.32	.36	.30	.6	80
805	Fryingpan Creek at Basalt	10-19-55	[3] 24	Low	385	7	.2	.00	C2-S1	−3.57	2.05	.29	2.6	0
		6- 1-58	1,680	High	91			.00	C1-S1	−.91	.70	.30	.4	21
		8- 1-58	111	Medium	300			.00	C2-S1	−2.65	1.81	.29	1.8	0
805A	Roaring Fork above Sopris Creek, near Basalt.	10-18-55	[3] 290	Low	496			.00		−4.81	2.79	.29	3.2	0
		6-12-56	[3] 2,050	High	169			.00	C1-S1	−1.57	1.04	.30	.8	0
816	Crystal River above Avalanche Creek, near Redstone.	10-22-57	120	Medium	502	10	.3	.00	C2-S1	−4.46	2.14	.29	3.8	0
		5-27-58	1,700	High	169			.00	C1-S1	−1.58	1.29	.30	.6	2
830	Thompson Creek near Carbondale.	10-22-57	12	Low	284	18	.5	.00	C2-S1	−2.22	2.41	.30	1.5	115
		5-27-58	344	High	94			.00	C1-S1	−.81	.85	.30	.6	80
840A	Cattle Creek near Glenwood Springs.	6-13-56			1,050	6	.3	.00	C3-S1	−11.13	3.95	.27	11	0
850	Roaring Fork at Glenwood Springs.	9-15-54	[2] 610	Medium	654	9	.3	.00	C2-S1	−5.60	2.96	.28	5.4	0
		10-18-55	[2] 365	Low	794	21	1.0	.00	C3-S1	−5.92	3.11	.27	8.4	0
		6- 3-58	8,250	High	171			.00	C1-S1	−1.50	1.11	.30	.8	0
855	Canyon Creek near New Castle	10-23-57	[2] 28	Medium	375	2	.1	.00	C2-S1	−3.37	2.82	.30	.9	0
		5- 6-58	[2] 127	High	236			.00	C1-S1	−2.45	2.27	.30	.5	28
875	Elk Creek at New Castle	10-23-57	33	Medium	604	7	.3	.00	C2-S1	−5.95	3.35	.29	4.4	0
		5- 6-58	265	High	280			.00		−2.91	2.49	.30	.6	0
		8-14-58	2.0	Low	1,040	13	.7	.00	C3-S1	−10.43	4.11	.26	12	0
895	West Divide Creek near Raven	10-30-57	4.2	Low	431	19	.6	.42	C2-S1	−3.14	3.89	.30	2.0	246
		5- 6-58	240	High	263			.11		−2.35	2.58	.30	.9	124
905B	Divide Creek near Silt	8- 1-58	[3] 1.0	Low	1,950	61	6.4	.69	C3-S1	−2.73	7.23	.24	29	1,110
910A	Colorado River at Rifle	4-11-49	[3] 1,500	Medium	805	40	2.0	.00		−3.31	2.01	.26	12	0
		10-18-49	[3] 900	Low	1,220	44	2.9	.00		−4.34	2.44	.24	21	0
915	East Rifle Creek near Rifle	3- 7-41	30	Low	530	4	.2	.00	C2-S1	−5.24	3.12	.29	3.2	0
		5-24-41	[2] 96	High	549	4	.1	.00		−4.91	3.81	.29	1.8	0
		6-27-41	56	Medium	572	2	.1	.00		−5.54	3.64	.29	2.8	0
915A	East Rifle Creek above West Rifle Creek, near Rifle.	3- 7-41	17	Low	1,080	12	.6	.00	C3-S1	−11.22	3.51	.26	14	0
		5-24-41		High	637	6	.2	.00	C2-S1	−5.90	3.48	.29	3.4	0
		8- 2-41	32	Medium	698	7	.3	.00		−6.77	3.34	.28	5.3	0

See footnotes at end of table.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Colorado River Basin above the Gunnison River, Colo.—Continued														
915B	West Rifle Creek near Rifle	10–23–57	[2] 1.2	Low	1,600	33	2.5	0.00	C3–S1	−10.44	4.72	0.25	18	0
		5–7–58	[2] 38	High	598	15	.6	.00	C2–S1	−5.13	3.04	.29	4.4	0
915C	Middle Rifle Creek near Rifle	4–25–41	[2] 3.3	Low	893	5	.2	.00	C3–S1	−8.42	3.12	.28	7.8	0
		5–24–41	--------	High	505	3	.1	.00	C2–S1	−4.32	2.85	.29	1.8	0
		6–27–41	11	Medium	642	4	.2	.00		−6.27	3.39	.29	4.2	0
915D	West Rifle Creek below Middle Rifle Creek, near Rifle.[3]	3–7–41	5.4	Low	1,570	20	1.3	.00	C3–S1	−13.25	3.87	.24	21	0
		5–24–41	--------	High	847	10	.4	.00		−5.93	3.55	.29	4.0	0
		6–27–41	12	Medium	861	15	.7	.00		−7.73	3.47	.27	8.3	0
920	Rifle Creek near Rifle	12–19–40	5.4	Low	1,460	15	1.0	.00		−14.75	3.89	.23	22	0
		5–24–41	[2] 143	High	663	8	.3	.00	C2–S1	−5.68	3.51	.29	3.6	0
		9–20–41	[2] 22	Medium	979	11	.6	.00	C3–S1	−9.21	3.78	.27	9.6	0
920A	Rifle Creek at Rifle	4–11–49	[3] 10	--------	1,630	29	2.1	.00		−11.25	4.26	.23	22	0
		10–24–55	[3] 11	--------	2,230	40	3.8	.00		−11.21	3.72	.18	39	0
926	Battlement Creek near Grand Valley.	5–7–58	32	High	232	--------	--------	.15	C1–S1	−1.90	2.20	.30	1.1	140
926A	Battlement Creek at mouth, near Grand Valley.	10–22–57	.6	Low	818	42	2.3	.47	C3–S1	−3.53	5.33	.29	7.5	489
935	Parachute Creek at Grand Valley.	10–22–57	22	Medium	1,180	39	2.5	.00		−5.88	5.79	.27	8.8	42
		5–5–58	327	High	577	29	1.3	.08	C2–S1	−3.98	4.78	.29	3.9	255
		8–1–58	2.9	Low	1,730	44	3.8	.00	C3–S1	−8.03	6.50	.24	21	0
935A	Colorado River at De Beque	4–11–49	--------	--------	927	43	2.4	.00		−3.39	2.32	.26	14	0
950A	Roan Creek at De Beque	10–21–57	50	Medium	1,610	48	4.1	.00		−6.02	4.86	.26	14	0
		5–5–58	288	High	767	34	1.7	.00		−4.46	4.87	.29	5.6	164
		8–1–58	5.8	Low	2,800	51	6.2	.00	C4–S2	−9.68	3.84	.14	54	0
955	Colorado River near Cameo	10– –55	[2] 1,476	Low	1,260	51	3.7	.00	C3–S1	−3.28	2.24	.23	23	0
		6– –56	[2] 10,700	High	377	33	1.1	.00	C2–S1	−1.98	1.54	.29	4.1	0
		7– –56	[2] 2,810	Medium	863	44	2.4	.00	C3–S1	−3.12	2.11	.26	13	0
965	Plateau Creek near Collbran	5–27–58	845	High	87	--------	--------	.00	C1–S1	−.79	.79	.30	.4	70
		8–8–58	8.4	Low	188	--------	--------	.09		−1.13	1.33	.30	.8	117
975	Buzzard Creek near Collbran	10–23–57	12	Medium	442	20	.7	.34	C2–S1	−3.53	4.11	.29	5.2	204
		5–27–58	350	High	214	--------	--------	.00	C1–S1	−2.16	2.09	.30	.6	54
		8–6–58	1.4	Low	715	36	1.9	.00	C2–S1	−4.13	6.14	.29	6.4	538
1045	Mesa Creek near Mesa	5–27–58	18	Medium	84	--------	--------	.19	C1–S1	−.43	.79	.30	1.1	154
1050	Plateau Creek near Cameo	9–17–47	[2] 88	Medium	833	37	2.0	.38	C3–S1	−4.52	6.11	.29	7.0	440
		11–11–50	[2] 35	Low	936	38	2.3	.35		−4.94	6.70	.28	8.2	477
		5–7–58	1,490	High	303	--------	--------	.10	C2–S1	−2.62	2.89	.30	1.1	133
1050A	Colorado River at Cameo	10–24–55	1,350	--------	1,000	50	3.2	.00	C3–S1	−3.04	4.27	.27	14	351
1060	Colorado River near Palisade	11–1–42	[2] 2,620	--------	1,370	49	3.7	.00		−4.01	2.57	.23	25	0
1065	Colorado River at Grand Junction	10–24–57	--------	--------	1,090	41	2.6	.00		−4.65	2.81	.25	16	0
		5–27–58	22,700	High	316	--------	--------	.00	C2–S1	−2.26	1.98	.29	2.0	2
		8–18–58	273	Low	2,080	41	3.8	.00	C3–S1	−10.01	1.95	.15	49	0
Gunnison River basin, Colorado														
1090	Taylor River below Taylor Park Reservoir.	6–18–58	345	--------	77	17	0.2	0.00	C1–S1	−0.64	0.66	0.30	0.6	75
1125	East River at Almont	10–23–57	130	Medium	289	6	.2	.00	C2–S1	−2.84	2.42	.30	.7	0
		5–20–58	1,950	High	166	--------	--------	.00	C1–S1	−1.56	1.33	.30	.6	16
1125A	Gunnison River at Almont	10–19–45	[3] 200	Medium	263	7	.2	.00	C2–S1	−2.58	2.29	.30	1.0	2
		5–2–46	[3] 860	High	185	5	.1	.00	C1–S1	−1.78	1.52	.30	.8	9
1145	Gunnison River near Gunnison	10–8–45	[2] 342	Medium	271	7	.2	.00	C2–S1	−2.66	2.47	.30	1.3	26
		5–7–58	2,100	High	166	--------	--------	.00	C1–S1	−1.44	1.33	.30	.8	44
1150	Larkspur ditch at Marshall Pass.	7–1–58	--------	--------	56	--------	--------	.08		−.44	.56	.30	.6	98
1155	Tomichi Creek at Sargents	5–8–58	266	High	105	--------	--------	.00		−.81	.82	.30	.7	73
		8–6–58	36	Medium	107	--------	--------	.00		−1.62	1.61	.30	.7	68
1165	Razor Creek near Doyleville	10–23–57	3.4	Medium	364	13	.4	.00	C2–S1	−3.11	2.47	.29	1.8	0
		5–8–58	41	High	238	14	.3	.00	C1–S1	−1.98	1.78	.30	1.1	23
1180B	Cochetopa Creek below West Pass Creek, near Parlin.	10–23–57	18	Medium	251	20	.5	.18	C2–S1	−1.90	2.29	.30	1.3	161
		5–8–58	262	High	121	--------	--------	.06	C1–S1	−.81	1.02	.30	1.0	119
1190	Tomichi Creek at Gunnison	9–11–54	[2] 24	Low	404	--------	--------	.00	C2–S1	−3.77	3.94	.30	1.6	110
		5–8–58	799	High	177	--------	--------	.00	C1–S1	−1.37	1.40	.30	1.1	77
		8–5–58	92	--------	341	--------	--------	.00	C2–S1	−3.07	3.18	.30	1.3	96
1205	Gunnison River at Iola	9–11–54	[3] 409	Medium	234	--------	--------	.00	C1–S1	−1.98	2.14	.30	1.4	108
1220A	Cebolla Creek near Iola	3–8–46	[3] 50	Medium	132	23	.5	.00		−1.14	1.25	.30	1.3	96
1230	Soap (Sapinero) Creek at Sapinero.	3–8–46	[2] 22	Medium	261	31	.9	.00	C2–S1	−1.52	1.74	.29	2.4	119
		9–11–54	[3] 5	Low	475	36	1.4	.05		−2.58	3.33	.29	4.4	243
		5–14–58	493	High	96	--------	--------	.00	C1–S1	−.82	.79	.30	.6	63
1230A	Gunnison River at Sapinero	5–9–45	[3] 2,400	High	158	4	.1	.00		−1.46	1.27	.30	.5	26
		10–17–45	[3] 480	Medium	260	11	.3	.00	C2–S1	−2.40	2.29	.30	1.2	44
1245	Lake Fork at Gateview	5–21–58	1,430	High	119	--------	--------	.00	C1–S1	−.91	.61	.30	.8	0
		8–6–58	186	Medium	140	--------	--------	.00		−1.13	.79	.30	.7	0
1245A	Lake Fork near Sapinero	3–8–46	[3] 60	Medium	191	15	.3	.00		−1.52	1.28	.30	1.1	14
1260	Cimarron Creek near Cimarron	5–21–58	585	High	80	--------	--------	.00		−.60	.67	.30	.7	87
1260B	Cimarron Creek below Little Cimarron Creek, near Cimarron.	2–19–52	[3] 23	Low	529	25	1.0	.00	C2–S1	−3.62	1.68	.28	5.1	0
1270	Cimarron Creek below Squaw Creek, at Cimarron.	10–21–57	38	Medium	898	25	1.3	.00	C3–S1	−6.56	3.03	.27	9.8	0
		5–21–58	1,040	High	146	--------	--------	.00	C1–S1	−1.07	1.04	.30	.9	63
		8–10–58	28	Low	1,050	25	1.4	.00	C3–S1	−7.90	3.60	.26	12	0

See footnotes at end of table.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
	Gunnison River basin, Colorado—Continued													
1280	Gunnison River below Gunnison tunnel.	10-30-57	570	Medium	256	13	0.3	0.00	C2-S1	−2.15	1.93	0.30	1.1	16
		5-29-58	12,500	High	122	--------	--------	.00	C1-S1	−1.04	1.03	.30	.7	68
1285	Smith Fork near Crawford	8-12-58	12	Medium	160	--------	--------	.00		−1.12	1.04	.30	1.0	51
1290	Smith Fork at Crawford	5-14-58	359	High	91	--------	--------	.00		−.74	.69	.30	.7	58
		8-12-58	11	Medium	345	--------	--------	.00	C2-S1	−2.89	1.80	.29	2.3	0
1295	Iron Creek near Crawford	5-14-58	54	High	688	19	.8	.00		−5.68	2.62	.28	6.6	0
		8- 6-58	[3] 10	Medium	1,680	14	1.0	.00	C3-S1	−16.06	4.67	.23	23	0
		9-12-58	3	Low	1,770	17	1.2	.00		−16.85	3.51	.21	28	0
1295B	Smith Fork 8 miles west of Crawford.	6-26-58	--------	--------	1,790	15	1.1	.00		−17.18	2.54	.21	31	0
		8- 6-58	--------	--------	3,040	15	1.5	.00	C4-S1	−31.72	.88	.05	84	0
1315	Muddy Creek at Bardine	10-24-57	62	Medium	262	15	.4	.24	C2-S1	−2.20	2.61	.30	1.2	166
		5-14-58	1,030	High	175	--------	--------	.06	C1-S1	−1.58	1.72	.30	.7	103
1325	North Fork Gunnison River near Somerset.	8-12-58	1	Low	160	--------	--------	.10		−1.18	1.43	.30	1.0	129
1360	North Fork Gunnison River near Hotchkiss.	10-22-57	276	Medium	954	23	1.2	.00	C3-S1	−7.30	2.80	.27	11	0
		5-13-58	3,860	High	203	--------	--------	.00	C1-S1	−1.56	1.51	.30	1.0	58
		7-31-58	52	Low	1,980	25	2.1	.00	C3-S1	−16.44	2.86	.19	37	0
1370A	Peach Valley Wash near Austin	11- -45	--------	--------	4,350	53	8.1	.00	C4-S3	--------	--------	--------	100	--------
		7- 5-46	--------	--------	1,360	41	3.1	.00	C3-S1	−6.96	2.30	.25	17	0
		9-13-46	--------	--------	1,900	47	4.2	.00		−7.22	2.07	.22	27	0
1420A	Tongue Creek above Surface Creek, near Cory.	10-23-57	73	Medium	1,540	28	1.9	.00		−10.53	4.06	.24	19	0
		5- 6-58	1,199	High	563	25	1.0	.00	C2-S1	−3.91	2.78	.29	4.2	0
		7-31-58	14	Low	2,410	33	3.1	.00	C4-S1	−16.54	3.12	.16	47	0
1430	Surface Creek near Cedaredge	5- 6-58	301	High	83	--------	--------	.03	C1-S1	−.68	.77	.30	.6	91
1435	Surface Creek at Cedaredge	8- 8-58	17	Medium	195	--------	--------	.00		−1.46	1.14	.30	1.1	0
1440A	Gunnison River at Delta	9-10-54	--------	--------	2,440	35	3.4	.00	C4-S1	−15.42	2.27	.15	51	0
1460	Uncompahgre River below Ouray.	8-10-58	95	Medium	406	--------	--------	.00	C2-S1	−3.36	.58	.29	4.6	0
1470	Dallas Creek near Ridgeway	10-23-57	2.3	Low	816	10	.5	.00	C3-S1	−8.13	2.86	.27	9.4	0
		5- 6-58	157	High	404	--------	--------	.00	C2-S1	−3.72	2.53	.29	2.2	0
		8- 5-58	33	Medium	980	12	.6	.00	C3-S1	−9.92	3.61	.27	11	0
1471	Cow Creek near Ridgeway	5- 9-58	152	High	160	--------	--------	.06	C1-S1	−1.14	1.35	.30	1.1	119
1475	Uncompahgre River at Colona	5-28-58	2,150	High	273	--------	--------	.00	C2-S1	−2.32	1.63	.30	1.5	0
		8- 7-58	193	Medium	781	16	.7	.00	C3-S1	−6.94	2.83	.28	8.2	0
1475A	Uncompahgre River above South Canal, at Uncompahgre.	11- -45	[3] 111	Medium	856	16	.8	.00		−7.91	2.66	.27	11	0
		7- 5-46	[3] 291	High	613	17	.7	.00	C2-S1	−5.89	2.21	.28	6.1	0
		9-13-56	[3] 21	Low	840	22	1.1	.00	C3-S1	−6.88	2.56	.28	8.0	0
1485A	Uncompahgre River near Montrose.	8- 8-48	[3] 237	Medium	488	--------	--------	.00	C2-S1	−4.35	2.45	.29	3.6	0
1490A	Drain (Cedar Creek) 5 miles east of Montrose.	11- -45	--------	--------	17,300	71	31	.00	C4-S4	--------	--------	--------	100	--------
		7- 5-46	--------	--------	2,700	59	7.5	.00	C4-S2	−4.91	1.11	.12	59	0
		9-13-46	--------	--------	3,820	65	10	.00	C4-S3	−2.99	.46	.02	95	0
1490B	Cedar Creek near Montrose	11- -45	--------	--------	1,960	27	2.3	.00	C3-S1	−15.07	2.21	.19	37	0
		7- 5-46	--------	--------	1,850	34	2.8	.00		−12.08	2.27	.20	33	0
		9-13-46	--------	--------	2,220	38	3.5	.00		−12.66	2.15	.18	39	0
1490C	Spring Creek near Montrose	11- -45	--------	--------	1,660	23	1.7	.00		−14.59	3.27	.22	28	0
		7- 5-46	--------	--------	1,310	16	1.0	.00		−13.24	4.63	.25	16	0
		10-23-57	49	--------	1,440	--------	--------	.00		−11.90	2.28	.24	21	0
1490D	Ironstone canal near Olathe	11- -45	--------	--------	2,070	33	2.9	.00		−13.37	2.37	.18	39	0
		7- 5-46	--------	--------	970	25	1.4	.00		−7.82	2.72	.26	12	0
		9-13-46	--------	--------	1,400	29	1.9	.00		−8.26	2.79	.26	14	0
1490E	Loutzenhizer Wash at Garnet headgate near Delta.	11- -45	--------	--------	4,080	45	6.2	.00	C4-S2	--------	--------	--------	100	--------
		7- 5-46	--------	--------	2,580	40	4.2	.00		−14.92	1.53	.12	61	0
		9-13-46	--------	--------	2,290	44	5.3	.00		−14.92	.95	.07	77	0
1491A	Garnet canal near Delta	11- -45	--------	--------	2,810	40	4.4	.00		−14.74	1.82	.11	62	0
		7- 5-46	--------	--------	2,020	38	3.5	.00	C3-S1	−12.03	2.40	.19	38	0
		9-15-46	--------	--------	2,110	38	3.3	.00		−10.97	2.48	.21	31	0
1491B	Cummings Gulch near Delta	11- -45	--------	--------	10,210	72	23	.00	C4-S4	--------	--------	--------	100	--------
		7- 5-46	--------	--------	3,700	60	9.0	.00	C4-S3	--------	--------	--------	100	--------
		9-13-46	--------	--------	8,200	70	19	.00	C4-S4	--------	--------	--------	100	--------
1491C	Dry Creek below Cushman Creek, near Delta.	10-24-57	24	--------	1,310	15	.9	.00	C3-S1	−11.65	3.34	.25	16	0
		4-22-58	232	--------	257	--------	--------	.00	C2-S1	−2.48	2.48	.30	.9	70
1491D	Dry Creek near Delta	11- -45	--------	--------	3,430	39	4.7	.00	C4-S2	--------	--------	--------	100	--------
		7- 5-46	--------	--------	1,940	23	1.8	.00	C3-S1	−17.14	2.84	.22	28	0
		9-13-46	--------	--------	1,560	25	1.7	.00		−12.22	2.80	.23	22	0
1491E	Drain at California Mesa near Delta.	11- -45	--------	--------	3,650	23	2.8	.00	C4-S1	--------	--------	--------	100	--------
		7- 5-46	--------	--------	3,420	25	2.8	.00		--------	--------	--------	100	--------
		9-13-46	--------	--------	3,760	25	2.9	.00		--------	--------	--------	100	--------
1492A	Drain near Delta	11- -45	--------	--------	2,500	26	2.5	.00		−20.47	1.65	.12	60	0
		7- 5-46	--------	--------	2,580	22	2.0	.00		−24.44	1.64	.11	62	0
		9-13-46	--------	--------	2,380	22	2.0	.00		−20.40	1.99	.16	46	0
1495	Uncompahgre River at Delta	4-22-58	1,090	High	782	27	1.3	.00	C3-S1	−5.41	2.96	.28	7.8	0
		8- 8-58	119	Medium	2,340	30	2.8	.00	C4-S1	−17.62	2.41	.15	49	0
1495A	Gunnison River below Uncompahgre River, near Delta.	8- 8-48	[3] 1,800	--------	1,310	30	2.0	.00	C3-S1	−8.89	2.72	.24	18	0
		5-26-50	[3] 6,000	High	377	--------	--------	.00	C2-S1	−2.85	1.61	.29	3.0	0
1505	Roubideau Creek at mouth, near Delta.	4-22-58	811	High	350	--------	--------	.00		−2.98	2.26	.29	1.9	0
		7-31-58	57	Medium	2,030	19	1.6	.00	C3-S1	−19.28	2.15	.18	41	0
1515	Escalante Creek near Delta	10-21-57	40	Medium	439	26	.9	.40	C2-S1	−2.76	3.59	.30	2.9	264
		4-22-58	451	High	237	--------	--------	.00	C1-S1	−2.31	2.32	.30	.7	73
		7-31-58	.6	Low	970	32	1.9	.00	C3-S1	−6.11	6.46	.28	7.9	147

See footnotes at end of table.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954) [1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Gunnison River basin, Colorado—Continued														
1520	Kahnah Creek near Whitewater.	10-21-57	23	Medium	275	10	0.2	0.00	C2-S1	−2.38	1.65	0.30	1.4	0
		5- 7-58	150	High	190	--------	--------	.00	C1-S1	−1.70	1.74	.30	.9	80
1520A	Kahnah Creek near mouth, near Whitewater.	5- 7-58	55	Medium	902	25	1.3	.00	C3-S1	−6.38	2.45	.27	11	0
		7-30-58	.5	Low	3,360	36	4.2	.00	C4-S2	--------	--------	--------	100	--------
1520C	Gunnison River at Whitewater	11-11-50	[3] 510	--------	2,410	31	2.9	.00	C4-S1	−16.97	2.58	.16	48	0
		9-10-54	[3] 967	Medium	2,090	28	2.4	.00	C3-S1	−15.38	2.54	.19	38	0
1525	Gunnison River near Grand Junction.	9- -56	[2] 341	Low	2,520	32	3.2	.00	C4-S1	−17.43	1.43	.12	60	0
		2- -57	[2] 986	Medium	1,550	33	2.5	.00	C3-S1	−9.55	2.77	.23	24	0
		6- -57	[2] 19,630	High	360	18	.5	.00	C2-S1	−2.70	2.07	.29	2.3	0
Colorado River Basin between the Gunnison and Green Rivers														
1530A	Little Salt Wash near Fruita, Colo.	4-18-58	[4] 21	--------	1,410	48	3.7	0.00	C3-S1	−4.81	2.81	0.23	22	0
		7-30-58	[4] 29	--------	2,030	43	3.9	.00		−9.05	2.36	.17	43	0
1530C	East Salt Creek near Mack, Colo.	10-25-57	[4] 115	High	3,920	39	5.1	.00	C4-S2	--------	--------	--------	100	--------
		4-18-58	[4] 21	--------	2,190	45	4.4	.00	C3-S2	−9.68	3.86	.19	37	0
		7-30-58	[4] 4.6	Low	4,650	36	5.0	.00	C4-S2	--------	--------	--------	100	--------
1530D	West Salt Creek near Mack, Colo.	7-30-58	[4] 45	--------	1,510	42	3.2	.00	C3-S1	−6.52	2.37	.21	28	0
1635	Colorado River near Colorado-Utah State line.	10-22-57	[4] 6,000	Medium	1,380	35	2.5	.00		−7.65	2.68	.24	21	0
		5-29-58	[4] 45,300	High	337	--------	--------	.00	C2-S1	−2.51	1.94	.29	2.1	0
		8-12-58	[4] 1,300	--------	2,070	36	3.2	.00	C3-S1	−11.95	1.99	.16	45	0
1635A	Little Dolores River near Colorado-Utah State line.	10-23-57	[4] 2.3	--------	539	15	.6	.00	C2-S1	−4.73	4.60	.29	2.3	37
		5- 1-58	[4] 28	--------	301	--------	--------	.00		−2.62	2.43	.30	1.2	26
		9-17-58	[4] .1	Low	1,560	29	2.0	.00	C3-S1	−10.50	4.01	.22	27	0
1650	Dolores River below Rico, Colo.	10-25-57	[4] 42	--------	467	0	.0	.00	C2-S1	−4.87	2.12	.29	4.0	0
		5- 7-58	[4] 646	--------	202	--------	--------	.00	C1-S1	−1.95	1.48	.30	.7	0
1660A	Dolores River 4 miles above Dolores, Colo.	4-14-48	1,580	--------	187	--------	--------	.00		−2.00	1.68	.30	.6	0
1665	Dolores River at Dolores, Colo.	5-16-41	4,080	High	234	12	.3	.00		−1.81	1.52	.30	.4	2
		11-15-56	25	Low	476	19	.7	.00	C2-S1	−3.40	1.34	.28	5.4	0
		4- 8-57	100	Medium	421	19	.6	.00		−2.98	1.76	.29	4.1	0
1670	Lost Canyon Creek at Dolores, Colo.	5- 7-58	[4] 171	--------	69	--------	--------	.00	C1-S1	−.64	.57	.30	.5	54
1675	Dolores River near McPhee, Colo.	7-28-46	20	--------	311	--------	--------	.00	C2-S1	−2.68	2.36	.30	1.4	0
1685	Disappointment Creek near Cedar, Colo.	6- 9-53	--------	High	823	28	1.4	.00	C3-S1	−5.30	1.96	.27	9.6	0
		10-24-57	[4] 6.5	Medium	2,080	26	2.2	.00		−16.61	2.16	.18	41	0
		8- 6-58	[4] .5	Low	6,440	47	8.7	.00	C4-S3	--------	--------	--------	100	--------
1685A	Dolores River at Gladel, Colo.	8-13-47	--------	--------	700	32	1.5	.00	C2-S1	−3.98	2.39	.27	8.4	0
1685B	La Sal Creek near La Sal, Utah.	7- 2-49	--------	--------	140	13	.2	.00	C1-S1	−.94	.90	.30	.8	61
		9- 1-49	--------	--------	360	16	.4	.00	C2-S1	−1.81	1.57	.30	1.5	14
1690B	La Sal Creek near Paradox, Colo.	12-15-54	--------	--------	--------	9	.3	.00		−3.43	3.16	.30	.8	7
1695	Dolores River at Bedrock, Colo.	10-25-57	[4] 149	--------	1,450	24	1.6	.00	C3-S1	−11.02	1.59	.22	26	0
		5- 8-58	[4] 3,410	High	324	--------	--------	.00	C2-S1	−2.72	2.20	.30	1.6	0
		8-11-58	[4] 5.1	Low	2,210	70	8.3	.00	C3-S2	−.01	1.02	.10	72	260
1710	West Paradox Creek near Bedrock, Colo.	5- 8-58	[4] 8.4	--------	566	--------	--------	.00	C2-S1	−5.07	2.31	.28	5.0	0
1710A	Dolores River near Uravan, Colo.	8-13-47	--------	Medium	12,400	75	25	.00	C4-S4	--------	--------	--------	100	--------
		5- 9-48	--------	High	373	35	1.2	.00	C2-S1	−1.93	1.99	.29	4.0	82
		11-12-50	--------	Low	32,200	93	95	.00	C4-S4	--------	--------	--------	100	--------
1725	San Miguel River near Placerville, Colo.	1-13-49	70	Medium	396	--------	--------	.00	C2-S1	−3.46	2.30	.29	2.4	0
		8- 7-58	[4] 1.8	Low	420	--------	--------	.00		−3.29	1.67	.29	2.9	0
1750A	Naturita Creek near Naturita, Colo.	1-12-49	--------	--------	2,580	26	2.4	.00	C4-S1	−20.85	2.46	.13	57	0
1755	San Miguel River at Naturita, Colo.	10-24-57	[4] 287	Medium	702	16	.7	.00	C2-S1	−6.02	2.54	.28	7.2	0
		5- 8-58	[4] 3,000	High	318	--------	--------	.00		−2.97	2.33	.30	1.3	0
		8- 7-58	[4] 86	--------	730	17	.7	.00		−6.12	2.27	.28	7.8	0
1765A	Tabeguache Creek near Uravan, Colo.	8-10-58	[4] .02	Low	614	33	1.5	.25		−3.59	4.63	.29	5.2	311
1770	San Miguel River at Uravan, Colo.	8-13-47	[3] 250	Medium	783	16	.7	.00	C3-S1	−6.85	2.05	.27	9.3	0
		5- 9-48	[3] 1,600	High	311	--------	--------	.00	C2-S1	−2.58	1.83	.29	2.0	0
		11-12-50	[3] 70	Low	1,420	13	.8	.00	C3-S1	−13.52	2.48	.24	21	0
1770B	San Miguel River at mouth, near Uravan, Colo.	8-13-47	[3] 250	Medium	802	18	.8	.00		−6.64	2.02	.27	9.5	0
		11-12-50	[3] 70	Low	1,690	29	2.2	.00		−11.28	1.20	.20	34	0
1770C	Mesa Creek near Uravan, Colo.	5- 9-48	--------	--------	291	--------	--------	.00	C2-S1	−2.74	2.73	.30	1.0	68
1790	Roc Creek near Uranium, Colo.	11-12-50	.1	Low	2,610	59	6.8	.00	C4-S2	−4.21	.62	.03	91	0
		5- 8-58	[4] 14	--------	250	--------	--------	.00	C2-S1	−1.35	1.51	.29	2.7	105
1790A	Dolores River near Uranium, Colo.	5-27-50	--------	--------	496	29	1.1	.00		−2.91	1.81	.28	5.9	0
		11-12-50	--------	--------	6,290	80	20	.00	C4-S4	--------	--------	--------	100	--------
1790B	Salt Creek Wash near Gateway, Colo.	9-29-51	--------	--------	44,400	88	85	.00		--------	--------	--------	100	--------
1790C	West Creek at Gateway, Colo.	5- 9-48	--------	--------	148	--------	--------	.00	C1-S1	−1.30	1.37	.30	.9	87
		10- 1-48	--------	--------	428	--------	--------	.00	C2-S1	−3.98	4.07	.30	1.4	91
1795	Dolores River at Gateway, Colo.	3- -49	386	Medium	2,680	64	8.0	.00	C4-S2	--------	--------	--------	100	--------
		9- -50	80.1	Low	5,280	72	14	.00	C4-S4	--------	--------	--------	100	--------
		5- -52	5,929	High	296	16	.4	.00	C2-S1	−2.27	1.94	.30	1.6	0
1800	Dolores River near Cisco, Utah.	3-18-32	[3] 450	Medium	--------	51	4.3	.00	--------	−4.29	2.11	.20	35	0
		5-21-32	[3] 5,600	High	--------	20	.6	.00	--------	−2.68	2.22	.29	2.5	0
		10-22-32	[3] 86	Low	--------	71	15	.00	--------	--------	--------	--------	100	--------
1805	Colorado River near Cisco, Utah.	9- -56	1,369	Low	2,350	37	3.5	.00	C4-S1	−12.91	1.39	.13	58	0
		2- -57	3,018	Medium	1,720	46	3.8	.00	C3-S1	−6.27	2.13	.20	33	0
		6- -57	48,040	High	360	19	.6	.00	C2-S1	−2.58	2.02	.29	2.4	0

See footnotes at end of table.

TABLE 27.—*Suitability of surface waters for irrigation in the subbasins in the Grand division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff (1954)	After Eaton (1954) [1]				
										Calcium *a* (Milliequivalents per liter)	Calcium *b* (Milliequivalents per liter)	Calcium *c* (Milliequivalents per liter)	Required leaching (percent)	Required gypsum (lb per acre-ft)
	Colorado River Basin between the Gunnison and Green Rivers—Continned													
1810	Onion Creek near Moab, Utah	4-19-47	[3]0.5	------	5,360	57	9.4	0.00	C4-S3	------	------	------	100	------
		10-22-57	[4]1.2	------	5,530	45	7.0	.00		------	------	------	100	------
		8-11-58	[4].3	Low	8,980	66	16	.00	C4-S4	------	------	------	100	------
1815	Professor (Rock) Creek near Moab, Utah.	3-17-47	[3].7	------	2,710	63	7.7	.00	C4-S2	------	------	------	100	------
		10-22-57	[4]1.6	------	1,370	23	1.4	.00	C3-S1	−10.36	2.17	0.23	24	0
		8-11-58	[4].03	Low	8,150	86	30	.00	C4-S4	------	------	------	100	------
1820	Castle Creek above diversions, near Moab, Utah.	5-8-58	[4]719	High	201	------	------	.00	C1-S1	−1.85	1.85	.30	1.4	70
		8-1-58	[4]1.1	Low	213	------	------	.00		−1.90	1.86	.30	.8	61
1820A	Castle Creek below Castleton, Utah.	7-1-49	------	------	2,650	50	5.2	.00	C4-S2	−7.20	.56	.04	85	0
1825	Castle Creek near Moab, Utah	3-17-47	[3].3	Low	1,830	44	3.7	.00	C3-S1	−7.15	1.92	.17	43	0
		9-21-47	3.3	------	2,730	47	5.0	.00	C4-S2	------	------	------	100	------
		5-8-58	[4]15	Medium	1,300	43	2.9	.00	C3-S1	−5.23	2.20	.23	24	0
1825A	Salt Wash near Moab, Utah	9-28-48	.5	------	2,430	76	11	.00	C4-S3	−2.01	.54	.04	98	606
1825B	Negro Bill Creek near Moab, Utah.	9-27-48	1.3	------	315	------	------	.00	C2-S1	−3.03	2.62	.30	1.3	0
1825C	Seven Mile Wash near Moab, Utah.	9-30-49	------	------	1,660	44	3.6	.00	C3-S1	−6.93	8.37	.24	22	393
1830A	Colorado River above Mill Creek, near Moab, Utah.	7-2-49	[3]22,900	High	410	31	1.1	.00	C2-S1	−2.04	1.53	.29	3.7	0
		9-1-49	[3]1,920	Low	2,100	31	2.3	.00	C3-S1	−9.96	1.44	.15	50	0
		Jan. 16-18, 21-24, 26, 1952.	[3]3,300	Medium	1,590	46	3.7	.00		−5.68	2.13	.21	30	0
1835	Mill Creek at Sheley tunnel, near Moab, Utah.	9-1-49	[3]6.0	Low	230	7	.2	.00	C1-S1	−1.96	1.79	.30	.9	30
1840	Mill Creek near Moab, Utah	8-22-56	6.8	Low	247	6	.1	.00		−2.28	2.04	.30	.7	14
		10-26-57	[4]13	Medium	238	6	.1	.00		−2.25	2.05	.30	.7	23
		5-9-58	[4]63	High	200	------	------	.00		−1.84	1.78	.30	.7	56
1845	Pack Creek at M4 Ranch, near Moab, Utah.	8-6-58	[4]1.4	------	963	17	.9	.00	C3-S1	−8.46	2.55	.26	12	0
1850	Pack Creek near Moab, Utah	7-2-49	[3].5	Low	1,530	17	1.0	.00		−12.14	3.00	.24	21	0
		5-8-58	[4]8.8	------	612	15	.6	.00	C2-S1	−5.16	2.55	.28	5.5	0
		8-6-58	[4]1.5	------	1,080	18	1.0	.00	C3-S1	−9.56	2.97	.26	14	0
1850B	Mill Creek at mouth, near Moab, Utah.	9-28-48	2.5	Low	1,290	14	.8	.00		−12.53	5.09	.26	15	0
1850C	Colorado River below Mill Creek, near Moab, Utah.	9-28-48	[3]2,400	Low	2,100	42	3.8	.00		−10.08	1.84	.15	48	0
1850D	Lockhart Creek near Moab, Utah.	9-28-48	[3]30	------	1,650	26	1.9	.00		−13.18	3.37	.22	27	0
1865	Indian Creek above Cottonwood Creek, near Monticello, Utah.	4-26-58	[4]50	High	266	------	------	.00	C2-S1	−2.46	2.36	.30	.9	47
1875	Indian Creek above Harts Draw, near Monticello, Utah.	4-26-58	[4]33	High	390	------	------	.00		−2.90	2.99	.30	1.6	91
1875A	Indian Creek near Moab, Utah	6-22-47	20	High	1,210	70	6.5	.98	C3-S2	−.01	4.09	.25	24	1,013
		9-29-48	[3].8	Low	548	47	2.2	.29	C2-S1	−1.90	3.23	.29	6.6	379
1875B	Colorado River near Moab, Utah.	6-22-47	[3]38,000	High	431	21	.7	.00		−3.16	1.94	.29	4.1	0
		9-29-48	2,630	Medium	2,100	40	3.7	.00	C3-S1	−10.47	1.80	.16	48	0

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[1] For good yield.
[2] Mean discharge.
[3] Estimated.
[4] From gage height or measurement at time of sampling.

TABLE 28.—*Transmountain diversions, in acre-feet, from the Gunnison River basin, water years 1914–57* [1]

Water year	Diversion		Total	Water year	Diversion		Total
	Larkspur ditch (Tomichi Creek)	Taber ditch (Cebolla Creek)			Larkspur ditch (Tomichi Creek)	Taber ditch (Cebolla Creek)	
1914		[2] 220	220	1936	536	254	790
1915		[2] 220	220	1937	115	4	119
1916		[2] 220	220	1938	255	35	290
1917		[2] 220	220	1939	167	258	425
1918		[2] 220	220	1940	12	278	290
1919		[2] 220	220	1941	480	72	552
1920		[2] 220	220	1942	0	28	28
1921		[2] 220	220	1943	0	238	238
1922		[2] 220	220	1944	0	77	77
1923		[2] 220	220	1945	0	243	243
1924		[2] 220	220	1946	76	549	625
1925		[2] 220	220	1947	448	559	1,007
1926		[2] 220	220	1948	0	163	163
1927		[2] 220	220	1949	394	0	394
1928		227	227	1950	24	255	279
1929		217	217	1951	121	396	517
1930		275	275	1952	422	308	730
1931		235	235	1953	217	182	399
1932		104	104	1954	0	174	174
1933		44	44	1955	16	31	47
1934		192	192	1956	35	167	202
1935	45	133	178	1957	0	788	788

[1] Does not include Tarbell ditch.
[2] Estimated.

TABLE 29.—*Summary of average annual dissolved-solids discharge between Colorado River near Cameo, Colo., and Colorado River near Cisco, Utah*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station	Dissolved-solids discharge (tons)
Colorado River near Cameo, Colo	1,578,000
Plateau Creek near Cameo, Colo	66,110
Gunnison River near Grand Junction, Colo	1,519,000
Dolores River near Cisco, Utah	460,200
Total	3,623,310
Colorado River near Cisco, Utah	4,120,000
Dissolved-solids increase in reach ... tons	496,690

TABLE 30.—*Annual contribution of dissolved-solids to the Colorado River between Colorado River near Cameo, Colo., and Colorado River near Cisco, Utah, water years 1934–57*

Plateau Creek near Cameo, Colo.: Water years 1937–57 computed on basis of annual flow-duration curves and a curve of relation of concentration of dissolved solids to water discharged based on 14 chemical analyses. Water years 1934–36 estimated on basis of comparable years of runnoff.

Dolores River near Cisco, Utah: Records for Dolores River at Gateway, Colo., used for water years 1948–51. Water years 1937–47 computed on basis of annual flow-duration curves and an average curve of relation of concentration of dissolved solids to water discharge. Water years 1934–36 estimated on basis of comparable years of runoff.

Water year	Annual dissolved-solids load, in tons per day							Increase in reach, in thousands of tons	
	Colorado River near Cameo, Colo.	Plateau Creek near Cameo, Colo.	Gunnison River near Grand Junction, Colo.	Dolores River near Cisco, Utah	Total inflow at four stations	Colorado River near Cisco, Utah	Increase in reach	Per year	Cumulative
1934	3,560	110	2,650	945	7,265	8,280	1,015	370	370
1935	3,660	230	3,330	1,180	8,400	10,470	2,070	756	1,126
1936	4,370	210	4,080	1,170	9,830	12,120	2,290	838	1,964
1937	4,180	147	3,950	1,290	9,567	11,980	2,413	881	2,845
1938	5,380	207	5,470	1,390	12,447	15,110	2,663	972	3,817
1939	4,140	148	4,120	1,040	9,448	11,640	2,192	800	4,617
1940	3,470	116	3,950	1,040	8,576	10,780	2,204	807	5,424
1941	4,390	205	5,280	1,600	11,476	14,960	3,484	1,272	6,696
1942	5,260	262	6,090	1,770	13,382	15,800	2,418	883	7,579
1943	4,220	169	4,420	1,160	9,969	12,620	2,651	968	8,547
1944	3,840	189	4,110	1,430	9,569	12,000	2,431	890	9,437
1945	4,160	184	4,140	1,210	9,694	11,760	2,066	754	10,191
1946	3,790	155	3,730	1,000	8,675	9,920	1,245	454	10,645
1947	4,440	179	4,200	1,130	9,949	12,190	2,241	818	11,463
1948	4,450	191	4,650	1,600	10,891	13,070	2,179	798	12,261
1949	4,460	187	4,410	1,660	10,717	12,900	2,183	797	13,058
1950	4,070	159	3,750	1,150	9,129	10,800	1,671	610	13,668
1951	4,220	112	3,200	781	8,313	10,250	1,937	707	14,375
1952	5,530	176	4,699	1,470	11,876	13,730	1,854	679	15,054
1953	4,160	137	3,700	1,080	9,077	10,690	1,613	589	15,643
1954	3,580	113	3,040	941	7,674	9,290	1,616	590	16,233
1955	3,830	132	3,190	1,030	8,182	9,230	1,048	383	16,616
1956	3,880	106	2,970	908	7,864	9,460	1,596	584	17,200
1957	5,220	192	5,180	1,620	12,212	13,920	1,708	623	17,823

TABLE 31.—*Summary of suspended-sediment discharge of Dolores and Colorado Rivers near Cisco, Utah*

Water year	Water discharge		Suspended sediment					
				Daily load (tons)			Concentration (ppm)	
	Cfs-days	Acre-ft	Load [1] (tons)	Average	Maximum	Minimum	Weighted mean	Maximum daily
1800. Dolores River near Cisco, Utah								
Mar. 8 to Sept. 30, 1951	63, 903	126, 760	518, 800	2, 510	[2] 150, 000	4	4, 010	----------
1952	547, 511	1, 086, 000	3, 979, 000	10, 870	138, 000	4	2, 690	17, 500
1953	146, 613	290, 800	692, 400	1, 900	[3] 111, 000	5	1, 750	27, 500
1954	105, 138	208, 500	1, 602, 000	4, 390	[3] [4] 442, 000	3	5, 640	74, 200
1955	181, 489	360, 000	2, 397, 000	6, 570	120, 000	1	4, 890	80, 500
1956	135, 947. 1	269, 700	1, 006, 000	2, 750	[3] 96, 100	<. 5	2, 740	42, 300
1957	547, 513	1, 086, 000	5, 467, 000	14, 980	[3] [4] 470, 000	0	3, 700	34, 000
1805. Colorado River near Cisco, Utah								
1930	3, 073, 820	6, 097, 000	18, 600, 000	50, 960	947, 000	----------	2, 240	----------
1931	1, 444, 695	2, 865, 000	9, 910, 000	27, 150	1, 520, 000	----------	2, 540	----------
1932	3, 371, 350	6, 687, 000	26, 400, 000	72, 130	767, 000	1, 400	2, 900	----------
1933	2, 334, 660	4, 631, 000	8, 190, 000	22, 440	324, 000	----------	1, 300	----------
1934	1, 119, 254	2, 220, 000	2, 720, 000	7, 450	138, 000	216	900	----------
1935	2, 360, 070	4, 681, 000	17, 840, 000	48, 880	470, 000	459	2, 800	----------
1936	2, 906, 660	5, 766, 000	17, 180, 000	46, 940	918, 000	243	2, 190	----------
1937	2, 351, 400	4, 664, 000	23, 560, 000	64, 550	1, 630, 000	637	3, 710	----------
1938	3, 741, 890	7, 422, 000	35, 700, 000	97, 810	879, 000	1, 040	3, 530	----------
1939	2, 143, 634	4, 252, 000	14, 470, 000	39, 640	409, 000	518	2, 500	----------
1940	1, 746, 223	3, 463, 000	9, 900, 000	27, 050	741, 000	451	2, 100	----------
1941	3, 315, 830	6, 576, 000	32, 200, 000	88, 220	1, 225, 000	543	3, 600	----------
1942	3, 885, 050	7, 706, 000	33, 850, 000	92, 740	2, 790, 000	443	3, 230	45, 800
1943	2, 589, 460	5, 137, 000	8, 173, 000	22, 390	----------	----------	1, 170	----------
1944	2, 976, 310	5, 903, 000	16, 070, 000	43, 910	----------	----------	2, 000	----------
1945	2, 726, 010	5, 407, 000	7, 510, 000	20, 580	----------	----------	1, 020	----------
1946	2, 048, 060	4, 062, 000	8, 018, 000	21, 970	----------	----------	1, 450	----------
1947	3, 050, 550	6, 051, 000	14, 200, 000	38, 900	870, 000	----------	1, 720	19, 500
1948	3, 304, 330	6, 554, 000	14, 980, 000	40, 930	706, 000	443	1, 679	26, 800
1949	3, 170, 000	6, 287, 000	8, 366, 000	22, 920	[3] 547, 000	0	977	18, 300
1950	2, 135, 410	4, 236, 000	4, 956, 000	13, 580	155, 000	132	860	7, 190
1951	1, 977, 050	3, 921, 000	5, 316, 000	14, 560	[3] 559, 000	84	996	30, 000
1952	3, 885, 890	7, 707, 000	15, 430, 000	42, 160	390, 000	175	1, 470	66, 300
1953	2, 035, 110	4, 037, 000	5, 283, 000	14, 470	[3] 639, 000	[2] 100	961	26, 300
1954	1, 174, 090	2, 329, 000	4, 864, 000	13, 330	[3] [5] 720, 000	195	1, 530	26, 800
1955	1, 633, 730	3, 241, 000	9, 970, 000	27, 320	414, 000	111	2, 260	18, 200
1956	1, 817, 250	3, 604, 000	6, 641, 000	18, 150	213, 000	72	1, 350	22, 400
1957	4, 278, 270	8, 486, 000	21, 540, 000	59, 010	[3] 930, 000	[4] 250	1, 860	21, 200

[1] Includes estimated loads for missing days.

[2] Computed from water-sediment discharge curves.

[3] Computed by subdividing day.

[4] Computed from estimated concentration graph.

[5] Computed from partly estimated concentration graph.

TABLE 32.—*Water budget, Grand division*

	Average annual (acre-ft)
Outflow from the division	5,534,000
Transmountain diversions	453,400
Irrigation consumptive use	739,100
Domestic and industrial consumptive use	8,800
Evapotranspiration loss	[1] 21,913,000
Total	28,648,300

[1] Includes 216,000 acre-feet estimated evaporation from water surfaces.

TABLE 33.—*Summary data on utilization of surface water in the Grand division for developments existing in 1957*

Water use	Subbasin			Total in division
	Colorado River Basin above the Gunnison River	Gunnison River basin	Colorado River Basin between the Green and Gunnison Rivers	
Storage reservoirs having usable capacities greater than 1,000 acre-feet:				
Number	16	10	7	33
Total usable capacity acre-ft	659,400	130,100	42,100	831,600
Transmountain diversions:				
Number	13	3	1	17
Acre-feet exported (average annual)	[1] 353,100	[1] 300	[2] 100,000	453,400
Irrigation:				
Acres irrigated	192,500	269,400	121,300	583,200
Estimated consumptive use (average annual) acre-ft	190,300	348,200	200,600	739,100
Domestic and industrial use:				
Population (1960)	26,200	38,000	66,000	130,200
Estimated consumptive use (average annual) acre-ft	1,800	2,600	4,400	8,800
Hydroelectric powerplants:				
Number	8	0	7	15
Installed capacity kw	37,400	0	10,210	47,610

[1] Diverted across the Continental Divide.

[2] Diverted to San Juan River basin.

TABLE 34.—*Summary of average annual water, dissolved-solids, and suspended-sediment discharges from the subbasins in the Grand Division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Data	Subbasin			Grand division
	Colorado River Basin above the Gunnison River	Gunnison River	Colorado River Basin between the Gunnison and Green Rivers	
Drainage area sq mi	8,670	8,020	9,810	26,500
Water discharge acre-ft	3,168,200	1,884,000	[1] 481,800	[1] 5,534,000
Dissolved-solids discharge:				
Total tons	1,644,100	1,519,000	1,041,500	4,204,600
Probable from natural sources do	1,242,100	542,000	469,900	2,254,000
Do tons per sq mi	143	68	48	85
Probable from activities of man tons	402,000	977,000	571,600	1,950,600
Do tons per acre irrigated	2.1	3.6	4.7	3.4
Suspended-sediment discharge tons	9,269,000	2,067,000	9,159,000	20,495,000

[1] Does not include runoff from 2,400 square miles between the gaging station on Colorado River near Cisco, Utah, and the Green River.

Surface-Water Resources of the Green Division

By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

WATER RESOURCES OF THE UPPER COLORADO RIVER BASIN—TECHNICAL REPORT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 441-D

Analysis and appraisal of the water resources of the Green division of the Upper Colorado River Basin, with special emphasis on surface water and its quality

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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SURFACE-WATER RESOURCES OF THE GREEN DIVISION

By W. V. Iorns, C. H. Hembree, and G. L. Oakland

ABSTRACT

This chapter presents the results of an appraisal of the surface-water resources of the Green division, which includes the 44,700 square miles of the Green River drainage basin. Water uses existing in 1957 are reported; and interpretations are made of stream behavior, chemical quality of water, and sediment yield on the basis of the average that would have occurred if the 1957 developments had existed throughout water years 1914–57. The appraisal will be useful in planning future development of surface-water supplies and in evaluating changes in streamflow, chemical quality of water, and sediment yield that may result from water-development projects constructed after 1957.

Annual precipitation in the division averaged about 39,645,900[1] acre-feet in the water years 1914–57. Had the developments in 1957 existed throughout the 44-year period, the average annual consumption of water would have been about 728,900 acre-feet for irrigation and about 6,700 acre-feet for domestic and industrial uses. Annually, about 112,200 acre-feet would have been diverted out of the division, and 4,660,100 acre-feet would have been discharged in the Green River. Evapotranspiration probably accounted for the remaining 34,138,000 acre-feet, on the assumption that there was no ground-water outflow.

An average of about 19,300 tons of dissolved solids in 112,200 acre-feet of water was annually carried out of the division by the transmountain diversions existing in 1957. These diversions have caused an increase of about 7 parts per million in the weighted-average concentration of dissolved solids of the Green River at its mouth. The annual discharge of dissolved solids from the division in the Green River was computed to average about 2,928,100 tons for water years 1914–57 adjusted to 1957 conditions. About 1,750,200 tons of the total dissolved-solids discharge comes from natural sources; about 48,600 tons of this total comes from thermal springs. The activities of man in the division, other than the diversion of water out of the basin, consume water and result in the addition of dissolved solids to the stream system—about 1,177,900 tons annually. The major part of the increase is attributed to irrigation. Domestic, industrial, and irrigation use of water has caused about five times as much increase in the dissolved-solids concentration of the Green River at its mouth for each acre-foot of water consumed as the transmountain diversions have caused for each acre-foot of water carried out.

The average annual suspended-sediment discharge of the Green River is about 27,875,000 tons. Of this amount, about 3,677,000 tons comes from the Green River basin above the Yampa River; about 1,807,000 tons, from the Yampa River basin; about 7,339,000 tons, from the Green River basin between the Yampa and White Rivers including the White River basin; and about 15,051,000 tons, from the Green River basin below the White River.

Most of the surface water in the streams, where they emerge from the mountains, is suitable for domestic and industrial uses. Downstream, the water of most streams increases in concentration of dissolved solids. Many streams, especially in their lower reaches, have higher concentrations of some chemical constituents than the maximums accepted for domestic use. Some of the tributary streams in their lower reaches are not suitable for agricultural use during periods of low flow.

INTRODUCTION

PURPOSE AND SCOPE

This chapter presents in detail an appraisal of the surface water resources of the Green division. In the appraisal the following items were considered: The present utilization of the surface-water supplies, the flow characteristics of the streams and the effects of environmental factors on streamflow, the chemical-quality characteristics of the streams and the influence of environmental factors on the quality of water, and the sediment yield of the streams.

The basic data, hydrologic techniques, and criteria used in this appraisal are discussed and explained in chapter B, which also contains a glossary of technical terms used.

LOCATION AND SUBBASINS

The Green division of the Upper Colorado River Basin has a drainage area of 44,700 square miles and is that part of Colorado, Wyoming, and Utah drained by the Green River. In this report the division is divided into four subbasins (fig. 2).

1. The Green River basin above the Yampa River is the drainage area (17,000 sq mi) above the mouth of the Yampa River. Green River near Greendale, Utah, gaging station measures the outflow from all but about 1,900 square miles of this subbasin.

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[1] To facilitate checking of the figures, they are given as computed rather than rounded off to reflect the probable of accuracy.

2. The Yampa River basin is the drainage area of the Yampa River (8,000 sq mi). Yampa River near Maybell, Colo., and Little Snake River near Lily, Colo., gaging stations measure the outflow from all but about 800 square miles of this subbasin.
3. The Green River basin between the Yampa and the White Rivers, including the White River basin, is the drainage area of the Green River between the mouth of the Yampa River and a point just below the mouth of the White River (10,500 sq mi). Green River near Ouray, Utah, gaging station measures the outflow from this subbasin and the two upstream subbasins. This station is 3¼ miles below the mouth of the White River, but the intervening drainage area is only about 33 square miles.
4. The Green River basin below the White River is the fourth subbasin. It includes 9,200 square miles of drainage area between the White River and the mouth of the Green River. Green River at Green River, Utah, and San Rafael River near Green River, Utah, gaging stations measure the outflow from all but about 2,400 square miles of the Green division.

HYDROLOGIC ENVIRONMENT

PHYSIOGRAPHY AND STREAM NET

The Green division extends from the sources of the Green River in the northern end of the Wind River Range, where altitudes are almost 14,000 feet, to the confluence of the Green River with the Colorado River at an altitude of about 3,880 feet. The east and west boundaries of the division are formed by a series of mountain ranges and plateaus of the Rocky Mountain system. In a clockwise direction from the mouth of the Green River, the principal mountain ranges and plateaus are the Wasatch Plateau, Wasatch Range, Wyoming Range, Wind River Range, Park Range, and White River Plateau. The Uinta Mountains cut transversely across the division from west to east and merge into hills which merge into the foothills of the Park Range on the east (fig. 80).

Powell (1875, p. 149), one of the first to describe the topographic features of the division, said:

> Mountains, hills, plateaus, plains, and valleys are here found, as elsewhere throughout the earth, but in addition to these topographic elements in the scenic features of the region we find buttes, outlying masses of stratified rocks, often of great altitude, not as dome-shaped or conical mounds but usually having angular outlines. Their sides are vertical walls, terraced or buttressed, and broken by deep, reentering angles, and often naked of soil and vegetation. Then we find lines of cliffs, abrupt escarpments of rock of great length and great height, revealing the cut edges of strata swept away from the lower side. Thirdly, we find canyons, narrow gorges, scores or hundreds of miles in length and hundreds or thousands of feet in depth, with walls of preciptous rocks.

The central part of the Wind River Range is a rugged wilderness of granitic spires and massive buttresses, formed by prolonged erosion of the anticlinal range. The higher, central part, is a large plateau that bears the imprint of past glaciation. Here, countless sparkling lakes of glacial origin form a band astride the sometimes indistinct divide. On the western side, where glaciers spilled off the high plateau into the valleys below, great glacier-gouged lakes protrude like tongues from the monutain canyons. Along the highest ridge, which reaches an altitude of 13,785 feet at the top of Gannett Peak, glaciers are still actively eroding their cirques.

Lakes are also numerous in the Uinta Mountains, the Wasatch and Park Ranges, and the White Plateau. Many are of glacial origin and are the beginning of the principal streams in the division. The rough topography and cool moist climate of the mountains are in great contrast to the broad and, in some places, deeply-gorged, valleys of the arid interior.

The Green River basin and Uinta Basin are the two principal structural basins of the Green River drainage basin. The Green River basin encompasses almost all the area north of the Uinta Mountains. The Uinta Basin is the area south of the Uinta Mountains and north of the Tavaputs Plateau, and includes the drainage basins of the Duchesne and White Rivers.

The rocks that compose the area range from Precambrian to Recent in age. In them are recorded the earth movements and the erosional and depositional history of the division. Rocks of Precambrian age are exposed in the Uinta Mountains and the Wind River and Park Ranges. Along the flanks of these mountains, rock formations of later age are exposed, in some places as narrow bands steeply dipping beneath even younger rocks. Along the western slope of the Wind River Range, rocks of pre-Quaternary age are completely blanketed by glacial deposits of Quaternary age. In the Wyoming Range, rocks of Pennsylvania to Cretaceous age have been so highly folded and contorted that they now stand almost vertically and are eroded into ridges and strike valleys. In the interior of the Green River basin and Uinta Basin, rocks of Tertiary age are at the surface or beneath a shallow soil mantle. An interesting hypothesis of the history of the Colorado Plateau during the Tertiary and Quaternary ages and the episodes of mountain building, erosion, and deposition which formed the topography of most of the division as it is today is contained in Professional Paper 279 (Hunt, 1956, p. 73–87).

The outcrop areas of rock formations are classified into eight units having similar hydrologic properties

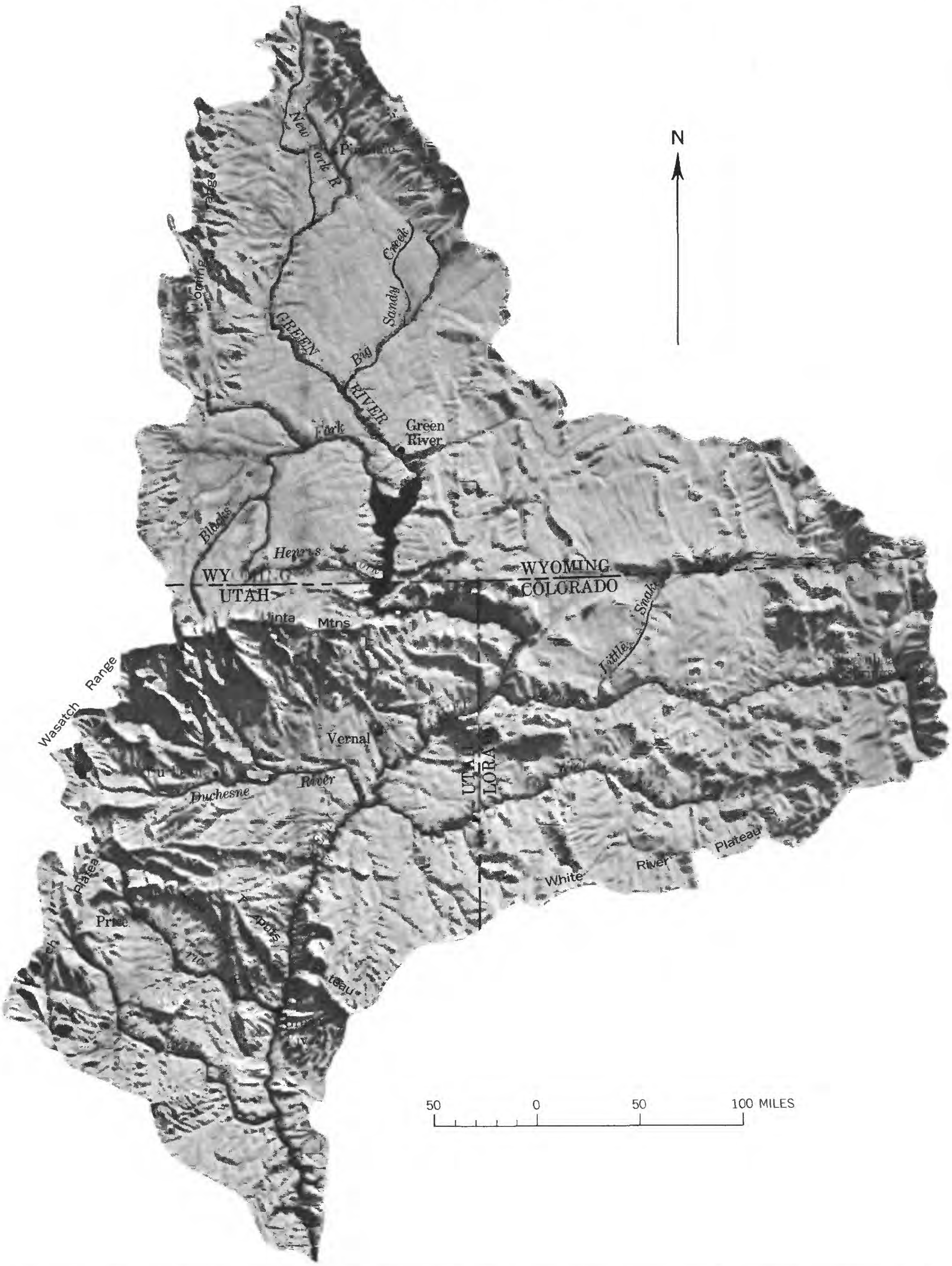


FIGURE 80.—Relief map of the Green division of the Upper Colorado River Basin. Adapted from photograph by I. V. Goslin, Upper Colorado River Commission.

(chap. A, table 1, pl. 2). The hydrologic units and their characteristics are discussed in chapter A.

The stream patterns and the influence of the rocks and structural features on these patterns have been the subject of discussion and speculation by many writers. Some of the earliest work on this problem was done by Powell and Davis (Hunt, 1956, p. 65). More recently, Bradley (1936, p. 168–189) and Hunt (1956, p. 65–71) have discussed the work of Powell and Davis and have given additional explanations for some of the anomalies of the drainage system.

The seeming disregard by the rivers of uplifted areas, Powell thought, was due either to antecedence or to the rivers being able to maintain their course across an uplift by downcutting during the period of uplift. Davis thought the streams were superimposed from a drainage pattern established on an overlying strata. Hunt (1956, p. 65) did not believe that these explanations were completely adequate and postulated that the present stream courses are the result of a combination of the two concepts and coined the word "anteposition" to apply to the sometimes concurrent processes of antecedence and superimposition. The routes of the Green and Yampa Rivers across the uplifted Uinta Mountains and associated structural features are classic examples of anteposition. (See fig. 80.)

The headwaters of the Green River are a network of streams originating in the Wind River and Wyoming Ranges (see fig. 80, pl. 6). The river flows southward in Wyoming across a desert plateau to near the eastern end of the Uinta Mountains. Here it is deflected eastward by the Uinta Mountains, from where it flows southwestward and then generally southward to its junction with the Colorado River. Big Sandy Creek and Blacks and Henrys Forks are the principal streams that enter the Green River in the desert plateau area of Wyoming. The Yampa and White Rivers, whose headwaters are on the western slope of the Rocky Mountains in Colorado, are the principal tributaries from the east. The Duchesne River, which drains most of the south slope of the Uinta Mountains, and the Price and San Rafael Rivers, which head on the eastern slope of the Wasatch Plateau, enter the river from the west in Utah.

SOILS

The unconsolidated material mantling the consolidated rocks, except in small areas of glacial deposits and alluvium along the streams, is principally residuum developed from the underlying or nearby parent rocks. In the mountains where moisture and temperature are favorable, moderately mature soils have developed in the upper part of the residuum. Where the parent rocks are mainly crystalline rocks of igneous, metamorphic, or volcanic origin, the residuum is relatively permeable and contains minerals that are relatively insoluble. In some of the mountainous areas, such as the Wasatch Plateau and Wyoming Range, sedimentary rocks predominate and the residuum contains large quantities of the soluble minerals that are present in the parent rock.

The broad valleys of the interior basin are predominately underlain by rocks of marine and continental origin of Cretaceous and Tertiary ages. Residuum developed from these rocks is generally high in soluble minerals. The interior has an arid climate, and the soils which have developed are shallow and immature.

The river alluvium in the headwater areas is principally derived from resistant rocks, is generally permeable, and for the most part contains minerals that are relatively insoluble. Downstream from the headwater areas, the river alluvium is a complex mixture derived from weathering of rocks from nearby and upstream sources. Where the underlying and nearby rocks are Mancos Shale and the Green River and Uinta Formations, the river alluvium generally contains an abundance of soluble minerals.

Plate 7 shows the irrigated lands, and by comparing this plate with plate 1, the type of rocks underlying the irrigated lands can be determined.

CLIMATE

EFFECT OF TOPOGRAPHY AND ALTITUDE

Climate in the Green division is markedly affected by altitude. The climate ranges from extremes of high precipitation and cold temperature in the mountains to scant precipitation and high summer temperature in the interior basins. The 5-degree change in latitude from the southern to the northern part also has an effect on temperature.

The mountains along the western side act as partial barriers to the movement of Pacific airmasses that cross the division and the Uinta Mountains act as a barrier to north-south movement of airmasses. Cold, polar airmasses at times cover the area north of the Uinta Mountains. The area south of these mountains is at times affected by warm, moist airmasses from the Gulf of Mexico and by Pacific airmasses originating off the coasts of Southern California and Baja California.

PRECIPITATION

The precipitation during the period October to April is more effective in producing runoff than precipitation in the summer months. Most of the precipitation from October to April, particularly in the high mountains, occurs as snow. North of the Uinta Mountains, the average seasonal precipitation patterns for the summer and winter periods are generally similar, as Pacific airmasses predominate. The area south of the Uinta Mountains is more exposed to the moist airmasses from the south and has different summer and winter precipitation patterns. Summer storms of high intensity are more common in the southern part.

Average annual precipitation in the division ranges from less than 6 inches in the southern part of the division to more than 60 inches in the Wind River Range (pl. 6). Areas of low precipitation are near the mouth of the San Rafael River, in the lower Duchesne River valley, and in the central part of the Green River basin north of the Uinta Mountains. Monthly distribution of precipitation at representative stations is shown in figure 81.

The distribution of average annual precipitation is shown on plate 6. This map, which is adjusted for topography, exposure to airmass movement, and climatic factors, is based on precipitation data observed during calendar years 1921–50. The average annual precipitation for this period, as planimetered from the map, is 16.13 inches. The following tabulation shows the areal distribution of precipitation over the 44,700 square miles of drainage area:

Precipitation range (inches)	*Area (sq mi)*	*Precipitation range (inches)*	*Area (sq mi)*
60–70	15	16–20	5, 711
50–60	129	12–16	11, 112
40–50	582	10–12	6, 499
30–40	3, 006	8–10	5, 796
25–30	2, 857	6–8	5, 051
20–25	3, 761	4–6	181

In computing precipitation data applicable to the base period adopted for this study and for other periods, 16 index-precipitation stations located in or adjacent to the division were used (tables 1, 2; pl. 6). As explained in chapter B (pp. 44–45), precipitation records at the index stations were used to compute the average annual precipitation. The average annual precipitation for the 44-year base period thus computed was 16.63 inches. On the 44,700 square miles of drainage area, this would be equivalent to 39,645,900 acre-feet of water.

The year of highest precipitation was 1947, when the average precipitation in the basin was 21.10 inches; and the year of lowest precipitation was 1934, when the average was 10.78 inches. The precipitation in these years was about 27 percent and 35 percent above and below the 44-year annual average, respectively. As indicated by the annual quantities, the precipitation was generally above average from 1914 to 1930, below average from 1931 to 1940, about average from 1941 to 1952, and below average for 1953 to 1956.

TEMPERATURE AND EVAPORATION

The average monthly temperature and length of frost-free season at five locations in the Green division are shown in figure 81. Temperature and length of growing season are influenced by latitude and altitude.

Isopleths of average annual lake evaporation, from a map by Kohler and others (1959, pl. 2), are shown on plate 6. The isopleths are generalized and do not take into account large variations in topography and exposure which may influence evaporation considerably at specific locations.

The average annual evaporation from water surfaces in the division as estimated by Meyers (1962) is given in the following tabulation:

	Annual evaporation (acre-ft)
Principal reservoirs and regulated lakes	45, 000
Other lakes over 500 acres	5, 000
Principal streams and canals	48, 000
Small ponds and reservoirs	80, 000
Small streams	56, 000
Total	234, 000

VEGETATION

Native species of vegetation in the Green division, except in the cultivated areas, are about the same ones that existed before settlement. In areas having a favorable climatic environment, the net hydrologic effect of native vegetative cover has probably changed little in the last hundred years; however, in the arid areas where native vegetation is always in a precarious state of existence, overgrazing may have locally resulted in some changes in the hydrologic effect of native vegetation. Data of runoff from the arid part of the basin are not sufficient to determine if any hydrologic change has taken place in the water years 1914–57.

The more important native plant communities are alpine meadow, subalpine forest, montane forest, mountain brush, pinyon-juniper, big sagebrush, shadscale, blackbrush, greasewood, grassland, saltbush, and summer-cypress. The species in these communities are described in chapter C, pp. 80–81. Plate 7 shows the native vegetation zones in the Green division and figures 82–84 shows the typical vegetation in the area.

GREEN RIVER BASIN ABOVE THE YAMPA RIVER

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Eighteen reservoirs that have usable-storage capacities greater than 1,000 acre-feet have been constructed (1957) in the Green River basin above the Yampa River (table 3, and pl. 6). The combined usable-storage capacity of these reservoirs in 1957 was 141,140 acre-feet, and all these reservoirs are used for irrigation. The first five reservoirs listed in table 3 are natural mountain lakes that have fairly small dams built across the outlets.

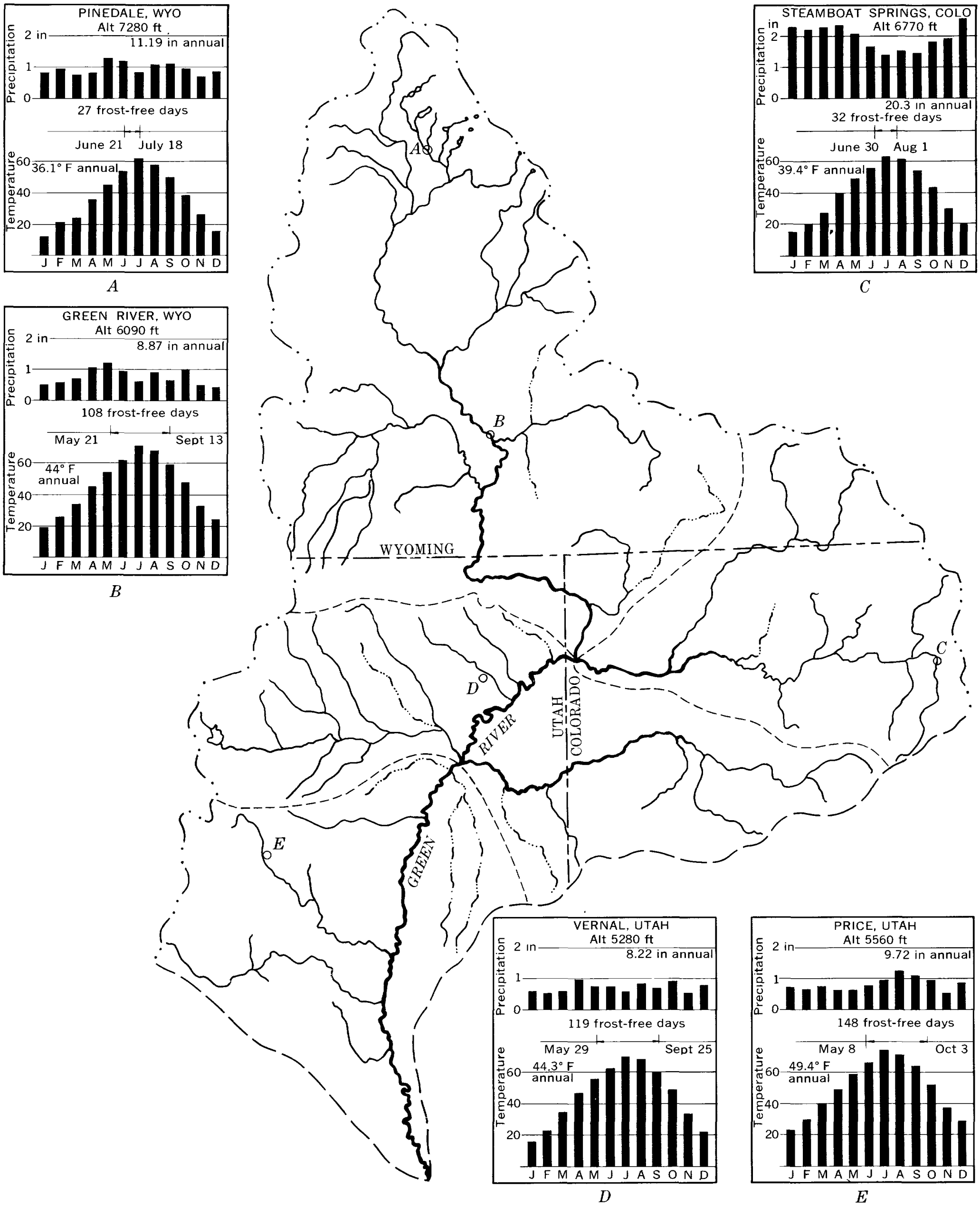


FIGURE 81.—Normal precipitation and temperature and frost-free seasons at representative stations in the Green division. Data from U.S. Weather Bureau normals (average for 1921–50 calendar years).

FIGURE 82.—Shadscale 22 miles south of La Barge, Wyo. Other shrubs present are nuttall horsebrush, big sagebrush, and rabbitbrush. Photograph by F. A. Branson.

FIGURE 84.—Pinyon-juniper about 10 miles north of Vernal, Utah. The trees are nearly all Utah juniper and have a very sparse understory of sand dropseed and Russian-thistle. Photograph by F. A. Branson.

FIGURE 83.—Greasewood along the Little Snake River 15 miles northwest of Maybell, Colo. This extensive pure stand is similar to that found on many square miles of the Upper Colorado River Basin. Photograph by F. A. Branson.

In addition to the reservoirs listed in table 3, numerous small lakes occur in the mountain areas and stock ponds are scattered throughout the subbasin. Most of the subbasin is at altitudes of more than 6,000 feet; and most lakes and reservoirs are at altitudes of more than 7,000 feet, where evaporation rates are relatively low.

TRANSMOUNTAIN DIVERSIONS

There are no known imports, and only one small export, of water from this subbasin. The Continental Divide ditch diverts water from the headwaters of Little Sandy Creek to Lander Creek in the North Platte River basin. The appropriation permit is for 13.8 cfs (cubic feet per second) to irrigate 964 acres, but no record of annual diversions is available.

IRRIGATION

The major use of water in the subbasin is for irrigation. The U.S. Bureau of the Census (1953) reported 255,500 acres of irrigated land in 1949. Between 1949 and 1957, the acreage was increased to about 258,400 acres through irrigation of new lands in the Eden project (table 4, and pl. 7). Of the irrigated lands, about 9,800 acres is in Utah, 500 acres in Colorado, and 248,100 acres in Wyoming. Except for a small increase in the later years, there was little change in the total irrigated acreage during the 1914–57 period. La Rue (1916, p. 133) estimated, on the basis of adjudicated water rights, that 248,000 acres were irrigated in the Wyoming part of this subbasin in 1913.

As most irrigated lands are at altitudes of more than 6,000 feet, the growing season is short and only the hardier forage crops are grown. Alfalfa, where grown, usually does not produce two full crops a year. Except on the Eden project near Farson, Wyo., irrigation consists chiefly of diverting snowmelt runoff onto the valley grasslands for several weeks while streamflow rates are high. This diversion is usually sufficient for the production of one cutting of wild hay.

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–57 average annual consumptive use of water in the subbasin by irrigation was about 218,000 acre-feet. The Commission estimated that about 226,300 acres was irrigated and that about

25,700 acres of land received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The 1960 population of the subbasin was only about 33,800, which averages about two persons per square mile. The largest communities and their population are: Rock Springs, 10,371; Green River, 3,497; Kemmerer, 2,028; Mountainview, 1,721; and Pinedale, 965. Principal means of livelihood are farming and ranching, mining, oil recovery, supplying these activities, and the tourist trade.

Rock Springs and Green River receive their water supply from the Green River. All other communities receive their supply from springs, wells, or mountain streams. Rock Springs treats its sewage waste before discharging the effluent into Bitter Creek, an intermittent stream. Inhabitants of a few small communities that are not along stream channels have septic tanks, but for the most part domestic wastes are discharged to the nearest stream channel.

Bituminous coal is mined in the vicinity of Kemmerer and Rock Springs, Wyo. Oil and gas fields have been partially developed, and large reserves have been explored in the vicinity of Big Piney. Extensive deposits of trona (sodium bicarbonate) are in the early stage of development. Only small amounts of water are used in the development of these deposits, and the waste products from the trona mines are ponded in isolated areas away from the streams.

One hydroelectric powerplant with an installed capacity of 180 kilowatts is on Pine Creek near Pinedale, Wyo.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Melting of snow that accumulates in the mountains provides most of the water supply. As temperatures rise in the late spring and early summer, the snow melts and causes the streams to rise. The streams then subside as the stored supply of snow is exhausted. Usually by late July, streams have subsided to near a base flow, which prevails until the cycle is repeated again the following spring. Relatively little runoff comes from much of the interior of the subbasin.

The seasonal patterns of the rise and fall of the streams are dependent on temperature and are similar, but the timing of peak flows and subsidence to base flows are somewhat staggered (fig. 85). Generally, the order of snowmelt runoff by streams is as follows: West-side streams, east-side streams, and streams draining the north slopes of the Uinta Mountains.

FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 30 stations. For 22 of these stations, curves representative of the 44-year base period adjusted to 1957 conditions were prepared. The historical and adjusted curves reduced to tabular form are given in table 5.

The usefulness of these curves in hydrologic studies, their characteristics, and the methods used to adjust flow-duration curves for short periods of record to the 44-year base period are explained in chapter B (pp. 45–48).

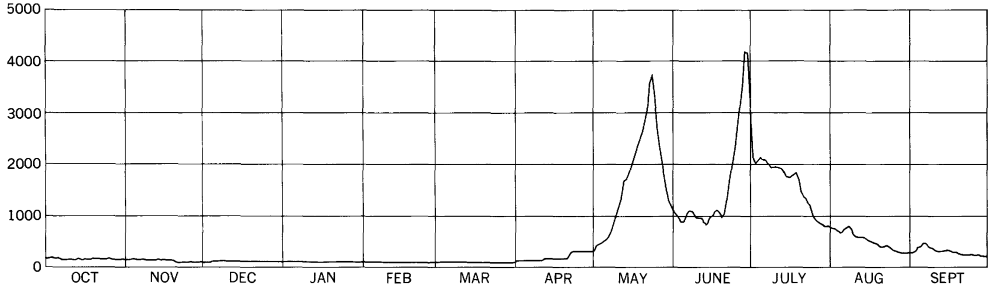
No streamflow record in the subbasin is complete for the 44-year period 1914–57, although records for some stations are complete except for a few years. Because little change in water developments occurred during the 44-year period, no adjustments for upstream developments were required to make the flow-duration curves representative of 1957 conditions; however, some minor changes occurred in irrigation and in storage on Big Sandy Creek and Blacks Fork. No adjustments for any effect that these changes had on the flow-duration curves for downstream stations were made because of lack of data; however, any error introduced in the flow-duration curves for downstream stations by this omission is negligible. For extending the record of Green River at Green River, Wyo., the records for the two stations operated "at" and "near" Green River were combined. For all practical purposes the discharge at the two sites is equivalent.

Table 6 outlines the methods used in adjusting the historical flow-duration curves to the 44-year base period and gives the author's rating of accuracy of the resultant long-term curves. Computations and data necessary to show the details of the adjustments are too voluminous for inclusion in this report.

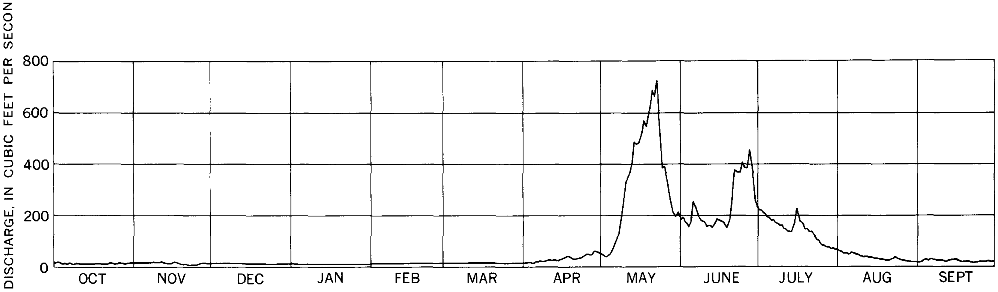
Typical flow-duration curves at four streamflow gaging stations are shown in figure 86. These curves show duration of water discharge for the Green River near its headwaters and downstream, and for tributary streams from the east and west sides of the basin.

The variability indices (Lane and Lei, 1950) and percentages of ground-water contribution to the stream systems (see chap. B, pp. 48–53) for the streams whose flow-duration curves are shown in figure 86 and for other selected streams are given in table 7. Figure 87 shows the relation between the two parameters.

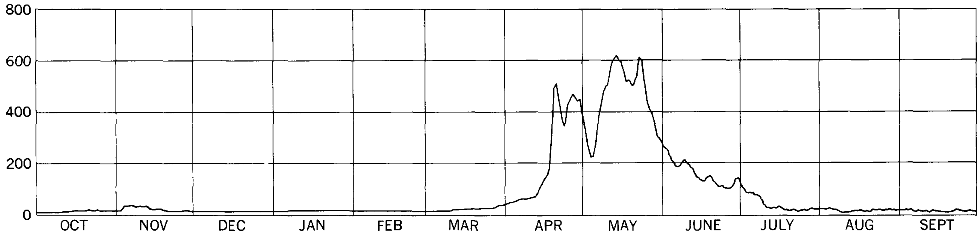
East Fork near Big Sandy, Wyo., has the highest variability index (0.72), and La Barge Creek near Viola, Wyo., has the lowest (0.28). The difference in slope of the flow-duration curves for the two stations is apparently caused by geologic and topographic factors. The East Fork drainage basin is underlain by relatively impermeable granitic rock, much of which is exposed. The drainage basin also has steep slopes. These factors would contribute to high variability-index



A. Green River at Warren Bridge, near Daniel, Wyo.



B. Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo.



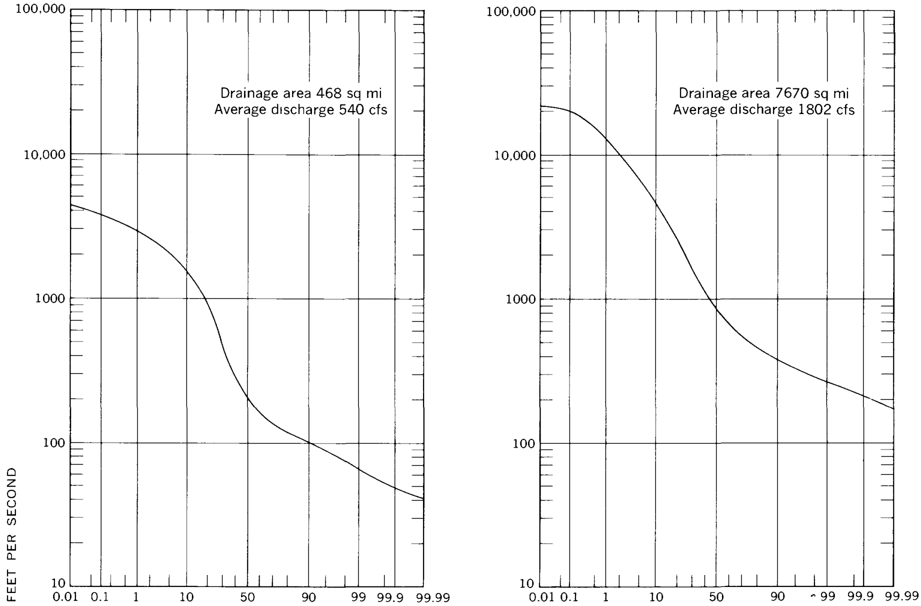
C. Hams Fork near Frontier, Wyo.

Figure 85.—Seasonal pattern of runoff of streams in the Green River basin above the Yampa River, 1954 water year.

values and little ground-water storage. The underlying rock in the La Barge Creek drainage basin is fractured limestone and other permeable rocks, covered mostly with residuum and alluvium. The valleys of the streams are filled with permeable alluvium, and the drainage basin has relatively flat slopes. These factors would be conducive to ground-water storage and hence to a low variability index for the basin. The drainage basin of Fontenelle Creek, which has the next lowest variability index and next highest percentage of ground-water contribution, has about the same environmental factors as La Barge Creek basin.

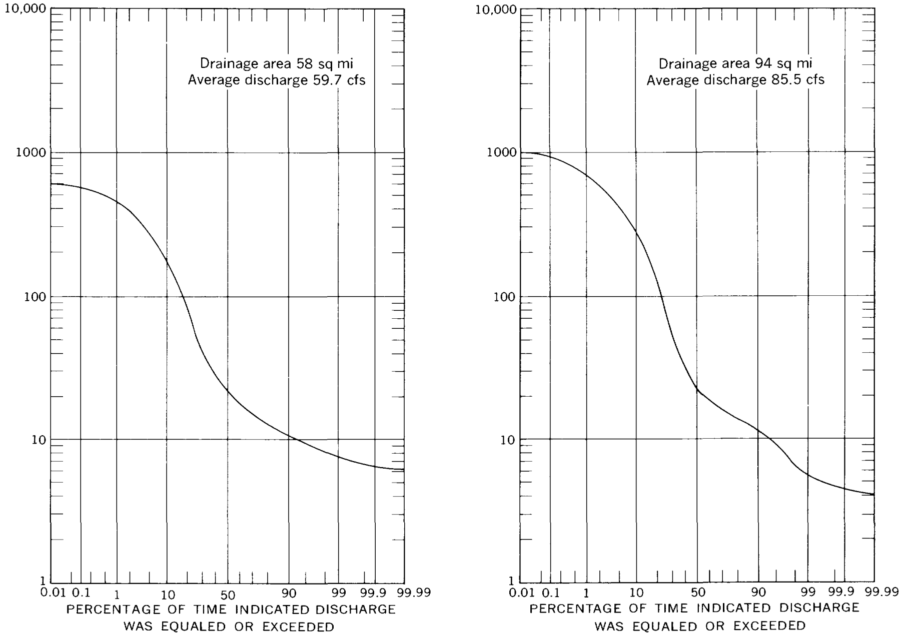
The drainage basin above the gaging station on Hams Fork near Elk Creek ranger station, Wyoming, which lies just west of the Fontenelle Creek drainage basin, is underlain principally by relatively impermeable shales. Though other environmental factors are similar to the Fontenelle Creek drainage, the impermeable shales would be conducive to a high index value and little ground-water storage. The variability indices and percentages of ground-water contribution for East Fork at Newfork, Wyo., and Green River at Green River, Wyo., are modified by upstream irrigation.

Explanations of the order of magnitude of the variability indices and ground-water contributions of the other stations in table 7 are not made as it is impossible to evaluate the cumulative effect of the various hydrologic factors where the values are grouped in a small



A. Green River at Warren Bridge, near Daniel, Wyo.

B. Green River at Green River, Wyo.



C. North Piney Creek near Mason, Wyo.

D. Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo.

Figure 86.—Flow-duration curves for streams in the Green River basin above the Yampa River, water years 1914–57 adjusted to 1957 conditions.

range. Logical explanations can be made only where the differences are large.

VARIABILITY OF ANNUAL RUNOFF

Annual water discharges at three gaging stations for the base period are shown in figure 88. None of the station records were complete for the base period, and the records for missing years were estimated. The record for Green River at Warren Bridge, near Daniel, Wyo., was estimated for water years 1914–31; that for Green River at Green River, Wyo., was estimated for water years 1914 and 1940–51; and that for Hams Fork near Frontier, Wyo., was estimated for water years 1914–17 and 1933–45. The histogram for Green River at Warren Bridge, Wyo., exhibits considerably less variability of annual discharges than the histograms for the other two stations.

The coefficients of variation of annual discharges (chap. B, pp. 53–57) for 12 selected streams are given in table 8. These coefficients are also shown on plate 6. Except for New Fork near Boulder, Wyo., and Green River at Green River, Wyo., the period from about 1940 to 1957 was used in computing the coefficients.

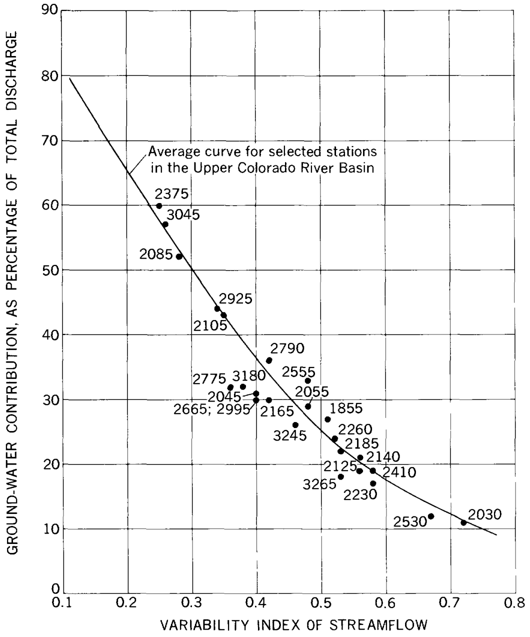


FIGURE 87.—Relation between the variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water for selected stations in the Green division, water years 1914–57 adjusted to 1957 conditions.

All streams draining the Wind River Range, except Green River at Warren Bridge near Daniel, Wyo., have an average coefficient of about 0.25. The coefficients of variation of the streams draining the Wyoming Range probably range from about 0.32 at the northern end to about 0.46 at the southern end of the mountains. The coefficients of streams draining the north slope of the Uinta Mountains, except Blacks Fork near Millburne, Wyo., probably average between 0.25 and 0.29.

If the ground-water storage in the drainage basins above the gaging stations on Green River at Warren Bridge, near Daniel, Wyo., and Blacks Fork near Millburne, Wyo., is sufficient to maintain the streams in drought years and cause the relatively low coefficients of variation, the variability indices for these two stations should also be relatively low, but they are not (table 7). The cause for the lack of consistency is unknown.

If the average annual discharge and coefficient of variation of the stations listed in table 8 are assumed to be representative of the 44-year base period, the data may be used for estimating probable future streamflow for periods of various length and confidence limits, as explained in chapter B (pp. 57–58). The data for Green River at Warren Bridge, near Daniel, Wyo., may be used as an example. The average annual discharge at Warren Bridge for the water years 1914–57 is 532 cfs and the coefficient of variation is 0.18. The probable deviations for a 50 percent chance for periods of various length in the future from the 44-year average annual discharge are given in the following tabulation:

Period of years	*Probable deviation, in cfs, from average annual discharge*	*Period of years*	*Probable deviation, in cfs, from average annual discharge*
1	±64	10	±35
2	±55	20	±29
4	±46	44	±25

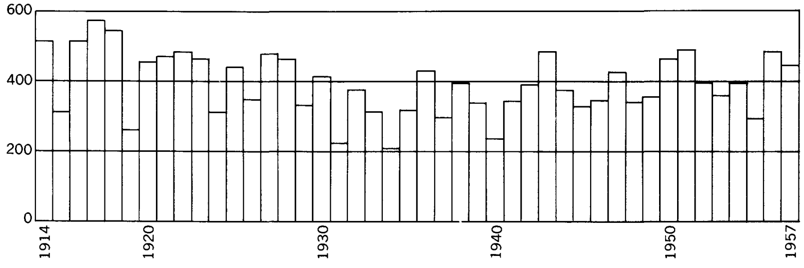
CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

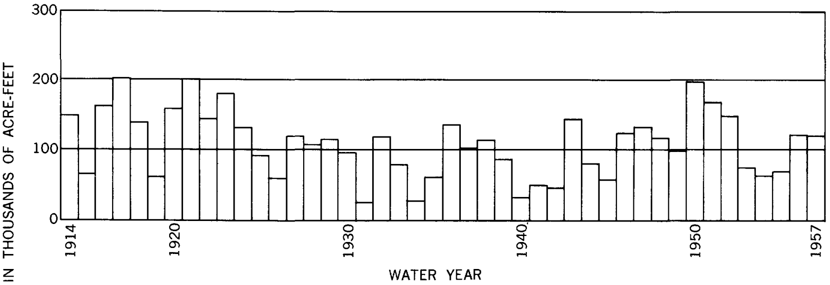
Daily chemical-quality data have been obtained at five stations in the Green River basin above the Yampa River. Monthly and annual weighted-average chemical analyses of water at these stations are given in the basic data report (Iorns and others, 1964, tables 187–192).

In addition to the daily data obtained at the five stations, chemical-quality analyses of streams at other sites in the subbasin have been obtained. The dissolved-solids discharge for the daily stations and for some of the other sites have been computed (table 9).

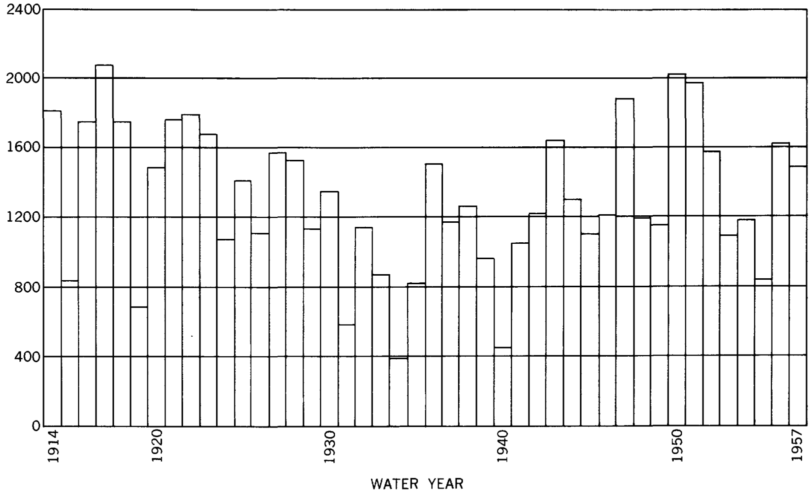
Duration tables of dissolved-solids concentration and discharge for the stations listed in table 9 are given in tables 10 and 11. In the computation for these tables, the analyses of water samples, water discharge at the



A. Green River at Warren Bridge, near Daniel, Wyo.



B. Hams Fork near Frontier, Wyo.



C. Green River near Green River, Wyo.

Figure 88.—Variability of annual discharges of streams in the Green River basin, above the Yampa River, water years 1914–57.

time of sampling, curves of relation of dissolved-solids concentration and water discharge, and flow-duration curves of water discharge were used. In Chapter B (pp. 58–59) the method used to compute the data is described.

The average annual dissolved-solids discharge for streams in and along the flanks of the Wind River Range ranges from 4 to 75 tons per day and the dissolved-solids yield ranges from 28 to 63 tons per square mile (table 9). Dissolved-solids discharges and yields for streams in the Uinta Mountains are similar in magnitude to those in the Wind River Range.

Most of the water passing the gaging station on Green River near Greendale, Utah, comes from the mountain area, which is relatively small compared with the area of the drainage basin; but a large part of the dissolved solids passing the station comes from the interior, which produces little runoff (table 9 and fig. 89). For example, of the water and dissolved solids passing the Greendale station, about 42 percent of the water and about 11 percent of the dissolved solids come from the mountainous area above Green River at Warren Bridge, New Fork River below New Fork Lake, Pine Creek above Fremont Lake, and East Fork at New Fork gaging stations. The area above these stations is only about 6 percent of that above Greendale station. In contrast, about 3 percent of the water and about 24 percent of the dissolved solids come from the interior area above Green River at Green River gaging station and below Green River near Fontenelle, Big Sandy Creek at Leckie Ranch, and Little Sandy Creek near Elkhorn gaging stations. This area is about 24 percent of that above Greendale station.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in dissolved-solids concentration of most streams is typical of snowmelt-type streams and similar to that illustrated in figure 90. The concentrations are lowest in the months of maximum discharge—May, June, and July—and concentrations are highest in the months of low flow when the streams are maintained largely by ground water. The seasonal pattern does not change much in years of low and high runoff, as indicated by figure 90; 1954 was a year of relatively low runoff, and 1957 was a year of relatively high runoff.

The coefficients of variation of annual weighted-average concentrations of dissolved solids and annual historical water discharges were computed for three streams in this subbasin and nine other streams in the Green division (table 12). Explanation of the procedure for determining these values is contained in chapter B (pp. 60–61). The relations of the coefficients for the streams in the Green division are shown in figure 91. The plot does not indicate as good a correlation between the coefficients for the streams in the Green division as was found for streams in the Grand division. If the data for Henrys Fork at Linwood, Utah, were eliminated from the group, the equation of a straight line (least-squares method) averaging the balance of the plotted points in figure 91 would be

$$V_d=0.37V_w-0.05,$$

where V_d is the coefficient of variation of weighted-average annual concentration of dissolved solids and V_w is the coefficient of variation of annual stream discharges.

The poorer correlation between the coefficients of variation for the Green division compared with the correlation between those for the Grand division may result from the shortness of available records, which are too short for a reliable statistical analysis. Another contributing factor may be that the dissolved-solids concentrations and the water discharges at some of the sites are greatly affected by the activities of man.

RELATION TO STREAMFLOW

The relation between streamflow and dissolved-solids concentration at four stations is shown in figure 92. Similar data are not available for headwater streams. However, from scanty data obtained in the Wind River Range and Uinta Mountains, the dissolved-solids concentration of the headwater streams is known to vary little between low and high discharges. This is principally due to the nearly insoluble rocks in the mountain areas.

The relation between the chemical composition of water and streamflow at five stations is given in table 13 and is illustrated in figure 93 for four of the stations. Contributions of dissolved solids to the streams after they leave the mountains cause an increase in dissolved solids at all rates of flow and increase the range in concentration between low and high rates of water discharge. Relations between water discharge and total dissolved-solids concentration at common percentage points for other sites may be obtained from the flow-duration table (table 5) and the duration table of dissolved-solids concentration (table 10).

RELATION TO GEOLOGY

Precipitation in the Wind River Range and the Uinta Mountains produce most of the runoff. The core of the Wind River Range is composed of granite and associated metamorphic rocks, and the rocks in the higher part of the Uinta Mountains are mostly quartzite. The rocks along the flank of the Uinta Mountains and in the Wyoming Range are sedimentary rocks of a type which is more resistant to chemical and mechanical weathering than the sedimentary rocks of Cretaceous and Tertiary ages that fill the interior of the basin (pl. 2). In these mountains and for different distances from them, the waters are dilute and have similar chemical composition. The weighted-average concentration of the streams in these reaches (see table 9) is usually less than 100 ppm (parts per million). Most of the waters are of the calcium bicarbonate type.

The dissolved-solids concentration of the streams that rise in the mountains increase progressively down-

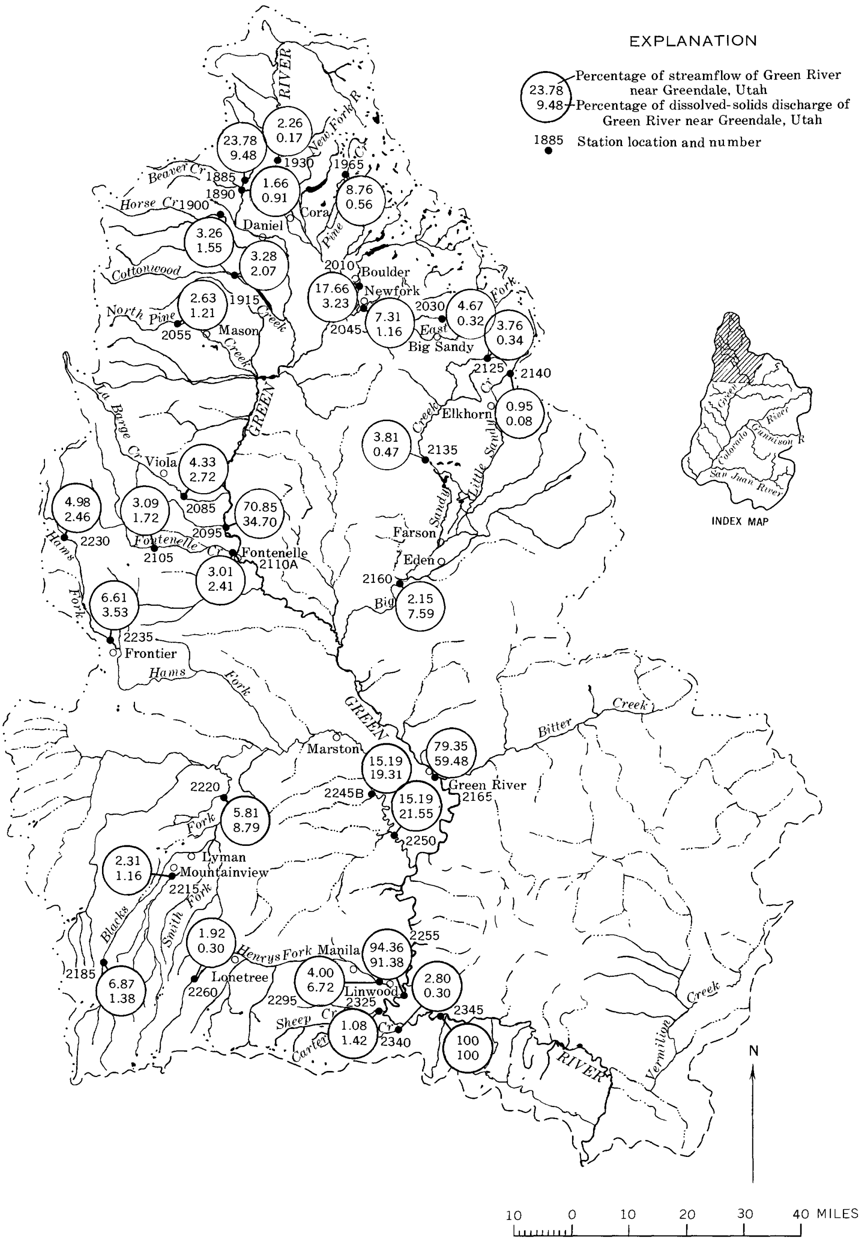


FIGURE 89.—Approximate dissolved-solids discharge and streamflow in the Green River basin above the Yampa River expressed as percentages of dissolved-solids discharge and streamflow of Green River near Greendale, Utah.

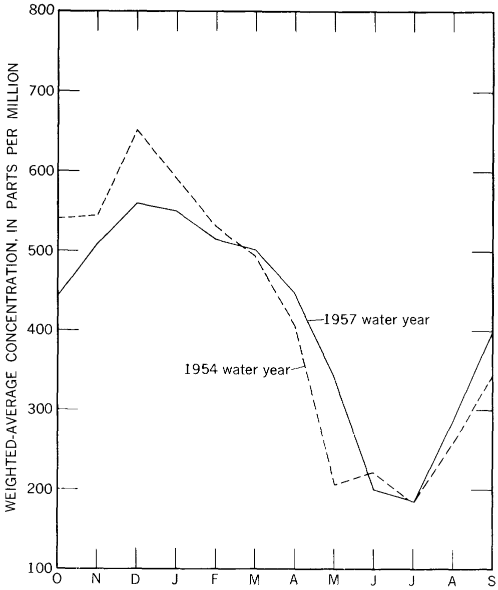


FIGURE 90.—Dissolved-solids concentration of Green River at Green River, Wyo., for the 1954 and 1957 water years.

stream. The chemical composition of the waters of the streams also progressively change from principally calcium bicarbonate to greater and greater percentages of magnesium, sodium, sulfate, and chloride. This is because the sedimentary rocks which underlie the interior of the subbasin are mostly siltstones, sandstones, shales, and mudstones with thin but extensive beds of marl and limestone. As these rocks contain soluble minerals in abundance, the streams that drain or pass through areas underlain by them pick up large quantities of soluble minerals.

Zones of weighted-average concentration of surface waters are delineated in figure 94. These zones indicate that most surface waters in the Green River basin above the Yampa River have a weighted-average concentration of less than 800 ppm and that only a few streams have a weighted-average concentration greater than 1200 ppm.

The diagrams in plate 2 show the geochemical character and ionic concentrations of surface waters at 63 sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flows. The significance of the size and shape of the diagrams is given in the explanation on plate 2.

RELATION TO GROUND WATER

Chemical analyses of ground water are given in the basic data report (Iorns and others, 1964, tables 227–229). Though these data are insufficient to permit a detailed appraisal of the effect of ground water on surface water, some of the relations between the quality of water in the ground-water reservoirs and in the streams can be pointed out.

Ground-water inflow to the streams comes from ground-water reservoirs recharged by precipitation,

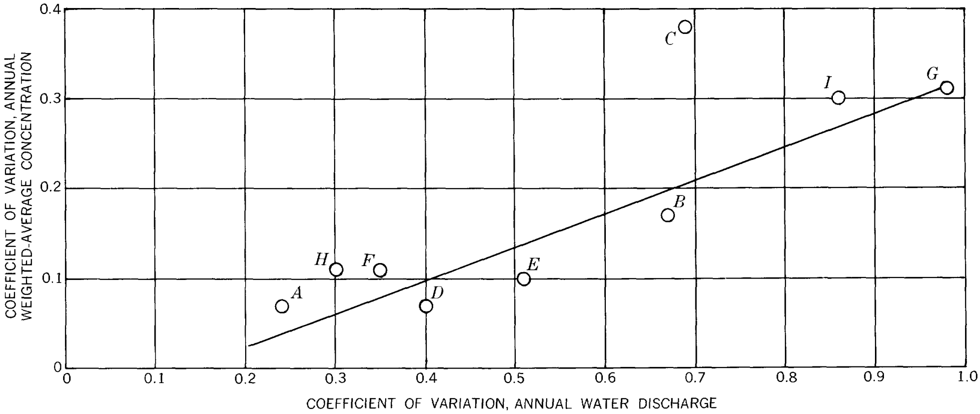
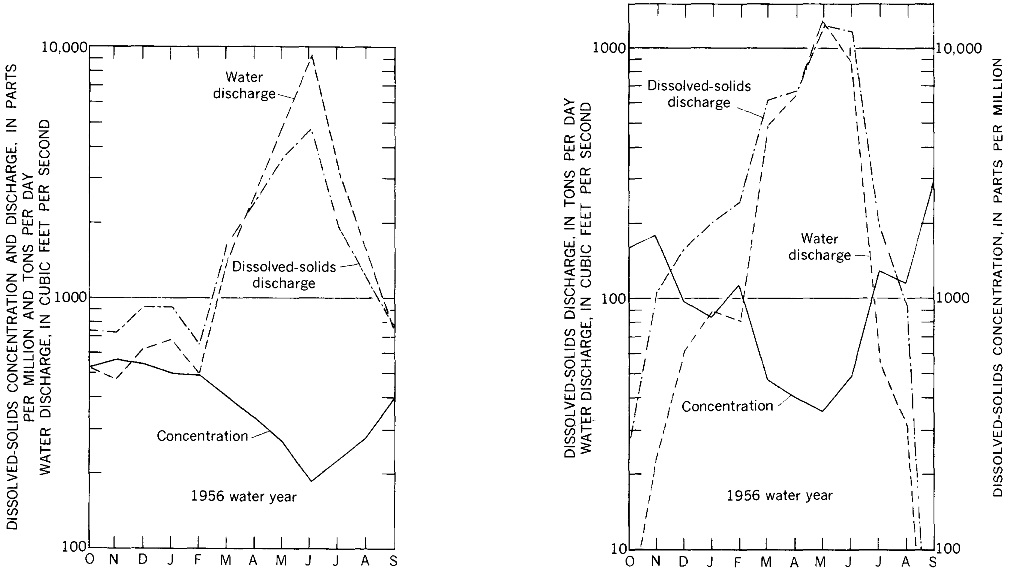
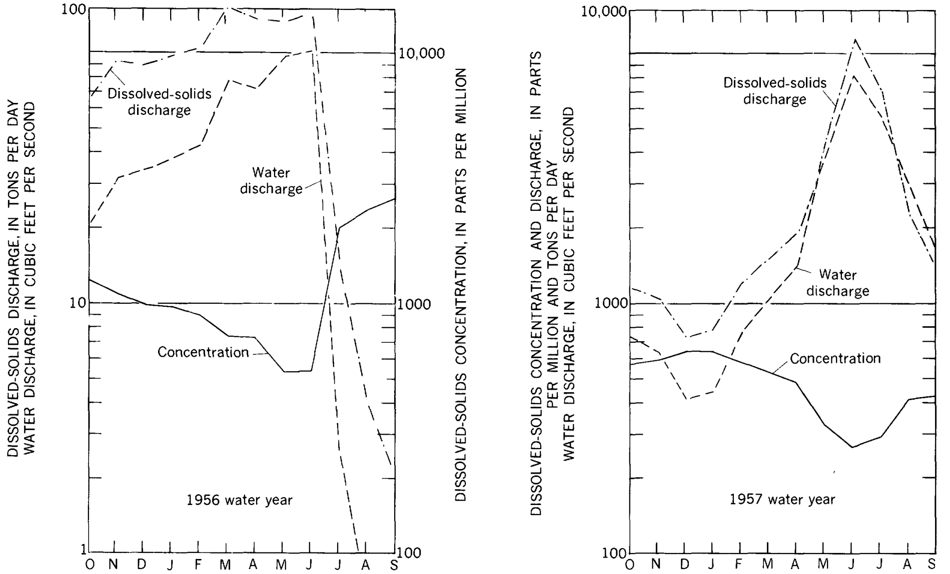


FIGURE 91.—Relation of the variability of dissolved-solids concentration to the variability of water discharge in the Green division. *A*, Green River at Green River, Wyo.; *B*, Blacks Fork near Marston, Wyo.; *C*, Henrys Fork at Linwood, Utah; *D*, Yampa River at bridge on county road, near Maybell, Colo.; *E*, Little Snake River at bridge on State Highway 318, near Lily, Colo.; *F*, White River near Watson, Utah; *G*, Price River at Woodside, Utah; *H*, Green River at Green River, Utah; *I*, San Rafael River near Green River, Utah.



A. Green River at Green River, Wyo.

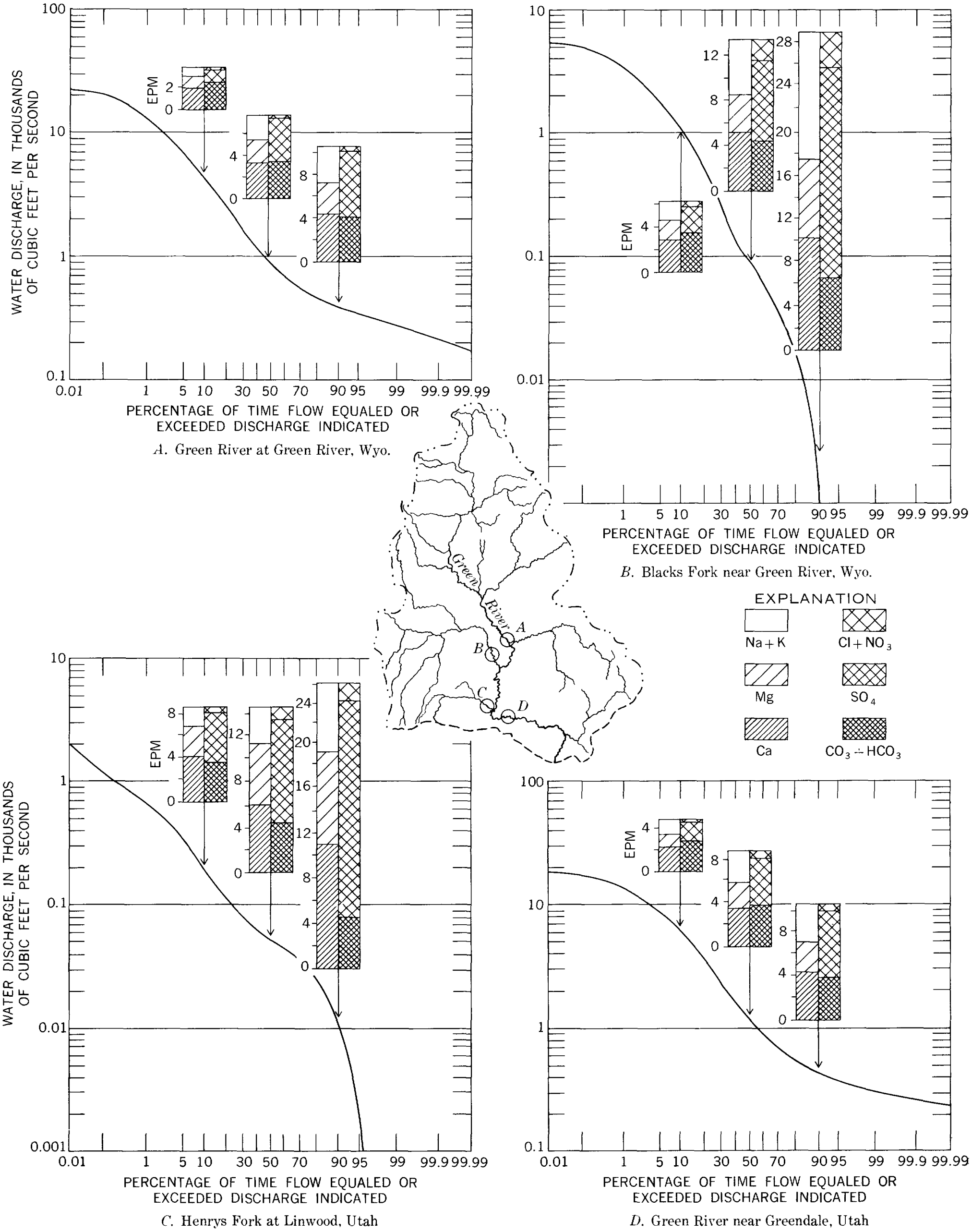
B. Blacks Fork near Marston, Wyo.



C. Henrys Fork at Linwood, Wyo.

D. Green River near Greendale, Utah

Figure 92.—Dissolved-solids concentration and discharge and water discharge at four daily stations in the Green River basin above the Yampa River.



A. Green River at Green River, Wyo.

B. Blacks Fork near Green River, Wyo.

C. Henrys Fork at Linwood, Utah

D. Green River near Greendale, Utah

Figure 93.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Green River basin above the Yampa River. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914–57 adjusted to 1957 conditions, except that for Blacks Fork near Green River, Wyo., which is for water years 1948–57.

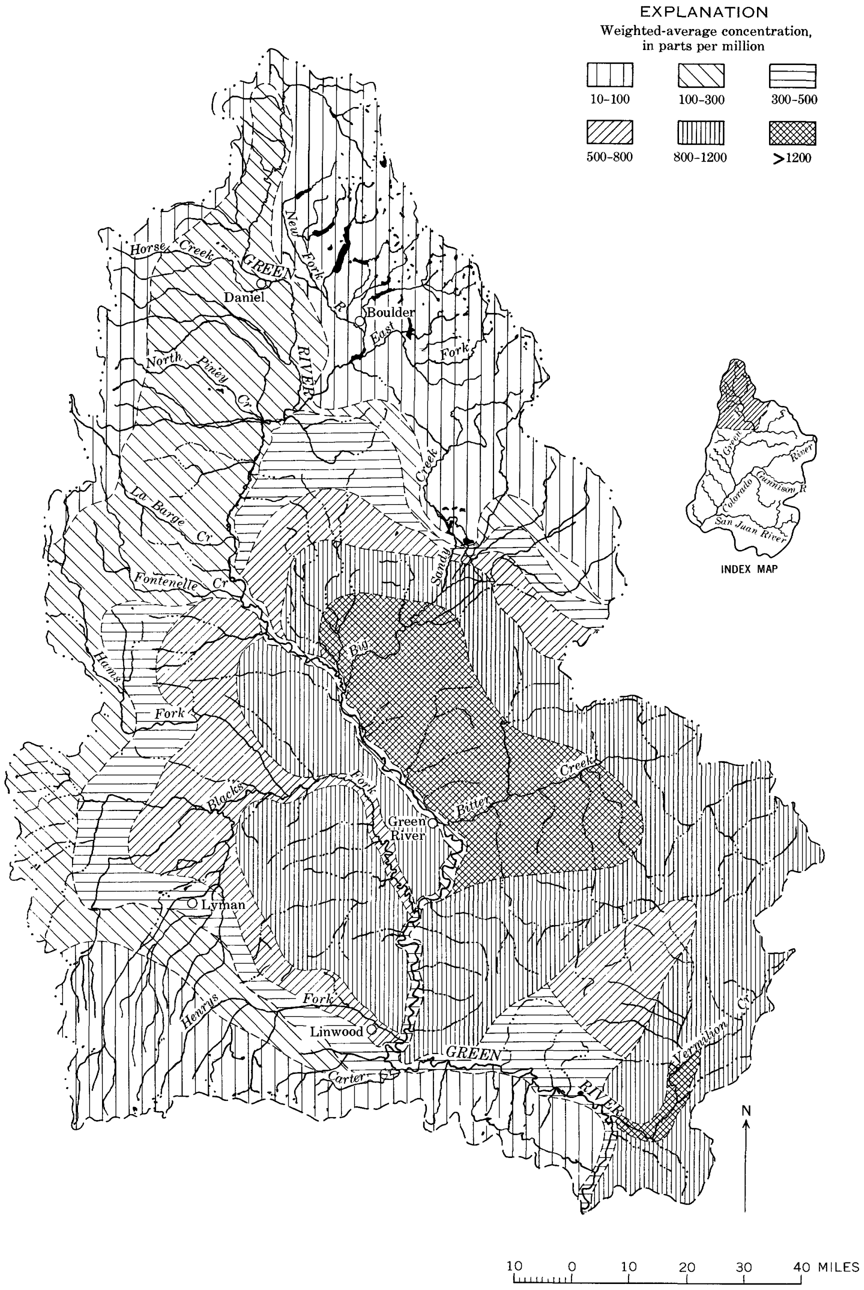


FIGURE 94.—Approximate weighted-average concentration of dissolved solids of streams in the Green River basin above the Yampa River.

from alluvium bordering the streams which is recharged from the streams, from thermal springs, and from ground-water return flow from irrigated lands. The chemical quality of the ground water entering the streams from these sources greatly influences the chemical quality of the water in the streams. During periods of low flow, most of the stream water is ground-water effluent and is a mixture of all ground water entering the stream system.

Ground-water reservoirs occur in the mountains, where precipitation is abundant. Quantitative estimates of the amount of dissolved solids carried into selected headwater streams by water discharged from these reservoirs have been made (table 14). They are based on the estimated amount of water contributed to the streams from ground-water reservoirs and the dissolved-solids concentration of the water in the streams during the times that the flow is maintained principally by effluent ground water. (See chap. B, pp. 57–60.) Comparison of the weighted-average concentration of dissolved solids in the ground water with the weighted-average concentration of dissolved solids in the stream shows that the ground water has a higher concentration than the surface water, even after mixing.

Ground water occurs in deeply buried permeable rocks underlying the interior of the subbasin. Recharge to these underlying beds probably comes from areas of fairly high precipitation, where the permeable rocks are exposed along the flanks of the mountains bordering the subbasin. This ground water, however, probably has little relation to the water in the streams of the subbasin as it is confined beneath beds of shale and mudstone.

In the interior, shallow ground water occurs in significant quantities in deposits of glacial outwash in the valleys of New Fork River and its tributaries, in deposits of river alluvium that border and underlie the other streams in the subbasin, and in unconsolidated terrace deposits, residuum, and alluvium that underlie irrigated lands. Ground water in the river alluvium is closely associated with the water in the streams. During high flows in the spring, the surface water from the streams enters the alluvium, circulates through it, and later returns to the stream. In journeying through the alluvium, the water picks up additional amounts of dissolved solids, which are added to the streams by the returning ground water. Much of the water diverted from the streams for irrigation returns to the streams as ground-water inflow.

Figures 95 and 96 show comparisons of the chemical composition of surface water during low flow and of ground water from the alluvium nearby. The analyses illustrated on figure 95 are of samples collected near the mountains, and those on figure 96 are of samples collected at downstream sites. At some of the sites, ground-water inflow would improve the quality of the water in the streams during low flow; but at others, it would have a deteriorating effect. Also, at some of the sites, the chemical composition of the ground water in the alluvium is much different from that of the surface water.

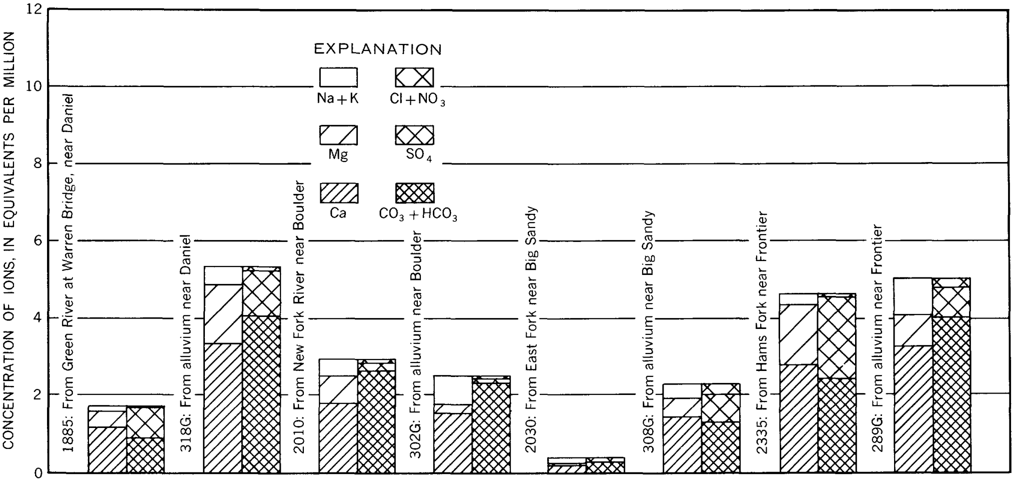


FIGURE 95.—Analyses of water from selected streams near the mountains in the Green River basin above the Yampa River and from alluvium nearby.

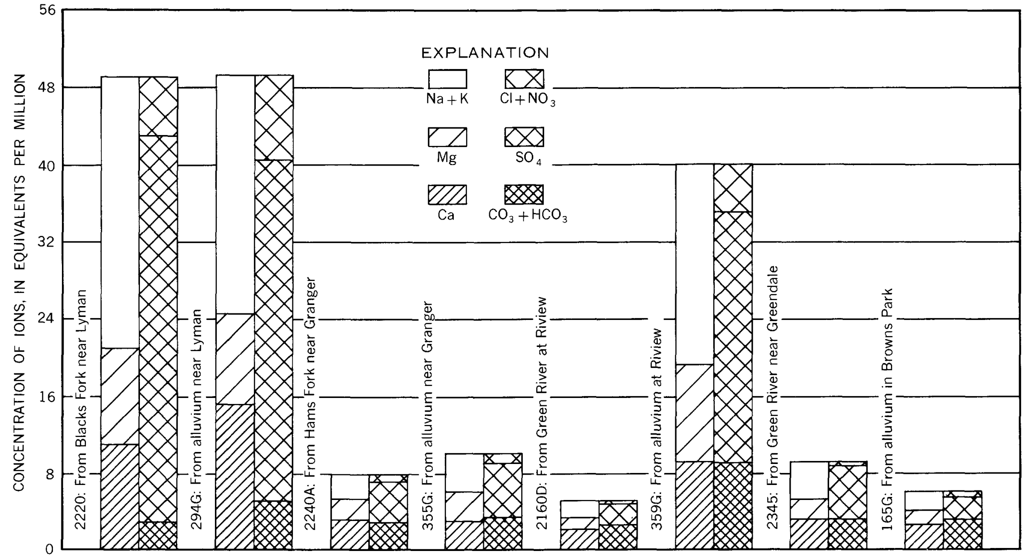


FIGURE 96.—Analyses of water from selected streams in the interior of the Green River basin above the Yampa River and from alluvium nearby.

The amount of ground-water discharge to the streams due to the seasonal rise and fall of the streams is probably not large, but the ground-water return flow from irrigation is probably considerable.

One thermal spring, Steele Hot Spring on the East Fork above New Fork, Wyo., has a flow of about 0.2 cfs and a dissolved-solids concentration of about 300 ppm. The water is of the sodium chloride bicarbonate type. Another spring, on the Green River above Warren Bridge, rises out of the Phosphoria Formation and flows 3 cfs of calcium sulfate type water (1,000 ppm). These two springs discharge about 3,000 tons of dissolved solids annually.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

The Continental Divide ditch which diverts water from Little Sandy Creek is the only transmountain diversion in this subbasin. No records are available on the amount of water diverted annually, but the average concentration of the water diverted probably does not greatly exceed 30 ppm. At this concentration, each acre-foot of water diverted would carry with it only 0.04 ton of dissolved solids.

EFFECT OF THE ACTIVITIES OF MAN

In chapter B (pp. 61–66) the effect of the activities of man, such as domestic and industrial uses of water and irrigation, on the dissolved-solids discharge of streams is discussed. Methods for computing the amount of dissolved solids added to the stream system by these uses are also described in that chapter. For this subbasin, determinations were made for five areas, where data were sufficient to provide a fairly reliable basis for identifying the amount of dissolved solids contributed to the streams by natural sources and the activities of man. In the determinations, water and dissolved-solids data not given in table 9 were estimated on the basis of streamflow records in the annual Water-Supply Papers of the Geological Survey and chemical analyses of water in the basic data report (Iorns and others, 1964, table 221). Dissolved-solids concentration of streams for which chemical analyses were not obtained are based on nearby streams with similar hydrologic and geologic characteristics.

In the drainage basin above the gaging station on New Fork River near Boulder, Wyo., about 29,000 acres is irrigated. The soils of the irrigated land overlie alluvium that is mostly of glacial origin. Table 15 gives an approximate budget of water and dissolved-solids discharge for the area.

The average annual water and dissolved-solids discharges of New Fork River below New Fork Lake and near Boulder are given in table 9. The average annual water discharges of Willow, Lake, Pine, Pole, and Fall Creeks are based on the relation of the discharge during periods of available record to the discharge of New Fork River near Boulder for corresponding periods and the 44-year period. The weighted-average concentrations of these creeks are based on chemical analyses of water obtained from them, from East Fork near Big

Sandy, Wyo., and from Little Sandy Creek near Elkhorn, Wyo. All these streams drain areas in the Wind River Range, consisting mostly of granitic rocks.

The average annual discharge of Duck Creek above the irrigated lands (drainage area, about 25 sq mi) is based on the yield of Willow Creek near Cora (153 acre-ft per sq mi per year). The altitude of the two drainage basins is about the same and the drainage basin of Duck Creek is underlain by Tertiary rocks. The concentration of dissolved solids in runoff from this area is estimated to range from 100 to 150 ppm.

There is about 215 square miles in the drainage basin below the listed gaging stations and Duck Creek above irrigation and above the gaging station on New Fork River near Boulder. Of the 215 square miles, about 55 square miles is mountainous terrain and has an environment similar to that above the gaging station on Willow Creek near Cora. Water yield and concentration of dissolved solids from the mountainous terrain are based on those for Willow Creek.

About 65 square miles of the 215 square miles consists of low hills and mesa underlain mostly by Tertiary rocks that receive about 12 to 16 inches of precipitation annually. The water yield from this area is estimated to average about 75 acre-feet per square mile annually, and the concentration of dissolved solids in the runoff is probably about the same as that for Duck Creek.

About 95 square miles in the ungaged area is underlain by alluvium of glacial origin. This land is mostly river bottom lands and broad flat alluvial fans. Much of this land is natural meadow, about half of which is irrigated. This area receives about 12 to 16 inches of precipitation annually. It is estimated that under natural conditions about 4,800 acre-feet (50 acre-ft per sq mi) annually was not consumed by the native vegetation but infiltrated to ground water and was effluent to the stream system. Chemical analyses of water from two wells in the area indicate that the concentration of dissolved solids of this ground water would probably range from 140 to 220 ppm.

Most of the increase in dissolved-solids discharge from the area is probably the result of irrigation, as there are no industries and the population is small. This increase is equivalent to about 0.5 tons per year per acre of irrigated land.

Between the gaging stations on Fontenelle Creek near Hershler Ranch, near Fontenelle, Wyo., and Fontenelle Creek at Fontanelle, Wyo., about 4,000 acres is irrigated. The irrigated areas are mostly on alluvium underlain by rocks of Tertiary age. An approximate budget of water and dissolved solids entering and leaving the stream reach between the two stations is given in table 15.

The water and dissolved-solids discharges of Fontenelle Creek at the two gaging stations are from table 9. Irrigation consumptive use in the area is estimated to be about 0.8 acre-foot per acre on 4,000 acres of irrigated land. The unmeasured inflow is the amount required to balance the inflow-outflow budget, and the weighted-average concentration of this inflow is estimated to be 211 ppm. This concentration is based on the similarity of environmental factors in the intervening reach to those above Fontenelle Creek near Hershler Ranch. Some water may bypass the gaging station on Fontenelle Creek near Fontenelle as underflow or in irrigation canals. However, if one assumes that the increase in dissolved solids in the reach is the result of irrigation and none bypasses the lower station, the increase is equivalent to about 1.3 tons per year per acre of irrigated land.

In the Big Sandy Creek basin about 13,000 acres is irrigated, mostly on lands underlain by the Bridger and Green River Formations of Tertiary age. In the area below the gaging stations on Big Sandy Creek near Farson, Wyo., Little Sandy Creek above Eden, Wyo., and Pacific Creek near Farson, Wyo., and above the gaging station on Big Sandy Creek below Eden, Wyo., about 11,000 acres is irrigated. An approximate budget of water and dissolved solids entering and leaving the area is given in table 15.

The water and dissolved-solids discharge of Big Sand Creek near Farson (drainage area, 320 sq mi) and below Eden (drainage area, 1,610 sq mi) are from table 9. The water discharge of Little Sandy Creek above Eden (drainage area, 170 sq mi) for the 1914–57 period is based on correlation with Little Sandy Creek near Elkhorn, Wyo., and the dissolved-solids concentration is based on water analyses obtained between November 1954 and July 1958. The water discharge of Pacific Creek near Farson (drainage area, about 500 sq mi) is based on water years 1950–60, which are probably representative of the long-term period. The dissolved-solids concentration of Pacific Creek is based on water analyses obtained between November 1954 and October 1958. The unmeasured inflow from the 620 square miles of intervening drainage area is estimated from the discharge of Pacific Creek (6 acre-ft per sq mi) because of similarity of environment. The concentration of dissolved solids in the runoff from the ungaged area is estimated to be the same as Pacific Creek because of similarity of underlying rocks. The depletion in the reach is the amount necessary to balance the inflow-outflow budget.

The depletion indicates a consumptive use of about 4 acre-feet per acre of irrigated land. The Upper Colorado River Basin Compact Commission (1948) estimated that irrigated lands in this area consumed about 1.3 acre-feet per acre. It may be that the water table under the irrigated lands has not reached a state of equilibrium and some of the applied water is going into ground-water storage, or that considerable underflow is passing Big Sandy Creek below Eden, Wyo. The relatively high runoff per square mile (29 acre-feet per year) from the Green River basin between Green River near Fontenelle Wyo., and Green River at Green River, Wyo., exclusive of Fontenelle and Big Sandy Creeks, indicates that underflow may occur. This area has low precipitation, about 8 to 10 inches (pl. 6). The increase of dissolved solids in the intervening area (49,000 tons), if all assigned to irrigation (11,000 acres), is equivalent to about 4.4 tons per year per acre of irrigated land. However, if water and dissolved solids are going into ground-water storage or underflow is occurring, the rate of dissolved solids leaching from the soil and rocks underlying the irrigated lands would be considerably higher.

In Blacks Fork basin about 74,500 acres of land is irrigated. Most of the irrigated lands are on river alluvium underlain by the Green River and Bridger Formations, except the irrigated lands along Hams Fork above Kemmerer, Wyo., which are partly underlain by the Wasatch Formation. Table 15 gives an approximate budget of water and dissolved-solids discharge for an area on Blacks Fork in which 59,500 acres is irrigated. The 1939–57 period of record is closely equivalent to the 1914–57 period.

The water and dissolved-solids discharges of Blacks Fork near Millburne (drainage area, 156 sq mi) and near Lyman (drainage area, 821 sq mi) are from table 9. The weighted-average concentrations of East (drainage area, 53 sq mi) and West (drainage area, 37 sq mi) Forks of Smith Fork are estimated to be the same as Blacks Fork near Millburne because their environments are similar. Below the three inflow gaging stations there is about 30 square miles of mountainous terrain that receives about 16 to 20 inches of precipitation annually. Runoff from this terrain is estimated to average about 200 acre-feet per year per square mile and to have the same dissolved-solids concentration as the headwater streams. The foothill area between the mountains and the lowlands receives an average annual precipitation of 12 to 16 inches. Annual runoff from the foothill area (drainage area, about 30 sq mi) is estimated to average about 50 acre-feet per square mile. This area is underlain by the Bridger and Browns Park Formations. The concentration of dissolved solids in the runoff from this area is 500 ppm, which is based on chemical analyses of Cottonwood Creek below Sage Creek, near Mountainview, Wyo. (See basic data report, Iorns and others, 1964, table 221.) The drainage basin of Cottonwood Creek is mostly underlain by the Bridger and Browns Park Formations.

River valley and lowlands occupy about 515 square miles of the intervening area between the Blacks Fork inflow and outflow stations. Average annual precipitation over this area is only about 7 to 10 inches, and annual runoff is estimated to average about 10 acre-feet per square mile and to have a dissolved-solids concentration of 500 ppm.

The depletion in the area is the amount necessary to balance the inflow-outflow budget. Most of the depletion of 77,500 acre-feet is probably due to irrigation consumptive use. The increase of dissolved solids in the reach, 52,800 tons, is equivalent to 0.9 ton per year per acre of irrigated land.

The water and dissolved-solids discharges for Hams Fork near Elk Creek ranger station and near Frontier are given in table 9. The irrigation consumptive use is estimated to be about 1.2 acre-feet per acre on the 4,000 acres of irrigated land. The unmeasured inflow is the amount required to balance the inflow-outflow budget. As the environmental factors in the intervening reach are similar to those above Hams Fork at Elk Creek ranger station, the concentration of dissolved-solids in the unmeasured inflow is probably the same. The increase in dissolved solids in the area is equivalent to 0.25 ton per year per acre of irrigated land. Table 15 gives a water and dissolved-solids budget for the area on Hams Fork, where about 4,000 acres are irrigated.

Estimates were made of the dissolved solids contributed by natural sources and the activites of man for other areas in the subbasin. The estimates were based on the indicated rates of yield per acre of irrigated land for the selected areas and other selected areas in the Upper Colorado River Basin, the geologic character of the formations underlying irrigated lands, and chemical analyses of water at miscellaneous sites in this subbasin. In the estimates it was assumed that the distribution of population and industry were approximately proportional to the distribution of irrigated lands. In table 16 the dissolved solids estimated to be contributed from natural sources and the activities of man are summarized at main-stem gaging stations and for the subbasin.

If there were no activities of man in the subbasin, the weighted-average concentration of dissolved solids of Green River near Greendale, Utah, would have been about 209 ppm as compared with a weighted-average of 378 ppm for water years 1914–57 adjusted to 1957 conditions. In this determination 2,300 acre-feet annually was estimated to be consumed by domestic and industrial uses and 218,000 acre-feet by irrigation.

The increase in dissolved solids due to irrigation is estimated to be about 317,100 tons per year. This estimate is based on assigning 100 tons per year per 1,000 people as the contribution of dissolved solids from domestic and industrial uses of water and attributing the balance of the dissolved solids to irrigation.

FLUVIAL SEDIMENT

Daily suspended-sediment records have been obtained at Green River at Green River, Wyo. The annual suspended-sediment discharges at this station are given in table 17. Estimates of the suspended-sediment discharge at several stations in the subbasin are given in table 18.

Apparently most of the sediment comes from the interior of the subbasin, which is underlain by rocks of Cretaceous and Tertiary ages. The suspended-sediment contribution to the Green River from the 5,130 square miles of drainage area between Green River at Green River, Wyo., Blacks Fork near Green River, Wyo., and Henrys Fork at Linwood, Utah, and the Yampa River is estimated to be about 1,946,400 tons annually. This estimate is computed by prorating, on the basis of drainage area, the difference in suspended-sediment discharge between Green River near Jensen, Utah, and the sum of suspended-sediment discharges at Green River at Green River, Wyo., Blacks Fork near Green River, Wyo., Henrys Fork at Linwood, Utah, Yampa River at bridge on county road near Maybell, Colo., and Little Snake River at bridge on State Highway 318, near Lily, Colo. The computed yield from the 7,280 square miles of intervening drainage area is 380 tons per square mile per year.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classification of the surface waters in the Green River basin above the Yampa River is based on water quality criteria for major uses. (See chap. B, pp. 66–73.)

Chemical analyses of the waters of the Green River and its perennial tributaries above the Yampa River indicate that the water of the main stem and of its tributaries in their headwaters are suitable for domestic purposes. In the lower reaches of some of the perennial tributaries and in the ephemeral streams that rise in the interior of the basin, concentrations of magnesium, chloride, and sulfate sometimes exceed the permissible maximum concentrations for domestic use. Hardness of the waters ranges from soft in the headwater areas to very hard in the middle and lower reaches of the tributaries. Nitrate is present in all the streams but usually in concentrations of less than 5 ppm.

AGRICULTURAL USE

Table 19 classifies most of the surface waters of the Green River basin above the Yampa River according to their suitability for use in irrigation under conditions of development existing in 1957. Chemical analyses of surface water that are representative of low, medium, and high flows for many sampling sites were used to prepare the table.

All the terms in the boxheads of table 19 are self-explanatory or are explained on pages 69–73 in chapter B, except the classification of water discharge as low, medium, or high. High flows are those greater than the flow exceeded 20 percent of the time, low flows are those less than the flow exceeded 80 percent of the time, and medium flows are those greater than the flow exceeded 80 percent of the time but less than the flow exceeded 20 percent of the time. The ranges of low, medium, and high discharges for most of the sampling sites were determined from table 5.

Only a few of the streams, even during low flows, contain residual sodium carbonate in excess of 1.25 epm (equivalents per million), which is the maximum considered to be safe for irrigation use.

The surface waters range from C1–S1 to C4–S4, but most of the water used for irrigation would be classified as C2–S1 water or better. According to the U.S. Salinity Laboratory Staff (1954), waters of C2 class "can be used if a moderate amount of leaching occurs. Plants with moderate salt tolerance can be grown in most cases without special practices for salinity control." S1 signifies that the water "can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium."

The required leaching computed by Eaton's formulas is generally low and can easily be satisfied on most of the irrigated lands. Though many of the waters indicate that addition of gypsum is required, this would not be necessary as most of the soils probably contain sufficient available calcium.

INDUSTRIAL AND RECREATIONAL USES

The surface water in most of the headwaters can be used by many industries without treatment. However, most stream water near the centers of population would require treatment before it could be used for most industries.

Most of the lakes and perennial streams in the headwaters of the subbasin are ideal for recreational use. The economy of several towns, for example, Pinedale, Wyo., is partly based on hunting and fishing. The use of surface waters for recreational use is expanding rapidly and will probably continue to do so as the population continues to increase.

YAMPA RIVER BASIN

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Stillwater Reservoir No. 1, on the headwaters of Yampa River, capacity about 6,200 acre-feet (U.S. Geol. Survey, 1959, p. 194), is the only reservoir in the Yampa River Subbasin with storage capacity greater than 1,000 acre-feet. There are, however, many small lakes, small reservoirs, and stock ponds.

TRANSMOUNTAIN DIVERSIONS

There are no diversions out of this subbasin to the east slope of the Continental Divide. Two small diversions, on which no data are available, transport water from the subbasin to Rock Creek, a tributary of the Colorado River in the Grand division.

IRRIGATION

The U.S. Bureau of the Census (1953) reported a total of 73,700 acres of irrigated land in 1949 (table 4). Of this total, 22,000 acres is above Steamboat Springs, Colo., 20,400 acres is in the Little Snake River basin, and the remaining acreage is distributed along the Yampa River and tributary valleys. Of the total irrigated acreage, about 15,700 acres is in Wyoming and about 58,000 acres is in Colorado.

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water in the subbasin due to irrigation practices was about 82,000 acre-feet. The Commission estimated that 75,579 acres of land was irrigated; 11,551 acres was irrigated by natural overflow, and 24,344 acres of land received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The 1960 population was about 14,000, less than two persons per square mile. The five largest communities and their populations are Craig, 3,984; Steamboat Springs, 1,843; Hayden, 864; Mount Harris, 730; and Oak Creek, 666; all in Colorado. The principal means of livelihood are farming, ranching, and tourist trade.

The five largest communities receive their water supplies from surface-water sources. Craig has a per capita use of water of about 175 gpd (gallons per day) and Hayden has a per capita use of water of about 90 gpd (Gregg and others, 1961). No data are available for the other communities. For the report, the average consumptive use of water in the subbasin for domestic and industrial purposes is estimated to be about 60 gpd per capita, or about 900 acre-feet annually. The five largest communities have septic tanks for treatment of sewage.

Oil and gas deposits have been developed in an area south of Craig, in the Williams Fork basin. Other than a small meat-processing plant at Craig and milk and locker plants at Steamboat Springs, there are no industries in the subbasin and no hydroelectric plants.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

The Yampa River rises in the Park Range along the Continental Divide and flows westward to its junction with the Green River. Snowmelt is the principal source of water supply in the subbasin, and the pattern of seasonal runoff of the river and its tributaries is like that of other streams in the Upper Colorado River Basin that have similar environment (fig. 97). Generally, summer precipitation has small effect on the discharge of the principal streams. The base flow of the streams draining the high mountain areas is usually very uniform for about 9 months of each year. The streams draining the areas of lower altitude in the central and western part of the basin are intermittent.

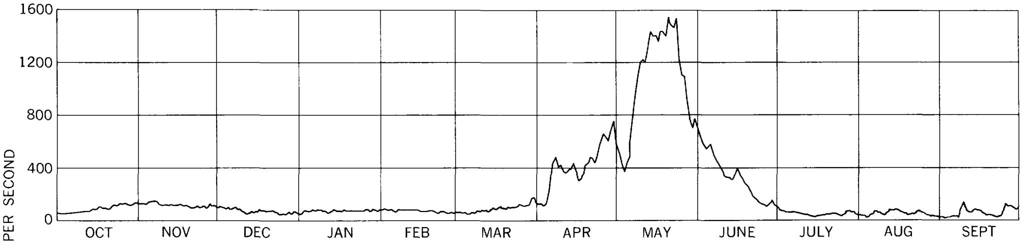
FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 13 stations. The record at one of the stations was complete for water years 1914–57, and three other records were complete for more than 34 years. Using the methods described in chapter B (pp. 46–48), flow-duration curves for 12 streams were adjusted to the 44-year base period. As there was apparently little change in irrigated acreage during the 1914–57 period, no adjustment of the historical data to conditions existing in 1957 was made. The data on the historical and adjusted curves are given in table 5. Two examples of flow-duration curves are shown in figure 98. Both curves are typical of snowmelt-type streams.

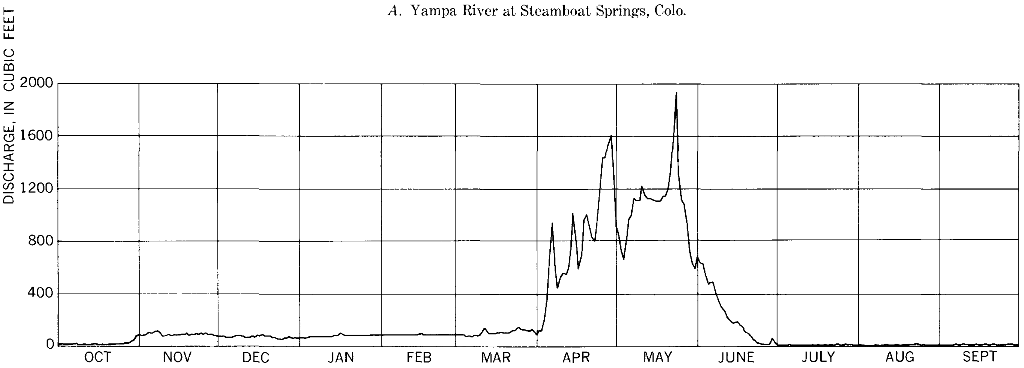
In table 6 the methods used in adjusting the historical flow-duration curves to the 44-year base period are outlined, and the authors' rating of accuracy of the resultant long-term curves are given.

Table 7 gives the variability indices of streamflow and percentage of average annual discharge estimated to be contributed to the streams by ground water at four streamflow stations. Only headwater streams not affected appreciably by irrigation are included in the listing, which is arranged in order of magnitude of the variability indices.

The water-producing area of the stream having the lowest index value and highest ground-water contribution (station 2375) is underlain by Tertiary volcanic rocks which are relatively permeable. A reser-



A. Yampa River at Steamboat Springs, Colo.



B. Little Snake River near Dixon, Wyo.

FIGURE 97.—Seasonal pattern of runoff in the Yampa River basin, 1954 water year.

voir of 6,200 acre-feet capacity is in the headwaters of this stream.

The water-producing areas of the two streams having the highest variability-index values and lowest percentage of ground-water contribution are underlain by Precambrian rocks. These rocks are relatively impermeable, which would tend to cause high index values and low ground-water contribution. The drainage basin of Savery Creek at upper station, near Savery, Wyo., is underlain in part by Precambrian rocks and in part by the Dakota Sandstone and Morrison Formation of Cretaceous age. The combination of relatively impermeable rocks of Precambrian age and the more permeable sandstones of Cretaceous age in the drainage basin causes the variability index and percentage of ground-water contribution to fall in the intermediate range.

The relation between the variability indices and percentage of ground-water contribution is shown in figure 87.

VARIABILITY OF ANNUAL RUNOFF

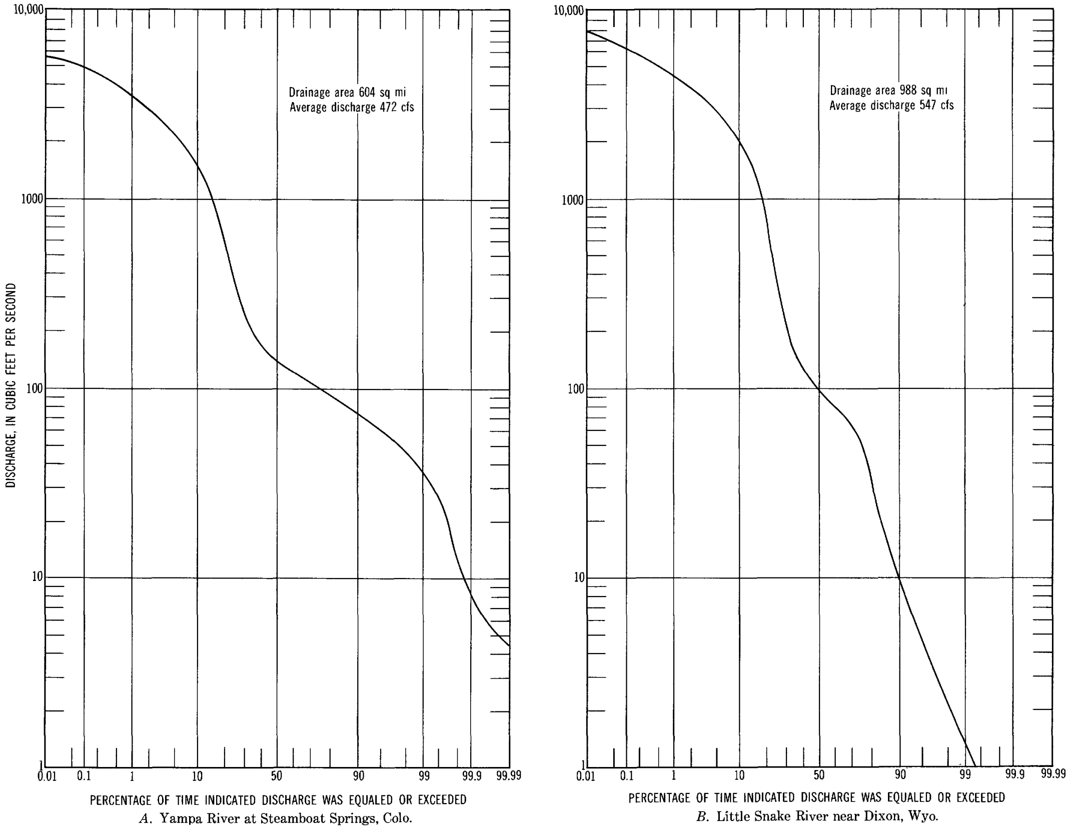
The histograms in figure 99 show that annual variations in discharge of the Yampa River are less than that of the Little Snake River. Less variation in annual precipitation in the Yampa River drainage basin above Steamboat Springs, Colo., than in the Little Snake River drainage basin is probably the principal cause for the greater variations in the Little Snake River. The streamflow record for the Yampa River at Steamboat Springs is complete for the 44-year period. The record for the Little Snake River near Dixon was estimated for water years 1924–38.

The coefficients of variation (chap. B, pp. 53–57) of annual discharges at four streamflow stations are given in table 8 and are plotted on plate 6. The greater variability of the discharge of the Little Snake River as compared with that of the Yampa River is shown by the higher coefficient. These data may be used in determining probable future water discharge for periods of various length. (See p. 191 and chap. B, pp. 57–58.)

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at two stations in the Yampa River basin. Monthly and annual weighted-average chemical analyses of water at these stations are given in the basic data report (Iorns and others, 1964, tables 193, 194). In addition to these data, chemical-quality analyses of streams at other sites in the subbasin have been obtained. The



A. Yampa River at Steamboat Springs, Colo.

B. Little Snake River near Dixon, Wyo.

Figure 98.—Flow-duration curves of two streams in the Yampa River basin, water years 1914–57 adjusted to 1957 conditions.

dissolved-solids discharge at the two daily stations and at other sites have been computed (table 9). The quantities given in the table are averages which would have occurred if the developments in 1957 had existed throughout water years 1914–57.

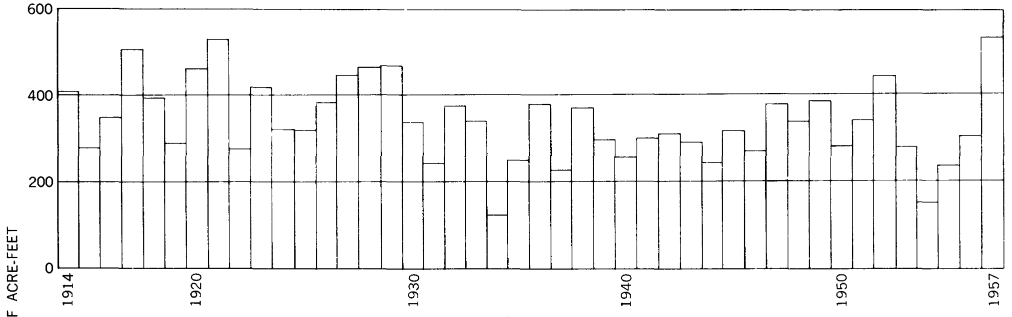
The average dissolved-solids discharge of the streams ranged from about 3 to 600 tons per day, and the average annual yield ranged from about 42 to 298 tons per square mile. The greatest yield per unit of runoff apparently comes from the more arid part of the basin, which is mostly underlain by sedimentary rocks of Tertiary age.

Duration tables of dissolved-solids concentration and discharge for the streams at sites listed in table 9 are given in tables 10 and 11. (See chap. B, pp. 58–59, for description of computation method.)

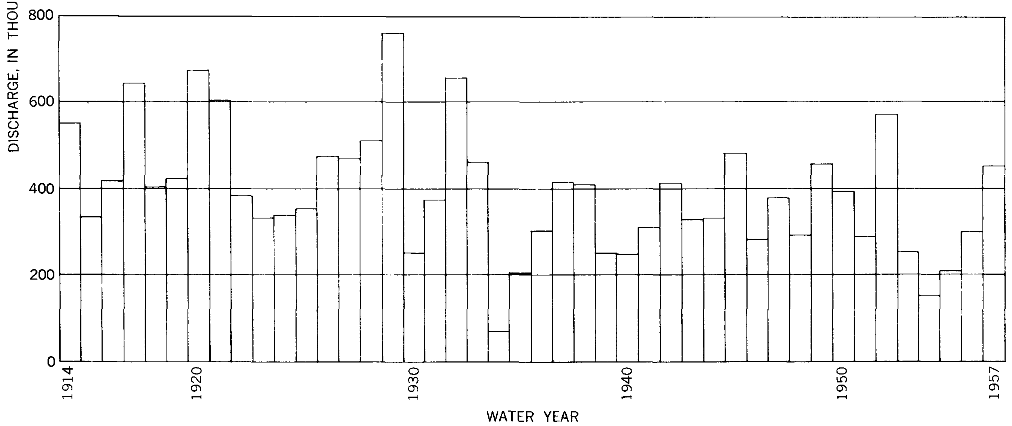
Most of the water comes from the mountain area of the basin, but most of the dissolved solids come from the area of relatively low altitude, which compose about two-thirds of the basin (table 9, fig. 100). Although the drainage area of the Little Snake River above the station near Lily is only about 240 square miles smaller than that of the Yampa River above the station near Maybell, it produces less than half as much water, but more than half as much dissolved solids.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in the dissolved-solids concentration of Yampa River near Maybell is illustrated in figure 101. The lowest concentrations occur during the months of high water, in the spring and early summer, and the highest concentrations occur in the months when the stream is maintained largely by ground water. The pattern of seasonal variation does not change greatly in years of low and high runoff. Water year 1954 was a year of relatively low



A. Yampa River at Steamboat Springs, Colo.



B. Little Snake River at Dixon, Wyo.

FIGURE 99.—Variability of annual discharges in the Yampa River basin, water years 1914–57.

runoff, and 1957 was a year of relatively high runoff.

The coefficients of variation of annual weighted-average concentration of dissolved solids and annual historical water discharge for two streams are given in table 12. The computed coefficients are for concurrent periods of record, which may be too short for a reliable statistical analysis.

RELATION TO STREAMFLOW

The concentration of dissolved solids in the streams that flow from the granite terrane of the Park Range is low; and, as in the streams that flow from similar terranes along the Continental Divide, the range in dissolved-solids concentration with changing discharge is small. After the streams leave the mountains, contributions of dissolved solids cause an increase in dissolved-solids concentration at all rates of flow, and the range in concentration increases between low and high flows. Figure 102 shows the relation between streamflow and dissolved solids at two sites in the lower part of the Yampa River basin. The relation between the chemical composition of water and streamflow at these two sites is given in table 13. Figure 103 also illustrates the relation between the chemical composition of water in the streams at these two sites and at two sites in the headwaters.

RELATION TO GEOLOGY

Precambrian granites and associated metamorphic rocks underlie the drainage areas of tributaries entering the Yampa River from the east above Elk River. These rocks also underlie the headwaters of Elk River and Little Snake River. The extreme headwaters of Williams Fork and some of the tributaries of the Yampa River above Elk River drain areas that are capped by Tertiary volcanics on the White River

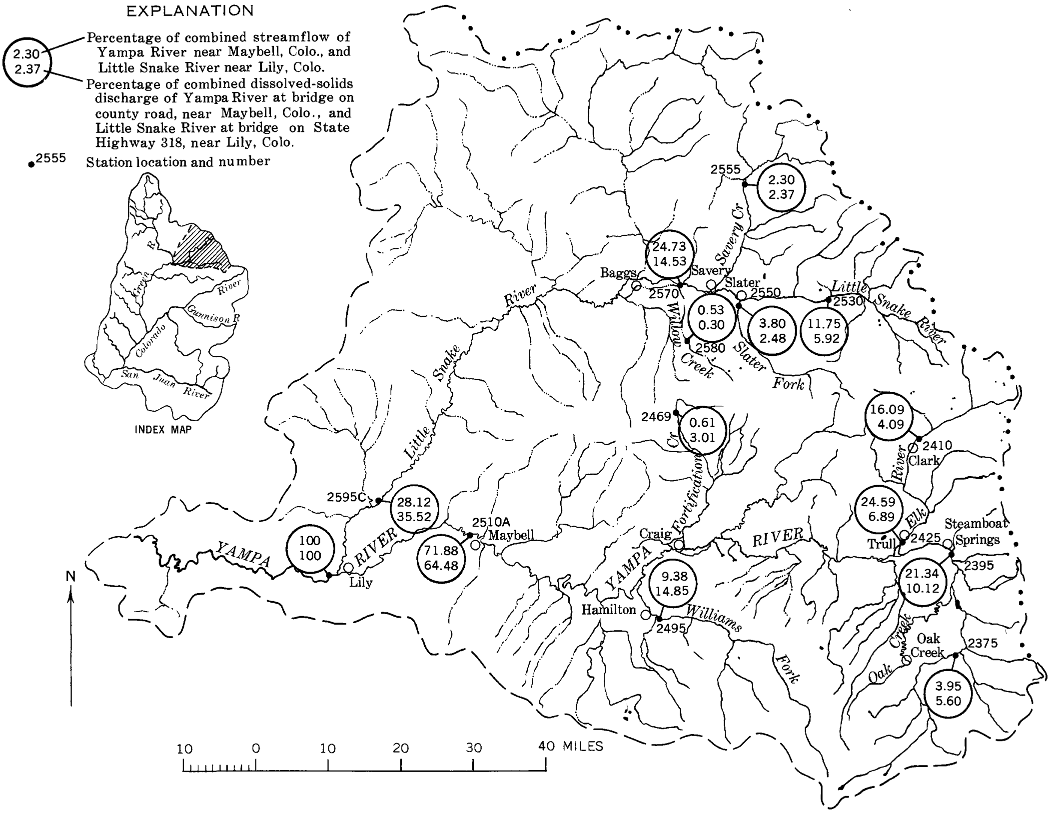


FIGURE 100.—Approximate dissolved-solids discharge and streamflow in the Yampa River basin expressed as percentages of combined dissolved-solids discharge and combined streamflow of Yampa and Little Snake Rivers near Maybell and Lily, Colo.

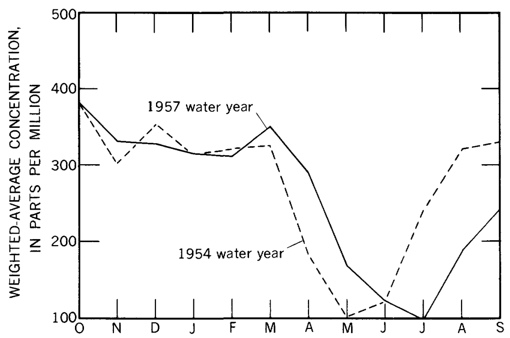
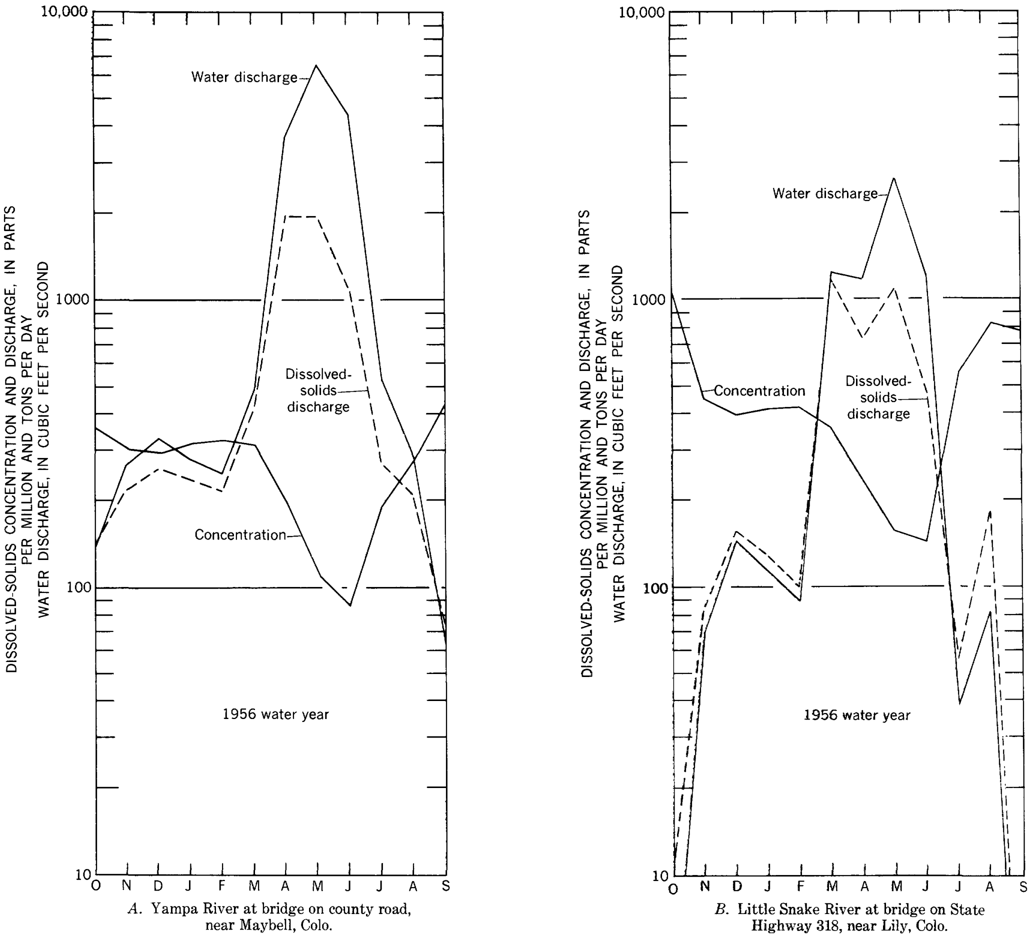


FIGURE 101.—Dissolved-solids concentration of Yampa River at bridge on county road, near Maybell, Colo., for the 1954 and 1957 water years.

Plateau. The remainder of the Yampa River basin is underlain by sedimentary rocks, which are mostly of Cretaceous and Tertiary age.

The Precambrian and associated metamorphis rocks are resistant to the solvent action of water; consequently, the streams draining them have low concentrations of dissolved solids. The water of Elk River at Clark, Colo., which has a weighted-average concentration of 40 ppm (table 9) and is of the calcium bicarbonate type, is representative of streams draining these rocks. Areas underlain by these rocks occur at high altitudes and receive precipitation averaging from 30 to more than 40 inches annually; the streams draining these areas provide most of the water supply in the subbasin.

The Cretaceous and Tertiary rocks contain an abundance of soluble minerals. Streams draining areas



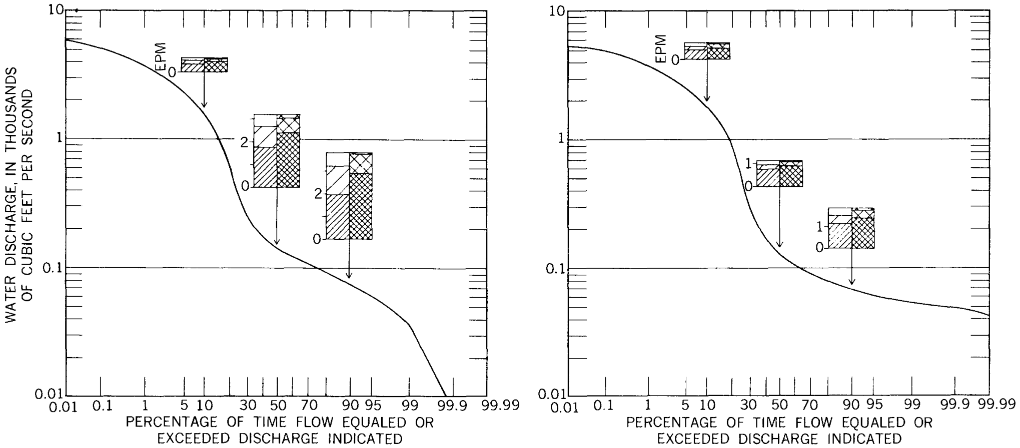
A. Yampa River at bridge on county road, near Maybell, Colo.

B. Little Snake River at bridge on State Highway 318, near Lily, Colo.

FIGURE 102.—Dissolved-solids concentration and discharge and water discharge of streams at two daily stations in the Yampa River basin.

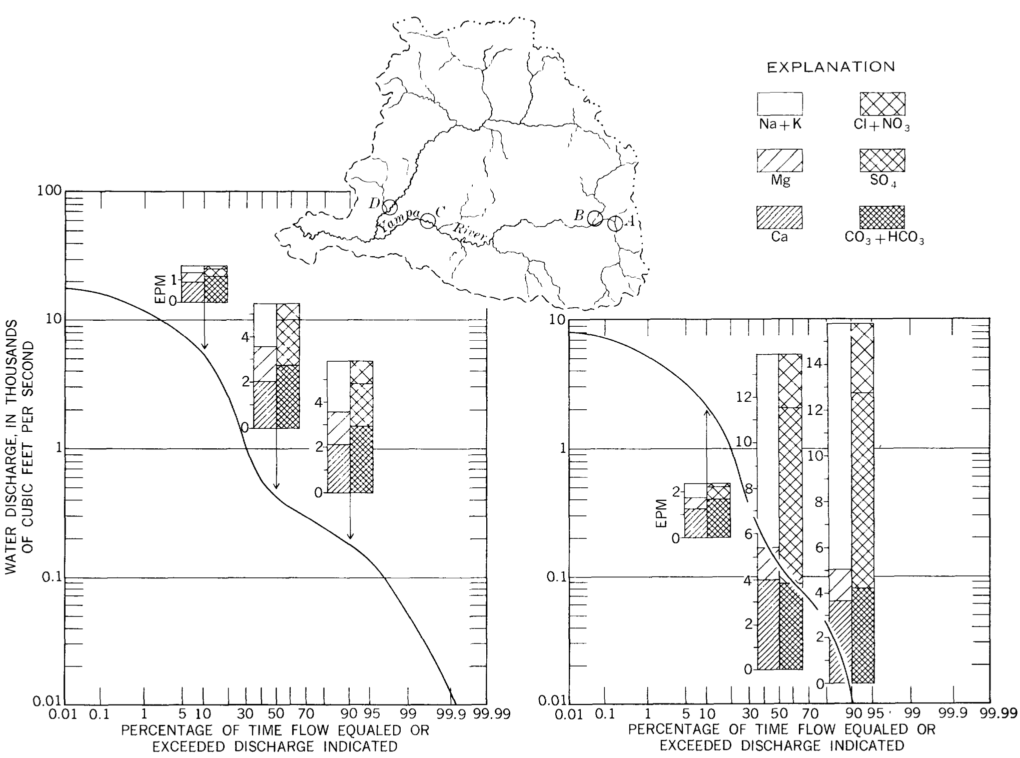
underlain by these rocks usually contain higher proportions of magnesium, sodium, and sulfate than streams draining areas underlain by Precambrian rocks. Most of the area underlain by these sedimentary rocks is semi-arid and produces little runoff in comparison with the headwater area; this results in only a moderate increase of dissolved-solids concentration downstream in the Yampa and Little Snake Rivers. For example, the weighted-average concentration in the Yampa River between Steamboat Springs and Maybell, Colo., only increases from 74 to 140 ppm, and part of this increase is caused by irrigation in the intervening reach. The concentration of dissolved solids of the Little Snake River between Dixon, Wyo., and the mouth only increases from about 90 to 200 ppm. However, unlike the water of the Yampa River, which is of the calcium bicarbonate type both in the headwaters and downstream near Maybell, the water of the Little Snake River changes from a calcium bicarbonate type in the headwaters to a sodium sulfate type near the mouth, except at high flows in the spring.

Figure 104 is a map of the Yampa River basin showing zones within which the weighted-average concentrations of dissolved solids of the surface water are between indicated limits. The weighted-average concentrations in the principal streams are less than 300 ppm. Some of the intermittent streams that drain areas underlain by sedimentary rocks in the arid parts of the



A. Yampa River at Steamboat Springs, Colo.

B. Elk River near Trull, Colo.



C. Yampa River at bridge on county road, near Maybell, Colo.

D. Little Snake River at bridge on State Highway 318, near Lily, Colo.

Figure 103.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Yampa River basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914–57 adjusted to 1957 conditions.

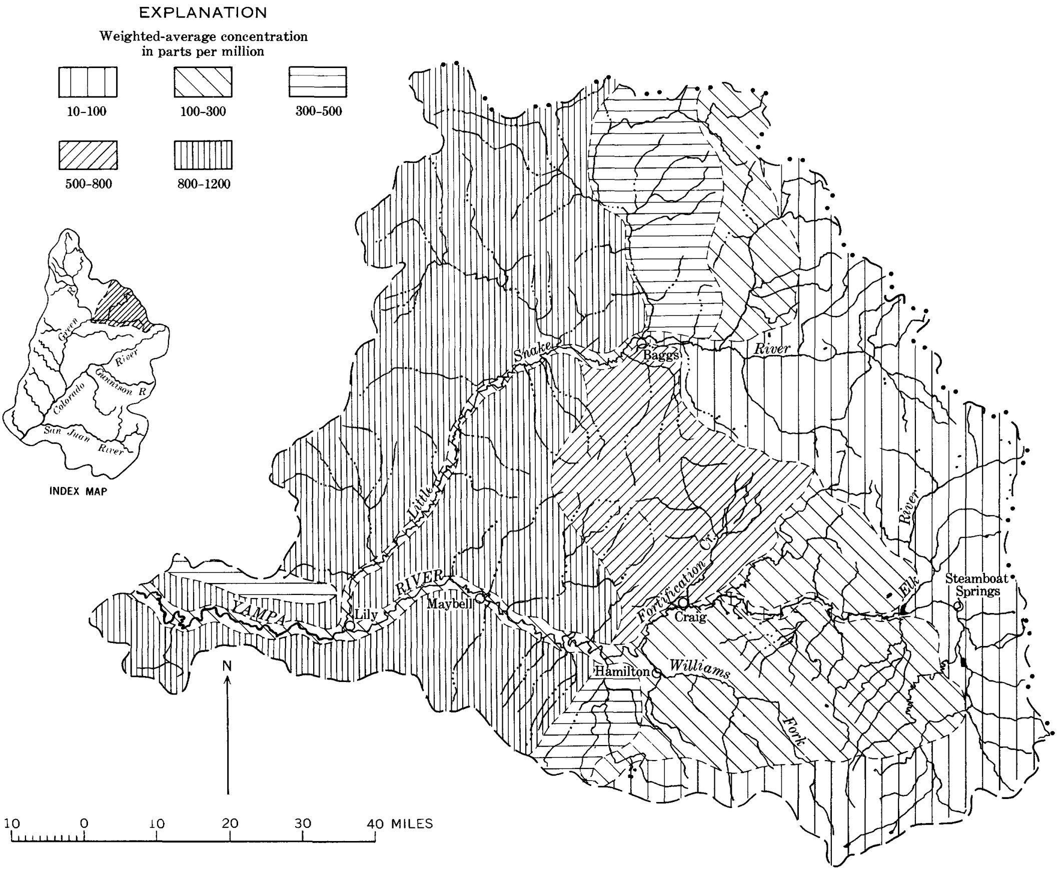


FIGURE 104.—Approximate weighted-average concentration of dissolved solids of streams in the Yampa River basin.

basin have weighted-average dissolved-solids concentrations of more than 800 ppm.

The diagrams on plate 2 show the geochemical character and ionic concentrations of surface waters at 28 sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flows. The significance of the size and shape of the diagrams is given in the explanation on plate 2.

RELATION TO GROUND WATER

Except in the headwater areas, ground water in the consolidated rocks has little effect on the streams. In the headwaters, the magnitude of the effect is closely related to the geologic environment. Table 14 gives the water and dissolved solids estimated to be contributed to some headwater streams by ground water. The weighted-average concentration of dissolved solids of the ground-water contribution is higher than the weighted-average concentration in the water in the streams, even after mixing.

Headwaters of the Yampa River above the gaging station near Oak Creek, Colo., are underlain by Tertiary volcanics, which are relatively permeable. These volcanic rocks overlie rocks of the Mesaverde Group and Mancos Shale, which contain an abundance of readily soluble minerals. The permeable volcanic rocks provide opportunity for recharge to ground-water reservoirs in contact with the underlying formations. Ground-water return flow from the irrigation of soils derived from Mancos Shale probably also contributes to the large percentage of dissolved solids contributed to the stream system by ground water in this headwater drainage basin.

The drainage basins above Elk River at Clark, Colo., and Little Snake River near Slater, Colo., are mostly underlain by rocks of Precambrian age. These rocks provide little opportunity for ground-water storage, and, in addition, the rocks are relatively insoluble. The headwater area of Savery Creek is underlain partly by Precambrian rocks and partly by the Dakota Sandstone and the Morrison Formation of Cretaceous age. The rocks of Cretaceous age are more permeable than the Precambrian rocks and contain more soluble minerals.

The low precipitation over the interior of the Yampa River basin provides little opportunity for ground-water recharge. In addition, the Cretaceous and Tertiary rocks, which are exposed over much of the interior of the basin, are poor aquifers. However, ground water does occur in the alluvial deposits in the stream valleys. In downstream areas, the river alluvium receives very little recharge except from the streams during high flows and from irrigation. The quantity of water involved in the recharge and discharge of ground water by the natural rise and fall of the streams would likely be small compared with the flow in the main streams. However, where irrigated lands are on alluvial deposits, the amount of ground water effluent to the streams would be substantially increased. For the most part, the river alluvium is composed of material derived from nearby sedimentary rocks and contains substantial quantities of soluble minerals.

In most places the ground water in the river alluvium has a higher concentration of dissolved solids than the water in the nearby stream, even during periods of low flow when the streams are at their maximum concentration (figs. 105, 106). The analyses of surface water shown in figures 105 and 106 are of samples collected in the late summer, when the streams were low. The water in the streams at this time of the year is mostly a mixture of all the ground water that has entered the stream above the sampling point.

The analysis of water in the alluvium at Steamboat Springs (253G, fig. 105) is probably representative of ground water in alluvium derived from Precambrian and associated rocks, which receives recharge from streams draining areas underlain by the same type of rocks and from local precipitation. This ground water would have a diluting effect on the Yampa River at low stages. However, other analyses of water from alluvium along the river upstream from Steamboat Springs show that concentrations of dissolved solids are about the same or greater than those of the water in the river at Steamboat Springs during low flow. Part of the valley fill upsteam was derived from the area of Cretaceous rocks above Morrison Creek.

At Steamboat Springs, the flow from several thermal springs enter the Yampa River. The spring water contains between 5,000 and 6,000 ppm dissolved solids,

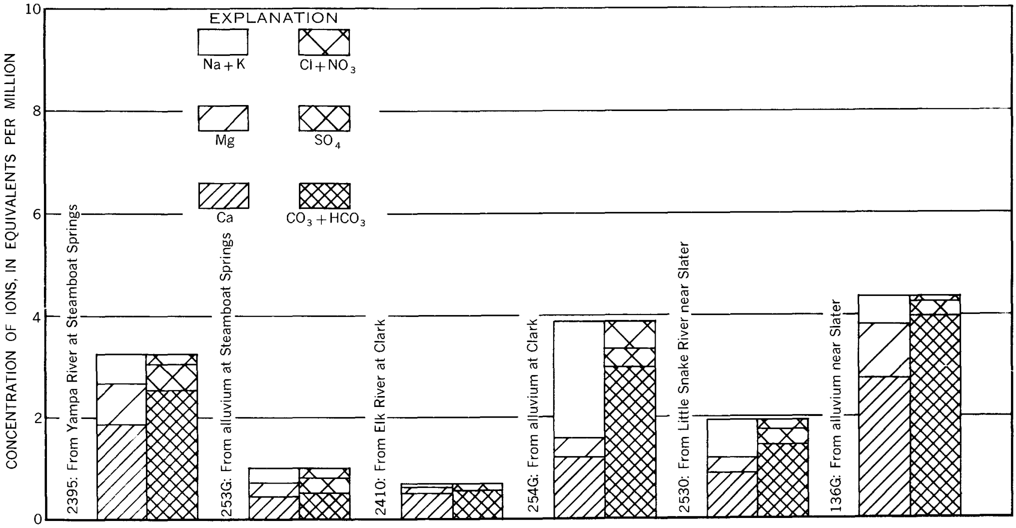


FIGURE 105.—Analyses of water from selected streams near the mountains in the Yampa River basin and from alluvium nearby.

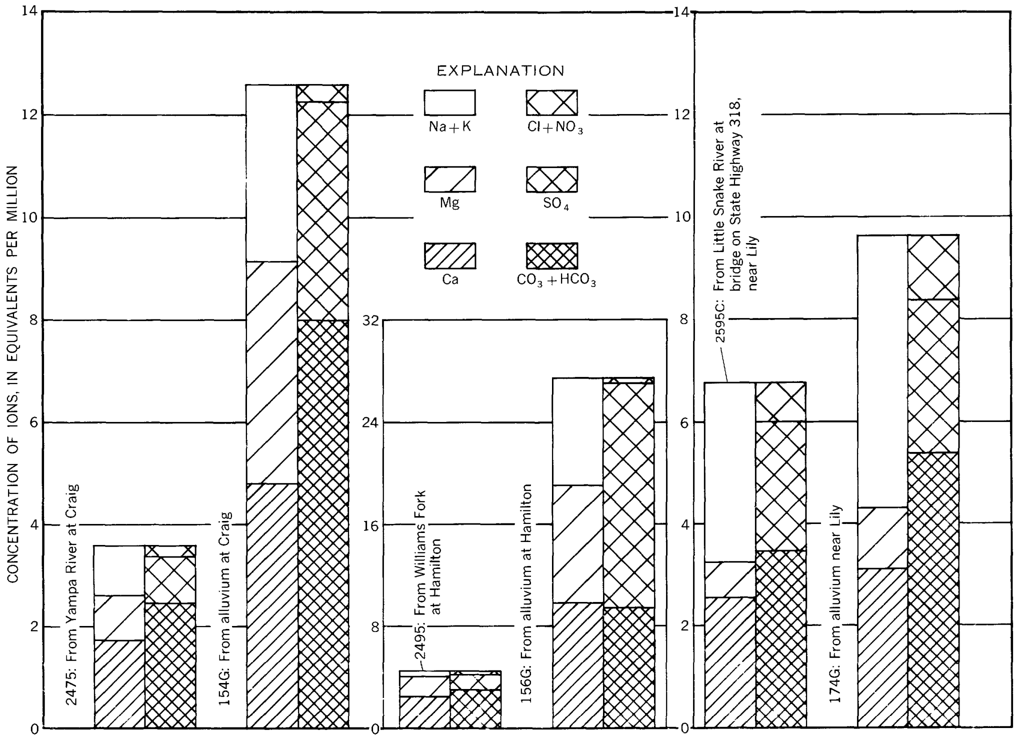


FIGURE 106.—Analyses of water from selected streams in the interior of the Yampa River basin and from alluvium nearby.

most of which are sodium, bicarbonate, and chloride. The spring water also contains as much as 15 ppm of fluoride and about 5 ppm of boron. About 22 thermal springs with an estimated total discharge of 7 cfs and a dissolved-solids concentration of about 5,000 ppm are known to occur in the Yampa River basin (George and other, 1920; Stearns and others, 1937). These springs discharge about 34,500 tons of dissolved solids annually.

EFFECT OF THE ACTIVITIES OF MAN

The amounts of dissolved solids contributed to stream systems by the activities of man were computed for three areas. In the determinations, which were made in a manner similar to that used in the Green River basin above the Yampa River, water and dissolved-solids data not given in table 9 were estimated on the basis of streamflow records in the annual Water-Supply Papers of the U.S. Geological Survey and chemical analyses of water in the basic data report (Iorns and others, 1964, table 222).

Between the gaging stations Yampa River near Oak Creek, Colo., and Yampa River at Steamboat Springs, Colo., about 12,000 acres is irrigated. The irrigated lands are mostly on alluvium of glacial origin. An approximate water and dissolved-solids budget for the area is given in table 15.

The water and dissolved-solids discharges for Yampa River near Oak Creek and at Steamboat Springs are from table 9. The long-term average annual water discharges of Oak, Fish, and Walton Creeks are based on the relation of discharge during the periods of available record to the discharge of Yampa River at Steamboat Springs for corresponding periods and the 44-year period. The weighted-average concentration of dissolved solids of Oak Creek is based on chemical analyses of Trout Creek near Phippsburg, Colo., an adjacent stream having similar environment. The concentrations for Walton and Fish Creeks are based on chemical analyses of the waters of these streams. (See basic data report, Iorns and others, 1964, table 222).

Of the ungaged area, about 48 square miles is in bottom lands and about 251 square miles is mountainous terrain. The bottom lands received about 20 inches of precipitation annually, of which an estimated 5 inches (12,800 acre-feet) infiltrated to the ground-water table and was effluent to the stream system. About half of the bottom lands are underlain by Cretaceous rocks. Chemical analyses of ground water from a well near the mouth of Oak Creek is probably representative of ground water under these lands. This well indicated a dissolved-solids concentration of 169 ppm (basic data report, Iorns and others, 1964, table 227, well 257G). Two other wells on the east side of the Yampa River had dissolved-solids concentrations of 46 and 71 ppm (basic data report, Iorns and others, 1964, table 227, wells 256G and 253G). An average of dissolved solids in the waters of these two wells is probably representative of ground-water quality in the alluvium of glacial origin underlain by Precambrian rocks that occupies the eastern half of the bottom lands.

The unmeasured inflow from the mountainous terrain (251 sq mi) is the amount required to balance the inflow-outflow budget, if 0.8 acre-foot per acre is allowed for consumptive use by the 12,000 acres of irrigated land. This unmeasured inflow is runoff from an area having the same environment as Walton and Fish Creeks; consequently, the concentration of dissolved solids would most likely be the same.

The minimum increase in dissolved solids in the reach between Morrison Creek and Steamboat Springs is equivalent to 0.15 ton per year per acre of irrigated lands.

The irrigated lands on Elk River are mostly residuum underlain by Mancos Shale but some are on river alluvium underlain by Mancos Shale. As this is an area of fairly high precipitation (20 to 30 inches annually), the shale and overlying residuum and alluvium have been subjected to much natural leaching and consequently would yield much less dissolved solids because of irrigation than similar material in areas of low precipitation. Table 15 gives a water and dissolved-solids budget for the part of the basin between the gaging stations on Elk River at Clark and near Trull, Colo., in which about 8,000 acres is irrigated.

The water and dissolved-solids discharges of Elk River at Clark and near Trull given in table 15 are from table 9. The water discharges of Big and Mad Creeks were computed on the basis of correlation with Elk River near Trull for periods of common record and the 44-year average discharge of that stream. The weighted-average concentration of these two creeks would be about the same as Walton and Fish Creeks because of similarity and environment. A thermal spring at Forest Camp with a dissolved-solids concentration of 458 ppm discharges about 250 gpm (gallons per minute) to the river.

About 42 square miles of the intervening ungaged drainage area is bottom lands and lands having little relief, and about 86 square miles consists of mountainous terrain. Only about 12 square miles of the bottom lands is underlain by alluvium predominantly of glacial origin; the balance is underlain by Mancos Shale. It is estimated that under natural conditions about 5 inches of the average annual precipitation (25 inches) would infiltrate into the alluvium and be effluent to the stream system. Chemical analyses of water from two wells in the area indicate this ground water would have an average dissolved-solids concentration of about 242 ppm (Iorns and others, 1964, table 227, wells 254G and 255G). The unmeasured surface water inflow from the 116 square miles of ungaged area (includes 30 sq mi of bottom land underlain by Mancos Shale) is the amount required to balance the inflow-outflow budget if 6,400 acre-feet is allowed for consumptive use by irrigation on 8,000 acres. This area is underlain by Mancos Shale and other rocks of Cretaceous age. The concentration of dissolved solids in the runoff would probably be about the same as that of Elkhead Creek near Elkhead, Colo. (Iorns and others, 1964, table 222), whose drainage is underlain by similar rocks; however, the concentration may be as low as that of Elk River at Clark (40 ppm). The computed minimum increase in dissolved solids in the area, if all attributed to irrigation, is equivalent to about 0.4 ton per year per acre of irrigated land.

In the Little Snake River basin between the gaging stations Little Snake River near Slater, Colo., and Little Snake River near Dixon, Wyo., about 4,000 acres is irrigated. Most of these lands are on river alluvium underlain by the Fort Union, Lance, and Bridger Formations of Tertiary age and Mancos Shale of Cretaceous age. Table 15 gives an approximate water and dissolved-solids budget for the area.

The data given in table 15 for Little Snake River near Slater, Slater Fork near Slater, Savery Creek at upper station near Savery, and Little Snake River near Dixon are from table 9. The water discharge of Battle Creek near Slater is based on the relation of the discharge for common periods of records of this station and Slater Fork near Slater and the 44-year average discharge of Slater Fork near Slater. The runoff of the east-side tributaries of Savery Creek is estimated to be about four-fifths of the difference between the discharge of Savery Creek at upper station and Savery Creek near Savery, Wyo., plus 1,500 acre-feet estimated to be consumptively used by irrigation in the reach. The drainage basins of Battle Creek and the east-side tributaries of Savery Creek are mostly underlain by Precambrian rocks. Walton and Fish Creeks near Steamboat Springs, whose drainage basins are underlain by similar rocks, have weighted-average concentrations of dissolved solids of 25 to 30 ppm. The concentration of dissolved solids of Battle Creek and the east-side tributaries of Savery Creek would probably be in the same range.

Irrigation in the reach (4,000 acres) is estimated to consume about three-fourths acre-foot per acre. Water to irrigate about 3,000 acres is carried in a canal that bypasses the gaging station on Little Snake River near Dixon. It is estimated that the bypassed water is equivalent to about 5 acre-feet per acre and that the water has the same dissolved-solids concentration as Little Snake River near Dixon.

The unmeasured inflow is the amount required to balance the inflow-outflow budget. Most of the ungaged drainage area is underlain by rocks similar to those underlying the drainage basin above the upper station on Savery Creek. Consequently, it could be expected that the dissolved-solids concentration of the unmeasured inflow would be about the same as Savery Creek at upper station. The minimum computed increase in dissolved solids in the reach, if all caused by irrigation, is equivalent to 1.2 tons per year per acre of irrigated land.

Estimates were made of the dissolved solids contributed by natural sources and as a result of the activities of man for other areas in the Yampa River basin by use of the same method used for the Green River basin above the Yampa River. In table 16 the dissolved solids contributed from the different sources are summarized for the basin and at two gaging stations. Of the dissolved solids attributed to the activities of man, it is estimated that about 1,400 tons annually is caused by domestic and industrial uses of water and about 61,000 tons annually is caused by irrigation.

FLUVIAL SEDIMENT

Daily suspended-sediment data have been obtained on Yampa River at bridge on county road, near Maybell, Colo. (table 17). In addition, some suspended-sediment data have been collected at other sites. These records and records of streamflow have been used to estimate the sediment discharge at four sites for the water years 1914–57 adjusted to 1957 conditions (table 18). The data indicate that about 3½ times more suspended sediment comes from the Little Snake River basin than from the Yampa River basin above Maybell. Also, most of the suspended sediment transported by the Little Snake River comes from the more arid parts of the drainage basin.

The suspended sediment contributed to the Yampa River from the 1,055 square miles of drainage area between the gaging stations Yampa River at bridge on county road, near Maybell, Colo., and Little Snake River at bridge on State Highway 318, near Lily, Colo., and the mouth of the Yampa River is estimated to be 400,400 tons annually. This estimate is based on a computed yield of 380 tons per square mile per year (see page 203). The total annual suspended-sediment discharge from the Yampa River basin is about 1,807,400 tons.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The water in the principal streams of the Yampa River basin is suitable for most domestic and agricultural uses. The classification of the surface waters in the basin is based on water criteria for major uses. (See chap. B, pp. 66–73.)

Most of the surface water comes from melting snow in the mountains and plateaus along the east and south boundaries of the basin. This water has a low concentration of dissolved solids and is of the calcium bicarbonate type. Very few of the perennial streams at any given time contain water whose concentrations of constituents exceed the maximum accepted limits for domestic use; however, during low flows, the waters of a few of the perennial tributaries in the south part of the basin contain concentrations of dissolved solids that do exceed the accepted limits.

Most intermittent tributaries of the Little Snake and Yampa Rivers in the arid parts of the basin contain total concentrations of dissolved solids that make them unsuitable for domestic use. The waters of these intermittent tributaries usually contain more than the allowable maximum of magnesium, chloride, and sulfate ions.

The waters of the streams range from soft to very hard. In general, the streams in the mountains are the only ones that have soft water. Nitrate is present in most of the streams but not in concentrations sufficiently great to be a danger. The water from some of the springs at Steamboat Springs, Colo., has concentrations of fluoride high enough to cause mottling of the teeth, if used continuously.

AGRICULTURAL USE

As in the Green River basin above the Yampa River, the principal use of water in this subbasin is for irrigation. Table 19 gives the suitability classification of stream waters for irrigation for low, medium, and high flows. The chemical analyses used for the classification are in the basic data report (Iorns and others, 1964). Most of the terms used in table 19 are self-explanatory, and those that are not are explained on page 203 and in chapter B (pp. 69–73).

The water in some of the intermittent streams, such as Sand Creek near Baggs, Wyo., should not be used for irrigation. However, streams of this type are not dependable sources of water and would rarely be used for irrigation. Most of the water that is used for irrigation would be classified as C2–S1 water or better. The required leaching is generally low, and the soils probably contain sufficient available calcium so that addition of gypsum would not be necessary.

INDUSTRIAL AND RECREATIONAL USES

In and near the mountains the surface waters can be used by many industries without treatment. The waters of the principal streams could be used after minor treatment, if treatment were required at all.

The water in the headwater areas is ideal for recreational use, particularly for fishing and hunting.

GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVERS INCLUDING THE WHITE RIVER BASIN

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Thirteen reservoirs with usable capacities greater than 1,000 acre-feet have been constructed (1957) in this subbasin (table 3). The combined usable capacity is 334,610 acre-feet, and all reservoirs are used for irrigation. All are in the Duchesne River basin, except one in the Pot Creek basin and two in the Brush Creek basin. Strawberry Reservoir stores water for diversion through Strawberry tunnel into the Great Basin. Except for a small amount of spillage in the early 1920's and again in 1952, all runoff from the 170 square miles of drainage area above Strawberry River dam has been diverted out of the subbasin during water years 1914–57.

There are, in addition, many small lakes and stock ponds scattered throughout the subbasin.

TRANSMOUNTAIN DIVERSIONS

Several transmountain diversions export water from the upper Duchesne River basin to the Great Basin. Diversion began through the Duchesne tunnel in the 1954 water year and through the Strawberry tunnel (from Strawberry Reservoir) in 1915. Strawberry River and Willow Creek ditches and the Hobble Creek ditch (all in the headwaters of the Strawberry River) began diverting water before 1914.

The records of annual diversions through the Duchesne and Strawberry tunnels are complete, but records for the Strawberry River and Willow Creek ditches and the Hobble Creek ditch are available only for water years 1950–57. Available records of diversions and estimated total diversion from the subbasin are given in table 20.

The average annual diversion from the headwaters of Strawberry River for water years 1950–57 was 71,590 acre-feet, and the average annual diversion through the Duchesne tunnel for water years 1954–57 was 30,500 acre-feet. For the report, it is assumed that these are representative of long-term averages for development existing in 1957.

IRRIGATION

The U.S. Bureau of the Census (1953) reported about 198,000 acres irrigated in 1949, which was about the same amount irrigated in 1957. (See table 4, pl. 7.) From 1914 to 1952 there was probably some increase in irrigated lands, but the increase was probably minor.

The altitude of the irrigated lands is generally high; only a small part of the lower Duchesne River valley is at altitudes of less than 5,000 feet. The benchlands north of the Duchesne River are at altitudes that average 6,000 feet or more, and some of the irrigated lands in these areas and in the White River basin are more than 7,000 feet in altitude. At these high altitudes, the climate limits crops to hardy species such as alfalfa, wild hay, sugar beets, grains, and a few other crops. Where flat slopes and fine-grained soil prevail, inadequate drainage also limits crop production.

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water by irrigation was about 326,300 acre-feet. The Commission estimated that about 200,100 acres was irrigated and that about 38,300 acres received water incidental to irrigation practices. Of the 326,300 acre-feet used consumptively by irrigation, about 238,600 acre-feet was consumed in the Duchesne River basin, about 33,600 acre-feet in the White River basin, and about 54,100 acre-feet in the remainder of the subbasin.

DOMESTIC AND INDUSTRIAL USES

The 1960 population of the subbasin was only about 24,600, of which about 19,000 lived in Utah. The population averages a little more than two persons per square mile. The five largest communities and their population are: Vernal, Utah, 3,665; Roosevelt, Utah, 1,802; Meeker, Colo., 1,655; Rangely, Colo., 1,464; and Duchesne, Utah, 770.

Vernal obtains its water supply from Ashley Springs, and Meeker and Rangely obtain their water supply from the White River. The per capita water use in Meeker is about 160 gpd. Similar data are not available for other communities in the subbasin, but most communities probably obtain their water supply from wells. The domestic and industrial consumptive use of water is estimated to be about 60 gpd per capita. Of the five largest communities, Rangely is the only community that does not have a sewage treatment plant.

Four hydroelectric powerplants in operation are: Ashley Creek (250 kw), Lake Fork (900 kw), Uinta River (1,200 kw), and White River (200 kw).

Oil and gas are produced at several fields in the subbasin; the Rangely field in the White River basin is the largest producer. Gilsonite is mined in the lower White River basin and is piped as a slurry to Grand Junction, where it is processed into gasoline and asphaltic products. Some of the water produced from oil wells in the Ashley Creek basin during the irrigation season is used for irrigation. In the past, some of the brines produced in oil production in the Red Wash oil field ran into natural drainage channels that lead to Green River, and some was evaporated in ponds. At present, however, the brines are injected back into the oil-producing horizons. In the Roosevelt oil field, the brines from oil wells are disposed of in evaporation ponds (Goode and Feltis, 1962, p. 9).

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Except for the water entering this subbasin in the Green River, most of the water supply comes from the melting of snow that accumulates on the south slopes of the Uinta Mountains and the north slopes of the White River Plateau. As temperatures rise in the late spring and early summer, the snow melts rapidly and causes the streams to rise. The streams then subside as the stored supply of snow is exhausted. Usually by late July, streams have subsided to near a base flow, which prevails until the cycle is repeated again the following spring.

Hydrographs for three streams are shown in figure 107. Although 1954 was a year of relatively low runoff, the hydrographs show the general seasonal pattern. In years of high runoff, the peak flow is generally in June and the snowmelt period lasts much longer than it did in the 1954 water year.

Three different conditions of streamflow are represented by the hydrographs in figure 107. Ashley Creek receives some water from the Oak Park Reservoir, and the inflow of this water is evinced by the increase in discharge on the hydrograph in late June. The hydrograph for Whiterocks River represents natural flow; only a small amount of irrigated land is above the station and regulation by small mountain lakes is negligible. The fairly high sustained flow in White River is probably the result of ground-water storage in the formations underlying the White River Plateau.

FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 26 sites. For all of the sites, curves representative of the 44-year base period adjusted to 1957 conditions of upstream development were prepared. The data for historical and adjusted curves are given in table 5.

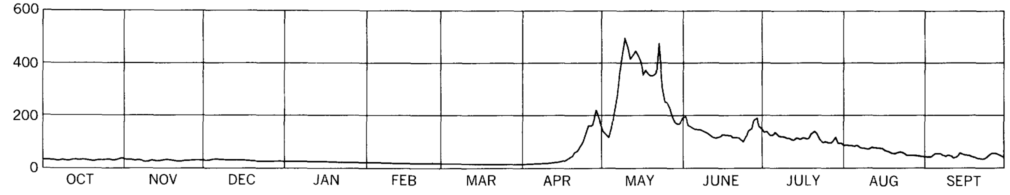
Table 21 outlines the methods used in adjusting the historical flow-duration curves to 1957 conditions and lists the upstream water developments in which changes occurred. The authors' accuracy ratings of the adjusted long-term curves are also given. No adjustments were made for the Strawberry Reservoir and diversions through the Strawberry tunnel. Storage began in the reservoir in 1912, and from that time through the 1957 water year spillage was practically nil.

Flow-duration curves for four streams are shown in figure 108.

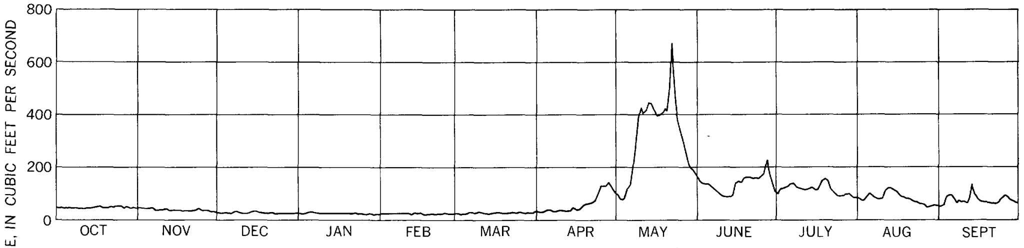
Table 7 gives the variability indices of streamflow and percentage of average annual discharge estimated to be contributed to the streams by ground water at six stations. Only headwater streams on which there is little irrigation are included in the listing, which has been arranged in order of magnitude of the variability indices.

The Whiterocks River and Rock, Ashley, and Yellowstone Creeks all head in areas underlain by Precambrian rocks in the Uinta Mountains and cross southward-dipping formations of limestone, sandstone, and shale ranging in age from Paleozoic to Jurassic (pl. 1). The gradient of the streams is steep, and deep canyons have been cut into the sedimentary rocks. Parts of the drainage basins are overlain by glacial debris and outwash gravel. Numerous small morainal and cirque lakes are in the headwaters, and most of the drainage basins between altitudes of about 9,000 and 11,000 feet are covered with dense growth of subalpine forest.

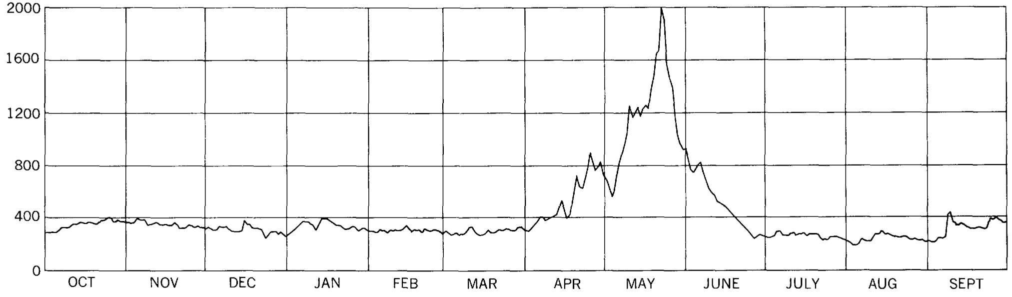
The environmental factors in the drainage basins of the Whiterocks River and Rock, Ashley, and Yellowstone Creeks cause the shape of their flow-duration curves to be very similar. However, the curve for the Whiterocks River is steeper at high and low discharges than the others, a fact indicating less ground-water storage in its drainage basin. The lower variability index and higher percentage of ground water for Yellowstone Creek compared with those for the other streams are probably caused by more extensive ground-water storage or natural-lake regulation in the Yellowstone Creek drainage basin than in the other basins.



A. Ashley Creek near Vernal, Utah



B. Whiterocks River near Whiterocks, Utah



C. White River near Meeker, Colo.

Figure 107.—Seasonal pattern of runoff in the Green River basin between the Yampa and White Rivers including the White River basin, 1954 water year.

The drainage basin of the West Fork Duchesne River is on the eastern slope of the Wasatch Range. This basin is underlain principally by sandstones of the San Rafael and Glen Canyon Groups. Tertiary volcanics underlie the extreme headwater area.

The White River has a relatively high sustained flow, the lowest variability index, and the highest percentage of ground-water contribution of the six streams listed in table 7. This stream drains the north slope of the White River Plateau, which is underlain by Pennsylvanian and Permian Rocks and partly capped with Tertiary volcanic rocks. These rocks, particularly the volcanic rocks, are permeable; and extensive ground-water reservoirs, which sustain the flow of the river, are apparently present.

VARIABILITY OF ANNUAL RUNOFF

Annual water discharges for three streams in the subbasin for the water years 1914–57 are shown in figure 109. The pattern of annual discharges for Ashley Creek and the Whiterocks River is very similar, but different from the pattern of White River. The coefficients of variation for these three streams and the Duchesne River at Duchesne, Utah, are given in table 8. These coefficients are also shown on plate 6. Other streams with shorter periods of record that drain the south slope of the Uinta Mountains were also studied; their coefficients ranged from about 0.30 to 0.37. The climate is almost the same along the length of the Uinta Mountains, but some streams apparently have ground-water reservoirs and lakes in their drainage basins that

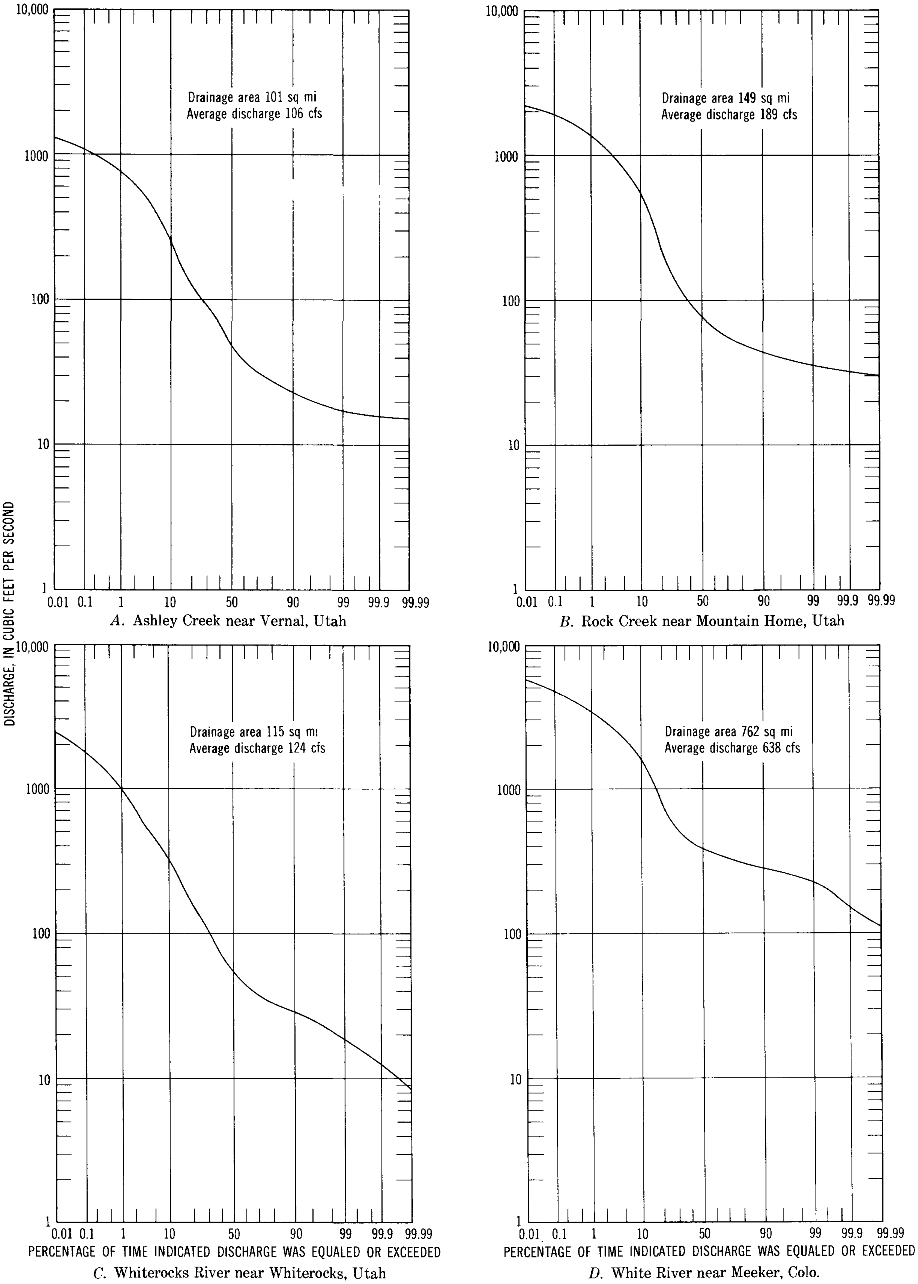
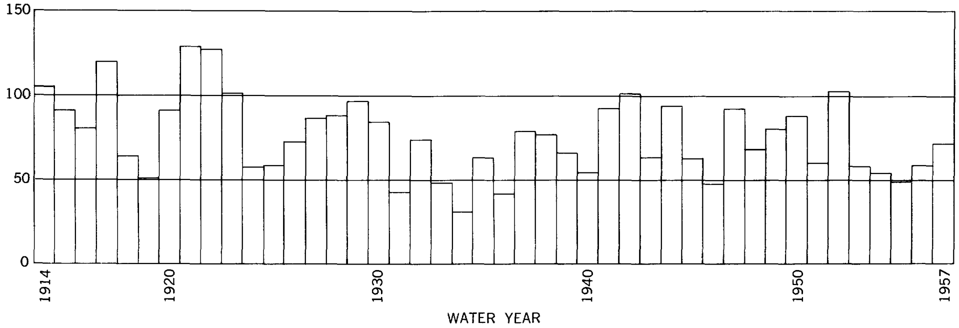
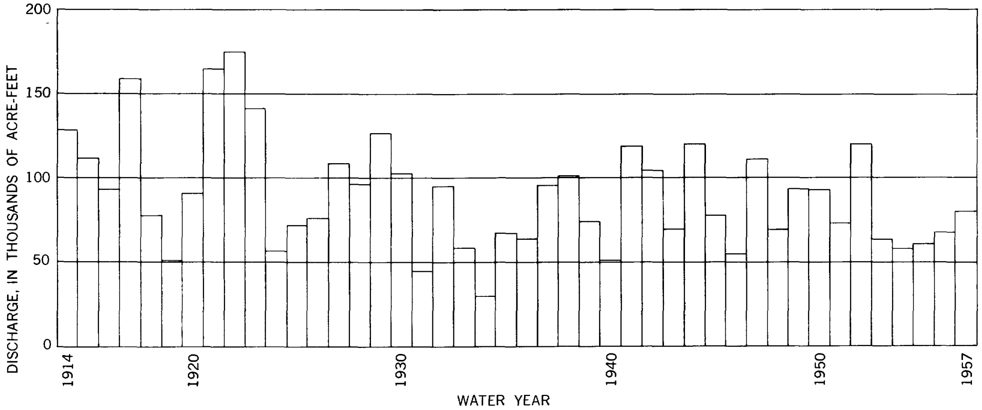


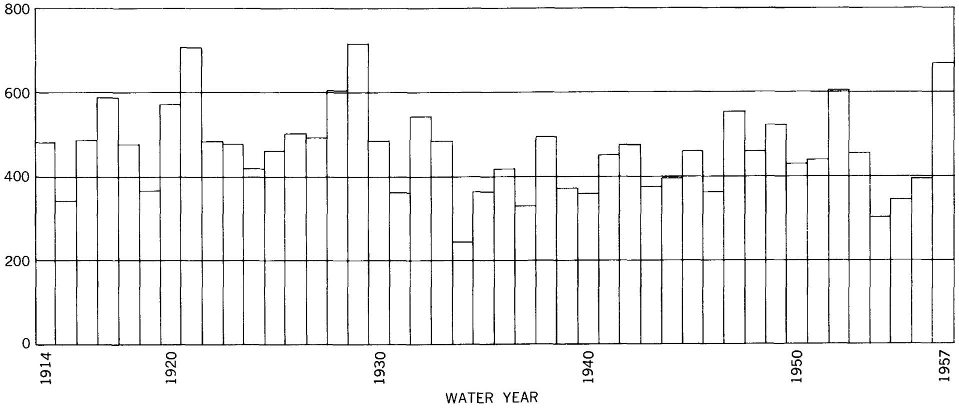
FIGURE 108.—Flow-duration curves of streams in the Green River basin between the Yampa and White Rivers including the White River basin, water years 1914–57 adjusted to 1957 conditions.



A. Ashley Creek near Vernal, Utah



B. Whiterocks River near Whiterocks, Utah



C. White River near Meeker, Colo.

FIGURE 109.—Variability of annual discharges of selected streams in the Green River basin between the Yampa and White Rivers including the White River basin, water years 1914–57.

sustain the flow during years of low precipitation. This results in coefficients of variation in the lower part of the range. Ground-water reservoirs in the permeable formations of the White River plateau are extensive enough to maintain good flows in the White River during periods of low precipitation. The data in table 8 may be used in determining probable future runoff for periods of various length. (See p. 191 and chap. B., pp. 57–58.)

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained on water at six stations in the subbasin. Monthly and annual weighted-average chemical analyses of water at these stations are given in the basic data report (Iorns and others, 1964, tables 195–201). In addition to the daily data at the six stations, chemical analyses of streams have been obtained at other sites. The dissolved-solids discharge for the daily stations and for some of the other sites have been computed (table 9). The quantities given in table 9 are averages which would have occurred if 1957 developments had been in operation throughout water years 1914–57.

Duration tables of dissolved-solids concentration and discharge for the stations listed in table 9 are given in tables 10 and 11. (See chap. B, pp. 58–59, for description of computation methods.)

In figure 110 the dissolved solids and water entering this subbasin via the Green River and the dissolved-solids and water discharges at selected sites (table 12), expressed as percentages of the dissolved-solids and water discharges of Green River near Ouray, Utah, are shown. About 28 percent of the water and about 43 percent of the dissolved solids passing the station near Ouray come from this subbasin. In terms of percentage of water and dissolved-solids discharge of Green River near Ouray, the White River contributes about the same amount of water to the Green River as the Duchesne River but contributes about 5 percent less dissolved solids.

VARIATIONS IN CHEMICAL QUALITY

The streams of this subbasin have a relatively small seasonal range in dissolved-solids concentration near their headwaters. Downstream, the seasonal range in dissolved-solids concentration increases. Table 10 shows the maximum seasonal range which may be expected if developments that existed in 1957 do not increase or decrease.

The monthly weighted-average concentration of some streams is considerably different in years of low and high runoff, as is shown by figure 111 for White River near Watson, Utah. Water year 1954 was a year of relatively low runoff, and 1951 was a year of relatively high runoff. The concentration is less variable during the winter than it is during the summer.

The coefficient of variation of annual weighted-average concentration of dissolved solids and of annual historical discharge for one stream in the subbasin is given in table 12. The computed coefficients are for the same period, but that period is probably too short for a reliable statistical analysis. (See p. 193 for discussion of relation between coefficients of variation in the Green division.)

RELATION TO STREAMFLOW

The dissolved-solids concentration of the streams varies nearly inversely with the streamflow, and the dissolved-solids discharge varies directly with the streamflow (fig. 112). An exception to this may be Lake Fork below the Lake Fork Reservoir, Utah, where the variation in dissolved-solids concentration is small because of mixing in the reservoir.

The waters of the streams near their headwaters are principally of the calcium bicarbonate type, but the chemical composition of most streams changes in their downstream reaches, particularly during low flow. Table 13 gives the chemical composition of water for different rates of discharge at seven sites on streams in the subbasin. The data at four of these sites are illustrated in figure 113.

RELATION TO GEOLOGY

The rocks in the higher parts of the Uinta Mountains are mostly quartzites of Precambrian age and are relatively resistant to the solvent action of water. Along the south flank of the mountains, sedimentary rocks of Paleozoic to Jurassic ages are exposed as narrow bands. These rocks are more resistant to the solvent action of water than are the rocks of Cretaceous and Tertiary ages that underlie the greater part of the subbasin west of the Green River.

Rocks of Cretaceous and Tertiary ages also underlie much of the subbasin east of Green River. In the headwaters of the White River, Pennsylvanian and Permian rocks, partly capped with Tertiary volcanics, are exposed.

Streams in the subbasin draining the areas underlain by rocks of Precambrian to Jurassic ages and Tertiary volcanics contain fairly low concentrations of dissolved solids, and the water is of the calcium bicarbonate type. The weighted-average concentration of dissolved solids in the waters of these streams usually does not exceed 300 ppm (table 9).

The sedimentary rocks of Cretaceous and Tertiary ages that underlie the greater part of the subbasin contain an abundant supply of soluble material, and they are in an area of low precipitation. From the headwaters of the main streams to their mouths, the waters

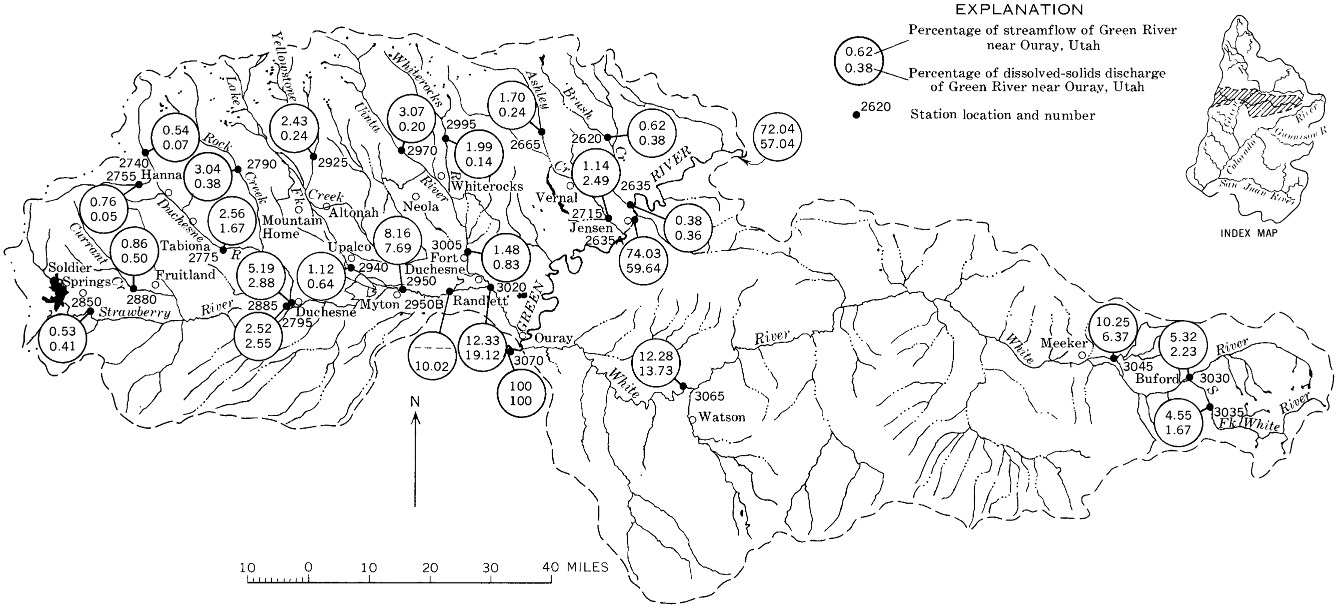


FIGURE 110.—Approximate dissolved-solids discharge and streamflow in the Green River basin between the Yampa and White Rivers including the White River basin expressed as percentages of dissolved-solids discharge and streamflow of Green River near Ouray, Utah.

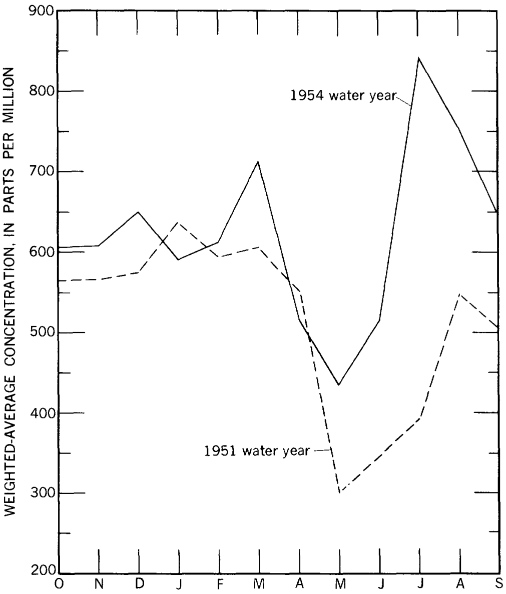


FIGURE 111.—Dissolved-solids concentration of White River near Watson, Utah, for the 1951 and 1954 water years.

of the streams become progressively more mineralized, and the chemical composition changes from a calcium bicarbonate type to a magnesium sodium sulfate or chloride type.

Most irrigated lands are in lower mountain valleys or in the interior of the subbasin (pl. 7). Here, the soils are derived from residuum and are closely associated with the underlying Cretaceous and Tertiary rocks. Return flow from the irrigated lands contains large quantities of dissolved material, leached from the soils and the underlying rocks. The addition of the return flow to the streams increases the concentration of dissolved solids in the streams and often causes a change in their chemical composition.

Figure 114 shows broad zones within which the weighted-average dissolved-solids concentrations of the streams are between certain limits. These zones correlate closely with the different rock types and the precipitation and indicate that the surface water in a large part of the subbasin contains high concentrations of dissolved minerals. Fortunately, the runoff from the areas that are capable of yielding high concentrations of dissolved-solids is so low that the total quantity of dissolved minerals is not sufficient to increase seriously the concentration of the water of the Green River insofar as local use is concerned.

The diagrams on plate 2 show the geochemical character and ionic concentrations of surface waters at 63 sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flows. The significance of the size and shape of the diagrams is given in the explanation on plate 2.

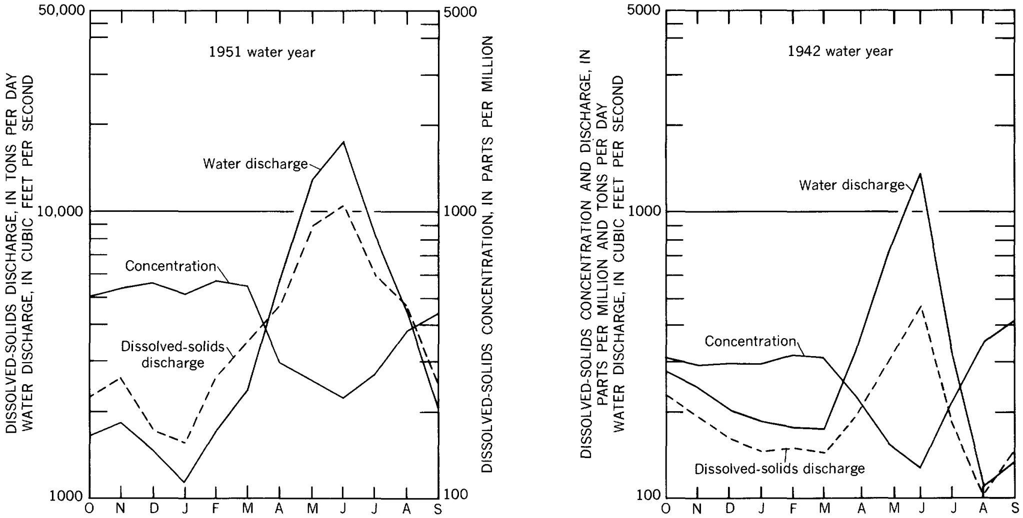
RELATION TO GROUND WATER

Ground water in the subbasin occurs in deposits of glacial origin in the mountains, in permeable beds of consolidated rocks, and in unconsolidated deposits in the valleys. The recharge areas of the permeable consolidated rocks are along the flanks of the Uinta Mountains and in the Wasatch and White River Plateaus. Except for places where the streams are deeply incised into permeable beds of the consolidated rocks along the flanks of the mountains, ground water in these beds has little relation to the chemical quality of the water in the streams. The permeable beds dip steeply beneath the floor of the subbasin and are deeply buried by relatively impermeable beds of Cretaceous and Tertiary rocks.

The glacial deposits in the mountains are derived principally from relatively insoluble rocks, and the ground water in these deposits is low in dissolved solids and is of the calcium bicarbonate type. Ground water which enters the streams from the incised permeable beds at the edge of the mountains is mostly of the calcium bicarbonate or calcium sulfate type. As this area is fairly close to the area of recharge, the ground water has low to moderate concentrations of dissolved solids.

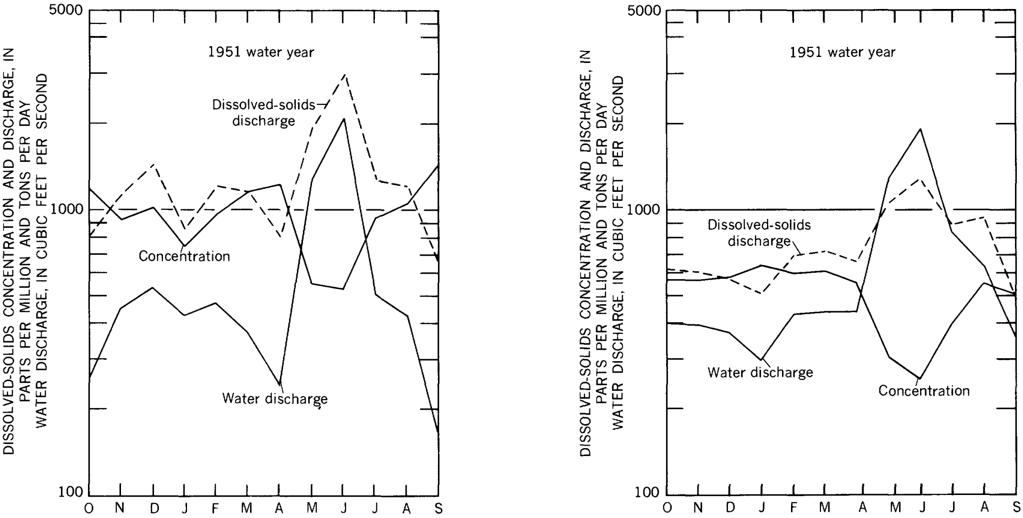
Table 14 gives the water and dissolved solids estimated to be contributed to selected headwater streams by ground water. The amount of dissolved solids contributed is dependent on the amount of ground water entering the streams and on the solubility of rock material in the ground-water reservoirs. As indicated by the data in table 14 the solubility of the rock complex underlying the drainage basins above the stations on Ashley Creek, West Fork Duchesne River, Rock Creek, Yellowstone Creek, and Whiterocks River is low, but the rocks of Pennsylvanian and Permian ages underlying much of the headwaters of White River apparently contain a relative abundance of soluble minerals.

Ground water in alluvium in the interior valleys originates principally by infiltration from streams and from irrigated lands. This alluvium is derived principally from rocks of Cretaceous and Tertiary ages and contains an abundance of soluble minerals. Figure 115 shows comparisons of analyses of water in the alluvium



A. Green River at Jensen, Utah

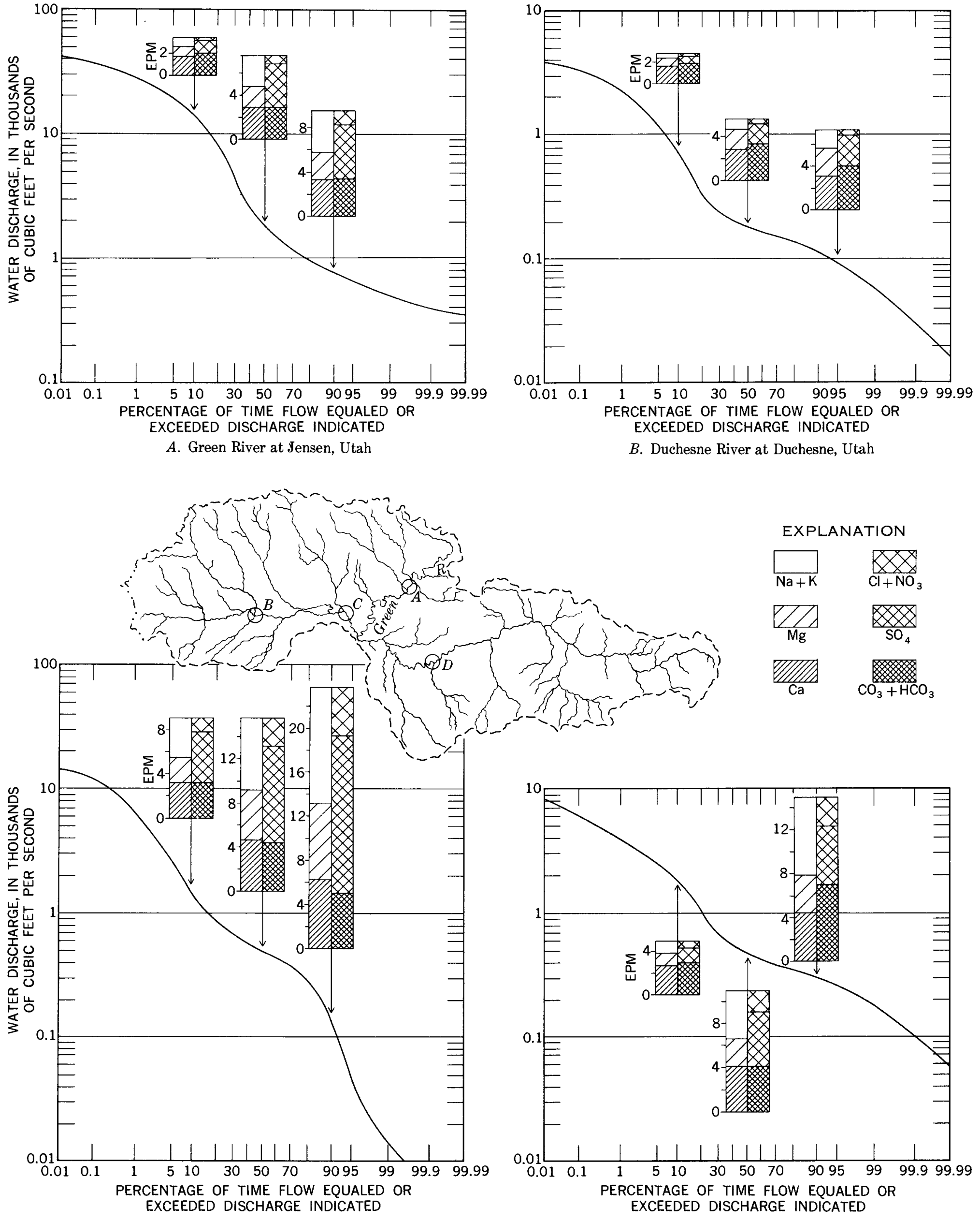
B. Duchesne River at Duchesne, Utah



C. Duchesne River near Randlett, Utah

D. White River near Watson, Utah

Figure 112.—Dissolved-solids concentration and discharge and water discharge at four daily stations in the Green River basin between the Yampa and White Rivers, including the White River basin.



A. Green River at Jensen, Utah

B. Duchesne River at Duchesne, Utah

C. Duchesne River near Randlett, Utah

D. White River near Watson, Utah

Figure 113.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Green River basin between the Yampa and White Rivers including the White River basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914-57 adjusted to 1957 conditions.

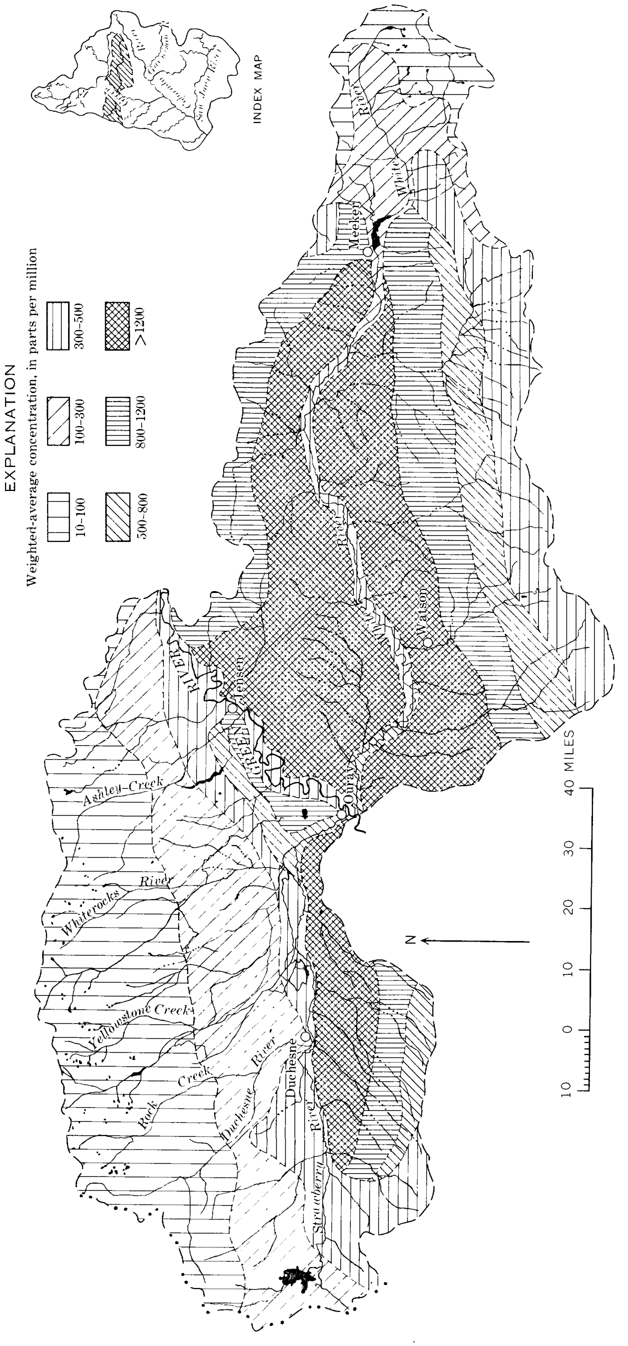


FIGURE 114.—Approximate weighted-average concentration of dissolved solids of streams in the Green River basin between the Yampa and White Rivers including the White River basin.

and in the nearby streams. The analyses of the water from alluvium and from Green River at Ouray, Utah, and White River near Watson, Utah, are examples of the chemical quality of ground water in alluvium that is recharged when the stream is high. In the other comparisons in figure 115, the ground water in the alluvium is recharged principally by irrigation.

The ground water in the alluvium, particularly in areas where recharge is from irrigation, contains fairly large quantities of calcium, magnesium, sodium, and sulfate ions. In some local areas of the subbasin, nitrate is present in concentrations approaching the maximum considered to be safe for domestic use.

In the western part of the subbasin, ground water contributes boron to some of the northward-flowing streams. Boron in these streams at times exceeds 10 ppm.

Warm Springs, a group of thermal springs which flow into the Green River from both sides of the channel about 12 miles north of Jensen, Utah, has an estimated flow of 12 cfs (Thomas, 1952, p. 12). The water from the springs has a dissolved-solids concentration of about 940 ppm, and the annual dissolved-solids discharge is about 11,100 tons.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

Several canals and tunnels divert water from the headwaters of the Strawberry and Duchesne Rivers to the Great Basin (see p. 216). The effect of these diversions has been to reduce the water and dissolved-solids discharges and increase the weighted-average concentration of dissolved solids in the Strawberry and Duchesne Rivers at downstream points. The weighted-average concentration of the diverted water is less than that of the streams from the points of diversion to the mouth of the Duchesne River.

The weighted-average concentration of dissolved solids in the 71,600 acre-feet of water diverted annually from the Strawberry River is about 170 ppm (Iorns and others, 1964, table 223). The effect of the diversion on Strawberry River at Duchesne, Utah, has been to decrease the dissolved-solids discharge about 16,600 tons annually and increase the weighted-average concentration about 87 ppm (see chap. B, p. 61 for method of computation). If the water were not diverted, the weighted-average concentration of Strawberry River at Duchesne, Utah, would be about 309 ppm instead of 396 ppm.

The weighted-average concentration of dissolved solids in the 30,500 acre-feet annually diverted through Duchesne tunnel is about 25 ppm (Iorns and others, 1964, table 223). The effect of this diversion on Duchesne River at Duchesne, Utah, has been to decrease the dissolved-solids discharge about 1,040 tons and increase the weighted-average concentration about 22 ppm. If the water were not diverted, the weighted-average concentration of Duchesne River at Duchesne, Utah, would be about 196 ppm instead of 218 ppm.

The diversions from the headwaters of the Strawberry and Duchesne Rivers have caused the long-term weighted-average concentration of Duchesne River

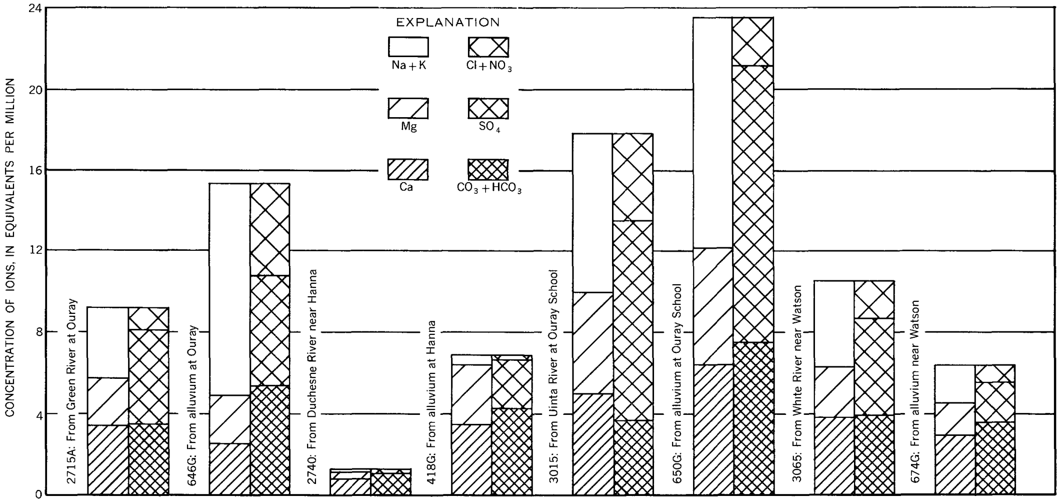


FIGURE 115.—Analyses of water from selected streams in the Green River basin between the Yampa and White Rivers including the White River basin and from alluvium nearby.

near Randlett, Utah, to increase from about 533 ppm to 608 ppm.

EFFECT OF THE ACTIVITIES OF MAN

In this subbasin, the dissolved solids contributed to the stream systems in three areas were determined. General descriptions of the three areas and computations of the dissolved-solids contributions are given in the following paragraphs.

In Ashley Creek basin below Ashley Creek near Vernal, Utah, and Dry Fork at the mouth, near Dry Fork, Utah, and above Ashley Creek near Jensen, Utah, about 23,800 acres of land underlain by alluvium and by Mancos Shale is irrigated. Several oil wells in the area produce water which is discharged to irrigation canals. In 1960 these wells discharged about 2,400 acre-feet of water with dissolved-solids concentrations ranging from 416 to 1,960 ppm (Goode and Feltis, 1962, table 2). The 2,400 acre-feet of oil-well water contained an estimated 4,000 tons of dissolved solids. An average of about 3,500 acre-feet of water is diverted annually out of the basin, and about 600 acre-feet of underflow bypasses the Jensen gaging station (Thomas and Wilson, 1952). Table 15 gives an approximate water and dissolved-solids budget for the area.

The water discharge of Dry Fork at mouth, near Dry Fork, Utah, (19,000 acre-feet) is the difference between the discharge of Ashley Creek at Sign of the Maine, near Vernal (95,800 acre-feet), and the discharge of Ashley Creek near Vernal (76,800 acre-feet). The weighted-average dissolved-solids concentration of Dry Fork at mouth was computed from the water discharge and chemical analyses for Ashley Creek at Sign of the Maine (weighted-average concentration about 71 ppm, Iorns and others, 1964, table 223), the water discharge and weighted-average concentration for Ashley Creek near Vernal, and the water discharge for Dry Fork at mouth.

The weighted-average concentration of dissolved solids of the water diverted out of the area is assumed to be the same as that of Ashley Creek at Sign of the Maine. The concentration of dissolved solids of the ground-water outflow is based on analyses of Ashley Creek near Jensen at times of low flow (table 10 and Iorns and others, 1964, table 223).

In the budget the 42,500 acre-feet consumed in the area is the amount required to balance the inflow-outflow budget. This amount is equivalent to a consumptive-use rate of 1.8 acre-feet per acre of irrigated land. This rate is of the right order of magnitude for the environment and type of crops grown and indicates that any other inflow into the area is probably negligible. Average annual precipitation over the intervening area is only about 9 to 15 inches.

The increase in dissolved solids from other sources, 49,400 tons annually, is equivalent to 2.1 tons per year per acre of irrigated land.

Along the Duchesne River between the gaging stations near Tabiona and at Duchesne, Utah, about 6,500 acres is irrigated. The irrigated lands are underlain by the Uinta Formation of Tertiary (Eocene) age. Duchesne River near Tabiona, Utah, and Rock Creek near Mountain Home, Utah, record most of the inflow to the area (table 9). In addition to the water flowing out of the area in the Duchesne River at the Duchesne gaging station (table 9), some water is carried past the station in a canal, and some underflow probably occurs in the valley fill. Average annual precipitation over the intervening drainage area between the inflow and outflow stations is only about 9 to 12 inches. It is estimated that the runoff from this area would be about half an inch annually, or about 4,000 acre-feet from the 159 square miles of intervening area. This runoff is estimated to have the same weighted-average concentration of dissolved solids as Duchesne River near Tabiona. An approximate budget of water and dissolved solids for the area is given in table 15.

Irrigation in the intervening reach (6,500 acres) is estimated to have the same consumptive-use rate as Ashley Creek basin (1.8 acre-ft per acre). The canal bypassing the Duchesne River near the Duchesne gaging station for the irrigation of 1,000 acres on the north side of the Duchesne River below the station is estimated to bypass about 5,000 acre-feet annually (5 acre-ft per acre). About one-half of the irrigated lands in the area is above the point of diversion of this canal. The weighted-average concentration of dissolved solids of the bypassed water is estimated to be 180 ppm. This concentration was computed by averaging the concentration of dissolved solids for Duchesne River at Duchesne (218 ppm) and the weighted-average concentration for Duchesne River near Tabiona and Rock Creek near Mountain Home (144 ppm).

The estimated ground-water underflow of 5,100 acre-feet is the amount required to balance the inflow-outflow budget. This amount is equivalent to about 7 cfs. The concentration of dissolved solids of the ground water is estimated to be the same as the concentration of water from Duchesne River at Duchesne during low flow.

The computed increase of dissolved solids in the reach (22,700 tons) is equivalent to about 3.3 tons per year per acre of irrigated land.

In the White River drainage basin below White River at Buford, Colo., and South Fork White River near Buford, Colo., and above White River near

Meeker, Colo., about 11,000 acres is irrigated. In the upper part of the area, Permian rocks underlie the irrigated lands; but the lower part of the area, where most of the irrigated lands are located, is underlain by Mancos Shale. A canal supplying water for about 300 acres bypasses White River at Buford, Colo., gaging station and about 3,000 acres are irrigated by water that bypasses White River near Meeker, Colo., gaging station. Table 15 gives an approximate water and dissolved-solids budget for the area.

Water and dissolved-solids discharges for the gaging stations named in table 15 are from table 9. The canals that bypass the gaging stations are estimated to carry about 5 acre-feet per year for each acre irrigated. The dissolved-solids concentration of water in the canal bypassing White River at Buford is estimated to be the same as that at this gaging station. The dissolved-solids concentration of the canals bypassing the station near Meeker is taken to be equal to the weighted-average of White River at Buford and South Fork White River near Buford.

The amount of water consumed by irrigation is based on a consumptive use of 1 acre-foot per acre, and the unmeasured inflow in the reach is the amount required to balance the inflow-outflow budget. Most of the unmeasured inflow is runoff from the White River Plateau, and as indicated by the stations at and near Buford would have a weighted-average concentration of dissolved solids between 144 and 164 ppm. However, some of the unmeasured inflow comes from Coal Creek, a north-side tributary above Meeker. The drainage basin of this creek is underlain by Mancos Shale, and the weighted-average concentration of its water would probably be above 200 ppm. As the amount of inflow from such streams as Coal Creek is small compared with the inflow from streams draining the White River Plateau, the weighted-average concentration of all the unmeasured inflow could be expected to range from 150 to 180 ppm.

If the minimum increase from other sources in table 15 were all caused by irrigation, it would be equivalent to 4.8 tons per year per acre of irrigated land.

Estimates were made of the dissolved solids contributed by natural sources and the activities of man for other areas in the subbasin. In table 16, the total computed and estimated quantities contributed by natural sources and activities of man are summarized for two principal gaging stations and for the subbasin.

If there had been no activities of man in the Duchesne River basin (exclusive of transmountain diversions), the weighted-average concentration of dissolved solids of Duchesne River near Randlett, Utah, would have been about 125 ppm as compared with a weighted-average concentration of 608 ppm for water years 1914–57 adjusted to 1957 conditions. In this determination, the amount of water consumptively used by irrigation was estimated to be 234,000 acre-feet annually, and the water consumed by domestic and industrial uses of water was considered to be negligible.

If there had been no activities of man in the White River Basin, the weighted-average concentration of dissolved solids of White River at Watson, Utah, would have been about 209 ppm instead of 439 ppm for water years 1914–57, adjusted to 1957 conditions. In this determination, 33,600 acre-feet of water was considered to be the amount consumptively used by irrigation, and the domestic and industrial consumptive use was considered to be negligible.

The increase in dissolved solids due to irrigation in the subbasin is estimated to be about 555,800 tons per year. This estimate is based on assigning 100 tons per year per 1,000 people as the contribution of dissolved solids from domestic and industrial uses of water, 4,000 tons per year from oil wells, and the remainder from irrigation.

FLUVIAL SEDIMENT

Daily suspended-sediment data have been obtained only at Green River near Jensen, Utah (table 17). In addition, suspended-sediment discharges have been measured at a few other sites. Estimated long-term suspended-sediment data for the station near Jensen and for White River at Buford, Colo., are given in table 18.

The total suspended-sediment discharge from the subbasin is estimated to be about 7,339,400 tons annually. This estimate is based on the difference between the suspended-sediment discharges of Green River near Jensen, Utah, (table 18) and Green River near Ouray, Utah, (table 18), plus an estimated pickup of 417,400 tons annually between the Yampa River and the station near Jensen. The estimated pickup between the Yampa River and the station near Jensen is based on a computed yield of 380 tons per square mile per year from 1,100 square miles of drainage area (see p. 203).

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classifications of the surface water in this subbasin is based on water-quality criteria for major uses. (See chap. B, pp. 66–73.)

In and close to the Uinta Mountains and the White River Plateau, the waters of the streams are suitable for domestic purposes. Concentrations of iron, chloride, and fluoride in all the streams are generally low and do not exceed the maximums considered to be harmful. The limitation on concentration of magnesium (125 ppm) is exceeded in some of the streams, but only for short periods of time.

In the more arid part of the area, close to the mouths of all tributaries of the Green River except the White River, concentrations of sulfate in the streams exceed the maximum limit accepted for this report for 50 percent or more of the time. In many of these tributary streams, the concentration of dissolved solids in the water exceeds 1,000 ppm as much as half the time and exceeds 500 ppm at least 80 percent of the time.

The waters of all the streams, except in the mountains, range from moderately hard to very hard and are mostly very hard.

AGRICULTURAL USE

As in other parts of the Green division, the principal use of water in this subbasin is for irrigation. Table 19 classifies low, medium, and high flows of streams at selected sites according to their suitability for use in irrigation. Most of the terms used in the table are self-explanatory. Terms that are not self-explanatory are explained on page 203 and in chapter B (pp. 69–73).

The values for residual sodium carbonate given in table 19 indicate that the water of most of the streams is free of residual sodium carbonate or contains much less than 1.25 epm. Warm springs on the Strawberry River (2880B and 2880C) have high residual sodium bicarbonate values. The source of the sodium bicarbonate is probably the shales of the Green River Formation which underlie the Uinta Formation in this area. Discharge from these and other springs along the Strawberry River are apparently sufficient to cause the residual sodium carbonate to be fairly high in the Strawberry River at Duchesne, Utah, at times of medium and low flow. As indicated by the residual sodium carbonate in Indian Creek near Duchesne, Utah, and Piceance Creek near White River, Colo., similar springs probably occur along these streams.

Most of the water used for irrigation in the subbasin is C2–S1 category or better. This water is suitable for irrigation if a moderate amount of leaching occurs, and there is little danger of development of harmful levels of exchangeable sodium. In their lower reaches during times of low flow, many of the streams in the subbasin below irrigated land are classified as C3–S1 or poorer. Lands on which such water is used must have adequate drainage.

Percent sodium of the irrigation water is not a hazard, and the required leaching of most of the water used is usually less than 20 percent.

Fairly high concentrations of boron occur in groundwater contributions to the Strawberry River, Lake Canyon Creek, and Indian Creek above Duchesne, Utah. This is indicated by analyses of water from springs and from Indian Creek when the discharge of that stream consisted mostly of ground water (table 22). The ground water also contains high concentrations of sodium, bicarbonate, and sulfate (see Iorns and others, 1964, table 229). The area in which the ground water occurs is underlain by the Wasatch and Green River Formations. The total ground-water discharge is apparently too small to cause a boron hazard in the main streams, except possibly at times of exceptionally low flow.

INDUSTRIAL AND RECREATIONAL USES

The water of most of the perennial streams in their headwaters can be used for many industries without treatment. The concentration of dissolved solids progressively increases downstream; and in the middle and lower reaches of most of the streams in this subbasin, the surface waters could not be used for many industries without treatment.

Most of the streams and lakes in the Uinta Mountains and White River Plateau are ideal for recreation. The use of surface waters for this purpose will, no doubt, continue to expand rapidly.

GREEN RIVER BASIN BELOW THE WHITE RIVER

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Nine irrigation reservoirs that have capacities greater than 1,000 acre-feet have been constructed (1957) in the Green River basin below the White River (table 3, and fig. 4). There are, in addition, several small natural lakes on the Wasatch Plateau and many stock ponds scattered throughout the subbasin.

TRANSMOUNTAIN DIVERSIONS

In all, 13 ditches and tunnels divert water from this subbasin to the Sevier River basin. Records on the diversions are only available for water years 1950–57 (table 23). Fairview ditch diverts water from the headwaters of both the Price and San Rafael Rivers, and the others divert water from the headwaters of the San Rafael River.

On the basis of information on water rights, canal capacities, time of enlargements of canal capacities, and other data, estimates of annual diversions were made for the water years 1914–49. These estimates and total diversion for water years 1950–57 are given in table 24. The average annual diversions during water years 1950–57 was 10,100 acre-feet. For this report, 10,100 acre-feet is assumed to be representative of the diversions for water years 1914–57 and developments existing in 1957.

IRRIGATION

Irrigation is confined chiefly to the middle and upper reaches of the San Rafael and Price Rivers. A total of about 60,000 acres is irrigated (table 4), of which about 20,500 acres is above Green River at Green River, Utah. Crops are chiefly alfalfa, wild hay, and grains.

The Upper Colorado River Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water by irrigation was about 102,600 acre-feet. The Commission estimated that 61,740 acres was irrigated and that 9,330 acres of land received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The 1960 population was about 27,000, which averages about 3 persons per square mile. The five largest communities, all in Utah, and their population are: Price, 6,802; Dragerton, 2,959; Helper, 2,459; Sunnyside, 1,740; and Green River, 1,075. The principal means of livelihood in the four largest communities are coal mining and related activities; however, farming and ranching are the principal means of livelihood of over half the people in the subbasin. No data are available on the amount of water used by the communities; however, it is estimated that domestic and industrial uses consumed about 60 gpd per person or about 1,800 acre-feet annually. There are no known hydroelectric powerplants in the subbasin.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

Streams flowing from the west into the Green River receive most of their water supply from melting snow along the east slope of the Wasatch Mountains. The tributaries that enter the Green River from the east rise on the East Tavaputs Plateau. Snowfall on this plateau is light, and the average annual precipitation in the water-producing areas is only about 18 inches. Willow Creek, the principal tributary of Green River from the east, is dry at times in its lower reaches. Many of the smaller streams and washes that drain the areas at lower altitudes are intermittent and flow only in the early spring months or following thunderstorms.

Figure 116 shows hydrographs of two west-side streams and the Green River. Green River at Green River, Utah, and San Rafael River near Green River contribute practically all the outflow from the Green River basin.

FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 14 sites. The historical and adjusted curves in table form are given in table 5. Table 21 outlines the methods used in adjusting the historical flow-duration curves and lists the upstream water developments in which changes took place. This table also gives the authors' accuracy rating of the adjusted long-term curves.

Flow-duration curves for two west-side streams are shown in figure 117. That for Price River above Scofield Reservoir, Utah, is representative of most west-side streams near their headwaters. The curve for Huntington Creek is materially different and reflects the effect of both geology and storage. The hydrographs (fig. 116) also reflect the different runoff characteristics.

Table 7 gives the variability indices of streamflow and percentage of total discharge estimated to be contributed by ground water for three streams in the subbasin. The drainage basin of Huntington Creek is underlain by the Blackhawk Formation and Star Point Sandstone of Late Cretaceous age; that of Cottonwood Creek is underlain mostly by the North Horn Formation of Tertiary (Paleocene) and Late Cretaceous age, and that of Ferron Creek is underlain by the Flagstaff Limestone (late Paleocene and early Eocene(?) age) and the North Horn Formation. Of the three drainage basins, the rocks underlying Huntington Creek basin are apparently the most permeable, and the Flagstaff Limestone underlying part of the Ferron Creek Basin is the least permeable.

VARIABILITY OF ANNUAL RUNOFF

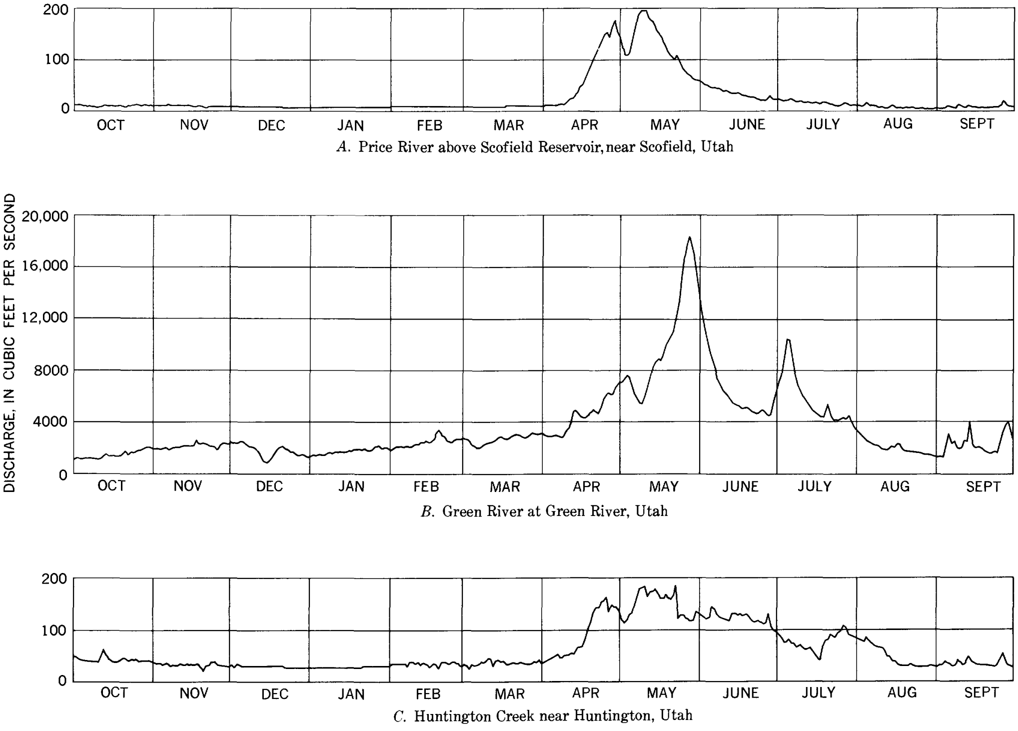
Figure 118 shows the historical annual discharges of Price River near Heiner, Utah, Huntington Creek near Huntington, Utah, and Green River at Green River, Utah. The histogram for Price River near Heiner, Utah, is the combined record for a station operated near Helper for water years 1914–34 and the station near Heiner for water years 1935–57. For all practical purposes, the discharge at these two sites is the same.

The coefficients of variation of three headwater streams and Green River at Green River, Utah, are given in table 8. The close agreement of the coefficients of the headwater streams is probably due to the uniformity of the climate and other hydrologic factors. The data in the table may be used in determining the probable future runoff for periods of various length. (See p. 191 and chap. B, pp. 57–58.)

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at five stations in the Green River basin below the White River. Monthly and annual weighted-average chemical analyses of water at these stations are given in the basic data report (Iorns and others, 1964, tables 202–206). In addition, chemical analyses of streams at



A. Price River above Scofield Reservoir, near Scofield, Utah

B. Green River at Green River, Utah

C. Huntington Creek near Huntington, Utah

FIGURE 116.—Seasonal pattern of runoff in the Green River basin below the White River, 1954 water year.

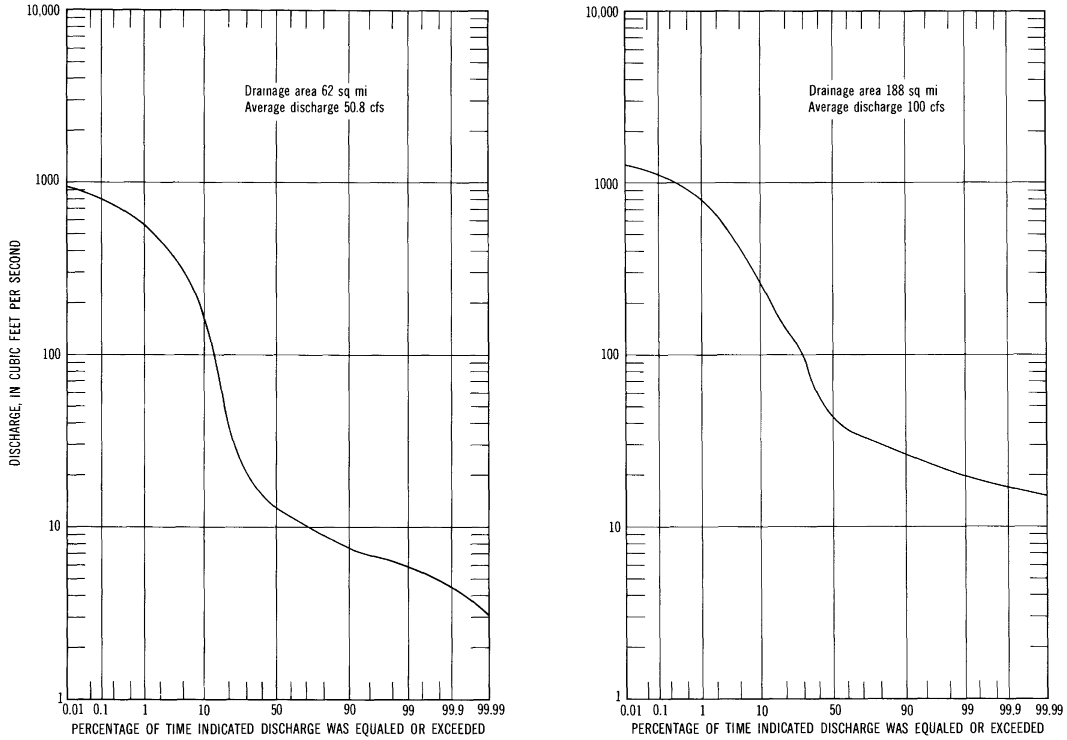
other sites have been obtained. The dissolved-solids discharges at the five stations and at other sites have been computed (table 9). The quantities given in the table are averages which would have occurred if developments in 1957 had existed throughout water years 1914–57.

Duration tables of dissolved-solids concentration and discharge for the stations given in table 9 are given in tables 10 and 11. (See chap. B, pp. 58–59, for description of computation method.)

A daily chemical-quality station was operated on Green River near Ouray, Utah, in water years 1951, 1952, and 1957. The weighted-average concentration for the period of record is 383 ppm compared with the computed weighted-average concentration of 393 ppm for the water years 1914–57 adjusted to 1957 conditions. The long-term weighted-average concentration is almost identical with the weighted-average concentration of 387 ppm for Colorado River near Cameo, Colo. However, the yield from the 35,500 square miles above the station near Ouray, Utah, is only 68 tons per square mile compared with 196 tons per square mile for the 8,060 square miles above the station on Colorado River near Cameo, Colo. An average of about 2,407,000 tons of dissolved solids passes the Ouray station each year.

The weighted-average concentration of dissolved solids of Willow Creek near Ouray, Utah, for the water years 1951–52 was 994 ppm, and the computed weighted-average concentration for the water years 1914–57 adjusted to 1957 conditions is 869 ppm. Although the concentration is relatively high, the low runoff from the 967 square miles of drainage area (24,700 acre-ft per yr) results in a low average annual yield of dissolved solids (30 tons per sq mi).

The daily records of dissolved-solids discharge of Price River at Woodside, Utah, for the water years 1952–57 show that the weighted-average concentration of the river water for this period is 2,350 ppm. For this station the computed dissolved-solids concentration for the water years 1914–57 (2,110 ppm) is less than that for the period of record. The principal reason the weighted-average concentration for the period of record is higher than for the computed long-term



A. Price River above Scofield Reservoir, near Scofield, Utah

B. Huntington Creek near Huntington, Utah

FIGURE 117.—Flow-duration curves for two tributary streams in the Green River Basin below the White River, water years 1914–57 adjusted to 1957 conditions.

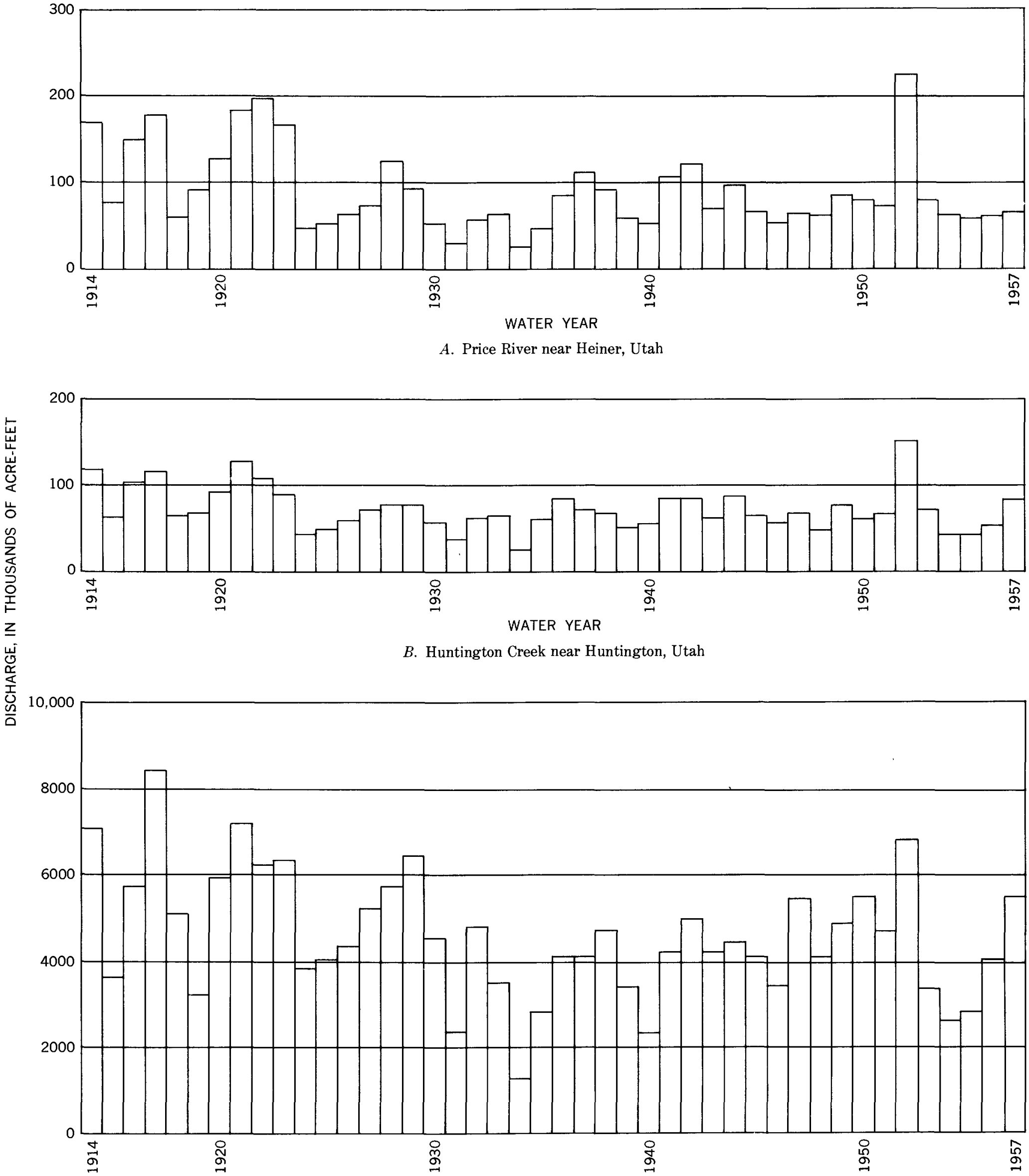
weighted-average concentration is probably because the record includes a period of drought.

The daily records of chemical quality of water for Green River at Green River, Utah, are for the water years 1929–57. The weighted-average concentration for this period is 443 ppm compared with the computed weighted-average concentration of 427 ppm for the water years 1914–57. The yield from the 40,600 square miles above the station at Green River is 65 tons per square mile, which is slightly less than that for the area above the station near Ouray. On the average, about 2,652,000 tons of dissolved solids a year passes the station on Green River at Green River, Utah.

San Rafael River near Green River, Utah, had a weighted-average concentration of 1,540 ppm for the water years 1948–57 compared with the computed weighted-average concentration of 1,370 ppm for water years 1914–57. The average annual dissolved-solids yield from the 1,690 square miles above this station for the water years 1914–57 was computed to be 113 tons per square mile. About 190,300 tons of dissolved-solids passes the station each year.

The dissolved-solids and water entering this subbasin in the Green River are recorded at Green River near Ouray, Utah. Most of the dissolved solids and water leaving the subbasin are recorded at Green River at Green River, Utah, and San Rafael near Green River, Utah. Figure 119 shows the dissolved solids and water entering the subbasin in Green River and the dissolved-solids and water discharges at selected sites in the subbasin (table 9) expressed as percentages of the combined dissolved-solids discharges and combined water discharges of Green River at Green River, Utah, and San Rafael River near Green River, Utah.

This subbasin produces about 18 percent of the dissolved-solids discharge of the Green River below the San Rafael River but only about 3 percent of the water discharge. Most of the increase in dissolved solids comes from the Price and San Rafael Rivers.



A. Price River near Heiner, Utah

B. Huntington Creek near Huntington, Utah

C. Green River at Green River, Utah

FIGURE 118.—Variability of annual discharges in the Green River Basin below the White River, water years 1914–57.

VARIATIONS IN CHEMICAL QUALITY

The range of dissolved-solids concentration in headwater streams of the San Rafael River is less than 100 ppm, but in the lower reaches of the river the range is about 3,500 ppm (table 10). This is probably typical of other streams in the subbasin that rise in the Wasatch Plateau.

Figure 120 shows the variations of chemical quality by months for a daily station on the Green River and for stations on three tributaries during years of relatively high and low runoff. The differences in monthly weighted-average concentration of dissolved solids for a year of high streamflow and a year of low streamflow for a particular month is not great for Green River at Green River, Utah. In contrast to the small variations in chemical quality for the same months in different years for the Green River, the variations in the monthly weighted-average concentration for individual months for the three tributaries may be large.

The coefficients of variation of annual weighted-average concentration of dissolved solids and annual water discharge for three streams are given in table 12. The period is probably too short for a reliable statistical analysis. See page 193 for discussion of the relation between coefficients of variation for water discharge and coefficients of variation of dissolved-solids concentration in the division.

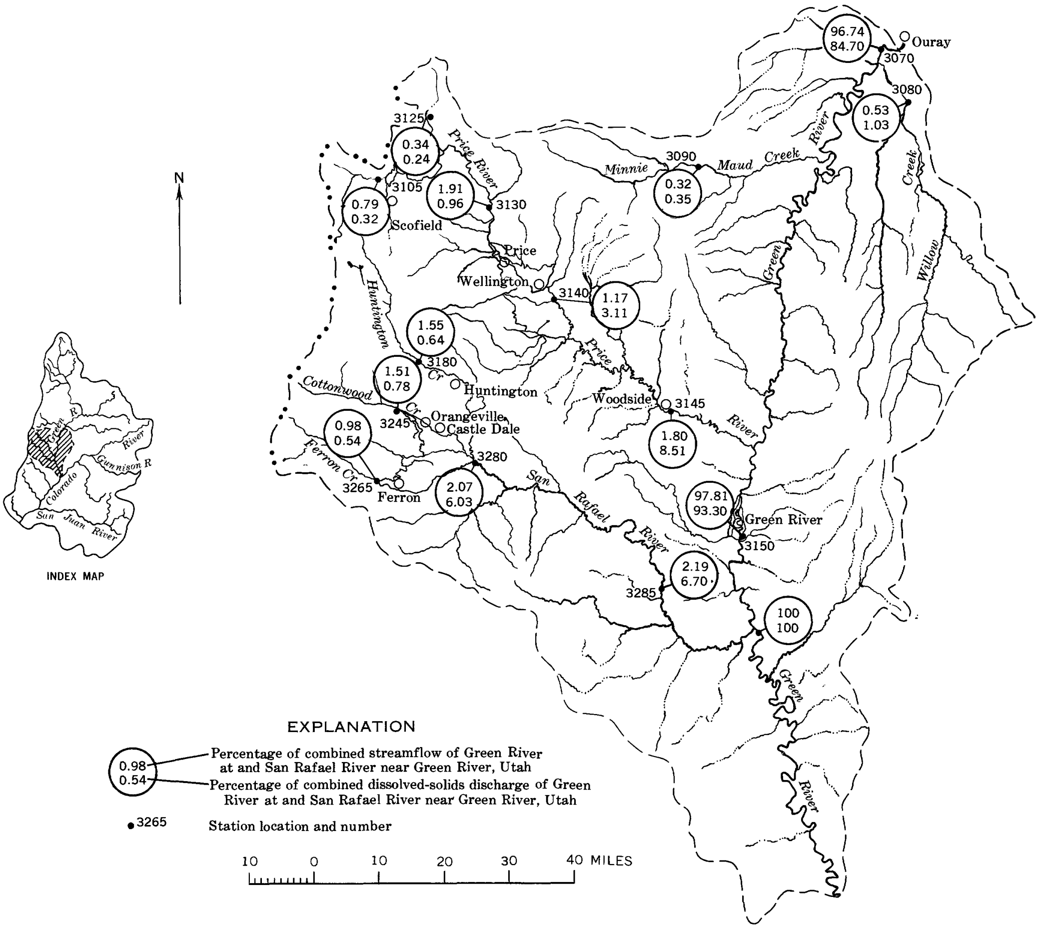
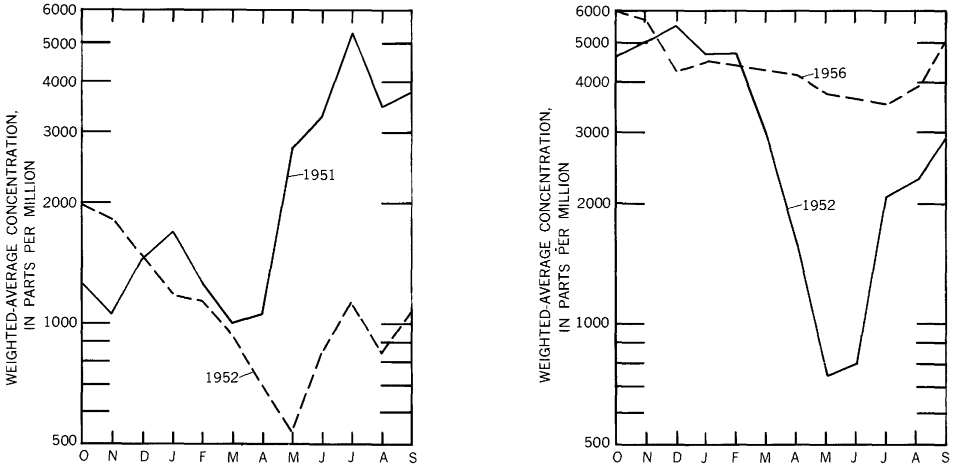
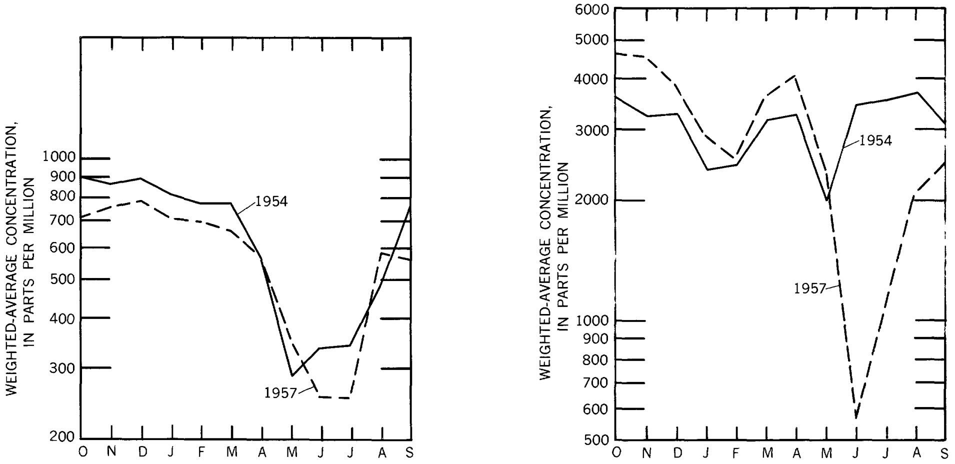


FIGURE 119.—Approximate dissolved-solids discharge and streamflow in the Green River basin below the White River expressed as percentages of the combined dissolved-solids discharge and combined streamflow of Green River at Green River, Utah, and San Rafael River near Green River, Utah.



A. Willow Creek near Ouray, Utah

B. Price River at Woodside, Utah



C. Green River at Green River, Utah

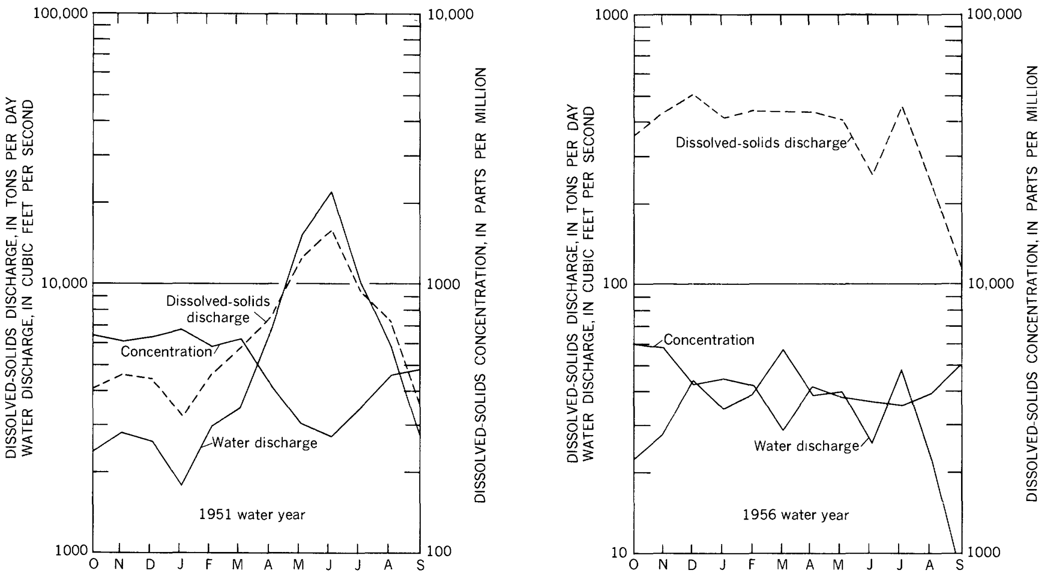
D. San Rafael River near Green River, Utah

FIGURE 120.—Dissolved-solids concentration at four stations in the Green River basin below the White River for two water years for each station.

RELATION TO STREAMFLOW

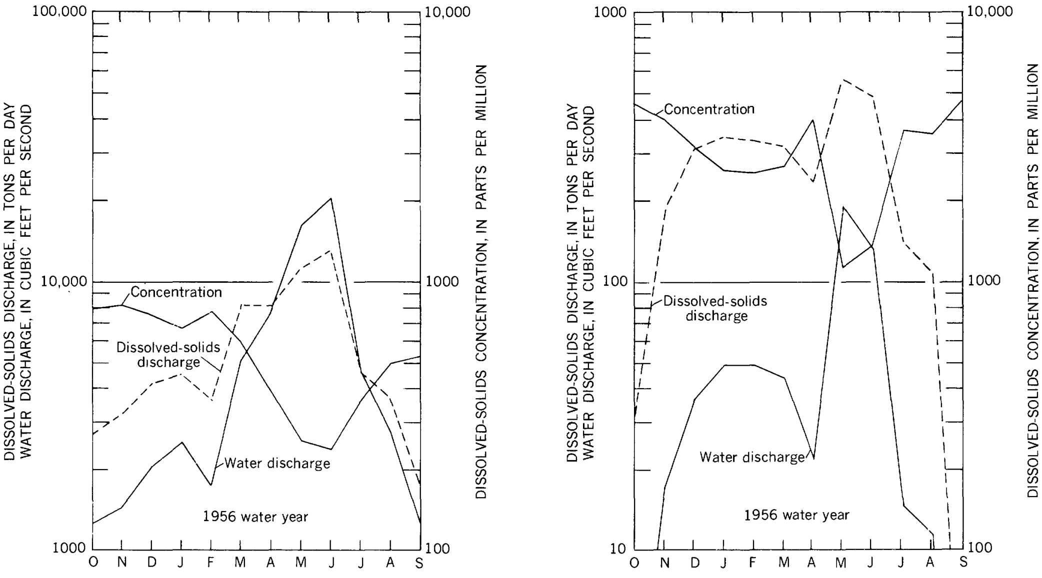
The dissolved-solids concentration of the water in the streams of this subbasin, as in most of the streams in the Upper Colorado River Basin, decreases as the water discharge increases (fig. 121). In the headwaters of the San Rafael and Price Rivers, the variation in concentration with change in water discharge is not as large as it is in the same streams at lower altitudes where the climate is more arid. For example, the estimated dissolved-solids concentration of the water in Cottonwood Creek near Orangeville, Utah, a tributary of the San Rafael River, ranged from about 210 ppm for the highest flows to about 290 ppm for the lowest flows (table 10), whereas, the concentration of San Rafael River near Castle Dale, Utah, which is downstream from Orangeville, ranged from about 390 ppm to 3,700 ppm.

The chemical composition of water for different rates



A. Green River near Ouray, Utah

B. Price River at Woodside, Utah



C. Green River at Green River, Utah

D. San Rafael River near Green River, Utah

FIGURE 121.—Dissolved-solids concentration and discharge and water discharge at four stations in the Green River basin below the White River.

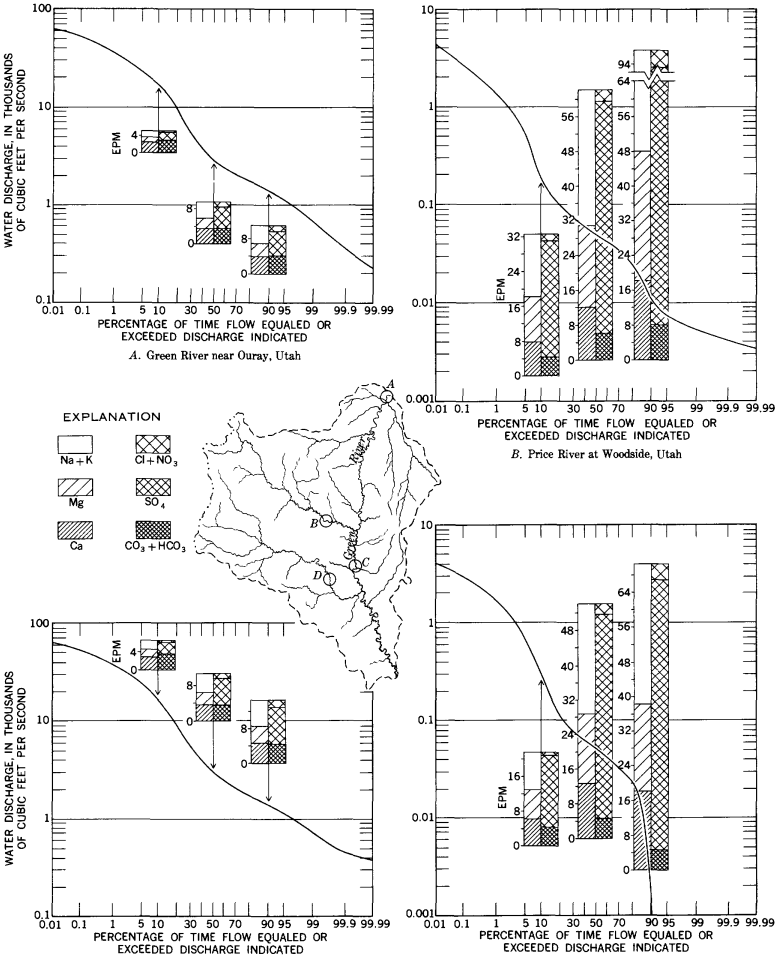
of discharge at five stations where daily chemical-quality data have been obtained is given in table 13. Data for four of these sites are illustrated in figure 122.

The variation in concentration and composition with change in water discharge for the two stations on the Green River is much less than that in the lower reaches of the Price and San Rafael Rivers. Also, the inflow from tributaries between the stations on Green River near Ouray and at Green River does not greatly increase the dissolved-solids concentration of the water of the Green River. This is because the total inflow from tributaries is small compared with the flow of the Green River.

RELATION TO GEOLOGY

The Green River basin below the White River is underlain by sedimentary rocks that range in age from Permian to Recent. However, most of the exposed rocks are of Cretaceous and Tertiary ages.

The drainage basin of Willow Creek, which flows into the Green River several miles below the chemical-quality station on Green River near Ouray, Utah, is



A. Green River near Ouray, Utah

B. Price River at Woodside, Utah

C. Green River at Green River, Utah

D. San Rafael River near Green River, Utah

FIGURE 122.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Green River basin below the White River. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for the water years 1914–57 adjusted to 1957 conditions.

underlain mostly by the Green River Formation of Tertiary (Eocene) age. The lowest part of this basin is underlain by the Uinta Formation of Tertiary (Eocene) age. The water of the creek is of the sodium calcium magnesium bicarbonate sulfate type, and the weighted-average concentration for the water years 1914–57 adjusted to 1957 conditions is about 870 ppm (table 47). Monthly weighted-average concentrations for the period of record ranged from about 540 ppm to 5,200 ppm.

The Green River Formation underlies about 75 percent of the drainage basin of Minnie Maud Creek, which flows into the Green River below Willow Creek; however, in the headwaters of Minnie Maud Creek, other rocks such as the North Horn Formation of Cretaceous and Tertiary ages and the Wasatch Formation of Tertiary age are present. The water of the creek is of the magnesium bicarbonate type and at low flows contains large amounts of sodium and sulfate. The weighted-average concentration of the water of Minnie Maud Creek at Nutter Ranch, Utah, which is below most of the irrigated land in the basin, is about 490 ppm.

The Price River is the next stream of appreciable size which enters the Green River below Minnie Maud Creek. Most of the Price River basin is underlain by rocks of Cretaceous age; however, rocks of Jurassic and Tertiary ages are also present. Along the Roan and Book Cliffs, which form the southern edge of the West Tavaputs Plateau, and the Wasatch Plateau to the west, the Price River and Blackhawk Formations and the Star Point Sandstone of the Mesaverde Group and the North Horn Formation crop out. The remainder of the basin, except for some areas where rocks of the Morrison Formation and San Rafael Group are exposed along the south side of the Price River in its lower reaches, is underlain by Mancos Shale.

In the headwaters of the Price River and its tributaries in the Wasatch Plateau, the waters of the streams are a calcium bicarbonate type. Downstream from the headwaters, Price River and its tributaries contain progressively more magnesium, sodium, and sulfate. For example, the waters of Willow Creek at Castlegate, Utah, are of the magnesium bicarbonate type. The waters of Gordon Creek near Price, Utah, are of the magnesium sulfate type. At Woodside, below most of the irrigation, the water of the Price River is of the sodium sulfate type.

The weighted-average dissolved-solids concentration of Price River above Scofield Reservoir, Utah, is about 180 ppm. The concentration increases downstream from 226 ppm near Heiner, Utah, to 1,190 ppm near Wellington, Utah, and to 2,110 ppm at Woodside, Utah (table 9). Most of the irrigated land in the Price River basin is above the station at Woodside.

Huntington, Cottonwood, and Ferron Creeks are the three principal tributaries of the San Rafael River. The headwaters of Huntington Creek are mostly underlain by the Blackhawk Formation and the Star Point Sandstone of the Mesaverde Group of Late Cretaceous age. The headwaters of Cottonwood Creek are mostly underlain by the North Horn Formation of Tertiary and Late Cretaceous age. Ferron Creek drainage basin is underlain by the Flagstaff Limestone and the North Horn Formation. For 12 to 20 miles eastward from the base of the Wasatch Plateau, the drainage basin of the San Rafael River is underlain by Mancos Shale. Most of the irrigated lands are in this area. The lower two-thirds of the basin is underlain by rocks of the San Rafael Group of Middle and Late Jurassic age and by rocks of Permian and Triassic ages.

Above irrigated areas, the water of headwater tributaries of the San Rafael River is of the magnesium or calcium bicarbonate type. Below the irrigated areas, the water of the San Rafael River and its tributaries is of the sodium sulfate type and contains large percentages of magnesium and calcium. Sodium sulfate type water containing large percentages of magnesium and calcium seems to be typical of streams that are influenced by runoff and irrigation return flow from areas underlain by Mancos Shale.

The weighted-average concentration of dissolved solids in the water of the Green River between the station near Ouray, Utah, and the station at Green River, Utah, increases from 392 ppm to 427 ppm; however, the composition of the water does not change greatly. Most of the change is an increase of sodium and sulfate ions but the water continues to be of the calcium sulfate type. Although the chemical quality of the water of the Green River is affected by inflow from tributaries, the volume of inflow is insufficient to cause a large change in the quality of the water.

Figure 123 is a map of this subbasin showing zones within which the weighted-average dissolved-solids concentrations of the surface water are between indicated limits. The zones indicate that the waters of the Green River and some of the tributaries in their headwaters have weighted-average concentrations of less than 500 ppm. In contrast, most of the tributaries of the Green River at their mouths have weighted-average concentrations of more than 1,200 ppm.

The diagrams on plate 2 show the geochemical character and ionic concentrations of surface waters at many sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flows. The

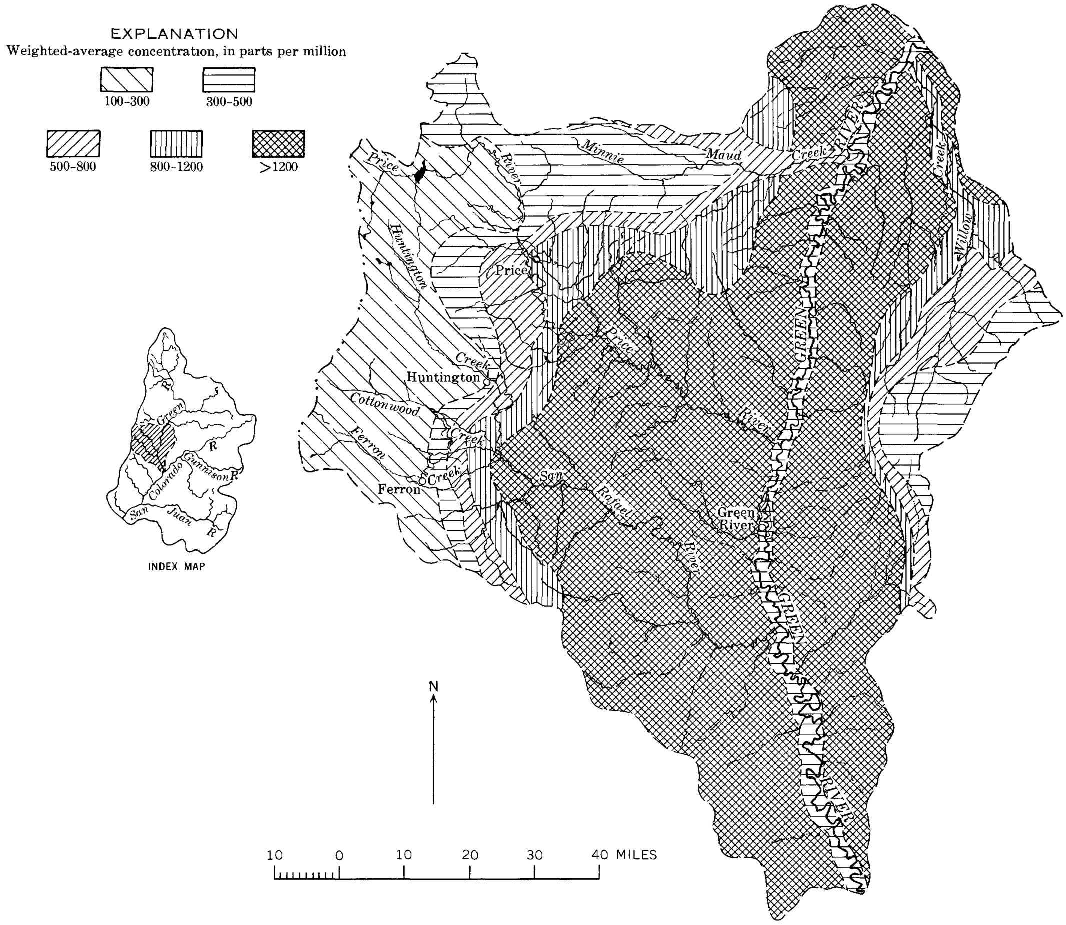


FIGURE 123.—Approximate weighted-average concentration of dissolved solids of streams in the Green River basin below the White River.

significance of the size and shape of the diagrams is given in the explanation on plate 2.

RELATION TO GROUND WATER

Table 14 gives the water and dissolved-solids discharges estimated to be contributed to selected headwater streams by ground water. The amount of dissolved solids contributed by ground water is dependent on the amount of ground water contributed to the stream system and the solubility of rock material in the ground-water reservoirs. Apparently the Flagstaff Limestone in the Ferron Creek drainage basin is relatively soluble but also relatively impermeable. The solubility of the rock material in the North Horn Formation is apparently less than in the Flagstaff Limestone but more than in the Blackhawk Formation and Star Point Sandstone of the Huntington Creek drainage basin.

The ground water in the alluvium along streams in the interior of the subbasin is similar in composition to the water in the streams during low flow, but the ground water usually contains a greater amount of dissolved solids (fig. 124).

In the lower reaches of the Price and San Rafael Rivers and along the Green River, the precipitation is low and most of the ground water in the alluvium comes from the streams. In the irrigated areas, part of the water that enters the alluvium is water that was diverted and spread on the irrigated fields. Almost all the ground water that enters the streams from the alluvium, whether it comes from the irrigated fields or is water that has circulated from the stream to the alluvium and back, is usually of poorer quality than the water of the river at the point of inflow. This inflow of ground water usually has an adverse effect on the water in the stream.

The flow and dissolved-solids concentration of a group of thermal springs along the Green River in Labyrinth Canyon, below the mouth of the San Rafael River, are unknown but the flow was stated to be small by Stearns and others (1937).

EFFECT OF TRANSMOUNTAIN DIVERSIONS

The long-term average annual transmountain diversion from the headwaters of the Price and San Rafael Rivers to the Sevier River basin was estimated to be about 10,100 acre-feet for developments existing in 1957 (p. 230). Chemical analyses of the diverted water and of streams from which diversions are made indicate that the weighted-average concentration of dissolved solids in the diverted water is about 125 ppm; and from this the dissolved solids carried out of the subbasin in the diverted water was computed to be about 1,700 tons annually. So little of the diverted water comes from the Price River basin that the effect of the diversions on the chemical quality of water in the Price River is negligible.

If all water diverted to the Sevier River basin is assumed to have come from the headwaters of the San Rafael River, the effect of the diversion on San Rafael River near Green River, Utah, has been to increase the dissolved-solids concentration by about 112 ppm.

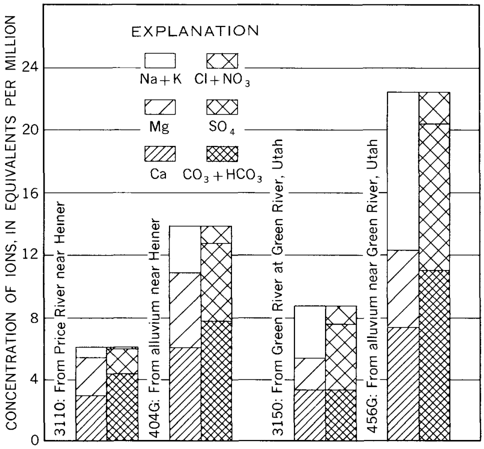


FIGURE 124.—Analyses of water from selected streams in the Green River basin below the White River and from alluvium nearby.

The effect of all transmountain diversions from the Green division has been to increase by about 7 ppm the weighted-average concentration of the Green River at the mouth. This increase is equivalent to about 6 ppm for each 100,000 acre-feet of water exported out of the division.

EFFECT OF THE ACTIVITIES OF MAN

The population (1960) in the subbasin is about 27,000, and about 60,000 acres is irrigated. The soils of the irrigated lands were mostly developed from residuum derived from Mancos Shale and contain an abundance of soluble minerals. The return flow from the irrigated lands contributes large quantities of dissolved solids to the streams.

Crystal Geyser well, which is on the left bank of Green River below the town of Green River, has an annual flow and dissolved-solids discharge of about 362 acre-feet and 7,000 tons, respectively (Thomas, 1952, p. 31). This well is an abandoned oil prospect.

Sufficient data are available in the San Rafael River basin for an approximate determination of the amount of dissolved solids added to the stream system by other than natural sources. In the area above San Rafael River near Castle Dale, Utah, and below the gaging stations on Huntington, Cottonwood, and Ferron Creeks, about 36,000 acres is irrigated. The gaging stations on the creeks are above irrigation diversions and record practically the entire inflow to the area which is underlain mostly by shales of Cretaceous age. Runoff from the intervening area between the inflow and outflow stations is considered negligible, as the average annual precipitation is only about 8 to 10 inches. Table 15 gives an approximate budget of water and dissolved solids based on water and dissolved-solids discharges given in table 9. The increase in dissolved solids from other sources is equivalent to 3.2 tons per year per acre of irrigated land.

Estimates were made of the amount of dissolved solids contributed by natural sources and the activities of man in other areas of the subbasin. These estimates are summarized at gaging stations and for the subbasin in table 16. The estimated amounts attributed to the activities of man are the increase over and above that which would normally come from inflow in each area. Of the estimated 232,700 tons of dissolved solids added to the streams by the activities of man, about 9,400 tons is added by domestic and industrial uses of water and the Crystal Geyser well near Green River, Utah, and about 223,300 tons is added by irrigation. In these estimates, 100 tons per year per 1,000 people was assigned as the contribution of dissolved solids by domestic and industrial uses of water.

FLUVIAL SEDIMENT

Daily suspended-sediment data have been obtained at three stations (table 17). In addition, suspended-sediment data have been obtained at other sites. These data and streamflow data have been used to estimate the suspended-sediment discharges for Price River at Woodside, Utah, and San Rafael River near Green River, Utah (table 18). The San Rafael River contributes less than one-quarter as much suspended sediment as the Price River, although the water discharge of the San Rafael River is greater than that of the Price River. The difference in the sediment discharge from the two river basins apparently is mostly caused by the different types of rocks that underlie the two basins.

The suspended-sediment contribution to the Green River between Green River near Ouray, Utah, and Green River at Green River, Utah, is 7,967,000 tons annually. The contribution to the river from the 2,410 square miles below Green River at Green River, Utah, and San Rafael River near Green River, Utah, and above the Colorado River is estimated to average 6,144,000 tons annually. This estimate is obtained by prorating, on the basis of drainage area, the suspended-sediment increase between the downstream suspended-sediment stations in this division and in the Grand division and the upstream suspended-sediment stations in the San Juan division. The computed yield from the 5,850 square miles of intervening drainage area is 2,560 tons per square mile per year.

A statistical analysis of the annual loads for the period of record shows that the variability of the suspended-sediment load for Green River at Green River, Utah, is greater than either the variability of the water discharge or the chemical quality of the water at this station. The standard deviation for the annual suspended-sediment discharge of Green River at Green River, Utah, was 11.7 million tons, or 56 percent of the average annual load for the period of record.

During the period of record for Green River at Green River, Utah, changes have taken place in the relation of suspended-sediment concentration to water discharges. During the water years 1930–42, the average annual suspended-sediment concentration of Green River at Green River, Utah, was greater than that for the water years 1943–56 (table 17). The reasons for these changes are unknown, but may be associated with periods of below normal and above normal precipitation or possibly with changes in the intensity of summer storms. The changes seem to be regional, as the pattern of the changes for Green River at Green River, Utah, is almost identical with that for Colorado River near Cisco, Utah.

An examination of the precipitation records of the U.S. Weather Bureau indicates that during the water years 1930–41 most of the years had below-normal precipitation, and during the water years 1942–52 most of the years had above normal precipitation. A more significant fact may be that the amount of summer precipitation did not vary greatly between the periods. The below normal precipitation for the water years 1930–41 seems to have resulted largely from below normal recipitation during the winter months. The vegetation on the more arid areas, from which most of the sediment comes, may have deteriorated during the period of subnormal winter precipitation. Consequently, the land surface would have been more susceptible to erosion. Another possible reason for higher suspended-sediment concentrations during 1930–41, and perhaps the major factor, is that the lower runoff from the mountains during this period coupled with what might have been a constant yield of sediment from the arid areas would have resulted in increased concentration during years when the flow was low.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classification of the surface water in the Green River basin below the White River is based on water-quality criteria for major uses. (See chap. B, pp. 66–73.)

About 70 percent of the time, the concentration of the dissolved solids in Green River near Ouray, Utah, exceeds the maximum concentration permitted by the standards for domestic use accepted for this report. The concentrations of iron, manganese, magnesium, chloride, and fluoride are, at all times, less than the accepted maximum concentrations; but the concentration of sulfate at times exceeds the accepted maximum. The water of the Green River at this station is very hard and softening would be desirable for most purposes. Nitrate is usually less than 5 ppm.

The water of Willow Creek, which enters the Green River from the east, at all times contains more than 250 ppm of sulfate and much of the time contains more than 500 ppm of this constituent. At times, the concentration of sulfate in the water of Willow Creek near Ouray, Utah, exceeds 2,000 ppm. Magnesium often exceeds the maximum of 125 ppm permitted by the standards for domestic use and may exceed 200 ppm. The maximum of 125 ppm permitted for chloride is apparently never exceeded. The total dissolved-solids concentration is usually more than 1,000 ppm and at times exceeds 3,000 ppm. The concentration of fluoride is always low and the concentration of nitrate is usually less than 8 ppm. The water of Willow Creek is very hard at all times.

The dissolved-solids constituents in the water of Minnie Maud Creek, which enters the Green River from the west downstream from Willow Creek, do not exceed the maximums permitted by the standards for domestic use, except for sulfate. The concentration of sulfate in the water of Minnie Maud Creek is usually slightly greater than 250 ppm. The total dissolved solids in the water of this creek sometimes exceeds 500 ppm but is seldom greater than 1,000 ppm. The concentration of nitrate in the water is usually less than 4 ppm.

In the headwaters of the Price River above Helper, Utah, the concentrations of all the constituents considered to be important for use as a domestic supply are less than the maximum permitted by the standards accepted for this report. The water is hard to very hard and softening would be required for laundries and most industries and would be profitable for most purposes.

Concentrations of magnesium, sulfate, and total dissolved solids of Price River at Woodside, Utah, always exceed the maximum permitted by the standards for domestic use. The concentrations of dissolved solids of most of the tributaries of Price River below Price, Utah, are similar to those of the Price River. At Woodside, Utah, the concentration of magnesium in the water of the Price River always exceeds 125 ppm, is usually more than 200 ppm, and sometimes exceeds 300 ppm. At Woodside, sulfate usually exceeds a concentration of 2,000 ppm, and the total dissolved solids is more than 3,000 ppm most of the time. The concentrations of fluoride and iron are usually less than 0.6 ppm and 0.3 ppm, respectively. The water of the Price River at Woodside, Utah, is very hard at all times.

The suitability for domestic use of the water of Green River at Green River, Utah, is about the same as that of Green River near Ouray, Utah. The maximum concentration of sulfate permitted by the standards accepted for this report is slightly exceeded at all times except during the spring runoff.

The waters of the tributaries of the San Rafael River in the Wasatch Plateau and above irrigated lands are suitable for domestic use; however, the waters of the streams are very hard, and softening would be profitable for most uses.

At the chemical-quality station on San Rafael River near Green River, Utah, the concentration of magnesium is more than 125 ppm, except during the spring runoff, and often exceeds 200 ppm. The concentration of iron is usually less than 0.1 ppm, and the concentration of chloride seldom exceeds 100 ppm. The total dissolved solids of the stream is usually more than 2,000 ppm and sometimes is more than 4,000 ppm. The concentration of sulfate is always more than 500 and frequently is more than 2,000 ppm. Nitrate is usually present in concentrations of less than 4 ppm. The water of the stream is very hard.

AGRICULTURAL USE

Table 19 gives the classification of the waters of many streams in this subbasin as to their suitability for irrigation. The classifications are based on chemical analyses in the basic data report (Iorns and others, 1964). Most of the terms used in the table are self-explanatory. The terms that are not self-explanatory are explained on page 203 and in Chapter B (pp. 69–73).

None of the waters of the streams listed in table 19 contains as much as 1.25 epm of residual sodium carbonate, and the waters are thus suitable for use as irrigation water insofar as this measure of the suitability is concerned. Only a very few streams contain any residual sodium carbonate.

Most of the water used for irrigation in the subbasin is classified as C2–S1 or better. The water of the Green River, except at times of high flow, is in the category C3–S1. Development of harmful levels of sodium in the soils by use of this water is not probable, but moderate leaching is required to control salinity. The waters of the Price and San Rafael Rivers in their lower reaches are not suitable for irrigation.

INDUSTRIAL USE

According to the water-quality tolerances for industrial applications given in chapter B (table 16), the waters in this subbasin would require treatment for most industrial applications. A few of the streams in the extreme headwaters could be used by some industries without treatment.

SUMMARY

The Green division (drainage area 44,700 sq mi) is bounded on the east by the Wind River and Park Ranges and the White River Plateau, and on the west by the Wyoming and Wasatch Ranges and the Wasatch Plateau. The east-trending Uinta Mountains divide the division into two major topographic areas. The Green River flows generally southward near the north-south axis of the division from its source in the northern end of the Wind River Range to its junction with the Colorado River.

The area is a region of great contrasts. Towering mountains and uplifted plateaus, some of which approach altitudes of 14,000 feet, form the boundaries. North of the Uinta Mountains, the interior of the basin is a broad desert plateau. South of the Uinta Mountains, the streams which join the Green River from the east and west have carved broad, rugged valleys and deep, tortuous canyons. All the division is at altitudes of more than 3,880 feet.

The exposed rocks range in age from late Precambrian to Recent, and the system of exposure of much of the rocks is complex owing to uplift, folding, faulting, and weathering. In the interior, vast areas are underlain by rocks of Tertiary age. These rocks and rocks of Cretaceous age also are exposed on some of the uplifted plateaus, which partly form the boundaries of the division and the divides between the valleys in the interior. The unconsolidated mantle, except for areas of glacial deposits and alluvium along the streams, is principally residuum developed from the underlying or nearby parent rocks.

The climate is largely governed by topography and altitude. The average annual precipitation ranges from less than 6 inches in the southern part to more than 60 inches in the Wind River Range in the northern part. The precipitation on nearly four-fifths of the division is less than 20 inches. The average annual precipitation is 16.63 inches (water years 1914–57). Temperatures are closely related to altitude. The 5-degree change in latitude from the southern to the northern part of the division also has an effect on the temperature. At Price, Utah, where the altitude is 5,580 feet, the average annual temperature is 49.4°F. At Green River, Wyo., where the altitude is 6,090 feet, the average annual temperature is 44°F, and at Pinedale, Wyo., where the altitude is 7,280 feet, the average annual temperature is 36.1°F.

The runoff varies with the seasons. Snow that accumulates in the mountains during the winter months provides most of the water supply. As the snow melts in the late spring and early summer, the flow in the perennial streams rises to a peak and then subsides as the supply of snow is exhausted. Usually by late July, the flow in the streams has subsided to a base flow, which generally prevails until the following spring. Many of the small streams and washes that drain areas of low altitude are intermittent and flow only in the early spring months or after thunderstorms.

The major use of water is for irrigation. Table 25 summarizes data on storage reservoirs and water utilization.

Table 26 shows an approximate water budget for the division. The budget is based on the assumptions that the contribution to the Green River between the San Rafael River and the Colorado River is equal to the natural loss in the reach and that no water is lost from the basin by underflow. The average annual precipitation supply is 39,645,900 acre-feet, which is equivalent to an average annual precipitation of 16.63 inches. All the precipitation supply not accounted for in outflow from the basin, transmountain diversions, and consumptive use due to the activities of man is considered to be evapotranspiration loss from the land and water surfaces and native vegetation. This loss is 86.1 percent of the precipitation supply and is equivalent to a depth of 14.32 inches of water over the drainage basin.

Flow-duration curves, which show the percentage of time during which specified rates of flow were equaled or exceeded, were developed and adjusted to be representative of the streamflows that would have occurred if the water-use developments in 1957 had existed throughout water years 1914–57. The average discharges of the streams for the 44-year base period were computed from these curves.

The effect of environmental factors on the flow of the streams was analyzed by comparing the slopes of the flow-duration curves of different streams and by comparing the variability of annual discharges of these streams. The variability indices (slopes of flow-duration curves) ranged from 0.25 to 0.72. The relative permeability of underlying rocks seems to be the major cause of difference in the variability indices of the snowmelt-type streams which predominate in the division. Climate is the major factor influencing the variability of annual discharges, but geologic formations exert a pronounced influence on some streams. The coefficient of variation (ratio of standard deviation to average discharge) of the streams for which statistical analyses of annual flows were made ranged from 0.18 to 0.46.

Daily records of chemical quality have been obtained at 18 stations. In addition to the daily records of chemical quality, samples of water from many other sites have been collected and analyzed. The records from the daily stations and analyses of samples collected at other sites were used in conjunction with the flow-duration tables to develop duration tables of dissolved-solids concentration and discharge and other chemical-quality-of-water data for the water years 1914–57 adjusted to 1957 conditions. The weighted-average concentration at these sites ranged from 23 to 2,110 ppm, and the average annual yield of dissolved solids ranged from 13 to 298 tons per square mile of drainage area.

The differences in the chemical quality of the streams are the result of hydrologic and other environmental factors prevailing in the drainage basins. The major environmental factors that determine the chemical quality of each stream are apparently precipitation, type of rocks and soils that underlie each drainage basin, and the activities of man.

Most of the streams are of the snowmelt type, which have the normal pattern of dissolved-solids concentration—the lowest concentrations occur in the months of maximum water discharge and the highest concentrations occur in the months of low discharge, when the streams are largely maintained by ground water.

A statistical analysis of the variations in the annual weighted-average concentration of dissolved solids and annual water discharges was made for nine stations where daily chemical-quality data have been obtained. A plot of the data showed a relatively poorer correlation between the coefficients of variation of weighted-average concentration of dissolved solids and water discharge for the Green division as compared with those for the Grand division. The poorer correlation is probably due to the available records being too short for a reliable statistical analysis.

Streams draining mountainous areas underlain by granitic and associated metamorphic rocks of Precambrian age, such as in the Wind River and Park Ranges and the Uinta Mountains, have low concentrations of dissolved solids and are of the calcium bicarbonate type. The weighted-average concentration of dissolved solids of headwater streams in these areas rarely exceeds 50 ppm, and the range in concentration between high and low flows is small. Where the mountains are principally underlain by sedimentary rocks—such as in the Wyoming Range, the Wasatch Plateau, and part of the White River Plateau—the streams have higher concentrations of dissolved solids; and though the water contains greater percentages of other ions than does the water from the areas underlain by the Precambrian rocks, it is still mostly of the calcium bicarbonate type. The weighted-average concentration of dissolved solids of headwater streams in these areas often exceeds 200 ppm and the range in concentration between high and low flows is relatively small. The chemical composition of water from most headwater streams does not change from high to low flows, as the water is generally of the calcium bicarbonate type for all flows.

The interior areas are mostly underlain by sedimentary rocks of Cretaceous and Tertiary ages. As the streams flow across the interior areas, they increase in dissolved-solids concentration. The increase is due to natural causes and the activities of man. The principal natural causes for the increase are the relatively higher dissolved-solids concentration of the runoff from downstream areas underlain by sedimentary rocks, pickup by the streams as they flow over formations containing soluble minerals, and natural ground-water discharge. Among the principal activities of man that cause the concentration to increase are the consumptive use of water, the discharge of domestic and industrial wastes to the streams, and the leaching of soluble minerals from the soils and underlying rocks by irrigation.

The concentration of dissolved solids in the water of most streams increases below their headwater areas, and the range in concentration between high and low flow becomes greater. The chemical composition of most streams also changes in a downstream direction, from principally calcium bicarbonate to greater percentages of magnesium, sodium, sulfate, and chloride. The increase is enough in many streams to result in a different type of water than is present in the headwaters. These changes are partly caused by natural factors and partly by the activities of man.

The chemical quality of ground water affects the chemical quality of the water in the streams. This effect is greatest during periods of low flow when streamflow is largely maintained by ground water. At these times the water in the streams at any point is a mixture of all ground water entering the stream above that point. During periods of high flow, the relatively higher dissolved-solids concentration of the ground-water contribution to the streams is diluted by surface runoff. As a general rule, within any one area the concentration of dissolved solids in the ground water is higher than that in the adjacent stream.

In some areas there is an interchange of water between the streams and flood-plain alluvium owing to the rise and fall of the streams. The concentration of dissolved solids in the streams is usually much less than that of the ground water in the alluvium. During periods of low flow, the movement of water from the alluvium to the stream increases the concentration of dissolved solids in the stream.

The concentration of ground-water return flow from irrigation is many times higher than that of the applied water. Movement of this water back to the stream system increases the dissolved-solids concentration of the streams.

Thermal springs add appreciable quantities of dissolved solids to some of the streams. About 48,600 tons of dissolved solids in 15,900 acre-feet of water is added to the streams annually by thermal springs. About 70 percent of the 48,600 tons of dissolved solids comes from thermal springs in the Yampa River basin.

Table 27 summarizes streamflow and dissolved-solids data at stations on the Green River from near the headwaters to Green River, Utah. At all stations from Green River, Wyo., downstream, the yield per square mile is similar. For example, the average annual yield from 7,670 square miles above Green River, Wyo., was computed to be 66 tons per square mile. The average annual yield from 40,600 square miles above Green River, Utah, was computed to be 65 tons per square mile. The weighted-average concentration of dissolved solids increased progressively downstream except between the Greendale and Jensen stations. The decrease in the concentration between these stations is probably the result of the inflow of the water of the Yampa River, which contains less dissolved solids.

Water diverted out of the division carries with it the dissolved minerals in the diverted water. The effect of the exportation on the master stream at downstream points is to deplete the flow and to decrease the dissolved-solids discharge. The effect of the transmountain diversion of water has been to decrease the average annual discharge of the Green River by about 112,200 acre-feet of water and 19,300 tons of dissolved solids. The effect of transmountain diversion has increased the weighted-average concentration of dissolved solids in the Green River at its mouth by about 7 ppm. This is equivalent to about 6 ppm for each 100,000 acre-feet of water exported.

Domestic, industrial, and irrigation uses of water result in the consumption of about 735,600 acre-feet annually (table 25). These activities of man add about 1,177,900 tons of dissolved solids to the stream system (table 28) of which about 11,000 tons comes from oil wells and abandoned oil prospects. The activities of man (exclusive of transmountain diversions) have caused an increase of about 223 ppm in the weighted-average concentration of the Green River at its mouth. This increase is equivalent to an average increase of about 30 ppm for each 100,000 acre-feet of water consumed, or about five times the increase caused by the exportation of an equivalent amount of water. The major part of the increase in dissolved-solids concentration is attributed to irrigation.

The average annual suspended-sediment discharge from the Green division is estimated to be about 27,875,400 tons (table 28). Of this amount, about 13 percent comes from the Green River basin above the Yampa River; about 7 percent, from the Yampa River basin; about 26 percent, from the Green River basin between the Yampa and White Rivers including the White River basin; and about 54 percent, from the Green River basin below the White River.

Determinations of suspended-sediment discharge were made at 6 stations on the Green River and at 9 stations on tributaries. Of the 15 areas, the drainage basin of Savery Creek above the upper station near Savery, Wyo., had the smallest rate of yield—39 tons per square mile per year. The drainage basin of Price River above the station at Woodside, Utah, had the highest rate—2,586 tons per square mile. However, the average annual yield from the Green River basin below the San Rafael River was estimated to be 2,560 tons per square mile per year.

Concentrations of dissolved solids in many streams, especially in their headwaters, are below the maximum accepted limits for domestic use. The concentrations of dissolved solids in the lower reaches of some of these streams, however, exceed the accepted maximum limits. In the lower reaches of some of the tributaries of Green River, concentrations of many constituents, as well as total dissolved solids, exceed the maximum accepted limits for domestic use. Some of the springs at Steamboat Springs, Colo., have concentrations of fluoride so high that sustained use of the water might cause mottling of teeth. Nitrate in surface water is apparently not a hazard in the Green division.

Except during periods of low flow when the waters of some tributary streams in their lower reaches should not be used for irrigation, the waters of the streams are suitable for agricultural use.

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TABLES 1–28

TABLE 1.—*Average monthly and annual precipitation, in inches, at 16 index-precipitation stations in the Green division*

[Data are for the water years 1914–57]

Station	October	November	December	January	February	March	April	May	June	July	August	September	Annual
Lander, Wyo	1.48	0.84	0.56	0.49	0.69	1.08	2.40	2.60	1.24	0.79	0.55	1.12	13.84
Bedford, Wyo	1.64	1.60	2.00	2.03	1.77	1.83	1.65	2.08	1.86	.97	1.12	1.34	19.89
Border, Wyo	1.27	.97	1.16	1.29	1.11	1.02	1.20	1.26	1.08	.74	.78	1.10	12.98
Evanston, Wyo	1.16	.85	.81	.97	1.03	1.07	1.19	1.27	.98	.84	1.04	.88	12.09
Green River, Wyo	.96	.44	.38	.44	.50	.58	1.00	1.18	.79	.54	.77	.76	8.34
Encampment, Wyo	1.39	.85	.84	.78	.80	1.24	1.55	1.64	1.12	1.18	1.24	1.15	13.78
Hayden, Colo	1.58	1.03	1.37	1.36	1.14	1.33	1.46	1.61	1.07	1.31	1.38	1.44	16.08
Steamboat Springs, Colo	1.96	1.83	2.46	2.48	2.33	2.32	2.29	2.18	1.47	1.58	1.71	1.58	24.19
Meeker, Colo	1.53	1.13	1.15	1.22	.92	1.42	1.71	1.50	1.00	1.62	1.92	1.43	16.55
Vernal, Utah	.96	.59	.64	.61	.47	.63	.95	.84	.57	.54	.81	.85	8.46
Elkhorn-Ashley, Utah	1.25	.81	1.08	1.09	.95	1.07	1.24	1.34	1.07	1.13	1.33	1.37	13.73
Duchesne, Utah	.95	.47	.61	.59	.57	.74	.70	.85	.73	1.01	1.28	.95	9.45
Snake Creek, Utah	1.68	2.07	2.96	3.12	2.88	2.58	1.99	1.49	.93	.99	1.23	1.17	23.09
Spanish Fork, Utah	1.60	1.59	1.81	1.88	1.50	1.94	2.02	1.64	.92	.83	.93	.88	17.54
Moroni, Utah	.94	.77	.97	1.04	.95	1.03	.93	.92	61	.80	.92	.70	10.58
Green River, Utah	.74	.37	.47	.43	.35	.40	.48	.43	.49	.57	.87	.62	6.22
Average	1.32	1.01	1.20	1.24	1.12	1.27	1.42	1.43	1.00	.97	1.12	1.08	14.18

TABLE 2.—*Annual precipitation at 16 index-precipitation stations and weighted-average precipitation, in inches, for the Green division for water years 1914–57*

Water year	Index stations																	Green division weighted average
	Lander	Encampment	Border	Evanston	Green River	Bedford	Hayden	Steamboat Springs	Meeker	Vernal	Elkhorn-Ashley	Duchesne	Snake Creek	Spanish Fork	Moroni	Green River	Average	
1914	10.86	14.71	15.78	17.53	5.84	22.28	21.72	33.43	18.35	8.04	13.11	11.02	23.97	21.15	21.94	7.85	16.72	19.61
1915	17.35	11.35	11.80	16.44	7.63	20.65	11.90	18.99	11.81	7.63	10.71	9.11	21.86	18.42	14.41	6.68	13.55	15.89
1916	7.80	11.77	7.52	12.03	4.40	11.62	17.76	26.84	18.19	7.83	12.18	8.42	27.55	14.26	16.73	6.91	13.24	15.53
1917	14.67	13.30	13.66	16.69	8.01	15.45	19.92	28.72	18.45	9.85	18.85	13.26	27.32	20.61	14.93	7.26	16.31	19.13
1918	13.05	9.33	11.94	11.82	5.25	17.08	15.50	25.58	15.15	6.12	11.09	8.09	22.13	12.99	10.45	3.58	12.45	14.60
1919	7.47	7.86	8.00	8.74	3.60	13.95	12.48	14.33	12.00	6.84	13.31	8.49	23.10	12.58	9.55	5.11	10.46	12.27
1920	17.88	11.98	15.08	14.54	6.68	19.06	18.19	27.58	15.77	10.88	12.57	9.27	24.23	24.03	12.18	5.84	15.36	18.02
1921	19.58	12.27	12.92	13.01	9.96	19.89	19.31	32.46	17.99	10.02	15.39	9.62	30.59	24.27	12.12	9.78	16.82	19.73
1922	11.61	8.53	15.41	14.68	5.34	19.57	13.05	22.86	12.86	12.39	18.91	10.45	29.35	21.62	8.57	6.10	14.46	16.96
1923	19.90	12.73	19.56	18.69	10.09	18.95	19.47	28.44	15.46	9.34	15.10	10.27	26.74	24.14	10.20	5.36	16.53	19.39
1924	16.72	7.79	10.84	14.81	5.24	12.98	12.53	20.99	11.28	6.03	7.28	7.52	13.44	12.85	8.10	5.68	10.88	12.76
1925	8.46	16.05	16.26	17.09	13.24	25.02	20.94	25.46	22.85	7.96	12.84	10.76	24.01	19.16	10.45	7.13	16.10	18.89
1926	12.90	13.10	12.21	13.11	7.49	16.80	13.69	23.43	14.42	7.13	9.01	9.24	23.87	15.93	8.34	5.78	12.90	15.13
1927	14.78	11.42	11.26	15.39	9.83	22.90	17.61	30.10	20.49	11.85	22.84	15.05	29.18	18.64	11.91	10.94	17.14	20.11
1928	10.12	15.56	11.30	10.98	4.84	17.62	15.73	24.15	12.46	7.21	15.49	6.72	19.63	17.57	8.89	6.96	12.83	15.05
1929	17.24	16.27	14.75	15.41	10.28	22.19	21.92	28.02	19.55	13.46	22.67	11.78	25.19	21.89	12.09	9.73	17.65	20.70
1930	17.58	13.74	11.04	13.02	9.76	20.07	17.21	21.18	14.74	7.50	15.11	8.77	17.22	17.13	12.88	7.69	14.04	16.47
1931	12.97	12.68	9.48	6.59	5.77	14.35	14.87	16.99	16.05	4.79	10.32	7.59	12.35	13.67	6.12	3.01	10.48	12.29
1932	8.78	12.99	13.33	12.19	8.51	18.35	19.34	24.23	17.30	8.39	14.27	10.44	24.77	16.56	10.93	6.70	14.19	16.64
1933	15.13	13.57	9.67	8.32	7.04	15.24	16.64	24.65	14.68	6.90	8.54	6.12	19.60	14.03	7.85	5.41	12.09	14.18
1934	10.89	14.42	6.95	9.00	3.51	12.84	12.03	14.62	13.45	4.31	7.62	5.99	13.82	9.37	4.89	3.34	9.19	10.78
1935	13.98	13.21	11.84	9.87	8.53	15.40	14.72	19.75	15.30	9.11	11.53	7.85	18.92	17.64	9.38	5.78	12.68	14.87
1936	11.74	17.02	15.84	12.48	7.54	24.85	16.28	23.38	13.40	5.43	12.09	10.62	24.80	16.23	12.51	4.52	14.30	16.77
1937	17.08	16.05	13.94	12.83	11.51	17.50	13.44	25.43	17.27	12.42	18.80	16.30	22.75	17.11	10.64	5.23	15.52	18.20
1938	11.80	14.66	15.88	10.14	10.75	23.48	15.08	27.02	20.78	10.56	16.08	11.34	25.49	17.53	9.86	6.74	15.45	18.12
1939	11.04	10.54	12.28	7.53	6.89	12.46	12.06	22.18	16.77	11.59	14.16	9.87	19.58	14.97	10.91	6.73	12.47	14.63
1940	10.51	11.88	10.90	8.39	8.80	18.65	14.09	23.04	15.98	7.98	12.25	9.94	15.25	15.18	10.81	6.51	12.51	14.67
1941	18.94	16.96	15.66	12.15	11.99	23.20	16.32	22.40	18.89	12.60	19.28	13.00	25.15	19.26	11.69	10.67	16.76	19.66
1942	14.41	15.65	12.13	9.67	7.84	18.04	14.38	24.71	17.42	9.29	13.03	7.22	22.12	17.68	8.34	6.31	13.64	16.00
1943	14.66	11.87	15.20	10.14	7.58	23.22	13.52	22.68	20.93	7.65	14.39	8.07	25.47	14.00	11.01	5.57	14.12	16.56
1944	19.57	13.04	12.60	12.75	10.42	20.63	10.24	19.63	17.29	10.05	17.30	8.80	22.65	20.09	12.97	6.53	14.66	17.20
1945	15.75	20.75	13.45	13.56	9.89	28.62	15.94	26.19	21.10	7.93	15.75	8.07	25.99	22.73	11.73	4.86	16.39	19.23
1946	11.50	15.33	14.53	11.75	7.30	20.82	12.77	21.06	9.62	5.91	9.74	7.18	22.12	15.39	7.64	5.20	12.37	14.51
1947	19.91	18.38	18.17	17.61	16.67	24.52	19.95	26.65	18.74	12.99	16.51	11.24	28.10	19.92	12.85	5.70	17.99	21.10
1948	11.76	11.47	12.00	13.91	8.66	22.25	16.25	22.66	16.14	7.66	11.76	6.69	20.93	16.49	6.99	7.60	13.33	15.64
1949	12.98	17.04	13.26	8.55	9.00	19.53	20.06	26.67	16.42	9.40	16.53	12.24	26.64	17.33	8.79	6.29	15.05	17.65
1950	18.39	18.60	17.86	10.64	11.55	26.32	14.33	21.47	13.67	10.69	14.66	7.66	26.69	16.25	8.35	3.91	15.07	17.68
1951	13.20	12.33	13.55	9.70	9.23	22.46	15.74	25.93	14.19	4.61	10.60	7.92	24.48	15.85	7.64	5.79	13.36	15.67
1952	13.15	14.67	12.55	11.78	10.73	22.24	19.42	30.34	21.53	11.24	18.18	15.91	34.16	26.79	12.27	7.45	17.65	20.70
1953	11.84	14.97	11.05	7.24	5.56	20.04	13.03	20.83	17.94	5.80	9.52	4.70	20.53	14.98	8.17	4.62	11.93	13.99
1954	7.87	14.15	10.32	8.21	7.31	23.29	15.11	20.63	18.69	7.14	11.29	8.39	19.28	14.39	10.60	6.03	12.67	14.86
1955	11.17	12.19	12.72	8.77	8.26	20.37	13.78	19.54	15.19	5.45	10.13	8.83	20.83	16.88	10.50	4.69	12.46	14.62
1956	11.05	14.49	12.72	8.45	6.20	23.10	16.47	25.95	14.09	3.93	8.58	5.81	22.02	13.11	8.28	2.23	12.28	14.40
1957	20.87	19.60	13.99	15.74	12.50	27.13	22.56	33.00	23.51	8.19	14.74	10.20	22.25	21.26	9.93	8.10	17.72	20.79
44-year average	13.84	13.78	12.98	12.09	8.34	19.89	16.08	24.19	16.55	8.46	13.73	9.45	23.09	17.54	10.58	6.22	14.18	16.63

TABLE 3.—*Reservoirs in the subbasins in the Green division*

[Sources of data, U.S. Dept. of the Interior (1947) and files of the State Engineer of Utah]

Reservoir	Location	Usable capacity (acre-ft)	Reservoir	Location	Usable capacity (acre-ft)
Green River basin above the Yampa River					
New Fork Lake	New Fork River	22,700	Eden No. 1	Little Sandy Creek (off channel)	16,000
Willow Lake	Lake Creek	15,120	Pacific No. 2	Pacific Creek	1,400
Fremont Lake	Pine Creek	10,760	Patterson Lake	Blacks Fork	1,870
Boulder Lake	Boulder Creek	12,820	Uinta No. 3	do	2,000
Silver Lake	Silver Creek	1,220	Piedmont	Big Muddy Creek	1,090
Sixty Seven	North Piney (off channel)	4,330	Kemmerer	Hams Fork	1,060
Middle Piney	Middle Piney Creek	4,200	Hoop Lake	Beaver Creek (Henrys Fork)	3,930
Black Joe Lake	Big Sandy Creek	1,100	Beaver Meadows	Last Chance (Burnt Fork)	1,790
Big Sandy	do	38,300			
Elkhorn	Little Sandy Creek	1,450	Total		141,140
Green River basin between the Yampa and White Rivers including the White River basin					
Warner	Pot Creek	1,520	Fox Lake	Shale Creek (Uinta River)	1,200
Oaks Park	Brush Creek	6,250	Lake Atwood	Lake Atwood Creek (Unita River)	2,700
East Park	Little Brush Creek	1,300	Paradise Park	Whiterocks River	3,140
Strawberry	Strawberry River	[1] 265,400	John Starr	Cottonwood Creek (Uinta River)	2,370
Midview	Duchesne River (off channel)	5,800	Montez Creek	Montez Creek (Unita River)	1,260
Kidney Lake	Duck Creek (Lake Fork)	3,920			
Moon Lake	Lake Fork	35,800	Total		334,610
Twin Pots	do	3,950			
Green River basin below the White River					
Fairview	Gooseberry Creek (Price River)	1,900	Millers Flat	Huntington Creek (San Rafael)	5,560
Scofield	Price River	65,780	Ferron	Indian Creek (San Rafael)	1,200
Desert Lake	do	7,300	Buckhorn	Buckhorn Draw (San Rafael)	1,520
Olson	do	3,500			
Huntington	Huntington Creek (San Rafael)	4,410	Total		93,490
Cleveland	do	2,320			

[1] Maximum usable capacity with stop logs.

TABLE 4.—*Irrigated acreage in the subbasins in the Green division*

[Source of data, U.S. Bur. of the Census (1953), except as indicated]

Location	*Irrigated acreage*
Green River basin above the Yampa River	
Source of the Green River	0
Intervening area	2, 000
Total area, Green River at Warren Bridge, near Daniel, Wyo	2, 000
Intervening area	1, 000
Beaver Creek tributary area	2, 000
Intervening area	3, 000
Horse Creek tributary area	4, 500
Intervening area	10, 000
Cottonwood Creek tributary area	15, 400
Intervening area	2, 500
New Fork tributary area	48, 500
Intervening area	2, 500
Piney Creeks tributary area	31, 600
Intervening area	2, 500
La Barge Creek tributary area	6, 100
Intervening area	0
Total area, Green River near Fontenelle, Wyo	131, 600
Intervening area	0
Fontenelle Creek tributary area	5, 000
Intervening area	0
Big Sandy Creek tributary area	[1] 13, 000
Intervening area	2, 000
Total area, Green River at Green River, Wyo	151, 600
Intervening area	0
Blacks Fork tributary area	74, 500
Intervening area	1, 000
Total area, Green River near Linwood, Utah	227, 100
Intervening area	0
Henrys Fork tributary area	22, 300
Intervening area	0
Sheep Creek tributary area	6, 000
Intervening area	3, 000
Total area, Green River above Yampa River	258, 400
Yampa River basin	
Source of the Yampa River	0
Intervening area	12, 000
Total area, Yampa River at Oak Creek, Colo	12, 000
Intervening area	10, 000
Total area, Yampa River at Steamboat Springs, Colo	22, 000
Intervening area	2, 000
Elk River tributary area	8, 100
Intervening area	8, 000
Fortification Creek tributary area	1, 500
Intervening area	500
Yampa River basin—Continued	
Williams Fork tributary area	3, 000
Intervening area	6, 200
Total area, Yampa River near Maybell, Colo	51, 300
Intervening area	1, 500
Little Snake River tributary area	20, 400
Intervening area	500
Total area, mouth of the Yampa River	73, 700
Green River basin between the Yampa and White Rivers including the White River basin	
Mouth of the Yampa River	0
Intervening area	500
Brush Creek tributary area	1, 600
Intervening area	1, 000
Ashley Creek tributary area	24, 300
Intervening area	2, 500
Total area, above Duchesne River	29, 900
Intervening area	0
Duchesne River above Duchesne, Utah, tributary area	11, 500
Intervening area	0
Strawberry River above Duchesne, Utah, tributary area	4, 500
Intervening area	119, 700
Duchesne River above Randlett, Utah, tributary area	135, 700
Intervening area	2, 000
Total Duchesne River tributary area	137, 700
Intervening area	0
White River tributary area	30, 400
Intervening area	0
Total area, Green River basin between the Yampa and White Rivers including the White River basin	198, 000
Green River basin below the White River	
Total area, Green River below White River	0
Intervening area	0
Willow Creek tributary area	2, 000
Intervening area	0
Minnie Maud Creek tributary area	1, 500
Intervening area	0
Price River tributary area	17, 000
Intervening area	3, 500
San Rafael River tributary area	36, 000
Intervening area	0
Total, Green River basin below the White River	60, 000

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[1] Furnished by U.S. Bureau of Reclamation.

TABLE 5.—*Flow-duration table for stations in the subbasins in the Green division*

[Water years of historical periods of record are indicated and 1914–57 extension adjusted to 1957 conditions are italicized]

Station No.	Streamflow station	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Mean discharge (cfs)	Mean annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Green River basin above the Yampa River																					
1885	Green River at Warren Bridge near Daniel, Wyo.	*4,400*	*3,920*	*3,600*	*3,100*	*2,600*	*2,200*	*1,820*	*1,430*	*960*	*500*	*300*	*210*	*160*	*139*	*119*	*101*	*81*	*61*	*49*	*540*	*391,200*
	1932–57	4,200	3,900	3,640	3,100	2,490	2,080	1,720	1,330	870	470	298	203	155	133	115	98	82	60	47	511	370,200
1890	Beaver Creek near Daniel, Wyo.	*1,070*	*940*	*830*	*600*	*360*	*230*	*144*	*79*	*34*	*19*	*14*	*9.4*	*6.5*	*4.1*	*1.7*	*.3*	*.1*	*.0*	*.0*	*37.8*	*27,380*
	1939–54	1,020	855	730	515	302	196	125	71	30	18	13	10	7.0	4.7	2.0	.3	.1	.0	.0	33.4	24,200
1900	Horse Creek near Daniel, Wyo.	*1,480*	*1,260*	*1,110*	*860*	*610*	*450*	*320*	*190*	*80*	*29*	*20*	*16*	*14*	*12*	*10*	*8.6*	*6.0*	*2.8*	*1.6*	*74.0*	*53,610*
	1932–54	1,240	1,080	970	750	530	395	272	154	62	26	20	16	14	12	10	8.1	5.8	2.7	1.6	63.7	46,150
1915	Cottonwood Creek near Daniel, Wyo.	*980*	*850*	*760*	*630*	*470*	*365*	*275*	*190*	*110*	*55*	*35*	*25*	*21*	*17*	*13*	*9.4*	*5.4*	*1.0*	*.0*	*74.5*	*53,970*
	1939–54	918	790	705	565	425	334	252	173	99	54	35	26	21	18	14	10	5.7	2.3	.2	69.7	50,490
2010	New Fork River near Boulder, Wyo.	*12,000*	*5,280*	*4,150*	*3,270*	*2,470*	*1,900*	*1,410*	*950*	*530*	*290*	*195*	*150*	*130*	*117*	*101*	*86*	*71*	*60*	*55*	*401*	*290,500*
	1915–57	12,000	5,280	4,150	3,270	2,450	1,880	1,410	938	515	285	195	150	130	116	100	85	71	60	52	397	287,600
2030	East Fork near Big Sandy, Wyo.	*1,700*	*1,580*	*1,450*	*1,170*	*845*	*650*	*475*	*290*	*143*	*46*	*24*	*15*	*13*	*11*	*8.6*	*5.6*	*2.3*	*1.3*	*1.1*	*106*	*76,790*
	1939–57	1,530	1,450	1,350	1,120	840	650	475	290	128	44	25	18	14	11	8.6	5.8	2.7	1.4	1.2	104	75,340
2045	East Fork at New Fork, Wyo.	*2,920*	*2,750*	*2,540*	*2,080*	*1,390*	*875*	*575*	*355*	*150*	*72*	*64*	*59*	*54*	*50*	*44*	*37*	*32*	*29*	*27*	*166*	*120,300*
	1905–06, 1915–24, 1931–32	2,940	2,840	2,720	2,350	1,630	1,020	590	345	119	73	62	55	51	45	38	32	30	28	27	171	123,900
2055	North Piney Creek near Mason, Wyo.	*600*	*570*	*544*	*480*	*382*	*295*	*224*	*149*	*82*	*41*	*28*	*22*	*18*	*15*	*13*	*11*	*8.6*	*7.2*	*6.4*	*59.7*	*43,250*
	1916, 1932–57	588	560	536	468	362	278	208	140	78	41	28	22	18	15	13	11	8.8	7.5	6.8	57.3	41,510
2085	LaBarge Creek near Viola, Wyo.	*595*	*580*	*575*	*555*	*502*	*424*	*309*	*192*	*110*	*76*	*66*	*58*	*53*	*47*	*42*	*37*	*32*	*21*	*15*	*98.4*	*71,290*
	1916, 1941–49	564	551	535	489	405	334	245	172	103	73	62	57	53	48	43	37	32	27	25	89.0	64,480
2095	Green River near Fontenelle, Wyo.	*13,600*	*13,500*	*13,000*	*10,800*	*8,300*	*6,750*	*5,250*	*3,700*	*2,350*	*1,480*	*1,000*	*740*	*600*	*510*	*435*	*365*	*320*	*255*	*225*	*1,609*	*1,166,000*
	1947–57	13,600	13,500	13,000	11,500	9,150	7,300	5,750	4,200	2,600	1,520	1,080	815	640	550	475	390	320	275	250	1,752	1,269,000
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo., 1952–57	600	560	525	460	370	300	232	165	91	49	39	34	31	28	25	22	19	18	15	70.2	50,860
2110	Fontenelle Creek near Fontenelle, Wyo.	*900*	*770*	*680*	*540*	*400*	*320*	*245*	*160*	*84*	*48*	*37*	*32*	*28*	*23*	*19*	*14*	*5.8*	*.4*	*.0*	*68.3*	*49,480*
	1916–19, 1932–53	900	790	700	550	405	315	232	150	78	46	36	31	27	23	19	13	4.6	.4	.0	66.2	47,960
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo.	*980*	*940*	*875*	*735*	*570*	*450*	*342*	*235*	*125*	*54*	*32*	*22*	*18*	*16*	*14*	*11*	*7.5*	*5.3*	*4.5*	*85.5*	*61,940*
	1940–57	980	940	880	740	570	450	345	238	125	54	35	25	19	16	14	11	8.6	6.8	5.7	86.6	62,740
2135	Big Sandy Creek near Farson, Wyo.	*1,200*	*1,080*	*980*	*790*	*598*	*467*	*350*	*235*	*115*	*51*	*33*	*25*	*21*	*17*	*14*	*10*	*5.6*	*2.4*	*1.5*	*86.6*	*62,740*
	1915–17, 1921–24, 1927–34, 1954–57	1,200	1,100	1,010	820	618	475	360	240	110	52	35	26	21	17	14	10	6.2	2.7	1.5	88.1	63,820
2140	Little Sandy Creek near Elkhorn, Wyo.	*252*	*230*	*210*	*175*	*135*	*105*	*81*	*57*	*33*	*16*	*9.0*	*6.7*	*5.4*	*4.4*	*3.6*	*2.6*	*1.5*	*.8*	*.5*	*21.5*	*15,580*
	1940–57	252	230	210	175	135	105	81	57	32	16	10	7.3	5.7	4.6	3.6	2.6	1.8	1.2	.9	21.7	15,720
2165	Green River at Green River, Wyo.	*21,800*	*20,700*	*19,000*	*14,500*	*10,100*	*7,500*	*5,550*	*3,900*	*2,550*	*1,640*	*1,130*	*845*	*675*	*550*	*465*	*380*	*310*	*250*	*210*	*1,802*	*1,305,000*
	1896–1906, 1915–39	21,800	20,800	19,200	15,300	10,800	8,100	5,990	4,110	2,620	1,620	1,100	810	635	515	438	350	272	220	190	1,849	1,340,000
2170	Green River near Green River, Wyo. 1952–57	16,500	15,600	14,600	12,600	9,600	7,350	5,500	3,900	2,530	1,640	1,170	880	720	610	510	410	320	275	236	1,787	1,295,000
2185	Blacks Fork near Millburne, Wyo. 1940–57	2,110	1,820	1,630	1,330	1,000	805	620	425	216	99	60	46	37	32	29	24	20	18	16	156	113,000
2215	Smith Fork at Mountainview, Wyo. 1942–57	760	740	710	610	430	300	188	98	50	30	24	20	17	15	13	8.6	5.5	4.1	3.3	52.5	38,030
2220	Blacks Fork near Lyman, Wyo. 1938–40, 1942–57	2,570	2,320	2,100	1,640	1,100	755	490	262	145	82	59	47	36	25	15	6.6	2.5	.9	.0	132	95,630

2230	Hams Fork near Elk Creek ranger station, Wyo.	*1,420*	*1,380*	*1,320*	*1,170*	*930*	*710*	*505*	*295*	*130*	*49*	*30*	*23*	*18*	*16*	*14*	*13*	*10*	*9.0*	*8.2*	*113*	*81,860*
	1953–57	965	920	880	780	645	530	404	260	117	41	24	19	17	15	15	14	12	11	10	90.1	65,270
2235	Hams Fork near Frontier, Wyo.	*2,100*	*1,950*	*1,820*	*1,580*	*1,200*	*960*	*705*	*430*	*180*	*58*	*35*	*27*	*21*	*17*	*13*	*11*	*4.2*	*1.9*	*1.2*	*150*	*108,700*
	1946–57	2,100	1,950	1,820	1,580	1,200	960	740	515	222	70	38	31	26	23	19	15	11	6.3	4.7	165	119,500
2250	Blacks Fork near Green River, Wyo. 1948–57	5,200	4,900	4,550	3,700	2,650	1,920	1,380	920	490	225	129	89	58	34	16	1.0	.0	.0	.0	345	249,900
2255	Green River near Linwood, Utah	*17,200*	*16,500*	*15,550*	*13,600*	*10,700*	*8,500*	*6,800*	*5,100*	*3,450*	*2,080*	*1,390*	*1,040*	*780*	*610*	*495*	*400*	*325*	*270*	*235*	*2,143*	*1,553,000*
	1929–57	17,200	16,400	15,200	12,800	9,950	7,900	6,325	4,720	3,100	1,900	1,275	925	710	575	480	390	312	258	228	1,979	1,434,000
2260	Henrys Fork near Lonetree, Wyo.	*1,280*	*900*	*720*	*475*	*302*	*224*	*159*	*117*	*52*	*23*	*17*	*13*	*11*	*9.5*	*8.0*	*6.3*	*4.7*	*4.0*	*3.8*	*43.6*	*31,590*
	1943–57	1,150	690	545	386	265	200	155	105	52	24	16	11	9.0	7.4	6.2	5.0	4.0	3.6	3.4	39.4	28,540
2275	West Fork Beaver Creek near Lonetree, Wyo. 1949–57	310	260	220	155	100	74	55	37	23	12	7.9	5.8	4.4	3.8	3.3	2.9	2.6	2.3	2.2	16.0	11,590
2295	Henrys Fork at Linwood, Utah	*2,000*	*1,320*	*1,030*	*765*	*540*	*390*	*275*	*174*	*115*	*80*	*61*	*52*	*44*	*36*	*25*	*9.7*	*.7*	*.1*	*.0*	*90.9*	*65,850*
	1929–57	2,100	1,290	1,000	690	455	320	220	145	96	69	56	47	39	31	20	4.0	.2	.0	.0	77.1	55,860
2325	Sheep Creek at mouth, near Manila, Utah 1947–57	324	320	310	260	185	118	69	33	20	16	14	13	12	11	9.7	8.6	7.4	6.4	5.7	24.5	17,750
2340	Carter Creek at mouth, near Manila, Utah	*950*	*810*	*720*	*562*	*410*	*325*	*230*	*149*	*76*	*41*	*31*	*25*	*22*	*18*	*16*	*13*	*12*	*11*	*10*	*63.6*	*46,080*
	1947–55	709	644	590	478	375	308	230	138	76	44	29	23	19	16	14	13	11	10	9.5	60.1	43,540
2345	Green River near Greendale, Utah	*17,900*	*17,400*	*16,700*	*14,300*	*11,100*	*9,150*	*7,500*	*5,250*	*3,490*	*2,200*	*1,500*	*1,150*	*870*	*680*	*540*	*426*	*340*	*296*	*260*	*2,271*	*1,645,000*
	1951–57	19,200	18,700	17,900	15,800	12,500	9,900	7,500	5,280	3,450	2,100	1,490	1,160	938	780	643	505	392	314	260	2,353	1,705,000
	Yampa River basin																					
2375	Yampa River near Oak Creek, Colo.	*880*	*790*	*710*	*570*	*420*	*320*	*230*	*150*	*98*	*76*	*66*	*58*	*52*	*46*	*40*	*34*	*27*	*19*	*15*	*87.3*	*63,250*
	1940–44	460	435	410	306	190	160	132	104	77	61	50	44	40	37	34	30	23	17	12	60.0	43,470
2395	Yampa River at Steamboat Springs, Colo.	*5,800*	*5,250*	*4,800*	*3,990*	*3,050*	*2,460*	*1,960*	*1,350*	*615*	*255*	*172*	*140*	*125*	*108*	*92*	*73*	*52*	*29*	*8.4*	*472*	*341,900*
	1905–06, 1910–57	5,800	5,400	4,980	4,000	2,990	2,400	1,950	1,350	650	255	172	140	125	109	93	74	54	31	9.0	474	343,400
2410	Elk River at Clark, Colo.	*4,400*	*3,900*	*3,540*	*2,830*	*2,200*	*1,850*	*1,560*	*1,100*	*505*	*200*	*112*	*87*	*75*	*66*	*56*	*46*	*37*	*31*	*27*	*356*	*257,900*
	1911–22, 1931–57	4,400	3,900	3,600	2,950	2,280	1,860	1,500	1,050	470	196	113	89	76	66	57	47	38	31	27	350	253,600
2425	Elk River near Trull, Colo.	*5,250*	*5,050*	*4,750*	*3,900*	*3,210*	*2,720*	*2,210*	*1,680*	*960*	*310*	*170*	*130*	*105*	*92*	*82*	*70*	*59*	*54*	*49*	*544*	*394,100*
	1905–06, 1910–27	5,290	5,050	4,830	4,300	3,500	2,950	2,450	1,780	1,010	370	195	145	120	105	93	80	64	54	47	593	429,600
2470	Fortification Creek at Craig, Colo.	*800*	*780*	*732*	*618*	*460*	*360*	*290*	*205*	*84*	*13*	*4.9*	*2.1*	*.8*	*.2*	*.0*	*.0*	*.0*	*.0*	*.0*	*57.2*	*41,440*
	1910–18, 1944–47	700	690	665	585	450	345	259	178	97	21	9.0	5.8	3.6	1.8	.1	.0	.0	.0	.0	57.0	41,290
2495	Williams Fork at Hamilton, Colo. 1905–06, 1910–27	3,200	2,800	2,480	1,900	1,400	1,115	880	590	265	125	84	70	64	60	54	38	24	17	15	218	157,900
2510	Yampa River near Maybell, Colo.	*17,300*	*16,200*	*14,950*	*12,500*	*9,750*	*8,050*	*6,600*	*4,750*	*2,540*	*950*	*550*	*410*	*332*	*280*	*235*	*182*	*108*	*36*	*12*	*1,590*	*1,152,000*
	1917–57	17,300	16,000	14,900	12,800	10,000	8,200	6,540	4,650	2,450	960	555	420	343	286	239	183	106	36	12	1,587	1,150,000
2530	Little Snake River near Slater, Colo.	*2,830*	*2,770*	*2,650*	*2,190*	*1,740*	*1,400*	*1,240*	*905*	*390*	*91*	*54*	*41*	*32*	*27*	*23*	*19*	*16*	*13*	*11*	*260*	*188,400*
	1943–47, 1951–57	2,830	2,690	2,500	2,090	1,660	1,390	1,090	730	245	72	44	34	30	26	23	19	15	12	10	220	159,400
2550	Slater Fork near Slater, Colo.	*1,350*	*1,230*	*1,120*	*880*	*610*	*470*	*363*	*250*	*106*	*32*	*24*	*20*	*17*	*14*	*12*	*8.4*	*4.6*	*1.9*	*.0*	*84.0*	*60,850*
	1932–57	1,280	1,080	950	740	550	435	330	210	77	29	22	18	16	13	11	7.0	3.5	1.3	.0	73.0	52,890
2555	Savery Creek at upper station near Savery, Wyo.	*515*	*475*	*440*	*370*	*288*	*229*	*178*	*128*	*74*	*38*	*27*	*22*	*18*	*15*	*12*	*9.3*	*4.2*	*.9*	*.5*	*50.8*	*36,800*
	1941, 1953–57	411	380	350	290	220	173	135	96	53	26	20	17	15	13	11	6.7	3.5	1.5	.8	38.5	27,890
2570	Little Snake River near Dixon, Wyo.	*7,800*	*6,650*	*5,950*	*4,880*	*3,880*	*3,200*	*2,540*	*1,790*	*803*	*228*	*129*	*99*	*80*	*63*	*32*	*10*	*3.0*	*1.0*	*.0*	*547*	*396,300*
	1911–23, 1939–57	8,960	7,700	6,800	5,320	3,950	3,100	2,420	1,630	750	208	135	105	86	68	45	11	4.8	2.4	1.1	534	386,900
2580	Willow Creek near Dixon, Wyo.	*148*	*138*	*127*	*104*	*73*	*54*	*41*	*29*	*18*	*9.5*	*6.0*	*4.1*	*3.2*	*2.6*	*2.2*	*1.8*	*1.0*	*.3*	*.1*	*11.8*	*8,550*
	1954–57	102	94	86	72	55	44	35	26	15	6.8	3.6	2.9	2.5	2.3	2.1	1.7	.6	.2	.0	9.4	6,820
2600	Little Snake River near Lily, Colo.	*8,000*	*7,550*	*7,000*	*5,750*	*4,340*	*3,460*	*2,720*	*1,920*	*946*	*350*	*190*	*123*	*87*	*65*	*41*	*11*	*.1*	*.0*	*.0*	*622*	*450,600*
	1922–57	7,800	7,300	6,700	5,520	4,170	3,300	2,580	1,750	880	324	180	120	86	64	37	7.6	.1	.0	.0	586	424,500

TABLE 5.—*Flow-duration table for stations in the subbasins in the Green division*—Continued

[Water years of historical periods of record are indicated and 1914–57 extension adjusted to 1957 conditions are italicized]

Station No.	Streamflow station	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Mean discharge (cfs)	Mean annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Green River basin between the Yampa and White Rivers, including the White River basin																					
2610	Green River near Jensen, Utah	*40,000*	*36,800*	*34,500*	*28,900*	*22,600*	*19,100*	*16,100*	*12,500*	*7,700*	*4,150*	*2,450*	*1,820*	*1,450*	*1,185*	*965*	*765*	*580*	*460*	*396*	*4,607*	*3,338,000*
	1947–57	36,200	35,500	34,000	28,900	23,000	20,000	16,700	12,500	7,500	4,150	2,450	1,820	1,530	1,270	1,050	840	640	510	440	4,670	3,383,000
2620	Brush Creek near Vernal, Utah	*300*	*296*	*290*	*272*	*248*	*223*	*149*	*77*	*32*	*23*	*19*	*18*	*16*	*15*	*14*	*13*	*12*	*11*	*10*	*38.5*	*27,890*
	1940–57	300	284	274	258	239	207	131	67	34	24	19	17	15	14	13	12	11	10	9.3	36.1	26,150
2635	Brush Creek near Jensen, Utah	*570*	*450*	*380*	*272*	*183*	*146*	*98*	*40*	*21*	*16*	*14*	*12*	*7.2*	*3.3*	*1.2*	*.4*	*.2*	*.1*	*.0*	*23.4*	*16,950*
	1940–57	500	370	310	225	167	138	87	34	21	16	13	8.6	2.3	1.0	.4	.2	.1	.0	.0	20.3	14,710
2665	Ashley Creek near Vernal, Utah	*1,325*	*1,170*	*1,060*	*860*	*640*	*485*	*350*	*214*	*131*	*93*	*68*	*49*	*39*	*33*	*28*	*23*	*19*	*17*	*16*	*106*	*76,790*
	1916, 1920, 1922–27, 1930–57	1,430	1,200	1,050	840	600	435	300	190	127	89	64	47	38	32	27	23	19	16	15	98.8	71,580
2715	Ashley Creek near Jensen, Utah	*1,480*	*1,360*	*1,270*	*1,020*	*665*	*415*	*180*	*80*	*57*	*47*	*42*	*37*	*31*	*26*	*18*	*7.9*	*2.5*	*1.3*	*.7*	*71.2*	*51,580*
	1947–57	1,280	1,190	1,100	870	575	362	160	75	57	48	40	31	23	15	8.0	3.0	1.0	.4	.2	61.5	44,550
2740	Duchesne River near Hanna, Utah	*910*	*750*	*650*	*490*	*335*	*203*	*95*	*49*	*32*	*18*	*12*	*9.4*	*9.0*	*8.8*	*8.6*	*8.4*	*8.0*	*7.5*	*7.0*	*33.9*	*24,560*
	1922–23, 1947–57	1,490	1,400	1,310	1,120	845	634	458	244	97	47	29	23	20	17	13	8.0	6.6	6.0	5.5	99.9	72,370
2755	West Fork Duchesne River near Hanna, Utah	*550*	*530*	*500*	*423*	*325*	*238*	*165*	*103*	*54*	*33*	*22*	*18*	*17*	*15*	*14*	*12*	*10*	*9.2*	*8.4*	*47.5*	*34,410*
	1923, 1946–57	550	530	500	423	325	255	189	118	54	32	22	19	18	16	15	14	12	11	10	50.3	36,440
2775	Duchesne River near Tabiona, Utah	*1,930*	*1,620*	*1,430*	*1,140*	*800*	*583*	*420*	*252*	*152*	*129*	*114*	*103*	*97*	*93*	*85*	*74*	*58*	*44*	*34*	*159*	*115,200*
	1919–57	2,500	2,280	2,040	1,610	1,150	875	655	395	209	153	129	116	107	99	90	78	61	46	35	209	151,400
2790	Rock Creek near Mountain Home, Utah	*2,200*	*1,980*	*1,840*	*1,520*	*1,160*	*910*	*690*	*460*	*223*	*131*	*97*	*78*	*64*	*56*	*50*	*44*	*38*	*34*	*32*	*189*	*136,900*
	1938–57	2,200	1,980	1,840	1,500	1,140	860	635	401	190	112	82	65	56	51	47	44	38	34	32	172	124,600
2795	Duchesne River at Duchesne, Utah	*3,830*	*3,460*	*3,150*	*2,520*	*1,800*	*1,373*	*1,025*	*632*	*317*	*234*	*200*	*180*	*166*	*151*	*137*	*113*	*79*	*50*	*30*	*323*	*234,000*
	1918–57	4,450	4,080	3,600	3,050	2,240	1,710	1,240	730	370	253	210	188	172	160	142	115	74	48	33	369	267,300
2850	Strawberry River near Soldier Springs, Utah	*682*	*560*	*430*	*204*	*138*	*105*	*77*	*56*	*40*	*32*	*27*	*23*	*19*	*17*	*15*	*13*	*10*	*9.6*	*9.3*	*33.0*	*23,910*
	1943–56	682	605	490	220	119	88	67	50	37	30	25	22	19	17	15	13	12	11	10	31.2	22,600
2880	Currant Creek near Fruitland, Utah	*1,260*	*900*	*688*	*425*	*273*	*198*	*144*	*98*	*64*	*44*	*36*	*32*	*28*	*25*	*21*	*18*	*14*	*11*	*8.5*	*53.8*	*38,980*
	1936–57	1,260	820	620	410	250	185	136	94	58	39	32	29	27	24	21	18	14	9.8	7.1	49.9	36,150
2885	Strawberry River at Duchesne, Utah	*3,490*	*2,800*	*2,300*	*1,540*	*920*	*610*	*410*	*268*	*175*	*123*	*102*	*89*	*79*	*70*	*61*	*48*	*31*	*8.9*	*1.6*	*157*	*113,700*
	1915–57	3,420	2,700	2,240	1,500	940	630	425	278	178	125	105	91	80	70	60	48	30	9.6	2.6	159	115,200
2895	Lake Fork above Moon Lake, near Mountain Home, Utah	*1,710*	*1,500*	*1,330*	*990*	*710*	*545*	*415*	*275*	*147*	*85*	*60*	*48*	*40*	*33*	*28*	*24*	*19*	*16*	*15*	*116*	*84,040*
	1943–55	1,710	1,500	1,330	990	678	520	385	250	138	72	48	39	34	29	26	24	21	17	16	107	77,520
2925	Yellowstone Creek near Altonah, Utah	*2,210*	*1,890*	*1,650*	*1,190*	*780*	*594*	*450*	*310*	*188*	*122*	*96*	*78*	*67*	*60*	*54*	*49*	*44*		*39*	*151*	*109,400*
	1945–57	1,500	1,330	1,180	930	670	530	393	270	170	117	90	73	63	56	52	48	45	43	42	135	97,800
2940	Lake Fork near Upalco, Utah	*6,100*	*3,200*	*2,480*	*1,460*	*530*	*230*	*118*	*88*	*79*	*68*	*55*	*39*	*16*	*5.6*	*1.7*	*.3*	*.0*	*.0*	*.0*	*69.7*	*50,490*
	1943–55	4,100	2,030	1,740	1,120	420	185	104	87	78	68	53	29	9.6	3.0	1.0	.5	.3	.1	.0	58.8	42,600
2950	Duchesne River at Myton, Utah	*12,800*	*8,300*	*6,900*	*4,800*	*3,100*	*2,100*	*1,420*	*900*	*540*	*410*	*355*	*320*	*282*	*240*	*173*	*64*	*11*	*2.2*	*1.2*	*508*	*368,000*
	1912–24, 1926–57	12,800	9,200	7,600	5,400	3,600	2,600	1,820	1,100	610	450	370	335	295	250	180	68	12	2.7	1.3	580	420,200
2955	Uinta River below Gilbert Creek, near Neola, Utah	*1,200*	*895*	*740*	*510*	*330*	*248*	*182*	*121*	*63*	*36*	*23*	*15*	*12*	*10*	*8.6*	*6.8*	*5.3*	*4.5*	*3.9*	*49.6*	*35,930*
	1951–55	757	640	544	405	265	197	140	92	55	32	19	12	9.9	8.4	7.3	6.4	5.6	5.2	5.1	39.8	28,830
2970	Uinta River near Neola, Utah	*2,700*	*2,320*	*2,020*	*1,460*	*965*	*725*	*540*	*384*	*260*	*176*	*129*	*102*	*84*	*73*	*65*	*56*	*49*	*43*	*40*	*191*	*138,400*
	1926, 1930–34, 1938–57	2,370	1,900	1,640	1,220	860	638	480	338	240	168	123	91	76	67	60	53	47	42	40	173	125,300

2995	Whiterocks River near Whiterocks, Utah	*2,470*	*1,970*	*1,670*	*1,170*	*730*	*510*	*385*	*260*	*160*	*106*	*74*	*55*	*44*	*38*	*33*	*29*	*24*	*17*	*12*	*124*	*89,830*
	1910, 1931–57	1,600	1,420	1,270	990	650	470	320	212	145	99	68	52	42	36	32	29	25	20	15	110	79,690
3005	Uinta River at Fort Duchesne, Utah	*3,800*	*3,200*	*2,700*	*1,720*	*920*	*500*	*200*	*122*	*84*	*66*	*55*	*39*	*20*	*12*	*6.3*	*2.8*	*1.2*	*.0*	*.0*	*92.1*	*66,720*
	1910, 1943–57	2,850	2,280	1,900	1,300	740	395	216	135	98	74	55	30	16	8.2	4.6	2.3	.8	.1	.0	82.9	60,060
3020	Duchesne River near Randlett, Utah	*14,200*	*12,600*	*11,000*	*7,740*	*4,500*	*2,950*	*2,000*	*1,280*	*845*	*655*	*550*	*485*	*427*	*365*	*280*	*132*	*29*	*11*	*6.2*	*767*	*555,700*
	1943–57	8,500	8,000	7,300	5,720	3,800	2,730	1,890	1,090	665	535	473	425	370	300	200	92	28	16	12	640	463,700
3030	White River at Buford, Colo.	*2,680*	*2,270*	*2,000*	*1,630*	*1,290*	*1,090*	*910*	*660*	*425*	*286*	*236*	*210*	*194*	*178*	*160*	*148*	*135*	*117*	*98*	*331*	*239,800*
	1904–06, 1911–15, 1920, 1952–57	3,150	2,790	2,500	2,000	1,490	1,180	920	644	388	275	228	200	182	170	158	148	135	122	112	332	240,500
3035	South Fork White River near Buford, Colo.	*3,600*	*3,280*	*2,880*	*2,260*	*1,690*	*1,290*	*920*	*595*	*300*	*210*	*168*	*138*	*121*	*107*	*95*	*86*	*78*	*71*	*66*	*283*	*205,000*
	1904–06, 1911–15, 1943–47	3,000	2,730	2,500	2,050	1,500	1,160	885	595	300	200	150	128	113	100	93	88	81	75	70	267	193,400
3045	White River near Meeker, Colo.	*5,700*	*4,800*	*4,350*	*3,600*	*2,890*	*2,400*	*1,900*	*1,310*	*725*	*490*	*420*	*378*	*350*	*330*	*305*	*278*	*249*	*205*	*147*	*638*	*462,200*
	1902–06, 1910–57	5,600	4,730	4,280	3,550	2,840	2,360	1,900	1,310	720	500	418	372	344	325	307	282	250	215	140	635	460,000
3065	White River near Watson, Utah	*8,200*	*6,400*	*5,400*	*4,150*	*3,190*	*2,590*	*2,100*	*1,590*	*1,000*	*660*	*550*	*470*	*418*	*380*	*349*	*300*	*230*	*150*	*96*	*764*	*553,500*
	1924–57	8,160	5,850	4,860	3,980	3,055	2,450	1,985	1,485	900	640	520	460	410	375	345	300	225	145	92	727	526,700
	Green River basin below the White River																					
3070	Green River near Ouray, Utah	*63,000*	*55,500*	*49,700*	*39,800*	*30,200*	*24,900*	*20,000*	*15,400*	*9,600*	*5,450*	*3,750*	*2,850*	*2,380*	*2,060*	*1,750*	*1,420*	*990*	*580*	*370*	*6,223*	*4,508,000*
	1948–55, 1957	44,000	42,000	40,200	36,600	30,500	25,700	20,750	15,400	8,900	5,050	3,600	2,830	2,430	2,100	1,800	1,440	1,140	960	820	6,125	4,437,000
3080	Willow Creek near Ouray, Utah	*800*	*700*	*615*	*385*	*141*	*96*	*75*	*60*	*47*	*37*	*30*	*24*	*19*	*14*	*9.1*	*3.1*	*.4*	*.1*	*.0*	*34.1*	*24,700*
	1948–55	500	408	345	219	138	99	74	53	39	29	22	17	13	9.2	4.7	1.2	.3	.1	.0	27.0	19,560
3090	Minnie Maud Creek at Nutter Ranch, near Myton, Utah	*660*	*588*	*525*	*365*	*130*	*72*	*47*	*32*	*22*	*16*	*13*	*10*	*8.9*	*7.1*	*4.9*	*2.6*	*.1*	*.0*	*.0*	*20.3*	*14,710*
	1948–55	580	530	480	365	170	95	55	31	20	14	11	9.0	7.3	5.5	3.4	1.3	.2	.1	.0	20.4	14,780
3105	Price River above Scofield Reservoir, near Scofield, Utah	*940*	*810*	*740*	*610*	*445*	*335*	*230*	*118*	*37*	*20*	*15*	*13*	*11*	*10*	*8.8*	*7.4*	*6.6*	*5.6*	*4.4*	*50.8*	*36,800*
	1939–57	940	858	768	580	390	280	195	113	45	23	15	12	10	9.0	8.0	7.1	6.4	5.6	4.9	47.5	34,410
3125	White River near Soldier Summit, Utah	*1,120*	*790*	*610*	*340*	*190*	*130*	*88*	*45*	*19*	*9.0*	*5.0*	*4.0*	*3.2*	*2.8*	*2.5*	*2.2*	*1.9*	*1.5*	*1.0*	*21.6*	*15,650*
	1940–57	1,120	855	655	255	159	118	82	48	21	9.6	5.3	4.1	3.4	3.1	2.9	2.5	1.9	1.4	1.1	20.8	15,070
3130	Price River near Heiner, Utah	*2,830*	*2,240*	*1,900*	*1,340*	*750*	*460*	*310*	*245*	*208*	*158*	*99*	*47*	*25*	*17*	*11*	*5.1*	*3.1*	*2.4*	*2.0*	*123*	*89,110*
	1935–57	2,040	1,860	1,700	1,020	560	372	292	245	200	148	100	58	27	17	11	7.0	4.7	3.4	2.6	114	82,590
3140	Price River near Wellington, Utah	*2,290*	*2,080*	*1,900*	*1,390*	*780*	*410*	*194*	*81*	*55*	*42*	*35*	*30*	*25*	*21*	*16*	*9.6*	*8.4*	*7.6*	*7.1*	*75.5*	*54,700*
	1950–57	2,290	2,180	2,020	1,680	725	225	130	79	52	42	36	31	26	22	18	14	10	9.1	8.4	71.1	51,510
3145	Price River at Woodside, Utah	*4,310*	*2,940*	*2,320*	*1,580*	*1,050*	*665*	*348*	*149*	*102*	*74*	*62*	*52*	*44*	*36*	*25*	*11*	*6.8*	*5.2*	*4.4*	*116*	*84,040*
	1947–57	4,310	3,330	2,620	1,650	800	335	224	134	95	73	61	52	44	36	29	21	14	8.7	6.8	101	73,170
3150	Green River at Green River, Utah	*63,430*	*56,430*	*51,450*	*41,720*	*32,100*	*25,850*	*20,210*	*14,800*	*9,267*	*5,614*	*3,881*	*2,966*	*2,439*	*2,091*	*1,793*	*1,424*	*1,006*	*637*	*462*	*6,292*	*4,558,000*
	1895–1899, 1906–57	67,000	59,000	53,900	44,000	34,100	27,500	21,400	15,650	10,300	5,895	4,050	3,100	2,500	2,130	1,790	1,410	1,010	698	500	6,658	4,823,000
3180	Huntington Creek near Huntington, Utah	*1,240*	*1,150*	*1,060*	*865*	*615*	*440*	*315*	*204*	*135*	*88*	*53*	*41*	*36*	*33*	*30*	*26*	*22*	*19*	*17*	*100*	*72,450*
	1911–17, 1922–29, 1931–57	1,240	1,150	1,060	850	580	425	315	200	135	87	53	41	36	32	29	25	21	17	13	98.4	71,290
3245	Cottonwood Creek near Orangeville, Utah	*1,820*	*1,630*	*1,420*	*1,040*	*735*	*530*	*362*	*223*	*109*	*56*	*37*	*30*	*26*	*23*	*20*	*16*	*12*	*9.5*	*8.8*	*96.9*	*70,200*
	1911–20, 1922–27, 1933–57	1,880	1,630	1,460	1,100	770	575	400	240	116	57	40	31	27	23	20	17	13	11	9.5	103	74,620
3265	Ferron Creek (upper station) near Ferron, Utah	*1,110*	*905*	*790*	*615*	*458*	*358*	*259*	*161*	*75*	*38*	*23*	*15*	*13*	*11*	*9.8*	*8.7*	*7.4*	*6.2*	*5.3*	*62.9*	*45,570*
	1912–23, 1948–57	1,110	990	890	720	535	403	282	180	95	50	29	20	15	12	10	8.4	6.1	4.2	3.0	72.7	52,670
3280	San Rafael River near Castle Dale, Utah	*3,840*	*2,950*	*2,520*	*1,940*	*1,350*	*830*	*465*	*210*	*98*	*64*	*53*	*44*	*38*	*32*	*25*	*12*	*2.0*	*.0*	*.0*	*133*	*96,350*
	1948–57	3,840	3,350	2,900	2,100	1,250	690	415	192	98	68	53	44	37	30	23	14	5.3	2.5	1.6	127	92,010
3285	San Rafael River near Green River, Utah	*4,050*	*3,150*	*2,690*	*2,020*	*1,370*	*865*	*475*	*242*	*117*	*76*	*64*	*51*	*41*	*32*	*24*	*1.4*	*.0*	*.0*	*.0*	*141*	*102,100*
	1910–18, 1946–57	4,200	3,920	3,500	2,630	1,660	1,090	657	380	190	115	85	67	54	44	31	16	.6	.1	.0	193	139,800

TABLE 6.—*Methods and accuracy of adjusting flow-duration data for selected stations in two subbasins in the Green division to base period and 1957 conditions*

Years of record: Number of years of available historical flow-duration data during water years 1914–57.
Base period adjustment method: Method used in adjusting historical data to base period; I, index-station method; S, substitute method.
Index-station No.: Index station used in adjusting flow-duration curve to base period or correlation station used in estimating data for missing periods of record.
Accuracy rating: Authors' rating of accuracy of adjusted flow-duration curve for water years 1914–57 to 1957 conditions. The accuracy rating indicates that the final developed flow-duration curve throughout its range is believed to be correct within the percentage indicated.

Station No.	Years of record	Base period adjustment method	Index-station No.	Accuracy rating (percent)	Station No.	Years of record	Base period adjustment method	Index-station No.	Accuracy rating (percent)
Green River basin above the Yampa River									
1885	26	I	2010	10	2125	18	S	1980, 2010, 2110, 2125	15
1890	16	I	1885 [1]	15	2135	19	S	2045, 2110, 2125	15+
1900	23	I	do	15	2140	18	I	2125 [1]	15
1915	16	I	do	15	2165	31	S	2255 [2]	10
2010	43	S		5	2230	5	I	2235	15+
2030	19	I	2125 [1]	15+	2235	12	I	2110	15+
2045	12	I	2010	10	2255	29	S	2165, 2305, 2350	15
2055	27	S	1885, 1980, 2010, 2110	15+	2260	9	I	2665	10
2085	10	I	2055,[1] 2110 [1]	15+	2295	29	S	2190, 2220, 2665 [2]	10
2095	11	I	2165 [1]	10	2340	9	I	2665	10
2110	26	S	2105, 2235, 2240	15	2345	7	I	2295 [1]	15
Yampa River basin									
2375	5	I	2395	15	2530	12	I	2600 [1]	15
2395	44			5	2550	26	I	2600 [1]	15
2410	36	S	2395, 2425, 2510	10	2555	6	I	2570 [1]	15+
2425	14	I	2410	15+	2570	29	I	2600 [1]	10
2470	9	I	2570 [1]	15	2580	4	I	2550 [1]	15+
2510	41	S	2395, 2410, 2495	5	2600	36	S	(2)	10

[1] Flow-duration curve and data for index station that had been adjusted to base period were used.

[2] Annual estimates of discharge by Upper Colorado River Compact Comm. (1948) were used.

TABLE 7.—*Variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water for selected streams in the subbasins in the Green division*

[Data are for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Station name	Variability index	Ground water (percent)
	Green River basin above the Yampa River		
2030	East Fork near Big Sandy, Wyo	0.72	11
2230	Hams Fork near Elk Creek ranger station, Wyo	.58	17
2140	Little Sandy Creek near Elkhorn, Wyo	.56	21
2125	Big Sandy Creek at Leckie Ranch, Wyo	.56	19
2185	Blacks Fork near Millburne, Wyo.[1]	.53	22
2260	Henrys Fork near Lonetree, Wyo	.52	24
1855	Green River at Warren Bridge, near Daniel, Wyo	.51	27
2055	North Piney Creek near Mason, Wyo	.48	29
2165	Green River at Green River, Wyo	.42	30
2045	East Fork at Newfork, Wyo	.40	31
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[2]	.35	43
2085	La Barge Creek near Viola, Wyo	.28	52
	Yampa River basin		
2530	Little Snake River near Slater, Colo	0.67	12
2410	Elk River at Clark, Colo	.58	19
2555	Savery Creek at upper station, near Savery, Wyo	.48	33
2375	Yampa River near Oak Creek, Colo	.25	60
	Green River basin between the Yampa and White Rivers including the White River basin		
2790	Rock Creek near Mountain Home, Utah	0.42	36
2665	Ashley Creek near Vernal, Utah	.40	30
2995	Whiterocks River near Whiterocks, Utah	.40	30
2755	West Fork Duchesne River near Hanna, Utah	.36	32
2925	Yellowstone Creek near Altonah, Utah	.34	44
3045	White River near Meeker, Colo	.26	57
	Green River basin below the White River		
3180	Huntington Creek near Huntington, Utah	0.38	32
3245	Cottonwood Creek near Orangeville, Utah	.46	26
3265	Ferron Creek (upper station) near Ferron, Utah	.53	19

[1] Water years 1940–57. [2] Water years 1952–57.

TABLE 8.—*Average discharge, standard deviation, and coefficient of variation for selected stations in the Green division*

Station No.	Station name	Period of record	Average discharge (cfs)	Standard deviation (cfs)	Coefficient of variation
	Green River basin above the Yampa River				
1885	Green River at Warren Bridge, near Daniel, Wyo	1940–57	532	98. 1	0. 18
1980	Pine Creek at Pinedale, Wyo	1940–54	128	34. 0	. 27
2010	New Fork River near Boulder, Wyo	1915–57	401	113	. 28
2030	East Fork near Big Sandy, Wyo	1939–57	104	25. 5	. 25
2055	North Piney Creek near Mason, Wyo	1940–57	60. 3	19. 7	. 32
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo	1940–57	86. 6	20. 0	. 23
2170	Green River at Green River, Wyo	1914–57	1, 802	577	. 32
2185	Blacks Fork near Millburne, Wyo	1940–57	156	27. 5	. 18
2200	East Fork Smiths Fork near Robertson, Wyo	1940–57	45. 0	11. 2	. 25
2235	Hams Fork near Frontier, Wyo	1940–57	143	65. 9	. 46
2260	Henrys Fork near Lonetree, Wyo	1943–57	39. 4	11. 3	. 29
2285	Burnt Fork near Burntfork, Wyo	1944–57	30. 2	8. 76	. 29
	Yampa River basin				
2395	Yampa River at Steamboat Springs, Colo	1914–57	472	126	0. 27
2410	Elk River at Clark, Colo	1914–57	356	91. 4	. 26
2510	Yampa River near Maybell, Colo	1914–57	1, 590	489	. 31
2570	Little Snake River near Dixon, Wyo	1914–57	547	185	. 34
	Green River basin between the Yampa and White Rivers including the White River basin				
2665	Ashley Creek near Vernal, Utah	1914–57	104	31. 9	0. 31
2795	Duchesne River at Duchesne, Utah	[1] 1914–57	385	121	. 31
2995	Whiterocks River near Whiterocks, Utah	1914–57	124	45. 4	. 37
3045	White River near Meeker, Colo	1914–57	638	142	. 22
	Green River basin below the White River				
3105	Price River above Scofield Reservoir, near Scofield, Utah	1939–57	47. 5	17. 3	0. 36
3150	Green River at Green River, Utah	1914–57	6, 358	2, 006	. 32
3180	Huntington Creek near Huntington, Utah	1914–57	100	34. 1	. 34
3265	Ferron Creek (upper station) near Ferron, Utah	1914–23, 1948–57	72. 8	26. 0	. 36

[1] Water years 1914–17 estimated.

TABLE 9.—*Water and dissolved-solids discharges of streams in the subbasins in the Green division*

[Water and dissolved-solids discharge for the 1914–57 water years adjusted to 1957 conditions, except as indicated]

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per sq mi (tons)	Average annual discharge (tons)
	Green River basin above the Yampa River							
1885	Green River at Warren Bridge, near Daniel, Wyo	468	540	391, 200	151	220	172	80, 360
1890	Beaver Creek near Daniel, Wyo	141	37. 8	27, 380	206	21	54	7, 670
1900	Horse Creek near Daniel, Wyo	124	74. 0	53, 610	180	36	106	13, 150
1915	Cottonwood Creek near Daniel, Wyo	202	74. 5	53, 970	239	48	87	17, 530
1930	New Fork River below New Fork Lake, near Cora, Wyo	36. 2	51. 4	37, 240	29	4. 0	40	1, 460
1965	Pine Creek above Fremont Lake, Wyo	75. 8	199	144, 200	25	13	63	4, 750
2010	New Fork River near Boulder, Wyo	552	401	290, 500	69	75	50	27, 390
2030	East Fork near Big Sandy, Wyo	79. 2	106	76, 790	26	7. 4	34	2, 700
2045	East Fork at New Fork, Wyo	348	166	120, 300	60	27	28	9, 860
2055	North Piney Creek near Mason, Wyo	58	59. 7	43, 250	174	28	176	10, 230
2085	La Barge Creek near Viola, Wyo	172	98. 4	71, 290	237	63	134	23, 010
2095	Green River near Fontenelle, Wyo	3, 970	1, 609	1, 166, 000	185	805	74	294, 000
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[1]	152	70. 2	50, 860	211	40	96	14, 610
2110A	Fontenelle Creek at Fontenelle, Wyo	224	68. 3	49, 480	304	56	91	20, 450
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo	94	85. 5	61, 940	34	7. 8	30	2, 850
2135	Big Sandy Creek near Farson, Wyo	320	86. 6	62, 740	47	11	13	4, 020
2140	Little Sandy Creek near Elkhorn, Wyo	20. 9	21. 5	15, 580	33	1. 9	33	694
2160	Big Sandy Creek below Eden, Wyo	1, 610	48. 8	35, 350	1, 340	176	40	64, 280
2165	Green River at Green River, Wyo	7, 670	1, 802	1, 305, 000	284	1, 380	66	504, 000
2185	Blacks Fork near Millburne, Wyo.[2]	156	156	113, 000	76	32	75	11, 690
2215	Smith Fork at Mountain View, Wyo.[3]	192	52. 5	38, 030	190	27	51	9, 860
2220	Blacks Fork near Lyman, Wyo.[4]	821	132	95, 630	572	204	91	74, 510
2230	Hams Fork near Elk Creek ranger station, Wyoming	128	113	81, 860	187	57	163	20, 820
2235	Hams Fork near Frontier, Wyo	298	150	108, 700	202	82	101	29, 950
2245B	Blacks Fork near Marston, Wyo.[5]	3, 010	345	249, 900	481	448	54	163, 600
2250	Blacks Fork near Green River, Wyo.[5]	3, 670	345	249, 900	537	500	50	182, 600
2255	Green River near Linwood, Utah	14, 300	2, 143	1, 553, 000	366	2, 120	54	774, 300
2260	Henrys Fork near Lonetree, Wyo	56	43. 6	31, 590	59	6. 9	45	2, 520
2295	Henrys Fork at Linwood, Utah	531	90. 9	65, 850	636	156	107	56, 980
2325	Sheep Creek at mouth, near Manila, Utah.[6]	111	24. 5	17, 750	499	33	109	12, 050
2340	Carter Creek at mouth, near Manila, Utah	110	63. 6	46, 080	40	6. 9	23	2, 520
2345	Green River near Greendale, Utah	15, 100	2, 271	1, 645, 000	378	2, 320	56	847, 400

See footnotes at end of table.

TABLE 9.—*Water and dissolved-solids discharges of streams in the subbasins in the Green division*—Continued

[Water and dissolved-solids discharge for the 1914-57 water years adjusted to 1957 conditions, except as indicated]

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per sq mi (tons)	Average annual discharge (tons)
	Yampa River basin							
2375	Yampa River near Oak Creek, Colo	227	87.3	63,250	221	52	84	18,990
2395	Yampa River at Steamboat Springs, Colo	604	472	341,900	74	94	57	34,330
2410	Elk River at Clark, Colo	206	356	257,900	40	38	67	13,880
2425	Elk River near Trull, Colo	415	544	394,100	44	64	56	23,380
2469	Fortification Creek near Craig, Colo	34.3	13.4	9,710	774	28	298	10,230
2495	Williams Fork at Hamilton, Colo.[7]	341	218	157,900	234	138	148	50,400
2510A	Yampa River at bridge on county road, near Maybell, Colo	3,590	1,590	1,152,000	140	599	61	218,800
2530	Little Snake River near Slater, Colo	285	260	188,400	78	55	70	20,090
2550	Slater Fork near Slater, Colo	161	84.0	60,850	101	23	52	8,400
2555	Savery Creek at upper station, near Savery, Wyo	189	50.8	36,800	160	22	43	8,040
2570	Little Snake River near Dixon, Wyo	988	547	396,300	91	135	50	49,310
2580	Willow Creek near Dixon, Wyo	24	11.8	8,550	88	2.8	42	1,020
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	3,355	622	450,600	196	330	36	120,500
	Green River basin between the Yampa and White Rivers including the White River basin							
2620	Brush Creek near Vernal, Utah	82	38.5	27,890	240	25	111	9,130
2635	Brush Creek near Jensen, Utah	255	23.4	16,950	380	24	34	8,770
2635A	Green River at Jensen, Utah	26,100	4,607	3,338,000	316	3,930	55	1,435,000
2665	Ashley Creek near Vernal, Utah	101	106	76,790	56	16	58	5,840
2715	Ashley Creek near Jensen, Utah	386	71.2	51,580	853	164	155	59,900
2740	Duchesne River near Hanna, Utah	78	33.9	24,560	49	4.5	21	1,640
2755	West Fork Duchesne River near Hanna, Utah	61	47.5	34,410	23	3.0	18	1,100
2775	Duchesne River near Tabiona, Utah	352	159	115,200	256	110	114	40,180
2790	Rock Creek near Mountain Home, Utah	149	189	136,900	49	25	61	9,130
2795	Duchesne River at Duchesne, Utah	660	323	234,000	218	190	105	69,400
2850	Strawberry River near Soldier Springs, Utah	212	33.0	23,910	303	27	47	9,860
2880	Currant Creek near Fruitland, Utah	142	53.8	38,980	227	33	85	12,050
2885	Strawberry River at Duchesne, Utah	1,040	157	113,700	396	168	59	61,360
2925	Yellowstone Creek near Altonah, Utah	131	151	109,400	39	16	45	5,840
2940	Lake Fork near Upalco, Utah	418	69.7	50,490	223	42	37	15,340
2950	Duchesne River at Myton, Utah	2,750	508	368,000	370	507	67	185,200
2950B	Duchesne River at Ouray School canal, near Randlett, Utah	2,790	508	368,000	481	660	86	241,100
2970	Uinta River near Neola, Utah	181	191	138,400	25	13	26	4,750
2995	Whiterocks River near Whiterocks, Utah	115	124	89,830	27	9.0	29	3,290
3005	Uinta River at Fort Duchesne, Utah	672	92.1	66,720	221	55	30	20,090
3020	Duchesne River near Randlett, Utah	3,920	767	555,700	608	1,260	117	460,200
3030	White River at Buford, Colo	254	331	239,800	164	147	211	53,690
3035	South Fork White River near Buford, Colo	156	283	205,000	144	110	258	40,180
3045	White River near Meeker, Colo	762	638	462,200	244	420	201	153,400
3065	White River near Watson, Utah	4,020	764	553,500	439	905	82	330,600

See footnotes at end of table.

TABLE 9.—*Water and dissolved-solids discharges of streams in the subbasins in the Green division*—Continued

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per sq mi (tons)	Average annual discharge (tons)
	Green River basin below the White River							
3070	Green River near Ouray, Utah	35,500	6,223	4,508,000	392	6,590	68	2,407,000
3080	Willow Creek near Ouray, Utah	967	34.1	24,700	869	80	30	29,220
3090	Minnie Maude Creek at Nutter Ranch, near Myton, Utah	231	20.3	14,710	493	27	43	9,860
3105	Price River above Scofield Reservoir, near Scofield, Utah	62	50.8	36,800	180	25	147	9,130
3125	White River near Soldier Summit, Utah	53	21.6	15,650	320	19	131	6,940
3130	Price River near Heiner, Utah	455	123	89,110	226	75	60	27,390
3140	Price River near Wellington, Utah	850	75.5	54,700	1,190	242	104	88,390
3145	Price River at Woodside, Utah	1,500	116	84,040	2,110	662	161	241,800
3150	Green River at Green River, Utah	40,600	6,292	4,558,000	427	7,260	65	2,652,000
3180	Huntington Creek near Huntington, Utah	188	100	72,450	185	50	97	18,260
3245	Cottonwood Creek near Orangeville, Utah	200	96.9	70,200	233	61	111	22,280
3265	Ferron Creek (upper station) near Ferron, Utah	157	62.9	45,570	247	42	98	15,340
3280	San Rafael River near Castle Dale, Utah	927	133	96,350	1,310	469	185	171,300
3285	San Rafael River near Green River, Utah	1,690	141	102,100	1,370	521	113	190,300

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[1] For water years 1952–57.
[2] For water years 1940–57.
[3] For water years 1942–57.
[4] For water years 1938–40, 1942–57.
[5] For water years 1948–57.
[6] For water years 1947–57.
[7] For water years 1905–06, 1910–27.

TABLE 10.—*Duration table of dissolved-solids concentration for selected stations in the subbasins in the Green division*

[Table based on measured or partly estimated streamflow for the water years 1914–57 adjusted to 1957 conditions and applicable chemical-quality records, except as indicated]

Station No.	Chemical-quality station	Dissolved-solids concentration, in parts per million, that was equaled or exceeded for indicated percentage of time																			Weighted-average concentration (ppm)
		99.99	99.94	99.85	99.4	98	96	93	88	80	70	60	50	40	30	20	10	3	0.6	0.1	
Green River basin above the Yampa River																					
1885	Green River at Warren Bridge, near Daniel, Wyo	80	80	80	80	82	87	93	103	124	177	246	300	340	360	380	398	415	420	420	151
1890	Beaver Creek near Daniel, Wyo	201	201	201	201	202	202	203	205	207	230	240	250	259	260	265	265	265	--------	--------	206
1900	Horse Creek near Daniel, Wyo	171	171	171	171	172	173	175	177	182	202	213	218	219	220	220	220	221	222	223	180
1915	Cottonwood Creek near Daniel, Wyo	230	230	230	230	230	230	231	233	236	245	259	272	279	283	289	290	291	293	--------	239
1930	New Fork River below New Fork Lake, near Cora, Wyo	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	29
1965	Pine Creek above Fremont Lake, Wyo	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	25
2010	New Fork River near Boulder, Wyo	40	41	42	42	43	44	46	50	61	97	120	130	135	138	141	144	147	148	148	69
2030	East Fork near Big Sandy, Wyo	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	26
2045	East Fork at New Fork, Wyo	30	30	30	31	32	35	40	53	86	107	110	111	112	113	116	117	119	119	120	60
2055	North Piney Creek near Mason, Wyo	155	155	155	155	156	156	158	160	170	198	217	228	233	240	244	248	250	250	250	174
2085	La Barge Creek near Viola, Wyo	179	179	179	180	180	181	183	193	217	259	282	301	314	330	342	355	367	378	380	237
2095	Green River near Fontenelle, Wyo	128	128	129	130	133	136	141	155	180	220	250	268	275	280	283	288	290	296	298	185
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[1]	180	180	180	180	182	187	191	201	226	241	243	244	244	244	244	244	244	244	244	211
2110A	Fontenelle Creek at Fontenelle, Wyo	297	297	297	297	297	297	297	297	300	304	308	310	311	313	318	321	330	330	--------	304
2125	Big Sandy at Leckie Ranch, near Big Sandy, Wyo	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	34
2135	Big Sandy Creek near Farson, Wyo	37	37	37	37	38	38	38	40	46	63	77	88	95	101	107	113	118	119	120	47
2140	Little Sandy Creek near Elkhorn, Wyo	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	33
2160	Big Sandy Creek below Eden, Wyo	270	278	285	310	375	490	750	1,190	1,600	1,920	2,200	2,480	2,730	2,990	3,100	3,200	3,220	3,230	3,240	1,340
2165	Green River at Green River, Wyo	190	190	190	190	191	197	202	219	255	313	378	435	485	535	570	608	635	655	660	284
2185	Blacks Fork near Millburne, Wyo.[2]	70	70	70	70	70	71	72	73	76	84	88	89	90	90	90	90	90	90	90	76
2215	Smith Fork at Mountain View, Wyo.[3]	140	140	140	140	140	143	152	185	232	260	267	270	272	275	278	280	282	282	282	190
2220	Blacks Fork near Lyman, Wyo.[4]	388	388	388	388	388	390	398	443	550	740	910	1,060	1,300	1,700	2,390	3,200	3,390	3,400	--------	572
2230	Hams Fork near Elk Creek ranger station, Wyoming	180	180	180	180	180	180	181	183	190	218	219	220	220	220	220	220	220	220	220	187
2235	Hams Fork near Frontier, Wyo	190	190	190	190	191	191	194	198	210	248	260	261	265	265	268	268	268	268	268	202
2245B	Blacks Fork near Marston, Wyo.[5]	370	370	370	370	371	376	388	415	500	650	820	960	1,140	1,380	1,670	2,220	--------	--------	--------	481
2250	Blacks Fork near Green River, Wyo.[5]	357	358	360	365	380	410	445	490	575	730	900	1,080	1,400	1,850	2,050	2,100	--------	--------	--------	537
2255	Green River near Linwood, Utah	320	320	320	321	325	329	331	340	350	378	408	440	470	490	495	499	500	500	500	366
2260	Henrys Fork near Lonetree, Wyo	42	42	42	43	44	46	49	53	70	84	88	88	90	90	90	91	91	91	91	59
2295	Henrys Fork at Linwood, Utah	270	295	308	329	365	408	470	570	680	790	870	920	975	1,050	1,190	1,570	2,300	2,300	--------	636
2325	Sheep Creek at mouth, near Manila, Utah [6]	122	122	122	123	125	132	195	455	710	819	870	900	925	950	975	980	998	1,000	1,000	499
2340	Carter Creek at mouth, near Manila, Utah	37	37	37	37	37	37	38	38	38	42	45	48	49	51	52	52	52	52	52	40
2345	Green River near Greendale, Utah	256	256	256	260	268	278	290	320	362	425	490	540	580	620	650	670	680	680	680	378
Yampa River basin																					
2375	Yampa River near Oak Creek, Colo	150	150	150	150	150	153	159	180	230	258	268	276	280	285	290	292	299	300	300	221
2395	Yampa River at Steamboat Springs, Colo	38	38	38	39	40	41	44	51	76	127	155	171	180	188	197	204	211	218	220	74
2410	Elk River at Clark, Colo	35	35	35	35	36	36	36	37	39	46	53	54	54	54	54	54	54	54	55	40
2425	Elk River near Trull, Colo	32	32	32	33	33	34	35	37	42	62	75	79	82	84	85	86	88	89	90	44
2469	Fortification Creek near Craig, Colo	760	760	760	760	760	770	775	780	780	782	789	800	800	800	801	818	820	--------	--------	774
2495	Williams Fork at Hamilton, Colo.[7]	230	230	230	230	230	230	231	232	234	236	237	237	238	238	239	239	240	240	240	234
2510A	Yampa River at bridge on county road, near Maybell, Colo	96	96	96	96	96	98	104	118	157	204	228	244	261	282	305	340	389	420	420	140
2530	Little Snake River near Slater, Colo	74	74	74	74	74	74	74	75	78	96	107	110	110	110	110	111	112	113	113	78
2550	Slater Fork near Slater, Colo	84	84	84	84	84	84	85	86	95	132	154	173	191	213	230	268	310	320	--------	101
2555	Savery Creek at upper station, near Savery, Wyo	140	140	140	140	140	143	145	148	155	171	184	195	205	218	228	238	250	255	255	160
2570	Little Snake River near Dixon, Wyo	79	79	79	80	80	80	80	81	87	127	157	176	191	208	253	290	290	290	--------	91
2580	Willow Creek near Dixon, Wyo	78	78	78	78	78	80	80	81	86	97	107	110	110	110	110	110	110	110	110	88
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	143	143	143	145	147	150	155	168	215	330	388	405	426	462	550	810	810	--------	--------	196

Green River basin between the Yampa and White Rivers including the White River basin

2620	Brush Creek near Vernal, Utah	137	137	137	137	137	137	138	157	287	360	400	408	430	440	450	460	465	475	480	240
2635	Brush Creek near Jensen, Utah	180	180	181	182	184	185	199	350	600	690	720	758	806	878	1,090	1,670	2,520	3,410	--------	380
2635A	Green River at Jensen, Utah	186	187	188	192	205	217	230	255	308	390	478	522	559	580	598	609	619	620	620	316
2665	Ashley Creek near Vernal, Utah	40	40	40	40	40	40	41	49	63	75	82	84	84	84	84	84	84	84	84	56
2715	Ashley Creek near Jensen, Utah	390	390	390	390	390	395	515	825	1,040	1,230	1,350	1,500	1,730	1,940	2,360	2,760	3,200	3,750	4,400	853
2740	Duchesne River near Hanna, Utah	29	29	29	29	29	29	40	64	77	80	80	80	80	80	80	80	80	80	80	49
2755	West Fork Duchesne River near Hanna, Utah	19	19	19	19	19	19	20	22	26	28	28	29	29	29	29	29	29	29	29	23
2775	Duchesne River near Tabiona, Utah	123	123	123	123	124	129	145	198	300	330	348	358	360	365	370	370	370	370	370	256
2790	Rock Creek near Mountain Home, Utah	34	34	34	35	35	35	35	39	55	68	71	72	72	72	72	72	72	72	72	49
2795	Duchesne River at Duchesne, Utah	132	132	132	133	134	137	141	157	220	273	301	319	332	348	360	381	400	408	415	218
2850	Strawberry River near Soldier Springs, Utah	220	220	220	230	250	265	288	306	320	325	328	330	330	330	330	330	330	330	330	303
2880	Currant Creek near Fruitland, Utah	168	168	170	172	178	186	198	218	244	260	267	270	270	271	272	275	276	276	276	227
2885	Strawberry River at Duchesne, Utah	253	254	257	260	272	288	323	370	430	478	500	515	528	538	545	560	578	595	610	396
2925	Yellowstoue Creek near Altonah, Utah	34	34	34	34	34	35	36	38	43	47	48	48	48	48	48	48	48	48	48	39
2940	Lake Fork near Upalco, Utah	170	170	170	170	172	182	212	233	244	258	282	328	443	560	598	600	--------	--------	--------	223
2950	Duchesne River at Myton, Utah	194	198	200	203	222	250	290	345	410	455	480	490	515	543	600	830	1,260	1,300	1,300	370
2950B	Duchesne River at Ouray School canal, near Randlett, Utah	197	199	200	202	214	245	291	391	538	630	685	725	775	842	995	1,500	2,420	2,490	2,500	481
2970	Uinta River near Neola, Utah	16	16	16	17	20	23	24	26	27	27	28	28	28	28	28	29	29	29	29	25
2995	Whiterocks River near Whiterocks, Utah	15	15	16	16	18	21	23	26	30	33	35	37	38	38	38	39	39	39	39	27
3005	Uinta River at Fort Duchesne, Utah	99	100	101	104	116	137	193	251	298	335	365	428	575	705	890	1,060	1,300	--------	--------	221
3020	Duchesne River near Randlett, Utah	149	155	162	188	247	319	415	550	695	790	868	920	972	1,040	1,160	1,410	1,600	1,650	1,700	608
3030	White River at Buford, Colo	132	132	132	133	135	137	140	147	161	178	185	190	191	193	197	199	200	200	200	164
3035	South Fork White River near Buford, Colo	114	114	114	115	115	117	122	133	161	173	178	179	180	180	180	180	180	180	180	144
3045	White River near Meeker, Colo	210	210	210	210	210	210	210	211	222	249	265	282	295	300	310	320	330	340	350	244
3065	White River near Watson, Utah	278	279	279	280	286	298	309	332	425	525	553	580	598	609	622	645	680	712	722	439

Green River basin below the White River

3070	Green River near Ouray, Utah	261	262	263	266	270	277	286	301	353	475	568	615	642	660	678	682	695	700	700	392
3080	Willow Creek near Ouray, Utah	465	466	468	475	595	658	715	775	845	930	1,000	1,100	1,210	1,380	1,640	2,620	5,150	6,000	--------	869
3090	Minnie Maud Creek at Nutter Ranch, near Myton, Utah	385	385	385	389	402	425	445	470	510	541	578	631	660	728	850	978	1,000	--------	--------	493
3105	Price River above Scofield Reservior, near Scofield, Utah	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	180
3125	White River near Soldier Summit, Utah	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	320
3130	Price River near Heiner, Utah	185	186	187	189	192	200	208	213	220	230	256	310	355	383	400	415	425	450	500	226
3140	Price River near Wellington, Utah	464	464	464	464	465	543	841	1,450	1,820	2,200	2,320	2,500	2,680	2,850	3,060	3,250	3,400	3,450	3,500	1,190
3145	Price River at Woodside, Utah	598	630	662	742	870	1,070	1,500	2,420	3,000	3,530	3,830	4,100	4,320	4,580	4,950	5,380	5,400	5,400	5,400	2,110
3150	Green River at Green River, Utah	222	222	222	225	230	240	270	326	430	570	655	700	735	755	775	800	820	850	860	427
3180	Huntington Creek near Huntington, Utah	145	145	145	145	147	151	157	171	194	217	230	232	232	232	232	232	232	232	232	185
3245	Cottonwood Creek near Orangeville, Utah	212	213	213	215	218	219	220	222	237	260	280	284	286	288	289	290	290	290	290	233
3265	Ferron Creek (upper station) near Ferron, Utah	218	218	219	219	220	222	227	236	263	300	325	340	341	344	345	345	345	345	345	247
3280	San Rafael River near Castle Dale, Utah	386	400	414	460	550	700	960	1,460	2,170	2,620	2,820	3,000	3,130	3,280	3,450	3,680	3,700	--------	--------	1,310
3285	San Rafael River near Green River, Utah	535	537	540	556	610	730	1,000	1,450	2,100	2,580	2,770	3,000	3,250	3,540	3,800	4,000	--------	--------	--------	1,370

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[1] For water years 1952–57.
[2] For water years 1940–57.
[3] For water years 1942–57.
[4] For water years 1938–40, 1942–57.
[5] For water years 1948–57.
[6] For water years 1947–57.
[7] For water years 1905–06, 1910–27.

TABLE 11.—*Duration table of dissolved-solids discharge for selected stations in the subbasins in the Green division*

[Dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Chemical-quality station	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Green River basin above the Yampa River																					
1885	Green River at Warren Bridge, near Daniel, Wyo	950	847	778	670	576	517	457	398	321	239	199	170	147	135	122	109	91	69	56	220	172
1890	Beaver Creek near Daniel, Wyo	581	510	450	326	196	125	79	44	19	12	9.1	6.3	4.5	2.9	1.2	.2	.1	0	0	21	54
1900	Horse Creek near Daniel, Wyo	683	582	512	397	283	210	151	91	39	16	12	9.4	8.3	7.1	5.9	5.1	3.6	1.7	1.0	36	106
1915	Cottonwood Creek near Daniel, Wyo	609	528	472	391	292	227	172	120	70	36	24	18	16	13	10	7.4	4.2	.8	0	48	87
1930	New Fork River below New Fork Lake, near Cora, Wyo	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	4.0	40
1965	Pine Creek above Fremont Lake, Wyo	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	13	63
2010	New Fork River near Boulder, Wyo	1,300	584	471	371	287	226	175	128	87	76	63	53	47	44	38	33	28	24	22	75	50
2030	East Fork near Big Sandy, Wyo	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	7.4	34
2045	East Fork near New Fork, Wyo	237	223	206	174	120	83	62	51	35	21	19	18	16	15	14	12	10	9.3	8.7	27	28
2055	North Piney Creek near Mason, Wyo	251	239	228	201	161	124	96	64	38	22	16	14	11	9.7	8.6	7.4	5.8	4.9	4.3	28	176
2085	La Barge Creek near Viola, Wyo	288	280	278	270	244	207	153	100	64	53	50	47	45	42	39	35	32	21	15	63	134
2095	Green River near Fontenelle, Wyo	4,700	4,670	4,530	3,790	2,980	2,480	2,000	1,550	1,140	879	675	535	446	386	332	284	251	204	181	805	74
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[1]	292	272	255	224	182	151	120	90	56	32	26	22	20	18	16	14	13	12	9.9	40	96
2110A	Fontenelle Creek near Fontenelle, Wyo	722	617	545	433	321	257	196	128	68	39	31	27	24	19	16	12	5.2	.4	0	56	91
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	7.8	30
2135	Big Sandy Creek near Farson, Wyo	120	108	98	79	61	48	36	25	14	8.7	6.9	5.9	5.4	4.6	4.0	3.1	1.8	.8	.5	11	13
2140	Little Sandy Creek near Elkhorn Wyo	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	1.9	33
2160	Big Sandy Creek below Eden, Wyo	620	544	504	434	349	298	263	247	233	218	202	187	170	137	100	69	42	28	22	176	40
2165	Green River at Green River, Wyo	11,180	10,620	9,750	7,440	5,210	3,990	3,030	2,310	1,760	1,390	1,150	992	884	794	716	624	531	442	374	1,380	66
2185	Blaeks Fork near Millburne, Wyo.[2]	399	344	308	251	189	154	121	84	44	22	14	11	9.0	7.8	7.0	5.8	4.9	4.4	3.5	32	75
2215	Smith Fork at Mountain View, Wyo.[3]	287	280	268	231	163	116	77	49	31	21	17	15	12	11	9.8	6.5	4.2	3.1	2.5	27	51
2220	Blacks Fork near Lyman, Wyo.[4]	2,690	2,430	2,200	1,720	1,150	795	527	313	215	164	145	135	126	115	97	57	23	8.3	0	204	91
2230	Hams Fork near Elk Creek ranger station, Wyo	690	671	642	569	452	345	247	146	67	29	18	14	11	9.5	8.3	7.7	5.9	5.3	4.9	57	163
2235	Hams Fork near Frontier, Wyo	1,080	1,000	934	811	619	495	369	230	102	39	25	19	15	12	9.4	8.0	3.0	1.4	.9	82	101
2245B	Blacks Fork near Marston, Wyo.[5]	5,190	4,900	4,550	3,700	2,650	1,950	1,450	1,030	662	395	286	231	179	127	72	6.0	0	0	0	448	54
2250	Blacks Fork near Green River, Wyo.[5]	5,010	4,740	4,420	3,650	2,720	2,130	1,660	1,220	761	443	313	260	219	170	89	5.7	0	0	0	500	50
2255	Green River near Linwood, Utah	14,860	14,260	13,440	11,790	9,390	7,550	6,080	4,680	3,260	2,120	1,530	1,240	990	807	662	539	439	365	317	2,120	54
2260	Henrys Fork near Lonetree, Wyo	145	102	82	55	36	28	21	17	9.8	5.2	4.0	3.1	2.7	2.3	1.9	1.5	1.2	1.0	.9	6.9	45

2295	Henrys Fork at Linwood, Utah	1,460	1,050	857	680	532	430	349	268	211	171	143	129	116	102	80	41	4.3	1.0	0	156	107
2325	Sheep Creek at mouth, near Manila, Utah [6]	107	105	102	86	62	42	36	41	38	35	33	32	30	28	26	23	20	17	15	33	109
2340	Carter Creek at mouth, near Manila, Utah	95	81	72	56	41	32	24	15	7.8	4.6	3.8	3.2	2.9	2.5	2.2	1.8	1.7	1.5	1.4	6.9	23
2345	Green River near Greendale, Utah	12,370	12,030	11,540	10,040	8,030	6,870	5,870	4,540	3,410	2,520	1,980	1,680	1,360	1,140	948	771	624	543	477	2,320	56
	Yampa River basin																					
2375	Yampa River near Oak Creek, Colo	356	320	288	231	170	132	99	73	61	53	48	43	39	35	31	27	22	15	12	52	84
2395	Yampa River at Steamboat Springs, Colo	595	539	493	420	329	272	233	186	126	87	72	65	61	55	49	40	30	17	5.0	94	57
2410	Elk River at Clark, Colo	416	369	335	267	214	180	152	110	53	25	16	13	11	9.6	8.2	6.7	5.4	4.5	4.0	38	67
2425	Elk River near Trull, Colo	454	436	410	348	286	250	209	168	109	52	34	28	23	21	19	16	14	13	12	64	56
3469	Fortification Creek near Craig, Colo	687	517	429	298	195	143	109	76	46	21	7.2	5.2	4.1	3.0	2.2	1.1	.4	0	0	28	298
2495	Williams Fork at Hamilton, Colo.[7]	1,990	1,740	1,540	1,180	869	692	549	370	167	80	54	45	41	39	35	25	16	11	9.7	138	148
2510A	Yampa River at bridge on county road, near Maybell, Colo	4,480	4,200	3,880	3,240	2,530	2,130	1,850	1,510	1,080	523	339	270	234	213	194	167	113	41	14	599	61
2530	Little Snake River near Slater, Colo	565	553	529	438	348	298	248	183	82	24	16	12	9.5	8.0	6.8	5.7	4.8	4.0	3.4	55	70
2550	Slater Fork near Slater, Colo	306	279	254	200	138	107	83	58	27	11	10	9.3	8.8	8.1	7.5	6.1	3.9	1.6	0	23	52
2555	Savery Creek at upper station, near Savery, Wyo	195	180	166	140	109	88	70	51	31	18	13	12	10	8.8	7.4	6.0	2.8	.6	.3	22	43
2570	Little Snake River near Dixon, Wyo	1,660	1,420	1,270	1,050	838	691	549	391	189	78	55	47	41	35	22	7.8	2.3	.8	0	135	50
2580	Willow Creek near Dixon, Wyo	31	29	27	22	15	12	8.9	6.3	4.2	2.5	1.7	1.2	1.0	.8	.7	.5	.3	.1	0	2.8	42
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	3,090	2,920	2,700	2,250	1,720	1,400	1,140	871	549	312	199	135	100	81	61	24	.2	0	0	330	36
	Green River basin between the Yampa and White Rivers including the White River basin																					
2620	Brush Creek near Vernal, Utah	111	109	107	101	92	82	56	33	25	22	21	20	19	18	17	16	15	14	13	25	111
2635	Brush Creek near Jensen, Utah	277	219	186	134	91	73	53	38	34	30	27	25	16	7.8	3.5	1.8	1.4	.9	0	24	34
2635A	Green River at Jensen, Utah	20,090	18,580	17,510	14,980	12,510	11,199	10,000	8,610	6,400	4,370	3,160	2,570	2,190	1,860	1,560	1,260	969	770	663	3,930	55
2665	Ashley Creek near Vernal, Utah	143	126	114	93	69	52	39	28	22	19	15	11	8.8	7.5	6.4	5.2	4.3	3.9	3.6	16	58
2715	Ashley Creek near Jensen, Utah	1,560	1,430	1,340	1,070	700	443	250	178	160	156	153	150	145	136	115	59	22	13	8.3	164	155
2740	Duchesne River near Hanna, Utah	71	59	51	38	26	16	10	8.5	6.7	3.9	2.6	2.0	1.9	1.9	1.9	1.8	1.7	1.6	1.5	4.5	21
2755	West Fork Duchesne River near Hanna, Utah	28	27	26	22	17	12	8.9	6.1	3.8	2.5	1.7	1.4	1.3	1.2	1.1	.9	.8	.7	.7	3.0	18
2775	Duchesne River near Tabiona, Utah	641	538	475	379	268	203	164	135	123	115	107	100	94	92	85	74	58	44	34	110	114
2790	Rock Creek near Mountain Home, Utah	202	182	169	144	110	86	65	48	33	24	19	15	12	11	9.7	8.6	7.4	6.6	6.2	25	61
2795	Duchesne River at Duchesne, Utah	1,360	1,230	1,120	905	651	508	390	268	188	172	163	155	149	142	133	116	85	55	34	190	105
2850	Strawberry River near Soldier Springs, Utah	405	333	255	127	93	75	60	46	35	28	24	20	17	15	13	12	8.9	8.6	8.3	27	47
2880	Currant Creek near Fruitland, Utah	572	408	316	197	131	99	77	58	42	31	26	23	20	18	15	13	10	8.2	6.3	33	85
2885	Strawberry River at Duchesne, Utah	2,380	1,920	1,600	1,080	676	474	358	268	203	159	138	124	113	102	90	73	48	14	2.6	168	59

See footnotes at end of table.

TABLE 11.—*Duration table of dissolved-solids discharge for selected stations in the subbasins in the Green division*—Continued

[Dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Chemical-quality station	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	Green River basin between the Yampa and White Rivers including the White River basin—Continued																					
2925	Yellowstone Creek Altonah, Utah	203	174	151	109	72	56	44	32	22	15	12	10	8.7	7.8	7.0	6.4	5.7	5.3	5.1	16	45
2940	Lake Fork near Upalco, Utah	2,800	1,470	1,140	670	246	113	68	55	52	47	42	35	19	8.5	2.7	.5	0	0	0	42	37
2950	Duchesne River at Myton, Utah	6,700	4,440	3,730	2,630	1,860	1,420	1,110	838	598	504	460	423	392	352	280	143	37	7.7	4.2	507	67
2950B	Duchesne River at Ouray School canal, near Randlett, Utah	6,810	4,460	3,730	2,620	1,790	1,390	1,120	950	784	697	657	626	590	546	465	259	72	13	6.8	660	86
2970	Uinta River near Neola, Utah	117	100	87	67	52	45	35	27	19	13	9.8	7.7	6.4	5.5	4.9	4.4	3.8	3.4	3.1	13	26
2995	Whiterocks River near Whiterocks, Utah	100	80	72	51	35	29	24	18	13	9.4	7.0	5.5	4.5	3.9	3.4	3.0	2.4	1.8	1.3	9.0	29
3005	Uinta River at Fort Duchesne, Utah	1,020	864	736	483	288	185	104	83	68	60	54	45	31	23	15	8.0	4.2	0	0	55	30
3020	Duchesne River near Randlett, Utah	5,710	5,270	4,810	3,930	3,000	2,540	2,240	1,900	1,590	1,400	1,290	1,200	1,120	1,020	877	503	125	49	28	1,260	117
3030	White River at Buford, Colo	955	809	713	585	470	403	344	262	185	137	118	108	100	93	85	80	73	63	53	147	211
3035	South Fork White River near Buford, Colo	1,110	1,010	886	702	525	408	303	214	130	98	81	67	59	52	46	42	38	35	32	110	258
3045	White River near Meeker, Colo	3,230	2,720	2,470	2,040	1,640	1,360	1,080	746	435	329	301	288	279	267	255	240	222	188	139	420	201
3065	White River near Watson, Colo	6,150	4,820	4,070	3,140	2,460	2,080	1,750	1,430	1,150	936	821	736	675	625	586	522	422	288	187	905	82
	Green River basin below the White River																					
3070	Green River near Ouray, Utah	44,400	39,260	35,290	28,580	22,020	18,620	15,440	12,520	9,150	6,990	5,750	4,730	4,130	3,670	3,200	2,610	1,860	1,100	699	6,590	68
3080	Willow Creek near Ouray, Utah	1,000	881	777	494	227	171	145	126	107	93	81	71	62	52	40	22	5.6	1.6	0	80	30
3090	Minnie Maud Creek Nutter Ranch, near Myton, Utah	686	611	546	383	141	83	56	41	30	23	20	17	16	14	11	6.9	.3	0	0	27	43
3105	Price River above Scofield Reservoir near Scofield, Utah	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	25	147
3125	White River near Soldier Summit, Utah	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	19	131
3130	Price River near Heiner, Utah	1,410	1,120	959	684	389	248	174	141	124	98	68	39	24	18	12	5.7	3.6	2.9	2.7	75	60
3140	Price River near Wellington, Utah	2,870	2,610	2,380	1,740	979	601	441	317	270	249	219	203	181	162	132	84	77	71	67	242	104
3145	Price River at Woodside, Utah	6,960	5,000	4,150	3,170	2,470	1,920	1,410	974	826	705	641	576	513	445	334	160	99	76	64	662	161
3150	Green River at Green River, Utah	38,020	33,820	30,840	25,350	19,930	16,750	14,730	13,030	10,760	8,640	6,860	5,610	4,840	4,260	3,750	3,080	2,230	1,460	1,070	7,260	65
3180	Huntington Creek near Huntington, Utah	485	450	415	339	244	179	134	94	71	52	33	26	23	21	19	16	14	12	11	50	97
3245	Cottonwood Creek near Orangeville, Utah	1,040	937	817	604	433	313	215	134	70	39	28	23	20	18	16	13	9.4	7.4	6.9	61	111
3265	Ferron Creek (upper station) near Ferron, Utah	653	533	467	364	272	215	159	103	53	31	20	14	12	10	9.1	8.1	6.9	5.8	4.9	42	98
3280	San Rafael River near Castle Dale, Utah	4,000	3,190	2,820	2,410	2,000	1,570	1,210	828	574	453	404	356	321	283	233	119	20	0	0	469	185
3285	San Rafael River near Green River, Utah	5,850	4,570	3,920	3,030	2,260	1,700	1,280	947	663	529	479	413	360	306	246	15	0	0	0	521	113

[1] For water years 1952–57.
[2] For water years 1940–57.
[3] For water years 1942–57.
[4] For water years 1938–40, 1942–57.
[5] For water years 1948–57.
[6] For water years 1947–57.
[7] For water years 1905–06, 1910–27.

TABLE 12.—*Variability of annual weighted-average concentration of dissolved solids as related to the variability of annual water discharge for daily stations in the subbasins in the Green division*

Station No.	Station name	Water years	Coefficients of variation	
			Water discharge	Weighted-average concentration
	Green River basin above the Yampa River			
2165	Green River at Green River, Wyo	1952–57	0. 24	0. 07
2245B	Blacks Fork near Marston, Wyo	[1] 1952–57	. 67	. 17
2295	Henrys Fork at Linwood, Utah	1952–57	. 69	. 38
	Yampa River basin			
2510A	Yampa River at bridge on county road, near Maybell, Colo	1951–57	0. 40	0. 07
2600	Little Snake River at bridge on State Highway 318, near Lily, Colo	1951–57	. 51	. 10
	Green River basin between the Yampa and White Rivers including the White River basin			
3020	White River near Watson, Utah	1951–57	0. 35	0. 11
	Green River basin below the White River			
3145	Price River at Woodside, Utah	1952–57	0. 98	0. 31
3150	Green River at Green River, Utah	1929–57	. 30	. 11
3285	San Rafael River near Green River, Utah	1948–57	. 86	. 30

[1] Includes equivalent data for water years 1952 and 1953 for Blacks Fork near Green River, Wyo.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as CaCO3		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN ABOVE THE YAMPA RIVER																
Green River at Green River, Wyo.																
21,800	34 *1.70*	7.4 *.61*	13 *.57*	1.2 *.03*	148 *2.43*	21 *.44*	1.6 *.05*	0.05	190	0.26	11,180	116	0	20	308	0.5
20,700	34 *1.70*	7.5 *.62*	13 *.57*	1.2 *.03*	148 *2.43*	21 *.44*	1.6 *.05*	.05	190	.26	10,620	116	0	20	308	.5
19,000	34 *1.70*	7.6 *.62*	13 *.57*	1.2 *.03*	148 *2.43*	23 *.48*	1.7 *.05*	.05	190	.26	9,750	116	0	20	308	.5
14,500	34 *1.70*	8.2 *.67*	13 *.57*	1.2 *.03*	148 *2.43*	27 *.56*	1.9 *.05*	.05	190	.26	7,440	118	0	19	308	.5
10,100	35 *1.75*	9.4 *.77*	14 *.61*	1.3 *.03*	148 *2.43*	37 *.77*	2.2 *.06*	.05	191	.26	5,210	126	4	19	309	.5
7,500	36 *1.80*	10 *.82*	15 *.65*	1.4 *.04*	149 *2.44*	41 *.85*	2.6 *.07*	.06	197	.27	3,990	131	9	20	320	.6
5,550	38 *1.90*	11 *.90*	16 *.70*	1.4 *.04*	150 *2.46*	50 *1.04*	3.0 *.08*	.06	202	.27	3,030	140	17	20	325	.6
3,900 [1]	41 *2.05*	13 *1.07*	19 *.83*	1.5 *.04*	151 *2.48*	63 *1.31*	3.6 *.10*	.07	219	.30	2,310	156	32	21	350	.7
2,550	44 *2.20*	15 *1.23*	25 *1.09*	1.6 *.04*	162 *2.66*	86 *1.79*	4.5 *.13*	.07	255	.35	1,760	172	38	24	410	.8
1,640	49 *2.45*	17 *1.40*	33 *1.44*	1.7 *.04*	167 *2.74*	117 *2.43*	5.9 *.17*	.08	313	.43	1,390	192	56	27	500	1.0
1,130	54 *2.69*	20 *1.64*	41 *1.78*	1.8 *.05*	171 *2.80*	148 *3.08*	7.2 *.20*	.09	378	.51	1,150	216	76	29	590	1.2
845 [2]	59 *2.94*	23 *1.89*	48 *2.09*	1.9 *.05*	182 *2.98*	179 *3.72*	8.0 *.23*	.10	435	.59	992	242	92	30	655	1.3
675	64 *3.19*	25 *2.06*	54 *2.35*	2.0 *.05*	192 *3.15*	203 *4.22*	8.6 *.24*	.11	485	.66	884	262	105	31	720	1.5
550	69 *3.44*	27 *2.22*	59 *2.57*	2.1 *.05*	200 *3.28*	226 *4.70*	9.0 *.25*	.12	535	.73	794	283	119	31	790	1.5
465	72 *3.59*	29 *2.38*	63 *2.74*	2.1 *.05*	209 *3.43*	243 *5.05*	9.4 *.27*	.13	570	.78	716	298	127	31	830	1.6
380 [3]	76 *3.79*	31 *2.55*	68 *2.96*	2.2 *.06*	218 *3.58*	261 *5.43*	9.6 *.27*	.13	608	.83	624	317	138	32	880	1.7
310	79 *3.94*	33 *2.71*	71 *3.09*	2.3 *.06*	227 *3.72*	278 *5.78*	9.8 *.28*	.14	635	.86	531	332	146	32	900	1.7
250	80 *3.99*	34 *2.79*	74 *3.22*	2.4 *.06*	235 *3.85*	289 *6.01*	9.8 *.28*	.14	655	.89	442	339	146	32	920	1.7
210	82 *4.09*	34 *2.79*	76 *3.31*	2.4 *.06*	241 *3.95*	293 *6.09*	9.8 *.28*	.14	660	.90	374	344	146	32	935	1.8
1,802	45 *2.25*	15 *1.23*	27 *1.17*	1.6 *.04*	162 *2.66*	93 *1.93*	4.6 *.13*	.07	284	.39	1,380	174	41	25	443	.9
Blacks Fork near Marston, Wyo.																
5,200	64 *3.19*	11 *.90*	24 *1.04*	2.9 *.07*	220 *3.61*	52 *1.08*	18 *.51*	0.12	370	0.50	5,190	204	24	20	580	0.7
4,900	64 *3.19*	11 *.90*	25 *1.09*	2.9 *.07*	220 *3.61*	53 *1.10*	19 *.54*	.12	370	.50	4,900	204	24	21	580	.8
4,550	64 *3.19*	11 *.90*	25 *1.09*	2.9 *.07*	220 *3.61*	54 *1.12*	19 *.54*	.12	370	.50	4,550	204	24	21	580	.8
3,700	64 *3.19*	12 *.99*	27 *1.17*	2.9 *.07*	220 *3.61*	60 *1.25*	20 *.56*	.12	370	.50	3,700	209	28	22	580	.8
2,650	65 *3.24*	13 *1.07*	29 *1.26*	3.0 *.08*	220 *3.61*	70 *1.46*	21 *.59*	.12	371	.50	2,650	216	35	22	580	.9
1,920	65 *3.24*	14 *1.15*	33 *1.44*	3.1 *.08*	220 *3.61*	81 *1.68*	22 *.62*	.12	376	.51	1,950	220	39	24	590	1.0
1,380	66 *3.29*	15 *1.23*	38 *1.65*	3.2 *.08*	220 *3.61*	96 *2.00*	24 *.68*	.12	388	.53	1,450	226	46	26	619	1.1
920 [1]	67 *3.34*	18 *1.48*	46 *2.00*	3.3 *.08*	220 *3.61*	118 *2.45*	27 *.76*	.13	415	.56	1,030	241	60	29	650	1.3
490	70 *3.49*	22 *1.81*	62 *2.70*	3.5 *.09*	220 *3.61*	165 *3.43*	37 *1.04*	.14	500	.68	662	265	84	33	780	1.7
225	77 *3.84*	29 *2.38*	89 *3.87*	3.8 *.10*	222 *3.64*	250 *5.20*	54 *1.52*	.17	650	.88	395	311	129	38	990	2.2
129	90 *4.49*	35 *2.88*	114 *4.96*	4.0 *.10*	224 *3.67*	345 *7.18*	61 *1.72*	.20	820	1.12	286	368	185	40	1,220	2.6
89 [2]	102 *5.09*	38 *3.12*	134 *5.83*	4.2 *.11*	224 *3.67*	420 *8.74*	68 *1.92*	.22	960	1.31	231	410	227	41	1,400	2.9
58	120 *5.99*	46 *3.78*	161 *7.00*	4.3 *.11*	225 *3.69*	530 *11.02*	74 *2.09*	.24	1,140	1.55	179	488	304	41	1,630	3.2
34	146 *7.29*	54 *4.44*	198 *8.61*	4.6 *.12*	225 *3.69*	700 *14.56*	82 *2.31*	.27	1,380	1.88	127	586	402	42	1,920	3.6
16	170 *8.48*	60 *4.93*	253 *11.01*	4.9 *.13*	225 *3.69*	880 *18.30*	94 *2.65*	.29	1,670	2.27	72	670	486	45	2,250	4.3
1.0 [3]	200 *9.98*	70 *5.75*	300 *13.05*	6.5 *.17*	230 *3.77*	1,010 *21.01*	160 *4.51*	.31	2,220	3.02	6.0	786	598	45	2,900	4.7
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345	71 *3.54*	19 *1.56*	53 *2.31*	3.3 *.08*	221 *3.62*	144 *3.00*	31 *.87*	.14	481	.65	448	255	74	31	738	1.4

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO$_3$)	Sulfate (SO$_4$)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN ABOVE THE YAMPA RIVER—Continued																
Blacks Fork near Green River, Wyo.																
5,200	58 *2.89*	16 *1.32*	27 *1.17*	4.2 *.11*	200 *3.28*	81 *1.68*	20 *.56*	0.10	357	0.49	5,010	210	46	21	570	0.8
4,900	58 *2.89*	16 *1.32*	28 *1.22*	4.2 *.11*	200 *3.28*	82 *1.71*	20 *.56*	.10	358	.49	4,740	210	46	22	570	.8
4,550	58 *2.89*	17 *1.40*	29 *1.26*	4.3 *.11*	200 *3.28*	85 *1.77*	20 *.56*	.10	360	.49	4,420	214	50	22	580	.9
3,700	58 *2.89*	17 *1.40*	32 *1.39*	4.3 *.11*	201 *3.30*	90 *1.87*	21 *.59*	.10	365	.50	3,650	214	50	24	580	1.0
2,650	59 *2.94*	18 *1.48*	38 *1.65*	4.4 *.11*	208 *3.41*	98 *2.04*	23 *.65*	.10	380	.52	2,720	221	50	27	600	1.1
1,920	60 *2.99*	19 *1.56*	45 *1.96*	4.5 *.12*	210 *3.44*	113 *2.35*	26 *.73*	.10	410	.56	2,130	228	56	30	650	1.3
1,380	62 *3.09*	20 *1.64*	52 *2.26*	4.6 *.12*	218 *3.58*	130 *2.70*	29 *.82*	.11	445	.61	1,660	236	58	32	690	1.5
920 [1]	64 *3.19*	21 *1.73*	64 *2.78*	4.7 *.12*	222 *3.64*	160 *3.33*	35 *.99*	.11	490	.67	1,220	246	64	36	760	1.8
490	70 *3.49*	24 *1.97*	85 *3.70*	4.9 *.13*	230 *3.77*	215 *4.47*	42 *1.18*	.14	575	.78	761	273	84	40	870	2.2
225	81 *4.04*	30 *2.47*	116 *5.05*	5.1 *.13*	245 *4.02*	295 *6.14*	55 *1.55*	.22	730	.99	443	326	124	43	1,080	2.8
129	98 *4.89*	38 *3.12*	145 *6.31*	5.3 *.14*	255 *4.18*	400 *8.32*	70 *1.97*	.28	900	1.22	313	400	192	44	1,300	3.2
89 [2]	106 *5.29*	47 *3.86*	177 *7.70*	5.4 *.14*	260 *4.26*	505 *10.50*	82 *2.31*	.32	1,080	1.47	260	458	244	45	1,530	3.6
58	125 *6.24*	64 *5.26*	215 *9.35*	5.6 *.14*	270 *4.43*	650 *13.52*	94 *2.65*	.34	1,400	1.90	219	575	354	45	1,900	3.9
34	149 *7.44*	86 *7.07*	278 *12.09*	5.8 *.15*	280 *4.59*	900 *18.72*	110 *3.10*	.36	1,850	2.52	170	726	496	45	2,450	4.5
16	170 *8.48*	103 *8.47*	330 *14.36*	6.0 *.15*	295 *4.84*	1,120 *23.30*	120 *3.38*	.40	2,050	2.79	89	848	606	46	2,650	4.9
1.0 [3]	175 *8.73*	103 *8.47*	350 *15.22*	6.8 *.17*	310 *5.08*	1,160 *24.13*	130 *3.67*	.43	2,100	2.86	5.7	860	606	47	2,700	5.2
0																
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345	69 *3.44*	24 *1.97*	71 *3.09*	4.7 *.12*	222 *3.64*	187 *3.89*	37 *1.04*	.14	537	.73	500	270	88	36	814	1.9
Henrys Fork at Linwood, Utah																
2,000	50 *2.50*	16 *1.32*	31 *1.35*	6.8 *.17*	200 *3.28*	90 *1.87*	7.0 *.20*	0.06	270	0.37	1,460	191	27	25	400	1.0
1,320	51 *2.54*	17 *1.40*	32 *1.39*	6.8 *.17*	203 *3.33*	95 *1.98*	7.4 *.21*	.06	295	.40	1,050	197	30	25	440	1.0
1,030	53 *2.64*	18 *1.48*	33 *1.44*	6.8 *.17*	208 *3.41*	105 *2.18*	8.2 *.23*	.06	308	.42	857	206	36	25	460	1.0
765	55 *2.74*	20 *1.64*	35 *1.52*	6.8 *.17*	210 *3.44*	118 *2.45*	9.1 *.26*	.07	329	.45	680	219	47	25	490	1.0
540	60 *2.99*	22 *1.81*	37 *1.61*	6.8 *.17*	217 *3.56*	133 *2.77*	11 *.31*	.08	365	.50	532	240	62	24	540	1.0
390	66 *3.29*	25 *2.06*	39 *1.70*	6.8 *.17*	220 *3.61*	154 *3.20*	12 *.34*	.09	408	.55	430	268	87	24	600	1.0
275	73 *3.64*	28 *2.30*	41 *1.78*	6.9 *.18*	230 *3.77*	180 *3.74*	14 *.39*	.10	470	.64	349	297	108	23	680	1.0
174 [1]	84 *4.19*	34 *2.79*	45 *1.96*	7.0 *.18*	235 *3.85*	225 *4.68*	17 *.48*	.12	570	.78	268	349	156	21	810	1.0
115	95 *4.74*	41 *3.37*	49 *2.13*	7.2 *.18*	240 *3.94*	275 *5.72*	21 *.59*	.15	680	.92	211	406	208	20	960	1.1
80	107 *5.34*	49 *4.03*	53 *2.31*	7.5 *.19*	250 *4.10*	340 *7.07*	25 *.70*	.18	790	1.07	171	468	264	19	1,100	1.1
61	119 *5.94*	55 *4.52*	57 *2.48*	8.0 *.20*	252 *4.13*	400 *8.32*	28 *.79*	.20	870	1.18	143	523	316	19	1,200	1.1
52 [2]	127 *6.34*	60 *4.93*	60 *2.61*	8.3 *.21*	255 *4.18*	430 *8.94*	31 *.87*	.21	920	1.25	129	564	354	19	1,250	1.1
44	137 *6.84*	64 *5.26*	63 *2.74*	8.9 *.23*	260 *4.26*	480 *9.98*	33 *.93*	.23	975	1.33	116	605	392	18	1,320	1.1
36	148 *7.39*	70 *5.75*	67 *2.91*	9.7 *.25*	260 *4.26*	530 *11.02*	37 *1.04*	.25	1,050	1.43	102	657	444	18	1,400	1.1
25	164 *8.18*	80 *6.58*	77 *3.35*	11 *.28*	270 *4.43*	620 *12.90*	43 *1.21*	.28	1,190	1.62	80	738	516	18	1,550	1.2
9.7 [3]	210 *10.48*	103 *8.47*	107 *4.65*	13 *.33*	290 *4.76*	840 *17.47*	56 *1.58*	.39	1,570	2.14	41	948	710	19	1,970	1.5
0.7	330 *16.47*	150 *12.33*	190 *8.26*	13 *.33*	350 *5.74*	1,400 *29.12*	78 *2.20*	.54	2,300	3.13	4.3	1,440	1,150	22	2,750	2.2
0.1	350 *17.46*	170 *13.97*	200 *8.70*	13 *.33*	360 *5.90*	1,550 *32.24*	84 *2.37*	.56	2,300	3.13	1.0	1,570	1,280	22	2,750	2.2
0																
90.9	92 *4.59*	40 *3.29*	48 *2.09*	7.5 *.19*	236 *3.87*	274 *5.70*	20 *.56*	.14	636	.86	156	394	200	21	890	1.1

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN ABOVE THE YAMPA RIVER—Continued																
Green River near Greendale, Utah																
17,900	40 *2.00*	8.6 *.71*	14 *.61*	2.1 *.05*	135 *2.21*	48 *1.00*	5.0 *.14*	0.07	256	0.35	12,370	136	25	18	400	0.5
17,400	40 *2.00*	8.6 *.71*	15 *.65*	2.1 *.05*	135 *2.21*	49 *1.02*	5.0 *.14*	.07	256	.35	12,030	136	25	19	400	.6
16,700	40 *2.00*	8.9 *.73*	15 *.65*	2.1 *.05*	136 *2.23*	49 *1.02*	5.1 *.14*	.07	256	.35	11,540	136	25	19	400	.6
14,300	41 *2.05*	9.3 *.76*	16 *.70*	2.1 *.05*	140 *2.30*	52 *1.08*	5.6 *.16*	.07	260	.35	10,040	140	26	20	410	.6
11,100	41 *2.05*	10 *.82*	18 *.78*	2.2 *.06*	143 *2.35*	56 *1.16*	6.5 *.18*	.07	268	.36	8,030	144	26	21	410	.6
9,150	41 *2.05*	11 *.90*	21 *.91*	2.2 *.06*	148 *2.43*	62 *1.29*	7.2 *.20*	.07	278	.38	6,870	148	26	23	420	.7
7,500	42 *2.10*	12 *.99*	23 *1.00*	2.2 *.06*	152 *2.49*	69 *1.44*	8.0 *.23*	.08	290	.39	5,870	154	30	24	430	.8
5,250[1]	44 *2.20*	14 *1.15*	29 *1.26*	2.3 *.06*	160 *2.62*	84 *1.75*	9.6 *.27*	.08	320	.44	4,540	168	36	27	460	1.0
3,490	46 *2.30*	17 *1.40*	36 *1.57*	2.4 *.06*	170 *2.79*	104 *2.16*	12 *.34*	.08	362	.49	3,410	185	46	29	520	1.2
2,200	50 *2.50*	20 *1.64*	46 *2.00*	2.4 *.06*	180 *2.95*	136 *2.83*	14 *.39*	.09	425	.58	2,520	207	60	32	600	1.4
1,500	55 *2.74*	24 *1.97*	56 *2.44*	2.5 *.06*	190 *3.12*	170 *3.54*	16 *.45*	.09	490	.67	1,980	236	80	34	680	1.6
1,150[2]	62 *3.09*	26 *2.14*	62 *2.70*	2.5 *.06*	198 *3.25*	200 *4.16*	17 *.48*	.10	540	.73	1,680	262	99	34	740	1.7
870	67 *3.34*	28 *2.30*	69 *3.00*	2.6 *.07*	204 *3.35*	228 *4.74*	18 *.51*	.10	580	.79	1,360	282	114	34	780	1.8
680	75 *3.74*	30 *2.47*	73 *3.18*	2.6 *.07*	211 *3.46*	258 *5.37*	19 *.54*	.10	620	.84	1,140	310	138	34	830	1.8
540	80 *3.99*	31 *2.55*	76 *3.31*	2.7 *.07*	220 *3.61*	273 *5.68*	20 *.56*	.11	650	.88	948	327	146	33	870	1.8
426[3]	84 *4.19*	32 *2.63*	79 *3.44*	2.7 *.07*	225 *3.69*	290 *6.03*	20 *.56*	.11	670	.91	771	341	156	33	900	1.9
340	88 *4.39*	33 *2.71*	80 *3.48*	288 *.07*	232 *3.80*	300 *6.24*	21 *.59*	.11	680	.92	624	355	165	33	940	1.8
296	89 *4.44*	33 *2.71*	80 *3.48*	2.8 *.07*	238 *3.90*	303 *6.30*	21 *.59*	.11	680	.92	543	358	162	33	950	1.8
260	90 *4.49*	34 *2.79*	81 *3.52*	2.8 *.07*	242 *3.97*	305 *6.34*	21 *.59*	.12	680	.92	477	364	166	32	960	1.8
2,271	49 *2.45*	17 *1.40*	37 *1.61*	2.3 *.06*	169 *2.77*	116 *2.41*	11 *.31*	.08	378	.51	2,320	192	54	29	541	1.2
YAMPA RIVER BASIN																
Yampa River at bridge on county road, near Maybell, Colo.																
17,300	14 *.70*	3.9 *.32*	3.2 *.14*	1.1 *.03*	60 *.98*	9.4 *.20*	1.3 *.04*		96	0.13	4,480	51	2	12	140	0.2
16,200	14 *.70*	3.9 *.32*	3.2 *.14*	1.1 *.03*	60 *.98*	9.5 *.20*	1.3 *.04*		96	.13	4,200	51	2	12	140	.2
14,950	14 *.70*	3.9 *.32*	3.3 *.14*	1.2 *.03*	60 *.98*	9.6 *.20*	1.4 *.04*		96	.13	3,880	51	2	12	140	.2
12,500	15 *.75*	4.1 *.34*	3.4 *.15*	1.2 *.03*	61 *1.00*	10 *.21*	1.5 *.04*		96	.13	3,240	54	4	12	140	.2
9,750	16 *.80*	4.5 *.37*	3.9 *.17*	1.3 *.03*	65 *1.07*	12 *.25*	1.8 *.05*		96	.13	2,530	58	5	13	140	.2
8,050	17 *.85*	4.9 *.40*	4.4 *.19*	1.3 *.03*	68 *1.12*	13 *.27*	2.1 *.06*		98	.13	2,130	62	6	13	140	.2
6,600	18 *.90*	5.2 *.43*	5.0 *.22*	1.4 *.04*	72 *1.18*	14 *.29*	2.4 *.07*		104	.14	1,850	66	8	14	150	.3
4,750[1]	19 *.95*	6.0 *.49*	6.1 *.27*	1.5 *.04*	79 *1.30*	17 *.35*	3.0 *.08*		118	.16	1,510	72	7	15	175	.3
2,540	22 *1.10*	7.2 *.59*	9.1 *.40*	1.7 *.04*	94 *1.54*	23 *.48*	4.7 *.13*		157	.21	1,080	84	8	19	240	.4
950	28 *1.40*	10 *.82*	17 *.74*	2.1 *.05*	122 *2.00*	36 *.75*	9.4 *.27*		204	.28	523	111	11	25	320	.7
550	32 *1.60*	12 *.99*	24 *1.04*	2.4 *.06*	142 *2.33*	47 *.98*	14 *.39*		228	.31	339	130	13	28	360	.9
410[2]	34 *1.70*	14 *1.15*	29 *1.26*	2.6 *.07*	153 *2.51*	55 *1.14*	17 *.48*		244	.33	270	142	17	30	390	1.1
332	36 *1.80*	15 *1.23*	33 *1.44*	2.7 *.07*	161 *2.64*	62 *1.29*	20 *.56*		261	.35	234	152	20	32	410	1.2
280	37 *1.85*	16 *1.32*	37 *1.61*	2.8 *.07*	168 *2.76*	70 *1.46*	22 *.62*		282	.38	213	158	20	33	450	1.3
235	38 *1.90*	17 *1.40*	41 *1.78*	2.9 *.07*	172 *2.82*	78 *1.62*	25 *.70*		305	.41	194	165	24	35	490	1.4
182[3]	40 *2.00*	18 *1.48*	48 *2.09*	3.1 *.08*	180 *2.95*	88 *1.83*	31 *.87*		340	.46	167	174	26	37	560	1.6
108	42 *2.10*	20 *1.64*	64 *2.78*	3.5 *.09*	190 *3.12*	105 *2.18*	44 *1.24*		389	.53	113	187	31	42	650	2.0
36	43 *2.15*	22 *1.81*	84 *3.65*	3.8 *.10*	190 *3.12*	120 *2.50*	71 *2.00*		420	.57	41	198	42	47	700	2.6
12	44 *2.20*	22 *1.81*	86 *3.74*	3.8 *.10*	190 *3.12*	125 *2.60*	72 *2.03*		420	.57	14	200	44	48	700	2.6
1,590	21 *1.05*	7.0 *.58*	9.9 *.43*	1.6 *.04*	89 *1.46*	23 *.48*	5.4 *.15*		140	.19	599	82	8	20	212	.5

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
YAMPA RIVER BASIN—Continued																
Little Snake River at bridge on State Highway 318, near Lily, Colo.																
8,000	25 *1.25*	5.0 *.41*	9.4 *.41*	0.8 *.02*	107 *1.75*	12 *.25*	1.4 *.04*	0.02	143	0.19	3,090	83	0	20	210	0.5
7,550	25 *1.25*	5.0 *.41*	9.5 *.41*	.8 *.02*	109 *1.79*	12 *.25*	1.4 *.04*	.02	143	.19	2,920	83	0	20	210	.5
7,000	25 *1.25*	5.1 *.42*	9.8 *.43*	.9 *.02*	110 *1.80*	13 *.27*	1.5 *.04*	.03	143	.19	2,700	84	0	20	210	.5
5,750	25 *1.25*	5.2 *.43*	11 *.48*	1.0 *.03*	110 *1.80*	14 *.29*	1.6 *.05*	.03	145	.20	2,250	84	0	22	220	.5
4,340	26 *1.30*	5.4 *.44*	12 *.52*	1.1 *.03*	115 *1.89*	15 *.31*	1.8 *.05*	.03	147	.20	1,720	87	0	23	220	.6
3,460	27 *1.35*	5.6 *.46*	13 *.57*	1.2 *.03*	120 *1.97*	17 *.35*	2.1 *.06*	.03	150	.20	1,400	90	0	24	230	.6
2,720	28 *1.40*	5.8 *.48*	14 *.61*	1.2 *.03*	124 *2.03*	19 *.40*	2.4 *.07*	.03	155	.21	1,140	94	0	24	240	.6
1,920 [1]	29 *1.45*	6.2 *.51*	17 *.74*	1.4 *.04*	133 *2.18*	23 *.48*	2.9 *.08*	.03	168	.23	871	98	0	27	260	.7
946	34 *1.70*	7.1 *.58*	22 *.96*	1.7 *.04*	148 *2.43*	33 *.69*	4.5 *.13*	.04	215	.29	549	114	0	29	330	.9
350	40 *2.00*	9.0 *.74*	36 *1.57*	2.2 *.06*	174 *2.85*	60 *1.25*	8.5 *.24*	.06	330	.45	312	137	0	36	520	1.3
190	46 *2.30*	11 *.90*	47 *2.04*	2.6 *.07*	192 *3.15*	89 *1.85*	13 *.37*	.07	388	.53	199	160	2	38	610	1.6
123 [2]	53 *2.64*	12 *.99*	60 *2.61*	2.9 *.07*	206 *3.38*	117 *2.43*	17 *.48*	.08	405	.55	135	182	12	41	630	1.9
87	57 *2.84*	14 *1.15*	72 *3.13*	3.2 *.08*	219 *3.59*	148 *3.08*	21 *.59*	.08	426	.58	100	200	20	43	650	2.2
65	60 *2.99*	15 *1.23*	83 *3.61*	3.5 *.09*	225 *3.69*	170 *3.54*	26 *.73*	.10	462	.63	81	211	26	46	710	2.5
41	70 *3.49*	16 *1.32*	100 *4.35*	4.0 *.10*	230 *3.77*	220 *4.58*	34 *.96*	.11	550	.75	61	240	52	47	840	2.8
11 [3]	76 *3.79*	18 *1.48*	143 *6.22*	4.3 *.11*	235 *3.85*	310 *6.45*	47 *1.33*	.15	810	1.10	24	264	71	54	1,200	3.8
0.1	80 *3.99*	20 *1.64*	165 *7.18*	4.6 *.12*	240 *3.94*	360 *7.49*	56 *1.58*	.17	810	1.10	0	282	84	56	1,200	4.3
0																
0																
622	31 *1.55*	6.7 *.55*	21 *.91*	1.5 *.04*	136 *2.23*	32 *.67*	4.4 *.12*	.04	196	.27	330	105	0	30	303	.9
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVER INCLUDING THE WHITE RIVER BASIN																
Green River at Jensen, Utah																
40,000	35 *1.75*	8.0 *.66*	9.8 *.43*	0.8 *.02*	127 *2.08*	33 *.69*	5.5 *.16*	0.02	186	0.25	20,090	120	16	15	300	0.4
36,800	36 *1.80*	8.3 *.68*	10 *.44*	.9 *.02*	129 *2.12*	35 *.73*	5.8 *.16*	.02	187	.25	18,580	124	18	15	300	.4
34,500	36 *1.80*	8.6 *.71*	11 *.48*	.9 *.02*	130 *2.13*	36 *.75*	6.0 *.17*	.02	188	.26	17,510	126	19	16	310	.4
28,900	38 *1.90*	9.1 *.75*	12 *.52*	1.0 *.03*	133 *2.18*	41 *.85*	6.7 *.19*	.02	192	.26	14,980	132	24	16	310	.5
22,600	40 *2.00*	10 *.82*	14 *.61*	1.2 *.03*	137 *2.25*	48 *1.00*	7.7 *.22*	.02	205	.28	12,510	141	28	18	330	.5
19,100	42 *2.10*	11 *.90*	15 *.65*	1.4 *.04*	140 *2.30*	53 *1.10*	8.4 *.24*	.02	217	.30	11,190	150	35	18	350	.5
16,100	43 *2.15*	11 *.90*	18 *.78*	1.6 *.04*	144 *2.36*	59 *1.23*	9.2 *.26*	.02	230	.31	10,000	152	34	20	370	.6
12,500 [1]	45 *2.25*	13 *1.07*	22 *.96*	2.0 *.05*	150 *2.46*	72 *1.50*	11 *.31*	.02	255	.35	8,610	166	43	22	410	.7
7,700	49 *2.45*	15 *1.23*	31 *1.35*	2.8 *.07*	160 *2.62*	100 *2.08*	14 *.39*	.02	308	.42	6,400	184	53	26	500	1.0
4,150	57 *2.84*	19 *1.56*	45 *1.96*	3.9 *.10*	174 *2.85*	145 *3.02*	19 *.54*	.03	390	.53	4,370	220	78	30	620	1.3
2,450	64 *3.19*	23 *1.89*	56 *2.44*	4.5 *.12*	187 *3.07*	186 *3.87*	24 *.68*	.03	478	.65	3,160	254	100	32	740	1.5
1,820 [2]	67 *3.34*	25 *2.06*	65 *2.83*	4.8 *.12*	195 *3.20*	207 *4.31*	28 *.79*	.03	522	.71	2,570	270	110	34	800	1.7
1,450	70 *3.49*	27 *2.22*	70 *3.04*	4.9 *.13*	200 *3.28*	225 *4.68*	31 *.87*	.03	559	.76	2,190	286	122	34	860	1.8
1,185	72 *3.59*	29 *2.38*	74 *3.22*	5.0 *.13*	208 *3.41*	240 *4.99*	34 *.96*	.03	580	.79	1,860	298	128	35	880	1.9
965	74 *3.69*	30 *2.47*	77 *3.35*	5.1 *.13*	213 *3.49*	248 *5.16*	36 *1.02*	.03	598	.81	1,560	308	134	35	910	1.9
765 [3]	76 *3.79*	33 *2.71*	80 *3.48*	5.2 *.13*	220 *3.61*	255 *5.30*	39 *1.10*	.03	609	.83	1,260	325	144	34	920	1.9
580	77 *3.84*	35 *2.88*	82 *3.57*	5.2 *.13*	230 *3.77*	260 *5.41*	43 *1.21*	.03	619	.84	969	336	148	34	930	1.9
460	78 *3.89*	37 *3.04*	84 *3.65*	5.3 *.14*	238 *3.90*	265 *5.51*	45 *1.27*	.03	620	.84	770	346	152	34	930	2.0
396	79 *3.94*	39 *3.21*	85 *3.70*	5.3 *.14*	245 *4.02*	265 *5.51*	47 *1.33*	.03	620	.84	663	358	156	34	930	2.0
4,607	50 *2.50*	16 *1.32*	32 *1.39*	2.6 *.07*	160 *2.62*	104 *2.16*	15 *.42*	.02	316	.43	3,930	191	60	26	500	1.0

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180°C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25°C)	Sodium-adsorption-ratio
										Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVER INCLUDING THE WHITE RIVER BASIN—Continued																	
Duchesne River at Duchesne, Utah																	
3,830	17 *.85*	3.5 *.29*	4.1 *.18*	1.2 *.03*	56 *.92*	0.7 *.02*	15 *.31*	2.1 *.06*	0.00	132	0.18	1,360	57	10	13	240	0.2
3,460	17 *.85*	3.6 *.30*	4.2 *.18*	1.2 *.03*	57 *.93*	.8 *.03*	15 *.31*	2.2 *.06*	.00	132	.18	1,230	58	10	13	240	.2
3,150	18 *.90*	3.7 *.30*	4.3 *.19*	1.2 *.03*	58 *.95*	.8 *.03*	16 *.33*	2.2 *.06*	.00	132	.18	1,120	60	11	13	240	.2
2,520	18 *.90*	4.0 *.33*	4.6 *.20*	1.2 *.03*	60 *.98*	.9 *.03*	17 *.35*	2.4 *.07*	.00	133	.18	905	62	11	14	240	.3
1,800	20 *1.00*	4.8 *.39*	5.3 *.23*	1.3 *.03*	68 *1.12*	1.1 *.04*	19 *.40*	2.9 *.08*	.00	134	.18	651	70	12	14	240	.3
1,373	22 *1.10*	5.6 *.46*	6.1 *.27*	1.3 *.03*	76 *1.25*	1.4 *.05*	22 *.46*	3.4 *.10*	.01	137	.19	508	78	13	15	250	.3
1,025	26 *1.30*	6.8 *.56*	7.6 *.33*	1.4 *.04*	88 *1.44*	2.0 *.07*	27 *.56*	4.0 *.11*	.01	141	.19	390	93	18	15	260	.3
632[1]	32 *1.60*	9.7 *.80*	10 *.44*	1.5 *.04*	112 *1.84*	3.6 *.12*	38 *.79*	5.3 *.15*	.02	157	.21	268	120	22	15	280	.4
317	44 *2.20*	16 *1.32*	16 *.70*	1.7 *.04*	150 *2.46*	6.9 *.23*	63 *1.31*	7.7 *.22*	.04	220	.30	188	176	42	16	380	.5
234	49 *2.45*	19 *1.56*	20 *.87*	1.8 *.05*	170 *2.79*	8.6 *.29*	76 *1.58*	8.0 *.23*	.06	273	.37	172	200	46	18	460	.6
200	52 *2.59*	21 *1.73*	22 *.96*	1.8 *.05*	180 *2.95*	9.7 *.32*	84 *1.75*	9.8 *.28*	.06	301	.41	163	216	52	18	500	.7
180[2]	55 *2.74*	22 *1.81*	24 *1.04*	1.9 *.05*	188 *3.08*	10 *.33*	90 *1.87*	10 *.28*	.07	319	.43	155	228	57	18	520	.7
166	57 *2.84*	23 *1.89*	26 *1.13*	1.9 *.05*	193 *3.17*	11 *.37*	94 *1.96*	11 *.31*	.08	332	.45	149	236	60	19	540	.7
151	58 *2.89*	24 *1.97*	27 *1.17*	1.9 *.05*	200 *3.28*	11 *.37*	99 *2.06*	11 *.31*	.08	348	.47	142	243	60	19	570	.8
137	60 *2.99*	25 *2.06*	29 *1.26*	2.0 *.05*	205 *3.36*	12 *.40*	106 *2.20*	11 *.31*	.08	360	.49	133	252	64	20	590	.8
113[3]	62 *3.09*	26 *2.14*	32 *1.39*	2.0 *.05*	216 *3.54*	13 *.43*	112 *2.33*	12 *.34*	.09	381	.52	116	262	63	21	610	.9
79	64 *3.19*	28 *2.30*	37 *1.61*	2.1 *.05*	230 *3.77*	14 *.47*	119 *2.48*	13 *.37*	.11	400	.54	85	274	62	23	650	1.0
50	64 *3.19*	28 *2.30*	40 *1.74*	2.2 *.06*	233 *3.82*	15 *.50*	120 *2.50*	13 *.37*	.12	408	.55	55	274	58	24	660	1.1
30	64 *3.19*	28 *2.30*	40 *1.74*	2.2 *.06*	233 *3.82*	15 *.50*	120 *2.50*	13 *.37*	.13	415	.56	34	274	58	24	670	1.1
323	38 *1.90*	13 *1.07*	15 *.65*	1.6 *.04*	130 *2.13*	5.6 *.19*	54 *1.12*	6.5 *.18*	.04	218	.30	190	148	32	18	372	.5
Strawberry River at Duchesne, Utah																	
3,490	27 *1.35*	16 *1.32*	34 *1.48*	1.5 *.04*	200 *3.28*	7.0 *.23*	26 *.54*	3.5 *.10*	0.06	253	0.34	2,380	134	0	35	410	1.3
2,800	27 *1.35*	16 *1.32*	34 *1.48*	1.5 *.04*	201 *3.30*	7.0 *.23*	28 *.58*	3.9 *.11*	.06	254	.35	1,920	134	0	35	420	1.3
2,300	28 *1.40*	16 *1.32*	35 *1.52*	1.6 *.04*	202 *3.31*	8.0 *.27*	30 *.62*	4.2 *.12*	.06	257	.35	1,600	136	0	36	420	1.3
1,540	28 *1.40*	17 *1.40*	36 *1.57*	1.6 *.04*	203 *3.33*	9.0 *.30*	34 *.71*	5.1 *.14*	.07	260	.35	1,080	140	0	36	430	1.3
920	29 *1.45*	18 *1.48*	40 *1.74*	1.7 *.04*	210 *3.44*	10 *.33*	39 *.81*	6.4 *.18*	.08	272	.37	676	146	0	37	440	1.4
610	32 *1.60*	19 *1.56*	43 *1.87*	1.8 *.05*	220 *3.61*	11 *.37*	46 *.96*	7.8 *.22*	.12	288	.39	474	158	0	37	470	1.5
410	35 *1.75*	20 *1.64*	48 *2.09*	1.8 *.05*	235 *3.85*	12 *.40*	52 *1.08*	9.6 *.27*	.16	323	.44	358	170	0	38	530	1.6
268[1]	37 *1.85*	23 *1.89*	54 *2.35*	1.9 *.05*	253 *4.15*	13 *.43*	61 *1.27*	12 *.34*	.22	370	.50	268	187	0	38	600	1.7
175	40 *2.00*	27 *2.22*	62 *2.70*	2.0 *.05*	280 *4.59*	16 *.53*	74 *1.54*	15 *.42*	.30	430	.58	203	211	0	39	690	1.9
123	44 *2.20*	32 *2.63*	70 *3.04*	2.1 *.05*	300 *4.92*	18 *.60*	90 *1.87*	18 *.51*	.40	478	.65	159	242	0	38	760	2.0
102	46 *2.30*	34 *2.79*	75 *3.26*	2.1 *.05*	315 *5.17*	19 *.63*	97 *2.02*	20 *.56*	.46	500	.68	138	254	0	39	800	2.0
89[2]	47 *2.35*	36 *2.96*	78 *3.39*	2.2 *.06*	325 *5.33*	20 *.67*	100 *2.08*	21 *.59*	.50	515	.70	124	266	0	39	820	2.1
79	48 *2.40*	38 *3.12*	81 *3.52*	2.2 *.06*	335 *5.49*	20 *.67*	105 *2.18*	22 *.62*	.55	528	.72	113	276	0	39	840	2.1
70	49 *2.45*	39 *3.21*	83 *3.61*	2.2 *.06*	345 *5.66*	21 *.70*	108 *2.25*	23 *.65*	.61	538	.73	102	283	0	39	860	2.1
61	50 *2.50*	40 *3.29*	86 *3.74*	2.2 *.06*	355 *5.82*	22 *.73*	111 *2.31*	23 *.65*	.67	545	.74	90	290	0	39	860	2.2
48[3]	52 *2.59*	42 *3.45*	89 *3.87*	2.3 *.06*	375 *6.15*	23 *.77*	115 *2.39*	24 *.68*	.80	560	.76	73	302	0	39	890	2.2
31	54 *2.69*	43 *3.53*	92 *4.00*	2.4 *.06*	380 *6.23*	25 *.83*	117 *2.43*	24 *.68*	1.0	578	.79	48	311	0	39	920	2.3
8.9	54 *2.69*	43 *3.53*	95 *4.13*	2.5 *.06*	390 *6.40*	26 *.87*	120 *2.50*	24 *.68*	1.9	595	.81	14	311	0	40	940	2.3
1.6	54 *2.69*	43 *3.53*	95 *4.13*	2.5 *.06*	390 *6.40*	26 *.87*	120 *2.50*	24 *.68*	2.5	610	.83	2.6	311	0	40	960	2.3
157	39 *1.95*	27 *2.22*	59 *2.57*	1.9 *.05*	270 *4.43*	15 *.50*	70 *1.46*	14 *.39*	.30	396	.54	168	208	0	38	638	1.8

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180°C): Parts per million	Dissolved solids (Residue at 180°C): Tons per acre-ft	Dissolved solids (Residue at 180°C): Tons per day	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Specific conductance (micromhos at 25°C)	Sodium-adsorption-ratio
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVER INCLUDING THE WHITE RIVER BASIN—Continued																	
Duchesne River at Myton, Utah																	
12,800	23 *1.15*	11 *.90*	17 *.74*	1.0 *.03*	119 *1.95*	7.9 *.26*	25 *.52*	4.9 *.14*	0.06	194	0.26	6,700	102	0	26	330	0.7
8,300	23 *1.15*	11 *.90*	18 *.78*	1.0 *.03*	119 *1.95*	8.0 *.27*	26 *.54*	5.0 *.14*	.06	198	.27	4,440	102	0	27	335	.8
6,900	24 *1.20*	11 *.90*	18 *.78*	1.0 *.03*	120 *1.97*	8.1 *.27*	28 *.58*	5.1 *.14*	.07	200	.27	3,730	105	0	27	340	.8
4,800	25 *1.25*	12 *.99*	20 *.87*	1.1 *.03*	124 *2.03*	8.2 *.27*	32 *.67*	5.4 *.15*	.08	203	.28	2,630	112	0	28	345	.8
3,100	27 *1.35*	13 *1.07*	22 *.96*	1.2 *.03*	129 *2.12*	8.7 *.29*	41 *.85*	6.2 *.17*	.10	222	.30	1,860	121	1	28	370	.9
2,100	31 *1.55*	14 *1.15*	26 *1.13*	1.3 *.03*	139 *2.28*	9.2 *.31*	53 *1.10*	7.5 *.21*	.12	250	.34	1,420	135	6	29	415	1.0
1,420	36 *1.80*	17 *1.40*	32 *1.39*	1.5 *.04*	154 *2.53*	9.8 *.33*	74 *1.54*	9.4 *.27*	.17	290	.39	1,110	160	17	30	475	1.1
900 [1]	44 *2.20*	22 *1.81*	41 *1.78*	1.8 *.05*	177 *2.90*	11 *.37*	108 *2.25*	13 *.37*	.28	345	.47	838	200	37	30	560	1.3
540	54 *2.69*	29 *2.38*	60 *2.61*	2.1 *.05*	205 *3.36*	12 *.40*	160 *3.33*	20 *.56*	.39	410	.56	598	254	66	34	650	1.6
410	60 *2.99*	33 *2.71*	71 *3.09*	2.3 *.06*	222 *3.64*	12 *.40*	197 *4.10*	24 *.68*	.48	455	.62	504	285	83	35	710	1.8
355	64 *3.19*	35 *2.88*	79 *3.44*	2.5 *.06*	230 *3.77*	12 *.40*	218 *4.53*	27 *.76*	.53	480	.65	460	304	95	36	750	2.0
320 [2]	67 *3.34*	37 *3.04*	84 *3.65*	2.6 *.07*	238 *3.90*	12 *.40*	235 *4.89*	29 *.82*	.57	490	.67	423	319	104	36	770	2.0
282	70 *3.49*	39 *3.21*	92 *4.00*	2.7 *.07*	245 *4.02*	13 *.43*	255 *5.30*	31 *.87*	.62	515	.70	392	335	112	37	800	2.2
240	73 *3.64*	42 *3.45*	102 *4.44*	2.8 *.07*	252 *4.13*	13 *.43*	285 *5.93*	34 *.96*	.69	543	.74	352	354	126	38	840	2.4
173	81 *4.04*	48 *3.95*	125 *5.44*	3.1 *.08*	270 *4.43*	14 *.47*	355 *7.38*	41 *1.16*	.82	600	.82	280	400	154	40	930	2.7
64 [3]	95 *4.74*	58 *4.77*	175 *7.61*	4.0 *.10*	280 *4.59*	15 *.50*	500 *10.40*	62 *1.75*	1.2	830	1.13	143	476	221	44	1,250	3.5
11	107 *5.34*	66 *5.43*	234 *10.18*	4.8 *.12*	298 *4.89*	16 *.53*	640 *13.31*	80 *2.26*	1.3	1,260	1.71	37	538	268	48	1,850	4.4
2.2	109 *5.44*	67 *5.51*	238 *10.35*	4.9 *.13*	299 *4.90*	17 *.57*	655 *13.62*	82 *2.31*	1.4	1,300	1.77	7.7	548	274	48	1,900	4.4
1.2	110 *5.49*	68 *5.59*	240 *10.44*	5.0 *.13*	300 *4.92*	17 *.57*	660 *13.73*	83 *2.34*	1.5	1,300	1.77	4.2	554	280	48	1,900	4.4
508	48 *2.40*	25 *2.06*	54 *2.35*	1.9 *.05*	186 *3.05*	11 *.37*	142 *2.95*	18 *.51*	.34	370	.50	507	223	52	34	589	1.6
Duchesne River above the mouth of the Uinta River (at Ouray School canal headgate), Utah [4,5]																	
12,800	34 *1.70*	12 *.99*	16 *.70*	1.2 *.03*	140 *2.30*		48 *1.00*	4.1 *.12*	0.12	197	0.27	6,810	134	20	20	334	0.6
8,300	35 *1.75*	12 *.99*	16 *.70*	1.2 *.03*	142 *2.33*		49 *1.02*	4.2 *.12*	.13	199	.27	4,460	137	20	20	337	.6
6,900	35 *1.75*	12 *.99*	16 *.70*	1.2 *.03*	143 *2.34*		49 *1.02*	4.2 *.12*	.13	200	.27	3,730	137	20	20	339	.6
4,800	35 *1.75*	12 *.99*	16 *.70*	1.2 *.03*	143 *2.34*		49 *1.02*	4.2 *.12*	.13	202	.27	2,620	137	20	20	340	.6
3,100	36 *1.80*	13 *1.07*	19 *.83*	1.2 *.03*	148 *2.43*		56 *1.16*	5.0 *.14*	.13	214	.29	1,790	144	22	22	359	.7
2,100	38 *1.90*	15 *1.23*	25 *1.09*	1.2 *.03*	150 *2.46*		78 *1.62*	6.2 *.17*	.13	245	.33	1,390	156	34	26	401	.9
1,420	41 *2.05*	18 *1.48*	35 *1.52*	1.3 *.03*	166 *2.72*		100 *2.08*	10 *.28*	.15	291	.40	1,120	176	40	30	470	1.1
900 [1]	47 *2.35*	24 *1.97*	52 *2.26*	1.6 *.04*	203 *3.32*		137 *2.85*	16 *.45*	.18	391	.53	950	216	50	34	605	1.5
540	55 *2.74*	32 *2.63*	71 *3.09*	1.9 *.05*	231 *3.79*		194 *4.04*	24 *.68*	.24	538	.73	784	268	79	36	800	1.9
410	60 *2.99*	36 *2.96*	86 *3.74*	2.1 *.05*	235 *3.85*		245 *5.10*	28 *.79*	.29	630	.86	697	298	105	38	920	2.2
355	62 *3.09*	39 *3.21*	98 *4.26*	2.2 *.06*	242 *3.97*		278 *5.78*	31 *.87*	.33	685	.93	657	315	116	40	996	2.4
320 [2]	64 *3.19*	40 *3.29*	104 *4.52*	2.3 *.06*	245 *4.02*		295 *6.14*	32 *.90*	.34	725	.99	626	324	123	41	1,030	2.5
282	66 *3.29*	43 *3.53*	114 *4.96*	2.4 *.06*	250 *4.10*		325 *6.76*	35 *.99*	.38	775	1.05	590	341	136	42	1,100	2.7
240	70 *3.49*	46 *3.78*	128 *5.57*	2.6 *.07*	263 *4.31*		363 *7.55*	38 *1.07*	.44	842	1.15	546	364	148	43	1,190	2.9
173	76 *3.79*	52 *4.27*	157 *6.83*	2.9 *.07*	273 *4.48*		447 *9.30*	45 *1.27*	.54	995	1.35	465	403	179	46	1,370	3.4
64 [3]	99 *4.94*	75 *6.16*	258 *11.22*	4.0 *.10*	308 *5.05*		745 *15.50*	66 *1.86*	1.09	1,500	2.04	259	555	302	50	1,980	4.8
11	134 *6.69*	113 *9.29*	444 *19.31*	6.1 *.16*	350 *5.74*		1,290 *26.83*	100 *2.82*	2.59	2,420	3.29	72	799	512	54	3,000	6.8
2.2	138 *6.89*	119 *9.78*	463 *20.14*	6.4 *.16*	397 *6.51*		1,330 *27.66*	102 *2.88*	2.72	2,490	3.39	13	834	508	54	3,090	7.0
1.2	139 *6.94*	119 *9.78*	465 *20.23*	6.4 *.16*	399 *6.54*		1,340 *27.87*	102 *2.88*	2.73	2,500	3.40	6.8	836	509	55	3,100	7.0
508	51 *2.54*	28 *2.30*	65 *2.83*	1.8 *.05*	202 *3.31*		184 *3.83*	20 *.56*	.25	418	.65	660	242	76	37	716	1.8

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVER INCLUDING THE WHITE RIVER BASIN—Continued																
Duchesne River near Randlett, Utah																
14,200	30 *1.50*	7.4 *.61*	14 *.61*	0.7 *.02*	102 *1.67*	42 *.87*	6.6 *.19*	0.11	149	0.20	5,710	106	22	22	257	0.6
12,600	31 *1.55*	7.4 *.61*	15 *.65*	.7 *.02*	104 *1.71*	45 *.94*	7.0 *.20*	.11	155	.21	5,270	108	22	23	266	.6
11,000	33 *1.65*	8.0 *.66*	15 *.65*	.7 *.02*	107 *1.75*	47 *.98*	7.3 *.21*	.12	162	.22	4,810	116	28	22	275	.6
7,740	35 *1.75*	9.4 *.77*	19 *.83*	.9 *.02*	117 *1.92*	57 *1.19*	9.0 *.25*	.13	188	.26	3,930	126	30	25	318	.7
4,500	42 *2.10*	13 *1.07*	28 *1.22*	1.4 *.04*	142 *2.33*	81 *1.68*	13 *.37*	.18	247	.34	3,000	158	42	28	408	1.0
2,950	50 *2.50*	17 *1.40*	39 *1.70*	1.9 *.05*	165 *2.71*	114 *2.37*	19 *.54*	.24	319	.43	2,540	195	60	30	518	1.2
2,000	57 *2.84*	22 *1.81*	52 *2.26*	2.1 *.05*	185 *3.03*	152 *3.16*	26 *.73*	.30	415	.56	2,240	232	81	33	660	1.5
1,280[1]	68 *3.39*	29 *2.38*	75 *3.26*	2.3 *.06*	214 *3.51*	215 *4.47*	38 *1.07*	.39	550	.75	1,900	288	113	36	850	1.9
845	78 *3.89*	37 *3.04*	100 *4.35*	2.4 *.06*	240 *3.94*	285 *5.93*	52 *1.47*	.28	695	.95	1,590	346	150	39	1,050	2.3
655	84 *4.19*	42 *3.45*	117 *5.09*	2.6 *.07*	250 *4.10*	325 *6.76*	61 *1.72*	.34	790	1.07	1,400	382	177	40	1,170	2.6
550	89 *4.44*	46 *3.78*	130 *5.66*	2.7 *.07*	265 *4.35*	370 *7.70*	70 *1.97*	.41	868	1.18	1,290	411	194	41	1,280	2.8
485[2]	93 *4.64*	49 *4.03*	143 *6.22*	3.0 *.08*	273 *4.48*	398 *8.28*	76 *2.14*	.45	920	1.25	1,200	434	210	42	1,350	3.0
427	96 *4.79*	52 *4.27*	155 *6.74*	3.0 *.08*	279 *4.58*	424 *8.82*	81 *2.28*	.49	972	1.32	1,120	453	224	43	1,420	3.2
365	99 *4.94*	55 *4.52*	165 *7.18*	3.5 *.09*	287 *4.71*	453 *9.42*	89 *2.51*	.54	1,040	1.41	1,020	473	238	43	1,500	3.3
280	106 *5.29*	61 *5.01*	188 *8.18*	4.0 *.10*	300 *4.92*	520 *10.82*	103 *2.90*	.64	1,160	1.58	877	515	269	44	1,660	3.6
132[3]	120 *5.99*	75 *6.17*	240 *10.44*	4.3 *.11*	327 *5.36*	660 *13.73*	133 *3.75*	.86	1,410	1.92	503	608	340	46	1,980	4.2
29	129 *6.44*	86 *7.07*	285 *12.40*	4.6 *.12*	345 *5.66*	770 *16.02*	157 *4.43*	1.04	1,600	2.18	125	676	392	48	2,210	4.8
11	132 *6.59*	88 *7.23*	292 *12.70*	4.7 *.12*	349 *5.72*	788 *16.39*	160 *4.51*	1.08	1,650	2.24	49	691	405	48	2,270	4.8
6.2	137 *6.84*	89 *7.32*	313 *13.62*	5.0 *.13*	357 *5.85*	824 *17.14*	169 *4.77*	1.13	1,700	2.31	28	708	416	49	2,320	5.1
767	70 *3.49*	32 *2.63*	89 *3.87*	2.3 *.06*	213 *3.49*	250 *5.20*	46 *1.30*	.33	608	.83	1,260	306	132	39	919	2.2
White River near Watson, Utah																
8,200	46 *2.30*	11 *.90*	28 *1.22*	1.1 *.03*	176 *2.89*	52 *1.08*	18 *.51*	0.03	278	0.38	6,150	160	16	27	450	1.0
6,400	46 *2.30*	11 *.90*	28 *1.22*	1.2 *.03*	176 *2.89*	52 *1.08*	18 *.51*	.04	279	.38	4,820	160	16	27	450	1.0
5,400	46 *2.30*	11 *.90*	28 *1.22*	1.3 *.03*	177 *2.90*	53 *1.10*	18 *.51*	.04	279	.38	4,070	160	15	27	450	1.0
4,150	47 *2.35*	11 *.90*	28 *1.22*	1.4 *.04*	178 *2.92*	55 *1.14*	18 *.51*	.04	280	.38	3,140	162	16	27	450	1.0
3,190	48 *2.40*	12 *.99*	30 *1.30*	1.5 *.04*	180 *2.95*	60 *1.25*	19 *.54*	.04	286	.39	2,460	170	22	27	460	1.0
2,590	50 *2.50*	12 *.99*	31 *1.35*	1.7 *.04*	181 *2.97*	66 *1.37*	20 *.56*	.05	298	.41	2,080	174	26	28	480	1.0
2,100	52 *2.59*	13 *1.07*	34 *1.48*	1.8 *.05*	187 *3.07*	74 *1.54*	23 *.65*	.05	309	.42	1,750	183	30	29	500	1.1
1,590[1]	54 *2.69*	15 *1.23*	41 *1.78*	2.0 *.05*	191 *3.13*	87 *1.81*	27 *.76*	.06	332	.45	1,430	196	40	31	530	1.3
1,000	61 *3.04*	18 *1.48*	58 *2.52*	2.3 *.06*	215 *3.53*	118 *2.45*	37 *1.04*	.06	425	.58	1,150	226	50	35	670	1.7
660	68 *3.39*	22 *1.81*	74 *3.22*	2.6 *.07*	230 *3.77*	158 *3.29*	50 *1.41*	.07	525	.71	936	260	72	38	830	2.0
550	72 *3.59*	24 *1.97*	82 *3.57*	2.7 *.07*	235 *3.85*	180 *3.74*	56 *1.58*	.08	553	.75	821	278	86	39	870	2.1
470[2]	75 *3.74*	25 *2.06*	88 *3.83*	2.9 *.07*	238 *3.90*	195 *4.06*	62 *1.75*	.08	580	.79	736	290	95	39	920	2.2
418	77 *3.84*	26 *2.14*	92 *4.00*	3.0 *.08*	240 *3.94*	205 *4.26*	67 *1.89*	.08	598	.81	675	299	102	40	950	2.3
380	78 *3.89*	27 *2.22*	96 *4.18*	3.1 *.08*	242 *3.97*	214 *4.45*	70 *1.97*	.09	609	.83	625	306	107	40	960	2.4
349	80 *3.99*	28 *2.30*	100 *4.35*	3.1 *.08*	243 *3.99*	222 *4.62*	74 *2.09*	.09	622	.85	586	314	115	41	980	2.5
300[3]	82 *4.09*	29 *2.38*	105 *4.57*	3.3 *.08*	244 *4.00*	235 *4.89*	80 *2.26*	.09	645	.88	522	324	124	41	1,000	2.5
230	85 *4.24*	31 *2.55*	113 *4.92*	3.5 *.09*	246 *4.03*	250 *5.20*	88 *2.48*	.10	680	.92	422	340	138	42	1,070	2.7
150	86 *4.29*	33 *2.71*	123 *5.35*	3.8 *.10*	250 *4.10*	265 *5.51*	97 *2.74*	.11	712	.97	288	350	145	43	1,130	2.9
96	87 *4.34*	33 *2.71*	125 *5.44*	4.2 *.11*	252 *4.13*	270 *5.62*	98 *2.76*	.13	722	.98	187	352	146	43	1,140	2.9
764	63 *3.14*	19 *1.56*	61 *2.65*	2.3 *.06*	211 *3.46*	131 *2.72*	42 *1.18*	.06	439	.60	905	235	62	36	697	1.7

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

GREEN RIVER BASIN BELOW THE WHITE RIVER

Green River near Ouray, Utah

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180° C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
63,000	45 *2.25*	12 *.99*	21 *.91*	1.8 *.05*	162 *2.66*	60 *1.25*	10 *.28*	0.07	261	0.35	44,400	162	29	22	410	0.7
55,500	45 *2.25*	12 *.99*	21 *.91*	1.8 *.05*	162 *2.66*	61 *1.27*	10 *.28*	.08	262	.36	39,260	162	29	22	410	.7
49,700	45 *2.25*	12 *.99*	21 *.91*	1.8 *.05*	162 *2.66*	62 *1.29*	11 *.31*	.08	263	.36	35,290	162	29	22	410	.7
39,800	46 *2.30*	12 *.99*	22 *.96*	1.8 *.05*	163 *2.67*	66 *1.37*	11 *.31*	.08	266	.36	28,580	164	31	22	420	.7
30,200	46 *2.30*	12 *.99*	25 *1.09*	1.9 *.05*	164 *2.69*	70 *1.46*	11 *.31*	.09	270	.37	22,020	164	30	25	420	.9
24,900	46 *2.30*	12 *.99*	28 *1.22*	1.9 *.05*	165 *2.71*	74 *1.54*	12 *.34*	.09	277	.38	18,620	164	29	27	430	1.0
20,000	47 *2.35*	13 *1.07*	31 *1.35*	1.9 *.05*	168 *2.76*	80 *1.66*	13 *.37*	.10	286	.39	15,440	171	33	28	440	1.0
15,400[1]	48 *2.40*	13 *1.07*	35 *1.52*	2.0 *.05*	170 *2.79*	88 *1.83*	14 *.39*	.11	301	.41	12,520	174	34	30	470	1.2
9,600	52 *2.59*	16 *1.32*	44 *1.91*	2.2 *.06*	178 *2.92*	112 *2.33*	19 *.54*	.12	353	.48	9,150	196	50	32	540	1.4
5,450	62 *3.09*	22 *1.81*	57 *2.48*	2.6 *.07*	193 *3.17*	171 *3.56*	29 *.82*	.14	475	.65	6,990	245	86	33	710	1.6
3,750	69 *3.44*	27 *2.22*	70 *3.04*	2.7 *.07*	210 *3.44*	213 *4.43*	36 *1.02*	.16	568	.77	5,750	283	111	35	840	1.8
2,850[2]	73 *3.64*	30 *2.47*	78 *3.39*	2.8 *.07*	222 *3.64*	236 *4.91*	40 *1.13*	.17	615	.84	4,730	306	124	35	910	1.9
2,380	75 *3.74*	32 *2.63*	83 *3.61*	2.8 *.07*	231 *3.79*	248 *5.16*	43 *1.21*	.18	642	.87	4,130	318	129	36	940	2.0
2,060	77 *3.84*	33 *2.71*	86 *3.74*	2.8 *.07*	239 *3.92*	252 *5.24*	44 *1.24*	.19	660	.90	3,670	328	132	36	970	2.1
1,750	78 *3.89*	35 *2.88*	90 *3.92*	2.9 *.07*	243 *3.99*	258 *5.37*	46 *1.30*	.19	678	.92	3,200	338	139	36	1,000	2.1
1,420[3]	79 *3.94*	36 *2.96*	93 *4.05*	2.9 *.07*	255 *4.18*	260 *5.41*	48 *1.35*	.20	682	93	2,610	345	136	37	1,000	2.2
990	80 *3.99*	37 *3.04*	94 *4.09*	2.9 *.07*	265 *4.35*	261 *5.43*	49 *1.38*	.23	695	.95	1,860	352	134	37	1,010	2.2
580	82 *4.09*	37 *3.04*	95 *4.13*	2.9 *.07*	270 *4.43*	262 *5.45*	49 *1.38*	.26	700	.95	1,100	356	135	36	1,020	2.2
370	82 *4.09*	37 *3.04*	96 *4.18*	3.0 *.08*	275 *4.51*	262 *5.45*	50 *1.41*	.30	700	.95	699	356	131	37	1,020	2.2
6,223	55 *2.74*	18 *1.48*	46 *2.00*	2.2 *.06*	185 *3.03*	129 *2.68*	22 *.62*	.12	392	.53	6,590	211	60	32	594	1.4

Willow Creek near Ouray, Utah

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (Residue at 180° C)			Hardness as CaCO$_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
800	68 *3.39*	38 *3.12*	20 *.87*		245 *4.02*	155 *3.22*	5.0 *.14*	0.08	465	0.63	1,000	326	124	12	720	0.5
700	69 *3.44*	39 *3.21*	21 *.91*		250 *4.10*	157 *3.27*	5.1 *.14*	.09	466	.63	881	332	128	12	730	.5
615	70 *3.49*	40 *3.29*	23 *1.00*		260 *4.26*	160 *3.33*	5.2 *.15*	.09	468	.64	777	339	126	13	730	.5
385	71 *3.54*	43 *3.53*	29 *1.26*		275 *4.51*	170 *3.54*	5.9 *.17*	.12	475	.65	494	354	128	15	740	.7
141	75 *3.74*	48 *3.95*	51 *2.22*		325 *5.33*	206 *4.28*	8.9 *.25*	.23	595	.81	227	384	118	22	900	1.1
96	76 *3.79*	51 *4.19*	64 *2.78*		350 *5.74*	232 *4.83*	11 *.31*	.29	658	.89	171	399	112	26	980	1.4
75	76 *3.79*	53 *4.36*	76 *3.31*		365 *5.99*	253 *5.26*	12 *.34*	.33	715	.97	145	408	108	29	1,050	1.6
60[1]	78 *3.89*	55 *4.52*	90 *3.92*		380 *6.23*	283 *5.89*	14 *.39*	.38	775	1.05	126	420	109	32	1,140	1.9
47	78 *3.89*	58 *4.77*	112 *4.87*		395 *6.48*	320 *6.66*	16 *.45*	.44	845	1.15	107	433	109	36	1,230	2.3
37	79 *3.94*	60 *4.93*	135 *5.87*		410 *6.72*	365 *7.59*	18 *.51*	.51	930	1.26	93	444	108	40	1,350	2.8
30	80 *3.99*	64 *5.26*	155 *6.74*		425 *6.97*	415 *8.63*	21 *.59*	.58	1,000	1.36	81	462	114	42	1,430	3.1
24[2]	80 *3.99*	67 *5.51*	185 *8.05*		440 *7.22*	475 *9.88*	24 *.68*	.66	1,100	1.50	71	475	114	46	1,550	3.7
19	82 *4.09*	71 *5.84*	220 *9.57*		460 *7.54*	540 *11.23*	27 *.76*	.76	1,210	1.65	62	496	120	49	1,700	4.3
14	83 *4.14*	78 *6.41*	265 *11.53*		480 *7.87*	650 *13.52*	33 *.93*	.91	1,380	1.88	52	528	134	52	1,900	5.0
9.1	84 *4.19*	92 *7.56*	340 *14.79*		520 *8.53*	830 *17.26*	41 *1.16*	1.2	1,640	2.23	40	588	161	56	2,220	6.1
3.1[3]	88 *4.39*	140 *11.51*	600 *26.10*		625 *10.25*	1,420 *29.54*	70 *1.97*	2.2	2,620	3.56	22	795	282	62	3,400	9.3
0.4	99 *4.94*	190 *15.62*	1,090 *47.42*		880 *14.43*	2,400 *49.92*	124 *3.50*	3.1	5,150	7.00	5.6	1,030	306	70	6,200	15
0.1	105 *5.24*	190 *15.62*	1,200 *52.20*		1,120 *18.37*	2,450 *50.96*	130 *3.67*	3.5	6,000	8.16	1.6	1,040	124	71	7,100	16
0																
34.1	78 *3.89*	58 *4.77*	122 *5.31*		386 *6.33*	349 *7.26*	17 *.48*	.46	869	1.18	80	433	116	38	1,250	2.6

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
GREEN RIVER BASIN BELOW THE WHITE RIVER—Continued																
Price River at Woodside, Utah																
4,310	92 *4.59*	34 *2.79*	62 *2.70*	1.9 *.05*	267 *4.38*	250 *5.20*	14 *.39*	0.11	598	0.81	6,960	369	150	27	870	1.4
2,940	94 *4.69*	38 *3.12*	74 *3.22*	2.6 *.07*	267 *4.38*	295 *6.14*	16 *.45*	.12	630	.86	5,000	390	172	29	910	1.6
2,320	95 *4.74*	40 *3.29*	83 *3.61*	3.1 *.08*	268 *4.40*	330 *6.86*	17 *.48*	.12	662	.90	4,150	402	182	31	960	1.8
1,580	98 *4.89*	47 *3.86*	100 *4.35*	3.9 *.10*	268 *4.40*	400 *8.32*	18 *.51*	.12	742	1.01	3,170	438	218	33	1,050	2.1
1,050	102 *5.09*	54 *4.44*	122 *5.31*	4.7 *.12*	268 *4.40*	490 *10.19*	21 *.59*	.13	870	1.18	2,470	476	256	35	1,220	2.4
665	107 *5.34*	64 *5.26*	155 *6.74*	5.6 *.14*	270 *4.43*	600 *12.48*	25 *.70*	.14	1,070	1.46	1,920	530	308	39	1,480	2.9
348	124 *6.19*	85 *6.99*	224 *9.74*	6.8 *.17*	272 *4.46*	860 *17.89*	33 *.93*	.17	1,500	2.04	1,410	659	436	42	1,980	3.8
149 [1]	160 *7.98*	135 *11.10*	365 *15.88*	8.0 *.20*	283 *4.64*	1,430 *29.74*	48 *1.35*	.23	2,420	3.29	974	954	722	45	3,000	5.1
102	183 *9.13*	165 *13.56*	470 *20.44*	8.5 *.22*	290 *4.76*	1,800 *37.44*	59 *1.66*	.26	3,000	4.08	826	1,130	896	47	3,650	6.1
74	205 *10.23*	190 *15.62*	558 *24.27*	8.8 *.23*	303 *4.97*	2,100 *43.68*	68 *1.92*	.29	3,530	4.80	705	1,290	1,040	48	4,200	6.8
62	217 *10.83*	205 *16.85*	603 *26.23*	9.0 *.23*	320 *5.25*	2,250 *46.80*	73 *2.06*	.31	3,830	5.21	641	1,380	1,120	48	4,500	7.1
52 [2]	230 *11.48*	220 *18.08*	660 *28.71*	9.2 *.24*	335 *5.49*	2,440 *50.75*	78 *2.20*	.33	4,100	5.58	576	1,480	1,200	49	4,800	7.5
44	240 *11.98*	234 *19.23*	710 *30.88*	9.3 *.24*	345 *5.66*	2,600 *54.08*	83 *2.34*	.35	4,320	5.88	513	1,560	1,280	50	5,000	7.8
36	255 *12.72*	250 *20.55*	760 *33.06*	9.4 *.24*	349 *5.72*	2,780 *57.82*	88 *2.48*	.37	4,580	6.23	445	1,660	1,380	50	5,300	8.1
25	280 *13.97*	278 *22.85*	850 *36.98*	9.8 *.25*	351 *5.76*	3,120 *64.90*	97 *2.74*	.42	4,950	6.73	334	1,840	1,550	50	5,700	8.6
11 [3]	325 *16.22*	320 *26.30*	960 *41.76*	10 *.26*	352 *5.77*	3,600 *74.88*	105 *2.96*	.51	5,380	7.32	160	2,130	1,840	49	6,050	9.1
6.8	340 *16.97*	330 *27.13*	970 *42.20*	10 *.26*	354 *5.81*	3,700 *76.96*	105 *2.96*	.58	5,400	7.34	99	2,200	1,910	49	6,100	9.0
5.2	345 *17.22*	330 *27.13*	980 *42.63*	11 *.28*	355 *5.82*	3,800 *79.04*	106 *2.99*	.61	5,400	7.34	76	2,220	1,930	49	6,100	9.1
4.4	350 *17.46*	335 *27.54*	980 *42.63*	11 *.28*	360 *5.90*	3,800 *79.04*	107 *3.02*	.64	5,400	7.34	64	2,250	1,960	48	6,100	9.0
116	151 *7.53*	118 *9.70*	327 *14.22*	6.6 *.17*	288 *4.72*	1,240 *25.79*	43 *1.21*	.21	2,110	2.87	662	862	626	45	2,600	4.8
Green River at Green River, Utah																
63,430	44 *2.20*	10 *.82*	19 *.83*	1.9 *.05*	160 *2.62*	52 *1.08*	8.5 *.24*	0.07	222	0.30	38,020	151	20	21	345	0.7
56,430	44 *2.20*	10 *.82*	19 *.83*	1.9 *.05*	160 *2.62*	52 *1.08*	8.6 *.24*	.07	222	.30	33,820	151	20	21	350	.7
51,450	44 *2.20*	10 *.82*	19 *.83*	2.0 *.05*	160 *2.62*	52 *1.08*	8.6 *.24*	.07	222	.30	30,840	151	20	21	350	.7
41,720	44 *2.20*	10 *.82*	20 *.87*	2.0 *.05*	160 *2.62*	54 *1.12*	8.6 *.24*	.07	225	.31	25,350	151	20	22	350	.7
32,100	45 *2.25*	10 *.82*	21 *.91*	2.2 *.06*	160 *2.62*	59 *1.23*	8.8 *.25*	.08	230	.31	19,930	154	22	23	355	.7
25,850	45 *2.25*	11 *.90*	23 *1.00*	2.3 *.06*	160 *2.62*	64 *1.33*	9.2 *.26*	.08	240	.33	16,750	158	26	24	375	.8
20,210	45 *2.25*	11 *.90*	25 *1.09*	2.4 *.06*	160 *2.62*	69 *1.44*	10 *.28*	.08	270	.37	14,730	158	26	25	410	.9
14,800 [1]	46 *2.30*	12 *.99*	29 *1.26*	2.6 *.07*	162 *2.66*	80 *1.66*	11 *.31*	.09	326	.44	13,030	164	32	27	475	1.0
9,276	50 *2.50*	14 *1.15*	37 *1.61*	2.8 *.07*	169 *2.77*	104 *2.16*	15 *.42*	.09	430	.58	10,760	182	44	30	615	1.2
5,614	57 *2.84*	20 *1.64*	56 *2.44*	3.1 *.08*	193 *3.17*	153 *3.18*	23 *.65*	.10	570	.78	8,640	224	66	35	780	1.6
3,881	65 *3.24*	26 *2.14*	75 *3.26*	3.4 *.09*	214 *3.51*	210 *4.37*	30 *.85*	.11	655	.89	6,860	269	94	37	890	2.0
2,966 [2]	71 *3.54*	31 *2.55*	86 *3.74*	3.6 *.09*	228 *3.74*	252 *5.24*	36 *1.02*	.11	700	.95	5,610	304	118	38	945	2.1
2,439	74 *3.69*	34 *2.79*	95 *4.13*	3.8 *.10*	230 *3.77*	280 *5.82*	39 *1.10*	.11	735	1.00	4,840	324	136	39	1,000	2.3
2,091	76 *3.79*	36 *2.96*	100 *4.35*	3.9 *.10*	232 *3.80*	300 *6.24*	43 *1.21*	.12	755	1.03	4,260	338	148	39	1,030	2.4
1,793	78 *3.89*	39 *3.21*	106 *4.61*	4.0 *.10*	234 *3.84*	322 *6.70*	46 *1.30*	.12	775	1.05	3,750	355	163	39	1,060	2.4
1,424 [3]	81 *4.04*	41 *3.37*	112 *4.87*	4.2 *.11*	236 *3.87*	345 *7.18*	50 *1.41*	.12	800	1.09	3,080	370	177	39	1,100	2.5
1,006	83 *4.14*	42 *3.45*	119 *5.18*	4.5 *.12*	238 *3.90*	360 *7.49*	54 *1.52*	.13	820	1.12	2,230	380	184	40	1,130	2.7
637	85 *4.24*	43 *3.53*	122 *5.31*	5.0 *.13*	240 *3.94*	370 *7.70*	57 *1.61*	.14	850	1.16	1,460	388	192	40	1,170	2.7
462	87 *4.34*	44 *3.62*	122 *5.31*	5.4 *.14*	240 *3.94*	370 *7.70*	58 *1.64*	.14	860	1.17	1,070	398	201	40	1,170	2.7
6,292	54 *2.69*	18 *1.48*	45 *1.96*	2.8 *.07*	181 *2.97*	130 *2.70*	19 *.54*	.09	427	.58	7,260	208	60	32	608	1.4

See footnotes at end of table.

TABLE 13.—*Relation between water discharge and chemical quality of water at selected stations in the Green division*—Continued

[Data are for the water years 1914–57 adjusted to 1957 conditions. Chemical quality data and weighted averages are in parts per million and equivalents per million (italicized), except as indicated]

GREEN RIVER BASIN BELOW THE WHITE RIVER—Continued

San Rafael River near Green River, Utah

Mean discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
4,050	66 *3.29*	32 *2.63*	47 *2.04*	2.3 *.06*	227 *3.72*	202 *4.20*	7.4 *.21*	0.07	535	0.73	5,850	296	110	25	800	1.2
3,150	68 *3.39*	33 *2.71*	51 *2.22*	2.5 *.06*	227 *3.72*	210 *4.37*	8.1 *.23*	.08	537	.73	4,570	305	119	26	800	1.3
2,690	70 *3.49*	35 *2.88*	55 *2.39*	2.7 *.07*	228 *3.74*	235 *4.89*	8.6 *.24*	.08	540	.73	3,920	318	132	27	810	1.3
2,020	74 *3.69*	37 *3.04*	62 *2.70*	2.9 *.07*	230 *3.77*	265 *5.51*	9.5 *.27*	.09	556	.76	3,030	336	148	28	830	1.5
1,370	81 *4.04*	41 *3.37*	74 *3.22*	3.3 *.08*	230 *3.77*	320 *6.66*	11 *.31*	.10	610	.83	2,260	370	182	30	900	1.7
865	93 *4.64*	46 *3.78*	95 *4.13*	3.8 *.10*	232 *3.80*	400 *8.32*	14 *.39*	.11	730	.99	1,700	421	231	33	1,040	2.0
475	113 *5.64*	56 *4.60*	128 *5.57*	4.7 *.12*	238 *3.90*	550 *11.44*	18 *.51*	.13	1,000	1.36	1,280	512	317	35	1,380	2.5
242 [1]	146 *7.29*	74 *6.08*	186 *8.09*	5.8 *.15*	242 *3.97*	825 *17.16*	25 *.70*	.16	1,450	1.97	947	668	470	37	1,900	3.1
117	197 *9.83*	106 *8.71*	282 *12.27*	7.4 *.19*	280 *4.59*	1,230 *25.58*	35 *.99*	.21	2,100	2.86	663	927	698	40	2,600	4.0
76	238 *11.88*	130 *10.69*	360 *15.66*	8.3 *.21*	308 *5.05*	1,550 *32.24*	44 *1.24*	.25	2,580	3.51	529	1,130	876	41	3,130	4.7
64	255 *12.72*	140 *11.51*	390 *16.96*	8.8 *.23*	310 *5.08*	1,690 *35.15*	48 *1.35*	.26	2,770	3.77	479	1,210	958	41	3,350	4.9
51 [2]	280 *13.97*	151 *12.41*	430 *18.70*	9.3 *.24*	310 *5.08*	1,860 *38.69*	54 *1.52*	.28	3,000	4.08	413	1,320	1,060	41	3,600	5.1
41	299 *14.92*	162 *13.32*	465 *20.23*	10 *.26*	312 *5.12*	2,030 *42.22*	61 *1.72*	.29	3,250	4.42	360	1,410	1,160	42	3,800	5.4
32	318 *15.87*	173 *14.22*	500 *21.75*	11 *.28*	317 *5.20*	2,180 *45.34*	69 *1.95*	.31	3,540	4.81	306	1,500	1,240	42	4,150	5.6
24	335 *16.72*	183 *15.04*	540 *23.49*	12 *.31*	320 *5.25*	2,330 *48.46*	78 *2.20*	.32	3,800	5.17	246	1,590	1,330	42	4,400	5.9
1.4 [3]	378 *18.86*	220 *18.08*	580 *25.23*	14 *.36*	331 *5.43*	2,620 *54.50*	115 *3.24*	.37	4,000	5.44	15	1,850	1,580	40	4,600	5.9
0																
0																
0																
141	142 *7.09*	74 *6.08*	182 *7.92*	5.3 *.14*	254 *4.17*	790 *16.43*	24 *.68*	.15	1,370	1.86	521	658	450	37	1,760	3.1

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[1] 12 percentile of water discharge.

[2] 50 percentile of water discharge.

[3] 90 percentile of water discharge.

[4] Water discharge is assumed to be the same as Duchesne River at Myton, Utah.

[5] Values for bicarbonate include an average of about 10 ppm carbonate (CO_3).

TABLE 14.—*Water and dissolved solids contributed by ground water to selected streams in the subbasins in the Green division*

[Data are for the water years 1914–57 adjusted to 1957 conditions, except as indicated. Weighted-average concentration of dissolved solids of streams from table 9]

Station No.	Station name	Weighted-average concentration of dissolved solids (ppm)	Ground water		
			Discharge (acre-ft per yr)	Dissolved solids	
				Tons per year	Weighted-average concentration (ppm)
	Green River basin above the Yampa River				
1885	Green River at Warren Bridge, near Daniel, Wyo	151	105,800	48,000	187
2045	East Fork at Newfork, Wyo	60	37,700	5,770	112
2055	North Piney Creek near Mason, Wyo	174	12,700	3,940	228
2085	La Barge Creek near Viola, Wyo	237	37,100	15,800	313
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.[1]	211	21,400	7,060	243
2185	Blacks Fork near Millburne, Wyo.[2]	76	25,300	3,070	89
2230	Hams Fork near Elk Creek ranger station, Wyoming	187	13,700	4,090	220
2260	Henrys Fork near Lonetree, Wyo	59	7,600	930	90
	Yampa River basin				
2375	Yampa River near Oak Creek, Colo	221	37,900	14,200	256
2410	Elk River at Clark, Colo	40	50,100	3,700	54
2530	Little Snake River near Slater, Colo	78	23,500	3,500	110
2555	Savery Creek at upper station near Savery, Wyo	160	12,200	3,400	205
	Green River basin between the Yampa and White Rivers including the White River basin				
2665	Ashley Creek near Vernal, Utah	56	23,300	2,600	82
2755	West Fork Duchesne River near Hanna, Utah	23	11,000	430	29
2790	Rock Creek near Mountain Home, Utah	49	49,200	4,800	72
2925	Yellowstone Creek near Altonah, Utah	39	48,100	3,080	47
2995	Whiterocks River near Whiterocks, Utah	27	26,900	1,390	38
3045	White River near Meeker, Colo	244	265,400	102,400	284
	Green River basin below the White River				
3180	Huntington Creek near Huntington, Utah	185	23,500	7,500	235
3245	Cottonwood Creek near Orangeville, Utah	233	18,300	7,100	285
3265	Ferron Creek (upper station) near Ferron, Utah	247	8,000	3,700	340

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[1] Water years 1952–57. [2] Water years 1940–57.

TABLE 15.—*Water and dissolved-solids budgets in the subbasins in the Green division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
GREEN RIVER BASIN ABOVE THE YAMPA RIVER			
New Fork River basin, Wyoming			
Inflow:			
New Fork River below New Fork Lake, near Cora, Wyo	37, 200	29	1, 500
Willow Creek near Cora, Wyo	6, 400	25–30	200–300
Lake Creek near Cora, Wyo	21, 500	25–30	700–900
Duck Creek above irrigation	2, 500	100–150	300–500
Pine Creek above Fremont Lake, Wyo	127, 000	25	4, 300
Pole Creek below Little Half Moon Lake, near Pinedale, Wyo	79, 000	25–30	2, 700–3, 200
Fall Creek near Pinedale, Wyo	29, 000	25–30	1, 000–1, 200
Unmeasured surface water (55 sq mi)	8, 400	25–30	300
Unmeasured surface water (65 sq mi)	4, 900	100–150	700–1, 000
Unmeasured natural ground water	4, 800	140–220	900–1, 400
Total	320, 700	----------	12, 600–14, 600
Outflow:			
Consumed in bottom lands	30, 200	----------	----------
New Fork River near Boulder, Wyo	290, 500	69	27, 400
Total	320, 700	----------	27, 400
Increase from other sources	----------	----------	14, 800–12, 800
Fontenelle Creek basin, Wyoming			
Inflow:			
Fontenelle Creek near Hershler Ranch, near Fontenelle, Wyo	50, 800	211	14, 600
Unmeasured inflow	1, 900	211	500
Total	52, 700	----------	15, 100
Outflow:			
Consumed by irrigation	3, 200	----------	----------
Fontenelle Creek at Fontenelle, Wyo	49, 500	304	20, 400
Total	52, 700	----------	20, 400
Increase from other sources	----------	----------	5, 300
Big Sandy Creek basin, Wyoming			
Inflow:			
Big Sandy Creek near Farson, Wyo	62, 700	47	4, 000
Little Sandy Creek above Eden, Wyo	12, 200	188	3, 100
Pacific Creek near Farson, Wyo	3, 000	900	3, 700
Unmeasured inflow	3, 700	900	4, 500
Total	81, 600	----------	15, 300
Outflow:			
Depletion in reach	46, 200	----------	----------
Big Sandy Creek below Eden, Wyo	35, 400	1, 340	64, 300
Total	81, 600	----------	64, 300
Increase from other sources	----------	----------	49, 000

TABLE 15.—*Water and dissolved-solids budgets in the subbasins in the Green division*—Con.

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
GREEN RIVER BASIN ABOVE THE YAMPA RIVER—Continued			
Blacks Fork basin above Muddy Creek, Wyoming			
Inflow:			
Blacks Fork near Millburne, Wyo	113, 000	76	11, 700
East Fork Smith Fork near Robertson, Wyo	32, 600	76	3, 400
West Fork Smith Fork near Robertson, Wyo	14, 800	76	1, 500
Unmeasured runoff from mountainous terrain	6, 000	76	600
Unmeasured runoff from foothill area	1, 500	500	1, 000
Runoff from valley and lowland area	5, 200	500	3, 500
Total	173, 100	----------	21, 700
Outflow:			
Depletion in area	77, 500	----------	----------
Blacks Fork near Lyman, Wyo	95, 600	572	74, 500
Total	173, 100	----------	74, 500
Increase from other sources	----------	----------	52, 800
Hams Fork basin, Wyoming			
Inflow:			
Hams Fork near Elk Creek Ranger Station, Wyoming	81, 900	187	20, 800
Unmeasured inflow	31, 600	187	8, 000
Total	113, 500	----------	28, 800
Outflow:			
Consumed by irrigation	4, 800	----------	----------
Hams Fork near Frontier, Wyo	108, 700	202	30, 000
Total	113, 500	----------	30, 000
Increase from other sources	----------	----------	1, 200
YAMPA RIVER BASIN			
Yampa River basin between Morrison Creek and Steamboat Springs, Colorado			
Inflow:			
Yampa River near Oak Creek, Colo	63, 200	221	19, 000
Oak Creek near Oak Creek, Colo	6, 100	50–65	400–500
Walton Creek near Steamboat Springs, Colo	70, 500	25–30	2, 400–2, 900
Fish Creek near Steamboat Springs, Colo	63, 300	25–30	2, 200–2, 600
Unmeasured natural ground water	6, 400	169	1, 500
Unmeasured natural ground water	6, 400	58	500
Unmeasured surface water	135, 600	25–30	4, 600–5, 500
Total	351, 500	----------	30, 600–32, 500
Outflow:			
Consumed by irrigation	9, 600	----------	----------
Yampa River at Steamboat Springs, Colo	341, 900	74	34, 300
Total	351, 500	----------	34, 300
Increase from other sources	----------	----------	1, 800

TABLE 15.—*Water and dissolved-solids budgets in the subbasins in the Green division*—Con.

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
YAMPA RIVER BASIN—Continued			
Elk River basin, Colorado			
Inflow:			
Elk River at Clark, Colo	257, 900	40	13, 900
Big Creek near Steamboat Springs, Colo	40, 000	25–30	1, 400–1, 600
Mad Creek near Steamboat Springs, Colo	78, 000	25–30	2, 700–3, 200
Forest Camp Hot Springs	400	458	300
Unmeasured natural ground water	3, 200	242	1, 100
Unmeasured surface water	21, 000	40–70	1, 100–2, 000
Total	400, 500	----------	20, 500–22, 100
Outflow:			
Consumed by irrigation	6, 400	----------	----------
Elk River near Trull	394, 100	47	25, 200
Total	400, 500	----------	25, 200
Increase from other sources	----------	----------	4, 700–3, 100
Little Snake River basin above Dixon, Colorado			
Inflow:			
Little Snake River near Slater, Colo	188, 400	78	20, 100
Battle Creek near Slater, Colo	64, 000	25–30	2, 200–2, 600
Slater Fork near Slater, Colo	60, 800	101	8, 400
Savery Creek at upper station near Savery, Wyo	36, 800	160	8, 000
Savery Creek east-side tributaries below upper station	40, 000	25–30	1, 400–1, 600
Unmeasured inflow	26, 300	160	5, 700
Total	416, 300	----------	45, 800–46, 400
Outflow:			
Consumed by irrigation	5, 000	----------	----------
Bypassed in canal	15, 000	91	1, 900
Little Snake River near Dixon, Colo	396, 300	91	49, 300
Total	416, 300	----------	51, 200
Increase from other sources	----------	----------	5, 400–4, 800
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVERS INCLUDING THE WHITE RIVER BASIN			
Ashley Creek basin, Utah			
Inflow:			
Ashley Creek near Vernal, Utah	76, 800	56	5, 800
Dry Fork at mouth near Dry Fork, Utah	19, 000	132	3, 400
Water production from oil wells	2, 400	1, 200	4, 000
Total	98, 200	----------	13, 200
Outflow:			
Consumed in area	42, 500	----------	----------
Diverted out of intervening area	3, 500	71	300
Ground-water outflow	600	3, 000	2, 400
Ashley Creek near Jensen, Utah	51, 600	583	59, 900
Total	98, 200	----------	62, 200
Increase from other sources	----------	----------	49, 400

TABLE 15.—*Water and dissolved-solids budgets in the subbasins in the Green division*—Con.

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per year
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVERS INCLUDING THE WHITE RIVER BASIN—Continued			
Duchesne River basin above Duchesne, Utah			
Inflow:			
Duchesne River near Tabiona, Utah	115, 200	256	40, 200
Rock Creek near Mountain Home, Utah	136, 900	49	9, 100
Unmeasured inflow	4, 000	256	1, 400
Total	256, 100		50, 700
Outflow:			
Consumed by irrigation	12, 000		
Bypassed in canal	5, 000	180	1, 200
Estimated ground-water underflow	5, 100	400	2, 800
Duchesne River at Duchesne, Utah	234, 000	218	69, 400
Total	256, 100		73, 400
Increase from other sources			22, 700
White River basin between Buford and Meeker, Colorado			
Inflow:			
White River at Buford, Colo	239, 800	164	53, 700
Bypassed in canal	1, 500	164	300
South Fork White River near Buford, Colo	205, 000	144	40, 200
Unmeasured inflow	41, 900	150–180	8, 500–10, 300
Total	488, 200		102, 700–104, 500
Outflow:			
Consumed by irrigation	11, 000		
Bypassed in canals	15, 000	155	3, 200
White River near Meeker, Colo	462, 200	244	153, 400
Total	488, 200		156, 600
Increase from other sources			53, 900–52, 400
GREEN RIVER BASIN BELOW THE WHITE RIVER			
San Rafael basin, Utah			
Inflow:			
Huntington Creek near Huntington Utah	72, 400	185	18, 300
Cottonwood Creek near Orangeville, Utah	70, 200	233	22, 300
Ferron Creek (upper station) near Ferron, Utah	45, 600	247	15, 300
Total	188, 200		55, 900
Outflow:			
Consumed in area	91, 800		
San Rafael River near Castle Dale, Utah	96, 400	1, 310	171, 300
Total	188, 200		171, 300
Increase from other sources			115, 400

TABLE 16.—*Average annual dissolved-solids discharge and probable amounts of dissolved solids from natural sources and from the activities of man in the subbasins in the Green division*

[Data are for the water years 1914–57, adjusted to 1957 conditions]

Gaging station or subbasin	Drainage area (sq mi)	Acres irrigated	Dissolved-solids discharge				
			Total (tons)	Natural		Man caused	
				Tons	Tons per square mile	Tons	Tons per acre irrigated
Green River basin above the Yampa River							
Green River near Fontenelle, Wyo	3,970	131,600	294,000	182,200	46	111,800	0.8
Green River at Green River, Wyo	7,670	151,600	504,000	319,300	42	184,700	1.2
Green River near Linwood, Utah	14,300	227,100	774,300	513,800	36	260,500	1.1
Green River near Greendale, Utah	15,100	255,400	847,400	531,300	35	316,100	1.2
Green River basin above the Yampa River	17,000	258,400	967,100	646,600	38	320,500	1.2
Yampa River basin							
Yampa River at bridge on county road near Maybell, Colo	3,590	51,300	218,800	189,000	53	29,800	0.6
Little Snake River at bridge on State Highway 318, near Lily, Colo	988	20,400	120,500	90,100	91	30,400	1.5
Yampa River basin	8,000	73,700	405,800	343,400	43	62,400	.8
Green River basin between the Yampa and White Rivers including the White River basin							
Duchesne River near Randlett, Utah	3,920	135,700	460,200	134,700	34	325,500	2.4
White River near Watson, Utah	4,020	29,900	330,600	166,600	41	164,000	5.5
Green River basin between the Yampa and White Rivers including the White River basin	10,800	198,000	1,034,100	471,800	44	562,300	2.8
Green River basin below the White River							
Green River at Ouray, Utah	35,500	530,100	2,407,000	1,461,800	41	945,200	1.8
Green River at Green River, Utah	40,600	550,600	2,652,000	1,608,000	40	1,044,000	1.9
San Rafael River near Castle Dale, Utah	927	36,000	171,300	55,900	60	115,400	3.2
Green River basin below White River	8,900	60,000	521,100	288,400	32	232,700	3.9

TABLE 17.—*Summary of the suspended-sediment discharge at daily stations in the subbasins of the Green division*

Water year	Water discharge		Suspended sediment					
			Load [1] (tons)	Daily load (tons)			Concentration (ppm)	
	Cfs-days	Acre-ft		Mean	Maximum	Minimum	Weighted mean	Maximum daily
GREEN RIVER BASIN ABOVE THE YAMPA RIVER								
Green River at Green River, Wyo.								
May 1 to Sept. 30, 1951	753, 100	1, 493, 800	438, 500	2, 870	18, 300	31	216	1, 120
1952	793, 340	1, 574, 000	554, 500	1, 520	32, 900	22	259	3, 600
1953	547, 934	1, 087, 000	227, 900	624	[2] 23, 900	9	154	880
1954	594, 455	1, 179, 000	301, 600	826	16, 800	7	188	1, 780
1955	421, 453	836, 000	182, 200	499	12, 100	6	160	2, 640
1956	817, 065	1, 621, 000	757, 100	2, 070	48, 000	11	343	3, 870
1957	747, 490	1, 483, 000	489, 100	1, 340	21, 200	8	242	1, 750
YAMPA RIVER BASIN								
Yampa River at bridge on county road, near Maybell, Colo.								
Dec. 1, 1950, to Sept. 30, 1951	495, 896	1, 016, 000	235, 300	774	[3] 20, 100	1	176	6, 000
1952	729, 608	1, 447, 000	545, 700	1, 490	[4] 20, 800	3	277	3, 200
1953	418, 053	829, 200	247, 900	679	23, 100	4	220	1, 630
1954	263, 263	522, 200	125, 000	342	4, 970	3	176	1, 740
1955	389, 507	772, 600	401, 900	1, 100	23, 400	2	382	3, 420
1956	520, 947	1, 033, 000	397, 600	1, 090	14, 300	1	283	1, 400
1957	898, 077	1, 781, 000	607, 500	1, 660	16, 500	3	251	976
GREEN RIVER BASIN BETWEEN THE YAMPA AND WHITE RIVERS INCLUDING THE WHITE RIVER BASIN								
Green River near Jensen, Utah								
May 12 to Sept. 30, 1948	871, 268	1, 728, 000	3, 829, 000	26, 960	203, 000	--------	1, 630	3, 400
1949	1, 718, 274	3, 408, 000	8, 939, 000	25, 490	[4] 367, 000	--------	1, 930	7, 500
1950	2, 065, 399	4, 097, 000	10, 890, 000	29, 840	296, 000	144	1, 950	11, 100
1951	1, 851, 740	3, 673, 000	6, 086, 000	16, 670	[5] 138, 000	[3] 66	1, 220	7, 950
1952	2, 280, 133	4, 522, 000	14, 940, 000	40, 820	567, 000	78	2, 430	15, 800
1953	1, 256, 199	2, 492, 000	3, 818, 000	10, 460	181, 000	26	1, 130	3, 280
1954	1, 036, 598	2, 056, 000	2, 754, 000	7, 550	115, 000	19	984	--------
1955	1, 045, 677	2, 074, 000	3, 950, 000	10, 820	146, 000	82	1, 400	15, 000
1956	1, 716, 178	3, 404, 000	8, 922, 000	24, 380	424, 000	62	1, 930	15, 100
1957	2, 206, 763	4, 377, 000	7, 647, 000	20, 950	306, 000	41	1, 280	5, 350
GREEN RIVER BASIN BELOW THE WHITE RIVER								
3070. Green River near Ouray, Utah								
Dec. 1, 1950, to Sept. 30, 1951	2, 223, 040	4, 410, 000	10, 630, 000	29, 120	------------	--------	1, 770	--------
1952	3, 239, 060	6, 425, 000	26, 050, 000	71, 170	------------	--------	2, 980	--------
1953	1, 713, 550	3, 399, 000	7, 256, 000	19, 880	[5] 230, 000	--------	1, 570	--------
1954	1, 343, 350	2, 665, 000	6, 792, 000	18, 610	273, 000	197	1, 870	36, 700
1955	1, 420, 641	2, 818, 000	7, 488, 000	20, 520	163, 000	[4] 180	1, 950	--------
Nov. 1, 1956, to Sept. 30, 1957	2, 819, 560	5, 593, 000	18, 850, 000	56, 440	[5] 1, 100, 000	267	2, 480	67, 000

See footnotes at end of table.

TABLE 17.—*Summary of the suspended-sediment discharge at daily stations in the subbasins of the Green division*—Continued

Water year	Water discharge		Suspended sediment					
			Load [1] (tons)	Daily load (tons)			Concentration (ppm)	
	Cfs-days	Acre-ft		Mean	Maximum	Minimum	Weighted mean	Maximum daily
3150. Green River at Green River, Utah								
1930	2, 296, 154	4, 560, 000	34, 500, 000	94, 520	1, 490, 000	5, 570	5, 560	--------
1931	1, 205, 598	2, 390, 000	7, 450, 000	20, 410	252, 000	270	2, 290	--------
1932	2, 431, 343	4, 810, 000	36, 100, 000	98, 630	677, 000	162	5, 500	--------
1933	1, 776, 981	3, 530, 000	15, 360, 000	42, 080	471, 000	297	3, 200	--------
1934	658, 706	1, 306, 000	1, 780, 000	4, 880	136, 700	140	1, 000	--------
1935	1, 436, 756	2, 850, 000	14, 350, 000	39, 320	399, 000	216	3, 700	--------
1936	2, 090, 772	4, 147, 000	33, 800, 000	92, 350	2, 230, 000	135	5, 990	--------
1937	2, 083, 966	4, 134, 000	43, 400, 000	118, 900	1, 630, 000	562	7, 710	--------
1938	2, 393, 274	4, 747, 000	38, 200, 000	104, 700	1, 400, 000	672	5, 910	--------
1939	1, 724, 329	3, 420, 000	22, 800, 000	62, 470	862, 000	392	4, 900	--------
1940	1, 197, 930	2, 376, 000	8, 880, 000	24, 260	315, 000	<50	2, 750	49, 500
1941	2, 138, 858	4, 242, 000	31, 900, 000	87, 400	1, 384, 000	359	5, 520	39, 700
1942	2, 515, 812	4, 990, 000	30, 960, 000	84, 820	1, 050, 000	429	4, 560	24, 300
1943	2, 152, 590	4, 270, 000	15, 680, 000	42, 960	598, 000	0	2, 700	35, 700
1944	2, 256, 960	4, 476, 000	23, 230, 000	63, 470	916, 000	0	3, 810	19, 500
1945	2, 096, 850	4, 159, 000	13, 530, 000	37, 070	293, 000	286	2, 390	13, 800
1946	1, 748, 700	3, 469, 000	9, 400, 000	25, 760	213, 000	297	1, 990	24, 300
1947	2, 764, 370	5, 484, 000	28, 460, 000	77, 970	821, 000	583	3, 810	30, 300
1948	2, 091, 130	4, 148, 000	16, 730, 000	45, 710	505, 000	0	2, 960	14, 600
1949	2, 468, 740	4, 897, 000	22, 570, 000	61, 840	[3] 629, 000	270	3, 390	10, 400
1950	2, 778, 247	5, 511, 000	19, 330, 000	52, 960	295, 000	251	2, 580	10, 000
1951	2, 380, 580	4, 722, 000	14, 590, 000	39, 990	[3] 1, 200, 000	151	2, 270	38, 800
1952	3, 447, 270	6, 838, 000	32, 370, 000	88, 440	785, 000	151, 000	3, 480	15, 300
1953	1, 711, 600	3, 395, 000	7, 854, 000	21, 520	294, 000	129	1, 700	19, 800
1954	1, 320, 060	2, 618, 000	7, 381, 000	20, 220	[3 5] 748, 000	120	2, 070	62, 100
1955	1, 431, 336	2, 839, 000	11, 600, 000	31, 780	482, 000	213	3, 000	41, 800
1956	2, 045, 186	4, 056, 000	15, 820, 000	43, 220	445, 000	54	2, 860	13, 400
1957	2, 773, 028	5, 501, 000	23, 610, 000	64, 680	[3] 646, 000	94	3, 150	27, 000
3285. San Rafael River near Green River, Utah								
Mar. 1 to Sept. 30, 1948	24, 237. 9	48, 080	606, 100	2, 830	------------	--------	9, 260	--------
1949	65, 947. 3	130, 800	1, 767, 000	4, 840	------------	--------	9, 920	--------
1951	34, 420. 2	68, 280	1, 633, 000	4, 470	[4 5] 786, 000	1	17, 570	115, 000
1952	158, 681	314, 800	4, 760, 000	13, 010	[3 4] 236, 000	16	11, 110	67, 300
1953	40, 796. 4	80, 930	483, 300	1, 320	[3 4] 74, 000	<. 5	4, 390	49, 400
1954	20, 581. 6	40, 830	413, 800	1, 130	[4] 104, 000	<. 5	7, 450	62, 600
1955	16, 015. 5	31, 770	306, 700	840	[4] 50, 200	<. 5	7, 090	60, 500
1956	17, 254. 3	34, 230	359, 400	982	[4] 90, 400	0	7, 710	103, 000
1957	78, 160	155, 000	2, 124, 000	5, 820	[4] 292, 000	0	10, 060	85, 600

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[1] Includes estimated loads for missing days.

[2] Computed from concentration graph based on one size sample and a composite concentration.

[3] Computed from partly estimated concentration graph.

[4] Computed by subdividing day.

[5] Computed from estimated concentration graph.

TABLE 18.—*Estimated suspended-sediment discharge at selected stations in the subbasins in the Green division*

[Data are for the water years 1914–57 adjusted to 1957 conditions, except as indicated]

Station No.	Station name	Average water discharge (cfs)	Suspended sediment		
			Weighted-average concentration (ppm)	Load	
				Tons per year	Tons per sq mi per year
	Green River basin above the Yampa River				
1885	Green River at Warren Bridge, near Daniel, Wyo	540	36	19,000	41
2095	Green River near Fontenelle, Wyo	1,609	180	292,000	74
2165	Green River at Green River, Wyo	1,802	350	625,000	81
2250	Blacks Fork near Green River, Wyo	[1] 345	3,000	1,020,000	278
2295	Henrys Fork at Linwood, Utah	90.9	960	85,800	162
	Yampa River basin				
2510A	Yampa River at bridge on county road, near Maybell, Colo	1,590	196	308,000	90
2550	Slater Fork near Slater, Colo	84	212	17,500	109
2555	Savery Creek at upper station, near Savery, Wyo	50.8	146	7,300	39
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo	622	1,790	1,099,000	295
	Green River basin between the Yampa and White Rivers including the White River basin				
2610	Green River near Jensen, Utah	4,607	1,300	5,902,000	226
3030	White River at Buford, Colo	331	102	33,240	131
	Green River basin below the White River				
3070	Green River near Ouray, Utah [2]	6,140	2,120	12,824,000	361
3145	Price River at Woodside, Utah	116	33,900	3,879,000	2,586
3150	Green River at Green River, Utah [3]	5,614	3,760	20,800,000	512
3285	San Rafael River near Green River, Utah	141	6,700	931,400	551

[1] Water years 1948–57.

[2] December 1, 1950 to September 30, 1955, November 1, 1956, to September 30, 1957.

[3] Water years 1930–57.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
							Green River basin above the Yampa River							
1885	Green River at Warren Bridge, near Daniel, Wyo.	10-3-39	246	Medium	----	4	0.1	0.00	----	−3.54	1.45	0.29	2.7	0
		5-15-58	[2] 1,040	High	294	----	----	.00	C2-S1	−2.90	2.00	.30	1.4	0
1890	Beaver Creek near Daniel, Wyo.	8-2-58	[2] .5	----	448	----	----	.00		−4.78	4.77	.30	.9	68
1900	Horse Creek near Daniel, Wyo.	5-15-58	[2] 209	High	326	----	----	.00		−3.19	3.23	.30	.8	80
		8-3-58	[2] 10	Medium	375	----	----	.12		−3.57	3.88	.30	1.3	143
1915	Cottonwood Creek near Daniel, Wyo.	8-3-58	[2] 30	Medium	439	----	----	.00		−4.25	4.45	.30	1.5	117
1970	Pine Creek at Fremont Lake outlet, Wyo.	4-21-49	----	----	26	25	.2	.00	C1-S1	−.15	.09	.30	.6	56
1980	Pine Creek at Pinedale, Wyo.	8-31-39	48	----	----	3	.0	.00	----	−.24	.22	.30	.5	66
2010	New Fork River near Boulder, Wyo.	8-26-39	130	Medium	----	14	.3	.00	C1-S1	−1.80	1.86	.30	.8	84
		5-15-58	[2] 525	High	103	----	----	.09		−.80	.97	.30	.8	110
2030	East Fork near Big Sandy, Wyo.	5-17-58	[2] 295	High	34	----	----	.04		−.27	.34	.30	.5	87
		8-2-58	[2] 21	Medium	27	----	----	.02		−.19	.26	.30	.6	87
2045	East Fork at New Fork, Wyo.	5-15-58	[2] 458	High	63	----	----	.11		−.39	.59	.30	.8	117
2055	North Piney Creek near Mason, Wyo.	8-3-58	[2] 35	Medium	329	----	----	.00	C2-S1	−3.33	2.74	.30	1.2	0
2055A	North Piney Creek at Big Piney, Wyo.	10-10-39	[3] 20	Medium	----	29	1.5	.00	----	−4.96	5.02	.28	6.0	80
		5-15-58	[2] 94	High	1,060	40	2.6	.00	C3-S1	−5.33	5.92	.27	10	201
2085	La Barge Creek near Viola, Wyo.	10-8-47	72	Medium	463	4	.1	.00	C2-S1	−4.90	3.70	.29	2.2	0
		5-14-58	[2] 364	High	315	----	----	.00		−2.98	2.49	.30	1.0	0
2090A	Green River below La Barge, Wyo.	6-2-47	[3] 520	High	296	13	.4	.00		−2.56	2.42	.30	1.1	37
		10-8-47	[3] 1,020	Medium	319	12	.3	.00		−2.71	2.46	.30	1.4	12
2095	Green River near Fontenelle, Wyo.	5-14-58	[2] 3,970	High	317	----	----	.00		−2.68	2.48	.30	1.3	23
		8-4-58	[2] 1,080	Medium	326	----	----	.00		−2.59	2.55	.30	1.7	61
2105	Fontenelle Creek near Herschler Ranch, near Fontenelle, Wyo.	5-14-58	[2] 500	High	309	----	----	.00		−2.69	2.65	.30	1.2	61
		8-4-58	[2] 38	Medium	401	----	----	.00		−3.92	3.63	.30	1.2	2
2110A	Fontenelle Creek at Fontenelle, Wyo.	10-10-39	----	----	----	10	.4	.00	----	−4.60	3.78	.29	2.1	0
		5-14-58	[2] 259	High	446	----	----	.00	C2-S1	−4.03	3.56	.29	1.9	0
		8-4-58	[2] 6.0	Low	547	26	1.1	.00		−3.79	3.30	.29	4.0	0
2110B	Slate Creek near Fontenelle, Wyo.	10-24-57	[2] 1.2	----	1,490	43	3.3	.00	C3-S1	−6.54	3.36	.22	28	0
		5-14-58	[2] 12	----	720	41	2.1	.00	C2-S1	−3.19	2.46	.28	7.8	0
		8-5-58	[2] .5	Low	1,300	53	4.1	.00	C3-S1	−3.37	1.84	.24	19	0
2110C	Unnamed tributary of Green River, near Fontenelle, Wyo.	5-14-58	[2] .1	Low	1,100	47	3.0	.00		−3.41	.00	.25	16	0
2110D	Buckhorn Canyon Creek near Farson, Wyo.	5-14-58	----	----	4,660	76	16	.00	C4-S4	----	----	----	100	----
2125	Big Sandy Creek at Leckie Ranch, near Big Sandy, Wyo.	5-17-58	[2] 188	High	51	----	----	.02	C1-S1	−.30	.39	.30	.7	91
		8-2-58	[2] 27	Medium	47	----	----	.05		−.33	.41	.30	.5	89
2125A	Big Sandy Creek at Buckskin Crossing, near Big Sandy, Wyo.	5-(?)-39	----	----	----	33	.3	.10	----	−.16	.30	.30	.7	103
2130	Big Sandy Creek near Eden, Wyo.	5-(?)-39	----	----	----	17	.2	.00	----	−.46	.40	.30	.4	56
2135	Big Sandy Creek near Farson, Wyo.	1-7-57	5.0	Low	156	29	.6	.03	C1-S1	−.80	1.00	.30	1.2	117
		4-1-57	40	Medium	158	35	.8	.00		−.72	.85	.30	1.4	101
		7-1-57	835	High	65	29	.4	.00		−.35	.42	.30	.8	87
2135B	Continental Divide ditch near Little Prospect Mountain, Wyo.	5-17-58	[3] .5	----	37	----	----	.04		−.19	.30	.30	.7	96
2140	Little Sandy Creek near Elkhorn, Wyo.	5-17-58	[2] 38	High	38	----	----	.00		−.26	.31	.30	.6	82
		8-2-58	[2] 7.6	Medium	44	----	----	.05		−.35	.43	.30	.5	89
2145	Little Sandy Creek above Eden, Wyo.	1-7-57	.5	Low	1,250	38	2.6	.00	C3-S1	−6.28	3.41	.26	15	0
		4-29-57	23	Medium	540	45	2.0	.00	C2-S1	−1.80	1.54	.28	5.3	5
		7-1-57	147	High	140	32	.6	.00	C1-S1	−.70	.68	.30	1.2	66
2150	Pacific Creek near Farson, Wyo.	1-3-56	10	Medium	2,800	77	13	.22	C4-S3	3:21	3.87	.16	70	1,690
		3-26-56	70	High	990	59	4.3	.00	C3-S1	−1.56	3.40	.27	13	494
		11-19-56	.2	Low	4,130	83	20	3.04	C4-S4	----	----	----	100	----
2160	Big Sandy Creek below Eden, Wyo.	11-18-57	35	Medium	3,130	50	6.1	.00	C4-S2	−10.69	.49	.05	84	0
		1-27-58	6	Low	3,560	42	5.3	.00		----	----	----	100	----
		6-2-58	296	High	533	46	2.0	.00	C2-S1	−1.75	1.32	.28	5.4	0
2165	Green River at Green River, Wyo.	12-54	288	Low	927	32	1.7	.00	C3-S1	−5.58	3.75	.27	8.9	0
		3-57	928	Medium	731	34	1.7	.00	C2-S1	−4.07	2.91	.28	6.8	0
		6-57	8,007	High	326	18	.5	.00		−2.46	2.39	.30	1.8	54
2165A	Bitter Creek at Bitter Creek, Wyo.	5-17-58	[2] .6	----	1,510	84	12	2.87	C3-S3	3.27	4.44	.25	32	1,860
2165C	Bitter Creek at Thayer Junction, Wyo.	4-17-41	----	----	970	68	6.1	.00	C3-S2	−.23	3.12	.27	16	739
		5-17-58	[2] 3.3	----	1,530	72	7.5	.00		.38	2.97	.23	32	838
2165D	Salt Wells Creek near Thayer Junction, Wyo.	5-17-58	[2] 17	----	1,940	34	2.9	.00	C3-S1	−11.82	2.58	.19	36	0
2166A	Killpecker Creek near Rock Springs, Wyo.	5-17-58	----	----	1,450	80	9.7	.67	C3-S2	2.13	2.82	.24	32	1,210
		8-1-58	[3] .01	Low	22,400	67	29	.00	C4-S4	----	----	----	100	----
2166B	Bitter Creek 2 miles west of Rock Springs, Wyo.	5-18-58	[3] 15	----	1,940	43	3.8	.00	C3-S1	−8.60	2.35	.19	37	0

See footnotes at end of table.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*—Continued

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in exces of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
					Green River basin above the Yampa River—Continued									
2166C	Bitter Creek near Green River, Wyo.	6-29-57	[3] 0.3	Low	5,700	72	15	0.00	C4-S4				100	
		7-24-57	[3] 10	Medium	2,480	56	6.1	.00	C4-S2	−5.26	1.26	0.11	63	0
		8-29-58	[3] 30	High	2,030	43	3.9	.00	C3-S1	−8.88	1.83	.17	42	0
2185	Blacks Fork near Millburne, Wyo.	10-21-57	[2] 49	Medium	180	5	.1	.00	C1-S1	−1.55	1.48	.30	.6	54
		5-12-58	[2] 380	High	115			.00		−1.03	.98	.30	.5	58
2185A	Blacks Fork at Fort Bridger, Wyo.	8-20-53	8.0	Low	3,000	33	3.6	.00	C4-S2	−21.08	.24	.02	94	0
		7-23-57	[3] 35	Medium	2,650	20	1.8	.00	C4-S1	−23.34	2.06	.12	59	0
2190	Blacks Fork near Urie, Wyo.	5-13-58	[2] 167	High	489	25	.9	.00	C2-S1	−3.24	1.96	.29	4.3	0
		7-30-58	[2] 4.2	Low	3,220	32	3.6	.00	C4-S2				100	
2215	Smiths Fork at Mountain View, Wyo.	5-13-58	[2] 161	High	240			.00	C1-S1	−1.77	1.95	.30	1.7	112
		7-30-58	[2] 12	Medium	475	44	1.8	.00	C2-S1	−1.81	2.43	.29	5.7	213
2215A	Cottonwood Creek below Sage Creek, near Mountain View, Wyo.	10-23-57	[2] .3	Low	1,170	60	4.7	.00	C3-S1	−1.50	3.45	.25	20	515
		5-13-58	[2] 12		742	46	2.5	.24	C2-S1	−2.73	4.23	.28	8.9	417
2215B	Little Dry Creek near Mountain View, Wyo.	5-17-58	[2] .5		814	54	3.3	1.16	C3-S1	−1.93	4.75	.28	12	725
2215C	Smith Fork near Lyman, Wyo.	6-27-52			1,080	61	4.5	.26		−1.35	3.87	.26	16	651
		8-20-53			2,030	75	10	.00	C3-S3	1.66	3.44	.19	52	1,240
2220	Blacks Fork near Lyman, Wyo.	10-22-57	[2] 23	Medium	2,630	48	5.2	.00	C4-S2	−9.92	1.61	.12	60	0
		5-13-58	[2] 305	High	619	37	1.7	.00	C2-S1	−3.03	2.53	.28	6.1	0
		7-31-58	[2] 10	Low	3,390	52	6.8	.00	C4-S2				100	
2220A	Muddy Creek near Leroy, Wyo.	4-23-57	[3] 10		656	15	.6	.07	C2-S1	−5.78	6.18	.29	2.9	161
		10-22-57	[2] 6.8		1,330	46	3.4	.00	C3-S1	−4.05	5.20	.25	20	328
		5-12-58	[2] 146	High	278			.00	C2-S1	−2.65	2.69	.30	1.0	80
2220B	Muddy Creek at Carter, Wyo.	5-13-58	[2] 134	High	377	25	.8	.00		−2.56	2.87	.29	2.8	140
2220C	Little Muddy Creek above Albert Creek, near Brilliant, Wyo.	5-12-58	[2] 1.1		1,950	29	2.4	.00	C3-S1	−13.79	5.31	.21	31	0
		8- 5-58	[2] .1	Low	735	27	1.3	.00	C2-S1	−4.99	3.53	.28	7.1	0
2220D	Albert Creek near Brilliant, Wyo.	5-12-58	[2] 2.1		1,150	32	2.0	.00	C3-S1	−6.97	5.85	.26	12	0
2230	Hams Fork near Elk Creek ranger station, Wyoming.	8- 5-58	[2] 24	Medium	309			.00	C2-S1	−3.22	2.80	.30	.8	0
2235	Hams Fork near Frontier, Wyo.	5-14-58	[2] 965	High	322			.00		−3.17	2.93	.30	.8	14
		8- 4-58	[2] 25	Medium	430			.00		−4.24	2.37	.29	3.0	0
2240A	Hams Fork near Granger, Wyo.	10-23-57	[2] 25	Medium	723	25	1.1	.00		−5.04	2.71	.28	7.4	0
		5-13-58	[2] 841	High	400			.00		−3.50	3.06	.30	1.6	0
		7-31-58	[2] 4.9	Low	902	35	2.0	.00	C3-S1	−4.97	3.38	.27	9.6	0
2245	Blacks Fork below Hams Fork, at Granger, Wyo.	10-23-57	[3] 48	Medium	1,790	42	3.5	.00		−8.10	2.46	.21	31	0
		5-13-58	[2] 1,320	High	500	25	1.0	.00	C2-S1	−3.45	3.07	.29	3.5	0
		7-31-58	[2] 11	Low	2,710	47	5.3	.00	C4-S2	−10.87	1.01	.09	70	0
2245B	Blacks Fork near Marston, Wyo.	9-56	.5	Low	3,900	63	9.9	.00	C4-S3				100	
		6-57	2,000	High	627	34	1.6	.00	C2-S1	−3.25	3.11	.28	5.5	33
		8-57	82.8	Medium	1,790	46	4.0	.00	C3-S1	−6.92	2.13	.21	31	0
2245C	Dry Creek near Green River, Wyo.	10-27-57	[3] .4		2,100	76	10	.71	C3-S3	1.90	3.97	.20	49	1,420
		5-13-58	[3] .05	Low	2,410	77	11	.55	C4-S3	2.49	3.77	.17	61	1,500
2250	Blacks Fork near Green River, Wyo.	5-52	3,082	High	579	32	1.4	.00	C2-S1	−3.25	3.28	.29	4.8	75
		2-53	117	Medium	1,360	42	3.0	.00	C3-S1	−5.96	3.77	.24	19	0
		9-53	2.5	Low	2,070	60	6.5	.00	C3-S2	−3.23	2.33	.19	38	0
2255	Green River near Linwood, Utah.	6-11-47	10,600	High	514	23	.9	.00	C2-S1	−3.82	2.93	.29	3.9	0
		9-14-48	494	Medium	775	38	2.0	.00	C3-S1	−3.67	2.60	.28	7.8	0
2260	Henrys Fork near Lonetree, Wyo.	5-13-58	[2] 59	High	81			.00	C1-S1	−.63	.66	.30	.6	77
		7-29-58	[2] 24	Medum	63			.00		−.60	.52	.30	.4	51
2270	East Fork Beaver Creek near Lonetree, Wyo.	10-22-57	[2] 4.5		259	11	.3	.00	C2-S1	−2.27	2.05	.30	1.1	19
		7-30-58	[2] 27		92	16	.2	.00	C1-S1	−.77	.69	.30	.7	51
2290A	Henrys Fork near McKinnon, Wyo.	5-13-58	[2] 100	High	514	17	.6	.00	C2-S1	−4.18	2.86	.29	3.7	0
		7-29-58	[2] 19	Medium	1,160	18	1.1	.00	C3-S1	−10.28	3.98	.26	14	0
2295	Henrys Fork at Linwood, Utah.	10-56	7.6	Low	2,020	22	1.8	.00		−17.50	3.09	.19	38	0
		5-57	49.4	Medium	1,190	20	1.2	.00		−9.55	3.74	.26	15	0
		7-57	207	High	872	16	.8	.00		−7.47	3.55	.27	8.9	0
2310	Sheep Creek upper canal near Manila, Utah.	5-25-58	[2] 51		38			.00	C1-S1	−.34	.31	.30	.5	63
2312	Carter Creek canal near Manila, Utah.	5-25-58	[2] 13		32			.00		−.27	.20	.30	.4	54
2315	Sheep Creek lower canal near Manila, Utah.	5-25-58	[2] 86		34			.00		−.31	.20	.30	.4	44
2325	Sheep Creek at mouth, near Manila, Utah.	5-26-58	[2] 109	High	221			.00		−1.94	.93	.30	1.6	0
		7-31-58	[2] 11	Low	1,360	8	.5	.00	C3-S1	−14.84	2.44	.24	21	0
2335A	Carter Creek above Beaver Creek, near Manila, Utah.	7-25-57	[3] 55	High	55			.09	C1-S1	−.19	.39	.30	.8	117
2340B	Skull Creek near Manila, Utah.	9-14-48	[3] 1.5		349			.00	C2-S1	−3.49	3.59	.30	1.2	94
2340C	Trail Creek near Manila, Utah.	9-15-48	[3] .9		408			.00		−4.18	4.26	.30	1.0	89

See footnotes at end of table.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*—Continued

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
						Green River basin above the Yampa River—Continued								
2345	Green River near Greendale, Utah.	12-56	416	Low	945	32	1.8	0.00	C3-S1	−5.62	3.54	0.27	9.8	0
		3-57	1,069	Medium	795	33	1.7	.00		−4.54	3.49	.28	7.4	0
		6-57	11,420	High	420	25	.9	.00	C2-S1	−2.79	2.55	.29	2.8	12
2345B	Red Creek near Manila, Utah	6-13-47	[3] 4	--------	1,150	37	2.4	.00	C3-S1	−6.28	4.16	.26	14	0
		9-15-48	[3] .2	Low	2,350	52	5.5	.00	C4-S2	−7.04	2.32	.14	52	0
2350A	Beaver Creek near Ladore, Colo.	9-16-48	[3] .2	Low	783	18	.8	.00	C3-S1	−6.75	5.56	.29	4.6	0
2350B	Vermilion Creek at Ink Springs, near Greystone, Colo.	7-27-41	--------	--------	7,430	48	10	.00	C4-S4	--------	--------	--------	100	--------
		8-18-41	--------	--------	2,670	16	1.6	.00	C4-S1	−29.76	.60	.05	83	0
						Yampa River basin								
2375	Yampa River near Oak Creek, Colo.	6-1-58	[2] 352	High	245	--------	--------	0.00	C1-S1	−2.22	2.07	0.30	0.8	35
		8-9-58	[2] 81	Medium	432	--------	--------	.00	C2-S1	−4.01	3.85	.30	1.3	33
2375A	Yampa River near Sidney, Colo.	6-3-50	--------	--------	90	--------	--------	.00	C1-S1	−.68	.72	.30	.7	80
		11-9-50	--------	--------	291	--------	--------	.00	C2-S1	−2.70	2.56	.30	1.2	37
2385	Walton Creek near Steamboat Springs, Colo.	6-3-50	[3] 500	--------	26	--------	--------	.03	C1-S1	−.16	.21	.30	.5	82
		11-9-50	--------	--------	72	--------	--------	.26		−.42	.82	.30	1.0	164
2390	Fish Creek near Steamboat Springs, Colo.	6-3-50	[3] 500	--------	22	--------	--------	.02		−.14	.18	.30	.5	80
		11-9-50	--------	--------	42	--------	--------	.09		−.33	.49	.30	.7	108
2395	Yampa River at Steamboat Springs, Colo.	6-3-50	2,210	High	67	--------	--------	.00		−.56	.48	.30	.5	51
		11-9-50	117	Medium	270	--------	--------	.00	C2-S1	−2.44	2.36	.30	1.4	51
		10-20-55	67	Low	308	16	0.5	.00		−2.45	2.48	.30	1.6	77
2410	Elk River at Clark, Colo.	6-1-58	[2] 2,020	High	39	--------	--------	.00	C1-S1	−.34	.33	.30	.5	68
		8-11-58	[2] 92	Medium	72	--------	--------	.00		−.58	.59	.30	.5	73
2425	Elk River near Trull, Colo.	6-3-50	[3] 2,000	High	59	--------	--------	.03		−.42	.51	.30	.6	91
		10-20-55	[3] 50	Low	184	12	.2	.00		−1.36	1.33	.30	.9	63
		8-7-58	[2] 88	Medium	113	--------	--------	.00		−.89	.92	.30	.7	77
2430	Trout Creek near Phippsburg, Colo.	6-16-58	[2] 262	--------	74	--------	--------	.00		−.70	.69	.30	.5	68
		8-9-58	[2] 24	--------	119	--------	--------	.02		−1.14	1.20	.30	.6	84
2441	Fish Creek near Milner, Colo.	5-21-58	[2] 125	--------	224	--------	--------	.00		−2.11	1.87	.30	.7	14
		8-7-58	[2] .2	Low	672	29	1.4	.00	C2-S1	−4.48	4.13	.29	4.6	0
2450	Elkhead Creek near Elkhead, Colo.	5-21-58	[2] 581	High	113	--------	--------	.00	C1-S1	−.98	.95	.30	.6	63
		8-10-58	[2] 1.4	Low	244	--------	--------	.06		−1.87	2.16	.30	1.5	138
2469	Fortification Creek near Craig, Colo.	5-21-58	[2] 92	Medium	100	--------	--------	.00		−.78	.85	.30	.7	87
		8-10-58	[2] .2	Low	1,150	57	4.4	1.00	C3-S1	−2.53	6.09	.27	16	896
2475	Yampa River at Craig, Colo.	10-25-57	[2] 432	Medium	284	24	.7	.00	C2-S1	−1.95	2.05	.30	2.1	94
		6-5-58	[2] 7,240	High	82	--------	--------	.00	C1-S1	−.74	.62	.30	.5	42
		8-9-58	[2] 176	Low	330	26	.8	.00	C2-S1	−2.20	2.39	.29	2.3	112
2495	Williams Fork at Hamilton, Colo.	9-19-47	[3] 5.8	Low	395	--------	--------	.00		−3.90	3.15	.29	1.9	0
2495A	Williams Fork below Morapos Creek, near Hamilton, Colo.	10-25-57	[2] 82	Medium	434	16	.6	.00		−3.71	3.22	.29	1.8	0
		5-8-58	[2] 1.4	Low	304	--------	--------	.00		−2.88	2.60	.30	.9	5
2505	Milk Creek near Axial, Colo.	5-8-58	[2] 444	High	410	--------	--------	.00		−3.84	3.03	.29	1.7	0
		8-9-58	[2] 2.0	Low	1,880	27	2.1	.00	C3-S1	−14.87	4.32	.21	30	0
2510A	Yampa River at bridge on county road, near Maybell, Colo.	10-56	126	Low	629	41	1.9	.00	C2-S1	−2.62	3.14	.28	6.8	187
		3-57	467	Medium	549	35	1.5	.00		−2.82	2.71	.29	4.8	42
		6-57	11,430	High	173	16	.3	.00	C1-S1	−1.30	1.30	.30	1.0	70
2519	North Fork Little Snake River near Slater, Colo.	6-17-58	[2] 137	High	20	--------	--------	.02		−.14	.18	.30	.5	80
		8-11-58	[2] 7.7	Medium	58	--------	--------	.00		−.44	.49	.30	.6	82
2530	Little Snake River near Slater, Colo.	8-11-58	[2] 21	Medium	179	--------	--------	.24		−.89	1.43	.30	1.9	197
2550	Slater Fork near Slater, Colo.	5-19-58	[2] 530	High	110	--------	--------	.00		−1.00	.98	.30	.6	66
		8-13-58	[2] 1.6	Low	488	24	.9	.08	C2-S1	−3.64	4.21	.29	2.8	201
2555	Savery Creek at upper station, near Savery, Wyo.	10-24-57	[2] 14	Medium	402	15	.5	.00		−3.74	3.34	.30	1.2	0
		5-12-58	[2] 319	High	214	--------	--------	.00	C1-S1	−1.99	1.88	.30	.7	44
		8-12-58	[2] 5.0	Low	383	--------	--------	.00	C2-S1	−3.42	3.21	.30	1.4	21
2570	Little Snake River near Dixon, Wyo.	10-23-57	[2] 110	Medium	266	18	.5	.00		−2.11	2.28	.30	1.4	110
		5-20-58	[2] 4,400	High	109	--------	--------	.00	C1-S1	−.93	.92	.30	.6	68
		8-13-58	[2] 2.7	Low	460	32	1.2	.26	C2-S1	−2.67	3.55	.29	3.5	274
2580	Willow Creek near Dixon, Wyo.	5-20-58	[2] 43	High	101	--------	--------	.00	C1-S1	−.91	.89	.30	.5	66
		8-13-58	[2] 4.9	Medium	161	--------	--------	.11		−1.39	1.59	.30	.7	117
2590	Muddy Creek near Baggs, Wyo.	10-25-57	[2] 3.6	--------	1,790	64	6.7	.41	C3-S2	−1.46	5.68	.24	30	1,040
		5-20-58	[2] 43	--------	529	31	1.3	.00	C2-S1	−3.16	2.77	.29	3.9	0
2595A	Fourmile Creek at bridge on State Highway 13, near Baggs, Wyo.	5-21-58	[2] 60	--------	202	--------	--------	.01	C1-S1	−1.72	1.84	.30	.9	98
2595B	Sand Creek below Red Wash, near Baggs, Wyo.	10-25-57	[2] 1.0	--------	3,880	88	22	.62	C4-S4	--------	--------	--------	100	--------
2595C	Little Snake River at bridge on State Highway 318, near Lily, Colo.	10-56	7.2	Low	1,320	64	5.6	0.00	C3-S2	−1.13	3.28	.25	22	562
		6-57	3,632	High	205	21	.5	.10	C1-S1	−1.42	1.70	.30	1.3	136
		8-57	129	Medium	642	51	2.7	.25	C2-S1	−1.75	3.30	.28	7.8	428
2600A	Yampa River near Jensen, Utah.	6-16-47	[2] 5,320	High	198	--------	--------	.00	C1-S1	−1.54	1.53	.30	1.3	68
		9-18-48	[2] 94	Low	680	46	2.4	.00	C2-S1	−2.42	2.65	.27	9.5	117

See footnotes at end of table.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*—Continued

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
	Green River basin between the Yampa and White Rivers including the White River basin													
2605	Jones Hole Creek near Jensen, Utah.	10-25-57	[2] 23		318	4	0.1	0.00	C2-S1	−3.22	3.20	0.30	0.6	66
2605A	Sage Creek near Jensen, Utah	9-19-48	[3] .2	Low	905			.00	C3-S1	−10.51	2.77	.27	11	0
2610	Green River near Jensen, Utah	9-48	726	Low	900	39	2.2	.00		−4.17	3.04	.27	10	0
		2-57	1,838	Medium	980	37	2.2	.00		−5.16	3.63	.27	11	0
		6-57	32,180	High	420	24	.8	.00	C2-S1	−2.90	2.73	.29	2.7	28
2620	Brush Creek near Vernal, Utah	2-4-57	10	Low	475	2	.1	.00		−5.05	3.84	.29	1.9	0
		6-18-57	228	High	131	3	.1	.00	C1-S1	−1.22	.75	.30	.7	0
		10-7-57	17	Medium	391	4	.1	.00	C2-S1	−3.76	2.89	.30	1.4	0
2635	Brush Creek near Jensen, Utah	4-17-58	6.1	Medium	1,080	24	1.3	.00	C3-S1	−7.88	2.48	.26	14	0
		5-28-58	125	High	334	15	.4	.00	C2-S1	−2.56	1.76	.30	.8	0
		9-3-58	.1	Low	3,400	43	5.3	.00	C4-S2	−15.69	.35	.02	92	0
2665	Ashley Creek near Vernal, Utah.	5-20-58	[2] 610	High	58			.00	C1-S1	−.54	.52	.30	.5	66
		9-3-58	[2] 49	Medium	153			.01		−1.44	1.49	.30	.6	82
2705	Dry Fork at mouth, near Dry Fork, Utah	8-11-55			724	4	.2	.00	C2-S1	−7.71	4.43	.29	4.7	0
2715	Ashley Creek near Jensen Utah	4-17-58	21	Medium	2,740	25	2.4	.00	C4-S1	−22.30	1.19	.10	68	0
		5-28-58	888	High	583	16	.6	.00	C2-S1	−4.67	2.15	.28	5.3	0
		9-2-58	.6	Low	5,480	34	5.3	.00	C4-S2				100	
2735	Hades Creek near Hanna, Utah	8-16-56	5.4		103	4	.1	.00	C1-S1	−.87	.60	.30	.4	7
		11-8-56	.4	Low	148	6	.1	.00		−1.23	.89	.30	.6	0
2740	Duchesne River near Hanna, Utah.	5-22-58	[2] 745	High	40			.00		−.30	.30	.30	.6	70
		8-21-58	[2] 13	Medium	132			.00		−1.11	1.02	.30	.6	49
2755	West Fork Duchesne River, near Hanna, Utah.	5-22-58	[2] 340	High	302			.00	C2-S1	−3.11	2.80	.30	.6	0
		8-19-58	[2] 22	Medium	466			.00		−4.56	3.77	.29	1.8	0
2760	Wolf Creek above Rhodes Canyon, near Hanna, Utah.	11-8-56	4.0		505	6	.2	.00		−4.82	3.57	.29	2.2	0
2775	Duchesne River near Tabiona, Utah.	5-20-58	[2] 588	High	276			.00		−2.61	2.37	.30	.9	14
		8-18-58	[2] 89	Medium	600	17	.7	.00		−5.26	4.88	.29	2.8	0
2775A	Rock Creek above South Fork, near Hanna, Utah.	11-8-56	[3] 25	Low	115	6	.1	.00	C1-S1	−.94	.87	.30	.5	54
2790	Rock Creek near Mountain Home, Utah.	5-22-58	[2] 819	High	42			.00		−.36	.30	.30	.5	56
		8-25-58	[2] 88	Medium	122			.00		−1.27	1.02	.30	.5	12
2790A	Rock Creek near Duchesne, Utah.	5-14-47	[3] 504	High	86			.00		−.71	.62	.30	.7	49
		9-20-47	[3] 94	Medium	188	34	1.0	.16		−1.30	1.82	.30	2.2	192
2795	Duchesne River at Duchesne, Utah.	10-19-55	83	Low	607	19	.8	.00	C2-S1	−4.91	3.77	.29	4.1	0
		5-23-58	[2] 2,150	High	198			.00	C1-S1	−1.83	1.60	.30	.7	16
		8-22-58	[2] 121	Medium	779	24	1.2	.00	C3-S1	−5.79	3.82	.28	7.0	0
2800	Strawberry River and Willow Creek ditches near Heber, Utah.	10-23-57	[2] 2.4		368	4	.1	.00	C2-S1	−3.85	3.59	.30	.7	9
		6-3-58	[2] 36		79			.00	C1-S1	−.68	.71	.30	.6	77
2815	Hobble Creek ditch near Heber, Utah.	6-3-58	[2] 7.2		231			.00		−2.38	2.24	.30	.5	37
2825	Strawberry Reservoir near Soldier Springs, Utah.	9-10-49			310	13	.2	.09	C2-S1	−2.59	2.77	.30	1.4	112
		6-3-58			295			.00		−2.87	2.72	.30	.8	35
2850	Strawberry River near Soldier Springs, Utah.	10-10-51	23	Medium	577	15	.6	.00		−5.26	5.07	.29	2.3	23
2865	Red Creek near Fruitland, Utah.	7-2-49	[3] 8.0	Medium	1,140	50	3.5	.00	C3-S1	−3.26	4.05	.26	15	246
		5-7-58	[2] 87	High	408			.00	C2-S1	−3.37	3.47	.30	2.0	94
		8-22-58	[2] .1	Low	1,320	55	4.3	.39	C3-S1	−3.12	5.70	.25	22	662
2870A	Layout Creek at mouth, near Fruitland, Utah.	8-14-56	[3] 10		351	2	.1	.07	C2-S1	−3.48	3.58	.30	.8	94
2875B	Deep Creek above mouth, near Fruitland, Utah.	4-19-41			575	29	1.2	.33		−3.85	4.88	.29	3.8	309
2880	Currant Creek near Fruitland, Utah.	9-29-48	13	Low	468			.00		−4.72	4.65	.30	1.2	54
		5-7-58	[2] 260	High	302			.00		−2.97	2.96	.30	.8	68
		8-20-58	[2] 20	Medium	473	19	.7	.28		−3.92	4.59	.30	2.3	227
2880B	Warm Springs No. 1 near Murdock Ranch, near Duchesne, Utah.	5-18-41			11,380	99	232	117.75	C4-S4				100	
2880C	Warm Springs No. 2 near Murdock Ranch, near Duchesne, Utah.	5-18-41			6,790	99	146	59.08	C4-S4				100	
2885	Strawberry Riyer at Duchesne, Utah.	9-29-48	38	Low	812	39	2.2	.83	C3-S1	−4.15	6.28	.29	8.0	566
		10-22-57	[2] 96	Medium	820	43	2.4	1.32		−3.52	6.24	.29	8.5	704
		5-23-58	[2] 1,000	High	459	21	.8	.23	C2-S1	−3.53	4.18	.30	2.5	222
2885A	Indian Creek near Duchesne, Utah.	5-7-58	[2] 12		1,180	47	3.4	1.32	C3-S1	−4.53	7.99	.28	13	875
		7-28-58	[2] 1.0	Low	2,960	61	8.3	.23	C4-S2	−4.79	8.39	.17	53	882
2885B	Emil Munz Spring near Duchesne, Utah.	11-29-41			947	15	.8	.00	C3-S1	−8.60	5.19	.28	7.6	0
2885D	Duchesne River at Bridgeland, Utah.	6-9-48			291			.00	C2-S1	−2.04	2.13	.30	1.9	91
		9-29-48			1,340	41	3.0	.00	C3-S1	−6.40	4.36	.25	17	0
		11-6-50			756	29	1.4	.00		−5.12	4.77	.28	5.5	0
2890	Antelope Creek Near Myton, Utah.	7-31-41			2,590	34	3.4	.00	C4-S1	−16.14	3.29	.15	52	0
		7-2-49			3,150	43	5.0	.00	C4-S2	−13.74	1.58	.08	72	0
		9-10-49			770	35	1.7	.00	C3-S1	−3.66	4.51	.28	6.8	264
2910	Lake Fork below Moon Lake, near Mountain Home, Utah.	5-21-58	[2] 324	High	33			.01	C1-S1	−.20	.25	.30	.6	82
2925	Yellowstone Creek near Altonah, Utah.	5-20-58	[2] 427	High	44			.00		−.38	.31	.30	.5	54
		8-26-58	[2] 100	Medium	73			.00		−.57	.49	.30	.8	51
2935	Lake Fork near Altonah, Utah	5-21-41			67	6	.1	.00		−.61	.46	.30	.5	35
		9-10-49			900	20	.9	.00	C3-S1	−5.56	4.14	.27	8.8	0

See footnotes at end of table.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*—Continued

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Green River basin between the Yampa and White Rivers including the White River basin—Continued														
2940	Lake Fork near Upalco, Utah	5-18-48	--------	--------	175	14	0.3	0.00	C1-S1	−1.28	1.02	0.30	1.2	9
		7-28-58	[2] .7	Low	453	38	1.5	.00	C2-S1	−2.19	2.15	.29	4.1	58
2945	Lake Fork near Myton, Utah	4-20-41	--------	--------	1,160	39	2.5	.00	C3-S1	−5.61	3.66	.26	15	0
		6- 9-48	--------	--------	1,500	58	5.2	.00	C3-S2	−2.73	2.70	.23	24	47
2950	Duchesne River at Myton, Utah	6-42	1,763	High	347	34	1.1	.00	C2-S1	−1.85	1.99	.29	2.7	101
		9-42	52	Low	1,770	45	3.9	.00	C3-S1	−7.11	3.85	.22	27	0
		3-43	350	Medium	842	35	1.8	.00		−4.57	3.67	.28	8.0	0
2950B	Duchesne River at Ouray School canal, near Randlett, Utah.	10- 7-57	[3] 120	Low	1,740	50	4.4	.00		−5.38	3.35	.22	26	0
		4-18-58	[3] 450	Medium	770	36	1.8	.00		−4.00	3.60	.28	6.8	0
		5-27-58	[3] 3,600	High	346	20	.6	.00	C2-S1	−2.52	2.37	.29	1.9	33
2970	Uinta River near Neola, Utah	6-16-41	1,090	High	34	6	.1	.00	C1-S1	−.29	.21	.30	.4	51
		8-29-58	[2] 200	Medium	47	14	.1	.00		−.33	.33	.30	.5	70
2975	Uinta River near Whiterocks, Utah.	9-10-49	[3] 160	--------	420	7	.2	.56	C2-S1	−3.20	3.85	.30	1.8	222
2995	Whiterocks River near Whiterocks, Utah.	6-16-41	720	High	30	3	.0	.00	C1-S1	−.28	.21	.30	.4	54
2995A	Whiterocks canal at Tridell, Utah.	3- 3-49	--------	--------	151	14	.3	.00		−1.28	1.14	.30	.8	37
		7-27-49	--------	--------	79	24	.4	.07		−.62	.79	.30	.9	110
2995B	Whiterocks River at Park canal, near Ft. Duchesne, Utah.	4-18-58	[3] 15	Low	425	16	.5	.00	C2-S1	−3.44	3.27	.29	1.9	28
		5-27-58	[3] 800	High	83	10	.1	.00	C1-S1	−.62	.57	.30	.6	58
		6-30-58	[3] 335	Medium	192	22	.5	.00		−1.33	1.30	.30	.9	6
2995D	Deep Creek at Park canal crossing, near Ft. Duchesne, Utah.	5-27-58	[3] 15	--------	753	18	.8	.00	C3-S1	−6.09	2.56	.28	8.2	0
		6-30-58	[3] 1	Low	1,410	24	1.6	.00		−10.90	2.78	.24	21	0
3000	Deep Creek near Lapoint, Utah	7-28-58	[2] 1.5	Low	1,780	25	1.9	.00		−14.27	3.56	.21	30	0
3000A	Drain at Ft. Duchesne, Utah	4-24-42	--------	--------	7,370	44	8.5	.00	C4-S3	--------	--------	--------	100	--------
3005	Uinta River at Ft. Duchesne, Utah.	6-22-47	752	High	175	21	.4	.00	C1-S1	−1.29	1.10	.30	1.2	26
		9-29-48	.9	Low	1,770	24	1.8	.00	C3-S1	−14.46	3.71	.21	29	0
		3-14-56	34	Medium	776	22	1.0	.00		−5.86	3.20	.28	7.8	0
3010	Dry Gulch near Neola, Utah	5-21-58	52	--------	111	7	.1	.00	C1-S1	−1.05	1.02	.30	.5	63
3010A	Big Sand Wash near Upalco, Utah.	6-27-57	[3] 40	--------	132	9	.1	.00		−1.05	1.03	.30	.6	66
		4-30-58	[3] 10	--------	737	19	.9	.00	C2-S1	−5.88	5.36	.29	4.3	0
3010B	Cottonwood Creek at Monarch, Utah.	9-10-49	--------	--------	160	26	.5	.00	C1-S1	−.91	1.02	.30	1.4	96
3010C	Cottonwood Creek at Cedarview, Utah.	9-10-49	--------	--------	950	42	2.4	.00	C3-S1	−3.44	1.95	.26	13	0
3010D	Cottonwood Creek at Roosevelt, Utah.	6-16-41	--------	--------	981	33	1.8	.00		−5.53	2.94	.26	12	
3010E	Dry Gulch near Ft. Duchesne, Utah.	2-10-58	50	--------	2,230	44	4.2	.00	C3-S2	−9.19	2.65	.16	45	0
		5-27 58	200	High	1,160	42	2.7	.00	C3-S1	−4.77	2.69	.25	16	0
		9- 3-58	12	--------	3,900	56	8.0	.00	C4-S3	--------	--------	--------	100	--------
3015	Uinta River at Ouray School, Utah.	5-19-41	--------	--------	731	37	1.8	.00	C2-S1	−3.38	1.86	.27	9.7	0
		10- 2-51	[3] 90	--------	2,510	52	5.7	.00	C4-S2	−7.28	1.85	.11	63	0
3020	Duchesne River near Randlett, Utah.	1- 51	425	Medium	1,100	37	2.3	.00	C3-S1	−5.84	4.07	.26	13	0
		10-56	70.3	Low	2,100	47	4.5	.00	C3-S2	−8.06	3.27	.18	40	0
		6-57	3,095	High	492	29	1.1	.00	C2-S1	−2.95	2.47	.29	3.9	0
3020B	Duchesne River at Ouray, Utah.	5-13-47	[3] 2,400	High	494	27	1.0	.00		−3.28	2.36	.29	4.2	0
		10-14-49	[3] 370	Medium	1,520	39	2.9	.00	C3-S1	−7.32	4.09	.24	20	0
		8-26-54	[3] 10	Low	4,080	59	9.1	.00	C4-S3	--------	--------	--------	100	--------
3030	White River at Buford Colo.	5- 9-58	[2] 720	High	229	--------	--------	.00	C1-S1	−2.24	1.68	.30	.9	0
		8- 4-58	[2] 235	Medium	304	--------	--------	.00	C2-S1	−2.83	1.72	.29	1.8	
3035	South Fork White River near Buford, Colo.	5- 9-58	[2] 425	High	241	--------	--------	.00	C1-S1	−2.50	2.27	.30	.4	16
		8- 4-58	[2] 164	Medium	302	--------	--------	.00	C2-S1	−3.00	2.59	.30	.8	0
3045	White River near Mekeer, Colo.	5- 8-58	[2] 1,860	High	367	--------	--------	.00		−2.56	1.10	.29	2.9	0
		8- 4 58	[2] 361	Medium	446	--------	--------	.00		−3.98	2.66	.29	2.9	0
3045A	White River at bridge on State Highway 13, near Meeker, Colo.	8-25-54	[3] 225	Low	904	34	1.9	.00	C3-S1	−4.85	2.93	.26	12	0
3060	Piceance Creek near Rio Blanco, Colo.	10-21-57	[2] 2.4	--------	760	27	1.2	00		−4.50	4.64	.29	4.3	101
		5- 9-58	[2] 18	--------	472	--------	--------	.00	C2-S1	−4.06	3.39	.29	2.3	0
3060A	Piceance Creek near White River, Colo.	8-25-54	[3] 4	--------	7,890	91	43	72.70	C4-S4	--------	--------	--------	100	--------
		5- 9-58	[2] 19	--------	592	23	.9	.00	C2-S1	−4.48	4.33	.29	3.1	33
3060D	Wolf Creek near Massadona, Colo.	5- 7-58	[2] .1	Low	3,060	27	2.9	.00	C4-S1	−25.78	.32	.02	92	0
3061A	Spring Creek near Rangely, Colo.	9-16-54	--------	--------	7,680	58	13	.00	C4-S4	--------	--------	--------	100	--------
3061C	Douglas Creek near Rangely, Colo.	11- 8-50	--------	--------	2,600	45	4.8	.00	C4-S2	−11.52	3.58	.16	48	0
		5- 7-58	[2] 141	--------	1,140	35	2.3	.00	C3-S1	−6.60	5.70	.27	9.9	0
3061D	White River at Rangely, Colo.	5-13-47	[3] 2,800	High	358	23	.7	.00	C2-S1	−2.60	2.30	.29	2.4	0
		11- 8-50	[3] 400	Medium	854	38	2.1	.00	C3-S1	−4.08	3.15	.27	10	0
		8-25-54	[3] 200	Low	975	39	2.3	.00		−4.61	3.13	.26	13	0
3062A	Evacuation Creek near mouth, near Watson, Utah.	8-25-54	--------	--------	4,680	59	10	.00	C4-S3	--------	--------	--------	100	--------
3065	White River near Watson, Utah.	9-56	217	Low	997	38	2.2	.00	C3-S1	−4.59	2.99	.26	13	0
		3-57	497	Medium	1,110	43	2.8	.00		−4.57	3.63	.26	14	0
		6-57	3,661	High	545	23	.9	.00	C2-S1	−3.53	3.32	.29	3.4	19
3065A	Two Water Creek near Watson, Utah.	10-28-57	[2] .7	Low	8,060	37	7.2	.00	C4-S3	--------	--------	--------	100	--------
		5- 6-58	[2] 3.8	--------	5,020	36	5.4	.00	C4-S2	--------	--------	--------	100	--------
3065B	White River near Ouray, Utah.	5-13-47	[3] 2,800	High	424	30	1.1	.00	C2-S1	−2.75	2.67	.29	3.3	40
		9-29-48	[3] 370	Medium	982	39	2.3	.00	C3-S1	−4.75	3.16	.26	13	9
		8-26-54	[3] 170	Low	1,070	41	2.6	.00		−4.55	3.12	.26	15	0

See footnotes at end of table.

TABLE 19.—*Suitability of surface water for irrigation in the subbasins in the Green division*—Continued

[Calcium *a*, to adjust water to 70 percent sodium, calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos at 25° C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Green River Basin below White River														
3070	Green River near Ouray, Utah	9–52	2,787	Medium	870	38	2.1	0.00	C3–S1	−4.37	3.19	0.27	10	0
		1–57	1,350	Low	962	35	2.0	.00		−5.26	3.74	.27	11	0
		6–57	32,180	High	420	24	.8	.00	C2–S1	−2.90	2.73	.29	2.7	28
3080	Willow Creek near Ouray, Utah.	4–52	92.4	High	1,030	32	1.9	.00	C3–S1	−6.45	5.34	.27	8.7	0
		9–53	2.13	Low	3,180	62	8.8	.00	C4–S3	−4.69	4.12	.12	61	0
		2–54	24.1	Medium	1,200	42	2.9	.00	C3–S1	−5.51	5.73	.27	12	115
3085	Minnie Maud Creek near Myton, Utah.	5–6–58	[2]107	High	570	19	.8	.00	C2–S1	−4.63	4.72	.29	2.6	89
		8–27–58	[2]1.4	Low	750	31	1.5	.00	C3–S1	−4.83	5.15	.29	5.2	143
3090	Minnie Maud Creek at Nutter Ranch, near Myton, Utah.	5–6–58	[2]211	High	658	24	1.1	.00	C2–S1	−4.85	5.39	.29	3.7	194
		8–12–58	[2]2.0	Low	1,470	41	3.2	.00	C3–S1	−7.51	8.77	.26	14	356
3090A	Minnie Maud Creek near Ouray, Utah.	9–23–48	[2]12	Medium	1,220	38	2.6	.00		−6.54	6.89	.27	11	145
3090B	Rock Creek near Sunnyside, Utah.	9–24–48	[2]5.3	--------	606	26	1.2	.00	C2–S1	−4.45	4.94	.29	3.8	183
3090C	Chandler Creek near Columbia, Utah.	9–19–47	[2]1.0	--------	805	31	1.6	.00	C3–S1	−5.29	4.66	.28	6.2	0
3090D	Florence Creek near Columbia, Utah.	9–25–48	[2]1.3	--------	860	31	1.7	.00		−5.59	4.57	.28	7.1	0
3090E	Range Creek near Woodside, Utah.	9–25–48	[3]1.0	--------	1,080	47	3.2	.95		−3.93	6.83	.28	12	744
3091A	Coal Creek near Woodside, Utah.	9–20–47	[3].2	Low	3,010	57	7.4	.00	C4–S2	−6.92	2.22	.10	65	0
3091B	Rattlesnake Creek near Woodside, Utah.	9–20–47	[3].7	--------	2,420	53	6.0	.00		−7.03	4.50	.18	41	0
3095	Fairview ditch near Fairview, Utah.	6–30–58	[2]11	--------	271	--------	--------	.00	C2–S1	−2.86	2.82	.30	.5	61
3105	Price River above Scofield Reservoir, near Scofield, Utah.	5–19–58	[2]588	High	329	--------	--------	.00		−3.35	3.43	.30	.8	89
		7–28–58	[2]19	Medium	317	--------	--------	.00		−3.14	3.19	.30	.8	82
3125	White River near Soldier Summit, Utah.	5–19–58	[2]216	High	518	15	.6	.34		−4.74	5.42	.30	2.0	229
		7–28–58	[2]6.9	Medium	555	23	1.0	.83		−4.29	5.71	.30	3.3	402
3125A	Price River below White River, near Colton, Utah.	6–30–49	[3]310	High	580	19	.8	.77		−4.42	5.63	.30	3.3	353
3125B	Price River at Castlegate, Utah	7–19–47	[3]218	--------	371	--------	--------	.00		−3.84	3.54	.30	1.3	0
		2–15–51	[3]20	--------	681	20	.9	.00		−5.64	5.60	.29	3.6	58
3125C	Willow Creek at Castlegate, Utah.	7–19–47	--------	--------	747	35	1.8	.00		−4.33	4.82	.28	6.8	180
3130	Price River near Heiner, Utah	10–2–48	41	Medium	334	--------	--------	.00		−3.32	2.90	.30	1.0	0
		11–12–50	10	Low	704	18	.8	.00		−6.32	6.01	.29	3.6	0
		5–24–58	[2]851	High	439	--------	--------	.00		−3.95	4.12	.30	1.8	110
3135A	Gordon Creek near Price, Utah	6–30–49	--------	--------	1,050	17	.9	.00	C3–S1	−8.98	3.30	.26	13	0
3135B	Soldier Creek near Wellington, Utah.	4–25–47	--------	Low	6,440	47	8.9	.00	C4–S3	--------	--------	--------	100	--------
		6–30–49	--------	High	570	28	1.2	.11	C2–S1	−3.49	4.24	.29	4.0	243
3140	Price River near Wellington, Utah.	7–20–47	[3]14	Medium	3,350	39	4.7	.00	C4–S2	−19.03	.47	.02	93	0
		6–30–49	[3]84	High	1,640	22	1.4	.00	C3–S1	−9.95	3.59	.24	22	0
3140A	Desert Lake Reservoir near Elmo, Utah.	5–30–49	--------	--------	5,300	73	16	.00	C4–S4	--------	--------	--------	100	--------
3140B	Icelander Creek near Dragerton, Utah.	4–25–47	--------	--------	3,790	32	4.0	.00	C4–S2	--------	--------	--------	100	--------
3145	Price River at Woodside, Utah	9–56	8.33	Low	5,600	51	9.1	.00	C4–S3	--------	--------	--------	100	--------
		3–57	43.6	Medium	5,360	52	8.9	.00		--------	--------	--------	100	--------
		8–57	478	High	3,280	45	5.5	.00	C4–S2	−14.87	.35	.02	92	0
3150	Green River at Green River, Utah.	10–56	1,243	Low	1,040	42	2.6	.00	C3–S1	−4.50	2.99	.26	13	0
		3–57	3,846	Medium	980	44	2.7	.00		−3.80	2.96	.27	12	0
		6–57	31,440	High	393	25	.8	.00	C2–S1	−2.55	2.37	.29	2.6	26
3155	Saleratus Wash at Green River, Utah.	9–27–48	[3].2	Low	2,790	37	3.9	.00	C4–S2	−17.34	.68	.07	77	0
		10–21–57	[2]90	--------	1,740	19	1.4	.00	C3–S1	−15.36	1.83	.22	27	0
3155A	Salaratus Wash below sewer outfall, at Green River, Utah.	9–27–48	[2]6.3	--------	1,190	42	2.9	.00		−5.35	3.01	.25	17	0
3160	Brown's Wash near Green River, Utah.	9–27–48	[3].1	Low	5,830	49	8.8	.00	C4–S3	--------	--------	--------	100	--------
3175	Candland ditch near Mt. Pleasant, Utah.	6–12–58	[2]3.2	--------	223	--------	--------	.05	C1–S1	−2.28	2.39	.30	.6	96
3180	Huntington Creek near Huntington, Utah.	8–15–56	46	Medium	369	6	.2	.00	C2–S1	−3.56	3.47	.30	1.0	49
		5–20–58	[2]694	High	310	--------	--------	.00		−3.09	3.07	.30	.8	66
3190	Ephraim tunnel near Ephraim, Utah.	6–12–58	[2]30	--------	247	--------	--------	.02	C1–S1	−2.58	2.66	.30	.6	89
3240	Seeley Creek near Orangeville, Utah.	8–15–56	38	--------	468	12	.4	.13	C2–S1	−4.16	4.51	.30	1.8	152
3245	Cottonwood Creek near Orangeville, Utah.	6–30–49	284	High	450	9	.3	.00		−3.93	3.65	.30	1.1	5
		8–15–56	42	Medium	470	15	.5	.00		−4.05	4.19	.30	2.1	103
3250	Cottonwood Creek near Castledale, Utah.	4–13–48	6.5	Low	2,690	36	3.8	.00	C4–S2	−17.39	1.94	.11	64	0
3265	Ferron Creek (upper station) near Ferron, Utah.	10–26–57	[2]12	Medium	607	--------	--------	.00	C2–S1	−5.19	4.53	.29	3.0	0
		5–22–58	[2]750	High	407	--------	--------	.00		−3.78	3.87	.30	1.3	91
3280	San Rafael River near Castledale, Utah.	4–13–48	40	Medium	3,370	47	6.1	.00	C4–S2	−14.08	.18	.01	97	0
		5–25–58	[2]2,050	High	670	25	1.1	.00	C2–S1	−4.80	3.71	.29	4.8	0
		7–29–58	[2]24	Low	4,390	50	7.6	.00	C4–S3	--------	--------	--------	100	--------
3285	San Rafael River near Green River, Utah.	10–56	.85	Low	5,200	45	7.3	.00		--------	--------	--------	100	--------
		2–57	65.7	Medium	3,070	44	5.2	.00	C4–S2	−14.28	1.11	.07	78	0
		6–57	1,588	High	854	27	1.4	.00	C3–S1	−5.65	3.28	.27	8.3	0
3285A	Green River near Moab, Utah	6–22–47	[3]24,000	High	492	23	.8	.00	C2–S1	−3.50	2.55	.29	3.9	0
		9–29–48	[2]948	Low	914	46	2.8	.00	C3–S1	−3.47	3.01	.27	11	0

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[1] For good yield.

[2] From gage height or measurement at time of sampling.

[3] Estimated.

TABLE 20.—*Transmountain diversions, in acre-feet, from the Green River basin between the Yampa and White Rivers including the White River basin, water years 1914–57*

[Total includes estimates of diversions by the Strawberry River and Willow Creek ditches and the Hobble Creek ditch for water years 1914–49]

Water year	Duchesne tunnel	Strawberry tunnel	Strawberry River and Willow Creek ditches	Hobble Creek ditches	Total
1914	0	0			3,300
1915	0	10,410			13,700
1916	0	33,440			36,700
1917	0	60,710			64,000
1918	0	70,700			74,000
1919	0	72,870			76,200
1920	0	62,420			65,700
1921	0	65,880			69,200
1922	0	69,570			72,900
1923	0	79,500			82,800
1924	0	112,600			115,900
1925	0	82,580			85,900
1926	0	74,580			77,900
1927	0	64,740			68,000
1928	0	73,210			76,500
1929	0	57,800			61,100
1930	0	73,100			76,400
1931	0	73,840			77,100
1932	0	58,700			58,700
1933	0	51,520			54,800
1934	0	27,970			31,300
1935	0	43,490			46,800
1936	0	42,960			46,300
1937	0	50,230			53,500
1938	0	55,840			59,100
1939	0	70,760			74,100
1940	0	53,770			57,100
1941	0	44,910			48,200
1942	0	53,180			56,500
1943	0	58,140			61,400
1944	0	57,020			60,300
1945	0	49,180			52,500
1946	0	69,340			72,600
1947	0	59,780			63,100
1948	0	72,350			75,600
1949	0	63,270			66,600
1950	0	69,140	2,730	651	72,521
1951	0	68,170	2,500	1,330	72,000
1952	0	45,780	2,480	551	48,800
1953	0	80,970	1,990	1,260	84,220
1954	28,270	78,910	1,290	995	109,465
1955	32,060	71,450	2,610	1,160	107,280
1956	31,890	74,060	2,350	1,260	109,560
1957	29,790	57,960	2,380	717	90,847

TABLE 21.—*Upstream water developments and methods and accuracy of adjusting flow-duration data for selected stations in two subbasins in the Green division to base period and 1957 conditions*

Years of record: Number of years of available historical flow-duration data during water years 1914–57.

Base period adjustment method: Method used in adjusting historical data to base period; I, index-station method, M, monthly means method, S, substitute method.

Index-station No.: Index station used in adjusting flow-duration curve to base period or correlation station used in estimating data for missing periods of record.

Upstream water developments: Upstream transmountain diversions and reservoirs in which changes occurred in base period requiring adjustment in historical data to 1957 conditions.

Accuracy rating: Authors' rating of accuracy of adjusted flow-duration curve for water years 1914–57 to 1957 conditions. The accuracy rating indicates that the final developed flow-duration curve throughout its range is believed to be correct within the percentage indicated.

Station No.	Years of record	Base period adjustment method	Index-station No.	Upstream water developments	Accuracy rating (percent)
Green River basin between the Yampa and White Rivers including the White River basin					
2610	11	I	[1] 2255, [1] 2510, [1] 2600		10
2620	18	I	[2] 2665	Oak Creek Reservoir	10
2635	18	I	[2] 2665	do	15+
2665	36	M	(3)	Diversion from Oak Creek Reservoir and Vernal city water supply	5
2715	11	I	[1] 2665	Same as 2665	15+
2740	13	I	[2] 2775	Duchesne tunnel	10
2755	13	I	[2] 2775		10
2775	39	M	[3] 2665	Duchesne tunnel	5
2790	20	M	[3] 2665, 2775, 2795		10
2795	40	M	2885, 2950	Duchesne tunnel	5
2850	14	I	2885		10
2880	22	I	2885	Currant Creek feeder canal	10
2885	43	M	2950	Currant Creek feeder canal	5
2895	13	I	[2] 2790		15
2925	13	I	[2] 2995		10
2940	13	I	[1] 3005	Moon Lake	15+
2950	43	M		Duchesne tunnel, Currant Creek feeder canal, and Moon Lake	5
2955	5	I	[2] 2995		15
2970	26	I	[2] 2665, [2] 2995		10
2995	27	M	(3)		5
3005	15	I	[2] 2970, [2] 2995		15+
3020	15	M	(3)	Same as 2950	15
3030	9	I	3045		10
3035	17	I	3045		10
3045	44				5
3065	34	S	[3] 3045		15
Green River basin below the White River					
3070	9	I	3150	Duchesne tunnel	10
3080	8	I	[2] 3020		15+
3090	8	I	2950		15+
3105	19	I	[2] 3180		10
3125	18	I	[2] 3105, [2] 3180		15
3130	23	(4)		Schofield Reservoir	10
3140	8	I	3140	do	15
3145	11	I	[2] 3140	do	15+
3150	44			Duchesne tunnel	5
3180	39	S	(5)		10
3245	38	S	3180	Ephraim, Larsen, and Spring City tunnels and Reeder ditch	10
3265	22	I	[2] 3180		15
3280	10	I	[2] 3180, [2] 3245	Same as 3245	15+
3285	17	I	[2] 3180, [2] 3245	do	15+

---

[1] Flow-duration curve and data for index station that had been adjusted to base period and 1957 conditions were used.

[2] Flow-duration curve and data for index station that had been adjusted to base period were used.

[3] Annual estimates of discharge by Upper Colorado River Compact Commission (1948) were used.

[4] Records five miles downstream for Price River near Helper, Utah (3135), for water years 1914–33 are equivalent to records at this station. These records used to complete flow-duration data for base period.

[5] Partial records available for water years 1918–20 and 1930, which were used to estimate annual discharge.

TABLE 22.—*Total dissolved-solids concentration and concentration of boron in water in the upper part of the Duchesne River basin in 1960*

[Map and analysis number from Iorns and others (1964, pl. 1)]

Map No.	Location	Date	Estimated discharge (cfs)	Dissolved solids (ppm)	Boron (ppm)
1010G	Indian Creek, 0.1 mile above mouth	Feb. 20	1.5	1,930	7.6
1006G	Indian Creek, 1.6 miles above mouth	do	1.5	1,870	7.6
1007G	Indian Creek, 3.1 miles above mouth	do	1.5	1,750	6.2
1009G	Indian Creek, 3.8 miles above mouth	do	1.5	1,720	6.8
1008G	Indian Creek, 5.0 miles above mouth	do	1.5	1,610	6.6
1019G	Spring on Indian Creek, 7 miles above mouth	May 15	.5	1,840	6.3
1020G	Spring on Indian Creek, 7 miles above mouth	do	.2	1,860	6.5
1014G	Spring on North Fork Strawberry River, 1 mile above mouth	do	.01	1,500	1.1
1016G	Spring on Lake Canyon Creek, 0.8 miles above mouth	do	.05	2,910	7.7
1017G	Spring on Lake Canyon Creek, 7 miles above mouth	do	.5	2,710	6.6
1015G	Stinking Spring on Strawberry River, about 12 miles west of Duchesne, Utah.	May 16	.05	7,320	20.0

TABLE 23.—*Recorded transmountain diversions, in acre-feet, from the Green River basin below the White River, water years 1950–57*

Water year	Fairview ditch	Candland ditch	Ephraim tunnel	Larsen tunnel	Horseshoe tunnel	Coal Fork ditch	Twin Creek tunnel	Cedar Creek tunnel	Black Canyon ditch	Spring City tunnel	Reeder ditch	Madsen ditch	John August ditch	Totals
1950	1,490	132	3,070	750	698	158	163	314	206	1,370	266	7	186	8,810
1951	1,820	224	3,180	910	703	209	205	338	260	1,630	116	69	299	9,960
1952	2,060	583	3,920	2,280	1,000	630	462	718	500	1,660	138	13	206	14,170
1953	1,700	134	3,720	923	539	205	103	223	180	1,960	44	20	235	9,990
1954	1,000	164	2,480	705	362	167	144	191	217	1,430	75	4	224	7,160
1955	1,280	81	2,950	786	409	210	221	329	231	1,880	272	4	246	8,900
1956	1,540	155	3,520	913	492	206	121	237	254	1,890	474	104	183	10,090
1957	2,410	151	2,460	993	600	426	377	496	428	2,330	493	20	279	11,560

TABLE 24.—*Total transmountain diversions, in acre-feet, from the Green River basin below the White River, water years 1914–57*

[In totals, diversions prior to water year 1950 are estimated on basis of recorded water rights and reported dates of enlargement of canals]

Water year	Total	Water year	Total	Water year	Total	Water year	Total
1914	3,900	1925	4,100	1936	5,400	1947	10,880
1915	3,900	1926	4,200	1937	5,400	1948	9,360
1916	3,900	1927	4,200	1938	5,400	1949	10,970
1917	4,000	1928	4,200	1939	8,100	1950	8,810
1918	4,100	1929	4,200	1940	9,800	1951	9,960
1919	4,100	1930	4,300	1941	11,450	1952	14,170
1920	4,100	1931	4,800	1942	10,510	1953	9,990
1921	4,100	1932	5,200	1943	9,580	1954	7,160
1922	4,100	1933	5,300	1944	10,390	1955	8,900
1923	4,100	1934	5,400	1945	10,900	1956	10,090
1924	4,200	1935	5,400	1946	10,240	1957	11,560

TABLE 25.—*Summary data on utilization of surface water in the Green division for developments existing in 1957*

Water use	Subbasin				Total in division
	Green River basin above the Yampa River	Yampa River basin	Green River basin between the Yampa and White Rivers including the White River basin	Green River basin below the White River	
Storage reservoirs with usable capacities greater than 1,000 acre-feet:					
Number	18	1	13	9	41
Total usable capacity ... acre-ft	141, 100	6, 200	334, 600	93, 500	575, 400
Transmountain diversions:					
Number	1	2	4	13	20
Exported (average annual) ... acre-ft	(1)	(1)	102, 100	10, 100	[2] 112, 200
Irrigation:					
Irrigated ... acres	258, 400	73, 700	198, 000	60, 000	590, 100
Estimated consumptive use (average annual) ... acre-ft	218, 000	82, 000	326, 300	102, 600	728, 900
Domestic and industrial use:					
Population (1960)	33, 800	14, 000	24, 600	27, 000	99, 400
Estimated consumptive use (average annual) ... acre-ft	2, 300	900	1, 700	1, 800	6, 700
Hydroelectric powerplants:					
Number	1	0	4	0	5
Installed capacity ... kw	180	0	2, 550	0	2, 730

[1] Amount diverted annually is unknown, but reported to be small.

[2] Does not include amounts diverted annually by the three small diversions in the two upper subbasins.

TABLE 26.—*Water budget, Green division*

	Average annual (acre-ft)
Outflow from the division	4, 660, 100
Transmountain diversions	112, 200
Irrigation consumptive use	728, 900
Domestic and industrial consumptive use	6, 700
Evapotranspiration loss	[1] 34, 138, 000
Total	39, 645, 900

[1] Includes 234,000 acre-ft estimated evaporation from water surfaces.

TABLE 27.—*Average annual streamflow and dissolved-solids data at stations on the Green River*

[Based on water years 1914–57 adjusted to 1957 conditions]

Locations of stations on the Green River	Drainage area (sq mi)	Streamflow (acre-ft per sq mi)	Weighted-average concentration (ppm)	Dissolved-solids yield (tons per sq mi)
At Warren bridge near Daniel, Wyo	468	836	151	172
Near Fontenelle, Wyo	3, 970	294	185	74
At Green River, Wyo	7, 670	170	284	66
Near Linwood, Utah	14, 300	109	366	54
Near Greendale, Utah	15, 100	109	378	56
At Jensen, Utah	26, 100	128	316	55
Near Ouray, Utah	35, 500	127	392	68
At Green River, Utah	40, 600	112	427	65

TABLE 28.—*Summary of average annual water, dissolved-solids, and suspended-sediment discharge from the subbasins in the Green division*

[Based on water years 1914–57 adjusted to 1957 conditions]

Data	Subbasin				Green division
	Green River Basin above the Yampa River	Yampa River basin	Green River basin between the Yampa and White Rivers including the White River basin	Green River basin below the White River	
Drainage area____sq mi__	17,000	8,000	10,800	8,900	44,700
Water discharge____acre-ft__	[1] 1,645,000	[2] 1,602,600	[3] 1,260,400	[4] 152,100	[4] 4,660,100
Dissolved-solids discharge:					
Total____tons__	967,100	405,800	1,034,100	521,100	2,928,100
Probable from natural sources____tons__	646,600	343,400	471,800	288,400	1,750,200
Do____tons per square mile__	38	43	44	32	39
Probable from activities of man____tons__	320,500	62,400	562,300	232,700	1,177,200
Do____tons per acre irrigated__	1.2	0.8	2.3	3.9	2.0
Suspended-sediment discharge____tons__	3,677,200	1,807,400	7,339,400	15,051,400	27,875,400

[1] Does not include runoff from 1,900 sq mi in the subbasin between Green River near Greendale gaging station and the Yampa River.

[2] Does not include runoff from 800 sq mi in the subbasin between Yampa River near Maybell, Colo. and Little Snake River near Lily, Colo., gaging stations and the Green River.

[3] Includes runoff from the two areas described in footnotes 1 and 2.

[4] Does not include runoff from 2,400 sq mi between Green River at Green River, Utah, and San Rafael River near Green River, Utah, gaging stations and the Colorado River, but gain in the reach is approximately offset by water loss.

Surface-Water Resources of the San Juan Division

By W. V. IORNS, C. H. HEMBREE, *and* G. L. OAKLAND

WATER RESOURCES OF THE UPPER COLORADO RIVER
BASIN—TECHNICAL REPORT

GEOLOGICAL SURVEY PROFESSIONAL PAPER 441-E

Analysis and appraisal of the water resources of the
San Juan division of the Upper Colorado River Basin,
with special emphasis on surface water and its quality

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

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[Plates are in separate volume]

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SURFACE-WATER RESOURCES OF THE SAN JUAN DIVISION

By W. V. Iorns, C. H. Hembree, and G. L. Oakland

ABSTRACT

This chapter presents the results of an appraisal of the surface-water resources of the San Juan division, which includes the 38,300 square miles of drainage area of the Colorado River and its tributaries below the Green River and above "Lee Ferry," Ariz., a point 1 mile downstream from the mouth of the Paria River. Water uses existing in 1957 are reported, and interpretations are made of stream behavior, chemical quality of water, and sediment yield on the basis of the average that would have occurred if the 1957 level of upstream development had existed throughout water years 1914–57. The appraisal will be useful in planning additional development of surface-water supplies and in evaluating changes in streamflow, chemical quality of water, and sediment yield that may result from water-development projects constructed after 1957.

Annual precipitation in the division averaged 25,880,600 acre-feet in the water years 1914–57. Had the developments in 1957 existed throughout the 44-year period, the average annual consumption of water would have been about 301,100 acre-feet for irrigation and about 7,100 acre-feet for domestic and industrial uses. Annually, about 2,800 acre-feet would have been diverted out of the division, about 102,600 acre-feet would have been imported into the division, and about 2,539,000 acre-feet from the division would have been contributed to the Colorado River. Evapotranspiration probably accounted for the remaining 23,133,200 acre-feet of water, on the assumption that there was no ground-water outflow from the division. Annually, transmountain diversions export about 300 tons of dissolved solids and import about 17,700 tons. The annual contribution of dissolved solids to the stream system in the division is computed to average about 1,543,600 tons for the water years 1914–57 adjusted to 1957 conditions. Of this amount, about 351,800 tons is attributed to the activities of man, principally irrigation.

Suspended sediment contributed to the Colorado River in the division is estimated to average about 55,585,000 tons annually.

In the headwaters of the division most of the surface water in the streams is suitable for domestic and industrial use. The concentrations of dissolved solids in most streams increase downstream, and some exceed the standards for domestic use. The waters in the lower reaches of some of the tributary streams are not suitable for agricultural use during periods of low flow.

INTRODUCTION

PURPOSE AND SCOPE

This chapter of the report presents in detail the appraisal of the surface-water resources of the San Juan division. In the appraisal the following items were considered: The present utilization of the surface-water supplies, the flow characteristics of the streams and the effects of environmental factors on streamflow, the chemical-quality characteristics of the streams and the influence of environmental factors on the quality of water, and the sediment yield of the streams. The appraisal and the data presented will be useful in planning additional water-development projects and in managing water resources of the area.

The basic data, hydrologic techniques, and criteria used in the appraisal of the surface-water resources are discussed and explained in chapter B, which also contains a glossary of technical terms used.

LOCATION AND SUBBASINS

The San Juan division of the Upper Colorado River Basin has a drainage area of 38,300 square miles. It is those parts of Colorado, Utah, New Mexico, and Arizona drained by the Colorado River and its tributaries below the Green River and above "Lee Ferry"—an unmapped arbitrary point defined by the Colorado River Compact as "a point 1 mile downstream from the mouth of the Paria River." In this report this division is divided into two subbasins (chap. A, fig. 2).

The San Juan River basin is the drainage area of the San Juan River (24,900 sq mi). The gaging station on San Juan River near Bluff, Utah, records the outflow from 23,000 square miles of the basin.

The Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry" (13,400 sq mi) is the area drained by the Colorado River between the Green River and "Lee Ferry," Ariz., excluding the San Juan River basin. The gaging stations on Colorado and Paria Rivers at Lees Ferry, Ariz., record the outflow from the Upper Colorado River Basin. Lees Ferry is a small community above the mouth of the Paria River.

HYDROLOGIC ENVIRONMENT

PHYSIOGRAPHY AND STREAM NET

The San Juan division extends from the junction of the Green and Colorado Rivers to 1 mile below the mouth of the Paria River (fig. 125). Included in the division are the drainage basins of the Dirty Devil, Escalante, San Juan, and Paria Rivers. Principal high-

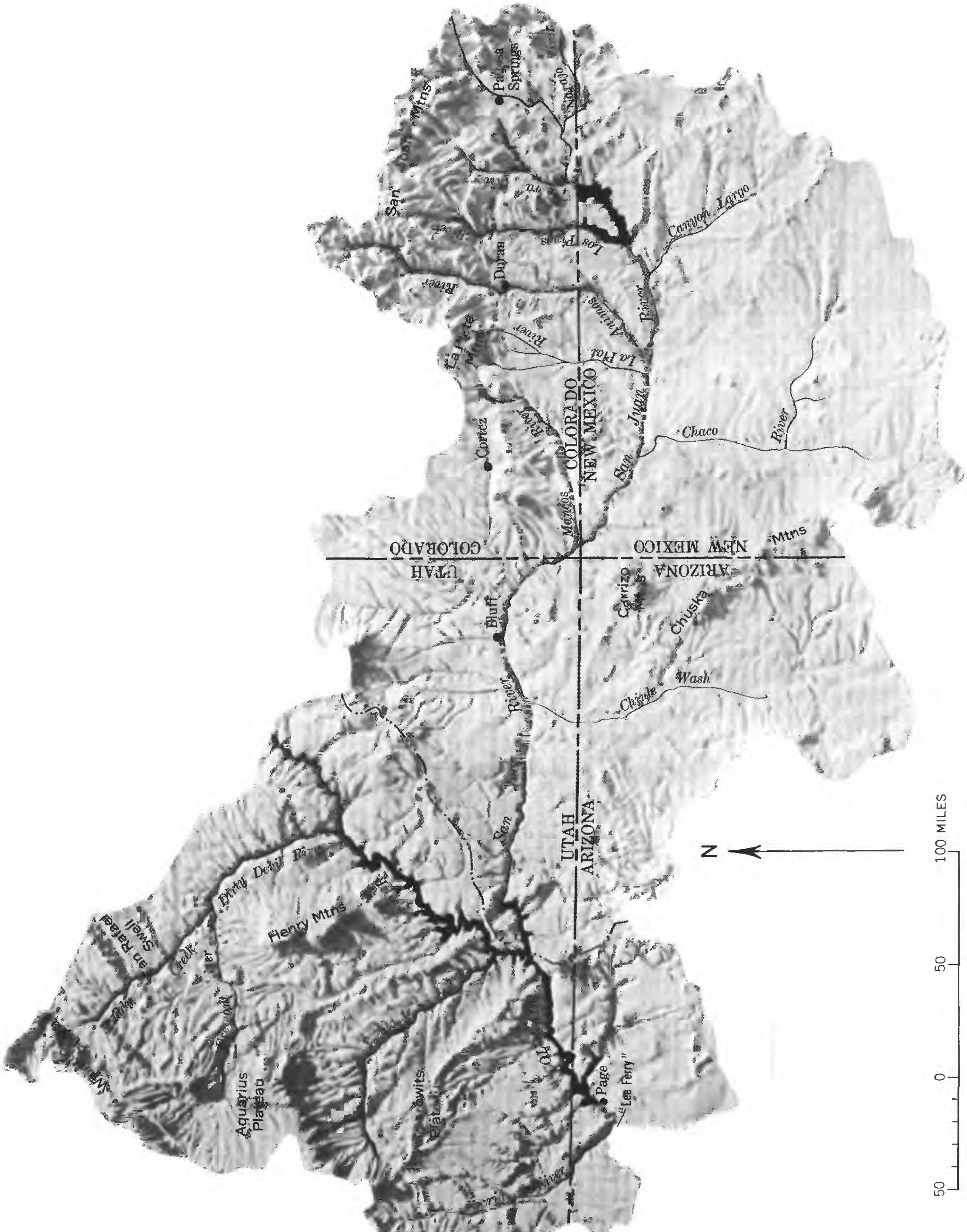

FIGURE 125.—Relief map of the San Juan division of the Upper Colorado River Basin. Adapted from photograph by I. V. Goslin, Upper Colorado River Compact Commission.

lands on the boundaries of the division are the San Juan and La Plata Mountains and the Aquarius and Wasatch Plateaus. Within the division are the Henry, Chuska, and Carrizo Mountains. The San Juan division is a region of great contrasts—parched deserts and lush mountain meadows; high mountains, deep canyons, and broad alluvial valleys; and dry washes and rushing mountain torrents.

The San Juan Mountains, from which most of the surface-water supply of the division comes, are composed chiefly of volcanic rocks of Tertiary age. In these mountains are also older rocks of Precambrian age and sedimentary rocks of the Paleozoic, Mesozoic, and Cenozoic Eras.

In other parts of the division the rocks are chiefly of sedimentary origin and range in age from late Paleozoic to Recent. South of the San Juan Mountains in New Mexico, the San Juan River basin is underlain mostly by sedimentary rocks of Cretaceous and Tertiary ages. Westward from New Mexico the basin is underlain by rocks of Permian, Triassic, and Jurassic ages. The remainder of the division to the west is also underlain by sedimentary rocks of similar ages. In addition, there are sedimentary rocks of Cretaceous age and igneous rocks of Tertiary age.

The outcrop areas of rock formations in the division have been classified into eight groups in each of which the hydrologic properties are generally similar. (See chap. A, table 1 and pl. 2.)

Hunt (1956, p. 2), in describing the Canyon Lands section of the San Juan division, which encompasses most of the division west of the Mancos River and north of the San Juan River, where the surface is generally 5,000 to 7,000 feet above sea level, said:

> This area has been epeirogenically upwarped, and on top of the upwarp are several huge folds. Throughout this area the drainage is deeply incised in canyons in the pre-Tertiary rocks. Geomorphic features of the area are the elevated plateaus on the upfolds, hogbacks on their flanks, lower plateaus between the upfolds, laccolithic mountains rising above the plateau surfaces, and an intricate set of deep canyons. Among the unusual geomorphic features are the natural bridges and the related alcove arches that provide huge shelters along the canyon walls.

South of the San Juan Mountains, in the eastern part of the division and south of the San Juan River west of the Mancos River, is the Navajo section of the Colorado River Plateau (Hunt, 1956, p. 2). The greater part of the San Juan basin is in this section, which according to Hunt is

> about as high as the Canyon Lands but much less dissected—it is an area of mesas and broad open valleys. The formations are similar to those in the Canyon Lands section, but they have been less folded. Locally, the drainage is deeply incised into the rocks, but examples are few as compared with the Canyon Lands section.

The stream valleys and canyons of the Colorado River, the San Juan River, and their tributaries give evidence of the effect of the rocks and structural features on the stream patterns. Hunt (1956, p. 67–71) believed that superposition or anteposition of the drainage patterns, or a combination of the two, occurred at least twice in the histories of the streams.

The courses of the Dirty Devil and one of its principal tributaries, the Fremont River, were evidently shifted northward by the doming of the Henry Mountains resulting from igneous intrusion.

The Escalante and Paria Rivers cut across uplifts in their courses and were probably at least partly superposed from younger rocks that once covered the upwarps.

The courses of the San Juan and Colorado Rivers in this division are anomalous in that both streams cross upwarps in their paths. Hunt (1956, p. 71), in his discussion of the seeming lack of any regard by some of the streams for uplifts in their paths, said:

> The relationship, or lack of relationship, of the Colorado River to the epeirogenic or regional structure of the plateau as a whole is anomalous and seems to be that of an antecedent or anteposed stream. The plateau tilts northeastward, and the Colorado and Green Rivers enter it at the Uinta Basin, which structurally is the lowest part of the plateau. From here, the rivers flow southwestward onto the epeirogenic platform in southeastern Utah and northeastern Arizona. At Grand Canyon, the Colorado River flows across one of the structurally highest parts of the rim of the plateau. This relationship is not that of a superposed stream, unless it is postulated that virtually the entire Colorado River Plateau, and all the ranges crossing the lower Colorado River, are exhumed. It seems more likely that the river's course is partly the result of antecedence and partly the result of anteposition dating from an early stage in the epeirogenic upwarp of the plateau.

The San Juan River, by far the largest tributary to the Colorado River in the division, rises on the south slopes of the San Juan Mountains and flows westward to its junction with the Colorado River. Major tributaries of the San Juan River are the Navajo, Piedra, Los Pinos, and Animas Rivers which also rise in the San Juan Mountains, and the La Plata and Mancos Rivers which rise in the La Plata Mountains. These headwater streams are all perennial and produce the major part of the water supply in the division.

South of the San Juan River, the region is dominated by desert topography characterized by buttes and mesas and broad dry washes which contain water only when the infrequent thunderstorms are of sufficient magnitude to cause surface runoff. These stormflows are heavily laden with sediment. Major streams draining this area are Canyon Largo, the Chaco River, and Chinle Wash.

Below Chinle Wash, the San Juan River flows through a deep canyon, and the small tributaries that enter the river also flow through deep canyons before reaching the main stream. The channels of the small tributaries are dry much of the time but become silt-laden torrents after intense thunderstorms, which occur infrequently.

The Colorado River below the mouth of the Green River is entrenched in a deep canyon, and the smaller tributaries entering the river have the same characteristics as those of the lower San Juan River. The larger tributaries—the Dirty Devil, Escalante, and Paria Rivers—also flow through deep canyons before reaching the main river. Though the headwaters of these tributaries are in high plateaus where melting snow produces most of their water supply, the lower reaches of the stream channels are dry at times. Infrequent but intense thundershowers cause flash floods laden with sediment.

SOILS

Except for small areas of alluvium along the streams and valley alluvium in the Little Navajo and Navajo River basins and in an area between the Animas and Los Pinos Rivers southeast of Durango, Colo., the unconsolidated mantle in the San Juan division is principally residuum developed by weathering of the underlying rocks. Because of the arid climate of much of the subbasin, the residuum is relatively thin and soils are poorly developed. These soils and the underlying residuum retain many of the geochemical characteristics of the parent rocks. Generally, where the underlying rock is shale, a relatively impermeable residuum has developed that is high in soluble minerals. Where the parent rock is sandstone the residuum is permeable and low in soluble minerals.

The valley alluvium (pl. 2) in the Little Navajo and Navajo River basins and in the area between the Animas and Los Pinos Rivers in Colorado is generally permeable and low in soluble minerals. The river alluvium along the streams draining the south slopes of the San Juan and La Plata Mountains is also generally permeable and low in soluble minerals. However, in the lower reaches of some of these streams and along the San Juan River below Rosa, N. Mex., where the underlying rocks are the Mancos Shale and rocks of Tertiary age, the river alluvium contains relatively large amounts of soluble minerals.

River alluvium along the streams draining the mountainous areas north of the Colorado River in the western part of the division is closely related to the underlying rocks. For the most part these rocks, and the alluvium derived from them, contain an abundance of soluble minerals.

CLIMATE

EFFECT OF TOPOGRAPHY AND ALTITUDE

The climate of the San Juan division ranges from extremes of high precipitation and low temperatures in the San Juan Mountains to scant precipitation and high summer temperatures at the lower altitudes. The major part of the basin is less than 6,000 feet in altitude and receives less than 8 inches of precipitation annually.

Airmasses from the Gulf of Mexico and, at times, from the Pacific Ocean predominate over the subbasin. The uplands forming the southern boundary are lower than those along most of the northern boundary and allow these airmasses to move from the south across the basin. In the eastern part of the basin, where the moisture-laden airmasses are lifted along the San Juan Mountains, precipitation is copious, especially at the higher altitudes. Thunderstorms over the large area of relatively low altitude in the arid part of the subbasin, where temperatures are high during the summer, cause infrequent downpours of high intensity.

Comparison of figure 125 with plate 8 demonstrates the effect of topography on the distribution of annual precipitation.

PRECIPITATION

Snow at the higher altitudes is the principal source of water supply for the division. The average annual precipitation generally ranges from 60 inches in some parts of the San Juan Mountains to 6 inches in the desert areas (pl. 8). Monthly distributions of precipitation at representative stations are shown in figure 126. In contrast to most of the rest of the Upper Colorado River Basin, the monthly precipitation during the summer is greater than that during other seasons.

The distribution of average annual precipitation over the division is shown in plate 8. This map—which is adjusted for topography, exposure to airmass movements, and climatic factors—is based on precipitation data observed during calendar years 1921–50. The average annual precipitation for this period as planimetered from the map is 12.72 inches. The following tabulation shows the areal distribution of precipitation over the 38,300 square miles of drainage area:

Precipitaton range (inches)	*Area (sq mi)*	*Precipitation range (inches)*	*Area (sq mi)*
60–70	31	16–20	3, 229
50–60	213	12–16	7, 108
40–50	627	10–12	6, 719
30–40	903	8–10	8, 029
25–30	745	6–8	8, 017
20–25	1, 132	4–6	1, 547

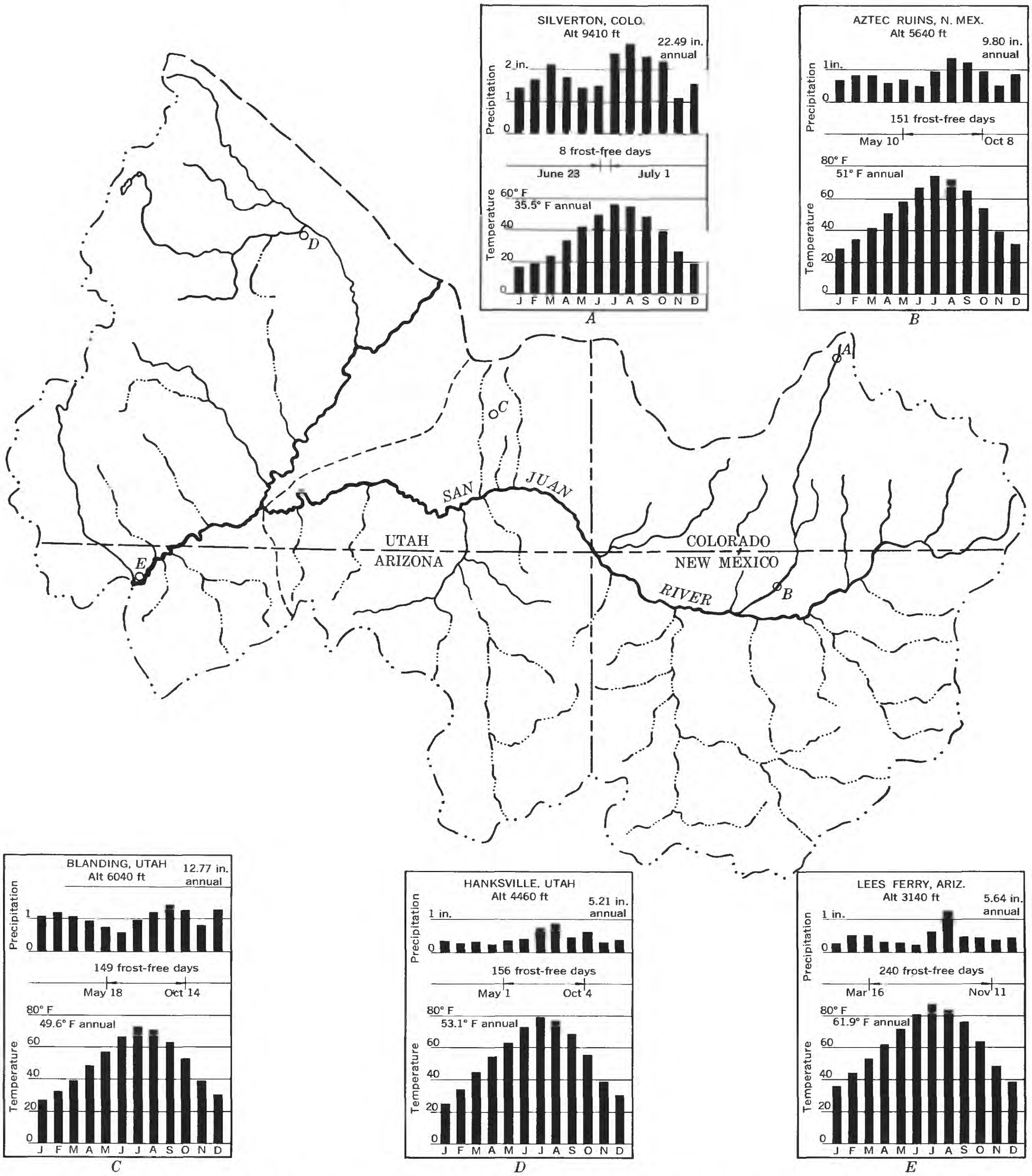

Figure 126.—Normal precipitation and temperature and frost-free seasons at representative stations in the San Juan division. Data from U.S. Weather Bureau normals (average for calendar years 1921–50).

For computing precipitation data applicable to the base period adopted for this study and for other periods, 13 index stations in or adjacent to the division were selected (tables 1 and 2, pl. 8). As explained in chapter B (pp. 44–45), precipitation records at the index stations were used to compute the average annual precipitation over the division, which for the 44-year base period was 12.67 inches, for a total of 25,880,600 acre-feet.

The greatest precipitation was 20.78 inches in 1941 and the least was 6.91 inches in 1956. These were about 64 percent above and 46 percent below the 44-year annual average, respectively. As indicated by the annual quantities, the precipitation over the division was generally above average from 1914 to 1929, below average from 1930 to 1940, above average from 1942 to 1949, and considerably below average from 1950 to 1956.

Table 2 is subdivided to include index stations applicable to the San Juan River basin and to the remainder of the division. Index stations for the San Juan River basin are applicable to the drainage area above the gaging station on San Juan River near Bluff, Utah. The average annual precipitation for the drainage area above this gaging station (23,000 sq mi) adjusted to water years 1914–57 is 13.75 inches, or 16,866,700 acre-feet.

TEMPERATURE AND EVAPORATION

The average monthly temperatures and length of frost-free season at five locations in the division are shown in figure 126. Comparison of the annual precipitation, temperature, and frost-free season at Lees Ferry, Ariz., with those at Silverton, Colo., shows the wide range of climate.

Isopleths of average annual evaporation, from a map by Kohler and others (1959, pl. 2), are shown in plate 8. The isopleths are generalized and do not take into account large variations in topography and exposure which may considerably influence evaporation at specific locations.

The average annual evaporation from water surfaces in the San Juan division, estimated by Meyers (1962, p. 71–100), is given in the following tabulation:

	Annual evaporation (acre-ft)
Principal reservoirs and regulated lakes	3, 000
Other lakes over 500 acres	11, 000
Principal streams and canals	68, 000
Small ponds and reservoirs	24, 000
Small streams	19, 000
Total	125, 000

FIGURE 127.—The blackbrush type of native vegetation, 7 miles north of Bluff, Utah. Photograph by F. A. Branson.

VEGETATION

The native species of vegetation in the San Juan division are about the same as those that existed before settlement. In mountainous areas where the climatic environment is favorable, the vegetative growth is lush. The net hydrologic effect of native vegetative cover in these areas has probably changed little in the last hundred years. In the semiarid and arid parts of the division the vegetation is sparse, and there are large areas of barren rock.

Much of the vegetative cover in the arid areas is in a precarious state of existence even at its best, and overgrazing may have resulted in some changes in the hydrologic effect of native vegetation in local areas. However, runoff data from the arid parts of the division are not sufficient to identify any resulting hydrologic change in water years 1914–57.

The most important plant communities in the area are the alpine meadow, subalpine forest, montane forest, mountain brush, pinyon-juniper, shadscale, black-

FIGURE 128.—Grasslands with mixed shrubs near the headwaters of the Chaco River. Photograph by D. A. Phoenix.

FIGURE 129.—The sparse vegetation and barren character of large areas in the western part of the San Juan division is illustrated by this view of the Bullfrog Creek valley at Eggnog, Utah, with Mount Hilliers in the background. Photograph by D. A. Phoenix.

brush, greasewood, grassland, and big sagebrush communities. The general zones of occurence of these communities are shown in plate 9, and the plant species in the communities are described in chapter C, pages 80–81. Vegetation that is typical of some of the zones is shown in figures 127–129.

SAN JUAN RIVER BASIN

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Twelve reservoirs that have usable storage capacities greater than 1,000 acre-feet have been constructed (1957) in the San Juan River basin (table 3, and pl. 8). Of these, 11 are for irrigation and 1 is for the generation of hydroelectric power. All receive their water supply from the drainage basin in which they are located except the Summit and Narraguinnep Reservoirs, for which the water supply is diverted from the Dolores River and Lost Canyon Creek in the Grand division.

In addition to the reservoirs listed in table 3, many small lakes, reservoirs, and stock ponds are scattered throughout the basin.

TRANSMOUNTAIN DIVERSIONS

Five small ditches divert water from headwaters of the San Juan River to the Rio Grande basin (table 4). The Treasure Pass ditch began diverting water in 1923, the Fuchs and Raber-Lohr ditches in 1937, the Squaw Pass ditch in 1938, and the Piedra Pass ditch in 1939. The average annual diversion by these ditches for water years 1948–57 was 2,754 acre-feet. For the purpose of the report, this average is assumed to be representative of the water supply for water years 1914–57 and of developments existing in 1957.

Water is imported into the McElmo Creek drainage basin from the Dolores River basin for the irrigation of about 37,000 acres. No records are available on the amount of water imported, but it has been estimated to average about 100,000 acre-feet annually (U.S. Dept. of the Interior, 1947, p. 128). These diversions were in operation before 1914.

IRRIGATION

Table 5 gives the approximate irrigated acreage in various drainage basins and reaches of the stream system in the San Juan River basin. Location of the irrigated lands is shown in plate 9. Generally, the streams draining the San Juan and La Plata Mountains furnish an adequate water supply for the irrigated lands dependent upon them. Supplies are deficient for much of the irrigated lands south of the San Juan River and lands along Montezuma and Recapture Creeks.

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 average annual consumptive use of water in the subbasin due to irrigation was 256,617 acre-feet. The Commission estimated that 189,900 acres was irrigated and that 24,962 acres received water incidental to irrigation practices.

DOMESTIC AND INDUSTRIAL USES

The San Juan River basin has a drainage area of about 24,900 square miles and had a population of about 100,000 in 1960. The two largest communities and their populations are Farmington, N. Mex., 23,786, and Durango, Colo., 10,530. Farming, stockraising, petroleum production, and tourist trade are the principal occupations.

The major industrial use of water in the basin is for the production of hydroelectirc power at the following sites:

Location of powerplant	*Installed capacity (kw)*
San Juan River at Pagosa Springs, Colo	150
Animas River near Tacoma, Colo	4, 500
Animas River at Aztec, N. Mex	80
Animas River at Farmington, N. Mex	200
	4, 930

Small amounts of water are used by uranium mills at Durango, Colo., Shiprock, N. Mex., and Mexican Hat, Utah, in their milling processes and by other small industrial plants. The estimated consumptive use of water for domestic and industrial purposes is about 6,700 acre-feet annually.

STREAMFLOW

VARIABILITY OF SEASONAL RUNOFF

In the San Juan River basin precipitation during the summer and fall produces a substantial part of the annual runoff. In marked contrast, summer and fall precipitation are of little consequence in producing runoff in the Grand and Green divisions and the other sub-

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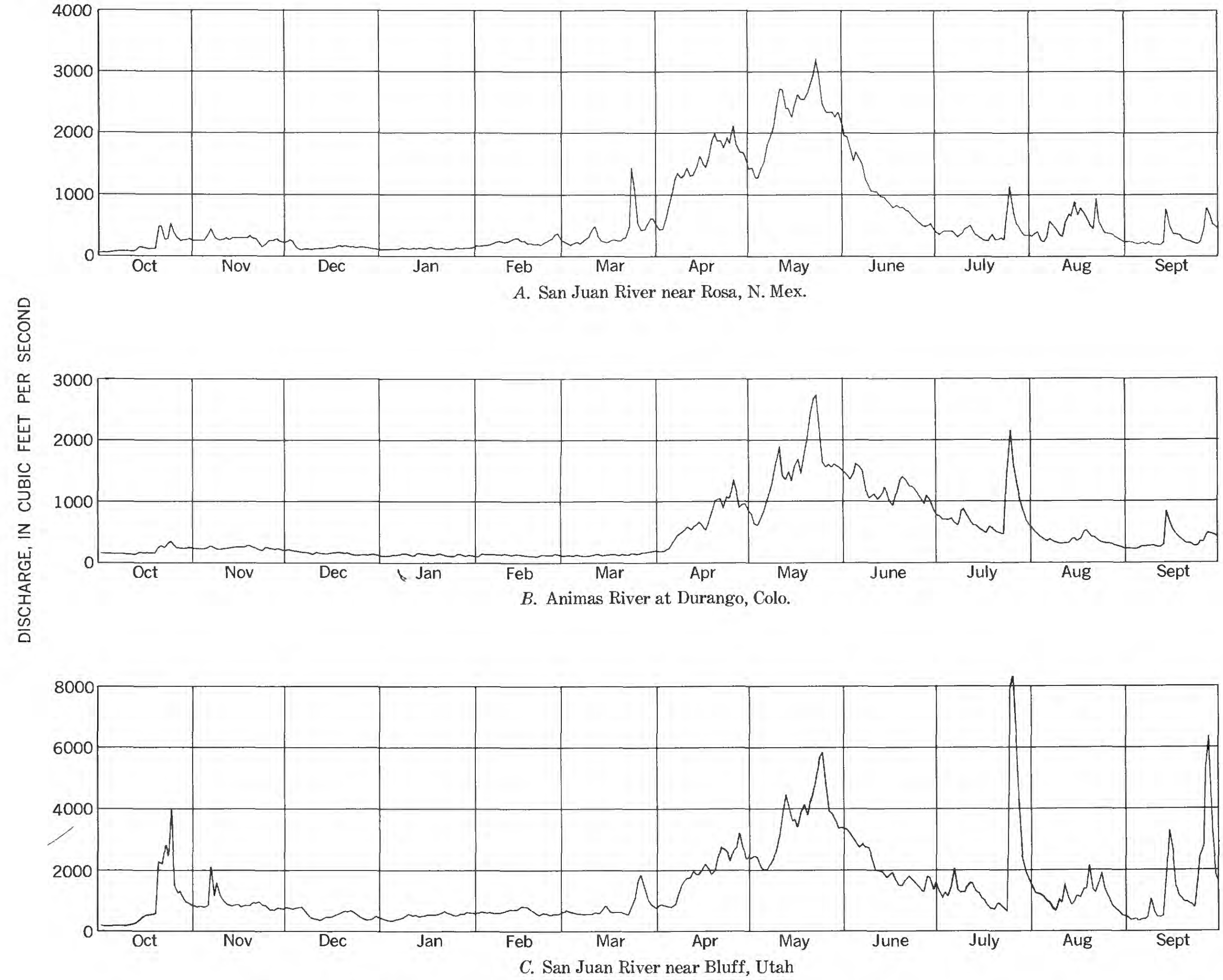


FIGURE 130.—Seasonal pattern of runoff of streams in the San Juan River basin, 1954 water year.

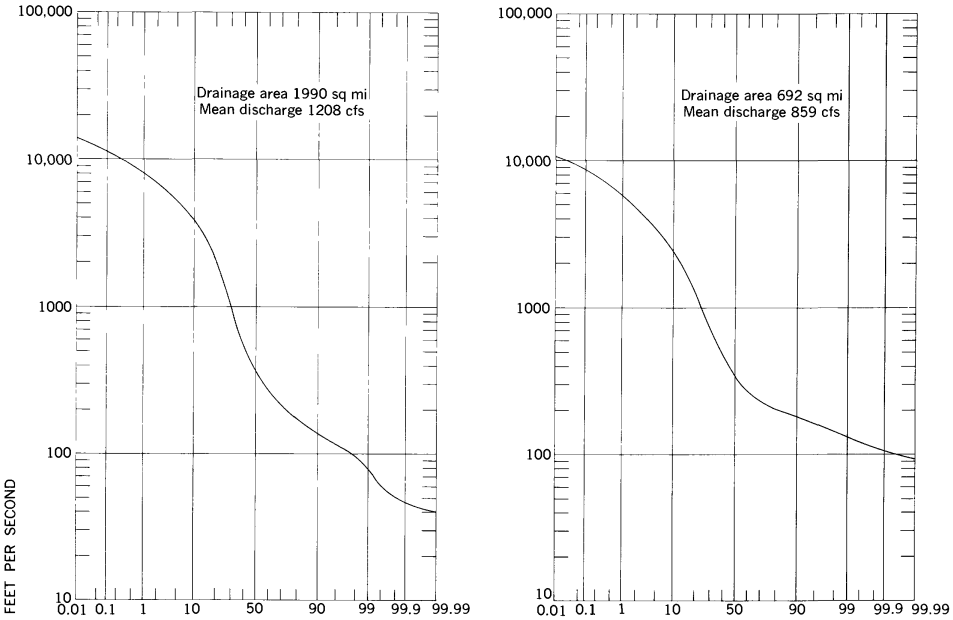
basin of this division. The hydrographs for three gaging stations (fig. 130) illustrate the relative effect of the summer and fall storms on the annual pattern of runoff. Although most of the runoff occurs in April, May, and June from the melting of winter snow in the mountains, the effect of summer and fall storms is very pronounced. These storms are usually of high intensity and, although some cover only small areas, others are of large areal extent. Their occurrence over the large area of sedimentary rocks at the lower altitudes produces much of the sediment carried by the subbasin's streams.

FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at 22 sites in the subbasin. The usefulness of these curves in hydrologic studies, their characteristics, and the methods used to adjust them for short periods of record to the 44-year base period are explained in chapter B (pp. 46–48). By use of these methods, flow-duration curves for all the streams except McElmo Creek near Colorado-Utah State line were adjusted to the 44-year base period and for developments existing in 1957. Only the curves for stations downstream from the Vallecitos Reservoir required adjustment to be representative of 1957 conditions of upstream development. The data for historical and adjusted flow-duration curves are given in table 6.

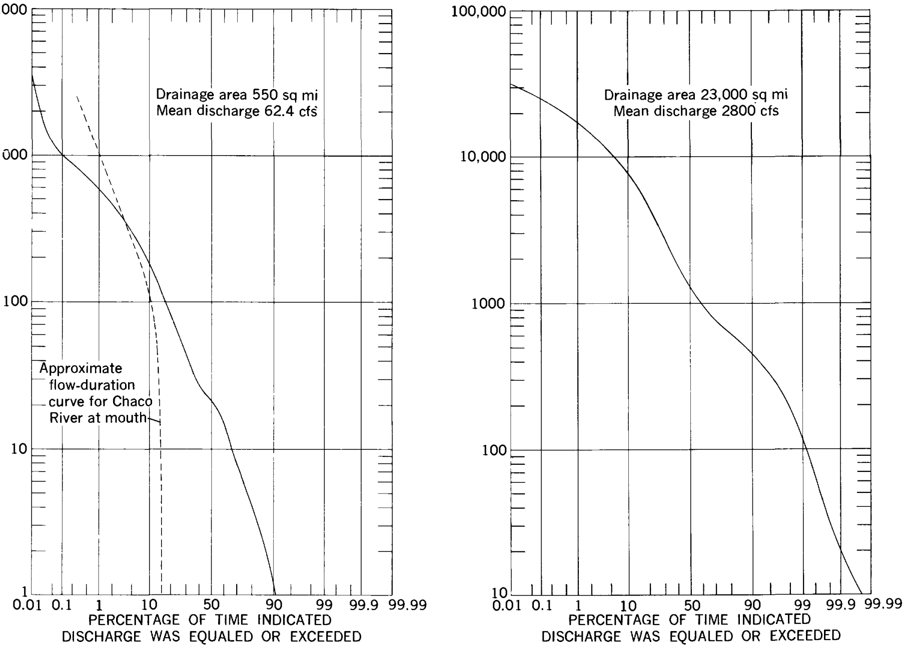
In table 7, the methods used in adjusting the historical flow-duration curves to the 44-year base period and for developments existing in 1957 are outlined. The authors' rating of accuracy of the resultant long-term curves is also given.

Flow-duration curves of streams at four sites are shown in figure 131. The curves for San Juan River at Rosa, N. Mex., and Animas River at Durango, Colo., are generally representative of streams draining the



A. San Juan River at Rosa, N. Mex.

B. Animas River at Durango, Colo.



C. Mancos River at Towaoc, Colo.

D. San Juan River near Bluff, Utah

Figure 131.—Flow-duration curves of streams in the San Juan River basin, water years 1914–57 adjusted to 1957 conditions.

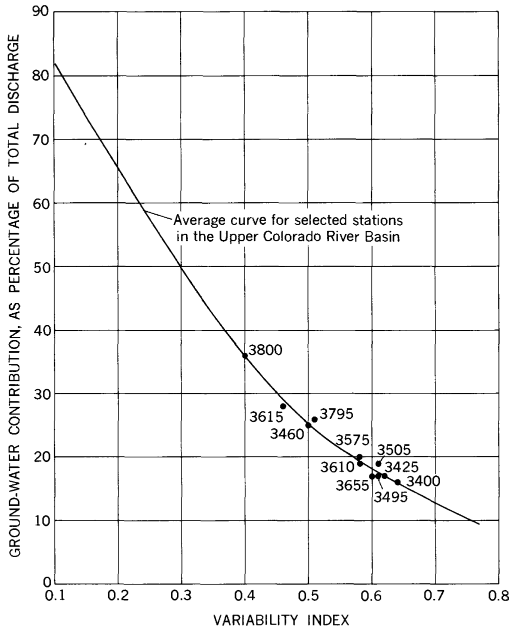


FIGURE 132.—Relation between the variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water for selected stations in the San Juan division, water years 1914–57 adjusted to 1957 conditions.

north side of the basin upstream from the La Plata River. The curve for Mancos River at Towaoc, Colo., is representative of streams whose drainage areas are mostly arid but have some mountains in the headwaters.

No streamflow data are available on the streams draining the southern part of the basin. However, on the basis of studies of storm runoff for Mancos River at Towaoc, Colo., and probable relation of average annual discharges, an approximate flow-duration curve for the Chaco River was developed (fig. 131*C*). This curve was prepared only to illustrate the most likely shape of the flow-duration curves for streams draining the southern and western parts of the subbasin. These streams are usually dry and flow only as a result of heavy storms.

The variability indices (Lane and Lei, 1950) and percentages of ground-water contribution to stream systems (see chap. B, pp. 48–53) were computed for selected streams in the subbasin (table 8). In general, there is an inverse relation between the two parameters (fig. 132). The average curve is based on selected streams in the Upper Colorado River Basin.

The headwaters of the San Juan, Piedra, and Animas Rivers are underlain mostly by Tertiary volcanics that have been highly altered, are clay rich, and are relatively impermeable. However, extensive outcrops of flow breccia and tuff in the headwater areas of the Animas River are probably responsible for the slightly lower variability index for Animas River at Howardsville, Colo., than for San Juan River near Pagosa Springs, Colo., and Piedra River near Piedra, Colo. The headwaters of the La Plata River are underlain by intrusive igneous rocks of Tertiary age and rocks of Permian and Pennsylvanian ages, and Hermosa Creek is underlain almost entirely by rocks of Permian and Pennsylvanian ages. These rocks are fairly impermeable.

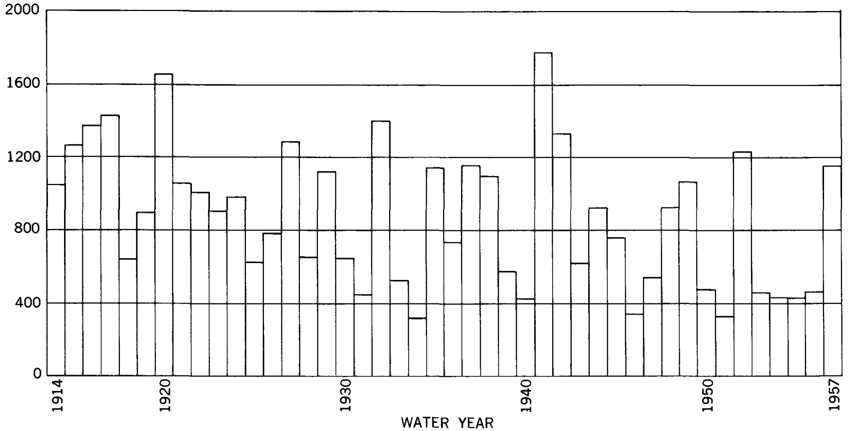
Extensive areas of valley alluvium underlie part of the drainage area above the gaging station on Navajo River at Edith, Colo. Ground-water storage in the alluvium is probably the cause of the lower variability index for this stream and greater percentage of ground-water contribution. Valley alluvium, irrigation, and regulation by the Electra Reservoir probably cause the relatively low variability index for Animas River at Durango, Colo.

VARIABILITY OF ANNUAL RUNOFF

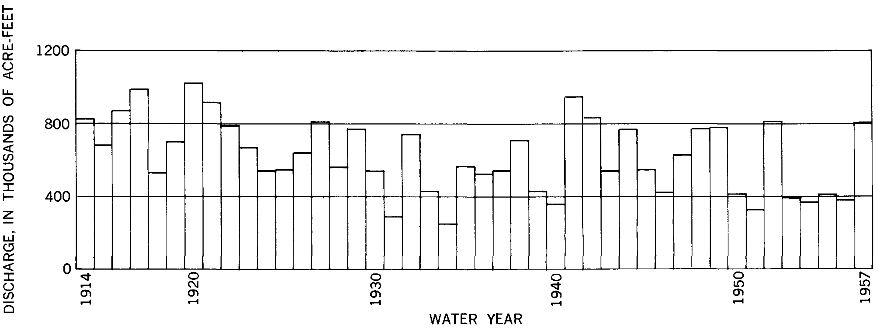
The annual water discharges adjusted for upstream transmountain diversions and reservoir regulation (Vallecitos Reservoir only) at three gaging stations in the San Juan River basin are shown in figure 133. The water discharge of San Juan River at Rosa, N. Mex., for water years 1914–20, is the sum of records of stations on Piedra and San Juan Rivers at and near Arboles, Colo. The record for San Juan River near Bluff, Utah, is estimated for water years 1914 and 1918–27.

The coefficients of variation of annual discharges at eight gaging stations in the basin are given in table 9. The coefficients for all stations have a relatively small range except those for the Animas and Mancos Rivers. Ground-water storage in the Animas River basin may be extensive enough to provide carryover from wet to dry years. The record for Mancos River near Towaoc, Colo., reflects storm runoff, which is much more variable than snowmelt runoff. The higher coefficients for San Juan River at Farmington, N. Mex., and near Bluff, Utah, are probably the result of storm runoff from large areas in the lower part of the subbasin.

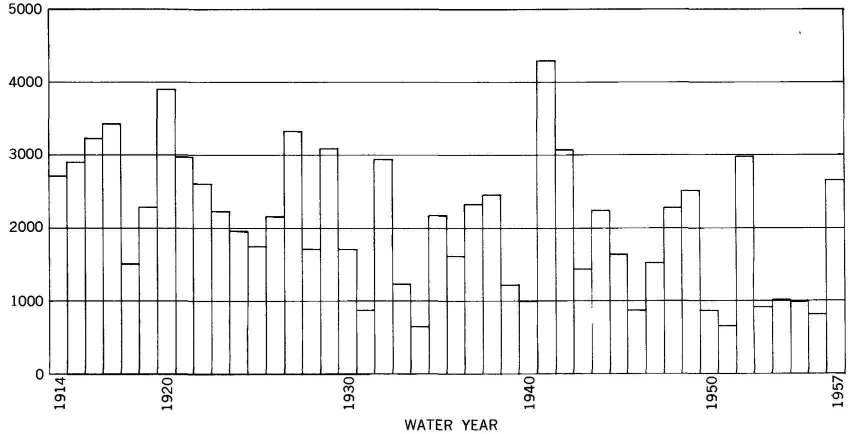
On the assumption that the average annual discharge and coefficients of variation of the stations listed in table 9 are representative of the 44-year base period, the data may be used for estimating probable future streamflow for periods of various length and confidence limits as explained in chapter B (pp. 57–58). The water-discharge data for Navajo River at Edith, Colo., may be used as an example. The computed average discharge



A. San Juan River at Rosa, N. Mex.



B. Animas River at Durango, Colo.



C. San Juan River near Bluff, Utah

FIGURE 133.—Variability of annual discharges of streams in the San Juan River basin, water years 1914–57.

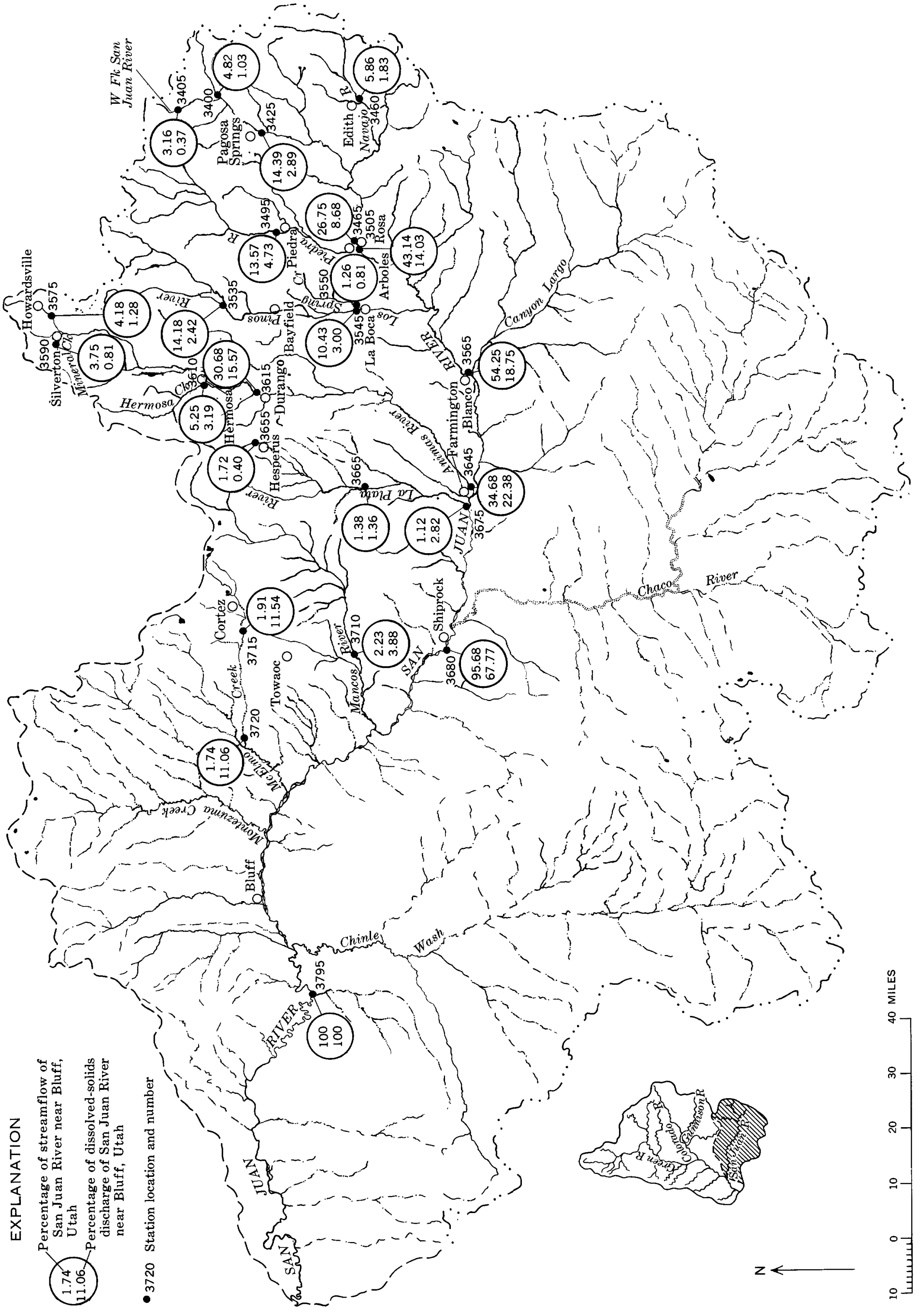


FIGURE 134.—Approximate dissolved-solids discharge and streamflow expressed as percentages of the dissolved-solids discharge and streamflow of San Juan River near Bluff, Utah.

at Edith for the water years 1914–57 is 165 cfs (cubic feet per second) and the coefficient of variation is 0.39. The probable deviations of average discharge for various periods in the future from the computed 44-year average for a 50-percent chance are given in the following tabulation:

Period of years	*Probable deviation, in cubic feet per second, from observed average annual discharge*	*Period of years*	*Probable deviation, in cubic feet per second, from observed average annual discharge*
1	±43	10	±24
2	±37	20	±19
4	±31	44	±17

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at six stations in the San Juan River basin. Monthly and annual weighted-average chemical analyses of water at these stations are given in the basic data report (Iorns and others, 1964, tables 211–216). The records for San Juan River near Archuleta, N. Mex., and San Juan River near Blanco, N. Mex., are equivalent. In addition to the daily data, chemical analyses of streams at other sites in the subbasin have been obtained. The dissolved-solids discharges for the daily stations and for some of the other sites have been computed (table 10). The quantities given in table 10 are averages that would have occurred if the developments in 1957 had existed throughout water years 1914–57.

Duration tables of dissolved-solids concentration and discharge for the stations listed in table 10 are given in tables 11 and 12. In computing these tables the analyses of water samples, water discharge at the time of sampling, curves showing relation of dissolved-solids concentration to water discharge, and flow-duration curves of water discharge were used. The methods used to compute the data are described in chapter B (pp. 58–59).

The concentrations of dissolved solids in the headwater streams listed in table 10 are less than 100 ppm except for Hermosa Creek near Hermosa, Colo., where the water has a weighted-average concentration of 219 ppm. The concentration of dissolved solids in many of the tributaries that drain the south slopes of the San Juan Mountains increases greatly in the lower reaches.

Computed dissolved-solids discharges for seven sites on the San Juan River show that the average dissolved-solids discharge increases from 28 tons per day near Pagosa Springs, Colo., to 2,730 tons per day near Bluff, Utah (table 10). In the same reach the dissolved solids carried by the river per unit of drainage area decreased from 118 to 43 tons per square mile. The decrease in dissolved-solids yield downstream is the result of a decrease in runoff per square mile and an increase in the size of the drainage basin.

The average annual discharges of dissolved solids and water in San Juan River near Bluff, Utah, was used as a base to compute the contribution (in percent) of dissolved solids and water from other parts of the basin (fig. 134). The data in figure 134 indicate that most of the water comes from the San Juan Mountains and most of the dissolved solids comes from areas downstream from the mountains. Almost 90 percent of the water comes from less than 20 percent of the total area of the San Juan River basin.

VARIATIONS IN CHEMICAL QUALITY

The seasonal variation in dissolved-solids concentration of San Juan River near Bluff, Utah, is large (fig. 135). Other streams whose major source of water supply is snowmelt have a similar pattern, but the variation is much less near their headwaters.

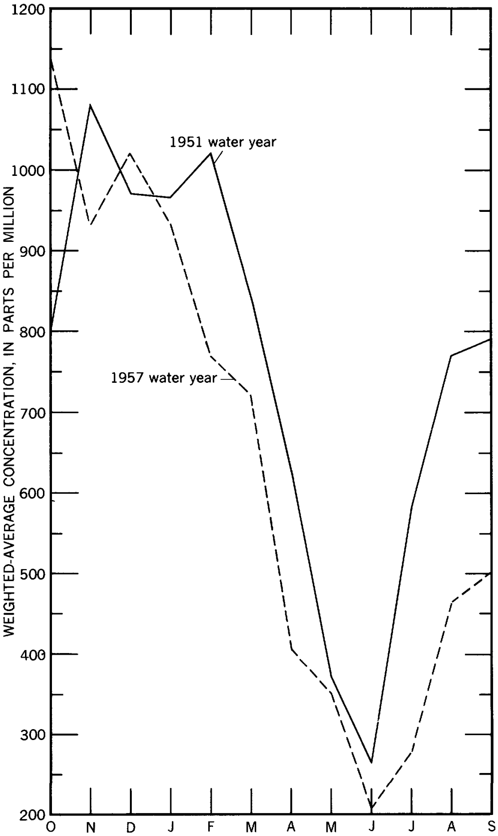


FIGURE 135.—Dissolved-solids concentration of San Juan River near Bluff, Utah, for the 1951 and 1957 water years.

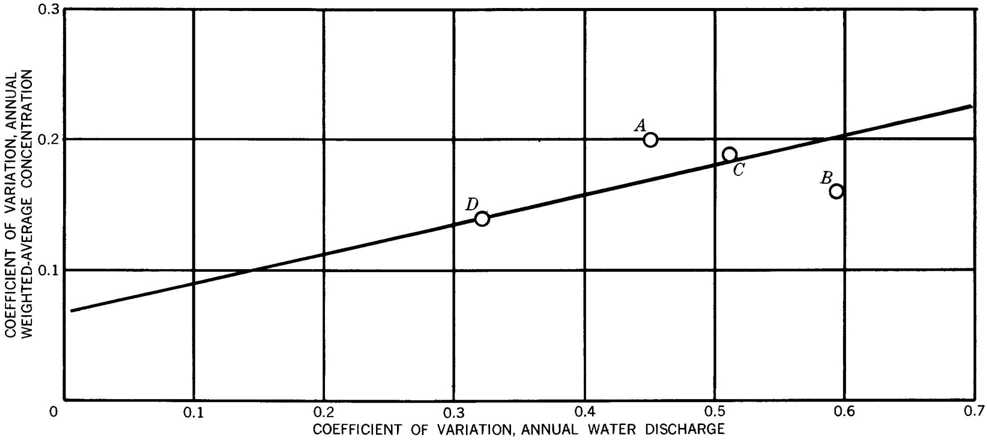


FIGURE 136.—Relation of the variability of dissolved-solids concentration to the variability of water discharge in the San Juan division. *A*, Animas River at Farmington, N. Mex.; *B*, San Juan River near Blanco, N. Mex.; *C*, San Juan River near Bluff, Utah; *D*, Colorado River at Lees Ferry, Ariz.

The coefficients of variation of annual weighted-average concentrations of dissolved solids and annual historical water discharges were computed for three streams in the San Juan River basin (table 13). (See chap. B, p. 60.) The relations of the coefficients for the three streams and for Colorado River at Lees Ferry, Ariz., are shown in figure 136. The correlation between the coefficients is not as reliable as was found for the other two divisions. However, the equation of a straight line (least-squares method) averaging the four points in figure 136 is:

$$V_d = 0.22V_w + 0.07,$$

where V_d is the coefficient of variation of weighted-average annual concentration of dissolved solids, and V_w is the coefficient of variation of annual stream discharges.

The poor correlation may be due to large additions of dissolved solids by runoff in the arid parts of the basin from infrequent thunderstorms, which contribute only a relatively small amount of water. Also, some of the records may be too short for a reliable statistical analysis.

RELATION TO STREAMFLOW

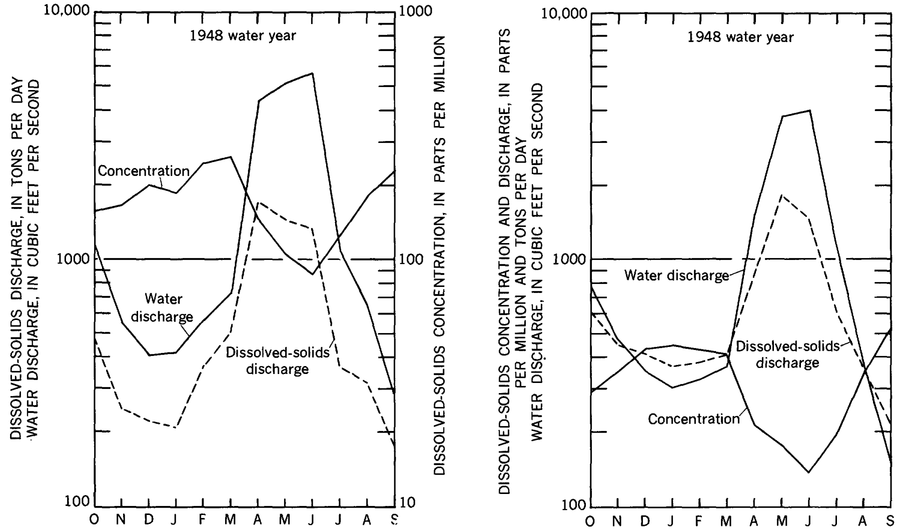
The patterns of relation between streamflow and dissolved solids at four stations in the San Juan River basin are shown in figure 137. These stations are all at downstream locations, and similar data are not available for headwater streams. However, from meager data obtained in the headwater areas the concentration of dissolved solids in most of the headwater streams probably varies little between low and high discharges.

The relation between the chemical composition of water and streamflow at the four stations is given in table 14 and illustrated in figure 138 for low, median, and high discharges. The waters of the streams, especially at downstream sites, have a different chemical composition during high flows than during low flows. The water of the San Juan River and its principal tributaries changes from the calcium bicarbonate type during high flows to the calcium sulfate type during median and low flows.

RELATION TO GEOLOGY

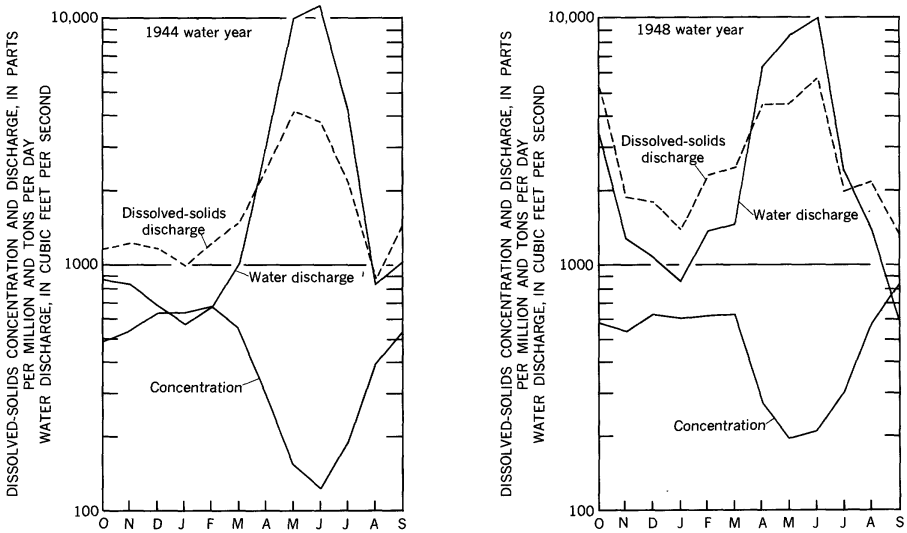
The headwaters of the principal tributaries of the San Juan River above Farmington, N. Mex., are in the San Juan Mountains. Near the Continental Divide and the divide between the San Juan and Gunnison River basins, the rocks are mostly volcanic rocks of Tertiary age. In the Animas and Los Pinos River basins, large areas are underlain by igneous and metamorphic rocks of Precambrian age. In the upper reaches of the Piedra and Navajo River basins and in the San Juan River basin above Pagosa Springs, Colo., large areas are underlain by sedimentary rocks of Cretaceous and older ages. The midreaches of the Animas and Los Pinos Rivers also are underlain by similar rocks. The lower reaches of all these tributaries except the Navajo River are underlain mostly by rocks of Tertiary and Quaternary ages.

The waters of the Los Pinos, Piedra, Navajo, and East and West Forks San Juan River in their upper reaches are of the calcium bicarbonate type, and the weighted-average concentration of dissolved solids is



A. San Juan River near Blanco, N. Mex.

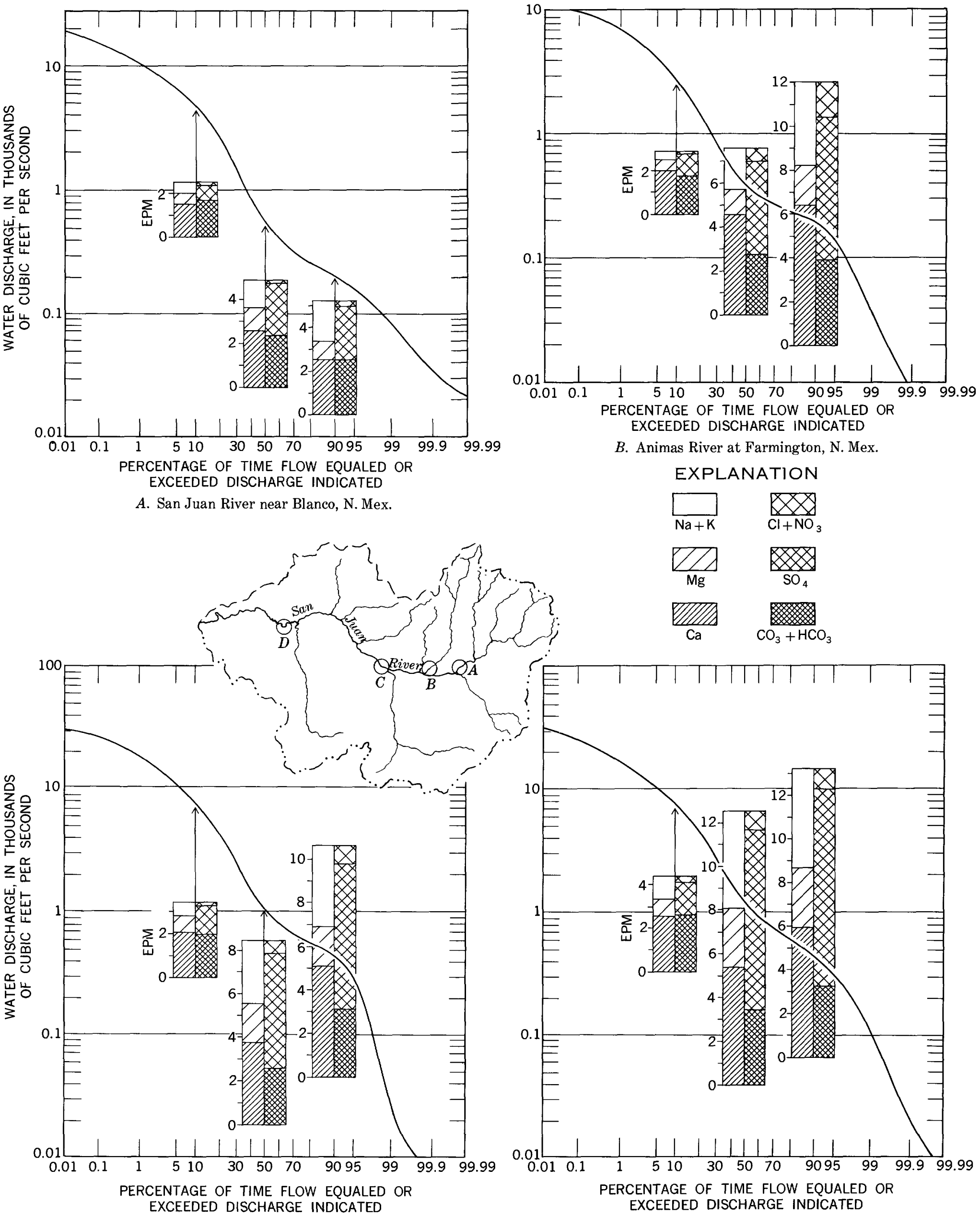
B. Animas River at Farmington, N. Mex.



C. San Juan River at Shiprock, N. Mex.

D. San Juan River near Bluff, Utah

FIGURE 137.—Dissolved-solids concentration and discharge, and water discharge at four daily stations in the San Juan River basin.



A. San Juan River near Blanco, N. Mex.

B. Animas River at Farmington, N. Mex.

C. San Juan River at Shiprock, N. Mex.

D. San Juan River near Bluff, Utah

FIGURE 138.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the San Juan River basin. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for water years 1914–57 adjusted to 1957 conditions.

low. In their middle and lower reaches, especially downstream from irrigated fields, the streams contain progressively more magnesium, sodium, and sulfate ions.

The waters of the Animas River differ from those of the other streams that drain the San Juan Mountains in that, even in the headwaters of the Animas River, calcium sulfate waters predominate, except during high flows in the spring. Most of the headwaters of the Animas River are underlain by the Silverton Volcanic Group, and calcium sulfate water from an area underlain by volcanic rocks is unusual. One possible explanation for the anomaly is that some of the formations in the Silverton Volcanic Group contain beds of limestone and calcareous shale, presumably somewhat gypsiferous. Larsen and Cross (1956, p. 79) said:

> A variable amount of fine-grained tuffs is usually found at the tops of the Burns quartz latite, especially in the region around the head of the Animas and farther eastward, and they locally reach a thickness of several hundred feet. Commonly these tuffs are similar to those of the lower horizon, but in places the upper 50 feet or more is made up of calcareous shales and thin beds of limestone. Plant remains and gastropod shells are present in the uppermost parts of these beds.

The tributaries of the San Juan River from the south between the Animas and Navajo Rivers are underlain by sedimentary rocks of Tertiary age. Only one sample of surface water from this large area has been collected. The analysis of this sample, from the drainage basin of Canyon Largo, suggests that water coming from this area would be of the sodium sulfate type and also would contain a large percentage of calcium and bicarbonate.

The next large tributary of the San Juan River from the south, west of Canyon Largo, is the Chaco River, whose drainage basin is underlain chiefly by sedimentary rocks of Cretaceous age. Analyses of samples collected in the headwaters of the Chaco River indicate that its waters would be of the sodium sulfate type, similar to waters in the Canyon Largo basin.

The La Plata River, which flows into the San Juan River a short distance below the mouth of the Animas River, rises in the La Plata Mountains, which are composed of igneous intrusives and sedimentary rocks of Late Permian and Pennsylvanian ages. In the La Plata Mountains the water of the La Plata River is of the calcium bicarbonate type at all flows. Between Hesperus, Colo., and the mouth of the La Plata River, large areas underlain by the Mesaverde Group of Cretaceous age are irrigated (pl. 9), and the return flow from irrigated fields is partly responsible for the high dissolved-solids concentration of the river water during and after the irrigation season. At these times the water is either of the sodium or of the calcium sulfate type.

The Mancos River drainage basin is underlain chiefly by sedimentary rocks of the Mesaverde Group, Mancos Shale, and other rocks of Cretaceous age. During high flows in the spring the water of the Mancos River is of the calcium bicarbonate type, during low flows in August through October the water is influenced by irrigation return flows and contains large percentages of magnesium and sulfate. Near Towaoc, Colo., which is downstream from about 10,000 acres of irrigated land, the water is of the calcium sulfate type at most stages of flow.

The drainage basin of McElmo Creek is underlain principally by rocks of Cretaceous age. Soils developed on these rocks are irrigated extensively in the Montezuma irrigation district, which imports water from the Dolores River basin. The water imported and applied to the land is low in dissolved solids—the weighted-average concentration being about 125 ppm (parts per million)—and is of the calcium bicarbonate type. At the station near Cortez, Colo., the flow is mainly return water from irrigated lands of Montezuma irrigation district (U.S. Geol. Survey, 1954, p. 516). At most flows, the water at the station has high concentrations of dissolved solids and is of the magnesium sulfate type but has large percentages of calcium and sodium. The weighted-average concentration of dissolved solids at this station for the water years 1914–57 adjusted to 1957 conditions is about 2,200 ppm. At the lowest flows the concentration may exceed 5,000 ppm (table 11).

Montezuma Creek and its tributaries that head in the Abajo Mountains near Monticello, Utah, usually contain less than 200 ppm of dissolved solids, and the waters are of the calcium bicarbonate type. No chemical analyses of the water of Montezuma Creek at its mouth are available. However, the rocks that underlie most of the drainage basin are similar to those in the drainage basins immediately to the west and are mostly of Cretaceous age. The water from the streams to the west, where they enter the San Juan River, contains 1,000 to 3,000 ppm of dissolved solids and is of the calcium sulfate type. The concentration of magnesium and sodium ions in these streams is also high.

The water of San Juan River near Bluff, Utah, is of the calcium sulfate type at all flows except during high flows in the spring, when the water is of the calcium bicarbonate type. The weighted-average analyses of the water for any year at this station indicates that the water is of the calcium sulfate type.

A map of the San Juan River basin, showing zones within which the weighted-average concentration of dissolved solids in waters of the streams is between indicated limits, is shown in figure 139. The zones indicate that the weighted-average concentrations of dissolved solids in the waters of the streams that supply

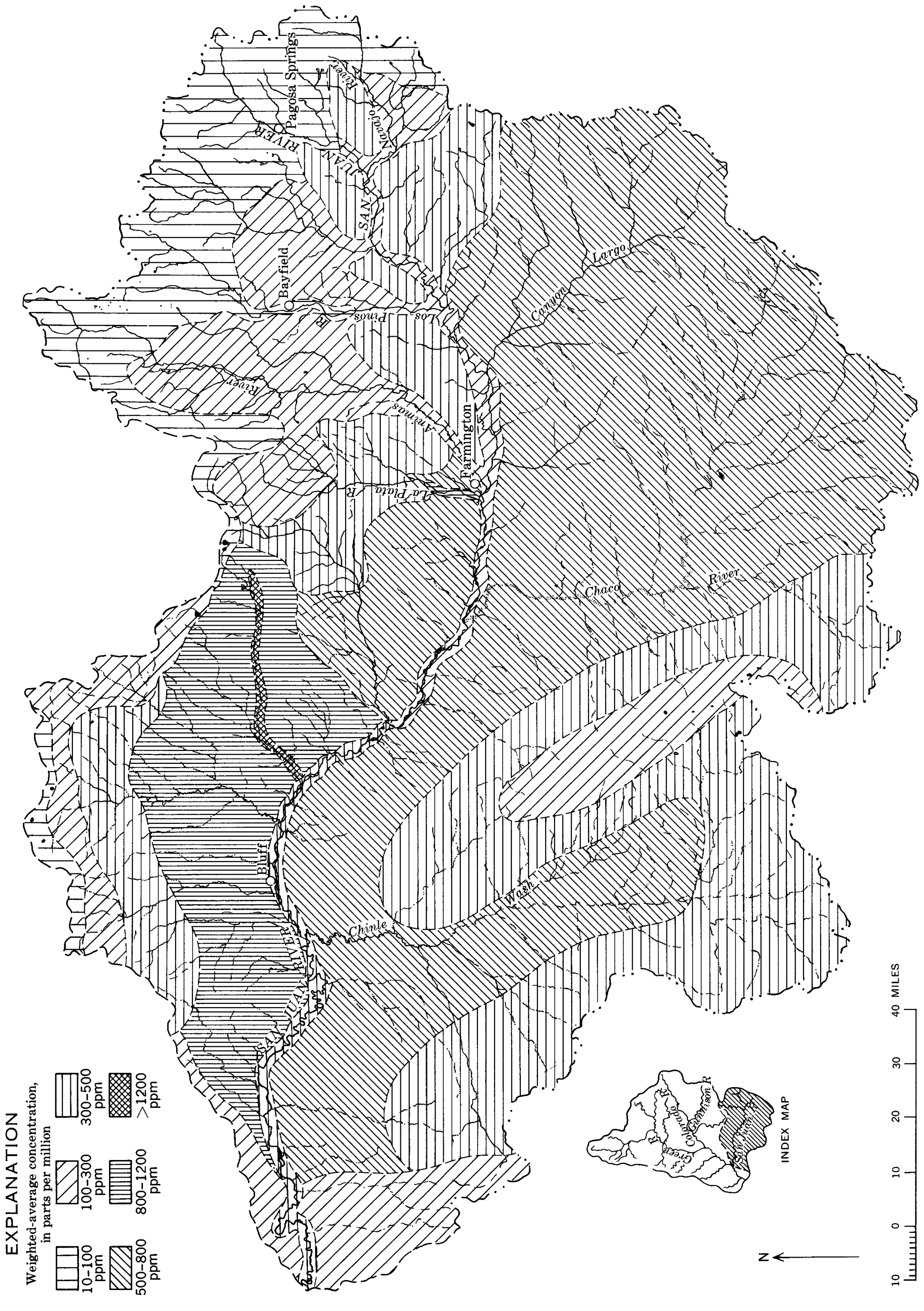


FIGURE 139.—Approximate weighted-average concentration of dissolved solids of streams in the San Juan River basin.

most of the water in the San Juan River basin do not exceed 300 ppm.

The diagrams in plate 2 show the geochemical character and ionic concentration of surface waters at 44 sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flow. The significance of the size and shape of the diagrams is given in the explanation in plate 2.

RELATION TO GROUND WATER

Natural recharge to ground-water reservoirs occurs in the mountainous areas of the basin, where precipitation is abundant. The water discharged from these reservoirs, which maintains the perennial streams during periods of low flow, has a higher concentration of dissolved solids than the water that runs off directly to the streams. Comparison of the weighted-average concentration of dissolved solids in the ground-water contribution to selected headwater streams with weighted-average concentration of the stream water (table 15) indicates the relative effect of ground water in the headwater areas on the chemical quality of water in the streams. (See chap. B, pp. 59–60 for an explanation of the method used in determining the amount of dissolved solids added to the streams by ground water.)

In most of the subbasin the precipitation is low, and very little ground water reaches the streams except from the alluvium along the perennial streams. There, water enters the alluvium chiefly during the high flows in the spring. During low flows, part of this water is returned to the stream. As the water circulates through the alluvium, it picks up additional dissolved solids which increase the concentration in the stream to which it returns. Figure 140 compares the quality

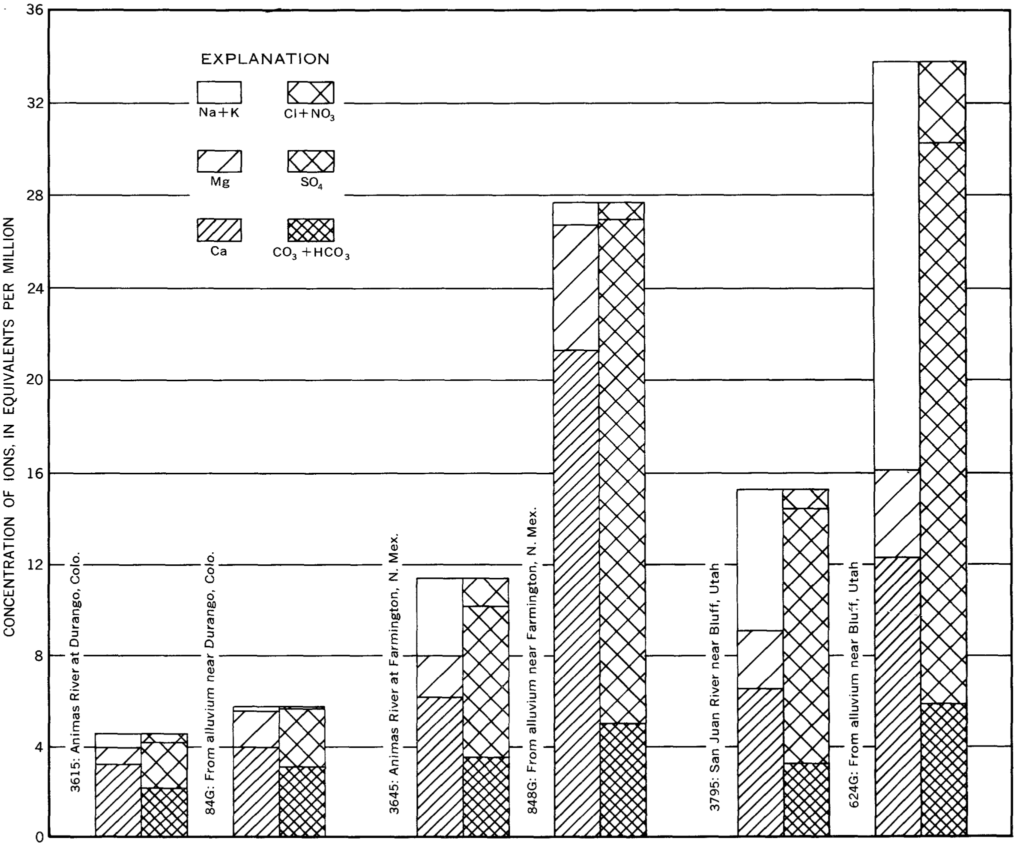


FIGURE 140.—Analyses of water from selected streams in the San Juan River basin and from alluvium nearby.

of the ground water along selected streams with water in the streams nearby during low flows.

In irrigated areas much of the applied water may return to the stream as ground-water inflow. This inflow is usually of poorer quality than the streams and thus adversely affects their quality.

The water from some of the thermal springs in this subbasin has high concentrations of dissolved solids which adversely affect the quality of water in the streams into which it flows. For example, the water entering the San Juan River from the springs at Pagosa Springs, Colo., contains about 3,600 ppm of dissolved solids and is of the sodium sulfate type. The flow is about 2 cfs, and the dissolved-solids discharge to the river thus is about 7,100 tons annually. Five thermal springs, having a total discharge of about 1 cfs and a dissolved-solids concentration of about 4,000 ppm, are known to be in the Animas River basin. The dissolved-solids discharge is about 4,000 tons annually. Other thermal springs, most of which have flows of less than 10 gallons per minute, but whose water is of unknown concentration, are in the basin (Stearns and others, 1937).

EFFECT OF TRANSMOUNTAIN DIVERSIONS

For the water years 1948–57, an average of about 2,750 acre-feet of water per year was diverted from the San Juan River basin to the Rio Grande basin. (See p. 305.) Most of this water was diverted from the headwaters of the Los Pinos River (2,500 acre-ft). These diversions from the San Juan River basin adversely affect the quality of the water downstream in that basin, but the amount diverted is so small that this effect on the quality is negligible. It is estimated that the 2,750 acre-feet of water diverted annually carries only about 260 tons of dissolved solids.

About 100,000 acre-feet of water is imported annually into the San Juan River basin from the Dolores River basin. The weighted-average concentration of dissolved solids of this water is about 125 ppm. The importation adds about 17,000 tons per year of dissolved solids to the McElmo Creek basin. The theoretical effect of this importation would be a decrease in the weighted-average concentration of San Juan River near Bluff, Utah. However, because this water is used for irrigation in the McElmo Creek basin, where the water picks up additional dissolved solids in the irrigated areas, the net effect is to increase the dissolved-solids concentration and discharge of San Juan River near Bluff. Although the importation of 17,000 tons per year of dissolved solids into this subbasin is a result of an activity of man, it is considered in this report to result from a natural source.

If no water were exported from or imported into the San Juan River basin, the theoretical average annual discharge of the river near Bluff, Utah, would be about 97,200 acre-feet (100,000 minus 2,800 acre-ft) less, and the average annual discharge of dissolved solids would be about 16,700 tons (17,000 minus 300 tons) less than the average for the water years 1914–57 adjusted to 1957 conditions. If no water had been imported the weighted-average concentration of dissolved solids of the river near Bluff would theoretically be 373 ppm, an increase of 12 ppm from that during 1957 conditions. In this determination it was assumed that the irrigated lands supplied by water diverted from the Dolores River obtained their supply from sources within the San Juan River basin.

EFFECT OF THE ACTIVITIES OF MAN

In chapter B (pp. 61–66) the effect of the activities of man (domestic, industrial, and irrigation uses) on the dissolved-solids discharge of streams is discussed, and the methods for computing the amount of dissolved solids added to the stream as a result of these uses are described. In chapters C and D (Grand and Green divisions) the amounts of dissolved solids contributed to streams as a result of the activities of man were computed for many areas. In the San Juan River basin, the La Plata River basin is the only area for which sufficient data are available to make similar computations.

In the area between gaging stations on La Plata River at Hasperus, Colo., and at Colorado-New Mexico State line, about 16,500 acres is irrigated on alluvium underlain mostly by the Mesaverde Formation. The consumptive use of water by irrigation in the area is estimated to be about 18,200 acre-feet annually (1.1 acre-ft per acre). An approximate water and dissolved-solids budget for the area is given in table 16.

Data for water and dissolved solids given in table 16 for the stations at Hesperus and at the State line are from table 10 and are rounded to three significant figures. The unmeasured inflow (11,100 acre-ft) is the amount required to balance the inflow-outflow budget. The weighted-average concentration of dissolved solids in the unmeasured inflow is based on Devil Creek near Piedra, Colo., and Stolsteimer Creek near Dyke, Colo. (Iorns and others, 1964, table 225). Drainage areas above these stations are underlain by similar rocks (Mesaverde Group of Cretaceous age), are about the same altitude, and have about the same precipitation as the drainage area of the unmeasured inflow. On the assumption that the dissolved-solids increase is mostly caused by irrigation, the irrigated lands yield about 0.4 tons per year per acre.

Between the gaging stations on La Plata River at Colorado-New Mexico State line and near Farmington, N. Mex., about 9,500 acres is irrigated on alluvium partly underlain by the Mesaverde Formation and partly by rocks of Tertiary age. An approximate water and dissolved-solids budget for the area is given in table 16.

The amount of water consumed by irrigation in the area is based on an annual consumptive use of 1.1 acre-feet per acre. The unmeasured inflow in the intervening area between the two gaging stations is the amount required to balance the inflow-outflow budget. The concentration of dissolved solids in the unmeasured inflow is based mostly on Cox Canyon Creek at Cedar Hill, N. Mex., during low flow (Iorns and others, 1964, table 225). The increase in dissolved solids from other sources in the reach is equivalent to 1.4 tons per year per acre of irrigated land.

In other areas of the San Juan basin for which sufficient data were not available to make similar determinations, calculations indicate that the amount of dissolved solids added to the streams as a result of irrigation ranges from about 0.4 ton to 2.6 tons per acre. Lands underlain by valley alluvium similar to that of irrigated areas in the Los Pinos River basin had the lower rate, and lands underlain by Mancos Shale similar to the irrigated lands along the Mancos River had the higher rate.

In table 17 the estimated amounts of dissolved solids from natural sources and as a result of the activities of man are summarized for three main-stem gaging stations and for the San Juan River basin.

If there had been no activities of man in the subbasin, the weighted-average concentration of dissolved solids of the San Juan River at the gaging station near Bluff, Utah, would have been about 228 ppm as compared with a weighted-average of 361 ppm for water years 1914–57 adjusted to 1957 conditions. In this determination 6,700 acre-feet of water annually was estimated to be used consumptively by domestic and industrial uses and 256,600 acre-feet annually by irrigation.

The increase in dissolved solids due to irrigation in the subbasin is estimated to be about 278,100 tons per year. This estimate is based on 100 tons per year per 1,000 people as the contribution of dissolved solids resulting from domestic and industrial uses of water and on the assumption that the remainder of the dissolved solids attributed to the activities of man was contributed as a result of irrigation.

FLUVIAL SEDIMENT

Daily suspended-sediment records have been obtained at the station on San Juan River near Bluff, Utah, since August 1928. Daily records have also been obtained at six other stations in the basin for shorter periods ranging from 6 months to almost 7 years. Records of suspended-sediment discharge at the seven stations are given in table 18. Suspended-sediment discharges have also been measured on a miscellaneous basis at several other sampling sites.

Estimated suspended-sediment discharges at five of the daily stations and at four other sites in the San Juan River basin for the water years 1914–57 adjusted to 1957 conditions are given in table 19. A large part of the sediment discharged by the river near Bluff probably comes from Canyon Largo, the Chaco River, and Chinle Wash.

During the period of record for the sediment station near Bluff, there have been several changes in the relation of the suspended-sediment discharge to water discharge. During the drought of the 1930's, the annual suspended-sediment concentration near Bluff was greater than during the wetter years of the 1940's.

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classification of the surface water in the San Juan River basin is based on water-quality criteria for major uses. (See chap. B, pp. 66–73.)

The chemical analyses of water from the San Juan River and the tributaries above Arboles, Colo., show that the water, except that from Pagosa Springs at Pagosa Springs, Colo., is suitable for domestic use by the standards accepted for this report. The water of Pagosa Springs has a sulfate concentration of about 1,500 ppm and contains about 3,600 ppm of dissolved solids. The spring water is very hard (700 ppm as $CaCO_3$) and contains between 50 and 70 ppm of silica. Stream water in this area is low in dissolved solids and is soft. However, the concentration of silica is usually about 20 ppm, which is a reflection of the effect of the volcanic rocks in the headwaters of the streams.

The water of the Piedra River, which enters the San Juan River at Arboles, Colo., has a higher concentration of dissolved solids, except in the headwaters, than the San Juan and its tributaries above Piedra. However, none of the constituents in the water of the Piedra and its tributaries exceed the maximum limits accepted for domestic use. In the upper reaches of the Piedra River, the water is dilute and soft but contains 20 to 25 ppm of silica. In the lower part of the Piedra River basin the waters of the Piedra River and some of its tributaries, such as Devil Creek and Stolsteimer Creek, contain about 250 ppm of sulfate, but apparently the sulfate seldom exceeds 250 ppm. In the lower reaches the waters of the Piedra and its tributaries are moderately hard.

The surface waters of the Los Pinos River basin are suitable for domestic use. Above Bayfield, Colo., they are dilute (dissolved-solids concentration usually less than 100 ppm) and soft. At La Boca, Colo., the dissolved-solids concentration of the river water usually does not exceed 200 ppm, and the water is moderately hard. Spring Creek at La Boca, Colo., is below land that is partly irrigated by water diverted from the Los Pinos River, and its water may contain more than 500 ppm of dissolved solids during low flows. The water may have a hardness of as much as 200 ppm during low flows and would require softening for use by laundries and some other industries.

The water of San Juan River at Bloomfield, N. Mex., which is upstream from the mouth of the Animas River and downstream from Canyon Largo, always contains less than 500 ppm of dissolved solids. However, the water is hard and would require softening for many uses.

The Animas River rises in the high peaks of the San Juan Mountains in a region underlain by volcanic rocks that produce water of the calcium sulfate type. Above Cedar Hill, N. Mex., the waters of the Animas River and its tributaries contain less than 500 ppm of dissolved solids, and the concentration of constituents considered to be important for domestic use never exceeds the maximum limits accepted for this report. The surface waters in the Animas River basin above Cedar Hill range from soft to hard and the concentration of silica is less than 10 ppm, except in some of the tributaries close to the divide. For example, a sample of water from Cement Creek near Silverton, Colo., which is near the divide, contained 34 ppm of silica.

At the mouth of Animas River at Farmington, N. Mex., the water may contain as much as 700 ppm of dissolved solids, of which about 300 ppm is sulfate. The maximum sulfate concentration permitted by the standards accepted for this report is 250 ppm. In most years these high sulfate concentrations occur in the fall and winter. The hardness of the water at Farmington generally ranges from 100 ppm during the high flows in the spring to 400 ppm in the fall. This range indicates that softening of the river water would be desirable for most purposes.

In its headwaters the water of the La Plata River has concentrations of dissolved solids similar to those of the Animas River in its headwaters and is suitable for all domestic uses. At the mouth of the river, however, the water never meets the requirements for domestic use. Here, the water may contain less than 700 ppm of dissolved solids; but during part of the year the concentration of magnesium exceeds 125 ppm, and the concentration of sulfate is never less than 300 ppm. The concentration of chloride is sometimes as high as 400 ppm. The water is very hard, even during the high flows in the spring.

The concentration of sulfate in San Juan River at Shiprock, N. Mex., and near Bluff, Utah, and at points between these two stations, exceeds 250 ppm for about half the year. During this period the water is not suitable for domestic use under the standards accepted for this report.

The concentration of nitrate in the surface waters of the San Juan basin is usually less than 6 ppm and, therefore, does not constitute a hazard for domestic use. Fluoride seldom exceeds 0.5 ppm. In the lower reaches of most streams, the water is very hard and would require softening for most purposes.

AGRICULTURAL USE

The principal use of water in the San Juan River basin is for irrigation. Table 20 classifies the waters of many of the streams in this subbasin of the San Juan division according to their suitability for irrigation. The classification of the water for the different sites is for high, medium, and low flows. The chemical analyses on which the classification is based are given in the basic data report (Iorns and others, 1964). Most of the terms used in the table are self-explanatory or are explained in chapter B (pp. 69–73), except the classification of water discharge as low, medium, or high. High flows are those greater than the discharge exceeded 20 percent of the time, low flows are those less than the discharge exceeded 80 percent of the time, and medium flows are those exceeded 80 percent of the time and less than the discharge exceeded 20 percent of the time. The range of discharge for low, medium, and high flows for most of the sampling sites was determined from table 6.

The values for residual sodium carbonate given in table 20 indicate that the water of all the perennial streams contains much less than 1.25 epm (equivalents per million) of residual sodium carbonate. The highest residual sodium carbonate for any of the perennial streams, most of which enter the San Juan River from the north, was 0.41 epm for Florida River at Bondad, Colo., and this occurred during low flow.

Chemical analyses of surface- and ground-water samples from the area south of the San Juan River show that many of the waters from intermittent streams may contain more than 1.25 epm of residual sodium bicarbonate. For example, water from two streams contained 1.35 and 1.49 epm (table 20).

The surface waters of the San Juan River basin, as classified for irrigation, range from C1–S1 to C4–S3. However, most sources of irrigation water in the basin are C2–S1 or better; hence, only a moderate amount of leaching is required, and there is little danger of development of harmful levels of sodium.

Percent sodium is low except in some spring waters and in some of the intermittent streams south of the San Juan River. The amount of required leaching is usually small except for the waters of a few streams—such as McElmo Creek near Cortez, Colo.—whose flow is principally return flow from irrigated lands.

Boron is apparently not a hazard in any of the surface waters of the basin.

INDUSTRIAL AND RECREATIONAL USES

The water of the principal headwater streams can be used by most industries without treatment. The water increases progressively in concentration of dissolved solids downstream, and in the lower reaches it could not be used by many industries without treatment.

Most of the streams and lakes in the San Juan Mountains are ideal for all types of recreational pursuits and are used extensively for this purpose. This use will continue to expand.

COLORADO RIVER BASIN BELOW THE GREEN AND SAN JUAN RIVERS AND ABOVE "LEE FERRY," ARIZ.

PRESENT UTILIZATION OF SURFACE WATER

STORAGE RESERVOIRS

Six irrigation reservoirs that have usable storage capacities greater than 1,000 acre-feet have been constructed (1957) in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry" (table 3, and pl. 8). Many small lakes, reservoirs, and stock ponds also are scattered throughout the subbasin.

TRANSMOUNTAIN DIVERSIONS

There are no transmountain diversions of water from this subbasin. The Topic and East Fork canal imports water from the East Fork of Sevier River (Great Basin) for irrigation in the upper Paria River basin. Available records of annual imports by this canal are given in table 21. The average annual discharge for water years 1950–57 was 2,600 acre-feet.

IRRIGATION

About 33,300 acres is irrigated in the subbasin (table 5). All the land is along the upper reaches of the three principal tributary streams (pl. 9).

The Upper Colorado River Basin Compact Commission (1948) estimated that the 1914–45 annual consumptive use of water in the subbasin due to irrigation was 44,518 acre-feet, of which 4,000 acre-feet was imported water. The Commission estimated that 32,620 acres was irrigated and 4,775 acres received water incidental to irrigation.

DOMESTIC AND INDUSTRIAL USES

The 1960 population of the subbasin was about 6,000. The five largest communities and their populations are Page, Ariz., 2,960; Escalante, Utah, 702; Bicknell, Utah, 366; Loa, Utah, 359; and Emery, Utah, 326. The population of Page, Ariz., is engaged mostly in the construction of Glen Canyon Dam and related activities. Other principal activities are farming and ranching.

A hydroelectric powerplant on the Fremont River at Torrey, Utah, has an installed capacity of 140 kilowatts and is the major industrial user of water in the subbasin.

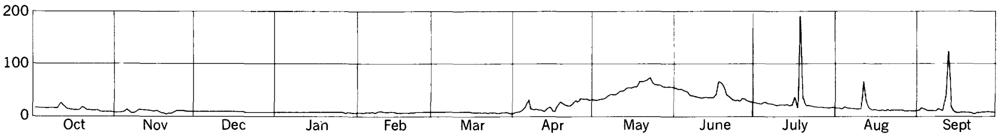
Escalante, Utah, obtains its water supply from springs. No data are available on sources of water supply for the other communities. However, for the purpose of the report it is estimated that the domestic consumptive use of water is about 60 gallons per day per capita, or about 400 acre-feet annually.

STREAMFLOW

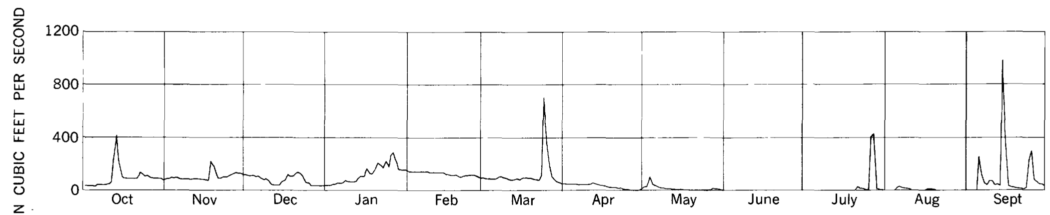
VARIABILITY OF SEASONAL RUNOFF

Most of the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry" is desert. Little or no snow accumulates during the winter except in the mountains that form the northwest boundary of the subbasin. The streams, except those draining the mountains, are intermittent and carry water only after infrequent thunderstorms, most of which are brief and cover only small areas. However, some of the storms are intense and cause flash floods. During the irrigation season most of the water from the headwaters of the perennial streams is diverted for irrigation or consumed by evapotranspiration in the long, meandering sand-filled channels. All tributaries have cut deep canyons in their lower reaches, where some tributaries intercept the water table and receive flow from seeps and springs.

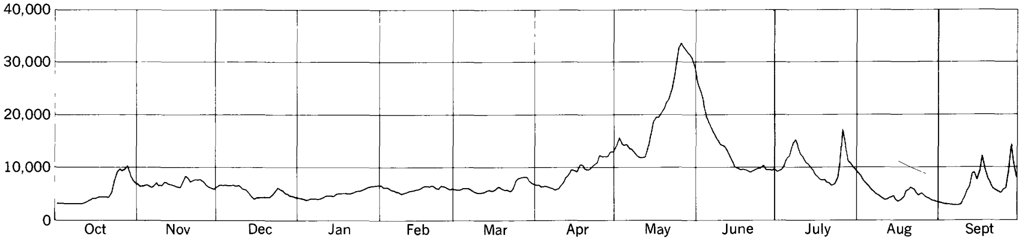
The hydrograph for Muddy Creek near Emery, Utah (fig. 141), which is a tributary of the Dirty Devil River, is typical of headwater streams that rise in the mountainous area in the northwestern part of the subbasin. The hydrograph for Dirty Devil River near Hite, Utah, shows the pattern of runoff of the river at its mouth. During the nonirrigation season, water usually flows in the river all the way from the mountains, where its principal tributaries rise, to its junction with the Colorado River. However, during the



A. Muddy Creek near Emery, Utah



B. Dirty Devil River near Hite, Utah



C. Colorado River at Lees Ferry, Ariz.

FIGURE 141.—Seasonal pattern of runoff of streams in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz., 1954 water year.

irrigation season, most of the water supply is diverted for irrigation of lands along the headwater streams, and the channels downstream are dry except at times of storms. Many of these storms occur in the drainage basin below the irrigated lands, as may be observed by comparing the time of occurrence of increases in discharges at the gaging stations on Muddy Creek and the Dirty Devil River.

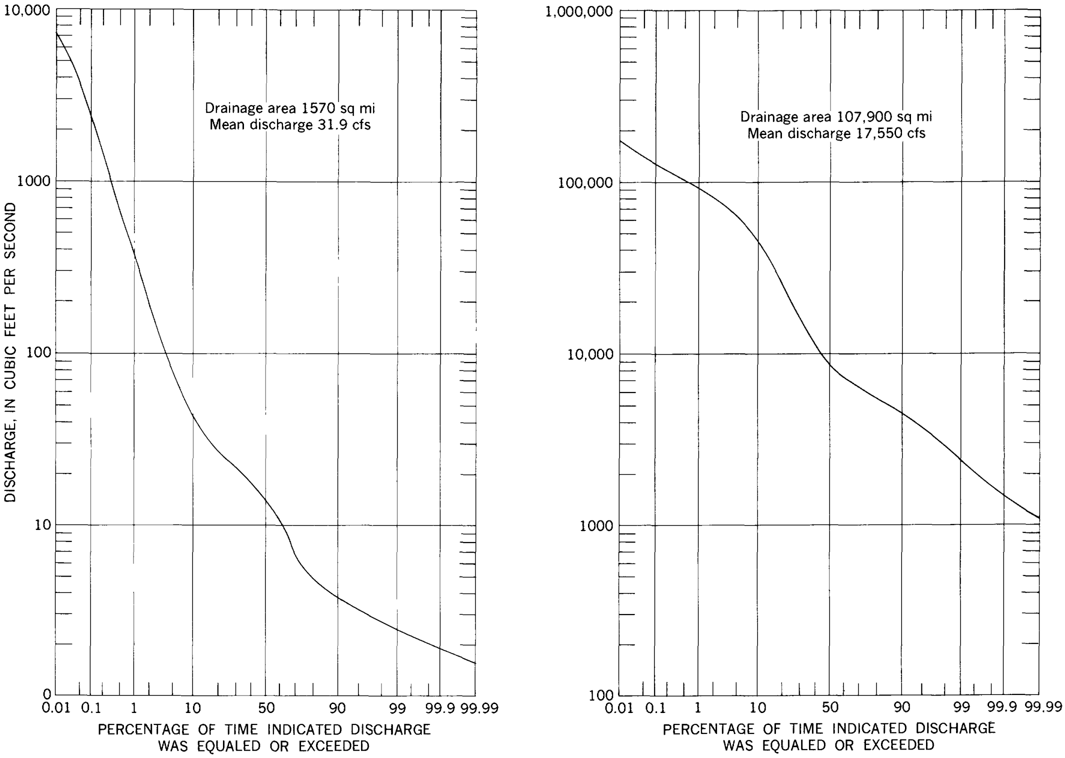
The pattern of flow of Colorado River at Lees Ferry, Ariz., is also shown in figure 141.

FLOW-DURATION CURVES

Historical flow-duration curves were developed for streams at eight sites in the subbasin. By use of the methods described in chapter B, the flow-duration curves for four of the sites were adjusted to the 44-year base period. The curves for four sites could not be extended to the 44-year base period because of the shortness of record and poor correlation with other stations having longer records. The curves for Colorado River at Hite, Utah, and Lees Ferry, Ariz., were adjusted to 1957 conditions of upstream development. Because no substantial change occurred in upstream developments on the tributary streams during the base period, no adjustments for upstream developments were made for these streams. Data on the historical and adjusted curves are given in table 6. Table 7 outlines the methods used in adjusting the historical flow-duration curves and the upstream developments in which changes occurred. The table also gives the authors' accuracy rating of the adjusted long-term curves.

The characteristic behavior of the principal tributary streams in the subbasin is shown in figure 142 by the flow-duration curve for Paria River at Lees Ferry, Ariz. The upper part of the curve (between about the 0.01 and 15 percentiles) is principally the result of storm runoff. The humped part of the curve (between about the 15 and 80 percentiles) is principally winter and snowmelt runoff. The part between about the 80 and 99.99 percentiles is mostly ground water discharged to the river in its lower reach.

The long-term adjusted flow-duration curve for Colorado River at Lees Ferry, Ariz., is also shown in figure 142.



A. Paria River near Lees Ferry, Ariz.

B. Colorado River at Lees Ferry, Ariz.

FIGURE 142.—Flow-duration curves for streams in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz., water years 1914–57 adjusted to 1957 conditions.

Variability indices and percentage of ground-water contribution for tributary streams were not computed for this subbasin because of the effect of summer storms on the pattern of runoff.

VARIABILITY OF ANNUAL RUNOFF

Figure 143 illustrates the variability of annual discharge of Colorado River at Lees Ferry, Ariz. Quantities shown are the historical discharge adjusted for increases in transmountain diversions and increases in storage in the principal reservoirs in the Upper Colorado River Basin, exclusive of the Strawberry Reservoir. On the assumption that irrigation consumptive use has been constant throughout the period, these data are considered to be the most reliable basis for studying the variability of annual discharges. The historical record for this station has been estimated for water years 1914–21 (U.S. Geol. Survey, 1954, p. 521). Table 22 gives the computed adjustments, due to transmountain diversions and change in storage in reservoirs, that were added to the historical record of Colorado River at Lees Ferry, Ariz., to adjust the data to the 1914 base.

The coefficients of variation of annual water discharges at five selected stations in the subbasin are given in table 9. To illustrate the effect of the activities of man, results of probability studies are given for three types of records for Colorado River at Lees Ferry. In this report depletions caused by irrigation have been assumed to be constant, and adjustments have been made only for increase in transmountain diversions and change in storage in reservoirs. As indicated by the values for the three given conditions, the adopted method would increase the slope of the frequency curve about 3½ percent over that for natural conditions; if the historical record had been used, the slope would have been increased 10 percent.

As shown by the data in table 9, the reconstructed record of the annual discharges representing virgin flow for water years 1914–57 for Colorado River at

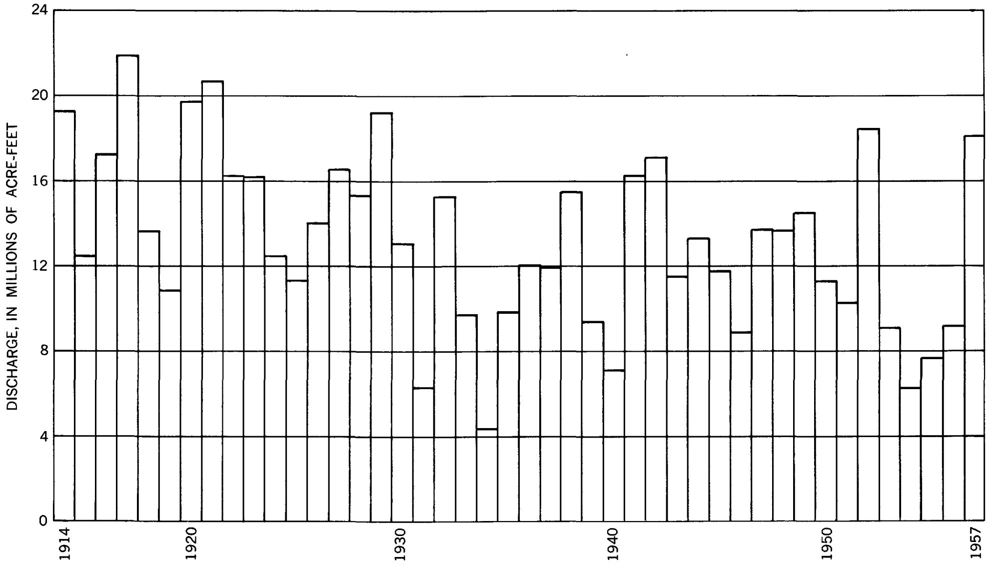


FIGURE 143.—Variability of annual discharges of Colorado River at Lees Ferry, Ariz., water years 1914–57 adjusted to the 1914 base.

Lees Ferry, Ariz., averages about 15.03 million acre-feet annually. The standard deviation of the annual discharges during this period is about 4.41 million acre-feet, and the coefficient of variation is 0.29. The following tabulation gives the probable deviation from the computed 44-year average annual discharge of 15.03 million acre-feet for a 50-percent chance for periods of various lengths in the future. (See chap. B, pp. 57–58.)

Period of years	*Probable deviation, in millions of acre-ft*	*Period of years*	*Probable deviation, in millions of acre-ft*
1	2. 95	10	1. 63
2	2. 56	20	1. 32
4	2. 12	44	1. 15

Because records for the tributary stations are short, the coefficients of variation given in table 9 may not be representative of a long-term period. The results for the headwater streams, Muddy Creek near Emery, Utah, and Escalante River near Escalante, Utah, as compared with the coefficients for similar headwater streams in other parts of the Upper Colorado River Basin appear to be reasonable, but those for Dirty Devil River near Hite, Utah, and Paria River at Lees Ferry, Ariz., are probably too low. Generally, the streams subject to runoff from infrequent thunderstorms have higher coefficients of variation than streams whose major source of water is snowmelt.

CHEMICAL QUALITY OF WATER

DISSOLVED-SOLIDS DISCHARGE AND CONCENTRATION

Daily chemical-quality data have been obtained at five stations in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry." At the end of the 1957 water year, the length of record at these stations ranged from 1 to 9 months for Dirty Devil River near Hanksville, Utah, and was as much as 15 years for Colorado River at Lees Ferry, Ariz. Monthly and annual weighted-average chemical analyses for streamflow at these stations are given in the basic data report (Iorns and others, 1964, tables 207–210, 217).

In addition to the daily data at the five stations, chemical analyses of streams at other sites in the subbasin have been obtained. The dissolved-solids discharge for the daily stations and for some of the other sites have been computed (table 10). The quantities given in table 10 are averages that would have occurred if the developments in 1957 had existed throughout water years 1914–57.

Duration tables of dissolved-solids concentration and discharge for the stations listed in table 10 are given in tables 11 and 12. The methods used to compute the data are described in chapter B (pp. 58–59).

Of all the tributaries to the Colorado River in this subbasin, exclusive of the San Juan River, the Dirty Devil River contributes by far the most dissolved solids. Its average water discharge (102 cfs) is but very little greater than the average water discharge of the Escalante River, yet its dissolved-solids discharge is almost eight times as great (table 10).

The combined average annual dissolved-solids discharges and combined water discharges of Colorado and Paria Rivers at Lees Ferry, Ariz., were used as a base to compute the contribution (in percent) of dissolved solids and water from other areas of this subbasin (fig. 144). The data show that the contribution of dissolved solids from this subbasin is relatively small—less than 6 percent of the dissolved solids from the entire Upper Colorado River Basin.

VARIATIONS IN CHEMICAL QUALITY

The dissolved-solids concentration in the streams in this subbasin, as is common in the rest of the Upper Colorado River Basin, is lowest during periods of high flow and highest during periods of low flow (fig. 145), except for the Paria River in which dissolved-solids concentration is highest at high flows. (See p. 329.)

The coefficient of variation of weighted-average concentration of dissolved solids is 0.14 and the coefficient of variation of water discharge is 0.32 for Colorado River at Lees Ferry, Ariz., for water years 1929–30, 1943–45, and 1948–57. The relation of the coefficients and their relation to the coefficients for other streams in the San Juan division are discussed on page 312.

RELATION TO STREAMFLOW

The dissolved-solids concentration of the streams, except for the Paria River, decreases as the water discharge increases. In the headwaters the range in concentration between high and low flow is not as great as it is in the lower reaches of the principal tributaries and in the Colorado River (table 11).

In the drier parts of the subbasin and downstream from irrigated land, the ratio of maximum to minimum concentration may be large. That for the Colorado River is greater than that for most of the tributaries. For example, the ratio at Hite, Utah, is 6.1 (1,100 to 180 ppm). In contrast, the ratio for Dirty Devil River near Hite, Utah, is 2.3 (3,400 to 1,500 ppm).

The relations between the chemical composition of water and streamflow for five streams where daily chemical-quality records have been obtained are given in table 14. The relations for low, median, and high discharges at four sites are illustrated in figure 146.

Not only do the waters of most of the streams in this subbasin have higher concentrations of dissolved solids during low flows than during high flows, but some also have different chemical compositions at the extremes of flow. The water of Dirty Devil River near Hite, Utah, is of the calcium sulfate type at all flows and the water of Escalante River at mouth, near Escalante, Utah, is of the calcium bicarbonate type for all except the lower flows. The water of Colorado River at Hite, Utah, and at Lees Ferry, Ariz., is of the calcium bicarbonate type during high flows and of the sodium or calcium sulfate type at median and low flows (fig. 146).

RELATION TO GEOLOGY

The three principal tributaries of the Colorado River in this subbasin rise in the high plateaus west of the main stem. Within a narrow band next to the divide, the waters of the tributaries of the Dirty Devil and Escalante Rivers usually contain less than 300 ppm of dissolved solids. These headwater areas are underlain mostly by rocks of Tertiary age.

In the Dirty Devil River basin downstream from the areas where the dissolved-solids concentration is relatively low, the streams cross areas underlain by rocks of Cretaceous age and older. These areas receive small amounts of precipitation, which fall mostly during thunderstorms. The rocks contain large amounts of soluble minerals, some of which are picked up by the runoff that results from the infrequent summer storms. In the headwaters of the Dirty Devil River, the water is of the calcium bicarbonate type. Downstream, the quality of the water is affected by return flow from irrigation and by runoff from areas underlain by the rocks that contain readily soluble minerals; consequently, the concentrations of dissolved solids and of magnesium, sodium, and sulfate ions increase downstream.

The Escalante River below the irrigated areas near Escalante, which are underlain mostly by rocks of Cretaceous age, contains more dissolved solids than it contains above the irrigated lands, where the water is of the calcium bicarbonate type but where, during low flows, the sulfate content (in equivalents per million) is almost as great as the bicarbonate content. Near the mouth of the river, the dissolved-solids concentration is less than at Escalante because of runoff from the drainage basin of Boulder Creek and the lower reaches of the Escalante River, which are underlain mostly by sandstones of the San Rafael and Glen Canyon Groups.

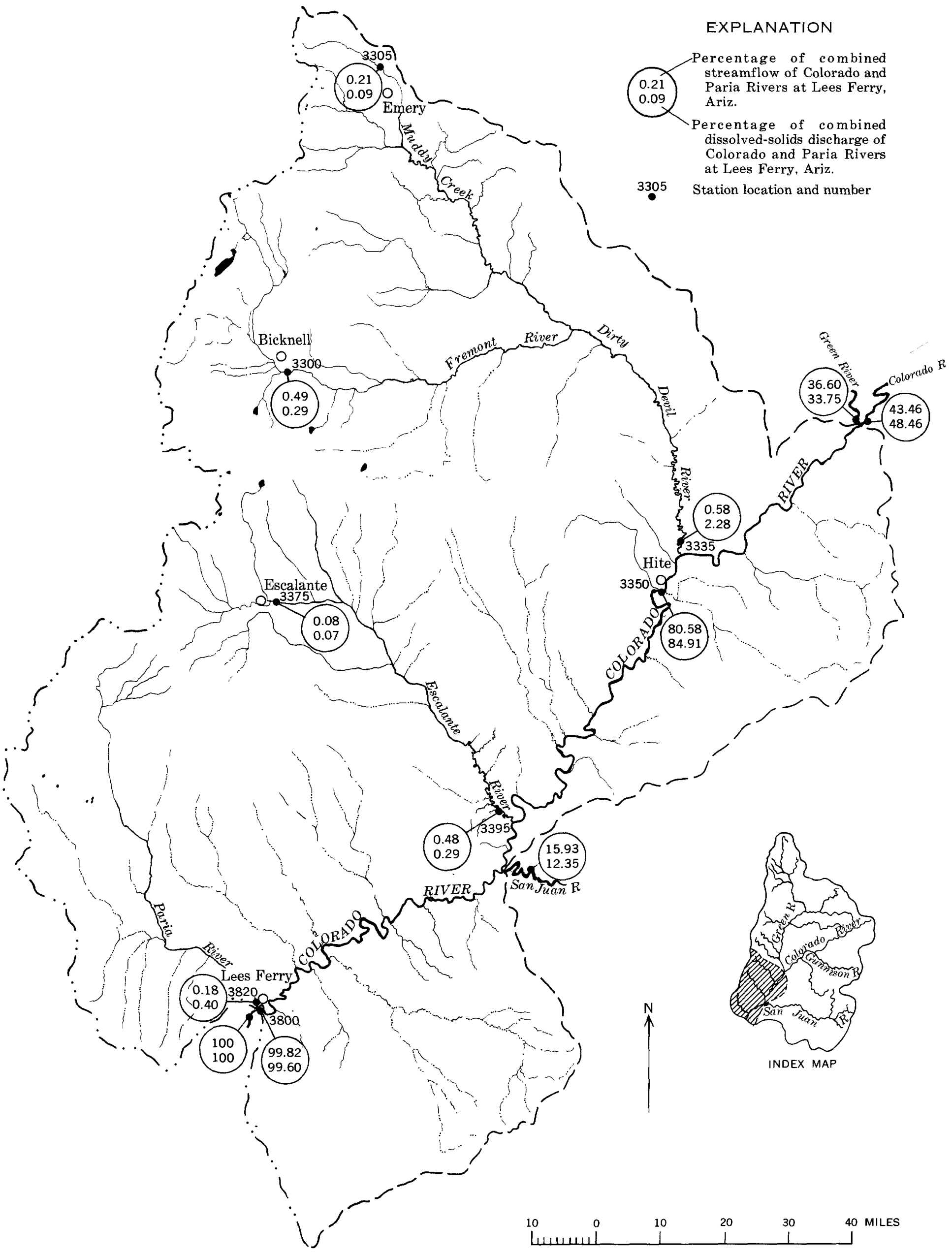
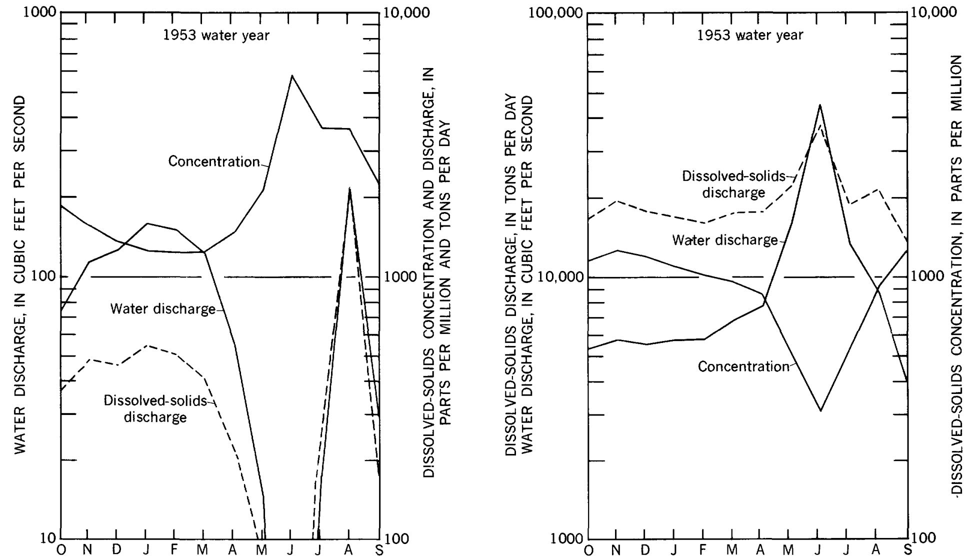
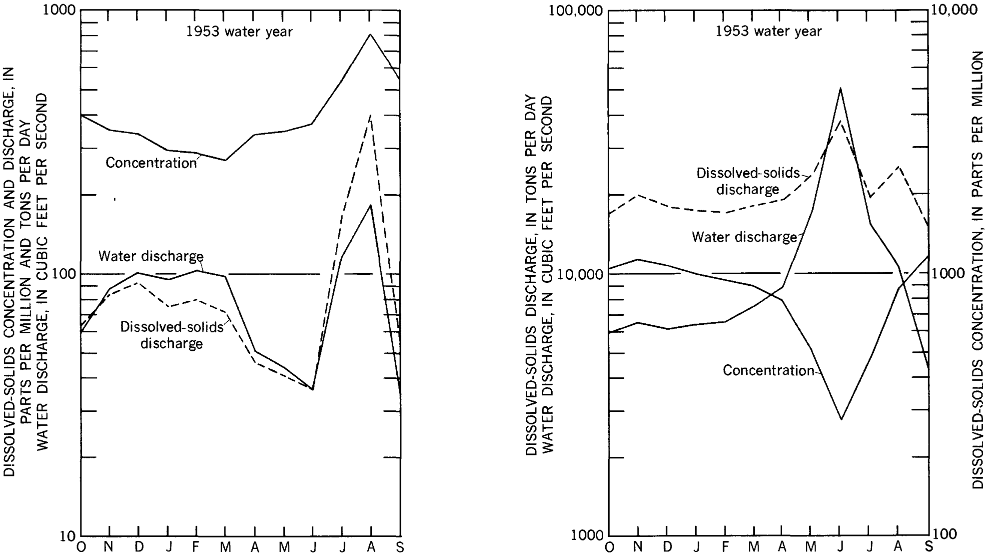


FIGURE 144.—Approximate dissolved-solids discharge and streamflow expressed as percentages of the combined dissolved-solids discharge and combined streamflow of Colorado and Paria Rivers at Lees Ferry, Ariz.



A. Dirty Devil River near Hite, Utah

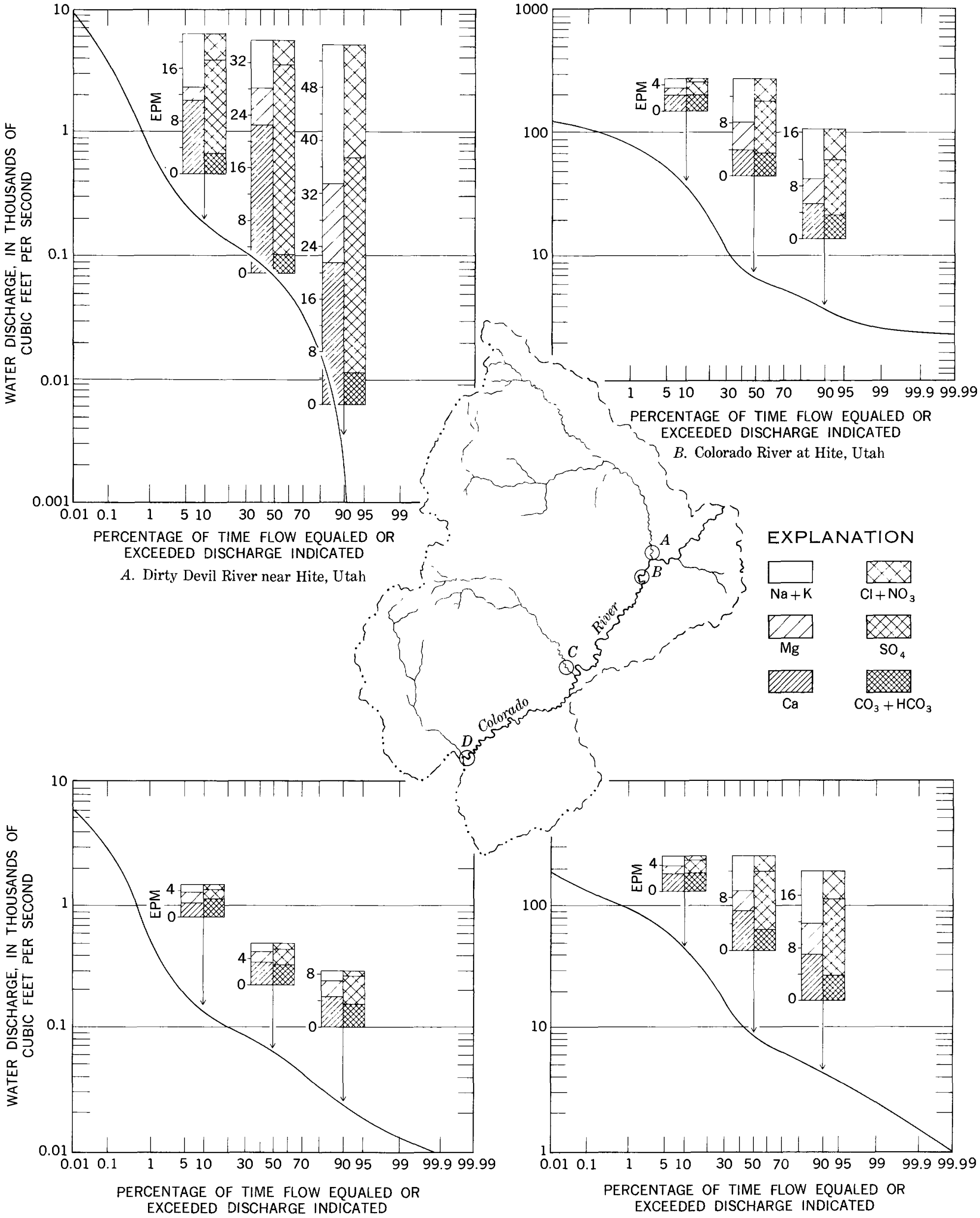
B. Colorado River at Hite, Utah



C. Escalante River at mouth, near Escalante, Utah

D. Colorado River at Lees Ferry, Ariz.

FIGURE 145.—Dissolved-solids concentration and water discharge at four daily stations in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.



A. Dirty Devil River near Hite, Utah

B. Colorado River at Hite, Utah

C. Escalante River at mouth, near Escalante, Utah

D. Colorado River at Lees Ferry, Ariz.

FIGURE 146.—Relation of the chemical composition and concentration of dissolved solids to water discharge in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz. The concentration of specific ions, in equivalents per million (epm), is shown for the 10th, 50th, and 90th percentiles of the flow-duration curve for each location. The flow-duration curves are for water years 1914–57 adjusted to 1957 conditions.

The water of the Paria River is of the sodium calcium magnesium sulfate type at most flows; near Cannonville, Utah, it is often of the sodium magnesium calcium sulfate type. The concentrations of dissolved solids in Paria River at Lees Ferry, Ariz., are highest when the water discharge is highest (table 14). This is an exception to the general coincidence of low concentration with highest flows for most of the streams in the Upper Colorado River Basin. The probable reason for this exception is that the water of the Paria during low flows comes from springs and seeps in the lower canyon reach of the stream. This water, which issues from rocks of the Glen Canyon and San Rafael Groups, is dilute compared with surface runoff, which originates mostly in the badlands near Bryce Canyon, a region underlain by rocks that contain large amounts of soluble minerals.

Figure 147 is a map of the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz., showing zones within which the approximate weighted-average concentration of dissolved solids of the streams is between indicated limits. Comparison of the zones with distribution of the rocks (pl. 1) and of the irrigated areas (pl. 9) indicates the general effect of the rock types and irrigation on the dissolved-solids concentration of the surface water.

The diagrams in plate 2 show the geochemical character and ionic concentrations of surface waters at 51 sites in the subbasin. The diagrams are representative of the chemical character of the streams during low flow, when the effect of geology on chemical quality is more evident than during high flows. The significance of the size and shape of the diagrams is given in the explanation in plate 2.

RELATION TO GROUND WATER

In most of this subbasin, the precipitation is low and very little ground water reaches the streams except in the lower canyon reaches and in some of the alluviated reaches that are under irrigation or that are flooded during storm runoff. In most of the canyon reaches the streams have cut to or below the water table, and the streams are sustained by ground-water inflow. Water levels in deep wells on both sides of the Colorado River near Page, Ariz., and the locations of springs along the river and in the side canyons indicate that the gradient of the water table toward the river is appreciable.

Between the gaging stations on Colorado River at Hite, Utah, and Lees Ferry, Ariz., about 2,450,000 acre-feet of water and about 1,275,000 tons of dissolved solids are added to the Colorado River annually (table 10). About 2,089,720 acre-feet of this water and about 1,022,300 tons of dissolved solids come from the Escalante River basin and from the area above San Juan River near Bluff, Utah. This leaves about 360,300 acre-feet of water and 252,700 tons of dissolved solids that must come from the remaining 6,290 square miles of drainage area. The channel loss by evaporation has been estimated to average 103,000 acre-feet per year from the reaches of the Colorado and San Juan Rivers in the 6,290 square miles of drainage area (Upper Colorado River Basin Compact Comm., 1948, p. 46–48). This loss, added to the residual of 360,300 acre-feet of water, indicates a total water contribution of 463,300 acre-feet.

On the basis of records of streams similar to those draining the area, the surface-water inflow is estimated to average 25,000 acre-feet annually (4 acre-ft per sq mi), leaving about 438,000 acre-feet which evidently comes from ground water. This ground water would have a weighted-average concentration of slightly more than 400 ppm, if one assumes that most of the dissolved solids contributed in the area (252,700 tons) were added by the ground water. That the 400-ppm concentration is reasonably correct is indicated by an average of 425 ppm for 24 springs and seeps along the river between Hite and "Lee Ferry."

In the subbasin there are about 277 miles of river channel along the San Juan and Colorado Rivers and an unknown length of channel in the numerous side canyons. If the side canyons were ignored and if it were assumed that all ground-water inflow occurred along the 277 miles of river channel, the inflow would be about 2.2 cfs for each mile of river channel. This is a relatively low rate of ground-water discharge if one considers the great depth to which the canyons are intrenched in permeable rocks. It is equivalent, however, to a ground-water recharge of about 70 acre-feet per year per square mile of drainage area.

Only one thermal spring, in Warm Springs Canyon, is known in this subbasin (Stearns and others, 1937). Its flow and dissolved-solids content are unknown, but the flow is probably small.

EFFECT OF TRANSMOUNTAIN DIVERSIONS

No water is diverted from this subbasin into areas outside the Colorado River Basin. However, the Tropic and East Fork canal has diverted water since about 1887 from the East Fork of Sevier River (Great Basin) to a tributary of the Paria River. This importation averaged about 2,600 acre-feet annually in water years 1950–57. The water, which has a weighted-average concentration of about 200 ppm of dissolved solids, adds about 700 tons per year to the Paria River. Above "Lee Ferry," Ariz., an average of about 468,700 acre-feet of water and about 37,500 tons of dissolved

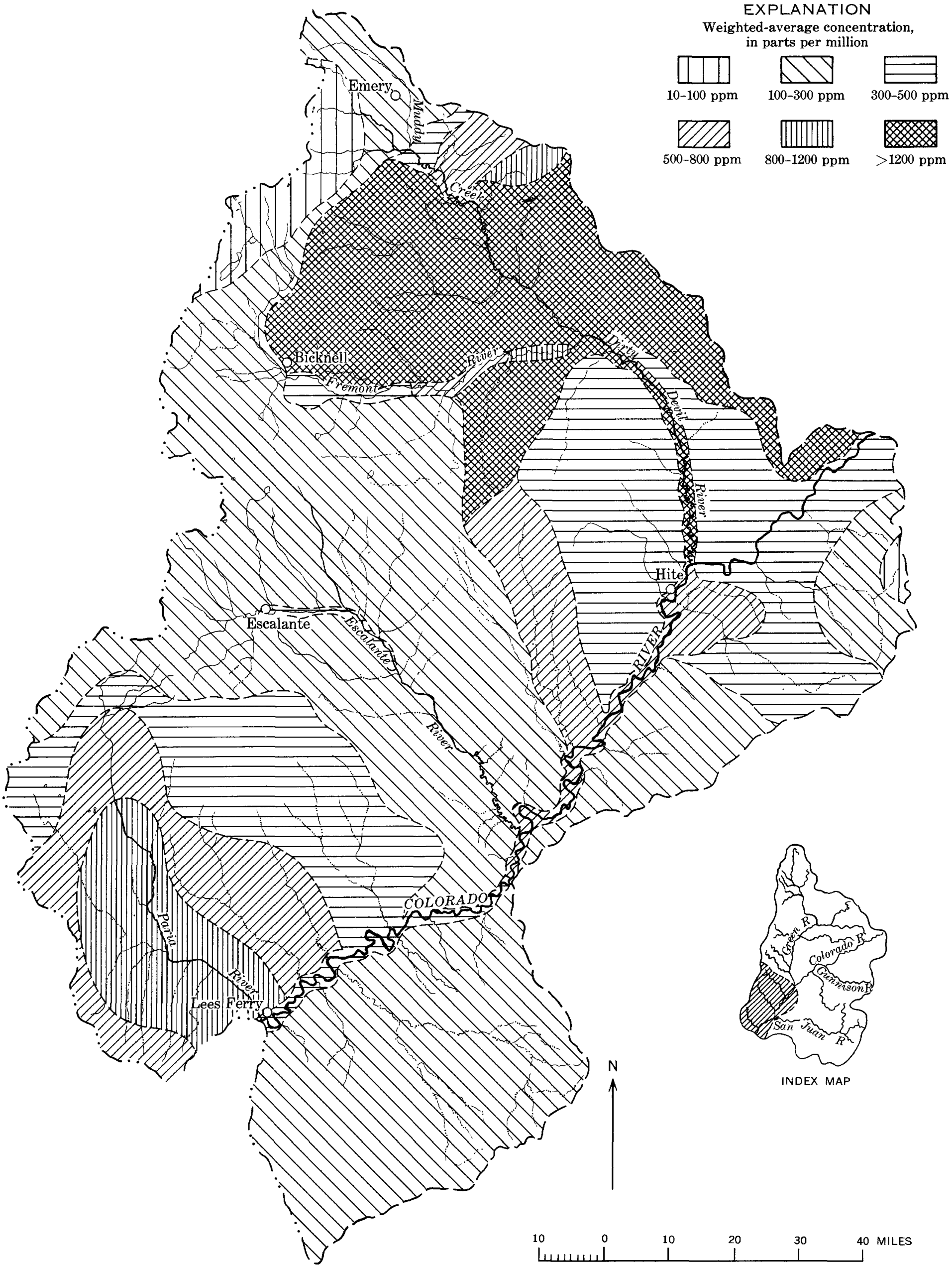


FIGURE 147.—Approximate weighted-average concentration of dissolved solids in streams in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.

solids are exported from the Colorado River Basin. The weighted-average concentration of the Colorado River at "Lee Ferry" is about 501 ppm for the 1957 level of development (computed from sum of weighted-average concentration and water discharge of Colorado River and Paria River at Lees Ferry, Ariz., table 10). If there were no transmountain diversions, the water and dissolved-solids discharges of the Colorado River at "Lee Ferry" would be about 13,201,400 acre-feet and 8,713,800 tons, respectively. The weighted-average concentration of the river at "Lee Ferry" for these conditions would be 485 ppm, or about 16 ppm less than that for the present level of upstream development. This is equivalent to about 3.4 ppm for each 100,000 acre-feet of water diverted.

EFFECT OF THE ACTIVITIES OF MAN

The activities of man in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry" affect the quality of surface waters in much the same way that man's activities affect the quality of surface waters in other areas of the Upper Colorado River Basin. They result in the addition of an estimated average of about 63,700 tons of dissolved solids to the streams in the subbasin annually. Of this amount 61,600 tons is estimated to be contributed from the part of the subbasin above the Paria River and about 2,100 tons from the Paria River basin, of which 700 tons is imported by the Tropic and East Fork canal. This estimate is based principally on indicated rates of dissolved-solids yield from irrigated lands in other parts of the Upper Colorado River Basin that are underlain by similar rocks. Chemical analyses of water at miscellaneous sites in the subbasin also are taken into account in the estimates. Table 17 summarizes data on dissolved solids contributed by natural sources and as a result of the activities of man.

The estimated amounts attributed to the activities of man are the increase over and above that which would naturally come from inflow in each subunit. Of the 63,000 tons of dissolved material estimated to be added to the streams as a result of the activities of man in this subbasin, exclusive of that in imported water, an estimated 600 tons is caused by domestic and industrial uses and 62,400 tons by irrigation. These estimates are based on the assumption that 100 tons per year per 1,000 people is added by domestic and industrial uses. The remainder is attributed to irrigation.

If there were no activities of man in the Upper Colorado River Basin, exclusive of transmountain diversions, the weighted-average concentration of dissolved solids of the water that would flow out of the basin would be about 263 ppm. This determination is based on average annual water and dissolved-solids discharges of 12,733,000 acre-feet and 8,676,300 tons, respectively, for the 1957 level of development and on an average annual consumptive use of 1,791,700 acre-feet of water by irrigation, domestic, and industrial uses, which result in the addition of an average of 3,479,600 tons of dissolved solids to the streams annually. The increase in dissolved-solids concentration of 238 ppm (501 ppm minus 263 ppm) because of domestic, industrial, and agricultural uses of water is equivalent to 13.3 ppm for each 100,000 acre-feet of water consumed, which is about four times as great as the increase caused by the diversion of 100,000 acre-feet of water out of the basin.

FLUVIAL SEDIMENT

Suspended-sediment data have been obtained daily at five stations in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry" (table 18) and at irregular intervals at other sites. These data are given in the basic data report (Iorns and others, 1964).

Estimated suspended-sediment discharges for the water years 1914–57 adjusted to 1957 conditions for the five stations where daily data have been obtained are given in table 19.

An average of 20,495,000 tons of suspended sediment is estimated to be discharged annually by the Colorado River above the Green River (chap. C, table 34) and 27,875,000 tons annually by the Green River (chap. D, table 28) into this subbasin. The annual suspended-sediment discharge of San Juan River near Bluff, Utah, is 37,100,000 tons (table 19), and that computed for Colorado and Paria Rivers at Lees Ferry, Ariz., is 103,955,000 tons, leaving a balance of 18,485,000 tons contributed to the Colorado River annually from this subbasin and from the San Juan basin below the station near Bluff, Utah. Of this amount about 9,412,000 tons annually is contributed by the Dirty Devil, Escalante, and Paria Rivers and 9,073,000 tons, or 1,440 tons per square mile per year, from other tributaries in this subbasin and in the lower part of the San Juan River basin. At a rate of 1,440 tons per square mile per year, 2,739,800 tons comes from the San Juan River basin below the Bluff station. This area of very low runoff is subject to infrequent but intense thunderstorms that carry large quantities of suspended sediment into the river. The estimated suspended-sediment contribution from the subbasin is 15,745,200 tons per year.

During the period of record for the sediment station on Colorado River at Lees Ferry, Ariz., several changes in the relation of suspended-sediment discharge to water discharge have taken place. During the drought of the 1930's, the concentration at the Lees Ferry station was greater than that during the wetter years of the early 1940's. As indicated by the similarity of changes at other stations in the Upper Colorado River Basin, the effects of the factors that caused the changes appear to have been similar in all parts of the basin (See chap. D, p. 242.)

SUITABILITY OF WATER FOR VARIOUS USES

DOMESTIC USE

The classifications of the surface waters in the Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz., are based on water-quality criteria for major uses. (See chap. B, pp. 66–73.)

Chemical analyses of waters from the headwater tributaries of the Dirty Devil and Escalante Rivers show that the water is suitable for domestic use. In the Dirty Devil River and in the lower reaches of its tributaries, the water usually contains more sulfate and total dissolved solids than is desirable. (See basic data report, Iorns and others, 1964.) The waters range from moderately hard in the upper part of the Dirty Devil River drainage basin to very hard in the middle and lower parts of the basin. Softening of the water would be necessary for most uses.

The dissolved-solids constituents in the water of the Escalante River below Boulder Creek are less than the maximum limits permitted by the standards accepted for this report. Below the irrigated areas near Escalante, the concentration of sulfate during part of the time exceeds the maximum of 250 ppm permitted by the standards for domestic use. The waters of the Escalante River and tributaries are hard to very hard.

The waters of the Paria River, except in the extreme headwaters, usually contain more than 500 ppm of sulfate, and the concentration of dissolved solids is often greater than 1,000 ppm. The water is very hard.

The waters of many of the small tributaries in the Glen Canyon reach of the Colorado River are comparatively dilute and are suitable for domestic use, except that they are hard to very hard.

The monthly summaries of chemical analyses for Colorado River at Hite, Utah, and Lees Ferry, Ariz., show that the concentrations of sulfate exceed 250 ppm during about three-quarters of each water year. During the spring runoff—usually in April, May, June, and July—the water is suitable for domestic use. After the Glen Canyon Reservoir is completed, the water in the reservoir would probably be suitable for domestic use because of the mixing of the dilute water from the spring runoff with the more concentrated water from runoff during the rest of the year.

Concentration of nitrate in the surface waters of this subbasin does not usually exceed about 5 ppm. Concentrations of boron and fluoride are usually less than 0.5 ppm.

AGRICULTURAL USE

The principal use of water in this subbasin, as in all parts of the Upper Colorado River Basin, is for irrigation. In table 20 the waters of many of the streams are classified as to their suitability for irrigation. The classification is for high, medium, and low flows or for flows for which chemical analyses are available. The chemical analyses on which the classification is based are given in the basic data report (Iorns and others, 1964). Most of the terms used in the table are self-explanatory or are explained on page 320 or in chapter B (pp. 69–73).

The values for residual sodium carbonate in table 20 indicate that all the waters contain very much less than 1.25 epm of residual sodium carbonate and, therefore, are suitable for irrigation insofar as this property is concerned.

As indicated in table 20, most of the stream waters presently used for irrigation are in the C2–S1 category or better. To control salinity only moderate leaching is required, and there is little danger of the development of harmful levels of exchangeable sodium. Most waters in the poorer categories are in downstream reaches or canyon areas and are not used for irrigation.

Required leaching for the waters in this subbasin is low except in a few local areas. The concentrations of boron do not appear to be a hazard.

INDUSTRIAL AND RECREATIONAL USES

The concentration of dissolved solids in the waters of the principal tributaries of the Colorado River is high, except a few tributaries in the extreme headwaters where the waters could not be used by most industries without treatment.

The streams and lakes in the high plateau areas in the headwaters of the Dirty Devil and Escalante Rivers furnish recreation for many people. Boat trips down the canyons of the Colorado and San Juan Rivers climax the vacations of the large number of people who visit this scenic area every year, and fishing on Lake Powell and below Glen Canyon Dam will furnish recreation for thousands of people.

SUMMARY

The San Juan division is a region of great contrasts—towering mountains, desert plateaus, and deep canyons. All the area is above an altitude of 3,120 feet, but the major part of the land surface ranges from 5,000 to 7,000 feet in altitude.

The exposed rocks range in age from late Precambrian to Recent. The San Juan Mountains are composed chiefly of volcanic rocks of Tertiary age, but the lower parts of the San Juan basin in Colorado and New Mexico are underlain mostly by sedimentary rocks of Cretaceous and Tertiary ages. Parts of the area at intermediate altitudes are underlain mostly by sedimentary rocks of Permian, Triassic, and Jurassic ages. Except for river alluvium along the streams and valley alluvium in the Navajo River basin and in an area between the Animas and Los Pinos Rivers, unconsolidated deposits that mantle the consolidated rocks are chiefly material weathered from the underlying rocks but not transported far.

The climate ranges from extremes of high precipitation and low temperatures in the mountains to scant precipitation and high temperatures in the lower altitudes. The average annual precipitation generally ranges from 6 inches at the lower altitudes to 60 inches in parts of the San Juan Mountains. Ninety percent of the basin receives an annual average precipitation of less than 20 inches, and 46 percent receives less than 10 inches.

Snow that accumulates in the mountains provides most of the water supply of the perennial streams, and runoff varies with the seasons. As the snow melts in the late spring and early summer, the flow in the perennial streams rises to a peak and then subsides as the supply of snow is exhausted. Usually by late July the flow of these streams has subsided to nearly a minimum (base flow). This base flow generally prevails until the following spring. Infrequent localized thunderstorms occur along the front of the mountains and at the lower altitudes of the division. These storms at times produce flash floods in the usually dry washes that drain the intermediate and lower altitudes.

Flow-duration curves, which show the percentages of time during which specified water discharges were equaled or exceeded, were developed and adjusted to be representative of the streamflows that would have occurred if the developments in 1957 had existed throughout water years 1914–57. From these curves the 44-year average discharges of the streams adjusted to 1957 conditions of upstream development were computed.

The effect of environmental factors on the flow of the streams was analyzed by comparing the slopes and shapes of the flow-duration curves of different streams and by comparing the variability of annual discharges of these streams. The variability indices (slopes of flow-duration curves) for headwater streams that rise in the San Juan and La Plata Mountains ranges from 0.46 to 0.64. The shape of the flow-duration curves for these streams in their headwaters indicates that about 16 to 28 percent of the average annual discharge was contributed to the stream systems by ground water. The relative permeability of the underlying rocks and extent of permeable alluvial deposits appear to be the major causes of differences in variability indices and ground-water contributions to the headwater streams in the San Juan River basin.

The coefficients of variation (ratio of standard deviation to average discharge) of the streams in the San Juan River basin for which statistical analyses of annual flows were made ranged from 0.32 to 0.64. The Animas River, which had the lowest coefficient, apparently has ground-water reservoirs extensive enough to provide carryover from wet to dry years. The Mancos River, which had the highest coefficient, receives a major part of its annual discharge from summer storms.

The coefficient of variation of historical annual water discharges of Colorado River at Lees Ferry, Ariz., for water years 1914–57 is computed to be 0.32, and the coefficient of variation for the same period of years of annual discharges representing virgin flow is 0.29. In the analytical procedure used to adjust streamflow to 1957 conditions, the assumption was made that the depletions caused by irrigation were constant and that the historical annual discharges needed to be adjusted only for increase in transmountain diversions and change in storage in reservoirs. The computed coefficient of variation for water years 1914–57, adjusted to 1957 conditions, is 0.30, which is only about 3 percent greater than that for virgin-flow conditions.

The major use of water is for irrigation. Table 23 summarizes data on storage reservoirs and water utilization in the San Juan division for developments existing in 1957.

Table 24 shows an approximate water budget for the division. The total average annual water supply from precipitation is 25,880,600 acre-feet, which is equivalent to an average of 12.67 inches. All the precipitation not accounted for in outflow, transmountain diversions, and consumptive use due to the activities of man is considered to be evapotranspiration loss from land and water surfaces and from native vegetation. This loss is computed to be 89.4 percent of the precipitation, or 11.32 inches of water.

In the San Juan division, records of chemical quality of streams have been obtained daily at 11 stations and at irregular intervals at many other sites. These records were used in conjunction with the flow-duration tables to develop duration tables of dissolved-solids concentration and other chemical-quality data for the water years 1914–57 adjusted to 1957 conditions and for other periods. The weighted-average concentration of dissolved solids at these sites ranges from 42 to 2,180 ppm, and the average annual yield of dissolved solids ranges from 13 to 494 tons per square mile of drainage area.

The difference in the chemical quality of the streams is the result of hydrologic and other environmental factors prevailing in the drainage basins. The major environmental factors that determine the chemical quality of each stream are apparently precipitation, type of rocks and soils, and the activities of man.

The perennial streams in the division are of the snowmelt type, in which dissolved-solids concentration is lowest during the months of maximum water discharge and highest during periods of low flow, when the streams are maintained largely by ground water. One of the streams, however, Paria River at Lees Ferry, Ariz., has highest concentrations at times of high discharge and lowest concentrations at times of low discharge. Ground-water inflow in the lower reaches of the Paria River has a lower concentration of dissolved solids than runoff from the headwaters area, which is underlain by the Mancos Shale.

A statistical analysis of the variations in the annual weighted-average concentration of dissolved solids and water discharges of streams was made for four stations in the division. Plotting of the data showed poor correlation between the coefficients of variation of weighted-average concentration of dissolved solids and water discharge. The poor correlation is possibly due to the shortness of the available records.

Except in the mountains, the precipitation is so low that there is little opportunity for ground-water recharge, even where the exposed rocks are relatively permeable. Consequently, even though the main streams in much of the basin flow in deep canyons cut to or below the water table, the amount of ground water that enters these streams in the canyon reaches is relatively small as compared with the flow of water in the main streams. Analyses of water of springs and seeps in the canyon reaches along the Colorado River indicate that the average concentration of dissolved solids in the ground water is probably about 400 ppm. Because the weighted-average concentration of dissolved solids of Colorado River at Lees Ferry, Ariz., is 499 ppm, the ground-water inflow in the canyon reaches apparently improves the quality of water in the river slightly.

Ground-water contributions to headwater streams draining the San Juan and La Plata Mountains are computed to provide about 16 to 20 percent of the average annual water discharge of the streams. The weighted-average concentration of dissolved solids in the ground-water contribution to these streams is greater than that in the streams. Exchange of water between the streams and the alluvium bordering and underlying the streams in their downstream reaches and return flow from irrigation add dissolved solids to the stream system. The effect of these actions on the dissolved-solids concentration of the streams is greatest during the periods of low flow.

Thermal springs in the division add about 11,000 tons of dissolved solids and about 2,200 acre-feet of water to the streams. The principal thermal springs are along the San Juan River at Pagosa Springs, Colo., and on the upper Animas River.

Water diverted out of the San Juan division carries with it the dissolved minerals in the diverted water. The effect of the diversion on the master stream at downstream points is to deplete the flow and to decrease the dissolved-solids load. The effect of the exportation of water has been to decrease the average annual water contribution in the division by about 2,800 acre-feet and the average annual dissolved-solids discharge by about 300 tons. On the other hand, the importation of water into the division increases the water supply and increases the dissolved-solids discharge of the streams. The water imported from the Dolores and East Fork of Sevier Rivers increases the water supply by about 102,600 acre-feet and the dissolved-solids discharge by about 17,700 tons annually. Part of the water imported is consumptively used in irrigation, but the imported dissolved solids have to be kept flushed out of the soils in the irrigated areas to maintain a salt balance.

In the basin the principal uses of water by man that affect the chemical quality of water in the streams are those for domestic, industrial, and irrigation purposes. Of the total dissolved solids estimated to be added to the stream system in the division as a result of the activities of man, about 97 percent is estimated to be caused by irrigation. Table 25 summarizes data on water and dissolved solids contributed to the stream system from the two subbasins in the San Juan division.

About 468,700 acre-feet of water containing about 37,500 tons of dissolved solids is diverted out of the Upper Colorado River Basin annually. If this water were not diverted, the weighted-average concentration of the Colorado River at "Lee Ferry" would be about 19 ppm less than the weighted-average concentration for conditions of upstream development existing in 1957 (501 ppm). The change of 19 ppm is equivalent to about 3.4 ppm for each 100,000 acre-feet of water diverted.

Domestic, industrial, and irrigation uses of water in the entire Upper Colorado River Basin result in the consumption of about 1,791,700 acre-feet of water and in the addition of about 3,379,600 tons of dissolved solids to the Colorado River annually. These uses, exclusive of transmountain diversions, have caused an increase in the weighted-average concentration of dissolved solids of the Colorado River at "Lee Ferry" of about 241 ppm, which is equivalent to about 13 ppm for each 100,000 acre-feet of water consumed, or about four times the increase caused by the diversion of an equivalent amount of water from the basin.

The average annual suspended-sediment contribution to the stream system in the San Juan division is estimated to be 55,585,000 tons (table 22). Of this amount about 72 percent comes from the San Juan River basin, about 9 percent from the Dirty Devil River basin, about 3 percent from the Escalante River basin, about 5 percent from the Paria River basin, and about 11 percent from the remainder of the division.

Determinations of suspended-sediment discharge in the division were made at four sites on the San Juan River, two sites on the Colorado River, and eight sites on tributary streams. San Juan River near Blanco, N. Mex., had the highest rate of yield (2,607 tons per sq mi per yr) and Los Pinos River near Bayfield, Colo., the lowest (6 tons per sq mi per yr). Of the subareas in the division for which suspended-sediment data can be computed, the 1,228 square miles of drainage area below the gaging stations on San Juan River at Rosa, N. Mex., Los Pinos River near Bayfield, Colo., and Spring Creek at La Boca, Colo., and above the gaging station on San Juan River near Blanco, N. Mex., has the highest rate of yield (3,946 tons per sq mi per yr). The next highest is from the drainage area between the junction of the Colorado and Green Rivers and above the gaging station at Hite, Utah, exclusive of the Dirty Devil River basin. The rate of yield from this drainage area (1,040 sq mi) is about 2,560 tons per square mile per year.

An annual average of about 48,370,000 tons of suspended sediment is contributed to the Colorado River from the Grand and Green divisions. With the contribution from the San Juan division, about 103,955,000 tons of suspended sediment is discharged annually from the Upper Colorado River Basin.

Chemical-quality data indicate that the water in many streams in the division, especially in their headwaters, is suitable for domestic use. The concentrations of dissolved solids in the lower reaches of some streams, however, exceed the maximum limits acceptable for domestic use.

The waters in the lower reaches of some tributary streams in the division are not suitable for agricultural use during periods of low flow.

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TABLES 1–25

TABLE 1.—*Average monthly precipitation, in inches, at 13 index-precipitation stations in the San Juan division, water years 1914–57*

Station	October	November	December	January	February	March	April	May	June	July	August	September	Annual
San Juan River basin													
Silverton, Colo	2.20	1.22	1.63	1.63	1.63	2.35	1.79	1.53	1.49	2.72	2.89	2.44	23.52
Hermit, Colo	1.70	.93	.89	1.02	.70	1.05	1.31	1.20	1.02	2.35	2.29	1.73	16.19
Ignacio, Colo	1.36	.87	1.16	1.30	1.12	1.26	1.18	1.07	.81	1.87	1.94	1.46	15.40
Fort Lewis, Colo	1.68	.96	1.49	1.54	1.63	1.52	1.39	1.20	.86	2.19	2.20	1.90	18.56
Aztec Ruins, N. Mex	.87	.57	.79	.74	.66	.79	.63	.65	.50	1.06	1.25	1.05	9.56
Regina, N. Mex	1.25	.70	1.04	.98	1.18	1.15	1.23	1.15	.85	2.54	2.58	1.65	16.30
Crownpoint, N. Mex	.72	.46	.58	.61	.57	.54	.58	.64	.62	2.09	1.94	1.22	10.57
Blanding, Utah	1.35	.88	1.30	1.32	1.21	1.00	.92	.75	.56	1.12	1.34	1.20	12.95
Average	1.39	.83	1.11	1.14	1.09	1.21	1.13	1.02	.84	1.99	2.05	1.58	15.38
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.													
Emery, Utah	0.75	0.30	0.53	0.54	0.44	0.47	0.45	0.64	0.50	0.83	1.21	0.82	7.48
Hanksville, Utah	.57	.27	.35	.35	.27	.25	.34	.38	.33	.67	.88	.51	5.17
Piute Dam, Utah	.73	.52	.56	.58	.49	.71	.64	.70	.55	1.01	.96	.72	8.17
Orderville, Utah	1.05	.88	1.62	1.92	1.74	1.40	1.16	.74	.46	1.18	1.32	1.11	14.58
Lees Ferry, Ariz	.48	.36	.47	.38	.52	.47	.37	.30	.22	.72	1.19	.46	5.94
Average	.72	.47	.72	.75	.69	.66	.59	.55	.41	.88	1.11	.72	8.27

TABLE 2.—*Annual precipitation, in inches, at 13 index-precipitation stations in the San Juan division and weighted-average precipitation in the subbasins and in the division, water years 1914–57*

Water year	San Juan River basin										Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.							San Juan division	
	Index stations									Weighted average	Index stations						Weighted average	Average 13 index stations	Weighted average
	Silverton	Hermit	Ignacio	Fort Lewis	Aztec Ruins	Regina	Crownpoint	Blanding	Average		Emery	Hanksville	Piute Dam	Orderville	Lees Ferry	Average			
1914	27.25	21.02	21.19	19.67	13.18	18.28	13.06	19.12	19.10	17.08	11.49	8.88	10.64	21.92	5.91	11.77	15.70	16.28	16.37
1915	21.95	18.49	18.70	23.29	11.07	19.68	10.95	20.56	18.09	16.17	6.36	3.60	7.30	14.30	4.77	7.27	9.70	13.92	14.00
1916	28.98	19.96	15.51	23.98	5.94	15.49	8.50	13.75	16.51	14.76	8.33	7.88	10.95	24.32	7.65	11.83	15.78	14.71	14.79
1917	27.06	22.29	16.58	16.02	4.37	13.98	7.70	16.48	15.56	13.91	13.70	8.74	9.07	16.90	11.16	11.91	15.89	14.16	14.24
1918	16.87	16.65	10.37	14.74	4.50	16.89	4.05	7.08	11.39	10.18	7.16	5.16	7.16	14.19	4.44	7.62	10.17	9.94	9.99
1919	25.53	21.01	17.18	21.62	6.53	25.29	16.76	12.25	18.27	16.33	9.56	5.32	8.45	9.93	5.94	7.84	10.46	14.26	14.34
1920	22.99	26.83	16.65	20.00	8.13	19.31	8.91	16.37	17.39	15.55	4.11	3.14	6.93	16.69	5.88	7.35	9.80	13.53	13.60
1921	31.03	16.25	19.99	10.39	11.91	21.01	9.81	13.10	16.69	14.92	6.16	4.38	8.52	14.94	5.49	7.90	10.54	13.31	13.38
1922	22.23	15.22	13.55	10.89	6.30	10.58	10.06	14.69	12.94	11.57	7.32	5.03	9.01	19.29	3.76	8.88	11.85	11.38	11.44
1923	23.98	21.03	15.93	18.40	9.92	13.52	13.01	14.32	16.26	14.54	6.27	3.96	7.51	13.44	7.01	7.64	10.19	12.95	13.02
1924	15.33	11.77	12.76	13.89	9.47	15.03	14.63	11.46	13.04	11.66	5.00	3.65	4.57	8.53	3.46	5.04	6.72	9.96	10.01
1925	37.04	16.62	19.57	18.82	9.48	15.62	13.41	12.06	17.83	15.94	7.95	2.79	7.87	13.60	7.25	7.89	10.53	14.00	14.08
1926	30.65	13.30	19.39	18.08	13.49	17.57	9.86	14.40	17.09	15.28	5.02	2.95	7.27	11.05	8.05	6.87	9.16	13.16	13.23
1927	36.43	22.81	23.60	26.37	13.43	19.30	17.53	20.01	22.44	20.06	10.15	8.48	10.07	18.10	6.83	10.73	14.31	17.93	18.03
1928	20.82	11.83	11.81	13.21	7.31	10.88	9.01	11.27	12.02	10.75	8.69	4.54	7.11	9.19	5.32	6.97	9.30	7.93	7.97
1929	30.88	22.38	25.49	24.20	16.26	21.48	14.97	16.13	21.47	19.19	7.12	6.79	10.17	12.83	5.84	8.55	11.41	16.50	16.59
1930	18.71	13.85	10.55	14.96	5.58	12.43	7.59	10.66	11.79	10.54	10.71	6.78	7.59	13.69	4.23	8.60	11.47	10.56	10.62
1931	17.74	16.40	11.15	16.77	9.64	14.49	14.16	8.81	13.65	12.20	2.51	3.45	4.24	10.67	3.61	4.90	6.54	10.28	10.34
1932	30.24	15.27	19.89	24.24	10.28	19.38	14.50	17.01	18.85	16.85	7.62	7.65	10.19	21.40	7.22	10.82	14.43	15.76	15.85
1933	22.70	15.19	10.80	16.52	7.44	13.07	8.61	10.73	13.13	11.74	8.31	5.72	5.22	9.81	4.51	6.71	8.95	10.66	10.72
1934	18.42	13.32	7.56	13.13	7.83	17.09	9.46	7.76	11.82	10.57	4.73	4.00	5.75	8.21	6.91	5.92	7.90	9.55	9.60
1935	23.70	16.97	16.99	22.04	10.76	18.74	10.73	13.36	16.66	14.89	6.25	3.44	5.75	16.03	6.62	7.62	10.16	13.18	13.25
1936	23.98	12.98	14.23	21.16	8.48	16.59	12.68	9.18	14.91	13.33	6.84	4.82	10.16	14.21	5.54	8.31	11.09	12.37	12.44
1937	21.09	12.19	17.31	19.15	13.33	16.82	12.91	15.80	16.07	14.37	10.02	7.07	11.57	23.65	5.81	11.62	15.50	14.36	14.44
1938	29.95	16.72	14.70	18.48	12.74	19.95	11.29	13.99	17.23	15.40	7.58	5.87	9.16	13.03	6.80	8.49	11.33	13.87	13.95
1939	20.37	14.49	10.89	16.44	7.11	16.42	7.20	10.22	12.89	11.52	8.71	4.29	8.18	17.39	5.36	8.79	11.73	11.31	11.37
1940	19.80	11.86	14.64	20.23	10.19	13.57	9.21	12.88	14.05	12.56	6.95	2.72	8.48	17.66	5.20	8.20	10.94	11.80	11.86
1941	30.93	24.05	25.00	32.69	22.91	28.63	16.91	22.69	25.48	22.78	14.59	6.50	13.09	21.45	9.33	12.99	17.33	20.67	20.78
1942	23.44	17.98	14.94	19.47	10.16	16.36	6.67	12.16	15.15	13.54	7.24	6.38	7.97	14.08	5.10	8.15	10.87	12.46	12.53
1943	25.38	16.30	16.61	20.37	9.37	16.83	8.41	10.07	15.42	13.79	5.78	3.73	8.17	15.50	4.38	7.51	10.02	12.38	12.45
1944	21.68	17.82	13.95	19.09	9.01	13.04	10.42	11.57	14.57	13.03	5.52	2.83	8.75	13.02	3.69	6.76	9.02	11.57	11.63
1945	17.96	13.95	13.29	14.70	9.86	16.00	8.60	10.53	13.11	11.72	4.91	4.33	7.37	11.04	4.85	6.50	8.67	10.57	10.63
1946	20.73	12.62	10.86	17.41	6.69	17.08	11.15	9.93	13.31	11.90	5.04	3.72	9.46	11.20	7.07	7.30	9.74	11.00	11.06
1947	26.47	16.30	15.34	18.26	9.29	19.14	11.06	12.14	16.00	14.30	12.06	6.82	11.13	14.41	5.45	9.97	13.30	13.68	13.75
1948	23.46	19.65	13.26	19.56	10.45	16.92	12.25	15.69	16.41	14.67	5.36	7.52	8.90	14.42	8.35	8.91	11.89	13.52	13.59
1949	22.64	11.15	17.08	22.46	13.39	16.11	11.43	16.59	16.36	14.63	9.32	9.70	8.14	17.31	5.76	10.05	13.41	13.93	14.01
1950	17.94	10.95	8.14	15.53	5.80	11.27	4.65	8.58	10.36	9.26	5.55	5.29	6.40	13.03	4.08	6.87	9.16	9.02	9.07
1951	15.32	9.12	9.88	13.72	4.13	9.42	5.93	7.50	9.38	8.39	7.09	4.13	6.89	10.66	5.49	6.85	9.14	8.41	8.46
1952	30.01	18.35	17.86	22.71	11.67	14.08	11.71	12.80	17.40	15.56	8.98	7.17	10.41	17.19	8.12	10.37	13.83	14.70	14.78
1953	16.25	11.39	11.48	13.44	5.61	12.64	5.98	12.20	11.12	9.94	5.07	3.79	4.39	9.43	7.98	6.13	8.18	9.20	9.25
1954	20.82	17.20	17.60	19.02	10.62	18.31	12.86	11.57	16.00	14.30	8.68	4.44	6.66	15.37	6.69	8.37	11.17	13.06	13.13
1955	18.14	11.63	14.92	15.39	8.41	13.81	8.86	9.53	12.59	11.26	6.52	2.63	7.86	12.21	3.26	6.50	8.67	10.24	10.30
1956	14.43	8.50	8.19	10.87	5.82	8.84	5.57	5.74	8.50	7.60	3.57	.84	5.23	9.03	2.67	4.27	5.70	6.87	6.91
1957	23.57	18.65	22.35	25.33	12.98	16.42	11.93	16.98	18.53	16.57	9.33	6.64	9.99	17.27	8.32	10.31	13.75	15.37	15.45
Average	23.52	16.19	15.40	18.56	9.56	16.30	10.57	12.95	15.38	13.75	7.48	5.17	8.17	14.58	5.94	8.27	11.03	12.60	12.67

TABLE 3.—*Reservoirs in the subbasins in the San Juan division*

[Source of data: U.S. Dept. of the Interior (1947) and files of the State Engineer of Utah]

Reservoir	Location	Usable capacity (acre-ft)
San Juan River basin		
Vallecitos	Lake Pinos River	126,300
Electra Lake	Cascade Creek (Animas River)	21,000
Juans Lake	Kimenola Wash (Chaco River)	5,000
Captain Tom	Toadlena Wash (Chaco River)	1,730
Jackson Gulch	West Mancos River	9,800
Bauer Lake	Chicken Creek (Mancos River)	1,070
Summit	Lost Canyon Creek (Dolores River)	4,800
Narraguinnep	Dolores River	9,300
Wheatfield	Wheatfield Creek (Chinle Wash)	1,000
Many Farms	Chinle Wash	25,000
Lower Rock Point	do	1,000
Marsh Pass	Laguna Creek (Chinle Wash)	1,160
Total		207,160
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.		
Fish Lake	Fremont River (Dirty Devil River)	4,000
Johnson Valley	do	4,000
Forsythe	do	3,400
Mill Meadows	do	5,200
Bourns	Oak Creek (Dirty Devil River)	3,150
Spectacle Lake	Escalante River	1,250
Total		21,000

TABLE 4.—*Transmountain diversions, in acre-feet, from the San Juan River basin, water years 1923–57*

Water year	San Juan River	Piedra River		Los Pinos River		Total
	Treasure Pass ditch	Piedra Pass ditch	Squaw Pass ditch	Fuchs ditch	Raber Lohr ditch	
1923	[1] 100	0	0	0	0	100
1924	[1] 130	0	0	0	0	130
1925	[1] 130	0	0	0	0	130
1926	[1] 130	0	0	0	0	130
1927	[1] 130	0	0	0	0	130
1928	[1] 130	0	0	0	0	130
1929	218	0	0	0	0	218
1930	154	0	0	0	0	154
1931	154	0	0	0	0	154
1932	188	0	0	0	0	188
1933	33	0	0	0	0	33
1934	128	0	0	0	0	128
1935	119	0	0	0	0	119
1936	192	0	0	0	0	192
1937	361	0	0	247	301	909
1938	82	0	76	57	255	470
1939	265	0	183	360	663	1,471
1940	199	148	230	256	412	1,245
1941	115	150	226	480	1,570	2,541
1942	31	128	107	234	870	1,370
1943	201	182	190	960	2,090	2,623
1944	38	0	153	219	543	953
1945	259	46	183	526	1,620	2,634
1946	78	62	243	473	1,480	2,336
1947	186	0	88	532	1,300	2,106
1948	29	0	145	319	1,590	2,083
1949	0	0	0	90	422	512
1950	69	0	208	361	976	1,614
1951	160	67	159	175	735	1,296
1952	198	0	240	536	1,730	2,704
1953	96	42	192	381	1,340	2,051
1954	60	0	211	1,110	3,650	5,031
1955	90	0	71	696	3,490	4,347
1956	128	84	177	941	2,630	3,960
1957	0	0	0	1,260	2,680	3,940

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[1] Estimated.

TABLE 5.—*Irrigated acreage in the subbasins in the San Juan division*

[Source of data: U.S. Bur. of the Census (1953), and Upper Colorado River Basin Compact Comm. (1948)]

Location	*Irrigated acreage*
San Juan River basin	
Source	0
Intervening area	5, 500
Total area, San Juan at Pagosa Springs, Colo	5, 500
Intervening area	4, 500
Navajo River basin tributary area	2, 800
Intervening area	500
Piedra River basin tributary area	5, 000
Intervening area	0
Total area, San Juan River near Rosa, N. Mex	18, 300
Intervening area	2, 500
Los Pinos River basin tributary area	40, 200
Intervening area	600
Total area, San Juan River at Blanco, N. Mex	61, 600
Intervening area	9, 000
Animas River near Durango, Colo., tributary area	5, 500
Intervening area	30, 000
Animas River basin tributary area	35, 500
Intervening area	200
La Plata River at Colorado-New Mexico State line tributary area	16, 500
Intervening area	9, 500
La Plata River basin tributary area	26, 000
Intervening area	8, 000
San Juan River basin—Continued	
Chaco River basin tributary area	5, 800
Intervening area	800
Total area, San Juan River at Shiprock, N. Mex	146, 900
Intervening area	0
Mancos River basin tributary area	12, 900
Intervening area	0
McElmo Creek basin tributary area	37, 800
Intervening area	0
Montezume Creek basin tributary area	3, 000
Intervening area	0
Recapture Creek basin tributary area	2, 000
Intervening area	0
Chinle Creek basin tributary area	3, 800
Intervening area	0
Total area, San Juan River near Bluff, Utah	206, 400
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.	
Dirty Devil River tributary area	23, 300
Escalante River tributary area	7, 000
Paria River tributary area	3, 000
Total area, Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz	33, 300

TABLE 6.—*Flow-duration table for stations in the subbasins in the San Juan division*

[Italic figures are for the water years 1914–57 adjusted to 1957 conditions; figures opposite indicated water years are historical flow-duration data]

Station No.	Streamflow station	Daily discharge, in cubic feet per second, that was equaled or exceeded for indicated percentage of time																			Average discharge (cfs)	Average annual discharge (acre-ft)
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	San Juan River basin																					
3400	San Juan River near Pagosa Springs, Colo.	*1,710*	*1,570*	*1,400*	*1,160*	*880*	*710*	*553*	*375*	*205*	*93*	*51*	*33*	*25*	*20*	*17*	*14*	*10*	*8.2*	*6.8*	*135*	*97,800*
	1936–57	1,710	1,570	1,400	1,140	850	665	505	338	180	79	46	31	23	19	16	13	10	7.8	6.5	124	89,830
3405	West Fork, San Juan River above Borns Lake, near Pagosa Springs, Colo.	*1,200*	*1,090*	*980*	*770*	*575*	*460*	*342*	*227*	*130*	*63*	*37*	*26*	*20*	*17*	*14*	*11*	*8.5*	*7.1*	*6.6*	*88.5*	*64,110*
	1938–53	1,200	1,090	980	770	570	445	331	209	110	56	35	24	19	16	14	11	9.2	7.6	6.8	83.3	60,350
3425	San Juan River at Pagosa Springs, Colo.	*4,640*	*4,390*	*4,090*	*3,420*	*2,640*	*2,100*	*1,615*	*1,130*	*630*	*275*	*149*	*98*	*76*	*62*	*52*	*43*	*31*	*19*	*14*	*403*	*292,000*
	1936–57	4,640	4,390	4,080	3,390	2,530	1,990	1,500	1,030	545	230	135	95	71	60	51	41	30	18	13	372	269,500
3460	Navajo River at Edith, Colo.	*2,000*	*1,660*	*1,470*	*1,170*	*885*	*720*	*582*	*422*	*265*	*143*	*83*	*60*	*47*	*41*	*35*	*29*	*23*	*18*	*15*	*164*	*118,800*
	1913, 1915–18, 1921–23, 1925, 1927, 1928, 1936–57	2,000	1,580	1,390	1,090	855	695	545	398	260	135	80	58	47	41	35	29	23	18	14	158	114,500
3495	Piedra River near Piedra, Colo.	*4,400*	*4,170*	*3,840*	*3,090*	*2,380*	*1,900*	*1,490*	*1,020*	*620*	*300*	*140*	*95*	*74*	*63*	*54*	*45*	*35*	*29*	*23*	*380*	*275,300*
	1940–57	4,400	4,170	3,840	3,090	2,230	1,695	1,260	850	490	220	118	87	70	60	51	43	33	26	21	328	237,600
3505	San Juan River at Rosa, N. Mex.	*13,600*	*12,000*	*10,800*	*8,800*	*6,800*	*5,600*	*4,510*	*3,405*	*2,050*	*1,030*	*540*	*360*	*265*	*213*	*173*	*139*	*105*	*66*	*47*	*1,208*	*875,100*
	1931–36, 1938–57	13,600	11,900	10,600	8,500	6,380	5,050	4,000	2,785	1,675	830	490	330	255	205	168	134	102	60	45	1,060	767,900
3535	Los Pinos River near Bayfield, Colo.	*4,030*	*3,050*	*2,680*	*2,180*	*1,730*	*1,450*	*1,170*	*890*	*640*	*500*	*375*	*259*	*139*	*78*	*54*	*40*	*30*	*22*	*17*	*397*	*287,600*
	1928–57	5,000	3,250	2,800	2,280	1,770	1,390	1,075	815	580	405	275	180	115	78	57	42	31	25	21	354	256,500
3545 3550	Los Pinos River at La Boca, Colo. 1952–57 Spring Creek at La Boca, Colo. 1952–57	*5,800*	*4,400*	*3,550*	*2,500*	*1,640*	*1,220*	*930*	*655*	*415*	*288*	*225*	*177*	*137*	*103*	*79*	*62*	*49*	*41*	*36*	*313*	*226,800*
		5,500	4,000	3,200	2,180	1,500	1,130	780	425	230	178	147	120	94	78	66	55	44	36	32	233	168,800
3565	San Juan River near Blanco, N. Mex.	*19,250*	*16,200*	*14,200*	*11,400*	*8,580*	*6,950*	*5,550*	*4,000*	*2,450*	*1,300*	*760*	*530*	*388*	*302*	*252*	*200*	*130*	*64*	*34*	*1,519*	*1,100,000*
	1931–54	20,100	16,850	14,800	11,200	8,300	6,600	5,100	3,550	2,040	1,080	685	480	355	288	235	180	105	44	24	1,376	996,900
3575	Animas River at Howardsville, Colo.	*1,360*	*1,260*	*1,160*	*960*	*710*	*565*	*448*	*305*	*180*	*92*	*52*	*36*	*27*	*22*	*18*	*16*	*13*	*11*	*9.6*	*117*	*84,760*
	1936–57	1,360	1,210	1,120	890	670	540	420	285	158	81	45	31	24	20	17	15	13	11	10	107	77,520
3590	Mineral Creek near Silverton, Colo.	*1,240*	*1,130*	*1,030*	*840*	*630*	*485*	*375*	*265*	*165*	*89*	*52*	*37*	*27*	*21*	*18*	*16*	*12*	*7.5*	*5.2*	*105*	*76,070*
	1937–49	1,240	1,100	1,000	820	620	510	390	280	168	90	52	35	27	21	18	16	14	11	7.4	107	77,520
3610	Hermosa Creek near Hermosa, Colo.	*2,460*	*2,050*	*1,800*	*1,400*	*1,020*	*785*	*578*	*380*	*206*	*93*	*56*	*41*	*33*	*26*	*21*	*17*	*13*	*8.8*	*5.6*	*147*	*106,500*
	1921–28, 1941–57	2,460	2,100	1,820	1,395	1,020	790	570	358	203	92	56	41	32	26	21	17	13	9.0	5.7	145	105,000
3615	Animas River at Durango, Colo.	*10,700*	*9,180*	*8,170*	*6,400*	*4,750*	*3,740*	*2,900*	*2,090*	*1,290*	*730*	*470*	*338*	*272*	*235*	*203*	*180*	*152*	*123*	*106*	*859*	*622,300*
	1898, 1900, 1913–25, 1928–57	10,700	9,000	7,980	6,250	4,620	3,650	2,830	2,060	1,280	725	465	330	267	228	200	177	152	122	106	844	611,400
3645	Animas River at Farmington, N. Mex.	*11,000*	*9,950*	*9,200*	*7,700*	*5,740*	*4,450*	*3,350*	*2,350*	*1,430*	*770*	*505*	*375*	*308*	*265*	*232*	*192*	*83*	*25*	*8.3*	*971*	*703,500*
	1914, 1920–25, 1931–57	11,000	9,900	9,100	7,500	5,550	4,200	3,150	2,180	1,290	730	475	355	300	270	238	182	70	20	5.0	918	665,100
3650	San Juan River at Farmington, N. Mex.	*29,000*	*25,800*	*23,300*	*19,000*	*14,200*	*11,700*	*9,250*	*6,550*	*4,080*	*2,390*	*1,390*	*950*	*720*	*600*	*505*	*410*	*245*	*97*	*50*	*2,589*	*1,876,000*
	1931–57	30,000	25,000	21,800	17,400	13,000	10,300	7,900	5,450	3,400	1,855	1,160	825	670	565	485	381	208	67	39	2,239	1,622,000
3655	La Plata River at Hesperus, Colo.	*774*	*670*	*605*	*470*	*353*	*268*	*185*	*122*	*67*	*31*	*18*	*13*	*10*	*8.0*	*6.5*	*5.1*	*3.9*	*2.7*	*1.7*	*48.3*	*34,990*
	1918–57	774	660	585	460	325	245	178	118	66	30	18	13	9.8	7.8	6.5	5.1	3.9	3.0	1.8	46.4	33,610
3665	La Plata River at Colorado-New Mexico State line	*1,120*	*870*	*720*	*490*	*300*	*206*	*139*	*86*	*48*	*26*	*17*	*12*	*8.6*	*5.4*	*3.1*	*1.2*	*.0*	*.0*	*.0*	*38.5*	*27,890*
	1921–57	1,120	820	655	420	268	184	122	76	46	24	16	12	7.7	5.0	2.9	1.1	.0	.0	.0	35.1	25,430
3680	San Juan River at Shiprock, N. Mex.	*30,100*	*27,100*	*24.800*	*20,000*	*15,000*	*12,000*	*9,300*	*6,600*	*4,150*	*2,450*	*1,450*	*1,020*	*800*	*640*	*560*	*440*	*168*	*15*	*6.0*	*2,679*	*1,941,000*
	1935–57	30,900	26,500	23,600	18,700	13,900	10,800	8,200	5,650	3,450	1,980	1,300	940	750	622	545	425	178	46	16	2,370	1,717,000
3710	Mancos River near Towaoc, Colo.	*3,500*	*1,150*	*920*	*675*	*455*	*335*	*241*	*150*	*81*	*44*	*27*	*21*	*15*	*8.0*	*4.1*	*1.2*	*.0*	*.0*	*.0*	*62.4*	*45,210*
	1922–43, 1952–57	3,050	1,040	870	640	420	310	215	130	69	36	24	19	13	7.3	3.6	1.0	.0	.0	.0	55.7	40,350

3715	McElmo Creek near Cortez, Colo 1927–29, 1941–43, 1951–54	*1,900* 1,900	*1,100* 1,080	*630* 700	*288* 308	*180* 185	*150* 148	*127* 122	*99* 97	*76* 75	*58* 58	*47* 47	*38* 38	*32* 31	*26* 25	*21* 20	*16* 14	*8.1* 6.3	*3.9* 3.1	*2.5* 2.2	*53.5* 53.0	*38,760* 38,400
3720	McElmo Creek near Colorado-Utah State line, 1952–57	1,300	890	398	250	163	116	84	63	47	37	31	27	23	19	13	3.6	.6	.4	.0	36.3	26,300
3795	San Juan River near Bluff, Utah 1916. 1928, 1930–57	*32,000* 33,000	*27,000* 26,900	*24,000* 23,000	*19,100* 17,600	*14,400* 12,900	*11,400* 10,400	*9,200* 8,150	*6,900* 5,850	*4,400* 3.800	*2,690* 2,290	*1,810* 1,500	*1,240* 1,100	*930* 880	*750* 715	*610* 570	*440* 400	*240* 185	*76* 42	*20* .0	*2,800* 2,468	*2,028,000* 1,788,000

Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.

3300	Fremont River near Bicknell, Utah, 1938–43, 1947–57	1,040	925	750	260	138	123	113	105	98	91	85	80	76	72	68	62	55	47	41	85.8	62,160
3305	Muddy Creek near Emery, Utah 1911–13, 1950–57	*840* 840	*498* 530	*420* 450	*310* 330	*222* 240	*169* 180	*117* 128	*81* 89	*48* 61	*27* 38	*18* 23	*15* 17	*13* 13	*11* 11	*9.2* 8.7	*7.6* 6.9	*6.6* 4.9	*5.4* 3.6	*4.0* 2.5	*36.1* 40.6	*26,150* 29,410
3335	Dirty Devil River near Hite, Utah, 1949–57	9,400	5,000	2,700	1.100	480	310	220	166	130	107	89	71	52	34	16	1.7	.0	.0	.0	102	73,890
3350	Colorado River at Hite, Utah 1948–57	*124,000* 108,000	*113,000* 102,500	*106,000* 99,000	*88,500* 87,000	*69,000* 69,000	*57.000* 56,000	*46,000* 44,400	*34,300* 31,400	*20,300* 17,400	*11 800* 10,400	*8,250* 7,430	*6,800* 6,400	*6,000* 5,780	*5,300* 5,200	*4,600* 4,600	*3,780* 3,780	*2,800* 3,030	*2,480* 2,700	*2,350* 2,520	*14,167* 13,308	*10,260,000* 9,641,000
3375	Escalante River near Escalante, Utah, 1912, 1943–55	980	285	205	133	78	51	36	26	17	13	9.2	6.6	4.6	3.4	2.5	1.6	.9	.5	.4	13.2	9,560
3395	Escalante River at mouth near Escalante, Utah, 1951–55	6,100	3,750	2,350	870	315	205	150	120	99	85	73	62	53	43	34	24	16	12	9.2	85.2	61,720
3800	Colorado River at Lees Ferry, Ariz 1922–57	*178,200* 165,000	*137 300* 140,000	*122,200* 127,000	*101,500* 103,000	*82,090* 80,200	*69,120* 67,000	*55,060* 55,500	*41,660* 40,700	*25,690* 24,500	*16,120* 15,000	*11,280* 10,400	*8,678* 8,100	*7.428* 6,970	*6,492* 6,200	*5,646* 5,440	*4,584* 4,400	*3,263* 3,050	*2,162* 2,030	*1,493* 1,410	*17,550* 16,944	*12,710,000* 12,280,000
3820	Paria River at Lees Ferry, Ariz 1924–57	*7,500* 7,300	*3,400* 2,900	*1,800* 1,470	*570* 570	*190* 190	*97* 92	*60* 58	*38* 37	*27* 27	*22* 21	*18* 18	*14* 14	*11* 10	*6.8* 6.6	*4.9* 4.8	*3.8* 3.7	*2.9* 2.9	*2.3* 2.3	*1.9* 1.9	*31.9* 30.7	*23,110* 22,240

TABLE 7.—*Methods and accuracy of adjusting flow-duration data for stations in the subbasins in the San Juan division to base period and 1957 conditions*

Index-station No.: Index station used in adjusting flow-duration curve to base period of correlation station used in estimating data for missing periods of record.
Years of record: Number of years of available historical flow-duration data during water years 1914–57.
Base period adjustment method: Method used in adjusting historical data to base period; I, index-station method, M, monthly means method, S, substitute method.
Upstream water developments: Upstream reservoirs, irrigation, and transmountain diversions in which changes occurred in base period requiring adjustment in historical data to 1957 conditions.
Accuracy rating: Authors' rating of accuracy of adjusted flow-duration curve for water years 1914–57 to 1957 conditions. The accuracy rating indicates that the final developed flow-duration curve throughout its range is believed to be correct within the percentage indicated.

Station No.	Index-station No.	Years of record	Base-period adjustment method	Upstream water developments	Accuracy rating (percent)
San Juan River basin					
3400	[1] 3425	22	I		15
3405	[1] 3425	16	I		15
3425	3460, 3495, 3505, 3615	22	M, S		10
3460	(2)	32	S		10
3495	[1] 3505	18	I		15
3505	(2)	26	M, S		10
3535	3540, 3615, 3630	30	M	Vallecitos Reservoir	10
3545	3540, 3645	6	M	do	15+
3550					
3565	[2] 3540, 3505	24	S	Vallecitos Reservoir and irrigation.	15
3575	3615	22	I		15
3590	3615	13	I		15+
3610	3575, 3655, 3590	25	S		15
3615	(2)	42	S		5
3645	(2)	34	S		10
3650	(2)	27	M, S	Vallecitos Reservoir and irrigation.	10
3655	3610, 3615	40	S		5
3665	(2)	37	S		5
3680	[3] 3650	23	I	Vallecitos Reservoir and irrigation.	10
3710	[2] 3655, 3665	28	S		15
3715	(2)	10	S		15+
3795	(4)	30	S	Vallecitos Reservoir and irrigation.	10
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.					
3305	[1] 3265	8	I		15+
3350	[3] 1805, [3] 3150	10	I	(5)	10
3800	(6)	36	M	(7)	5
3820	(2)	34	S		10

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[1] Flow-duration curve and data for index station that had been adjusted to base period were used.

[2] Annual estimates of discharge by Upper Colorado River Compact Commission (1948) were used.

[3] Flow-duration curve and data for index station that had been adjusted to base period and 1957 conditions were used.

[4] Annual estimates by U.S. Geol. Survey (1954) were used.

[5] Berthoud Pass ditch, Moffat tunnel, Grand River ditch, Colorado-Big-Thompson project, Willow Creek Reservoir, Williams Fork Reservoir, Jones Pass and Hoosier Pass tunnels, Green Mountain Reservoir, Columbine and Wurtz ditches, Twin Lakes and Busk-Ivanhoe tunnels, Taylor Park Reservoir, Gunnison tunnel, and Duchesne tunnel.

[6] Monthly estimates of discharge by the Upper Colorado River Compact Commission (1948) were used.

[7] Berthoud Pass ditch, Moffat tunnel, Grand River ditch, Colorado-Big-Thompson project, Willow Creek Reservoir, Williams Fork Reservoir, Jones Pass and Hoosier Pass tunnels, Green Mountain Reservoir, Columbine and Wurtz ditches, Twin Lakes and Busk-Ivanhoe tunnels, Taylor Park Reservoir, Gunnison tunnel, Duchesne tunnel, and Vallecito Reservoir.

TABLE 8.—*Variability index of streamflow and percentage of average annual discharge estimated to be contributed by ground water for selected streams in the San Juan River basin, Colo.*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Station name	Variability index	Ground water (percent)
3400	San Juan River near Pagosa Springs	0.64	16
3425	San Juan River at Pagosa Springs	.62	17
3495	Piedra River near Piedra	.61	17
3505	San Juan River at Rosa	.61	19
3655	La Plata River at Hesperus	.60	17
3575	Animas River at Howardsville	.58	20
3610	Hermosa Creek near Hermosa	.58	19
3460	Navajo River at Edith	.50	25
3615	Animas River at Durango	.46	28

TABLE 9.—*Average discharge, standard deviation, and coefficient of variation for selected streams in the subbasins in the San Juan division*

Station No.	Station name	Period of record	Average discharge (cfs)	Standard deviation (cfs)	Coefficient of variation
	San Juan River basin				
3425	San Juan River at Pagosa Springs, Colo	1914, 1936–57	376	159	0.42
3460	Navajo River at Edith, Colo	1914–57	165	64.7	.39
3505	San Juan River at Rosa, N. Mex	1914–57	1,208	523	.43
3615	Animas River at Durango, Colo	1914–57	859	278	.32
3650	San Juan River at Farmington, N. Mex	1914–57	2,633	1,160	.44
3655	La Plata River at Hesperus, Colo	1918–57	46.2	18.4	.40
3710	Mancos River near Towaoc, Colo	1921–43, 1952–57	58.8	37.8	.64
3795	San Juan River near Bluff, Utah	1914–57	2,842	1,275	.45
	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.				
3305	Muddy Creek near Emery, Utah	1950–57	38.4	20.6	0.54
3335	Dirty Devil River near Hite, Utah	1949–57	102	34.7	.34
3375	Escalante River near Escalante, Utah	1943–55	11.4	6.8	.59
3800	Colorado River at Lees Ferry, Ariz	1914–57	[1] 18,120 [2] 18,300 [3] 20,750	[1] 5,770 [2] 5,560 [3] 6,090	[1] .32 [2] .30 [3] .29
3820	Paria River at Lees Ferry, Ariz	1924–57	30.7	11.4	.37

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[1] Historical record.

[2] Historical record plus transmountain diversions and adjustment for change in storage reservoirs.

[3] Reconstructed record of annual discharge values representing virgin flow (Leopold, 1959) and later data furnished by I. V. Goslin (oral commun., 1960).

TABLE 10.—*Water and dissolved-solids discharge in the subbasins in the San Juan division*

[Water and dissolved-solids discharge for the water years 1914–57 adjusted to 1957 conditions except as indicated]

Station No.	Chemical-quality station	Drainage area (sq mi)	Water discharge		Dissolved solids			
			Average (cfs)	Average annual (acre-ft)	Weighted-average concentration (ppm)	Average discharge (tons per day)	Average annual yield per sq mi (tons)	Average annual discharge (tons)
	San Juan River basin							
3400	San Juan River near Pagosa Springs, Colo	86.9	135	97,800	77	28	118	10,230
3405	West Fork San Juan River above Borns Lake, near Pagosa Springs, Colo	41.2	88.5	64,110	42	10	89	3,650
3425	San Juan River at Pagosa Springs, Colo	298	403	292,000	73	79	97	28,850
3460	Navajo River at Edith, Colo	165	164	118,800	113	50	111	18,260
3460B	San Juan River near Arboles, Colo	1,340	748	541,900	104	211	57	77,000
3495	Piedra River near Piedra, Colo	371	380	275,300	126	129	127	47,120
3505	San Juan River at Rosa, N. Mex	1,990	1,208	875,100	117	383	70	139,900
3535	Los Pinos River near Bayfield, Colo	284	397	287,600	62	66	85	24,110
3545	Los Pinos River at La Boca, Colo	510	278	201,400	108	81	58	29,590
3550	Spring Creek at La Boca, Colo	58	35.3	25,570	231	22	139	8,040
3565	San Juan River near Blanco, N. Mex	3,560	1,519	1,100,000	125	512	53	187,000
3575	Animas River at Howardsville, Colo	55.9	117	84,760	111	35	229	12,780
3590	Mineral Creek near Silverton, Colo	43.9	105	76,070	78	22	183	8,040
3610	Hermosa Creek near Hermosa, Colo	172	147	106,500	219	87	185	31,780
3615	Animas River at Durango, Colo	692	859	622,300	183	425	224	155,200
3645	Animas River at Farmington, N. Mex	1,360	971	703,500	233	611	164	223,200
3655	La Plata River at Hesperus, Colo	37	48.3	34,990	84	11	109	4,020
3665	La Plata River at Colorado-New Mexico State line	331	38.5	27,890	356	37	41	13,510
3675	La Plata River near Farmington, N. Mex	583	31.4	22,750	908	77	48	28,120
3680	San Juan River at Shiprock, N. Mex	12,900	2,679	1,941,000	256	1,850	52	675,700
3710	Mancos River near Towaoc, Colo	550	62.4	45,210	629	106	70	38,720
3715	McElmo Creek near Cortez, Colo	233	53.5	38,760	2,180	315	494	115,100
3795	San Juan River near Bluff, Utah	23,000	2,800	2,028,000	361	2,730	43	997,100
	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.							
3300	Fremont River near Bicknell, Utah[1]	776	85.8	62,160	302	70	33	25,570
3305	Muddy Creek near Emery, Utah	89	36.1	26,150	213	21	86	7,670
3335	Dirty Devil River near Hite, Utah[2]	4,360	102	73,890	1,960	541	45	197,600
3350	Colorado River at Hite, Utah	76,600	14,167	10,260,000	527	20,170	96	7,367,000
3375	Escalante River near Escalante, Utah[3]	315	13.2	9,560	477	17	20	6,210
3395	Escalante River at mouth, near Escalante, Utah[4]	2,010	85.2	61,720	300	69	13	25,200
3800	Colorado River at Lees Ferry, Ariz	107,900	17,550	12,710,000	499	23,660	80	8,642,000
3820	Paria River at Lees Ferry, Ariz	1,570	31.9	23,110	1,090	94	22	34,330

[1] For water years 1938–43, 1947–57.

[2] For water years 1949–57.

[3] For water years 1943–55.

[4] For water years 1951–55.

TABLE 11.—*Duration table of dissolved-solids concentration for selected stations in the subbasins in the San Juan division*

[Table based on measured or partly estimated streamflow for the water years 1914–57 adjusted to 1957 conditions and on applicable chemical-quality records]

Station No.	Chemical-quality station	Dissolved-solids concentration, in parts per million, that was equaled or exceeded for indicated percentage of time																			Weighted-average concentration (ppm)
		99.99	99.94	99.85	99.4	98	96	93	88	80	70	60	50	40	30	20	10	3	0.6	0.1	
	San Juan River basin																				
3400	San Juan River near Pagosa Springs, Colo	67	67	67	67	68	68	69	72	78	94	100	101	102	103	103	103	103	104	104	77
3405	West Fork San Juan River above Berns Lake, near Pagosa Springs, Colo	36	36	37	37	37	37	38	39	42	50	54	55	55	55	55	55	55	55	55	42
3425	San Juan River at Pagosa Springs, Colo	50	50	50	50	51	52	53	58	80	124	138	140	140	140	141	141	142	143	143	73
3460	Navajo River at Edith, Colo	72	72	72	73	75	78	81	100	114	155	178	180	182	183	185	186	188	188	188	113
3460B	San Juan River near Arboles, Colo	75	76	76	77	79	81	83	86	98	120	156	193	205	212	218	219	220	220	220	104
3495	Piedra River near Piedra, Colo	94	94	94	94	95	96	98	105	121	159	218	242	253	259	262	264	266	266	266	126
3505	San Juan River at Rosa, N. Mex	82	83	84	85	88	91	95	101	115	140	174	199	218	229	239	248	255	261	261	117
3535	Los Pinos River near Bayfield, Colo	56	57	58	58	59	60	60	61	62	62	63	64	66	68	69	70	71	72	73	62
3545	Los Pinos River at La Boca, Colo	74	75	75	76	77	80	84	92	107	123	134	148	166	180	190	195	197	198	198	108
3550	Spring Creek at La Boca, Colo	152	153	153	154	160	165	170	177	190	209	231	258	295	354	477	760	800	805	805	231
3565	San Juan River near Blanco, Colo	84	84	85	86	86	88	91	97	113	150	195	230	264	286	300	317	335	340	345	125
3575	Animas River at Howardsville, Colo	75	75	76	76	78	80	84	98	123	160	170	172	174	175	176	176	176	177	180	111
3590	Mineral Creek near Silverton, Colo	66	66	66	66	66	66	66	66	67	73	92	112	137	160	174	184	208	235	248	78
3610	Hermosa Creek near Hermosa, Colo	150	150	150	151	152	159	170	191	243	345	388	400	400	400	400	400	400	400	400	219
3615	Animas River at Durango, Colo	118	118	119	120	121	125	132	148	186	250	286	294	297	299	300	300	301	304	305	183
3645	Animas River at Farmington, N. Mex	137	137	137	138	138	140	146	168	213	293	370	430	475	511	560	608	698	751	800	233
3655	La Plata River at Hesperus, Colo	81	81	81	81	81	82	82	82	84	87	93	99	106	113	118	122	125	125	126	84
3665	La Plata River at Colorado-New Mexico State line	231	231	232	233	234	241	259	305	390	532	658	766	880	1,010	1,110	1,160	------	------	------	356
3675	La Plata River near Farmington, N. Mex	470	470	475	495	565	658	795	1,050	1,420	1,710	2,000	2,350	2,670	2,950	3,050	3,100	3,100	------	------	908
3680	San Juan River at Shiprock, N. Mex	135	136	136	138	144	153	165	190	235	305	410	505	565	620	650	690	720	730	735	256
3710	Mancos River near Towaoc, Colo	222	225	230	243	282	348	458	670	963	1,160	1,200	1,200	1,200	1,200	1,200	1,200	------	------	------	629
3715	McElmo Creek near Cortez, Colo	1,370	1,370	1,370	1,380	1,450	1,510	1,600	1,760	1,990	2,240	2,460	2,720	2,940	3,240	3,550	4,000	5,100	5,600	5,600	2,180
3795	San Juan River near Bluff, Utah	183	190	194	203	217	230	243	265	308	385	500	660	780	845	900	960	1,050	1,080	1,100	361
	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.																				
3300	Fremont River near Bicknell, Utah [1]	258	259	260	280	298	300	300	301	302	303	304	304	305	305	305	306	306	308	308	302
3305	Muddy Creek near Emery, Utah	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	213
3335	Dirty Devil River near Hite, Utah [2]	1,500	1,500	1,500	1,530	1,620	1,700	1,780	1,880	1,990	2,090	2,200	2,380	2,600	2,860	3,100	3,400	------	------	------	1,960
3350	Colorado River at Hite, Utah	278	278	278	279	280	282	292	323	410	658	835	942	1,020	1,070	1,160	1,250	1,300	1,300	1,300	527
3375	Escalante River near Escalante, Utah [3]	182	199	203	213	237	265	302	354	472	600	760	890	1,000	1,040	1,040	1,050	1,050	1,060	1,060	477
3395	Escalante River at mouth, near Escalante, Utah [4]	190	190	190	198	220	241	269	290	312	328	342	359	372	387	400	410	410	410	410	300
3800	Colorado River at Lees Ferry, Ariz	250	253	256	262	270	280	295	322	420	580	730	860	935	990	1,040	1,120	1,170	1,200	1,210	499
3820	Paria River at Lees Ferry, Ariz	295	300	330	430	570	770	940	1,000	1,030	1,060	1,080	1,100	1,110	1,130	1,140	1,150	1,170	1,190	1,200	1,090

[1] For water years 1938–43, 1947–57.

[2] For water years 1949–57.

[3] For water years 1943–55.

[4] For water years 1951–55.

TABLE 12.—*Duration table of dissolved-solids discharge for selected stations in the subbasins in the San Juan division*

[Dissolved-solids discharge for water years 1914–57, adjusted to 1957 conditions, except as indicated]

Station No.	Chemical-quality station	Daily discharge, in tons per day, that was equaled or exceeded for indicated percentage of time																			Tons per day	Tons per sq mi per yr
		0.01	0.06	0.15	0.6	2.0	4.0	7.0	12	20	30	40	50	60	70	80	90	97	99.4	99.9		
	San Juan River basin																					
3400	San Juan River near Pagosa Springs, Colo	309	284	253	210	162	130	103	73	43	24	14	9.0	6.9	5.6	4.7	3.9	2.8	2.3	1.9	28	118
3405	West Fork San Juan River above Borns Lake, near Pagosa Springs, Colo	117	106	98	77	57	46	35	24	15	8.5	5.4	3.9	3.0	2.5	2.1	1.6	1.3	1.1	1.0	10	89
3425	San Juan River at Pagosa Springs, Colo	626	593	552	462	364	295	231	177	136	92	56	37	29	23	20	16	12	7.3	5.4	79	97
3460	Navajo River at Edith, Colo	389	323	286	231	179	152	127	114	82	60	40	29	23	20	17	15	12	9.1	7.6	50	111
3460B	San Juan River near Arboles, Colo	1,680	1,490	1,340	1,100	864	722	605	474	344	233	158	130	97	77	58	41	28	19	15	211	57
3495	Piedra River near Piedra, Colo	1,120	1,060	975	784	610	492	394	289	203	129	82	62	51	44	38	32	25	21	17	129	127
3505	San Juan River at Rosa, N. Mex	3,010	2,690	2,450	2,020	1,620	1,380	1,160	929	637	389	254	193	156	132	112	93	72	47	33	383	70
3535	Los Pinos River near Bayfield, Colo	609	469	420	341	276	235	190	147	107	84	64	45	25	14	10	7.6	5.8	4.3	3.4	66	85
3545	Los Pinos River at La Boca, Colo	1,110	849	687	489	321	246	194	146	103	80	67	58	51	42	35	31	25	21	19	81	58
3550	Spring Creek at La Boca, Colo	106	85	65	49	41	37	35	33	30	27	24	22	19	16	13	7.6	5.2	3.7	2.6	22	139
3565	San Juan River near Blanco, N. Mex	4,370	3,670	3,260	2,650	1,990	1,650	1,360	1,050	747	526	400	329	277	233	204	171	118	59	32	512	53
3575	Animas River at Howardsville, Colo	275	255	238	197	150	122	102	81	60	40	24	17	13	10	8.6	7.6	6.2	5.3	4.7	35	229
3590	Mineral Creek near Silverton, Colo	221	201	184	150	112	86	67	47	30	18	13	11	10	9.1	8.5	7.9	6.7	4.8	3.5	22	183
3610	Hermosa Creek near Hermosa, Colo	996	830	729	571	419	337	265	196	135	87	59	44	36	28	23	18	14	9.5	6.0	87	185
3615	Animas River at Durango, Colo	3,410	2,920	2,630	2,070	1,550	1,260	1,030	835	648	493	363	268	218	190	164	146	124	101	87	425	224
3645	Animas River at Farmington, N. Mex	4,070	3,680	3,400	2,870	2,140	1,680	1,320	1,070	822	609	505	435	395	366	351	315	156	51	18	611	164
3655	La Plata River at Hesperus, Colo	169	147	132	103	77	59	41	27	15	7.3	4.5	3.5	2.9	2.4	2.1	1.7	1.3	.9	.6	11	109
3665	La Plata River at Colorado-New Mexico State line	699	543	451	308	190	134	97	71	51	37	30	25	20	15	9.3	3.8	0	0	0	37	41
3675	La Plata River near Farmington, N. Mex	3,620	2,260	1,490	722	430	320	234	162	107	78	59	41	27	13	5.8	2.5	.8	--------	--------	77	48
3680	San Juan River at Shiprock, N. Mex	10,970	9,950	9,110	7,450	5,830	4,960	4,140	3,390	2,630	2,020	1,610	1,390	1,220	1,070	983	820	327	30	12	1,850	52
3710	Mancos River near Towaoc, Colo	2,100	699	571	443	346	315	298	271	211	138	87	68	49	26	13	3.9	0	0	0	106	70
3715	McElmo Creek near Cortez, Colo	7,030	4,070	2,330	1,070	705	612	549	470	408	351	312	279	254	227	201	173	112	59	38	315	494
3795	San Juan River near Bluff, Utah	15,810	13,850	12,570	10,470	8,440	7,080	6,040	4,940	3,660	2,800	2,440	2,210	1,960	1,710	1,480	1,140	680	222	59	2,730	43
	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.																					
3300	Fremont River near Bicknell, Utah[1]	724	647	527	197	111	100	92	85	80	74	70	66	63	59	56	51	45	39	34	70	33
3305	Muddy Creek near Emery, Utah	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	21	86
3335	Dirty Devil River near Hite, Utah[2]	38,070	20,250	10,940	4,540	2,100	1,420	1,060	843	699	604	529	456	365	263	134	16	0	0	0	541	45
3350	Colorado River at Hite, Utah	93,080	84,820	79,560	66,670	52,160	43,400	36,270	29,910	22,470	20,960	18,600	17,300	16,520	15,310	14,410	12,760	9,830	8,700	8,250	20,170	96
3375	Escalante River near Escalante, Utah[3]	482	153	112	76	50	36	29	25	22	21	19	16	12	10	7.0	4.5	2.6	1.4	1.1	17	20
3395	Escalante River at mouth, near Escalante, Utah[4]	3,130	1,920	1,210	465	187	133	109	94	83	75	67	60	53	45	37	27	18	13	10	69	13
3800	Colorado River at Lees Ferry, Ariz	120,300	93,790	84,460	71,800	59,840	52,250	43,860	36,220	29,130	25,240	22,230	20,150	18,760	17,350	15,870	13,850	10,300	7,000	4,870	23,660	80
3820	Paria River at Lees Ferry, Ariz	24,300	10,920	5,690	1,770	585	296	180	113	79	63	50	38	28	14	7.5	4.4	2.6	1.9	1.5	94	22

[1] For water years 1938–43, 1947–57.
[2] For water years 1949–57.
[3] For water years 1943–55.
[4] For water years 1951–55.

TABLE 13.—*Variability of annual weighted-average concentration of dissolved solids as related to the variability of annual water discharge for daily stations in the San Juan River basin*

Station No.	Station name	Water years	Coefficient of variation	
			Water discharge	Weighted-average concentration
3645	Animas River at Farmington, N. Mex	1941–57	0.45	0.20
3565	San Juan River near Blanco, N. Mex	1946–54	.59	.16
3795	San Juan River near Bluff, Utah	1930–57	.51	.19

TABLE 14.—*Relation between water discharge and chemical quality of water at selected stations in the San Juan division*

[Chemical-quality data and weighted averages are in parts per million and equivalents per million (italicized) except where indicated; data are for the water years 1914–57 adjusted to 1957]

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
San Juan River near Blanco, N. Mex.																
19,250	19 *.95*	3.4 *.28*	5.2 *.23*	1.0 *.03*	65 *1.07*	19 *.40*	1.9 *.05*	0.03	84	0.11	4,370	62	8	15	120	0.3
16,200	19 *.95*	3.4 *.28*	5.2 *.23*	1.0 *.03*	65 *1.07*	19 *.40*	1.9 *.05*	.03	84	.11	3,670	62	8	15	120	.3
14,200	19 *.95*	3.4 *.28*	5.3 *.23*	1.0 *.03*	65 *1.07*	19 *.40*	1.9 *.05*	.03	85	.12	3,260	62	8	15	123	.3
11,400	19 *.95*	3.5 *.29*	5.4 *.23*	1.0 *.03*	66 *1.08*	19 *.40*	1.9 *.05*	.03	86	.12	2,650	62	8	15	124	.3
8,580	19 *.95*	3.5 *.29*	5.7 *.25*	1.0 *.03*	66 *1.08*	19 *.40*	1.9 *.05*	.03	86	.12	1,990	62	8	16	124	.3
6,950	19 *.95*	3.5 *.29*	6.0 *.26*	1.0 *.03*	66 *1.08*	20 *.42*	1.9 *.05*	.03	88	.12	1,650	62	8	17	128	.3
5,550	20 *1.00*	3.5 *.29*	6.4 *.28*	1.1 *.03*	68 *1.12*	20 *.42*	1.9 *.05*	.04	91	.12	1,360	64	8	18	132	.3
4,000 [1]	20 *1.00*	3.6 *.30*	7.3 *.32*	1.1 *.03*	70 *1.15*	21 *.44*	2.0 *.06*	.04	97	.13	1,050	65	8	19	142	.4
2,450	22 *1.10*	3.8 *.31*	9.3 *.40*	1.2 *.03*	75 *1.23*	26 *.54*	2.1 *.06*	.04	113	.15	747	70	9	22	168	.5
1,300	26 *1.30*	4.5 *.37*	13 *.57*	1.5 *.04*	90 *1.48*	33 *.69*	2.5 *.07*	.04	150	.20	526	84	10	25	230	.6
760	31 *1.55*	5.9 *.48*	19 *.83*	2.2 *.06*	110 *1.80*	47 *.98*	3.3 *.09*	.04	195	.27	400	102	12	28	305	.8
530 [2]	35 *1.75*	7.2 *.59*	24 *1.04*	2.9 *.07*	124 *2.03*	60 *1.25*	4.3 *.12*	.04	230	.31	329	117	16	30	360	1.0
388	40 *2.00*	8.3 *.68*	29 *1.26*	3.5 *.09*	138 *2.26*	76 *1.58*	5.6 *.16*	.04	264	.36	277	134	21	31	410	1.1
302	44 *2.20*	9.0 *.74*	34 *1.48*	3.9 *.10*	150 *2.46*	92 *1.91*	6.7 *.19*	.04	286	.39	233	147	24	33	440	1.2
252	47 *2.35*	9.4 *.77*	39 *1.70*	4.0 *.10*	157 *2.57*	102 *2.12*	7.3 *.21*	.04	300	.41	204	156	28	35	460	1.4
200 [3]	49 *2.45*	9.8 *.81*	44 *1.91*	4.2 *.11*	165 *2.71*	113 *2.35*	8.0 *.23*	.04	317	.43	171	163	28	36	485	1.5
130	50 *2.50*	11 *.90*	47 *2.04*	4.2 *.11*	170 *2.79*	121 *2.52*	9.2 *.26*	.04	335	.46	118	170	30	37	510	1.6
64	50 *2.50*	12 *.99*	48 *2.09*	4.3 *.11*	172 *2.82*	124 *2.58*	10 *.28*	.04	340	.46	59	174	34	37	520	1.6
34	51 *2.54*	12 *.99*	49 *2.13*	4.3 *.11*	173 *2.84*	125 *2.60*	12 *.34*	.04	345	.47	32	176	34	37	520	1.6
1,519	24 *1.20*	4.3 *.35*	11 *.48*	1.5 *.04*	81 *1.33*	31 *.64*	2.5 *.07*	.04	125	.17	512	78	11	23	187	.5

See footnotes at end of table.

TABLE 14.—*Relation between water discharge and chemical quality of water at selected stations in the San Juan division*—Con.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
Animas River at Farmington, N. Mex.																
11,000	32 *1.60*	3.1 *.25*	5.4 *.23*	1.1 *.03*	82 *1.34*	35 *.73*	2.9 *.08*		137	0.19	4,070	92	26	11	225	0.2
9,950	32 *1.60*	3.2 *.26*	5.4 *.23*	1.1 *.03*	82 *1.34*	36 *.75*	2.9 *.08*		137	.19	3,680	93	26	11	225	.2
9,200	33 *1.65*	3.2 *.26*	5.5 *.24*	1.1 *.03*	83 *1.36*	37 *.77*	2.9 *.08*		137	.19	3,400	96	28	11	225	.2
7,700	34 *1.70*	3.3 *.27*	5.6 *.24*	1.2 *.03*	84 *1.38*	38 *.79*	3.0 *.08*		138	.19	2,870	98	30	11	230	.2
5,740	34 *1.70*	3.6 *.30*	6.3 *.27*	1.2 *.03*	86 *1.41*	41 *.85*	3.1 *.09*		138	.19	2,140	100	30	12	230	.3
4,450	35 *1.75*	3.8 *.31*	6.9 *.30*	1.4 *.04*	88 *1.44*	44 *.92*	3.4 *.10*		140	.19	1,680	103	31	12	230	.3
3,350	36 *1.80*	4.2 *.35*	7.8 *.34*	1.5 *.04*	90 *1.48*	48 *1.00*	3.9 *.11*		146	.20	1,320	108	34	13	240	.3
2,350 [1]	40 *2.00*	4.9 *.40*	9.4 *.41*	1.8 *.05*	96 *1.57*	57 *1.19*	4.8 *.14*		168	.23	1,070	120	42	14	275	.4
1,430	48 *2.40*	6.7 *.55*	13 *.57*	2.3 *.06*	110 *1.80*	78 *1.62*	6.7 *.19*		213	.29	822	148	58	16	340	.5
770	67 *3.34*	10 *.82*	23 *1.00*	3.2 *.08*	143 *2.35*	125 *2.60*	11 *.31*		293	.40	609	208	90	19	460	.7
505	80 *3.99*	13 *1.07*	33 *1.44*	3.9 *.10*	163 *2.67*	166 *3.45*	15 *.42*		370	.50	505	253	120	22	580	.9
375 [2]	90 *4.49*	15 *1.23*	42 *1.83*	4.5 *.12*	177 *2.90*	200 *4.16*	19 *.54*		430	.58	435	286	141	24	670	1.1
308	97 *4.84*	16 *1.32*	49 *2.13*	4.9 *.13*	186 *3.05*	222 *4.62*	22 *.62*		475	.65	395	308	156	25	740	1.2
265	102 *5.09*	17 *1.40*	53 *2.31*	5.1 *.13*	191 *3.13*	240 *4.99*	25 *.70*		511	.69	366	324	168	26	770	1.3
232	106 *5.29*	18 *1.48*	57 *2.48*	5.3 *.14*	197 *3.23*	254 *5.28*	27 *.76*		560	.76	351	338	177	26	840	1.3
192 [3]	111 *5.54*	19 *1.56*	62 *2.70*	5.6 *.14*	202 *3.31*	274 *5.70*	30 *.85*		608	.83	315	355	190	27	910	1.4
83	124 *6.19*	22 *1.81*	79 *3.44*	6.4 *.16*	220 *3.61*	330 *6.86*	41 *1.16*		698	.95	156	400	220	30	1,000	1.7
25	130 *6.49*	24 *1.97*	94 *4.09*	7.0 *.18*	230 *3.77*	360 *7.49*	51 *1.44*		751	1.02	51	423	234	32	1,070	2.0
8.3	133 *6.64*	24 *1.97*	102 *4.44*	7.2 *.18*	235 *3.85*	370 *7.70*	56 *1.58*		800	1.09	18	430	238	34	1,140	2.1
971	52 *2.59*	7.2 *.59*	17 *.74*	2.4 *.06*	115 *1.89*	91 *1.89*	8.3 *.23*		233	.32	611	159	64	19	369	.6
San Juan River at Shiprock, N. Mex.																
30,100	29 *1.45*	4.9 *.40*	12 *.52*	1.0 *.03*	98 *1.61*	35 *.73*	2.2 *.06*	0.02	135	0.18	10,970	92	12	22	210	0.5
27,100	29 *1.45*	4.9 *.40*	12 *.52*	1.0 *.03*	98 *1.61*	35 *.73*	2.3 *.06*	.02	136	.18	9,950	92	12	22	210	.5
24,800	29 *1.45*	4.9 *.40*	12 *.52*	1.0 *.03*	98 *1.61*	35 *.73*	2.3 *.06*	.02	136	.18	9,110	92	12	22	210	.5
20,000	30 *1.50*	4.9 *.40*	13 *.57*	1.1 *.03*	99 *1.62*	37 *.77*	2.5 *.07*	.02	138	.19	7,450	95	14	23	220	.6
15,000	30 *1.50*	5.0 *.41*	14 *.61*	1.2 *.03*	100 *1.64*	39 *.81*	2.7 *.08*	.02	144	.20	5,830	96	14	24	225	.6
12,000	31 *1.55*	5.0 *.41*	16 *.70*	1.3 *.03*	102 *1.67*	43 *.89*	3.0 *.08*	.02	153	.21	4,960	98	14	26	240	.7
9,300	32 *1.60*	5.3 *.44*	18 *.78*	1.5 *.04*	103 *1.69*	48 *1.00*	3.5 *.10*	.02	165	.22	4,140	102	18	27	260	.8
6,600 [1]	34 *1.70*	5.9 *.48*	22 *.96*	1.9 *.05*	105 *1.72*	65 *1.35*	4.3 *.12*	.03	190	.26	3,390	109	23	30	300	.9
4,150	38 *1.90*	7.3 *.60*	31 *1.35*	2.5 *.06*	111 *1.82*	90 *1.87*	5.9 *.17*	.03	235	.32	2,630	125	34	35	370	1.2
2,450	48 *2.40*	9.6 *.79*	43 *1.87*	3.0 *.08*	130 *2.13*	130 *2.70*	9.0 *.25*	.04	305	.41	2,020	160	53	36	470	1.5
1,450	66 *3.29*	13 *1.07*	57 *2.48*	3.3 *.08*	150 *2.46*	190 *3.95*	14 *.39*	.05	410	.56	1,610	218	95	36	620	1.7
1,020 [2]	77 *3.84*	17 *1.40*	67 *2.91*	3.3 *.08*	160 *2.62*	240 *4.99*	19 *.54*	.06	505	.69	1,390	262	131	35	750	1.8
800	86 *4.29*	20 *1.64*	73 *3.18*	3.3 *.08*	163 *2.67*	282 *5.87*	22 *.62*	.06	565	.77	1,220	296	163	35	820	1.8
640	92 *4.59*	21 *1.73*	77 *3.35*	3.4 *.09*	165 *2.71*	304 *6.33*	25 *.70*	.06	620	.84	1,070	316	180	34	900	1.9
560	100 *4.99*	22 *1.81*	79 *3.44*	3.4 *.09*	167 *2.74*	328 *6.82*	27 *.76*	.06	650	.88	983	340	203	33	940	1.9
440 [3]	104 *5.19*	22 *1.81*	81 *3.52*	3.4 *.09*	168 *2.76*	340 *7.07*	30 *.85*	.06	690	.94	820	350	212	33	1,000	1.9
168	107 *5.34*	23 *1.89*	84 *3.65*	3.4 *.09*	175 *2.87*	340 *7.07*	33 *.93*	.07	720	.98	327	362	218	33	1,030	1.9
15	109 *5.44*	24 *1.97*	86 *3.74*	3.5 *.09*	185 *3.03*	345 *7.18*	34 *.96*	.07	730	.99	30	370	219	33	1,050	1.9
6.0	110 *5.49*	24 *1.97*	86 *3.74*	3.5 *.09*	187 *3.07*	345 *7.18*	34 *.96*	.07	735	1.00	12	373	220	33	1,050	1.9
2,679	44 *2.20*	8.3 *.68*	31 *1.35*	2.1 *.05*	117 *1.92*	102 *2.12*	7.5 *.21*	.03	256	.35	1,850	144	48	32	392	1.1

See footnotes at end of table.

TABLE 14.—*Relation between water discharge and chemical quality of water at selected stations in the San Juan division*—Con.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
San Juan River near Bluff, Utah																
32,000	39 *1.95*	8.4 *.69*	14 *.61*	1.9 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	0.05	183	0.25	15,810	132	35	18	285	0.5
27,000	39 *1.95*	8.6 *.71*	14 *.61*	2.0 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	.05	190	.26	13,850	133	36	18	295	.5
24,000	39 *1.95*	8.6 *.71*	14 *.61*	2.0 *.05*	118 *1.94*	60 *1.25*	3.7 *.10*	.05	194	.26	12,570	133	36	18	305	.5
19,100	40 *2.00*	8.9 *.73*	14 *.61*	2.1 *.05*	118 *1.94*	64 *1.33*	3.8 *.11*	.05	203	.28	10,470	136	40	18	315	.5
14,400	41 *2.05*	9.2 *.76*	15 *.65*	2.2 *.06*	119 *1.95*	68 *1.41*	4.0 *.11*	.05	217	.30	8,440	140	43	18	340	.5
11,400	43 *2.15*	9.4 *.77*	16 *.70*	2.4 *.06*	120 *1.97*	74 *1.54*	4.2 *.12*	.05	230	.31	7,080	146	48	19	355	.6
9,200	44 *2.20*	9.8 *.81*	17 *.74*	2.5 *.06*	121 *1.98*	80 *1.66*	4.5 *.13*	.05	243	.33	6,040	150	52	19	375	.6
6,900[1]	46 *2.30*	10 *.82*	18 *.78*	2.6 *.07*	123 *2.02*	86 *1.79*	5.2 *.15*	.05	265	.36	4,940	156	55	20	410	.6
4,400	52 *2.59*	12 *.99*	22 *.96*	2.8 *.07*	130 *2.13*	112 *2.33*	6.6 *.19*	.06	308	.42	3,660	179	72	21	470	.7
2,690	64 *3.19*	14 *1.15*	33 *1.44*	3.1 *.08*	145 *2.38*	157 *3.27*	9.3 *.26*	.06	385	.52	2,800	217	98	25	590	1.0
1,810	76 *3.79*	17 *1.40*	48 *2.09*	3.4 *.09*	160 *2.62*	210 *4.37*	13 *.37*	.06	500	.68	2,440	260	128	28	750	1.3
1,240[2]	91 *4.54*	23 *1.89*	70 *3.04*	3.7 *.09*	174 *2.85*	305 *6.34*	17 *.48*	.07	660	.90	2,210	322	179	32	950	1.7
930	105 *5.24*	29 *2.38*	85 *3.70*	3.9 *.10*	182 *2.98*	375 *7.80*	22 *.62*	.08	780	1.06	1,960	381	232	32	1,100	1.9
750	113 *5.64*	33 *2.71*	94 *4.09*	4.0 *.10*	187 *3.07*	415 *8.63*	26 *.73*	.09	845	1.15	1,710	418	264	33	1,170	2.0
610	117 *5.84*	36 *2.96*	102 *4.44*	4.2 *.11*	191 *3.13*	445 *9.26*	29 *.82*	.10	900	1.22	1,480	440	284	33	1,250	2.1
440[3]	123 *6.14*	39 *3.21*	111 *4.83*	4.5 *.12*	197 *3.23*	480 *9.98*	33 *.93*	.11	960	1.31	1,140	468	306	34	1,330	2.2
240	125 *6.24*	40 *3.29*	122 *5.31*	5.1 *.13*	201 *3.30*	500 *10.40*	39 *1.10*	.12	1,050	1.43	680	476	312	35	1,450	2.4
76	128 *6.39*	42 *3.45*	130 *5.66*	6.4 *.16*	201 *3.30*	540 *11.23*	46 *1.30*	.12	1,080	1.47	222	492	327	36	1,480	2.6
20	130 *6.49*	43 *3.53*	135 *5.87*	8.2 *.21*	202 *3.31*	550 *11.44*	49 *1.38*	.12	1,100	1.50	59	501	336	36	1,500	2.6
2,800	58 *2.89*	14 *1.15*	31 *1.35*	2.8 *.07*	136 *2.23*	143 *2.97*	8.6 *.24*	.06	361	.49	2,730	202	90	25	539	.9
Dirty Devil River near Hite, Utah																
9,400	200 *9.98*	34 *2.79*	89 *3.87*	7.3 *.19*	126 *2.07*	580 *12.06*	94 *2.65*	0.15	1,500	2.04	38,070	638	535	23	1,950	1.5
5,000	206 *10.28*	35 *2.88*	90 *3.92*	7.3 *.19*	135 *2.21*	590 *12.27*	94 *2.65*	.15	1,500	2.04	20,250	658	548	23	1,950	1.5
2,700	208 *10.38*	36 *2.96*	91 *3.96*	7.4 *.19*	142 *2.33*	610 *12.69*	95 *2.68*	.16	1,500	2.04	10,940	667	550	23	1,950	1.5
1,100	220 *10.98*	38 *3.12*	97 *4.22*	7.4 *.19*	155 *2.54*	650 *13.52*	96 *2.71*	.17	1,530	2.08	4,540	705	578	23	1,970	1.6
480	239 *11.93*	40 *3.29*	108 *4.70*	7.4 *.19*	165 *2.71*	710 *14.77*	98 *2.76*	.17	1,620	2.20	2,100	761	626	23	2,100	1.7
310	250 *12.48*	42 *3.45*	113 *4.92*	7.6 *.19*	170 *2.79*	740 *15.39*	100 *2.82*	.18	1,700	2.31	1,420	796	657	23	2,200	1.7
220	263 *13.12*	45 *3.70*	120 *5.22*	7.8 *.20*	176 *2.89*	805 *16.74*	102 *2.88*	.19	1,780	2.42	1,060	841	696	23	2,280	1.8
166[1]	274 *13.67*	47 *3.86*	125 *5.44*	8.0 *.20*	180 *2.95*	835 *17.37*	105 *2.96*	.21	1,880	2.56	843	876	729	23	2,400	1.8
130	287 *14.32*	50 *4.11*	136 *5.92*	8.3 *.21*	184 *3.02*	880 *18.30*	112 *3.16*	.22	1,990	2.71	699	922	770	24	2,500	1.9
107	299 *14.92*	53 *4.36*	147 *6.39*	8.6 *.22*	187 *3.07*	930 *19.34*	117 *3.30*	.23	2,090	2.84	604	964	810	25	2,560	2.1
89	310 *15.47*	56 *4.60*	160 *6.96*	9.0 *.23*	190 *3.12*	990 *20.59*	123 *3.47*	.25	2,200	2.99	529	1,000	848	26	2,750	2.2
71[2]	325 *16.22*	60 *4.93*	180 *7.83*	9.6 *.25*	193 *3.17*	1,070 *22.26*	133 *3.75*	.27	2,380	3.24	456	1,060	899	27	2,940	2.4
52	348 *17.37*	68 *5.59*	206 *8.96*	11 *.28*	200 *3.28*	1,200 *24.96*	148 *4.17*	.31	2,600	3.54	365	1,150	984	28	3,200	2.6
34	380 *18.96*	81 *6.66*	244 *10.61*	13 *.33*	207 *3.39*	1,330 *27.66*	180 *5.08*	.36	2,860	3.89	263	1,280	1,110	29	3,450	3.0
16	440 *21.96*	102 *8.38*	316 *13.75*	18 *.46*	220 *3.61*	1,640 *34.11*	245 *6.91*	.48	3,100	4.22	134	1,520	1,340	31	3,700	3.5
1.7[3]	540 *26.95*	140 *11.51*	400 *17.40*	22 *.56*	265 *4.35*	1,740 *36.19*	580 *16.36*	.85	3,400	4.62	16	1,920	1,710	31	4,000	4.0
0																
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102	279 *13.92*	50 *4.11*	139 *6.05*	8.6 *.22*	177 *2.90*	874 *18.18*	116 *3.27*	.22	1,960	2.67	541	902	756	25	2,470	2.0

See footnotes at end of table.

TABLE 14.—*Relation between water discharge and chemical quality of water at selected stations in the San Juan division*—Con.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as $CaCO_3$		Percent sodium	Specific conductance (micromhos per cm at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
Colorado River at Hite, Utah																
124,000	43 *2.15*	9.2 *.76*	20 *.87*	2.1 *.05*	146 *2.39*	58 *1.21*	8.6 *.24*	0.07	278	0.38	93,080	146	26	23	450	0.7
113,000	44 *2.20*	9.6 *.79*	21 *.91*	2.1 *.05*	146 *2.39*	61 *1.27*	9.4 *.27*	.07	278	.38	84,820	150	30	23	450	.7
106,000	45 *2.25*	9.7 *.80*	21 *.91*	2.1 *.05*	146 *2.39*	62 *1.29*	9.6 *.27*	.07	278	.38	79,560	152	33	23	450	.7
88,500	46 *2.30*	10 *.82*	23 *1.00*	2.1 *.05*	147 *2.41*	68 *1.41*	11 *.31*	.08	279	.38	66,670	156	36	24	450	.8
69,000	48 *2.40*	11 *.90*	25 *1.09*	2.1 *.05*	149 *2.44*	76 *1.58*	13 *.37*	.08	280	.38	52,160	165	43	25	460	.8
57,000	49 *2.45*	12 *.99*	27 *1.17*	2.2 *.06*	150 *2.46*	84 *1.75*	15 *.42*	.08	282	.38	43,400	172	49	25	460	.9
46,000	51 *2.54*	13 *1.07*	29 *1.26*	2.2 *.06*	152 *2.49*	93 *1.93*	17 *.48*	.08	292	.40	36,270	180	58	26	470	.9
34,300 [1]	54 *2.69*	15 *1.23*	33 *1.44*	2.3 *.06*	154 *2.53*	110 *2.29*	22 *.62*	.08	323	.44	29,910	196	70	27	520	1.0
20,300	60 *2.99*	19 *1.56*	50 *2.18*	2.7 *.07*	165 *2.71*	152 *3.16*	33 *.93*	.10	410	.56	22,470	228	92	32	640	1.4
11,800	73 *3.64*	26 *2.14*	79 *3.44*	3.5 *.09*	182 *2.98*	230 *4.78*	53 *1.49*	.12	658	.89	20,960	289	140	37	990	2.0
8,250	86 *4.29*	34 *2.79*	117 *5.09*	4.3 *.11*	200 *3.28*	325 *6.76*	76 *2.14*	.14	835	1.14	18,600	354	190	41	1,230	2.7
6,800 [2]	97 *4.84*	42 *3.45*	135 *5.87*	4.8 *.12*	210 *3.44*	390 *8.11*	92 *2.59*	.16	942	1.28	17,300	414	242	41	1,370	2.9
6,000	107 *5.34*	46 *3.78*	146 *6.35*	5.2 *.13*	218 *3.58*	430 *8.94*	104 *2.93*	.17	1,020	1.39	16,520	456	277	41	1,460	3.0
5,300	115 *5.74*	49 *4.03*	155 *6.74*	5.5 *.14*	220 *3.61*	462 *9.61*	114 *3.21*	.18	1,070	1.46	15,310	488	308	40	1,550	3.0
4,600	123 *6.14*	53 *4.36*	166 *7.22*	5.8 *.15*	223 *3.66*	505 *10.50*	125 *3.52*	.18	1,160	1.58	14,410	525	342	40	1,640	3.2
3,780 [3]	133 *6.64*	57 *4.69*	180 *7.83*	6.2 *.16*	228 *3.74*	550 *11.44*	140 *3.95*	.19	1,250	1.70	12,760	566	380	41	1,750	3.3
2,800	143 *7.14*	60 *4.93*	194 *8.44*	6.8 *.17*	230 *3.77*	595 *12.38*	157 *4.43*	.20	1,300	1.77	9,810	604	415	41	1,800	3.4
2,480	144 *7.19*	61 *5.01*	199 *8.66*	6.9 *.18*	231 *3.79*	605 *12.58*	162 *4.57*	.21	1,300	1.77	8,700	610	420	41	1,820	3.5
2,350	145 *7.24*	62 *5.10*	200 *8.70*	7.0 *.18*	231 *3.79*	610 *12.69*	164 *4.62*	.21	1,300	1.77	8,250	617	428	41	1,830	3.5
14,167	68 *3.39*	23 *1.89*	66 *2.87*	3.1 *.08*	172 *2.82*	197 *4.10*	44 *1.24*	.11	527	.72	20,170	264	123	35	795	1.8
Escalante River at mouth, near Escalante, Utah																
6,100	39 *1.95*	11 *.90*	15 *.65*	2.2 *.06*	144 *2.36*	43 *.89*	12 *.34*		190	0.26	3,130	142	21	18	295	0.5
3,750	40 *2.00*	11 *.90*	15 *.65*	2.2 *.06*	145 *2.38*	43 *.89*	12 *.34*		190	.26	1,920	145	26	18	295	.5
2,350	41 *2.05*	11 *.90*	15 *.65*	2.3 *.06*	148 *2.43*	43 *.89*	13 *.37*		190	.26	1,210	148	26	18	295	.5
870	42 *2.10*	12 *.99*	16 *.70*	2.5 *.06*	155 *2.54*	44 *.92*	14 *.39*		198	.27	465	154	28	18	310	.6
315	45 *2.25*	15 *1.23*	18 *.78*	2.9 *.07*	165 *2.71*	52 *1.08*	18 *.51*		220	.30	187	174	38	18	340	.6
205	47 *2.35*	16 *1.32*	19 *.83*	4.2 *.11*	169 *2.77*	60 *1.25*	19 *.54*		241	.33	133	184	45	18	380	.6
150	50 *2.50*	17 *1.40*	21 *.91*	4.4 *.11*	171 *2.80*	70 *1.46*	21 *.59*		269	.37	109	195	55	18	430	.7
120 [1]	51 *2.54*	18 *1.48*	22 *.96*	4.6 *.12*	172 *2.82*	76 *1.58*	23 *.65*		290	.39	94	201	60	19	460	.7
99	52 *2.59*	19 *1.56*	24 *1.04*	4.7 *.12*	173 *2.84*	83 *1.73*	24 *.68*		312	.42	83	208	66	20	500	.7
85	53 *2.64*	19 *1.56*	25 *1.09*	4.9 *.13*	175 *2.87*	90 *1.87*	26 *.73*		328	.45	75	210	66	20	520	.8
73	54 *2.69*	20 *1.64*	26 *1.13*	5.0 *.13*	176 *2.89*	96 *2.00*	28 *.79*		342	.47	67	216	72	20	550	.8
62 [2]	56 *2.79*	21 *1.73*	28 *1.22*	5.1 *.13*	178 *2.92*	103 *2.14*	29 *.82*		359	.49	60	226	80	21	580	.8
53	58 *2.89*	22 *1.81*	29 *1.26*	5.3 *.14*	179 *2.94*	110 *2.29*	31 *.87*		372	.51	53	235	88	21	600	.8
43	59 *2.94*	23 *1.89*	31 *1.35*	5.5 *.14*	180 *2.95*	118 *2.45*	33 *.93*		387	.53	45	242	94	21	620	.9
34	60 *2.99*	24 *1.97*	34 *1.48*	5.7 *.15*	182 *2.98*	129 *2.68*	35 *.99*		400	.54	37	248	99	22	640	.9
24 [3]	61 *3.04*	26 *2.14*	38 *1.65*	6.0 *.15*	186 *3.05*	140 *2.91*	38 *1.07*		410	.56	27	259	106	24	650	1.0
16	62 *3.09*	28 *2.30*	40 *1.74*	6.4 *.16*	190 *3.12*	152 *3.16*	39 *1.10*		410	.56	18	270	114	24	650	1.1
12	63 *3.14*	29 *2.38*	41 *1.78*	6.7 *.17*	191 *3.13*	157 *3.27*	40 *1.13*		410	.56	13	276	120	24	650	1.1
9.2	64 *3.19*	31 *2.55*	42 *1.83*	7.0 *.18*	193 *3.17*	160 *3.33*	41 *1.16*		410	.56	10	287	128	24	650	1.1
85.2	51 *2.54*	18 *1.48*	24 *1.04*	4.4 *.11*	171 *2.80*	82 *1.71*	24 *.68*		300	.41	69	201	61	20	478	.7

See footnotes at end of table.

TABLE 14.—*Relation between water discharge and chemical quality of water at selected stations in the San Juan division*—Con.

Discharge (cfs)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO₃)	Sulfate (SO₄)	Chloride (Cl)	Boron (B)	Dissolved solids (residue at 180° C)			Hardness as CaCO₃		Percent sodium	Specific conductance (micromhos per cm at 25° C)	Sodium-adsorption-ratio
									Parts per million	Tons per acre-ft	Tons per day	Calcium, magnesium	Noncarbonate			
Colorado River at Lees Ferry, Ariz.																
178,200	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	80 *1.66*	10 *.28*	0.09	250	0.34	120,300	168	46	22	405	0.7
137,300	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	80 *1.66*	11 *.31*	.09	253	.34	93,790	168	46	22	410	.7
122,200	46 *2.30*	13 *1.07*	22 *.96*	3.5 *.09*	149 *2.44*	81 *1.68*	11 *.31*	.09	256	.35	84,460	171	49	22	415	.7
101,500	47 *2.35*	13 *1.07*	23 *1.00*	3.5 *.09*	149 *2.44*	82 *1.71*	12 *.34*	.09	262	.36	71,800	171	49	22	425	.8
82,090	48 *2.40*	13 *1.07*	24 *1.04*	3.5 *.09*	150 *2.46*	83 *1.73*	13 *.37*	.09	270	.37	59,840	174	50	23	440	.8
69,120	49 *2.45*	13 *1.07*	26 *1.13*	3.5 *.09*	152 *2.49*	87 *1.81*	14 *.39*	.09	280	.38	52,250	176	52	24	460	.9
55,060	50 *2.50*	14 *1.15*	29 *1.26*	3.5 *.09*	154 *2.53*	95 *1.98*	16 *.45*	.09	295	.40	43,860	182	56	25	480	.9
41,660 [1]	53 *2.64*	15 *1.23*	35 *1.52*	3.5 *.09*	158 *2.59*	115 *2.39*	20 *.56*	.09	322	.44	36,220	194	64	28	520	1.1
25,690	62 *3.09*	19 *1.56*	51 *2.22*	3.7 *.09*	170 *2.79*	160 *3.33*	31 *.87*	.09	420	.57	29,130	232	93	32	660	1.5
16,120	76 *3.79*	25 *2.06*	74 *3.22*	4.0 *.10*	184 *3.02*	235 *4.89*	48 *1.35*	.11	580	.79	25,240	292	142	35	890	1.9
11,280	90 *4.49*	31 *2.55*	100 *4.35*	4.8 *.12*	199 *3.26*	310 *6.45*	66 *1.86*	.14	730	.99	22,230	352	189	38	1,120	2.3
8,680 [2]	103 *5.14*	37 *3.04*	122 *5.31*	5.3 *.14*	208 *3.41*	372 *7.74*	83 *2.34*	.16	860	1.17	20,150	409	238	39	1,300	2.6
7,430	112 *5.59*	40 *3.29*	135 *5.87*	5.8 *.15*	213 *3.49*	410 *8.53*	95 *2.68*	.18	935	1.27	18,760	444	270	39	1,400	2.8
6,490	118 *5.89*	44 *3.62*	145 *6.31*	6.2 *.16*	218 *3.58*	445 *9.26*	105 *2.96*	.19	990	1.35	17,350	476	296	39	1,470	2.9
5,650	125 *6.24*	48 *3.95*	150 *6.52*	6.6 *.17*	221 *3.62*	480 *9.98*	115 *3.24*	.20	1,040	1.41	15,870	510	328	39	1,550	2.9
4,580 [3]	133 *6.64*	53 *4.36*	157 *6.83*	7.2 *.18*	226 *3.71*	510 *10.61*	130 *3.67*	.21	1,120	1.52	13,850	550	364	38	1,620	2.9
3,260	142 *7.09*	60 *4.93*	165 *7.18*	7.8 *.20*	230 *3.77*	550 *11.44*	145 *4.09*	.23	1,170	1.59	10,300	601	412	37	1,700	2.9
2,160	146 *7.29*	66 *5.43*	173 *7.53*	8.3 *.21*	230 *3.77*	590 *12.27*	151 *4.26*	.23	1,200	1.63	7,000	636	448	37	1,720	3.0
1,490	147 *7.34*	68 *5.59*	175 *7.61*	8.6 *.22*	230 *3.77*	600 *12.48*	156 *4.40*	.23	1,210	1.65	4,870	646	458	37	1,720	3.0
17,550	70 *3.49*	23 *1.89*	62 *2.70*	4.2 *.11*	174 *2.85*	198 *4.12*	41 *1.16*	.11	499	.68	23,660	269	126	33	772	1.6
Paria River at Lees Ferry, Ariz.																
7,500	131 *6.54*	59 *4.85*	170 *7.40*		219 *3.59*	690 *14.35*	24 *.68*		1,200	1.63	24,300	570	390	39	1,600	3.1
3,400	131 *6.54*	59 *4.85*	170 *7.40*		219 *3.59*	685 *14.25*	24 *.68*		1,190	1.62	10,920	570	390	39	1,600	3.1
1,800	130 *6.49*	59 *4.85*	165 *7.18*		217 *3.56*	675 *14.04*	24 *.68*		1,170	1.59	5,690	567	389	39	1,600	3.0
570	129 *6.44*	59 *4.85*	155 *6.74*		216 *3.54*	660 *13.73*	24 *.68*		1,150	1.56	1,770	564	388	37	1,550	2.8
190	128 *6.39*	59 *4.85*	145 *6.31*		214 *3.51*	650 *13.52*	23 *.65*		1,140	1.55	585	562	386	36	1,550	2.7
97	126 *6.29*	59 *4.85*	135 *5.87*		210 *3.44*	630 *13.10*	23 *.65*		1,130	1.54	296	557	385	35	1,530	2.5
60	124 *6.19*	59 *4.85*	130 *5.66*		206 *3.38*	615 *12.79*	23 *.65*		1,110	1.51	180	552	383	34	1,500	2.4
38 [1]	122 *6.09*	58 *4.77*	125 *5.44*		198 *3.25*	600 *12.48*	23 *.65*		1,100	1.50	113	543	380	33	1,500	2.3
27	120 *5.99*	58 *4.77*	120 *5.22*		195 *3.20*	590 *12.27*	23 *.65*		1,080	1.47	79	538	378	33	1,490	2.3
22	118 *5.89*	58 *4.77*	117 *5.09*		191 *3.13*	580 *12.06*	23 *.65*		1,060	1.44	63	533	376	32	1,450	2.2
18	116 *5.79*	58 *4.77*	114 *4.96*		189 *3.10*	570 *11.86*	23 *.65*		1,030	1.40	50	528	373	32	1,410	2.2
14 [2]	112 *5.59*	57 *4.69*	109 *4.74*		181 *2.97*	550 *11.44*	22 *.62*		1,000	1.36	38	514	366	32	1,390	2.1
11	107 *5.34*	56 *4.60*	105 *4.57*		175 *2.87*	530 *11.02*	22 *.62*		940	1.28	28	497	354	31	1,310	2.0
6.8	90 *4.49*	43 *3.53*	76 *3.31*		162 *2.66*	395 *8.22*	19 *.54*		770	1.05	14	401	268	29	1,110	1.7
4.9	72 *3.59*	32 *2.63*	53 *2.31*		154 *2.53*	265 *5.51*	15 *.42*		570	.78	7.5	311	184	27	860	1.3
3.8 [3]	56 *2.79*	26 *2.14*	39 *1.70*		147 *2.41*	183 *3.81*	13 *.37*		430	.58	4.4	246	126	26	680	1.1
2.9	48 *2.40*	23 *1.89*	34 *1.48*		140 *2.30*	148 *3.08*	12 *.34*		330	.45	2.6	214	100	26	540	1.0
2.3	46 *2.30*	22 *1.81*	30 *1.30*		135 *2.21*	140 *2.91*	11 *.31*		300	.41	1.9	206	95	24	500	.9
1.9	45 *2.25*	22 *1.81*	30 *1.30*		133 *2.18*	140 *2.91*	11 *.31*		295	.40	1.5	203	94	24	495	.9
31.9	121 *6.04*	57 *4.69*	134 *5.83*		203 *3.33*	608 *12.65*	23 *.65*		1,090	1.48	94	536	370	36	1,480	2.5

[1] 12 percentile of water discharge.
[2] 50 percentile of water discharge.
[3] 90 percentile of water discharge.

TABLE 15.—*Water and dissolved solids contributed by ground water to selected streams in the San Juan River basin, Colo.*

[Data are for the water years 1914-57 adjusted to 1957 conditions; weighted-average concentration of dissolved solids from table 10]

Station No.	Station name	Weighted-average concentration of dissolved solids (ppm)	Ground water		
			Discharge (acre-ft per yr)	Dissolved solids	
				Tons per yr	Weighted-average concentration (ppm)
3400	San Juan River near Pagosa Springs	77	15, 400	2, 090	100
3425	San Juan River at Pagosa Springs	73	48, 800	9, 130	138
3460	Navajo River at Edith	113	29, 400	7, 300	183
3495	Piedra River near Piedra	126	48, 000	16, 600	254
3505	San Juan River at Rosa	117	166, 600	50, 000	221
3575	Animas River at Howardsville	111	17, 200	4, 050	173
3610	Hermosa Creek near Hermosa	219	20, 400	11, 400	411
3615	Animas River at Durango	183	171, 000	69, 800	300
3655	La Plata River at Hesperus	84	6, 100	950	115

TABLE 16.—*Water and dissolved-solids budget*

[Data are for the water years 1914-57 adjusted to 1957 conditions]

	Average annual discharge (acre-ft)	Dissolved solids	
		Weighted-average concentration (ppm)	Tons per yr
La Plata River basin in Colorado			
Inflow:			
La Plata River at Hesperus, Colo	35,000	84	4,000
Unmeasured inflow	11,100	200	3,000
Total	46,100		7,000
Outflow:			
Consumed by irrigation	18,200		
La Plata River at Colorado-New Mexico State line	27,900	356	13,500
Total	46,100		13,500
Increase from other sources			6,500
La Plata River basin in New Mexico			
Inflow:			
La Plata River at Colorado-New Mexico State line	27,900	356	13,500
Unmeasured inflow	5,400	200	1,500
Total	33,300		15,000
Outflow:			
Consumed by irrigation	10,500		
La Plata River near Farmington, N. Mex	22,800	908	28,100
Total	33,300		28,100
Increase from other sources			13,100

TABLE 17.—*Average annual dissolved-solids discharge and probable amounts of dissolved solids from natural sources and from the activities of man in the subbasins in the San Juan division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Gaging station or subbasin	Drainage area (sq mi)	Acres irrigated	Dissolved-solids discharge: Total (tons)	Natural: Tons	Natural: Tons per sq mi	Man-caused: Tons	Man-caused: Tons per acre irrigated
San Juan River basin							
San Juan River near Arboles, Colo	1,340	13,300	77,000	64,100	40	12,900	1.0
San Juan River near Blanco, N. Mex	3,560	61,600	187,000	147,000	41	40,000	.6
San Juan River near Bluff, Utah	23,000	206,400	997,000	708,900	31	288,100	1.4
San Juan River basin	24,900	206,400	1,073,000	784,900	32	288,100	1.4
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.							
Dirty Devil River near Hite, Utah	4,360	23,300	197,600	144,100	33	53,500	2.3
Escalante River at mouth, near Escalante, Utah	2,010	7,000	25,200	17,100	8.5	8,100	1.2
Paria River at Lees Ferry, Ariz	1,570	3,000	34,300	32,200	21	[1] 2,100	.7
Colorado River at Lees Ferry, Ariz	107,900	1,410,000	8,642,000	5,164,500	48	3,477,500	2.5
Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz	13,400	33,300	470,600	406,900	30	[1] 63,700	1.9

[1] Includes 700 tons imported in the Tropic and East Fork canal.

TABLE 18.—*Summary of the suspended-sediment discharge at daily stations in the subbasins in the San Juan division*

Water year	Water discharge: Cfs-days	Water discharge: Acre-ft	Suspended sediment: Load [1] (tons)	Daily load (tons): Average	Daily load (tons): Maximum	Daily load (tons): Minimum	Concentration (ppm): Weighted mean	Concentration (ppm): Maximum daily
SAN JUAN RIVER BASIN								
3505. San Juan River at Rosa, N. Mex.								
Mar. 25 to Sept. 30, 1949	495,411	982,600	1,412,000	7,430	77,400	0	1,060	12,800
1950	240,637	477,300	475,800	1,300	33,800	3	732	14,700
3555. San Juan River near Archuleta, N. Mex.								
Dec. 1, 1954, to Sept. 30, 1955	251,173	498,200	1,641,000	5,400	152,000	[2] 10	2,420	32,800
1956	281,295	558,000	1,276,000	3,490	[3] 67,600	10	1,680	34,200
1957	756,673	1,501,000	5,352,000	14,660	522,000	9	2,620	18,000
3565. San Juan River near Blanco, N. Mex.								
Mar. 15 to Sept. 30, 1949	641,117	1,271,740	3,505,000	17,520	141,000	0	2,020	17,800
1950	269,758	535,100	397,800	1,090	24,100	10	546	8,950
1951	167,079	331,400	455,300	1,250	52,900	1	1,010	11,300
1952	751,291	1,490,000	3,530,000	9,640	[3] 142,000	2	1,740	20,000
1953	257,083	509,900	589,000	1,610	[3] 48,400	4	849	13,700
1954	259,268	514,200	2,034,000	5,570	[3] 418,000	5	2,910	51,300

See footnotes at end of table.

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TABLE 18.—*Summary of the suspended-sediment discharge at daily stations in the subbasins in the San Juan division*—Con.

Water year	Water discharge		Suspended sediment					
				Daily load (tons)			Concentration (ppm)	
	Cfs-days	Acre-ft	Load [1] (tons)	Average	Maximum	Minimum	Weighted mean	Maximum daily
SAN JUAN RIVER BASIN—Continued								
3570. San Juan River at Bloomfield, N. Mex.								
Nov. 1, 1955, to Sept. 30, 1956	270, 842	537, 200	3, 949, 000	11, 790	[3] 520, 000	31	5, 400	101, 000
1957	782, 377	1, 552, 000	14, 230, 000	38, 990	1, 110, 000	103	6, 740	68, 000
3645. Animas River at Farmington, N. Mex.								
Dec. 15, 1950, to Sept. 30, 1951	132, 179	262, 200	341, 700	1, 180	59, 800	1	957	7, 850
1952	471, 497	935, 200	1, 036, 000	2, 830	64, 000	6	814	7, 180
1953	188, 368	373, 600	369, 800	1, 010	[3] 40, 500	1	727	13, 600
1954	189, 809	376, 500	1, 274, 000	3, 490	[3] 337, 000	2	2, 490	36, 100
1955	207, 978. 4	412, 500	827, 100	2, 270	[3] 50, 200	<. 5	1, 470	22, 500
1956	184, 081. 0	365, 100	503, 800	1, 380	22, 000	<. 5	1, 010	4, 440
1957	488, 855	969, 600	1, 876, 000	5, 140	121, 000	<. 5	1, 420	18, 000
3680. San Juan River at Shiprock, N. Mex.								
Dec. 16, 1950, to Sept. 30, 1951	300, 958	596, 390	3, 322, 000	11, 490	[3] 578, 000	5	4, 090	64, 800
1952	1, 251, 251	2, 482, 000	11, 190, 000	30, 570	369, 000	31	3, 310	33, 200
1953	440, 335	873, 400	2, 235, 000	6, 120	[3] 317, 000	16	1, 880	36, 600
1954	475, 621	943, 400	11, 630, 000	31, 860	1, 330, 000	36	9, 060	70, 600
1955	482, 200	956, 400	12, 030, 000	32, 960	1, 200, 000	46	9, 240	86, 000
1956	433, 623	860, 100	5, 094, 000	13, 920	[3] 490, 000	2	4, 350	82, 100
1957	1, 260, 680	2, 500, 000	21, 790, 000	59, 700	1, 700, 000	13	6, 400	48, 000
3795. San Juan River near Bluff, Utah								
Aug. 13 to Sept. 21, 1928	31, 028	61, 540	1, 494, 000	37, 350	158, 000	2, 670	17, 830	87, 300
July 1 to Sept. 30, 1929	631, 360	1, 252, 000	102, 000, 000	1, 110, 000	11, 400, 000	17, 100	57, 700	309, 000
1930	869, 130	1, 720, 000	58, 390, 000	160, 000	8, 620, 000	679	24, 880	230, 000
1931	447, 474	887, 000	15, 290, 000	41, 890	905, 000	27	12, 660	115, 000
1932	1, 486, 168	2, 950, 000	75, 310, 000	205, 800	5, 520, 000	351	18, 770	124, 000
1933	626, 152	1, 240, 000	23, 610, 000	64, 680	2, 120, 000	27	13, 970	146, 000
1934	333, 694	661, 900	21, 170, 000	58, 000	2, 700, 000	0	23, 500	267, 000
1935	1, 100, 755	2, 183, 000	42, 710, 000	117, 000	2, 940, 000	11	14, 370	88, 400
1936	822, 196	1, 631, 000	32, 490, 000	88, 770	2, 282, 000	756	14, 640	214, 000
1937	1, 177, 825	2, 336, 000	52, 170, 000	142, 900	2, 840, 000	216	16, 400	142, 000
1938	1, 243, 383	2, 466, 000	52, 100, 000	142, 700	5, 370, 000	428	15, 520	142, 000
1939	624, 777	1, 239, 000	21, 400, 000	58, 630	6, 210, 000	0	12, 690	209, 000
1940	502, 291	996, 300	26, 320, 000	71, 910	3, 960, 000	96	19, 410	163, 000
1941	2, 138, 675	4, 242, 000	112, 400, 000	307, 900	3, 370, 000	1, 610	19, 470	125, 000
1942	1, 552, 053	3, 078, 000	69, 080, 000	189, 300	12, 000, 000	42	16, 480	105, 000
1943	728, 495	1, 445, 000	11, 080, 000	30, 360	613, 000	607	5, 630	81, 700
1944	1, 154, 004	2, 289, 000	17, 800, 000	48, 630	749, 000	402	5, 710	66, 400
1945	816, 543	1, 620, 000	20, 000, 000	54, 790	1, 240, 000	682	9, 070	155, 000
1946	435, 938	864, 600	8, 708, 000	23, 860	1, 240, 000	165	7, 400	111, 000
1947	750, 458	1, 488, 000	28, 440, 000	77, 920	4, 790, 000	122	14, 040	103, 200
1948	1, 168, 885	2, 319, 000	33, 060, 000	90, 330	5, 460, 000	462	10, 480	103, 000
1949	1, 271, 897	2, 523, 000	34, 570, 000	94, 710	1, 730, 000	19	10, 070	68, 300
1950	454, 958	902, 300	5, 096, 000	13, 960	[3] 398, 000	41	4, 150	43, 000
1951	336, 953	668, 300	4, 131, 000	11, 320	----------	----------	4, 540	--------
1952	1, 281, 580	2, 542, 000	27, 970, 000	76, 420	[3] 976, 000	----------	8, 080	118, 000
1953	476, 686	934, 700	12, 500, 000	34, 250	[3] 1, 800, 000	174	9, 710	170, 000
1954	496, 529	984, 900	15, 800, 000	43, 290	[3] 1, 240, 000	347	11, 790	67, 000
1955	498, 084	988, 500	19, 250, 000	52, 740	[3] 1, 070, 000	102	14, 310	99, 100
1956	434, 373	861, 600	8, 592, 000	23, 480	[3] 691, 000	9	7, 330	143, 000
1957	1, 309, 174	2, 597, 000	34, 820, 000	95, 400	[3] 2, 490, 000	29	9, 850	55, 000

See footnotes at end of table.

TABLE 18.—*Summary of the suspended-sediment discharge at daily stations in the subbasins in the San Juan division*—Con.

Water year	Water discharge		Suspended sediment					
	Cfs-days	Acre-ft	Load [1] (tons)	Daily load (tons)			Concentration (ppm)	
				Average	Maximum	Minimum	Weighted mean	Maximum daily
COLORADO RIVER BASIN BELOW THE GREEN AND SAN JUAN RIVERS AND ABOVE "LEE FERRY," ARIZ.								
3335. Dirty Devil River near Hite, Utah								
July 1 to Sept. 30, 1948	8, 163. 9	16, 190	4, 006, 000	43, 540	2, 160, 000	<0. 05	163, 600	331, 000
1949	48, 079. 8	95, 380	3, 148, 000	8, 620	397, 000	2	24, 250	119, 000
1950	40, 077. 8	79, 500	5, 107, 000	13, 990	2, 570, 000	<. 05	45, 510	214, 000
1951	36, 910. 3	73, 210	8, 415, 000	23, 050	[4] 6, 500, 000	<. 05	81, 420	--------
1952	57, 942. 1	114, 900	9, 958, 000	2, 720	2, 750, 000	<. 05	61, 380	220, 000
1953	32, 737. 2	64, 930	2, 303, 000	6, 310	[4] 400, 000	0	26, 050	--------
Oct. 1, 1953, to June 30, 1954	21, 845. 0	43, 340	1, 100, 000	3, 010	390, 000	0	18, 650	126, 000
3350. Colorado River at Hite, Utah								
1949	5, 610, 990	11, 130, 000	42, 360, 000	116, 100	778, 000	1, 010	2, 800	11, 100
1950	4, 909, 690	9, 738, 000	40, 280, 000	110, 400	542, 000	707	3, 040	15, 500
1951	4, 428, 370	8, 784, 000	28, 260, 000	77, 420	[3] 1, 770, 000	447	2, 360	34, 300
1952	7, 454, 050	14, 780, 000	71, 120, 000	194, 300	1, 560, 000	980	3, 530	23, 000
1953	3, 915, 880	7, 767, 000	24, 900, 000	68, 220	731, 000	1, 360	2, 360	27, 900
1954	2, 528, 310	5, 015, 000	14, 340, 000	39, 290	451, 000	913	2, 100	27, 000
1955	3, 144, 420	6, 238, 000	27, 800, 000	76, 160	712, 000	1, 440	3, 270	21, 400
1956	3, 878, 910	7, 694, 000	30, 540, 000	83, 440	716, 000	454	2, 920	12, 500
1957	7, 205, 080	14, 291, 000	65, 270, 000	178, 800	[3] 2, 500, 000	541	3, 360	36, 500
3395. Escalante River at mouth, near Escalante, Utah								
Mar. 1 to Sept. 30, 1951	19, 289. 8	38, 260	2, 238, 000	10, 460	1, 280, 000	2	41, 440	98, 000
1952	36, 787	72, 980	918, 000	2, 510	266, 000	5	9, 240	56, 500
1953	30, 640	60, 770	2, 353, 000	6, 450	829, 000	3	28, 440	118, 000
3800. Colorado River at Lees Ferry, Ariz.								
1929	9, 673, 940	19, 200, 000	352, 000, 000	964, 400	9, 450, 000	8, 980	13, 480	53, 500
1930	6, 580, 330	13, 100, 000	195, 000, 000	534, 200	9, 000, 000	19, 000	10, 980	80, 200
1931	3, 214, 460	6, 380, 000	57, 200, 000	156, 700	1, 460, 000	9, 740	6, 590	55, 100
1932	7, 688, 210	15, 300, 000	214, 000, 000	584, 700	8, 370, 000	18, 300	10, 310	62, 700
1933	4, 904, 900	9, 730, 000	112, 000, 000	306, 800	2, 350, 000	9, 710	8, 460	10, 900
Nov. 1, 1942, to Sept. 30, 1943	5, 500, 460	10, 910, 000	61, 410, 000	183, 900	------------	------------	4, 140	--------
1944	6, 655, 860	13, 200, 000	77, 270, 000	211, 100	------------	------------	4, 300	--------
1948	6, 890, 900	13, 670, 000	109, 400, 000	298, 900	4, 640, 000	5, 460	5, 880	46, 000
1949	7, 229, 760	14, 340, 000	96, 770, 000	265, 100	2, 410, 000	1, 220	4, 960	19, 000
1950	5, 567, 410	11, 040, 000	53, 510, 000	146, 600	1, 290, 000	3, 610	3, 560	17, 800
1951	4, 949, 340	9, 817, 000	47, 910, 000	131, 300	2, 090, 000	3, 140	3, 590	31, 900
1952	9, 055, 340	17, 960, 000	114, 900, 000	313, 900	1, 990, 000	4, 140	4, 700	25, 200
1953	4, 430, 270	8, 787, 000	41, 420, 000	113, 500	1, 250, 000	6, 220	3, 460	26, 200
1954	3, 075, 820	6, 101, 000	34, 520, 000	94, 580	1, 010, 000	6, 050	4, 160	26, 500
1955	3, 675, 000	7, 290, 000	58, 030, 000	159, 000	1, 550, 000	4, 560	5, 850	32, 400
1956	4, 406, 610	8, 740, 000	50, 950, 000	139, 200	1, 440, 000	1, 340	4, 280	13, 200
1957	8, 733, 860	17, 320, 000	120, 200, 000	329, 300	3, 000, 000	1, 870	5, 100	27, 500
3820. Paria River at Lees Ferry, Ariz.								
1948	9, 634. 6	19, 110	2, 643, 000	4, 180	------------	------------	94, 270	--------
1949	9, 873. 9	19, 590	2, 592, 000	5, 920	[3] 203, 000	0	90, 520	332, 000
1950	6, 803. 2	13, 490	1, 437, 000	3, 940	[3] 440, 000	0	75, 440	284, 000
1951	7, 014. 0	13, 910	1, 522, 000	4, 170	[3] 713, 000	<. 05	77, 500	209, 000
1952	9, 507. 2	18, 860	1, 975, 000	5, 400	[3] 910, 000	. 2	74, 190	411, 000
1953	9, 017. 8	17, 880	4, 553, 000	12, 470	1, 260, 000	<. 05	168, 300	283, 000
1954	7, 907. 0	15, 690	2, 300, 000	6, 300	[3] 999, 000	<. 05	100, 300	272, 000
1955	8, 903. 0	17, 670	4, 315, 000	11, 820	[3] 1, 100, 000	<. 05	161, 600	355, 000
1956	5, 006. 0	9, 940	1, 041, 000	2, 840	[3] 307, 000	<. 05	74, 270	317, 000
1957	8, 362. 8	9, 940	3, 198, 000	8, 760	[3] 697, 000	<. 05	131, 900	309, 000

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[1] Includes estimated loads for missing days.

[2] Estimated.

[3] Computed by subdividing day.

[4] Computed from water-sediment discharge curve.

TABLE 19.—*Estimated suspended-sediment discharge at selected stations in the subbasins in the San Juan division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Station No.	Station name	Average water discharge (cfs)	Suspended sediment		
			Weighted-average concentration (ppm)	Discharge	
				Tons per yr	Tons per sq mi per yr
	San Juan River basin				
3505	San Juan River at Rosa, N. Mex	1, 208	3, 800	4, 400, 000	2, 211
3535	Los Pinos River near Bayfield, Colo	397	5	1, 800	6
3550	Spring Creek at La Boca, Colo	35. 3	940	32, 000	552
3565	San Juan River near Blanco, N. Mex	1, 519	6, 400	9, 280, 000	2, 607
3645	Animas River at Farmington, N. Mex	971	1, 800	1, 720, 000	1, 263
3665	La Plata River at Colorado-New Mexico State line	38. 5	740	28, 000	85
3680	San Juan River at Shiprock, N. Mex	2, 679	11, 600	30, 600, 000	2, 372
3715	McElmo Creek near Cortez, Colo	53. 5	2, 600	141, 000	605
3795	San Juan River near Bluff, Utah	2, 800	13, 500	37, 100, 000	1, 613
	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.				
3335	Dirty Devil River near Hite, Utah	102	50, 200	5, 000, 000	1, 147
3350	Colorado River at Hite, Utah	14, 167	4, 000	55, 960, 000	731
3395	Escalante River at mouth, near Escalante, Utah	85. 2	20, 900	1, 757, 000	874
3800	Colorado River at Lees Ferry, Ariz	17, 550	5, 800	101, 300, 000	939
3820	Paria River at Lees Ferry, Ariz	31. 9	84, 400	2, 655, 000	1, 691

TABLE 20.—*Suitability of surface water for irrigation in the subbasins in the San Juan division*

[Calcium *a*, to adjust water to 70 percent sodium; calcium *b*, to offset bicarbonate precipitation; and calcium *c*, to supply calcium plus magnesium taken by plants in excess of sodium]

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
							San Juan River basin							
3400	San Juan River near Pagosa Springs, Colo.	5-29-58	[2] 740	High	81	--------	--------	0.00	C1-S1	-0.57	0.49	0.30	0.7	51
		10-21-57	[2] 47	Medium	130	--------	--------	.00		-1.00	1.04	.30	.9	80
3405	West Fork San Juan River above Burns Lake, near Pagosa Springs, Colo.	10-22-57	[2] 32	Medium	57	--------	--------	.07		-.30	.46	.30	.8	108
		5-29-58	[2] 762	High	38	--------	--------	.00		-.23	.28	.30	.6	82
3405A	West Fork San Juan River above Wolf Creek, near Pagosa Springs, Colo.	8- 8-58	[2] 26	Medium	53	30	0.4	.03		-.33	.43	.30	.7	94
3425	San Juan River at Pagosa Springs, Colo.	5-29-58	[2] 2,550	High	67	--------	--------	.04		-.38	.51	.30	.7	101
		8- 8-58	[2] 68	Medium	185	32	.8	.00		-1.05	1.27	.30	1.5	122
3425A	Pagosa Springs at Pagosa Springs, Colo.	10-21-57	--------	--------	4,240	72	13	.00	C4-S4	--------	--------	--------	100	--------
3440	Navajo River at Branded Peak Ranch, near Chromo, Colo.	5-28-58	[2] 814	High	85	--------	--------	.00	C1-S1	-.58	.56	.30	.7	66
3460	Navajo River at Edith, Colo	5-28-58	[2] 1,060	High	97	--------	--------	.00		-.65	.69	.30	.8	80
3465	San Juan River at Arboles, Colo.	1-11-50	[3] 140	Low	391	36	1.3	.00	C2-S1	-2.03	1.97	.29	3.2	54
3495	Piedra River near Piedra, Colo.	5- 9-58	[2] 1,770	High	153	--------	--------	.00	C1-S1	-1.46	1.19	.30	.5	7
		9-18-58	118	Medium	306	21	.6	.00	C2-S1	-2.10	1.45	.29	2.2	0
3495A	Devil Creek near Piedra, Colo	5-21-58	[2] 72	--------	170	--------	--------	.00	C1-S1	-1.57	1.19	.30	.7	0
		9-18-58	[3] .2	Low	622	11	.4	.00	C2-S1	-5.81	3.81	.29	4.0	0
3495B	Stolsteimer Creek at Dyke, near Piedra, Colo.	5-21-58	[2] 7.4	--------	367	--------	--------	.00		-3.09	2.41	.29	1.9	0
3495D	Stolsteimer Creek near Piedra, Colo.	8- 8-58	[2] 2.7	--------	733	15	.7	.00		-6.48	4.24	.28	5.6	0
3500	Piedra River at Arboles, Colo	1-11-50	[3] 60	Low	480	23	.8	.00		-3.51	2.38	.29	3.7	0
3505	San Juan River at Rosa, N. Mex.	4-19-49	3,760	High	249	--------	--------	.00	C1-S1	-2.03	1.45	.30	1.4	0
3525A	Los Pinos River above Vallecito Reservoir, Colo.	10-23-57	[2] 107	Medium	101	--------	--------	.04		-.82	.95	.30	.8	101
		6- 9-58	[2] 986	High	50	--------	--------	.01		-.37	.43	.30	.6	84
3535	Los Pinos River near Bayfield, Colo.	10-24-57	[2] 106	Medium	94	--------	--------	.11		-.78	.98	.30	.8	117
		6- 9-58	[2] 1,660	High	93	--------	--------	.00		-.79	.80	.30	.6	73
3545	Los Pinos River at La Boca, Colo.	11- 9-55	63	Low	336	33	1.1	.37	C2-S1	-1.85	2.69	.30	2.9	267
		9-24-57	242	Medium	156	23	.4	.00	C1-S1	-1.07	1.20	.30	.9	101
		5- 6-58	[2] 2,170	High	129	--------	--------	.00		-1.06	1.13	.30	.7	87
3550	Spring Creek at La Boca, Colo	7-14-55	81	High	280	34	1.0	.15	C2-S1	-1.40	1.95	.30	2.3	199
		12-15-55	4	Low	1,210	70	6.5	.16	C3-S2	.05	3.41	.26	20	870
		5- 8-56	31	Medium	405	39	1.4	.00	C2-S1	-1.71	2.24	.29	3.6	192
3555	San Juan River near Archuleta, N. Mex.	8- -56	374	Medium	374	24	.8	.00		-2.91	2.64	.29	2.6	5
		12- -56	143	Low	547	34	1.5	.00		-2.83	2.76	.29	4.7	51
		6- -57	8,064	High	147	25	.6	.08	C1-S1	-1.06	1.32	.30	1.4	131
3565	San Juan River near Blanco, N. Mex.	6- -52	7,241	High	136	16	.3	.00		-1.09	1.04	.30	.9	59
		3- -53	609	Medium	459	26	1.0	.00	C2-S1	-3.05	2.21	.29	3.7	0
		1- -54	177	Low	534	36	1.5	.00		-2.58	2.56	.29	12	63
3565A	Arroyo by Highway 44, 2 miles east of Lybrook, N. Mex.	9- 1-46	--------	--------	364	72	5.5	1.35		.27	3.39	.28	12	922
3570	San Juan River at Bloomfield, N. Mex.	3- 6-45	[3] 356	Medium	585	36	1.6	.00		-3.03	2.43	.28	5.2	0
3575	Animas River at Howardsville, Colo.	10-23-57	[2] 41	Medium	288	--------	--------	.00		-2.57	.64	.29	2.9	0
		5-26-58	[2] 666	High	125	--------	--------	.00	C1-S1	-.95	.38	.30	1.0	0
3590	Mineral Creek near Silverton, Colo.	10-23-57	[2] 45	Medium	400	--------	--------	.00	C2-S1	-3.60	.14	.28	5.0	0
		5-26-58	[2] 874	High	113	--------	--------	.00	C1-S1	-.88	.31	.30	.9	0
3600A	Animas River at Bakers Bridge, near Rockwood, Colo.	1-29-58	[3] 160	Low	327	5	.1	.00	C2-S1	-2.95	.96	.29	2.8	0
		5-23-58	[3] 3,600	High	121	5	.1	.00	C1-S1	-1.05	.58	.30	.7	0
		9-17-58	[3] 410	Medium	234	4	.1	.00		-2.13	.68	.29	2.0	0
3610	Hermosa Creek near Hermosa, Colo.	10-23-57	[2] 51	Medium	488	--------	--------	.00	C2-S1	-5.11	2.84	.29	3.0	0
		5- 7-58	[2] 1,240	High	248	--------	--------	.00	C1-S1	-2.37	2.27	.30	.8	47
3615	Animas River at Durango, Colo.	10-23-57	[2] 409	Medium	431	--------	--------	.00	C2-S1	-3.67	2.06	.29	3.4	0
		5-19-58	[2] 4,500	High	204	--------	--------	.00	C1-S1	-1.79	1.38	.30	1.0	0
3632	Florida River at Bondad, Colo	5-27-58	[2] 928	High	198	--------	--------	.00		-1.85	1.79	.30	.8	56
		3-25-58	144	Medium	362	24	.8	.00	C2-S1	-2.50	2.74	.29	2.4	124
		9-10-58	14	Low	361	36	1.2	.41		-1.78	2.72	.30	3.3	290
3635	Animas River near Cedar Hill, N. Mex.	9-12-45	285	Medium	549	15	.5	.00		-4.61	2.38	.28	5.2	0
	Animas River at Farmington, N. Mex.	10- -56	87	Low	1,140	29	1.8	.00	C3-S1	-7.24	3.28	.26	14	0
		3- -57	300	Medium	894	29	1.5	.00		-6.67	2.88	.27	10	0
		6- -57	6,077	High	226	10	.2	.00	C1-S1	-1.87	1.32	.30	1.3	0
3655	La Plata River at Hesperus, Colo.	5-28-58	[2] 368	High	106	--------	--------	.00		-.81	.84	.30	.8	77
		10-24-57	[2] 16	Medium	179	--------	--------	.00		-1.67	1.40	.30	.6	7
3665	La Plata River at Colorado-New Mexico State line.	5-28-58	[2] 302	High	298	--------	--------	.00	C2-S1	-2.45	1.61	.29	2.0	0
		8- 7-58	[2] 7.8	Low	1,020	15	.8	.00	C3-S1	-9.32	3.25	.26	12	0
3675	La Plata River near Farmington, N. Mex.	5-22-44	179	High	1,010	24	1.3	.00		-7.48	2.49	.26	13	0
		3- 7-45	22	Medium	2,180	28	2.4	.00		-16.45	2.45	.17	44	0
		9-20-46	1	Low	2,740	53	6.1	.00	C4-S2	-8.02	1.41	.10	67	0
3676B	Red Willow Wash near Tohatchi, N. Mex.	7-24 57	--------	--------	608	89	9.0	1.49	C2-S2	1.57	2.04	.28	11	910
3680	San Juan River at Shiprock, N. Mex.	9- -45	358	Low	978	42	2.6	.00	C3-S1	-4.15	2.54	.27	12	0
		7- -57	8,869	High	318	31	.9	.00	C2-S1	-1.84	1.78	.29	2.4	54
		9- -57	2,012	Medium	516	36	1.5	.00		-2.64	2.26	.29	4.3	0
3705	Mancos River at Mancos, Colo.	5-20-58	[2] 376	High	156	--------	--------	.00	C1-S1	-1.30	1.14	.30	.9	33
		8- 7-58	[2] 3.6	Low	436	10	.3	.00	C2-S1	-3.95	2.48	.29	3.1	0

See footnotes at end of table.

TABLE 20.—*Suitability of surface water for irrigation in the subbasins in the San Juan division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
San Juan River Basin—Continued														
3710	Mancos River near Towaoc, Colo.	10–24–57	[2]35	Medium	1,470	21	1.4	0.00	C3–S1	−12.83	3.06	0.23	23	0
		5– 7–58	[2]462	High	424	--------	--------	.00	C2–S1	−3.33	2.03	.29	3.2	0
3715	McElmo Creek near Cortez, Colo.	7–21–41	110	High	1,470	21	1.4	.00	C3–S1	−11.91	2.30	.23	22	0
		10–25–57	[2]3.2	Low	6,000	39	6.6	.00	C4–S3	--------	--------	--------	100	--------
		5–20–58	[2]32	Medium	1,690	27	2.0	.00	C3–S1	−12.59	2.31	.22	28	0
3720	McElmo Creek near Colorado-Utah State line.	10–25–57	[2]90	High	2,790	23	2.3	.00	C4–S1	−25.70	1.23	.07	75	0
		8– 6–58	[2]11	Low	3,440	27	3.1	.00		--------	--------	--------	100	--------
3750A	Montezuma Creek at Monticello, Utah.	7– 2–49	--------	--------	280	12	.3	.00	C2–S1	−2.29	1.95	.30	1.1	0
3770	Spring Creek near Monticello, Utah.	7– 2–49	--------	--------	370	11	.3	.00		−2.80	2.42	.29	1.7	0
3785A	Verdure Creek at Verdure, Utah.	4–26–47	[3]2	--------	351	--------	--------	.00		−3.40	3.02	.30	1.4	0
3785B	Recapture Creek near Blanding, Utah.	4–26–47	--------	--------	974	34	1.9	.00	C3–S1	−5.67	4.23	.27	9.4	0
		7– 2–49	--------	--------	280	12	.3	.00	C2–S1	−2.30	2.23	.30	2.2	54
3785C	Butler Wash near Bluff, Utah	3– 1–44	--------	--------	1,270	31	2.0	.00	C3–S1	−8.03	2.73	.25	17	0
3790	Comb Wash near Bluff, Utah	3– 1–44	--------	--------	3,710	34	4.1	.00	C4–S1	--------	--------	--------	100	--------
3790C	Lime Creek near Bluff, Utah	3– 1–44	--------	--------	2,280	19	1.6	.00		−21.26	.98	.13	57	0
3790D	Hilkito Wash near Bluff, Utah	6–16–44	--------	--------	147	--------	--------	.00	C1–S1	−1.21	1.18	.30	.7	63
3795	San Juan River near Bluff, Utah	9– –56	64.5	Low	1,470	45	3.4	.00	C3–S1	−5.66	1.88	.23	23	0
		3– –57	1,150	Medium	996	32	1.8	.00		−5.88	2.63	.26	12	0
		6– –57	13,220	High	318	21	.6	.00	C2–S1	−2.16	1.72	.29	2.0	0
3795A	San Juan River at mouth near Hite, Utah.	10– 6–48	876	Medium	952	34	1.9	.00	C3–S1	−5.42	2.82	.27	11	0
Colorado River Basin below Green and San Juan Rivers and above "Lee Ferry," Ariz.														
3285B	Colorado River below Green River, near Moab, Utah.	6–23–47	[3]60,000	High	434	21	0.7	0.00	C2–S1	−3.24	2.00	0.29	3.8	0
		3–26–57	[3]6,000	Meduim	1,590	46	3.6	.00	C3–S1	−5.82	2.18	.21	30	0
3285C	Clearwater Creek near Hite, Utah.	10– 2–48	[3].1	Low	325	23	.7	.00	C2–S1	−2.48	2.23	.29	2.1	9
3285D	Dark Canyon Creek near Hite, Utah.	6–25–47	[3].8	--------	1,100	--------	--------	.00	C3–S1	−11.70	2.24	.25	15	0
3290A	Sevenmile Creek above Johnson Valley Reservoir, near Fish Lake, Utah.	6– 4–58	[2]58	--------	109	--------	--------	.10	C1–S1	−.93	1.10	.30	.7	110
		8– 5–58	[2]11	--------	132	--------	--------	.06		−1.13	1.26	.30	.7	101
3295	Fremont River near Fremont, Utah.	10–22–57	[2]50	Low	217	21	.1	.02		−1.76	1.99	.30	1.1	124
		7–23–58	[2]170	High	195	--------	--------	.07		−1.58	1.78	.30	1.0	117
3300	Fremont River near Bicknell, Utah.	8–31–49	78	Medium	500	15	.5	.00	C2–S1	−3.70	2.51	.29	3.7	0
		10–22–57	[2]111	High	858	16	.7	.00	C3–S1	−7.33	2.90	.27	9.4	0
		5–23–58	[2]45	Low	433	--------	--------	.00	C2–S1	−3.43	2.36	.29	3.2	0
3300A	Bullberry Reservoir near Teasdale, Utah.	7– 1–49	--------	--------	710	33	1.4	.00		−3.29	2.03	.27	8.8	0
		8–31–49	--------	--------	570	33	1.7	.00		−2.16	1.88	.28	7.3	0
3300B	Fremont River near Fruita, Utah.	8–31–49	--------	--------	720	17	.7	.00		−5.23	2.61	.28	7.3	0
3300C	Sulphur Creek near Fruita, Utah.	8–31–49	--------	--------	3,400	16	1.6	.00	C4–S1	--------	--------	--------	100	----
3300D	Fremont River near Caineville, Utah.	7– 1–49	--------	--------	800	16	.7	.00	C3–S1	−5.99	2.37	.27	8.6	0
3300E	Fremont River near Hanksville, Utah.	5– 2–58	[2]148	High	835	17	.8	.00		−7.11	2.15	.27	10	0
		8– 5–58	[2]1.5	Low	1,850	26	2.0	.00		−14.46	1.56	.19	37	0
3305	Muddy Creek near Emery, Utah.	5–22–58	[2]254	High	357	--------	--------	.06	C2–S1	−3.27	3.52	.30	1.3	129
3310	Muddy Creek (lower station) near Emery, Utah.	7– 1–49	--------	Medium	500	25	1.0	.00		−3.23	3.65	.29	3.0	166
		8–30–49	--------	Low	910	50	3.2	.00	C3–S1	−2.68	2.80	.27	9.8	91
3315	Ivie Creek above diversions, near Emery, Utah.	7–29–58	[2]8.2	--------	243	--------	--------	.00	C1–S1	−2.19	2.18	.30	1.1	68
3315A	Quitechupah Creek near Emery, Utah.	7– 1–49	--------	--------	820	31	1.5	.00	C3–S1	−4.34	3.78	.28	6.4	0
		8–30–49	--------	--------	370	13	.4	.04	C2–S1	−3.14	3.37	.30	1.5	124
3325	Muddy Creek below Ivie Creek, near Emery, Utah.	5–21–58	[2]194	High	728	29	1.4	.00		−4.76	3.92	.28	5.6	0
3325A	Muddy Creek near Hanksville, Utah.	7– 1–49	--------	Low	4,000	43	5.7	.00	C4–S2	--------	--------	--------	100	--------
		5– 2–58	[2]72	Medium	2,240	38	3.5	.00	C3–S1	−12.40	1.55	.14	54	0
3330	Dirty Devil River near Hanksville, Utah.	7–47	21	Low	3,200	37	4.2	.00	C4–S2	--------	--------	--------	100	--------
		10–47	108	Medium	1,750	30	2.3	.00	C3–S1	−11.39	1.83	.20	34	0
		3–48	190	High	1,070	18	1.0	.00		−9.06	2.38	.26	15	0
3335	Dirty Devil River near Hite, Utah.	11–53	106	Medium	2,130	26	2.2	.00		−15.92	1.46	.15	50	0
		6–54	.12	Low	7,590	46	8.6	.00	C4–S3	--------	--------	--------	100	--------
		4–26–58	[2]405	High	1,490	17	1.1	.00	C3–S1	−13.63	1.53	.22	27	0
3335A	Hog Canyon Creek near Hite, Utah.	10– 7–48	[3].2	Low	633	31	1.4	.05	C2–S1	−3.94	4.78	.29	4.6	264
3350	Colorado River at Hite, Utah	9–56	2,697	Low	1,620	38	3.0	.00	C3–S1	−8.11	2.26	.21	30	0
		3–57	6,774	Medium	1,360	44	3.2	.00		−5.30	2.64	.24	22	0
		6–57	80,100	High	407	24	.8	.00	C2–S1	−2.64	2.19	.29	2.9	0
3350A	Trachyte Creek at Hite, Utah	10– 4–48	[3].4	Low	671	34	1.6	.00		−3.86	3.82	.29	5.2	58
		4–29–58	[2]6.3	--------	560	26	1.1	.00		−3.84	3.05	.29	4.1	0
3350B	Red Canyon Creek near Hite, Utah.	9– 8–57	[3]2.0	--------	2,510	51	5.5	.00	C4–S2	−7.30	1.10	.09	70	0

See footnotes at end of table.

TABLE 20.—*Suitability of surface water for irrigation in the subbasins in the San Juan division*—Continued

Station No.	Source	Date	Water discharge		Specific conductance (micromhos per cm at 25°C)	Percent sodium	Sodium-adsorption-ratio	Residual sodium carbonate	Classification					
			Cubic feet per second	Classification					After U.S. Salinity Laboratory Staff, 1954	After Eaton (1954)[1]				
										Calcium *a*	Calcium *b*	Calcium *c*	Required leaching (percent)	Required gypsum (lb per acre-ft)
										Milliequivalents per liter				
Colorado River Basin below Green and San Juan Rivers and above "Lee Ferry," Ariz.—Continued														
3350C	Warm Springs Creek near Hite, Utah.	10- 4-48	[3]0.5	Low	469	21	0.7	.00	C2-S1	−3.66	3.54	0.29	2.4	40
3350D	Cedar Creek near Hite, Utah	9-11-57	[3].5	Low	567	-----	-----	.00		−5.55	4.77	.29	2.2	0
3350E	Knowles Canyon Creek near Hite, Utah.	9- 9-57	[3].1	Low	500	28	1.2	.27		−3.91	4.83	.29	4.1	283
3351A	Smith Fork near Hite, Utah	9- 9-57	[3]1	-----	469	27	1.1	.20		−3.32	4.08	.29	3.2	246
3351B	Hansen Creek near Hite, Utah	9- 9-57	[3]1	-----	739	52	3.3	.00		−2.55	3.03	.27	10	176
3351C	Moki Creek near Hite, Utah	9- 9-57	[3]3	-----	439	31	1.2	.23		−2.72	3.54	.29	3.5	260
3351D	Bullfrog Creek near Hite, Utah	6-26-47	[3].3	Low	1,320	38	2.6	.00	C3-S1	−6.89	2.28	.25	18	0
		9- 9-57	[3]2	-----	728	33	1.6	.00	C2-S1	−4.29	2.77	.28	7.1	0
3351E	Halls Creek near Hite, Utah	9- 9-57	[3]2	-----	459	25	.9	.00		−3.34	2.63	.29	3.4	0
3352A	Lake Canyon Creek near Hite, Utah.	9-10-57	[3]3	-----	454	-----	-----	.00		−4.48	3.60	.29	1.9	0
3352B	Navajo Creek near Hite, Utah	10- 5-48	[3].4	-----	355	-----	-----	.00		−3.47	3.34	.30	1.4	40
3355	North Creek near Escalante, Utah.	10-22-57	[2]8.6	-----	357	8	.2	.00		−3.42	2.61	.29	1.9	0
		6-13-58	[2]48	-----	173	-----	-----	.00	C1-S1	−1.52	1.53	.30	.7	73
3370	Pine Creek near Escalante, Utah.	5-20-58	[2]170	-----	196	-----	-----	.00		−1.91	1.76	.30	.6	35
		8- 3-58	[2]10	-----	208	-----	-----	.00		−1.87	1.40	.30	1.1	0
3375	Escalante River near Escalante, Utah.	5-20-58	[2]203	High	275	-----	-----	.00	C2-S1	−2.31	2.17	.30	1.3	37
		8- 3-58	[2]3.4	Medium	1,770	44	3.7	.00	C3-S1	−7.20	4.50	.20	32	0
3380B	Boulder Creek above Deer Creek, near Boulder, Utah.	8- 4-58	[2]2.2	-----	308	-----	-----	.00	C2-S1	−2.55	2.74	.30	1.7	115
3395	Escalante River at mouth, near Escalante, Utah.	7-51	17.1	Low	670	25	1.1	.00		−4.19	2.70	.28	7.0	0
		10-51	69.4	Meduim	561	19	.7	.00		−4.27	2.80	.29	4.9	0
		5-52	158	High	379	17	.5	.00		−3.08	2.48	.29	2.5	0
3395A	Clear Creek near Escalante, Utah.	3- 3-51	-----	-----	244	-----	-----	.00	C1-S1	−2.41	2.45	.30	.8	80
3395B	Hole-in-Rock Creek near Escalante, Utah.	10- 5-48	[3].2	Low	258	-----	-----	.00	C2-S1	−2.58	2.56	.30	.9	66
3395C	Colorado River above San Juan River, Utah.	10- 6-48	[3]4,000	Low	1,930	40	3.4	.00	C3-S1	−9.72	2.30	.18	39	0
3795B	Oak Creek near Lees Ferry, Ariz.	9-11-57	-----	-----	363	-----	-----	.00	C2-S1	−3.26	3.17	.30	1.5	49
3795C	Aztec Creek near Lees Ferry, Ariz.	9-11-57	[3]2	-----	313	-----	-----	.06		−2.72	2.96	.30	1.4	126
3795D	Rock Creek near Lees Ferry, Ariz.	9-11-57	[3]1	-----	906	14	.7	.00	C3-S1	−8.45	1.99	.26	12	0
3795E	West Canyon Creek near Lees Ferry, Ariz.	10- 6-48	[3].8	Low	331	-----	-----	.00	C2-S1	−3.35	3.66	.30	.95	73
3796A	Last Chance Creek near Lees Ferry, Ariz.	9-12-57	[3]1.0	-----	1,190	20	1.2	.00	C3-S1	−9.50	2.76	.25	16	0
3796B	Cottonwood Creek near Lees Ferry, Ariz.	9-13-57	[3].5	Low	782	32	1.6	.00		−4.67	4.41	.28	6.6	5
3796C	Warm Creek near Lees Ferry, Ariz.	10-17-48	[3]2.5	-----	1,580	45	3.6	.00		−6.17	3.93	.22	28	0
3796D	Navajo Creek near Lees Ferry, Ariz.	10- 7-48	[2]4.2	-----	327	23	.7	.16	C2-S1	−2.53	3.02	.30	2.1	185
3796E	Wahweap Creek near Lees Ferry, Ariz.	10- 7-48	[2]7.6	-----	1,290	37	2.5	.00	C3-S1	−6.70	4.76	.25	17	0
3800	Colorado River at Lees Ferry, Ariz.	10-56	3,034	Low	1,830	38	3.1	.00		−9.44	2.10	.19	36	0
		3-57	8,108	Medium	1,340	42	2.9	.00		−5.73	2.88	.24	20	0
		6-57	94,860	High	452	21	.7	.00	C2-S1	−3.26	2.64	.29	3.1	0
3805A	Tropic and East Fork Canal near Tropic, Utah.	10-22-57	[2]12	-----	324	3	.1	.00		−3.72	3.50	.30	.50	19
		5-21-58	[2]17	-----	361	-----	-----	.00		−3.91	3.89	.30	.65	66
3815	Paria River near Cannonville, Utah.	10-25-57	[2]12	-----	1,530	40	3.0	.00	C3-S1	−7.02	3.04	.24	20	0
3820	Paria River at Lees Ferry, Ariz.	7-15-48	4.2	Low	556	26	1.0	.00	C2-S1	−3.61	1.82	.28	5.4	0
		12- 1-48	14	Medium	1,080	30	1.7	.00	C3-S1	−6.99	2.77	.26	13	0
		3- 1-49	137	High	1,440	42	3.2	.00		−6.75	2.75	.24	21	0

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[1] For good yield.
[2] From gage height or measurement at time of sampling.
[3] Estimated.

TABLE 21.—*Annual discharge of Tropic and East Fork canal near Tropic, Utah*

Water year	*Discharge (acre-ft)*	*Water year*	*Discharge (acre-ft)*
1950	3, 910	1954	2, 180
1951	2, 400	1955	2, 050
1952	4, 980	1956	934
1953	1, 880	1957	2, 490

TABLE 22.—*Adjustments, in thousands of acre-feet, added to historical streamflow record of Colorado River at Lees Ferry, Ariz., to adjust to 1914 base*

Water year		*Water year*		*Water year*		*Water year*	
1914	11	1925	22	1936	73	1947	256
1915	15	1926	21	1937	78	1948	48
1916	18	1927	25	1938	174	1949	192
1917	11	1928	21	1939	93	1950	247
1918	18	1929	30	1940	63	1951	437
1919	13	1930	22	1941	230	1952	497
1920	17	1931	16	1942	71	1953	269
1921	12	1932	27	1943	284	1954	223
1922	15	1933	24	1944	101	1955	462
1923	16	1934	17	1945	249	1956	435
1924	11	1935	42	1946	160	1957	755

TABLE 23.—*Summary data and utilization of surface water in the San Juan division, 1957*

Water use	Subbasin		San Juan division
	San Juan River basin	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.	
Storage reservoirs having usable capacities greater than 1,000 acre-ft:			
Number	12	6	18
Total usable capacity ..... acre-ft	207, 160	21, 000	228, 160
Transmountain diversions:			
Number	[1] 6	1	7
Exported (average annual) ..... acre-ft	2, 800	0	2, 800
Imported (average annual) ..... acre-ft	[2] 100, 000	[3] 2, 600	102, 600
Irrigation:			
Irrigated ..... acres	206, 400	33, 300	239, 700
Estimated consumptive use (average annual) ..... acre-ft	256, 600	44, 500	301, 100
Domestic and industrial use:			
Population (1960)	100, 000	6, 000	106, 000
Estimated consumptive use (average annual) ..... acre-ft	6, 700	400	7, 100
Hydroelectric powerplants:			
Number	4	1	5
Installed capacity ..... kw	4, 930	140	5, 070

[1] Of the six transmountain diversions, five export water out of the division and one imports water into the division.

[2] Imported from the Dolores River in the Grand division.

[3] Imported from East Fork of Sevier River in the Great Basin.

TABLE 24.—*Water budget, San Juan division*

	Average annual (acre-ft)
Outflow from division less inflow from the Colorado River above Green River and Green River	2, 539, 000
Transmountain exportation	2, 800
Transmountain importation	−102, 600
Irrigation consumptive use	301, 100
Domestic and industrial consumptive use	7, 100
Evapotranspiration loss	[1] 23, 133, 200
Total	25, 880, 600

[1] Includes 125,000 acre-ft estimated evaporation from water surfaces.

TABLE 25.—*Summary of average annual water, dissolved-solids, and suspended-sediment contributions in the San Juan division*

[Data are for the water years 1914–57 adjusted to 1957 conditions]

Data	Subbasin		San Juan division
	San Juan River basin	Colorado River Basin below the Green and San Juan Rivers and above "Lee Ferry," Ariz.	
Drainage area sq mi	24, 900	13, 400	38, 300
Water discharge acre-ft	[1] 2, 028, 000	[2] 511, 000	2, 539, 000
Dissolved-solids discharge:			
Total tons	1, 073, 000	470, 600	1, 543, 600
Probable from natural sources do	[3] 784, 900	406, 900	1, 191, 800
Do tons per sq mi	32	30	31
Probable from activities of man tons	288, 100	[4] 63, 700	351, 800
Do tons per acre irrigated	1. 4	1. 9	1. 5
Suspended-sediment discharge tons	30, 839, 800	15, 745, 200	55, 585, 000

[1] From San Juan River basin above gaging station near Bluff, Utah.

[2] Includes contribution from San Juan River basin below gaging station near Bluff, Utah.

[3] Includes 17,000 tons of dissolved solids in water imported from Dolores River.

[4] Includes 700 tons of dissolved solids in water imported in Tropic and East Fork canal.

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