Surface-Water Hydrology of Coastal Basins of Northern California

By S. E. RANTZ

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1758

Prepared in cooperation with the California Department of Water Resources

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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By S. E. Rantz

ABSTRACT

This report presents an analysis of the surface-water hydrology of those coastal basins of California that are north of the south boundary of the Eel River basin. Its purpose is to provide hydrologic information in convenient form for use in project planning by the California Department of Water Resources and other water agencies operating in the state.

Precipitation in the report area is distinctly seasonal, very little occurring from June through September. The mountainous topography influences the areal distribution of precipitation, causing rainfall to be heaviest on the western, or windward, slope of the coastal ranges. The runoff pattern is influenced not only by the distribution of precipitation, but also by the geology and topography of the region. From a consideration of physiography, the region can be divided into three subregions, or sections, each of which is hydrologically homogeneous. They are the northern California Coast Ranges, the Klamath Mountains, and the Southern Cascade Mountains and associated lava plateau.

The basins south of the Klamath River lie wholly in the northern California Coast Ranges. The mountains are relatively low and there is therefore little snowmelt runoff. Because of the impermeability of the mantle rock, base flow is poorly sustained. Consequently, the bulk of the runoff in the subregion occurs during and shortly after the rains of late fall and winter.

The Smith River and the lower 200-mile reach of the Klamath River drain the Klamath Mountains. Because a large part of the Klamath River basin is above 5,000 feet in elevation, much of the winter precipitation is stored as snow, and a large amount of snowmelt runoff occurs in late spring in addition to the storm runoff in the winter. The mantle rock is more permeable here than in the northern California Coast Ranges, and base flow is therefore better sustained.

The upper Klamath River basin and adjacent closed basins are in the Southern Cascade Mountains. The highly permeable and fractured volcanic rock of this subregion allows ready infiltration of precipitation and snowmelt, and base flow is therefore better sustained in this subregion than in either of the other two. Because of the high elevation of the subregion, the volume of snowmelt runoff is significantly large.

The basins studied in the three subregions have a total drainage area of 21,000 square miles. The average annual natural runoff from this area for the 60-year period, 1900–1959, is estimated to be 30.3 million acre-feet, which is equivalent to 27 inches of runoff from the entire region. There is a wide range, however, in areal distribution of runoff; some of the closed basins adjacent to the upper Klamath River basin have an average annual runoff of about 2 inches, whereas a large part of the Smith River basin has an average annual runoff of 90 inches.

The variability of runoff with time, reflecting the variability of precipitation from year to year, is also striking. Wet and dry periods lasting for several years are common, and during those periods average runoff departs widely from the long-term mean. Northern California experienced a prolonged wet period from 1890 to 1916 followed by a dry period from 1917 to 1937. In the 22 years since 1937, there have been two wet periods and one dry period. The driest single year of record was 1924, when runoff was generally about 20 percent of the 60-year (1900–1959) mean. Two of the wettest years of record were 1956 and 1958 when runoff was generally slightly more than twice the 60-year mean.

Study of the regimen of runoff in the region indicates that for any stream there is a close relationship between the flow-duration curve and the frequency curves for low flows of various durations. Both are influenced by basin characteristics, and the relationship is helped by the consistency of the precipitation distribution wherein little runoff-producing precipitation occurs during the 6-month period, mid-April to mid-October. The recurrence intervals of low flows sustained for periods ranging from 1 day to 183 days may be derived from the flow-duration curve with considerable confidence.

The greatest floods known in Northwestern California are those of the winter of 1861–62. The peak discharge of Klamath River at Klamath, Calif., for the flood of December 1861 has been computed, but for other streams only qualitative information concerning this flood is available. From this information, however, it has been deduced that the flood peaks of December 1955 were of approximately the same order of magnitude as those that occurred 94 years earlier. A flood-frequency study of the region indicates that the magnitude of the mean annual flood for any stream is related to (1) the size of drainage area and (2) the mean annual basin-wide precipitation, there being a different relationship in each of the physiographic provinces. In making the flood study, dimensionless flood-frequency curves for the various gaging stations were constructed, using annual peak discharges expressed as ratios to the mean annual flood. Comparison of these frequency curves indicates that the slope of the curve is related primarily to mean annual precipitation, and to a lesser degree, to the elevation of the basin. Generally speaking, the more humid the area, the less variable is the precipitation, and therefore there is a lesser difference in severity between the storms that produce the minor floods and those that produce the major floods. Consequently the flatter flood-frequency curves are associated with the more humid basins. Elevation influences the degree to which melting snow augments the runoff from precipitation during the storms of long duration that cause major floods in the region.

The method used in the analysis of magnitude, duration, and frequency of high flows closely paralleled that followed in the flood-frequency study. The mean discharges for various durations ranging from 1 day to 365 days were arrayed for each stream, and the values of discharge corresponding to a recurrence interval of 2.33 years were determined. The discharge figures so obtained were then related to (1) the size of drainage area and (2) the mean annual basin-wide precipitation. As found in the flood-frequency study, the relationship differs in each of the physiographic provinces. The slopes of the frequency curves for the various durations are affected by the same climatologic and physiographic factors that influence the slope of the flood-frequency curve, but the effect of differences in these factors rapidly diminishes with increasing length of duration period.

INTRODUCTION

PURPOSE AND SCOPE OF THE REPORT

This report on the surface-water hydrology of coastal basins of northern California has been prepared to provide hydrologic data for use in project planning by the California Department of Water Resources and other water agencies operating in the state. This project planning has for its broad objective the full conservation, control, and utilization of the water resources of California to meet present and future water needs.

The region studied has an area of 21,000 square miles and comprises the coastal drainage basins of California that are north of the south boundary of the Eel River basin. (See fig. 1.) Parts of the drainage basins of the northernmost streams lie in Oregon. It is estimated (California Water Resources Board, 1955, table 181) that more than 10 million acre-feet of water are annually surplus to the ultimate water requirements of the region and are therefore available for export to water-deficient areas of the state. A prerequisite, however, to the planning for full development of the water resources of the region is a detailed inventory of the supply, covering not only the areal distribution of runoff but also its distribution with time. This report is directed toward filling the need for that inventory. The great mass of data published by the U.S. Geological Survey in its annual water-supply paper series titled "Surface-Water Supply of the United States, Part 11, Pacific Slope Basins in California" has been analyzed and the results of the study are reported in this paper. This report is primarily an expansion and updating of an earlier preliminary study of the region (Rantz and others, 1956).

A 60-year base period, 1900 to 1959, has been used in this report for studying mean annual basin-wide precipitation, runoff, and water loss in drainage basins above key gaging stations and above the mouths of principal streams. This base period includes several series of wet and dry years, and the mean annual runoff for this period is therefore probably representative of the long-term mean. (Unless otherwise specified, "years," as used in this report, refers to the water year, a 12-month period ending September 30. The water year is commonly used in water-supply studies and is designated by the calendar date of the last 9 months of the period; for example, the period October 1, 1948 to September 30, 1949, is designated the 1949 water year.)

The regimen of runoff of the various streams is discussed in the report and analyzed in studies of flow duration, flood frequency, and frequency and duration of sustained high and low flows. The lack of long-term streamflow records necessitated the use of base periods shorter than 60 years for these analyses.

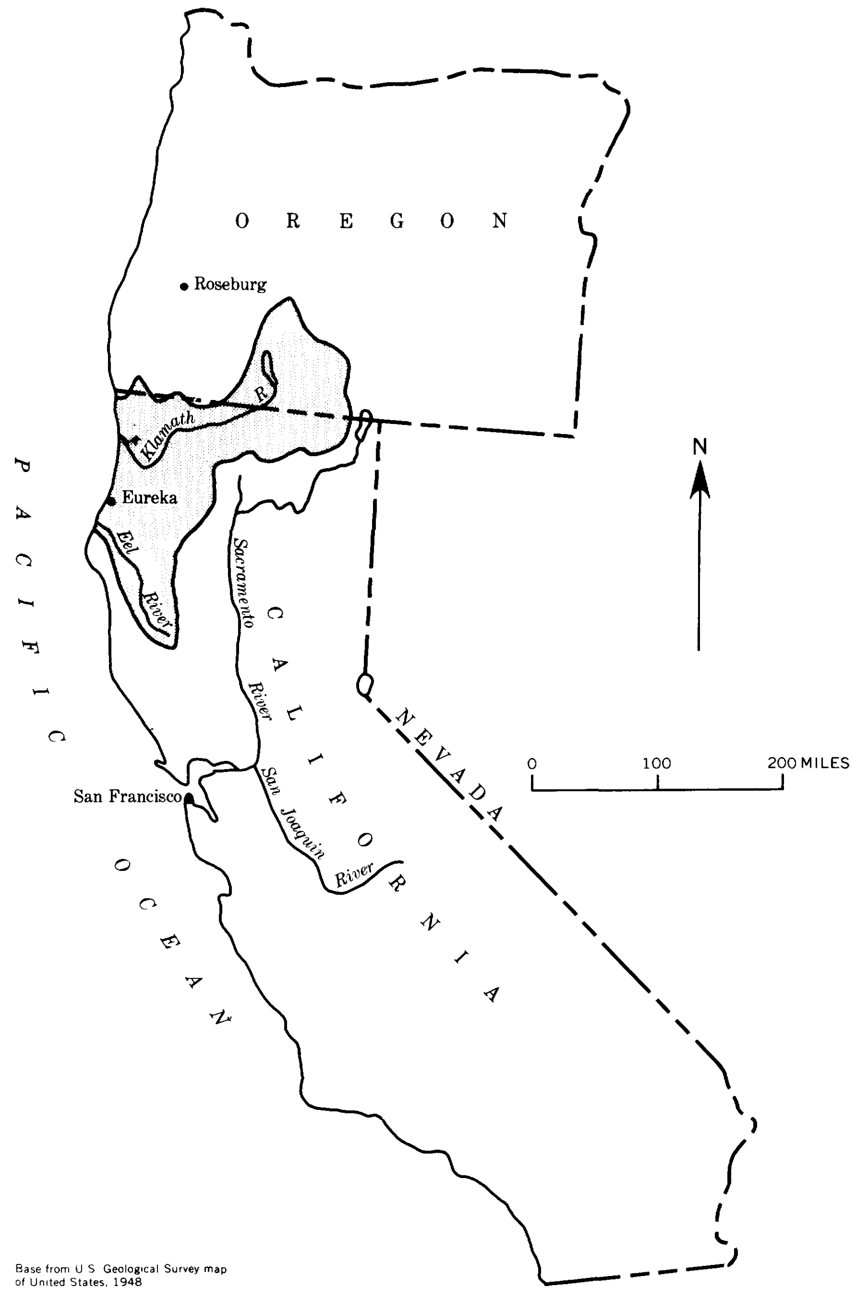

FIGURE 1.—Map showing location of report area.

Relatively few stream-gaging stations operated during all years of the various base periods used in this report, and it was therefore necessary to resort to correlation techniques to produce the synthetic streamflow figures needed to fill existing gaps in the records. Greater refinement in these correlative estimates of flow would have been possible had this study been postponed for years to permit the collection of additional data. The pressing need of the planning agencies, however, for information of the type presented in this report permitted no delay.

OTHER INVESTIGATIONS

The ground-water resources of the region have been studied in recent years, and the results of the investigations have been published in seven U.S. Geological Survey water-supply papers (Back, 1957; Evenson, 1959; Mack, 1959; Mack, 1960; Poole 1961; Wood, 1961; Cardwell, in preparation). Additional ground-water information is found in a report of the Pacific Southwest Field Committee of the U.S. Department of the Interior (Rantz and others, 1956), and in an open-file report of the Geological Survey (Newcomb and Hart, 1958).

There have also been investigations of the quality of water in the region. Information concerning surface-water quality is published by the U.S. Geological Survey in its water-supply paper series titled "Quality of Surface Waters of the United States, Parts 9–14." Information relating to the quality of ground-water supplies is published annually by the California Department of Water Resources as chapters to its Bulletin 66 titled "Quality of Ground Waters in California". A summary of the quality of both surface- and ground-water supplies is found in the previously mentioned report of the Pacific Southwest Field Committee of the U.S. Department of the Interior (Rantz and others, 1956).

ACKNOWLEDGMENTS

This study was performed under the terms of a cooperative agreement between the U.S. Geological Survey and the California Department of Water Resources. The report was prepared by the Geological Survey under the supervision of Walter Hofmann, district engineer. W. T. Rintala assisted in the computation and preparation of the data.

Acknowledgment is made of the assistance rendered by the California Department of Water Resources, Sacramento, Calif., in furnishing tabulations of precipitation data. The Bureau of Reclamation, Sacramento, Calif., helpfully furnished runoff information for the closed basins adjacent to the upper Klamath River basin.

DESCRIPTION OF REGION

The principal streams of the region are the Eel River, Mad River, Redwood Creek, Klamath River, and Smith River, all of which drain large interior basins. The smaller coastal streams studied, Elk River, Jacoby Creek, and Little River, drain the coastal slope only of the northern California Coast Ranges. Plate 1 delineates the principal drainage systems and those hydrologic units under consideration for project planning; table 1 lists these drainage basins and their size. More than half the region is drained by the Klamath River and its tributaries, the principal tributaries being the Williamson River in Oregon, and the Shasta, Scott, Salmon, and Trinity Rivers in California. The basins of Lost River and Lower Klamath Lake contribute little to the flow of the Klamath River.

TABLE 1.—*Basinwide precipitation, runoff, and water loss for hydrologic units in coastal basins of northern California (adjusted to base period 1900–59)*

No. (pl. 1)	Basin	Drainage area (sq mi)		Annual basinwide values: Precipitation (inches)	Runoff: 1000's of acre-ft		Runoff: Inches	Water loss (inches)
	Eel River Basin							
1A	Eel River above gage at Van Arsdale Dam	347		51	500		27.0	24
1B	Outlet Creek above mouth	162		57	315		36.4	21
1C	Remaining drainage into Eel River above Middle Fork	200		51	325		30.5	21
	Total or average, Eel River above Middle Fork		709	52		1,140	30.2	22
1D	Middle Fork Eel River below Black Butte River	367		60	689		35.2	25
1E	Remaining drainage into Middle Fork Eel River above mouth	386		49	481		23.4	26
	Total or average, Middle Fork Eel River above mouth		753	54		1,170	29.1	25
	Total or average, Eel River below Middle Fork		1,462	53		2,310	29.6	23
1F	North Fork Eel River above mouth		282	59		425	28.3	31
1G	Remaining drainage into Eel River above Alderpoint gage		335	56		447	25.0	31
1H	Drainage into Eel River between Alderpoint gage and mouth of South Fork		187	62		394	39.5	22
	Total or average, Eel River above South Fork		2,266	55		3,576	29.6	25
1J	South Fork Eel River above gage near Branscomb	43.9		79	122		52.1	27
1K	Tenmile Creek at mouth	65.8		66	145		41.3	25
1L	Remaining drainage into South Fork Eel River above gage near Miranda	427.3		70	1,030		45.2	25
	Total or average, South Fork Eel River above Miranda gage	537		70	1,297		45.3	25

TABLE 1.—*Basinwide precipitation, runoff, and water loss for hydrologic units in coastal basins of northern California (adjusted to base period 1900–59)*—Con.

No. (pl. 1)	Basin	Drainage area (sq mi)		Annual basinwide values: Precipitation (inches)	Runoff: 1000's of acre-ft		Runoff: Inches	Water loss (inches)
	Eel River Basin—Con.							
1M	Drainage into South Fork Eel River between Miranda gage and mouth	152		76	441		54.4	22
	Total or average, South Fork Eel River above mouth		689	71		1,738	47.3	24
1N	Remaining drainage into Eel River above gage at Scotia		158	66		406	48.2	18
	Total or average, Eel River above Scotia gage		3,113	59		5,720	34.4	25
1P	Van Duzen River above mouth of South Fork	85.3		74	246		54.1	20
1R	South Fork Van Duzen River above mouth	58.2		75	172		55.4	20
1S	Remaining drainage into Van Duzen River above gage near Bridgeville	70.5		67	169		45.0	22
	Total or average, Van Duzen River above Bridgeville gage	214		72	587		51.4	21
1T	Yager Creek above mouth	135		60	280		38.9	21
1U	Remaining drainage into Van Duzen River above mouth	80		50	128		30	20
	Total or average, Van Duzen River above mouth		429	64		995	43	21
1V	Remaining drainage into Eel River above mouth		83	41		93	21	20
	Total or average, Eel River above mouth		3,625	59		6,808	35	24
	Elk River Basin							
2A	Elk River above gage near Falk		44.2	49		57	24.2	25
	Jacoby Creek Basin							
3A	Jacoby Creek above gage near Freshwater		6.07	54		10.6	32.7	21
	Mad River Basin							
4A	Mad River above gage near Forest Glen		144	60		248	32.3	28
4B	Drainage into Mad River between Forest Glen gage and mouth of North Fork		256	68		620	45.4	23
4C	North Fork Mad River above mouth		49.5	66		122	46.2	20
4D	Remaining drainage into Mad River above gage near Arcata		35.5	55		66	34.9	20
	Total or average, Mad River above Arcata gage		485	64		1,056	40.8	23
	Little River Basin							
5A	Little River above gage at Crannell		44.3	65		98	41.5	23

TABLE 1.—*Basinwide precipitation, runoff, and water loss for hydrologic units in coastal basins of northern California (adjusted to base period 1900–59)*—Con.

No. (pl. 1)	Basin	Drainage area (sq mi)		Annual basinwide values: Precipitation (inches)	Runoff: 1000's of acre-ft		Runoff: Inches	Water loss (inches)
	Redwood Creek Basin							
6A	Redwood Creek above gage near Blue Lake	----------	67.5	80	----------	195	54.2	26
6B	Drainage into Redwood Creek between gages near Blue Lake and at Orick	----------	210.5	80	----------	601	53.5	26
	Total or average, Redwood Creek above gage at Orick	----------	278	80	----------	796	53.7	26
	Closed basins adjacent to Klamath River Basin							
7A	Lost River area above Boundary damsite	----------	1,180	16	----------	191	3.0	13
7B	Antelope and Butte Creek area	----------	240	26	----------	45	3.5	22
7C	Remaining closed drainage	----------	2,180	16	----------	233	2.0	14
	Total or average, all closed basins	----------	3,600	17	----------	469	2.4	15
	Trinity River Basin							
8A	Trinity River above gage at Lewiston	727	----------	59	1,304	----------	33.6	25
8B	Trinity River drainage between gages at Lewiston and near Burnt Ranch	711	----------	55	958	----------	25.3	30
	Total or average, Trinity River above Burnt Ranch gage	1,438	----------	57	2,262	----------	29.4	28
8C	Trinity River drainage between Burnt Ranch gage and mouth of South Fork	296	----------	59	547	----------	34.7	24
	Total or average, Trinity River above South Fork	----------	1,734	57	----------	2,809	30.4	27
8D	South Fork Trinity River above Hayfork Creek	342	----------	53	507	----------	27.8	25
8E	Hayfork Creek above Hayfork gage	87.2	----------	47	83.5	----------	18.0	29
8F	Hayfork Creek drainage between Hayfork gage and mouth	299.8	----------	42	289.5	----------	18.1	24
	Total or average, Hayfork Creek above mouth	387	----------	43	373	----------	18.1	25
8G	South Fork Trinity River drainage between Hayfork Creek and mouth	180	----------	57	331	----------	34.5	23
	Total or average, South Fork Trinity River above mouth	----------	909	50	----------	1,211	24.9	25
8H	Trinity River drainage between South Fork and mouth	----------	326	61	----------	601	34.5	27
	Total or average, Trinity River above mouth	----------	2,969	55	----------	4,621	29.2	26

TABLE 1.—*Basinwide precipitation, runoff, and water loss for hydrologic units in coastal basins of northern California (adjusted to base period 1900–59)*—Con.

No. (pl. 1)	Basin	Drainage area (sq mi)		Annual basinwide values: Precipitation (inches)	Runoff: 1000's of acre-ft		Runoff: Inches	Water loss (inches)
	Klamath River Basin							
9A	Williamson River above Sprague River	1,400		25	359		4.8	20
9B	Sprague River above mouth	1,600		23	454		5.3	18
9C	Wood River area	360		30	327		17.0	13
9D	Remaining drainage into Upper Klamath Lake	450		24	250		10.4	14
	Total or average, drainage into Upper Klamath Lake	3,810		24	1,390		6.8	17
9E	Klamath River drainage between Upper Klamath Lake and gage at Keno	110		14	12		2.0	12
	Total or average, Klamath River above Keno gage	3,920		24	1,402		6.7	17
9F	Klamath River drainage between gages at Keno and near Copco	450		32	220		9.2	23
	Total or average, Klamath River above Copco gage		4,370	25		1,622	7.0	18
9G	Shasta River above mouth		796	22		172	4.0	18
9H	Scott River above Callahan damsite	160		38	156		18.3	20
9J	Drainage into Scott River between Callahan damsite and gage near Fort Jones	502		32	330		12.3	20
9K	Drainage into Scott River between Fort Jones gage and mouth	151		45	169		21.0	24
	Total or average, Scott River above mouth		813	36		655	15.1	21
9L	Remaining drainage into Klamath River above gage near Seiad Valley		1,001	38		641	12.0	26
	Total or average, Klamath River above Seiad Valley gage		6,980	28		3,090	8.3	20
9M	Klamath River drainage between Seiad Valley gage and Happy Camp damsite		355	67		778	41.1	26
9N	Klamath River drainage between Happy Camp damsite and mouth of Salmon River		399	77		1,133	53.2	24
	Total or average, Klamath River above Salmon River		7,734	32		5,001	12.1	20
9P	South Fork Salmon River above mouth	290		50	451		29.2	21
9R	North Fork Salmon River above mouth	205		59	374		34.2	25
9S	Remaining drainage into Salmon River above mouth	256		63	514		37.7	25
	Total or average, Salmon River above mouth		751	57		1,339	33.4	24

TABLE 1.—*Basinwide precipitation, runoff, and water loss for hydrologic units in coastal basins of northern California (adjusted to base period 1900–59)*—Con.

No. (pl. 1)	Basin	Drainage area (sq mi)		Annual basinwide values: Precipitation (inches)	Runoff: 1000's of acre-ft		Runoff: Inches	Water loss (inches)
	Klamath River Basin—Con.							
9T	Klamath River drainage between Salmon and Trinity Rivers		295	77		929	59.1	18
	Total or average, Klamath River above Trinity River		8,780	36		7,269	15.5	20
8	Trinity River above mouth		2,969	55		4,621	29.2	26
9U	Remaining drainage into Klamath River above mouth		351	92		1,260	67.3	25
	Total or average, Klamath River above mouth		12,100	42		13,150	20.4	22
	Smith River Basin							
10A	Middle Fork above mouth of North Fork		130	100		515	74.3	26
10B	North Fork above mouth		158	115		760	90.2	25
10C	South Fork above mouth		295	116		1,415	89.9	26
10D	Remaining drainage into Smith River above gage near Crescent City		30	90		104	65.0	25
	Total or average, Smith River above Crescent City gage		613	111		2,794	85.5	26
10E	Remaining drainage into Smith River above mouth		106	90		366	65.0	25
	Total or average, Smith River above mouth		719	108		3,160	82.4	26

Most of the region is mountainous; many peaks are above 6,000 feet in elevation. Mount Shasta on the eastern divide at 14,161 feet is the highest. The mountainous areas are generally well covered with timber. The only valley areas of appreciable extent are those in the basins of the Scott, Shasta, Lost, and upper Klamath Rivers, and in the basin of Lower Klamath Lake. (A valley area is defined, for the purpose of this study, as one sloping less than 200 feet to the mile.) Irrigation is widely practiced in these valleys. The only storage or diversion works of large size are in the basins of the upper Eel, Trinity (project under construction as of May 1961), Shasta, Lost, and upper Klamath Rivers.

GEOLOGY

The report area includes large parts of three physiographic sections (pl. 5): the northern California Coast Ranges, the Klamath Mountains, and the Southern Cascade Mountains and associated lava plateau (Irwin, 1960). The geology and topography of these provinces significantly affect the climate and weather, drainage conditions, soils, and natural vegetation, and each province is hydrologically homogeneous. All the streams with the exception of the Smith River and the Klamath River and its tributaries lie wholly within the northern California Coast Ranges.

The northern California Coast Ranges are composed chiefly of a complex assemblage of sandstone and shale, and greenstones of probable Mesozoic Age, intruded by large masses of ultramafic rocks largely altered to serpentine. The general structure of the Coast Ranges, characterized by northwest-trending folds and faults, controls the drainage. Many of the streams and large valleys are along zones of weakness associated with major faults, and the drainage pattern is rudely trellised. Locally, the combination of sheared rocks, steep slopes, and heavy precipitation produces the landslides common to the area.

The Klamath Mountains section is a rugged region extending between the northern California Coast Ranges and the Southern Cascade Mountains. It adjoins the Coast Ranges along the South Fork Mountains, which have the rock types of the Klamath Mountains but the topography of the Coast Ranges. The Klamath Mountains have a complex structural pattern and a well-defined arcuate regional trend. The rocks are largely crystalline, consisting principally of highly metamorphosed volcanic and sedimentary rocks, intruded by granitic and ultramafic rocks. Streams in the Klamath Mountains are transverse and flow in deep narrow canyons. Their devious courses give little suggestion of order and are little related to geologic structure.

The Southern Cascade Mountains, lying east of the Klamath Mountains and north of the Sierra Nevada, consist of lava and pyroclastic rocks. From Keno, Oreg., to the mouth of Willow Creek, the Klamath River flows in a canyon cut into the volcanic rocks. Upstream from Keno, the Klamath River and its tributaries drain a plateau region likewise underlain by lava and pyroclastic rocks. The surface drainage pattern of the plateau is poorly developed, because the highly permeable and fractured volcanic rock allows ready infiltration of precipitation and snowmelt. Seeps are common and large springs are numerous.

CLIMATE

The climate along the coast is marked by moderate and equable temperatures, heavy and recurrent fogs, and prevailing west to northwest winds. Inland, temperatures have a wider range and winds are generally moderate. Temperatures are influenced largely by elevation and by local topography. Precipitation along the coast is

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of greater frequency and annual magnitude than anywhere else in California. It is heaviest on the western slopes of the coastal ranges and decreases, in general, from north to south. Precipitation is distinctly seasonal, very little occurring from June through September. This seasonal distribution of precipitation is largely controlled by the anticyclonic cell that is normally found off the California coast, particularly in summer. The frequent winter precipitation occurs usually when this anticyclone either is absent or is far south of its usual position. Snow falls in moderate amounts at elevations above 2,000 feet, but only at elevations above 4,000 feet does snow remain on the ground for appreciably long periods of time.

DESCRIPTION OF THE INDIVIDUAL BASINS

EEL RIVER BASIN

The Eel River, the southernmost stream in the region covered by this report, drains an area of 3,625 square miles. The drainage basin (area 1 on pl. 1) is almost entirely mountainous, and the tributary streams, for much of their length, follow roughly parallel courses between the northwestward-trending ridges of the northern California Coast Ranges. Sharp drops in streambed profile occur where the main stream and tributaries have cut westward through ridge lines. Elevations in the basin range from sea level to 7,000 feet.

On upper Eel River storage in Lake Pillsbury provides sufficient water for an average annual diversion of 148,000 acre-feet into the Russian River basin for power development and irrigation. The first large upstream tributary, Middle Fork, joins the main stream from the east, 40 miles below Lake Pillsbury. The river then flows through a canyon for about 100 miles. Near the mouth of its tributary, the Van Duzen River, it reaches the coastal plain, through which it meanders for 15 miles before entering the Pacific Ocean. The fall of the main stream ranges from about 19 feet per mile in the upper reaches to about 3.5 feet per mile in the coastal area. The other principal tributaries of the Eel River are the North Fork, which enters from the east, and the South Fork, which flows in a narrow valley to the west of the main river valley and parallels it for the greater part of its course. The east side tributaries are typical mountain streams flowing through canyons with steep gradients, their fall in the upper reaches being from 50 to 150 feet per mile.

ELK RIVER BASIN

The Elk River, draining an area (area 2 on pl. 1) on the west slope of the northern California Coast Ranges, derives its flow from two principal tributaries, the North Fork and the South Fork. The single gaging station in the basin is located just below the confluence of these tributaries, where the river debouches from the canyon onto the coastal plain. The streambed gradient above the gaging station is quite steep and averages about 150 feet to the mile; downstream from the gaging station the river slowly meanders into Humboldt Bay. Elevations in the basin range from sea level to about 2,400 feet. The drainage area above the mouth of Elk River is 56.1 square miles; above the gaging station near Falk the drainage area is 44.2 square miles.

JACOBY CREEK BASIN

Jacoby Creek flows in a northwesterly direction in a canyon along the coastal flank of the northern California Coast Ranges. The streambed gradient is extremely steep and in its upper 6½ miles averages more than 300 feet to the mile. In its lower two miles, the creek meanders through the coastal plain to empty into Humboldt Bay. Elevations in the basin range from sea level to about 2,200 feet. The total drainage area (area 3 on pl. 1) of the basin is 16.0 square miles; above the gaging station near Freshwater the drainage area is 6.07 square miles.

MAD RIVER BASIN

The Mad River has a drainage area of 497 square miles (area 4 on pl. 1) and is the first sizable stream in the northern California Coast Ranges north of the Eel River. Throughout its 100-mile length, the river flows generally northwest to empty into the Pacific Ocean. Its two principal tributaries are Pilot Creek and North Fork, neither of which is large.

Elevations in the basin range from sea level to about 6,000 feet. The main channel of the river heads at an elevation of 2,900 feet in the same valley trough in which, a few miles to the southwest, the Middle Fork Eel River starts its flow in an opposite direction. In the first 37 miles of its upper course, the Mad River traverses a mountain valley approximately one-half mile wide, having a fall averaging about 16 feet per mile. At an elevation of 2,300 feet, the river enters a canyon through a break in a ridge on the west. The river flows rapidly through this canyon section for 31 miles with a total drop of 1,900 feet. In the lower canyon the river cuts westward across a second ridge and emerges in a lower valley trough at an elevation of 400 feet. It continues along this trough for 24 miles to the coastal plain, through which it flows for the last 10 miles of its course to the ocean.

LITTLE RIVER BASIN

The Little River drains a 48.7-square mile area (area 5 on pl. 1) on the west slope of the northern California Coast Ranges and empties into the Pacific Ocean north of Humboldt Bay. The upper 14 miles of the river is incised in a canyon and has a fall of more than 200 feet to the mile. The lower 2½ miles meanders through the coastal plain and drops only 18 feet in its course to the ocean. Elevations in the basin range from sea level to about 3,200 feet.

REDWOOD CREEK BASIN

Redwood Creek drains an area (area 6 on pl. 1) of 282 square miles in the northern California Coast Ranges, north and east of the Little River. The basin is roughly rectangular in shape and is about 55 miles long. Redwood Creek flows in a northwesterly course for its entire length and has no large tributaries. It is joined by Prairie Creek, its principal tributary, about 3 miles from its mouth near Orick. Elevations in the basin range from sea level to about 5,000 feet.

KLAMATH RIVER BASIN AND ADJACENT CLOSED BASINS

The Klamath River, its tributaries, and the streams in the adjacent closed basins of Lost River and Lower Klamath Lake drain an area (areas 7–9 on pl. 1) of 15,700 square miles. Of this area, approximately 3,600 square miles, comprising the closed basins of Lost River and Lower Klamath Lake, normally do not contribute to the runoff of the Klamath River. The area upstream from Keno, Oreg. (including Lost River and Lower Klamath Lake basins) is a high volcanic plateau of about 7,500 square miles, lying east of the Cascade Mountains. This plateau, which is partly in Oregon and partly in California, is composed of broad, flat valleys separated by low hills and ridges. Elevations range, in general, from 4,000 to 5,000 feet above sea level in the valleys, and from 5,000 to 7,000 feet along the timbered mountain ridges; a few peaks rise above 9,000 feet. Agriculture is extensive in the valleys.

At Keno, the Klamath River crosses a hard lava ridge and enters a rugged winding canyon, in which it travels 235 miles to the Pacific Ocean. The 8,200-square-mile drainage area downstream from Keno lies south of the principal ridge of the Klamath Mountains and almost entirely in California. Practically all of this extensive area is mountainous; ridges range up to 7,000 feet in elevation and a few peaks even higher. Much of the area is forest covered. The only agricultural lands of any extent are found in the tributary basins of the Shasta and Scott Rivers.

The Williamson River in Oregon is considered the headwater stream of the Klamath River. It has its source in a spring, located on what was formerly the Klamath Indian Reservation, and flows for 30 miles into Klamath Marsh. Klamath Marsh, with an area of about 125 square miles, affords some grazing for cattle but is utilized principally as a refuge for migratory waterfowl. Fourteen miles downstream from Klamath Marsh, the Williamson River, fed by Spring Creek and many smaller springs, receives its principal tributary, the Sprague River. Twelve miles farther downstream, the Williamson River empties into Upper Klamath Lake. The Sprague River is likewise spring fed, and its principal tributary, the Sycan River, is subject to natural regulation in its course through Sycan Marsh. The area drained by the Williamson River is 3,000 square miles, of which 1,600 square miles is in the Sprague River basin.

In addition to the runoff from the Williamson River, Upper Klamath Lake receives runoff from a number of small basins on the north and west, including those of Wood River, Sevenmile, Cherry, and Fourmile Creeks. Crater Lake, a closed basin to the north of Wood River, is considered part of the Klamath River drainage area because some Crater Lake water may percolate into that basin. It is equally possible, however, that some percolation finds its way into the Rogue River basin to the west. Some water from Fourmile Lake, naturally draining into Upper Klamath Lake through Fourmile Creek, is diverted through the Cascade Canal into the Rogue River basin at Fish Lake. This diversion averages about 4,500 acre-feet per year. About 10 miles to the east of Upper Klamath Lake is the small closed basin of Swan Lake.

Upper Klamath Lake is a shallow body of water with a surface area of about 70,000 acres. There is a regulating dam for power and irrigation at the lower end of the lake. Water for irrigation in the U.S. Bureau of Reclamation Klamath Project is diverted into "A" canal which feeds canals and laterals on both sides of Klamath valley. Figures 2 and 3, which are schematic diagrams of the upper Klamath River basin and the closed basins of Lost River and Lower Klamath Lake, show the principal features of the Klamath Project. Upper Klamath Lake discharges into the Link River, which in turn flows into Lake Ewauna at Klamath Falls. The Link River is about 1 mile long and has a fall of about 60 feet. Lake Ewauna is about 2 miles long and one-half mile wide. It gradually narrows at its lower end and becomes the Klamath River. Because of the flat grade at the head of the river, there is no definite line marking the lower end of Lake Ewauna and the beginning of the Klamath River.

The Lost River drains most of the southern part of the plateau area. From its source in north-central California it flows northward into south-central Oregon, then westward and finally southward and southwestward into Tule Lake not far from its source. Tule Lake has no surface outlet, and all water reaching it is lost by evaporation and percolation. In the past, there was occasional interchange of water through a slough connecting the Lost River and the Klamath River, although generally, during flood periods, the flow was from the Klamath River into the Lost River. The construction of a dike

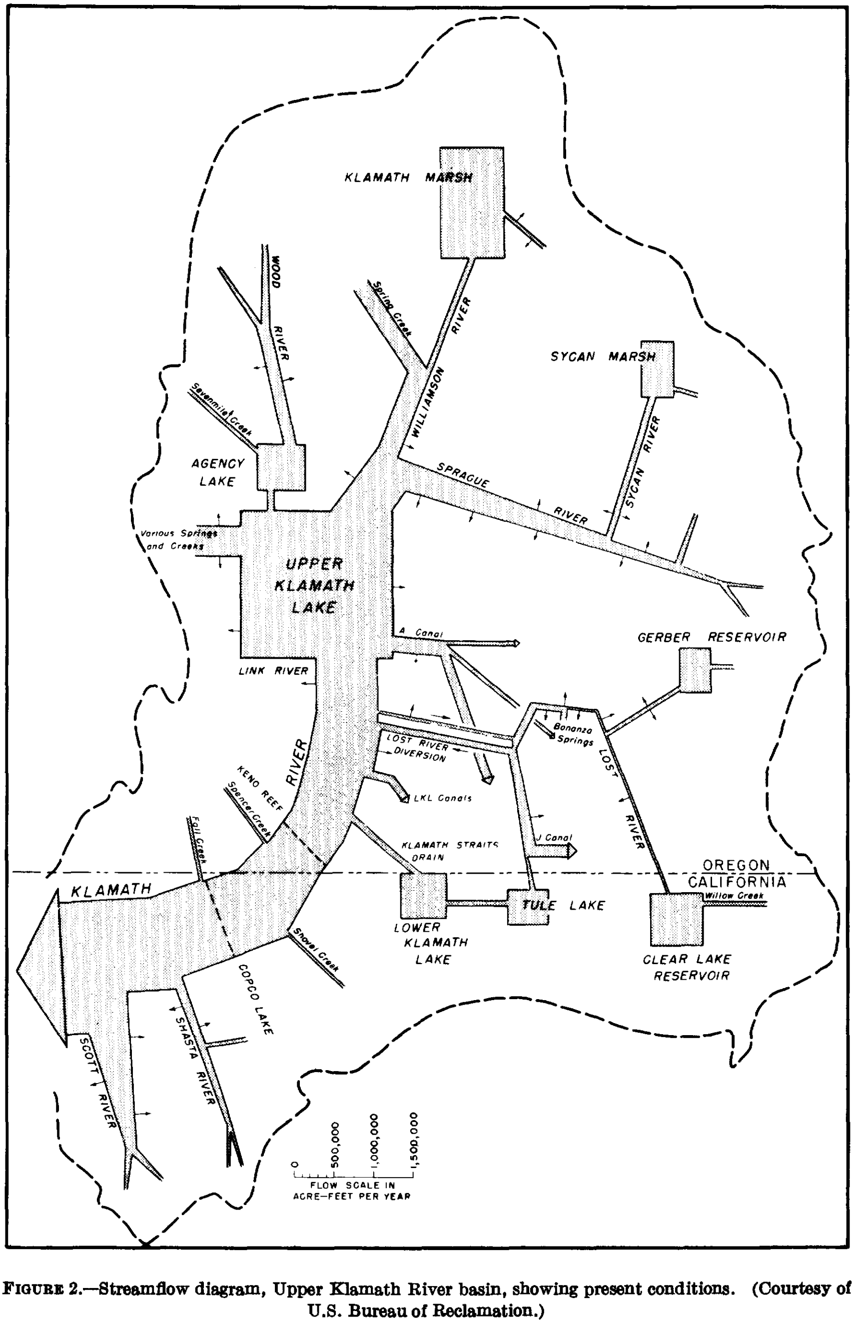


FIGURE 2.—Streamflow diagram, Upper Klamath River basin, showing present conditions. (Courtesy of U.S. Bureau of Reclamation.)

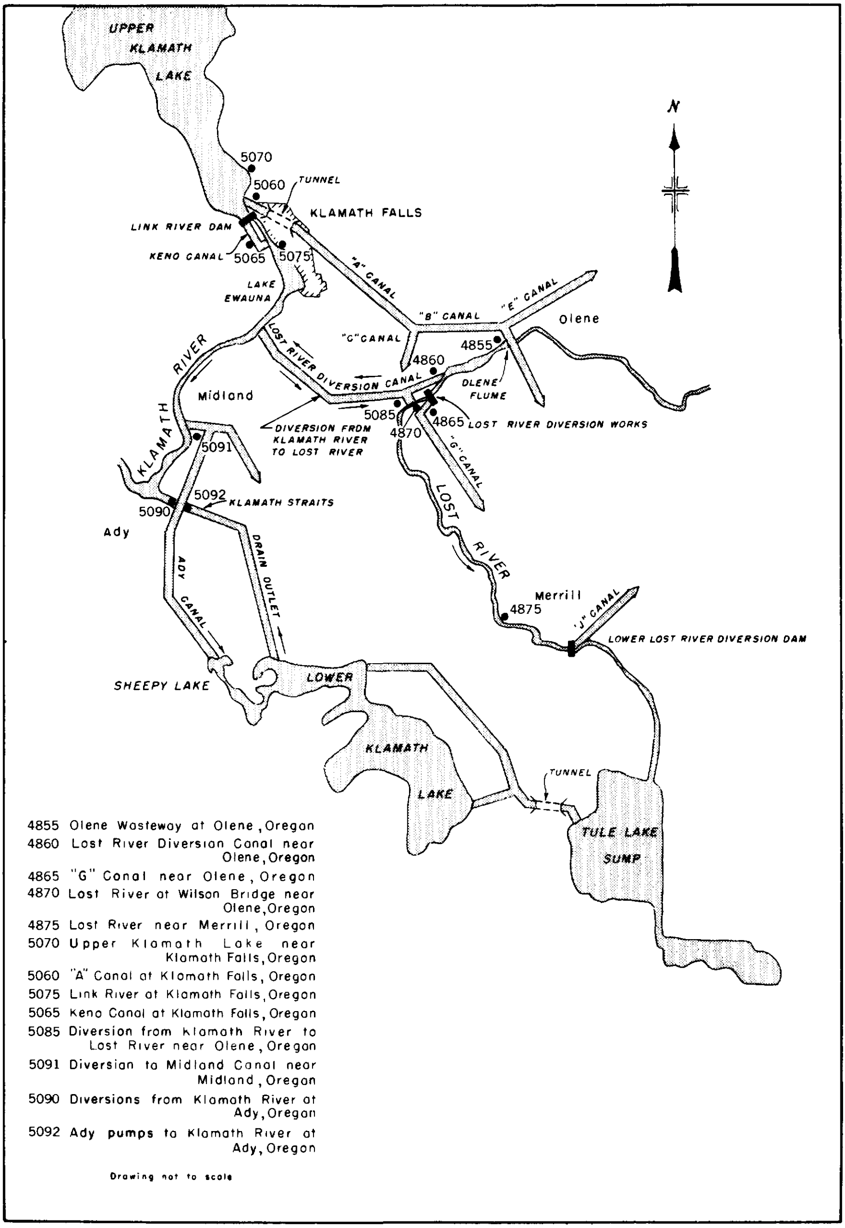


FIGURE 3.—Diagram of main canals and gaging stations, Klamath Project.

across the slough ended this condition, and since the construction of the Lost River diversion dam and canal, most of the flow of the Lost River, not needed for irrigation, is discharged into the Klamath River. These works and others, including the construction of Clear Lake and Gerber Reservoirs, have resulted in the drying up of most of Tule Lake. Crops are now cultivated on the former lakebed, but a part of it is utilized as a sump for flood protection in the event of flow in the Lost River exceeding the capacity of the Lost River diversion canal (capacity 2,100 cfs). During the irrigation season, when the demand in the lower Lost River and Tule Lake regions exceeds the water supply of the Lost River basin, the direction of flow in the Lost River diversion canal may be reversed to divert water from the Klamath River to the Lost River at a point just downstream from the Lost River diversion dam.

Klamath Straits, joining the main river between the Lost River diversion canal and Keno, formerly connected the Klamath River with Lower Klamath Lake, and a considerable quantity of water flowed annually from the river into the lake. In 1917, Klamath Straits was closed by gates, and a large part of Lower Klamath Lake has since dried up. A part of its bed is now cultivated, and during the irrigation season water is diverted from the Klamath River into this reclaimed area through the Midland Canal and Klamath Straits. A part of the old Lower Klamath Lake bed is utilized as a refuge for migratory waterfowl and as a sump, and at times water may be pumped from Lower Klamath Lake back into the Klamath River. The Lower Klamath Lake system is connected to the Tule Lake sump through a tunnel. This enables water to be pumped from Tule Lake sump through Lower Klamath Lake and Klamath Straits into the Klamath River.

Southwest of Lower Klamath Lake there are several closed basins from which either ground water or surface spill may find its way, in part, to Lower Klamath Lake. Two of the more important basins are those drained by Antelope and Butte Creeks. A part of the flow of these two creeks is used for irrigation.

At Keno, Oregon, about 15 miles downstream from Lake Ewauna, the Klamath River enters a canyon and in the next 60 miles drops over 2,000 feet. There are numerous small tributaries in this stretch of channel, but none of major economic importance. There is some irrigation, however, along these tributaries, principally on Cottonwood Creek. From Keene Creek, another of the small tributaries, there is a diversion into the Rogue River basin that amounts to about 8,000 acre-feet per year.

Sixty miles below Keno, the Shasta River enters the Klamath River. The Shasta River has its source on the east slope of China Mountain. at an elevation of 6,000 feet above sea level, and flows generally north and northwest in its 40-mile course to the Klamath River. It has a total fall of 4,000 feet; of this total, 3,000 feet occurs in the first 5 miles. The Shasta River drains an area of 796 square miles and has for its principal tributary the Little Shasta River. There is considerable irrigation in Shasta Valley, and virtually all the runoff above Dwinnell Reservoir is stored and diverted for that purpose. The drainage area above the reservoir is 139 square miles, and the reservoir itself has a usable storage capacity of 30,000 acre-feet. During the summer, flow downstream from Dwinnell Reservoir is maintained largely by springs.

The Scott River, the next tributary of importance, joins the Klamath River 34 miles downstream from the mouth of the Shasta River It is formed by the confluence of the East and South Forks at Callahan, from which point Scott River flows 50 miles to the Klamath River. There are numerous small tributaries below the forks of the river, most of which enter on the left. The area drained is 813 square miles. A large part of the valley is under irrigation, but there are no storage works on the river. Elevations in the basin range from about 2,600 feet to about 8,000 feet above sea level.

The next Klamath River tributary of importance downstream from the Scott River is the Salmon River. In the 77 miles between the mouths of the Scott and Salmon Rivers, numerous small tributary streams enter the Klamath River. Of these, Indian Creek is the most important.

Salmon River is formed by the confluence of the South and North Forks. Its headwaters drain an inaccessible region along the north and west slopes of the Salmon Mountains. Its length from the head of South Fork to the Klamath River is 50 miles. The river with its numerous tributaries drains an area of 751 square miles, all of it rough and mountainous. Elevations in the basin range from about 500 feet to about 8,000 feet above sea level.

The Trinity River, which enters the Klamath River 23 miles downstream from the Salmon River, is the principal tributary of the Klamath. The source of the Trinity River is about 20 miles southwest of Mount Shasta and about 10 miles from the headwaters of the Sacramento River. The river flows first south, then west, then northwest for about 130 miles and empties into the Klamath River at Weitchpec, 42 miles from the ocean. Its principal tributary is South Fork, whose principal tributary, in turn, is Hayfork Creek.

The Trinity River drainage basin, largely mountainous, comprises 2,969 square miles, about 30 percent of which is tributary to South Fork. Elevations in the basin range from about 250 feet to about 9,000 feet above sea level. A multipurpose project is under construction (as of May 1961) on the upper Trinity River near Lewiston; water in excess of the needs of the Trinity River basin will be diverted into the Sacramento River basin.

The only other Klamath River tributaries of any consequence are Bluff Creek and Blue Creek, both of which enter the river from the right. Bluff Creek with a drainage area of about 75 square miles, empties into the Klamath River about 5 miles upstream from the mouth of Trinity River; Blue Creek, with a drainage area of about 110 square miles, enters the Klamath River about 24 miles downstream from the mouth of the Trinity River.

SMITH RIVER BASIN

The Smith River, the northernmost stream in the region covered by this report, drains an area (area 10 on pl. 1) of 719 square miles. Except for a narrow coastal plain about 3½ miles wide, the entire basin lies in the Klamath Mountains. From the head of Middle Fork to the Pacific Ocean, the Smith River is about 45 miles long, and its principal tributaries are North Fork and South Fork. With the exception of a small valley area at Gasquet on Middle Fork and a similar area at Big Flat on South Fork, the river flows through deep gorges and canyons until it reaches the coastal plain. Elevations in the basin range from sea level to about 5,800 feet. Streambed slopes range from less than 10 feet per mile in the lower reaches to more than 100 feet per mile in the headwaters.

PRECIPITATION

Precipitation in the coastal basins of northern California is distinctly seasonal, very little occurring from June through September. Roughly three-fourths of the total precipitation falls during the five months, November through March. The distribution is illustrated by table 2, which gives mean monthly precipitation, in percent of the total, at six representative precipitation stations in the region. The bulk of the precipitation occurs during general storms of several days duration and relatively moderate intensity. Hourly precipitation volumes in excess of 1 inch are uncommon. Snow falls in moderate amounts at elevations above 2,000 feet, but only at elevations above 4,000 feet does snow remain on the ground for appreciably long periods of time.

TABLE 2.—*Mean monthly distribution of precipitation at selected stations*

Precipitation station	Mean annual precipitation 1900–59 (in.)	Mean monthly distribution of precipitation in percentage of mean annual precipitation											
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Crescent City, Calif. (No. 120)	82.4	7	14	16	16	15	13	8	5	2.5	0.5	0.5	2.5
Klamath Falls, Oreg. (No. 112)	13.3	7	13	15	16	12	9	7	7	6	2	2	4
Yreka, Calif. (No. 100)	18.0	7	14	17	17	14	10	6	6	3	2	1.5	2.5
Weaverville Ranger Station, Calif. (sta. 67)	37.1	6	14	18	18	16	11	8	4	2.6	.4	.3	1.7
Eureka WB City, Calif. (sta. 36)	38.3	7	13	16	17	15	14	8	5	2	.5	.5	2
Covelo Eel River Ranger Station, Calif. (sta. 11)	39.3	5	10	20	21	19	10	8	4	1	.5	.2	1.3

Mean annual precipitation is influenced by distance from the ocean, elevation, shape and steepness of mountain slopes, and direction of slopes in relation to the moisture-bearing winds. As a rule, precipitation increases from south to north and is much heavier on southern and western than on northern and eastern mountain slopes. This is seen on the isohyetal map (pl. 2), which presents a generalized picture of the areal distribution of mean annual precipitation, based on the 60-year period 1900–59. The wide range in mean annual precipitation is striking; precipitation decreases from a high of 120 inches in the northwest to a low of 10 inches in the northeast. Plate 3 is a location map showing the 126 precipitation stations within the region that were used in the construction of the isohyetal map; outlying precipitation stations that were used are not shown. With few exceptions, all the stations are or were operated by the U.S. Weather Bureau. Table 3, based on a tabulation furnished by the California Department of Water Resources, lists mean annual precipitation at each of the 126 stations. The precipitation figures have been adjusted by correlation procedures to the base period, 1900–59. Table 3 also includes, for each station, its location, elevation, and identifying number on plate 3.

TABLE 3.—*Mean annual precipitation for period 1900–59, at stations in coastal basins of northern California*

No. (pl. 3)	Station	Latitude	Longitude	Elevation (ft)	Period of record	Estimated 60-yr. mean annual precipitation (in)
	Eel River basin, California					
1	Parramore Springs	39°19′	122°53′	2,150	1928–44	50.0
2	Lake Pillsbury	39°25′	122°59′	1,900	1924–50	41.0
3	Willits Howard Forest Ranger Station	39°21′	123°19′	1,900	1935–59	48.0
4	Willits Northwestern Pacific Railroad Depot	39°24′	123°21′	1,365	1911–59	52.1
5	Hearst (near)	39°29′	123°09′	1,800	1910–16	47.5
6	Branscomb	39°39′	123°37′	2,000	1900–24, 1933–59	79.1
7	Laytonville 3 SW	39°40′	123°32′	1,900	1917–59	74.4
8	Laytonville	39°42′	123°29′	1,640	1940–59	55.1
9	Dos Rios	39°43′	123°21′	927	1917–59	46.4
10	Covelo	39°47′	123°15′	1,385	1921–59	39.3
11	Covelo Eel River Ranger Station	39°50′	123°05′	1,514	1939–59	39.3
12	Cummings	39°50′	123°38′	1,324	1927–59	72.2
13	Adanac Lodge	39°51′	123°42′	1,100	1950–59	73.1
14	Standish Hickey Park	39°52′	123°44′	850	1950–59	70.4
15	Harris 7 SSE	39°59′	123°37′	1,910	1953–59	67.0
16	Island Mountain	40°02′	123°30′	940	1943–59	41.7
17	Lake Mountain	40°01′	123°24′	3,170	1939–59	52.5
18	Old Harris	40°05′	123°40′	2,225	1956–59	76.3
19	Garberville Maintenance Station	40°06′	123°47′	540	1935–59	54.2
20	Miranda Spengler Ranch	40°12′	123°46′	400	1939–59	51.7
21	Alderpoint	40°11′	123°36′	435	1940–59	48.5
22	Zenia 1 SSE	40°11′	123°29′	2,880	1950–59	62.4
23	Blocksburg	40°16′	123°37′	1,700	1905–16	64.0
24	Myers Flat	40°16′	123°52′	175	1950–59	67.4
25	South Fork	40°21′	123°55′	155	1944–59	52.8
26	Shively	40°26′	123°58′	200	1912–21	55.9
27	Bridgeville 4 NNW	40°32′	123°49′	2,050	1954–59	58.6
28	Grizzly Creek Camp	40°30′	123°54′	425	1947–52	52.1
29	Cummings Creek Camp	40°31′	124°01′	160	1948–59	50.4
30	Scotia	40°29′	124°06′	139	1926–59	47.3
31	Rohnerville	40°34′	124°08′	150	1901–20	44.7
32	Fortuna	40°36′	124°09′	60	1956–59	39.8
33	Kneeland 10 SSE	40°38′	123°54′	2,356	1952–59	60.4
	Small coastal basins in California north of Eel River basin					
34	Table Bluff Lighthouse	40°42′	124°16′	160	1916–39	35.2
35	Eureka 4 SW	40°00′	124°00′	10	1913–36	37.9
36	Eureka WB City	40°48′	124°10′	43	1878–1959	38.3
37	Crannell	41°01′	124°04′	150	1933–48	53.5
38	Little River	41°02′	124°07′	150	1949–59	51.3
39	Trinidad Head Lighthouse	41°03′	124°09′	198	1918–39	41.9
40	Patricks Point State Park	41°08′	124°09′	250	1947–59	64.8
41	Orick 5 SSW	41°14′	124°06′	475	1951–56	66.2
42	Crescent City 1N	41°46′	124°12′	40	1946–59	64.4
43	Crescent City Maintenance Station	41°46′	124°12′	50	1941–59	63.0
44	Crescent City 5 NNE	41°49′	124°09′	55	1949–59	77.3
45	Crescent City Lake Earl	41°49′	124°10′	30	1949–57	75.4
	Mad River basin, California					
46	Long Prairie Ranch	40°56′	123°52′	1,875	1952–59	73.8
47	Korbel	40°52′	123°58′	180	1937–59	53.0
48	Mad River Ranger Station	40°27′	123°32′	2,775	1943–59	56.8
49	Ruth	40°19′	123°22′	2,925	1912–30	51.0
	Redwood Creek basin, California					
50	Orick Arcata Redwood	41°19′	124°03′	75	1954–59	66.4
51	Orick 3 NNE	41°19′	124°02′	50	1950–59	69.0
52	Orick Prairie Creek	41°20′	124°01′	161	1937–59	67.4
	Closed basins adjacent to Klamath River basin					
53	Dairy 3 NE Yonna, Oregon	42°16′	121°28′	4,150	1908–59	13.7
54	Gerber Dam, Oregon	42°12′	121°08′	4,900	1926–59	17.4
55	Steele Swamp, California	41°52′	120°57′	5,000	1923–49	13.0
56	Merrill 2 NW, California	42°03′	121°38′	4,080	1906–27, 1949–59	11.0

TABLE 3.—*Mean annual precipitation for period 1900–59, at stations in coastal basins of northern California*—Continued

No. (pl. 3)	Station	Latitude	Longitude	Elevation (ft)	Period of record	Estimated 60-yr. mean annual precipitation (in)
	Closed basins adjacent to Klamath River basin—Continued					
57	Malin, Oregon	42°01′	121°25′	4,050	1912–47	11.9
58	Tulelake, California	41°58′	121°28′	4,035	1932–59	9.9
59	Clear Lake Dam, California	41°56′	121°05′	4,500	1907–55	13.0
60	Tulelake Inspection Station, California	41°37′	121°14′	4,408	1953–59	16.4
61	Indian Wells, California	41°43′	121°30′	4,760	1940–45	11.9
62	Mount Hebron 11 ESE, California	41°44′	121°48′	4,380	1952–59	10.8
63	Mount Hebron Ranger Station, California	41°47′	122°00′	4,250	1942–59	10.1
	Trinity River basin, California					
64	Mumbo Basin	41°12′	122°32′	5,700	1946–59	51.3
65	Trinity Center Ranger Station	41°00′	122°41′	2,295	1941–59	46.9
66	Minersville Rock Ranch	40°50′	122°51′	2,400	1949–59	45.8
67	Weaverville Ranger Station	40°44′	122°56′	2,050	1871–92 1912–59	37.1
68	Big Bar Ranger Station	40°45′	123°15′	1,248	1943–59	38.0
69	Burnt Ranch 1 S	40°48′	123°29′	2,140	1945–59	38.8
70	Burnt Ranch Honor Camp 36	40°48′	123°29′	1,540	1942–58	37.0
71	China Flat	40°52′	123°35′	650	1908–55	47.5
72	Salyer Ranger Station	40°53′	123°35′	623	1943–59	46.5
73	Hoopa	41°03′	123°41′	350	1941–59	50.2
74	Hyampom	40°37′	123°28′	1,240	1940–59	39.7
75	Hayfork Ranger Station	40°33′	123°10′	2,346	1915–59	31.9
76	Forest Glen	40°23′	123°20′	2,340	1930–59	59.5
	Klamath River basin California					
77	Cecilville Sawyer Mountain View	41°06′	123°03′	3,000	1954–59	37.9
78	Blackbear (near)	41°10′	123°10′	3,550	1938–40	33.6
79	Blackbear King Solomon Mine	41°15′	123°11′	3,600	1941–45	37.5
80	Gilta	41°12′	123°20′	3,300	1910–15	54.4
81	Weitchpec 7 NNE	41°18′	123°41′	1,700	1910–17	77.8
82	Klamath	41°32′	124°02′	25	1941–59	79.4
83	Orleans	41°18′	123°32′	403	1903–59	50.8
84	Somesbar 1 W	41°23′	123°29′	550	1954–59	58.0
85	Sawyers Bar Ranger Station	41°18′	123°08′	2,169	1931–59	43.7
86	Callahan Ranger Station	41°18′	122°48′	3,136	1943–59	20.0
87	Etna	41°28′	122°54′	2,912	1940–59	24.9
88	Weed	41°26′	122°23′	3,506	1942–57	25.1
89	Edgewood	41°28′	122°26′	2,963	1888–1947	20.8
90	Gazelle	41°31′	122°31′	2,775	1943–59	11.0
91	Bray 10 WSW	41°34′	122°08′	5,759	1951–59	19.6
92	Gazelle 4 NNW	41°35′	122°32′	2,730	1949–59	10.4
93	Fort Jones 6 ESE	41°35′	122°43′	3,324	1941–59	18.2
94	Greenview	41°33′	122°54′	2,818	1943–59	20.9
95	Fort Jones Ranger Station	41°36′	122°51′	2,720	1936–59	20.8
96	Soap Creek	41°40′	122°45′	3,500	1941–47	20.8
97	Grenada Julien Ranch	41°39′	122°32′	2,560	1908–39	17.9
98	Montague	41°44′	122°31′	2,538	1888–1959	12.9
99	Montague 3 NE	41°45′	122°28′	2,640	1948–59	10.8
100	Yreka	41°43′	122°38′	2,631	1871–1959	18.0
101	Scott Bar Guard Station	41°45′	123°00′	1,800	1921–36	27.5
102	Happy Camp Ranger Station	41°48′	123°23′	1,090	1914–59	52.0
103	Horse Creek Hamaker Ranch	41°54′	123°02′	3,470	1941–59	39.4
104	Oak Knoll Ranger Station	41°50′	122°51′	1,963	1942–59	22.2
105	Betts Ranch	41°49′	122°30′	2,650	1943–59	14.8
106	Beswick 7 S	41°52′	122°14′	6,140	1952–59	34.3
107	Hornbrook	41°55′	122°33′	2,154	1888–1918	13.8
108	Hilts	42°00′	122°38′	2,900	1939–59	20.8
	Oregon					
109	Siskiyou	42°03′	122°36′	4,486	1899–1936	37.0
110	Copco Dam No. 1, California	41°59′	122°22′	2,700	1928–59	16.8
111	Keno	42°08′	121°56′	4,040	1927–59	18.9
112	Klamath Falls 2 SSW	42°13′	121°47′	4,098	1884–1959	13.3
113	Round Grove	42°20′	120°53′	4,888	1920–59	16.0
114	Chiloquin	42°35′	121°51′	4,200	1884–98 1909–59	17.3
115	Fort Klamath	42°42′	122°00′	4,200	1865–98	22.4
116	Sand Creek	42°51′	121°54′	4,682	1930–48	27.7
117	Crater Lake	42°54′	122°08′	6,475	1920–59	64.0
118	Chemult	43°12′	121°46′	4,760	1937–59	24.2

TABLE 3.—*Mean annual precipitation for period 1900–59, at stations in coastal basins of northern California*—Continued

No. (pl. 3)	Station	Latitude	Longitude	Elevation (ft)	Period of record	Estimated 60-yr. mean annual precipitation (in)
	Smith River basin, California					
119	Crescent City 11 E	41°45′	124°00′	360	1947–59	93.2
120	Crescent City 7 ENE	41°48′	124°05′	120	1913–59	82.4
121	Gasquet Ranger Station	41°52′	123°58′	384	1940–59	88.1
122	Patrick Creek Lodge	41°52′	123°51′	820	1951–59	83.2
123	Idlewild Maintenance Station	41°54′	123°46′	1,250	1946–59	77.2
124	Smith River 7 SSE	41°50′	124°07′	60	1952–59	79.6
125	Monumental	41°58′	123°48′	2,420	1904–10	104.5
126	Smith River 2 WNW	41°56′	124°11′	195	1951–59	96.6

There is wide variation from year to year in the annual precipitation at any particular site. For example, at the precipitation station at Dos Rios in the Eel River basin, the mean annual rainfall is 46.4 inches, but precipitation has ranged from 15.3 inches in 1924 to 85 inches in both 1956 and 1958. Time trends in precipitation are illustrated by graph (*A*) of figure 4 which shows accumulated departures of annual precipitation from the 81-year mean at Eureka, Calif., during the period 1879 to 1959. The progression shown is quite typical of that for the entire region. In a graph of this type, the plotting position for any particular year has little significance and only the slope of the graph is important. A downward slope indicates less than average precipitation; an upward slope indicates that precipitation exceeded the mean. It is seen that northern California experienced a prolonged wet period from 1890 to 1916, followed by a dry period from 1917 to 1937. In the 22 years since 1937, there have been two wet periods and one dry one. The driest single year of record was 1924; two of the wettest years of record were 1956 and 1958. The long-term base period chosen for use, 1900–59, has a mean annual precipitation at Eureka that differs by only 1.3 percent from the mean for the entire 81 years of record at that station.

Mean annual precipitation for the subbasins and hydrologic units listed in table 1 has been estimated by planimetering the isohyetal map on plate 2. It is recognized that estimates of basinwide precipitation, obtained for this rough mountainous country from the existing network of precipitation stations, are not precise; these estimates are of importance, nevertheless, as indexes of precipitation. The basinwide averages are given in table 1.

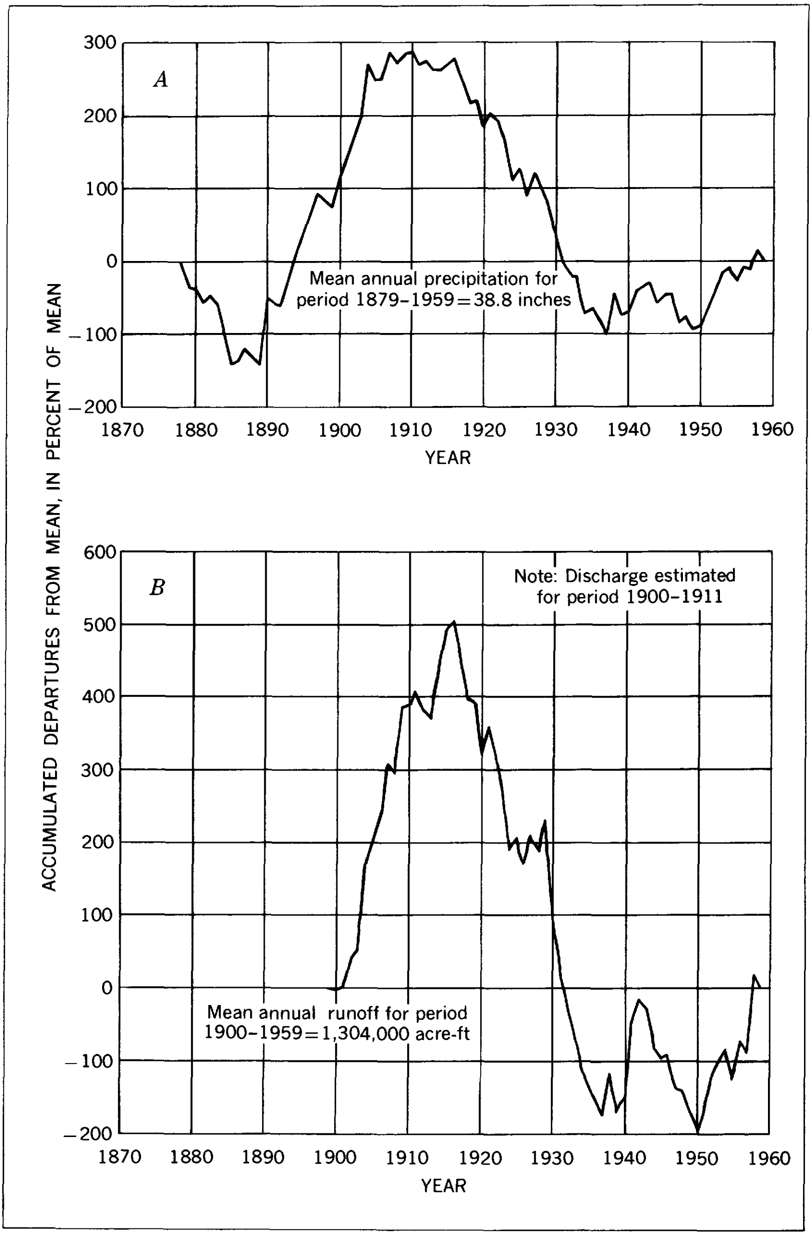


FIGURE 4.—Trends in precipitation and runoff. *A*, Accumulated annual departures from mean annual precipitation at Eureka, Calif.; *B*, accumulated annual departures from mean annual runoff of Trinity River at Lewiston, Calif.

RUNOFF

MEAN ANNUAL VOLUME

Mean annual runoff in the region, being directly related to mean annual precipitation, is influenced principally by such factors as latitude, distance from the ocean, elevation and steepness of the mountain slopes, and their exposure and orientation. This results in an areal distribution of mean annual runoff in which runoff tends to increase from south to north and from east to west. The Smith River basin in the northwestern corner of California, with an average annual runoff of 82 inches, has the largest volume of runoff per square mile of any major basin in the state.

Geologic characteristics usually have their primary effect on the time distribution of flow, but they also affect the total volume of runoff in the upper Klamath River basin and adjacent closed basins. These basins occupy a lava plateau that has poorly developed surface drainage, and the volume of surface runoff that passes a given point is often dependent on the location of the larger springs and seeps, and on the permeability of the streambed above the site. The extensive marsh areas of the upper Klamath River basin also cause large evapotranspiration losses.

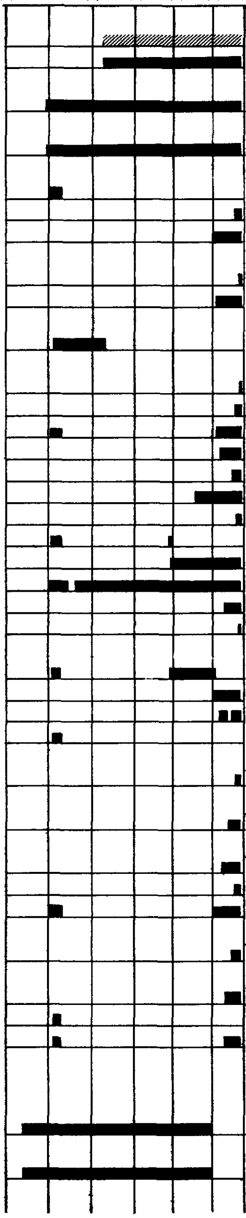
Runoff trends during the period 1900–1959, are illustrated by graph (*B*) of figure 4, which shows accumulated annual departures from the 60-year mean annual runoff for the Trinity River at Lewiston. This 60-year period is the longest period practicable for use in studying long-term runoff trends for the region. The trends depicted are similar to those shown by the precipitation graph (*A*) for Eureka, Calif. The driest single year of record was 1924, when runoff was generally about 20 percent of the 60-year mean. The driest decade of record was the period 1928–37 when runoff was about 62 percent of the long-term mean. Two of the wettest years of record were 1956 and 1958 when runoff was generally slightly more than twice the 60-year mean.

Plate 4 is a location map showing the 150 stream-gaging stations in the region for which runoff data have been compiled. The stations are numbered in downstream order in accordance with the permanent numbering system adopted by the Geological Survey in 1958. The scale of plate 4 is too small for an adequate depiction of the Bureau of Reclamation Klamath Project, and figure 3 is therefore provided as a supplement. Table 4 lists the 150 gaging stations, together with their drainage areas and identifying numbers on plate 4, and also presents a bar chart showing the period of record at each station.

Table 4.—Bar chart records of stream-gaging stations in coastal basins of northern California

Legend: ▬ Streamflow ▨ Reservoir contents

Period of record (1900, 1910, 1920, 1930, 1940, 1950, 1960)

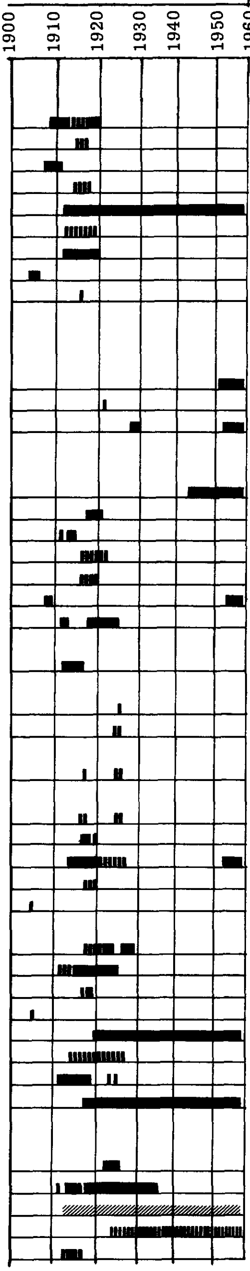


Gaging station	Drainage area (sq mi)	Station No.
Eel River basin, California		
Lake Pillsbury near Potter Valley	288	4700
Eel River below Scott Dam, near Potter Valley	290	4705
Potter Valley powerhouse tailrace near Potter Valley	--------	4710
Eel River at Van Arsdale Dam, near Potter Valley	347	4715
Eel River at Hearst	465	4720
Outlet creek near Longvale	159	4722
Eel River above Dos Rios	703	4725
Middle Fork Eel River:		
Black Butte River near Covelo	162	4729
Middle Fork Eel River below Black Butte River, near Covelo	367	4730
Middle Fork Eel River near Covelo	405	4735
Mill Creek:		
Short Creek near Covelo	15.4	4736
Mill Creek near Covelo	97.1	4737
Eel River below Dos Rios	1,481	4740
North Fork Eel River near Mina	251	4745
Eel River at Alderpoint	2,079	4750
South Fork Eel River near Branscomb	43.9	4755
Tenmile Creek near Laytonville	50.4	4757
South Fork Eel River at Garberville	468	4760
South Fork Eel River near Miranda	537	4765
Eel River at Scotia	3,113	4770
Van Duzen River near Dinsmores	80.2	4775
South Fork Van Duzen River near Bridgeville	36.2	4777
Van Duzen River at Bridgeville	200	4780
Van Duzen River near Bridgeville	214	4785
Yager Creek near Carlotta	127	4790
Yager Creek at Carlotta	134	4795
Elk River basin, California		
Elk River near Falk	44.2	4797
Jacoby Creek basin, California		
Jacoby Creek near Freshwater	6.07	4800
Mad River basin, California		
Mad River near Forest Glen	144	4805
North Fork Mad River near Korbel	40.5	4808
Mad River near Arcata	485	4810
Little River basin, California		
Little River at Crannell	44.3	4812
Redwood Creek basin, California		
Redwood Creek near Blue Lake	67.5	4815
Redwood Creek near Korbel	82.8	4820
Redwood Creek at Orick	278	4825
Lost River basin (closed basin adjacent to Klamath River basin)		
California		
Lost River at Clear Lake	550	4830
Oregon		
Miller Creek at Gerber Reservoir, near Lorella	220	4835

Table 4.—*Bar chart records of stream-gaging stations in coastal basins of northern California*—Continued

Legend ▬ Streamflow ////// Reservoir contents

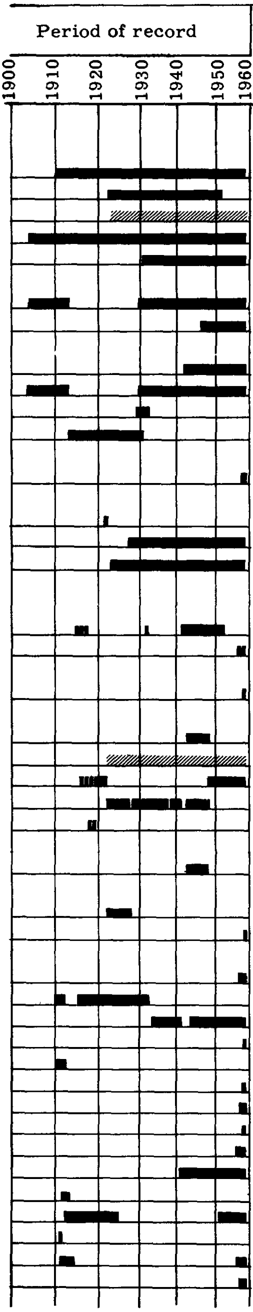
Period of record



Gaging station	Drainage area (sq mi)	Station No.
Lost River basin		
Oregon—(Continued)		
Miller Creek near Lorella	270	4840
Lost River above Olene	1,410	4845
Lost River at Olene	1,590	4850
Olene wasteway at Olene	---------	4855
Lost River diversion canal near Olene	---------	4860
"G" Canal near Olene	---------	4865
Lost River at Wilson Bridge, near Olene	1,620	4870
Lost River near Merrill	1,670	4875
Lost River at Merrill	1,680	4880
Lower Klamath Lake basin (closed basin adjacent to Klamath River basin)		
California		
Antelope Creek near Tennant	18.8	4895
Antelope Creek near Macdoel	30	4900
Butte Creek near Macdoel	178	4905
Klamath River basin		
Oregon		
Ady pumps to Klamath River at Ady	---------	4910
Williamson River near Silver Lake	220	4915
Miller Creek near Crescent	23.7	4920
Sand Creek near Fort Klamath	35	4925
Scott Creek near Fort Klamath	10	4930
Williamson River near Klamath Agency	1,290	4935
Williamson River above Spring Creek, near Klamath Agency	1,330	4940
Williamson River at Chiloquin	1,400	4945
South Fork Sprague River:		
Bly Canal near Bly	---------	4950
South Fork Sprague River near Bly	110	4955
North Fork Sprague River:		
Sprague River Irrigation Co.'s canal near Bly	---------	4960
North Fork Sprague River near Bly	45	4965
Fivemile Creek near Bly	40	4970
Sprague River near Beatty	513	4975
Sycan River near Silver Lake	100	4980
Sycan River at Sycan Marsh, near Silver Lake	220	4981
Long Creek near Silver Lake	40	4985
Sycan River near Beatty	540	4990
Whiskey Creek near Beatty	51	4995
Sprague River near Yainax	1,270	5000
Sprague River near Chiloquin	1,580	5010
Modoc Point Canal near Chiloquin	---------	5015
Sprague River at Chiloquin	1,600	5020
Williamson River below Sprague River, near Chiloquin	3,000	5025
Wood River:		
Anna Creek near Fort Klamath	40	5035
Wood River at Fort Klamath	90	5040
Fourmile Lake near Recreation	10.6	5045
Cascade Canal near Fish Lake	---------	5050
Fourmile Creek near Odessa	10.6	5055

Table 4.—*Bar chart records of stream-gaging stations in coastal basins of northern California*—Continued

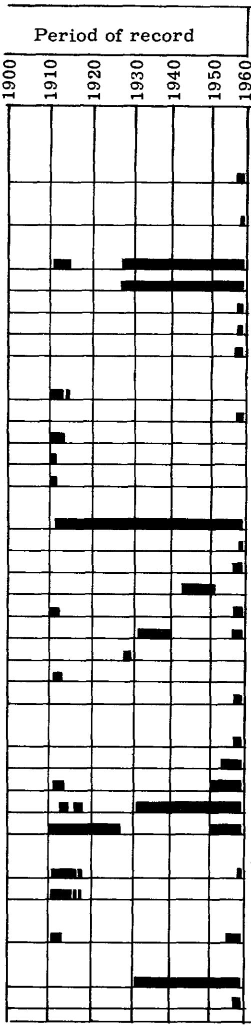
Legend ▬ Streamflow ▨ Reservoir contents



Gaging station	Drainage area (sq mi)	Station No.
Klamath River basin		
Oregon—(Continued)		
"A" Canal at Klamath Falls	---------	5060
Keno Canal at Klamath Falls	---------	5065
Upper Klamath Lake near Klamath Falls	3,810	5070
Link River at Klamath Falls	3,810	5075
Diversion from Klamath River to Lost River near Olene	---------	5085
Diversion from Klamath River at Ady	---------	5090
Diversion from Klamath River to Midland Canal near Midland	---------	5091
Ady pumps to Klamath River at Ady	---------	5092
Klamath River at Keno	3,920	5095
Spencer Creek near Keno	90	5100
Klamath River at Spencer Bridge near Keno	4,050	5105
Klamath River below Big Bend powerplant near Keno	4,080	5107
Shovel Creek near Macdoel, Calif.	19.5	5110
Fall Creek at Copco, Calif.	20	5120
Klamath River below Fall Creek near Copco, Calif.	4,370	5125
Jenny Creek:		
Grizzly Creek near Lilyglen	30.3	5128
Howard Prairie Reservoir near Pinehurst	34.7	5129
Howard Prairie Reservoir outlet near Pinehurst	34.7	5129.2
Beaver Creek at Pinehurst	12.9	5135
Hyatt Reservoir near Ashland	11.7	5140
Keene Creek near Ashland	12.1	5145
Keene Creek Canal near Ashland	---------	5150
Keene Creek at Keene ranch, near Ashland	17.7	5155
Keene Creek near Lincoln	19.3	5160
California		
Jenny Creek near Copco	211	5165
Klamath River near Hornbrook	4,870	5167
Shasta River:		
Little Shasta River near Montague	48.2	5169
Shasta River near Montague	670	5170
Shasta River near Yreka	796	5175
Beaver Creek near Klamath River	103	5178
East Fork Scott River near Callahan	57.6	5180
South Fork Scott River near Callahan	42.5	5182
Sugar Creek near Callahan	12.0	5183
Moffett Creek near Fort Jones	69	5186
Shackleford Creek near Fort Jones	17.7	5190
Scott River near Fort Jones	662	5195
Scott River near Scott Bar	813	5200
Klamath River near Seiad Valley	6,980	5205
Klamath River near Happy Camp	7,070	5210
Indian Creek near Happy Camp	118	5215
Elk Creek near Happy Camp	91.1	5222

Table 4.—Bar chart records of stream-gaging stations in coastal basins of northern California—**Continued**

Legend ▬ Streamflow ▨ Reservoir contents



Gaging station	Drainage area (sq mi)	Station No.
Klamath River basin California—(Continued)		
South Fork Salmon River near Forks of Salmon	252	5223
North Fork Salmon River near Forks of Salmon	205	5224
Salmon River at Somesbar	746	5225
Klamath River at Somesbar	8,480	5230
Red Cap Creek near Orleans	56.1	5230.3
Bluff Creek near Weitchpec	74.6	5230.5
Trinity River above Coffee Creek near Trinity Center	149	5232
Coffee Creek at Coffee	102	5235
Coffee Creek near Trinity Center	107	5237
Trinity River near Trinity Center	300	5240
Swift Creek near Trinity Center	34.8	5245
East Fork Trinity River near Trinity Center	109	5250
Trinity River at Lewiston	726	5255
Weaver Creek near Douglas City	49	5258
Browns Creek near Douglas City	71.6	5259
Trinity River near Douglas City	1,017	5260
North Fork Trinity River at Helena	151	5265
Trinity River near Burnt Ranch	1,438	5270
New River at Denny	180	5275
Trinity River near China Flat	1,733	5280
South Fork Trinity River near Hyampom	342	5282
Hayfork Creek near Hayfork	87.2	5284
Hayfork Creek near Hyampom	379	5285
South Fork Trinity River near Salyer	899	5290
Trinity River near Hoopa	2,846	5300
Klamath River near Klamath	12,100	5305
Smith River basin, California		
Middle Fork Smith River at Gasquet	130	5310
North Fork Smith River near Crescent City	158	5315
South Fork Smith River near Crescent City	295	5320
Smith River near Crescent City	613	5325
Rowdy Creek at Smith River	33.6	5327

The records of streamflow observed at many gaging stations in the Klamath River basin and adjacent closed basins (areas 7–9) are impaired to varying degrees by diversion for irrigation within the gaged subbasins. In these subbasins the diversions are numerous and many are unmeasured, and an undetermined amount of return flow finds its way back to the original stream. To adjust observed flow to natural flow, it is necessary to add the consumptive use of applied irrigation water to the observed runoff. Table 5 lists the estimated values of average annual consumptive use of applied irrigation water, based on a recent study (California Dept. Water Resources, 1960, table 30). The tabulation is restricted to those hydrologic units in which irrigation is practiced to an appreciable degree, and the names and numbers of the hydrologic units listed refer to those found on plate 1 and table 1. The values of consumptive use appear to be low in relation to the total acreage under cultivation, but an appreciable portion of the total acreage receives subirrigation from natural sources. The consumptive use of subirrigation water is not included in table 5, because the subirrigated lands are considered to have a naturally high water-table condition, and therefore a high evapotranspiration loss in their natural state.

TABLE 5.—*Average annual consumptive use of applied irrigation water, 1957*

No. (pl. 1)	Name of hydrologic unit	Average annual consumptive use of applied irrigation water (acre-ft)
7A	Lost River area above Boundary damsite	4,000
7B	Antelope and Butte Creek area	1,400
7C	Remaining drainage into closed basins adjacent to Klamath River basin	[1] 250,000
9A	Williamson River above Sprague River	10,000
9B	Sprague River above mouth	15,000
9C	Wood River area	41,000
9D	Remaining drainage into Upper Klamath Lake	13,000
9G	Shasta River above mouth (Yreka gage)	48,000
9J	Scott River above gage near Fort Jones	23,000

[1] Includes large quantities of water imported from Klamath River for U.S. Bur. Reclamation Klamath Project.

Table 1 gives estimated figures of mean annual runoff (natural flow) for the 60-year period 1900–59, for the various hydrologic units shown. Included in the annual runoff are the estimates of consumptive use of applied irrigation water listed in table 5, with an adjustment made for the change in irrigated acreage during the base period. For all Eel River hydrologic units downstream from Van Arsdale Dam (area 1A), runoff has been adjusted for evaporation and change in reservoir contents of Lake Pillsbury, and for diversion into the Russian River basin through the Potter Valley powerhouse. However, net evaporation losses from Upper Klamath Lake (area 9D), averaging about 150,000 acre-feet annually, have been omitted from the Klamath River estimates. This omission has been made because Upper Klamath Lake, although controlled for power and irrigation operations, has a water-surface area that is closely representative of natural conditions that existed in the past, and there is little likelihood that these conditions will be changed in the future. Evaporation and percolation losses from Clear Lake and Gerber Reservoir, as computed by the Bureau of Reclamation, are included in the estimates for the Lost River area (area 5A); in many years the losses from Clear Lake exceed the natural flow. Releases into the Klamath River from the closed basins of Lost River and Lower Klamath Lake are not included in the tabulation for the Klamath River.

The long-term runoff figures of table 1 have been obtained by correlating records for nearby gaging stations, some of which have been in existence only a few years. Estimates, however carefully made, that are based on short periods of observation are subject to considerable error, but their inclusion is justified by the fact that these records are needed now for use in preliminary project planning.

AVERAGE ANNUAL WATER LOSS AND EVAPORATION FROM WATER SURFACES

As used in this report, the average annual water loss of a drainage basin is the difference between the 60-year mean annual precipitation over the basin and the 60-year mean annual runoff. The use of long-term average figures in this computation reduces the effect of changes in surface or underground storage to insignificance in the final result. Computed average annual water loss for the various hydrologic units under consideration is listed in table 1. Because basinwide precipitation totals for the region are more properly considered index figures, rather than absolute values, the computed annual water loss figures fall in the same category and should be considered as indexes of annual water loss or evapotranspiration.

Variations in average annual water loss between basins are caused by variations in the factors that influence evapotranspiration, namely: (1) temperature and other climatic elements, (2) precipitation, (3) soil, (4) vegetal cover, (5) topography, and (6) geologic structure. The climatic factors—temperature, humidity, windspeed, and solar radiation—fix the upper limit of loss or the potential evapotranspiration. Potential evapotranspiration cannot be attained, however, unless the area affords the opportunity for evaporation. Evaporation opportunity is related, therefore, to the available moisture supply and is influenced largely by the volume and distribution of precipitation; it is influenced to a lesser degree by the last four factors listed above.

An index of potential evapotranspiration is the evaporation from the surface of bodies of water such as lakes and reservoirs. A recent study by the U.S. Weather Bureau (Kohler and others, 1959, pl. 2) has produced a generalized map of average annual lake evaporation in the United States, and a part of this map has been reproduced in figure 5. There are too few evaporation stations and first-order Weather Bureau stations in the region to permit refinement of the isopleths shown.

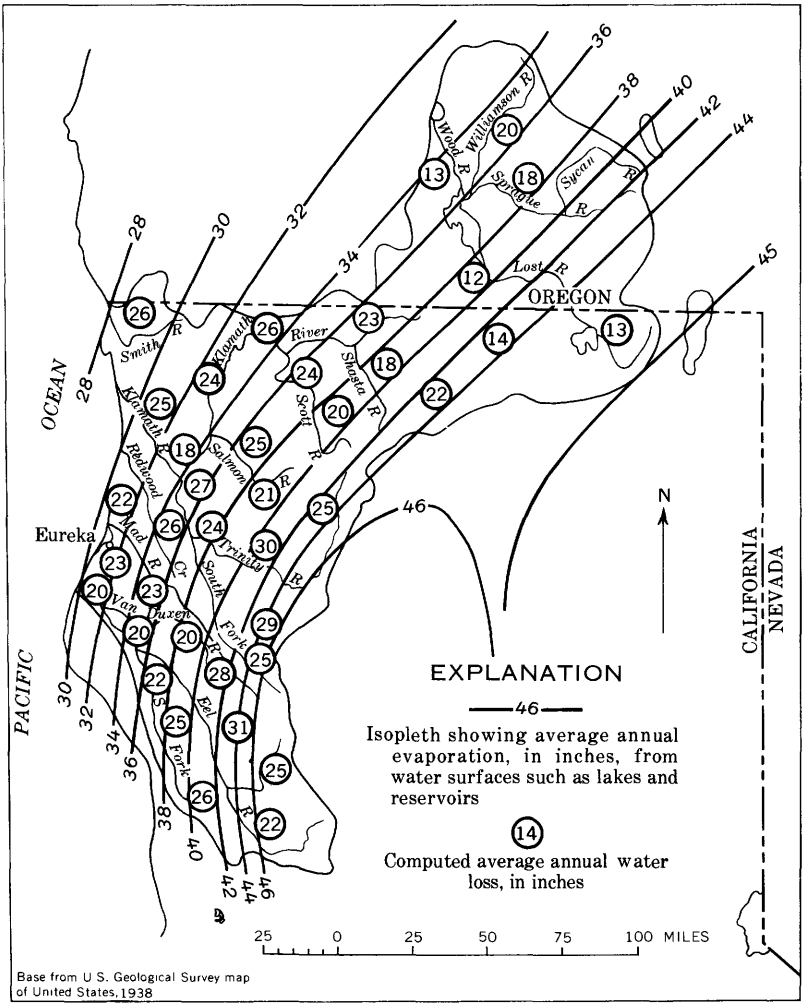


Figure 5.—Average annual water loss and evaporation from water surfaces.

Figure 5 indicates that evaporation increases with distance inland from the humid and often foggy coast. As a matter of interest, average annual water loss is also shown on figure 5 in the circled figures. Because figure 5 gives no clue to the evaporation opportunity, it should be supplemented by the isohyetal map (pl. 2). For example, the upper Klamath River basin has the greatest lake evaporation (potential evapotranspiration) but the lowest water loss, because precipitation is least in this area.

Variations in average annual water loss between basins are to be expected in view of the variability of the factors that influence this element, but some of the indicated variation undoubtedly results from discrepancies in the figures of water loss computed for this report. These discrepancies reflect the vagaries inherent in the determination of basinwide precipitation.

FLOW DURATION AND REGIMEN OF FLOW

The basic factors that affect the distribution of streamflow with respect to time are topography, tributary pattern, geologic structure, soil, vegetation, and meteorological conditions. The flow-duration curve is the simplest means of expressing the distribution of discharge, showing, as it does, the percent of time for a given period that any specified discharge is equaled or exceeded. It thus provides a useful device for analyzing the availability and variability of streamflow.

Flow-duration curves of daily natural discharge have been prepared for 25 gaging stations in the region that have five or more complete years of record of daily discharge virtually unaffected by regulation or diversion. The information given by these curves is summarized in table 6, where discharge equaled or exceeded during specified percentages of time is tabulated in both cubic feet per second and cubic feet per second per square mile. All discharges have been placed on a common basis for comparison by being adjusted to the base period 1912–59. Because of the lack of long-term gaging records, this is the longest base period feasible for use in this analysis. Correlation procedures were used to extend the shorter records. The number of significant figures used in the discharge columns of table 6 are not intended to imply great precision; they are included to enable the user of the table to conveniently reconstruct smooth flow-duration curves from the tabulated values.

Only one gaging station in the region meeting the criterion of 5 or more years of record of daily discharge unaffected by storage and diversion was omitted from the study. Station 4990, Sycan River near Beatty, Oreg., not only correlated poorly with the base station on Sprague River near Chiloquin, Oreg. (sta. 5010), but had only 4 complete years of concurrent record for use in the correlation. Duration curves for three selected stations, illustrating the different regimens of flow in the three physiographic sections in northern California, have been plotted on logarithmic normal probability paper on figure 6. Streamflow is shown as a ratio to mean annual discharge to facilitate comparison of the runoff characteristics indicated by the curves.

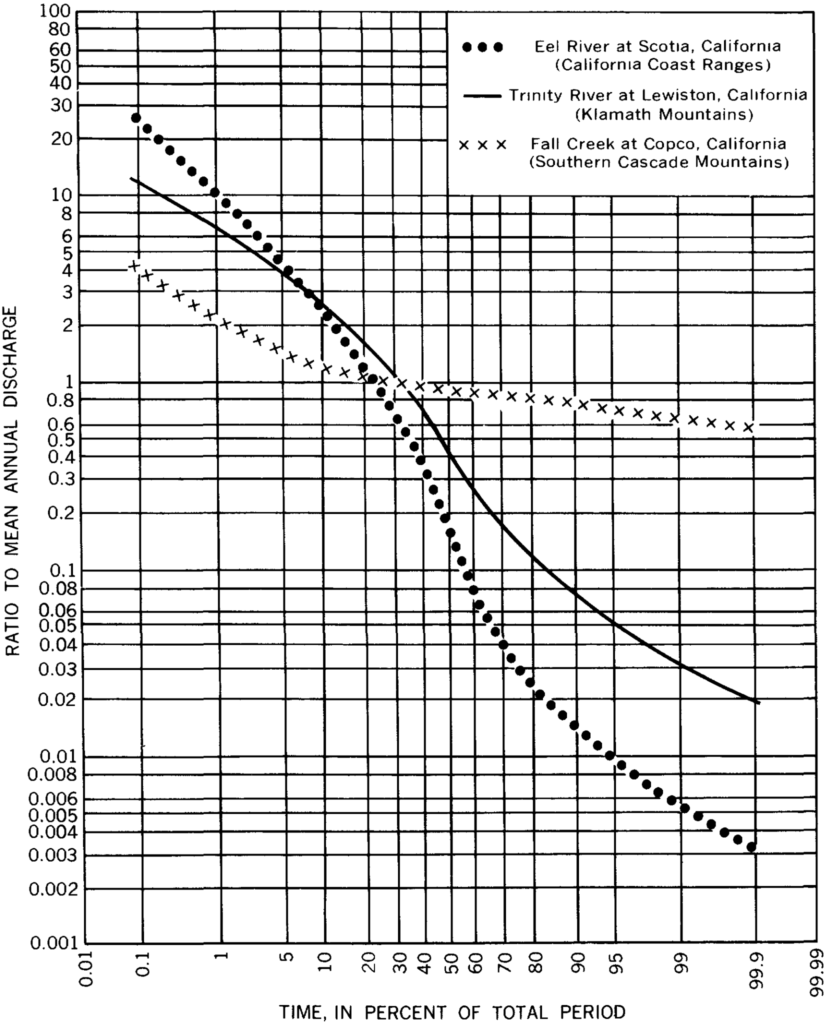


FIGURE 6.—Flow-duration curves for selected gaging stations for period 1912–59.

TABLE 6.—*Flow-duration summary for selected stream-gaging stations*

	Eel River basin															
Gaging station	Middle Fork Eel River below Black Butte River near Covelo, Calif. (4730)		North Fork Eel River near Mina, Calif. (4745)		South Fork Eel River near Branscomb, Calif. (4755)		South Fork Eel River near Miranda, Calif. (4765)		Eel River at Scotia, Calif. (4770)		Van Duzen River near Dinsmores, Calif. (4775)		Van Duzen River near Bridgeville, Calif. (4785)		Yager Creek near Carlotta, Calif. (4790)	
Period of record	1952–59		1954–59		1947–59		1941–59		1911–14, 1917–59		1954–58		1912–13, 1940–59		1954–55, 1957–59	
Drainage area	367 sq mi		251 sq mi		43.9 sq mi		537 sq mi		3,113 sq mi		80.2 sq mi		214 sq mi		127 sq mi	
	Discharge that is equaled or exceeded during percent of time indicated, adjusted to base period 1912–59															
Time (percent)	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi
99.9	2.4	0.007	0.07	0.0003	0.30	0.007	7.0	0.013	21	0.007	0.86	0.011	3.8	0.018	2.0	0.016
99.5	3.5	.010	.16	.0006	.52	.012	11.0	.020	31	.010	1.08	.013	4.6	.021	2.5	.020
99	4.3	.012	.24	.0010	.67	.015	13.5	.025	38	.012	1.21	.015	5.1	.024	2.8	.022
98	5.2	.014	.37	.0015	.90	.021	17.0	.032	47	.015	1.46	.018	5.9	.028	3.2	.025
95	7.4	.020	.76	.003	1.48	.034	25	.047	67	.022	1.90	.024	7.4	.035	4.1	.032
90	10.5	.029	1.5	.006	2.4	.055	37	.069	96	.031	2.65	.033	9.7	.045	5.4	.043
80	18.0	.049	3.8	.015	4.6	.105	62	.115	160	.051	4.6	.057	15.5	.072	8.4	.066
70	32	.087	8.6	.034	8.4	.191	96	.179	270	.087	10.0	.125	30	.140	15	.118
60	88	.240	22.0	.088	16.0	.364	167	.311	570	.183	31	.387	77	.360	30	.236
50	260	.708	68	.271	29	.661	300	.559	1,360	.437	69	.860	165	.771	64	.504
40	530	1.44	160	.637	52	1.18	540	1.01	2,800	.899	133	1.66	320	1.50	127	1.00
30	1,000	2.72	320	1.27	92	2.10	940	1.75	4,800	1.54	230	2.87	560	2.62	240	1.89
20	1,620	4.41	600	2.39	190	4.33	1,950	3.63	8,600	2.76	385	4.80	970	4.53	435	3.43
10	2,800	7.63	1,300	5.18	390	8.88	4,200	7.82	17,200	5.53	750	9.35	1,900	8.88	920	7.24
5	4,200	11.4	2,300	9.16	680	15.5	7,300	13.6	30,000	9.64	1,250	15.6	3,250	15.2	1,600	12.6
2	6,500	17.7	4,100	16.3	1,200	27.3	13,000	24.2	53,000	17.0	2,200	27.4	5,500	25.7	2,700	21.3
1	8,800	24.0	5,800	23.1	1,660	37.8	18,500	34.5	77,000	24.7	3,100	38.7	7,700	36.0	3,700	29.1
0.5	11,300	30.8	7,700	30.7	2,200	50.1	25,000	46.6	104,000	33.4	4,200	52.4	10,200	47.7	4,900	38.6
0.1	19,000	51.8	12,900	51.4	3,700	84.3	42,000	78.2	185,000	59.4	7,300	91.0	17,200	80.4	7,800	61.4

Gaging station	Mad River basin				Redwood Creek basin				Lower Klamath Lake basin		Klamath River basin							
	Mad River near Forest Glen, Calif. (4805)		Mad River near Arcata, Calif. (4810)		Redwood Creek near Blue Lake, Calif. (4815)		Redwood Creek at Orick, Calif. (4825)		Antelope Creek near Tennant, Calif. (4895)		Sprague River near Chiloquin, Oreg. (5010)		Fall Creek at Copco, Calif. (5120)		Scott River near Fort Jones, Calif. (5195)		Salmon River at Somesbar, Calif. (5225)	
Period of record	1954–59		1911–13, 1951–59		1954–58		1912–13, 1954–59		1953–59		1922–59		1929–59		1942–59		1928–59	
Drainage area	144 sq mi		485 sq mi		67.5 sq mi		278 sq mi		18.8 sq mi		1,580 sq mi		20 sq mi		662 sq mi		746 sq mi	
	Discharge that is equaled or exceeded during percent of time indicated, adjusted to base period 1912–59																	
Time (percent)	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi
99.9	0.15	0.001	9.4	0.019	2.5	0.037	4.2	0.015	2.5	0.133	89	0.056	22.0	1.10	8.0	0.012	56	0.075
99.5	.27	.002	11.5	.024	3.3	.049	6.7	.024	3.7	.197	116	.073	23.5	1.18	14	.021	72	.097
99	.37	.003	13.0	.027	3.8	.056	8.5	.031	4.5	.239	130	.082	24.5	1.22	18	.027	83	.111
98	.52	.004	15	.031	4.5	.067	11.0	.040	5.4	.287	147	.093	25.5	1.28	24	.036	99	.133
95	.89	.006	19	.039	5.8	.086	16.5	.059	7.3	.388	172	.109	27.0	1.35	35	.053	129	.173
90	1.45	.010	25	.052	7.4	.110	24.0	.086	9.4	.500	197	.125	28.5	1.42	49	.074	169	.227
80	2.95	.020	38	.078	11.0	.163	41	.147	12.5	.665	230	.146	30.5	1.52	74	.112	242	.324
70	6.2	.043	61	.126	17	.252	70	.252	15.5	.824	257	.163	32.5	1.62	107	.162	350	.469
60	17	.118	125	.258	32	.474	130	.468	18.0	.957	289	.183	34.0	1.70	160	.242	520	.697
50	50	.347	310	.639	70	1.04	270	.971	21.0	1.12	328	.208	35.5	1.78	261	.394	870	1.17
40	115	.799	640	1.32	127	1.88	485	1.74	25.5	1.36	385	.244	37.5	1.88	447	.675	1,350	1.81
30	212	1.47	1,100	2.27	205	3.04	760	2.73	32.0	1.70	480	.304	41.0	2.05	685	1.03	1,970	2.64
20	405	2.81	1,900	3.92	325	4.81	1,250	4.50	43	2.29	690	.437	45	2.25	995	1.50	2,750	3.69
10	810	5.62	3,600	7.42	580	8.59	2,300	8.27	66	3.51	1,180	.747	53	2.65	1,460	2.21	3,850	5.16
5	1,380	9.58	5,900	12.2	930	13.8	3,700	13.3	93	4.95	1,730	1.09	61	3.05	2,020	3.05	5,200	6.97
2	2,450	17.0	9,300	19.2	1,500	22.2	6,100	21.9	130	6.91	2,670	1.69	77	3.85	2,940	4.44	7,300	9.79
1	3,400	23.6	12,500	25.8	2,050	30.4	8,400	30.2	163	8.67	3,500	2.22	92	4.60	3,820	5.77	9,400	12.6
0.5	4,600	31.9	16,000	33.0	2,700	40.0	11,200	40.3	200	10.6	4,300	2.72	111	5.55	4,850	7.33	12,000	16.1
0.1	8,000	55.6	24,000	49.5	4,400	65.2	18,500	66.5	295	15.7	5,400	3.42	160	8.00	8,200	12.4	20,200	27.1

TABLE 6.—*Flow-duration summary for selected stream-gaging stations*—Continued

	Klamath River basin												Smith River basin			
Gaging station	Trinity River at Lewiston, Calif. (5255)		Trinity River near Douglas City, Calif. (5260)		Trinity River near Burnt Ranch, Calif. (5270)		Hayfork Creek near Hyampom, Calif. (5285)		South Fork Trinity River near Salyer, Calif. (5290)		Trinity River near Hoopa, Calif. (5300)		South Fork Smith River near Crescent City, Calif. (5320)		Smith River near Crescent City, Calif. (5325)	
Period of record	1912–59		1945–51		1932–39, 1957–59		1954–59		1912–13, 1951–59		1912–13, 1917–18, 1932–59		1912–13, 1955–59		1932–59	
Drainage area	726 sq mi		1,017 sq mi		1,438 sq mi		379 sq mi		899 sq mi		2,846 sq mi		295 sq mi		613 sq mi	
Time (percent)	Discharge that is equaled or exceeded during percent of time indicated, adjusted to base period 1912–59															
	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi	cfs	cfs per sq mi
99.9	32	0.044	37	0.036	50	0.035	5.7	0.015	19.0	0.021	98	0.034	66	0.224	145	0.237
99.5	47	.065	54	.053	70	.049	8.5	.022	27.5	.031	143	.050	71	.241	160	.261
99	57	.079	66	.065	85	.059	10.7	.028	33.5	.037	174	.061	76	.258	170	.277
98	71	.098	81	.080	106	.074	13.5	.036	41.0	.046	219	.077	83	.281	185	.302
95	97	.134	114	.112	152	.106	19.3	.051	57	.063	305	.107	99	.336	215	.351
90	132	.182	155	.152	212	.147	27.0	.071	79	.088	415	.146	123	.417	260	.424
80	195	.269	225	.221	335	.233	40	.106	117	.130	620	.218	175	.593	350	.571
70	285	.393	305	.300	510	.355	58	.153	170	.189	910	.320	252	.854	500	.816
60	425	.585	445	.438	780	.542	80	.211	254	.283	1,400	.492	410	1.39	790	1.29
50	730	1.01	790	.777	1,320	.918	120	.317	440	.489	2,450	.861	720	2.44	1,370	2.23
40	1,220	1.68	1,420	1.40	2,250	1.56	205	.541	790	.879	4,250	1.49	1,100	3.73	2,150	3.51
30	1,900	2.62	2,180	2.14	3,350	2.33	345	.910	1,290	1.43	6,600	2.32	1,600	5.42	3,350	5.46
20	2,780	3.83	3,050	3.00	4,700	3.27	610	1.61	2,150	2.39	9,600	3.37	2,250	7.63	5,000	8.16
10	4,150	5.72	4,850	4.77	6,900	4.80	1,230	3.25	4,150	4.62	14,500	5.09	3,650	12.4	8,000	13.1
5	5,750	7.92	7,000	6.88	9,400	6.54	2,060	5.44	6,800	7.56	20,500	7.20	5,700	19.3	12,500	20.4
2	8,300	11.4	10,300	10.1	13,500	9.39	3,500	9.23	11,000	12.2	30,500	10.7	9,300	31.5	20,800	33.9
1	10,500	14.5	13,400	13.2	17,200	12.0	4,700	12.4	14,500	16.1	39,000	13.7	13,300	45.1	29,500	48.1
0.5	13,100	18.0	16,500	16.2	21,300	14.8	6,000	15.8	18,100	20.1	48,500	17.0	18,200	61.7	39,500	64.4
0.1	20,200	27.8	25,000	24.6	32,500	22.6	9,300	24.5	27,000	30.0	76,000	26.7	32,500	110	66,000	108

One of the shortcomings of the flow-duration curve in presenting a picture of the distribution of discharge, is the fact that it ignores the chronology of streamflow. The value of the flow-duration curve is enhanced, therefore, when it is supplemented by a knowledge of the regimen of flow. The monthly distribution of runoff in the coastal basins of northern California follows several patterns, depending primarily on the elevation and geology of the individual basins. Elevation influences the percentage of annual runoff that results from snowmelt, this type of runoff being generally negligible in basins that do not have an appreciable part of their area above elevation 5,000 feet. Geology is the prime factor influencing the percentage of runoff that appears as base flow; the more permeable the mantle rock, the better sustained is the base flow. The graphs of figure 7 are representative of the monthly distributions of flow found in northern California coastal basins. Generally, the period of storm runoff is November through March; the period of snowmelt runoff (if any) is April through June; the period of base flow is July through October.

The monthly distribution of runoff shown for Eel River at Scotia, Calif. (sta. 4770), is typical of most basins in the northern California Coast Ranges. These basins have negligible snowmelt runoff and a relatively impermeable mantle rock. The distribution for Trinity River at Lewiston, Calif. (sta. 5255), is representative of most basins in the Klamath Mountains section. These basins have appreciable snowmelt runoff and a somewhat more permeable mantle rock. The monthly distribution of runoff for Fall Creek at Copco, Calif. (sta. 5120), represents the regimen of flow of streams that are almost entirely spring fed in the highly permeable lava area of the Southern Cascade Mountains section.

These three runoff distributions, illustrated by figures 6 and 7 can be classed as basic types, but actually the physiography and geology of the region are too complex to permit classification of all the subbasins in three simple categories. For example, the Smith River and South Fork Trinity River in the Klamath Mountains section have the fairly well sustained base flow typical of that section, but because they drain basins of relatively low elevation, they have little snowmelt runoff. The Middle Fork Eel River receives more snowmelt than other streams in the northern California Coast Ranges but has the low base flow that is typical of streams in that section. The Shasta River, whose monthly distribution of runoff is shown on figure 7, drains a very complex area. The mountainous western part of the basin has the runoff characteristics of Klamath Mountain basins, such as those of the Scott and Salmon Rivers, but the lava plateau to the east furnishes a well-sustained base flow which tends to equalize the monthly runoff. In the lava area of the upper Klamath River

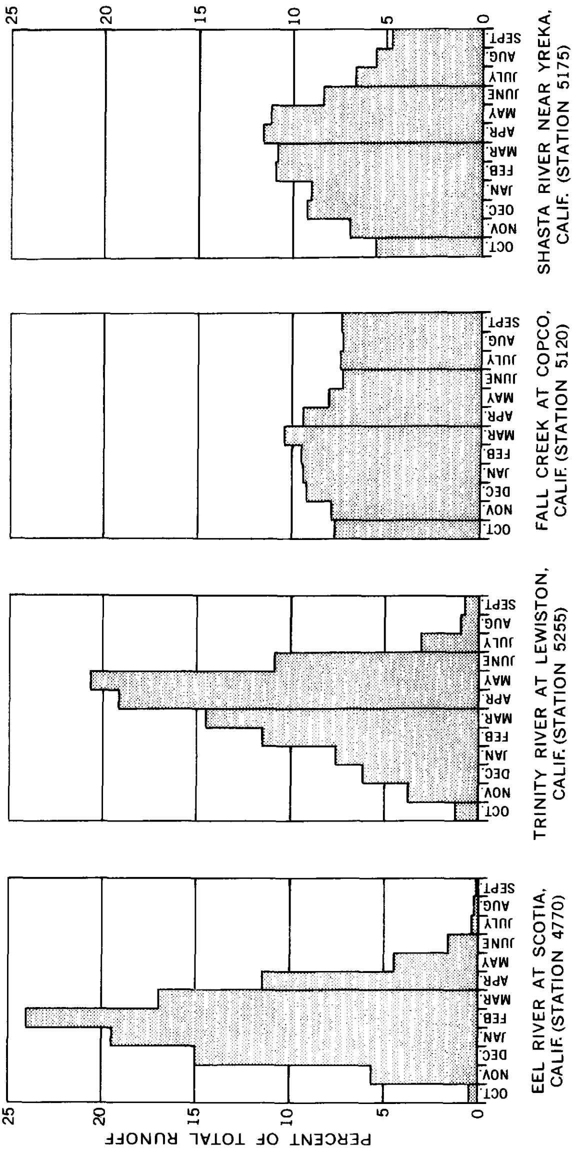


FIGURE 7.—Mean monthly distribution of runoff at selected gaging stations.

basin and adjacent closed basins, the permeability of the mantle rock varies, and consequently snowmelt may or may not cause relatively high volumes of runoff during the spring. Where marsh areas are extensive, as in the Sycan River basin, large evapotranspiration losses may greatly reduce base flow.

Examination of the duration curves for the region elicits some interesting information regarding their characteristics. Key points on the curves are Q_{10}, Q_{50}, Q_{90}, Q_{mean}, and P_{mean}, where

- Q_{10} is the discharge equaled or exceeded 10 percent of the time during the period 1912–59.
- Q_{50} is the median discharge for the period 1912–59.
- Q_{90} is the discharge equaled or exceeded 90 percent of the time during the period 1912–59.
- Q_{mean} is the mean discharge for the period 1912–59 (this discharge is about 8 percent smaller than that for the long-term base period, 1900–59).
- P_{mean} is the percent of time, in the 1912–59 period, during which Q_{mean} was equaled or exceeded.

These discharges, expressed in cubic feet per second per square mile, are listed in table 7 for the 25 gaging stations of table 6.

Simple index figures were desired to indicate, for each station, (1) the variability of discharge and (2) the regimen of flow. For an index of variability, the ratio of Q_{10} to Q_{90} was chosen, because the duration curves exhibit a linear trend between durations of 10 and 90 percent, when plotted on logarithmic normal probability paper. For an index of storm runoff the average percentage of total annual runoff occurring during the five months November through March was used. The average percentage of total annual runoff occurring during the three months April through June provides an index of snowmelt runoff. These various indexes are listed in table 7. The indexes of storm and snowmelt runoff are not precisely comparable from station to station, in that they do not represent a common period of record at all stations; the indexes were computed from whatever length of record was available. Nevertheless, these computed indexes are satisfactory for identifying the regimen of flow at the various gaging stations. An index figure greater than 60 for storm runoff is indicative of a basin whose runoff is predominantly from this source. An index figure greater than 30 for snowmelt runoff indicates that this type of runoff is of appreciable magnitude. Only 2 of the 25 gaging stations fail to fall clearly in one category or the other. The highly impermeable basin of Middle Fork Eel River upstream from the gage near Covelo, Calif. (sta. 4730), shows significantly high indexes in both categories, whereas the highly permeable basin of Fall Creek upstream from Copco, Calif. (sta. 5120), does not show significantly

TABLE 7.—*Flow characteristics at selected stream-gaging stations for base. 1912–59*

No. (pl. 4)	Stream-gaging station	Drainage area (sq mi)	Q_{10} (discharge in cfs per sq mi)	Q_{50}	Q_{90}	Q_{mean}	P_{mean} (percent)	Indexes: Variability	Storm runoff	Snowmelt runoff
	Eel River Basin									
4730	Middle Fork Eel River below Black Butte River near Covelo, Calif.	367	7.63	0.708	0.029	2.36	32	263	68	30
4745	North Fork Eel River near Mina, Calif.	251	5.18	.271	.006	1.92	23	863	86	13
4755	South Fork Eel River near Branscomb, Calif.	43.9	8.88	.661	.055	3.51	23	161	84	13
4765	South Fork Eel River near Miranda, Calif.	537	7.82	.559	.069	3.04	22	113	83	14
4770	Eel River at Scotia, Calif.	3,113	5.53	.437	.031	2.26	23	178	81	18
4775	Van Duzen River near Dinsmores, Calif.	80.2	9.35	.860	.033	3.75	24	283	81	17
4785	Van Duzen River near Bridgeville, Calif.	214	8.88	.771	.045	3.53	24	197	79	20
4790	Yager Creek near Carlotta, Calif.	127	7.24	.504	.043	2.73	24	168	81	17
	Mad River Basin									
4805	Mad River near Forest Glen, Calif.	144	5.62	.347	.010	2.17	24	562	83	16
4810	Mad River near Arcata, Calif.	485	7.42	.639	.052	2.80	26	143	82	15
	Redwood Creek Basin									
4815	Redwood Creek near Blue Lake, Calif.	67.5	8.59	1.04	.110	3.72	25	78	81	16
4825	Redwood Creek at Orick, Calif.	278	8.27	.971	.088	3.69	24	94	81	17
	Lower Klamath Lake Basin									
4895	Antelope Creek near Tennant, Calif.	18.8	3.51	1.12	.500	1.66	31	7	32	51
	Klamath River Basin (including Trinity River)									
5010	Sprague River near Chiloquin, Oreg.	1,580	.747	.208	.125	.354	26	6	37	47
5120	Fall Creek at Copco, Calif.	20	2.65	1.78	1.42	1.95	36	1.9	46	25
5195	Scott River near Fort Jones, Calif.	662	2.21	.394	.074	.860	34	30	52	41
5225	Salmon River at Somesbar, Calif.	746	5.16	1.17	.227	2.24	34	23	50	43
5255	Trinity River at Lewiston, Calif.	726	5.72	1.01	.182	2.27	33	31	43	51
5260	Trinity River near Douglas City, Calif.	1,017	4.77	.777	.152	1.86	33	31	44	50
5270	Trinity River near Burnt Ranch, Calif.	1,438	4.80	.918	.147	1.98	34	33	49	46
5285	Hayfork Creek near Hyampom, Calif.	379	3.25	.317	.071	1.18	25	46	78	19
5290	South Fork Trinity River near Salyer, Calif.	899	4.62	.489	.088	1.66	27	52	75	21
5300	Trinity River near Hoopa, Calif.	2,846	5.09	.861	.146	1.94	34	35	57	38
	Smith River Basin									
5320	South Fork Smith River near Crescent City, Calif.	295	12.4	2.44	.417	6.21	26	30	74	21
5325	Smith River near Crescent City, Calif.	613	13.1	2.23	.424	5.90	28	31	73	22

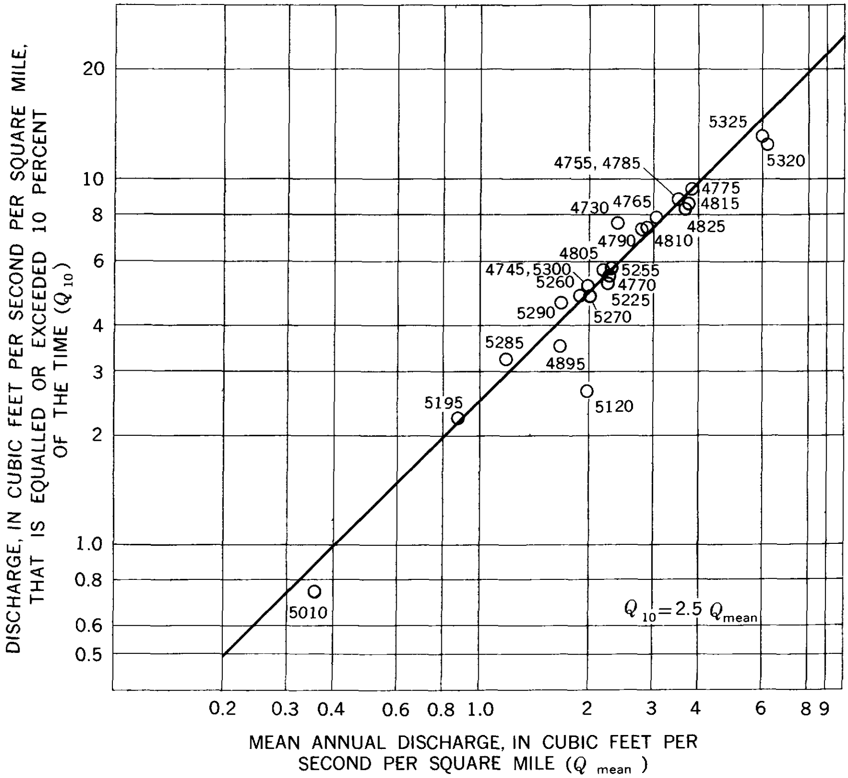


Figure 8.—Relation between Q_{mean} and Q_{10}. Station numbers used to identify plotted points.

high indexes in either category. The sum of the two indexes for the Fall Creek station and for the other two stations in the southern Cascades province—Antelope Creek near Tennant, Calif. (sta. 4895), and Sprague River near Chiloquin, Oreg. (sta. 5010)—total less than 85, thereby indicating well-sustained base flow.

In analyzing the tabulated data, the first characteristic investigated was the duration time (P_{mean}) of mean discharge (Q_{mean}). P_{mean} was found to be related to the regimen of flow and to be independent of the value of Q_{mean}. It is to be expected that those streams that experience snowmelt rises as well as storm peaks will have more days of discharge in excess of the mean, than will those streams that do not carry appreciable snowmelt. For those streams whose storm runoff index is greater than 60, Q_{mean} is equalled or exceeded about 24 percent of the time. For those streams whose snowmelt runoff index is greater than 30, Q_{mean} is equalled or exceeded about 34 percent of the time.

The average slope of the duration curve between Q_{10} and Q_{90}, or index of variability, was investigated next. Figure 8 indicates that

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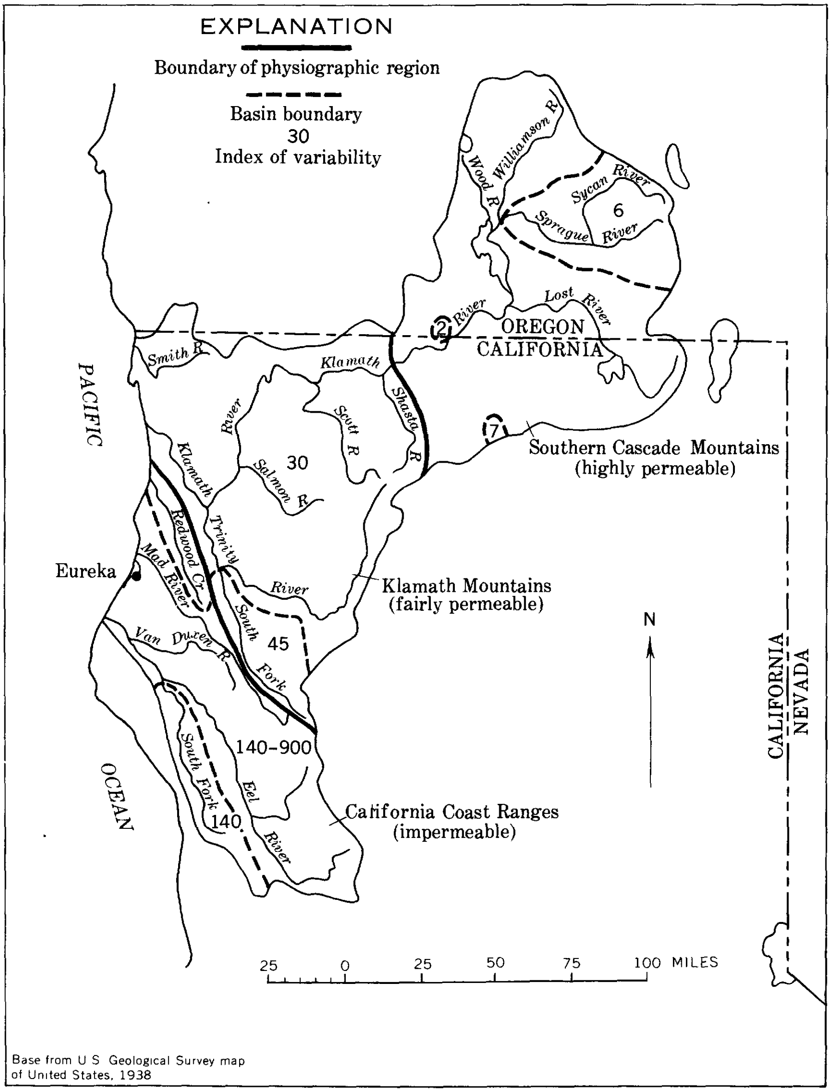


Figure 9.—Geographical distribution of index of variability.

Q_{10} is closely related to Q_{mean}, and, in general, is 2.5 times larger than Q_{mean}. The existence of this close relation is not surprising in view of the fact that both discharges are related to the mean annual precipitation, the bulk of which occurs in general storms that reach all basins. Geology has little effect on the large discharges represented in Q_{10} and Q_{mean}, except in the extremely permeable basin of Fall Creek (sta. 5120). Q_{90}, however is influenced primarily by the geology of the basins, being higher for the more permeable mantle rock. Because Q_{90} varies much more widely than does Q_{10}, the index of variability is much more closely related to Q_{90} than to Q_{10}. The variation in permeability in the region has been discussed earlier in the report, and on the basis of that discussion and the tabulation of the index of variability in table 7, the map on figure 9 has been prepared. This map depicts, in a general way, the geographical distribution of the index of variability. The wide range of values of the index in the impermeable northern California Coast Ranges is striking.

As for the upper and lower ends of the duration curves, they show the following characteristics:

1. All other things being equal, the part of the curve for discharges less than Q_{90} is flattest for those basins that have the most permeable mantle rock.
2. All other things being equal, the part of the curve for discharges greater than Q_{10} is influenced primarily by the regimen of flow, and is steepest for those basins that have little or no snowmelt runoff.

LOW FLOW—MAGNITUDE, DURATION, AND FREQUENCY

A prerequisite for any study involving water supply during periods of critically low runoff is a knowledge of the magnitude, duration, and frequency of deficient flow. To fill the need for this information, low-flow frequency graphs were prepared for 25 gaging stations, showing the probable recurrence interval of low flows of various magnitudes and durations. The stations used were those included in the previously described flow-duration analysis, because these were virtually the only ones in the region with five or more complete years of record of daily discharge that is not seriously affected by regulation or diversion. The duration periods used in this analysis were 1, 7, 15, 30, 60, 90, 120, and 183 days. The inclusion of a 3-day duration period was originally planned but was rejected when it was found that lowest mean discharge each year for 3 consecutive days was almost identical with the minimum daily discharge of each year. The base period selected for the study was April 1, 1912 to March 31, 1960. This 48-year period was the longest that was practical to use, and it included the extremely dry years that occurred during the decade 1924 to 1934. Using March 31 as the closing day of each year eliminated the possibility of a period of sustained low flow starting in one year and extending into the next.

In a step preliminary to the construction of the low-flow frequency graphs, the smallest mean discharges each year for 1 day, 7 consecutive days, 15 consecutive days, 30 consecutive days, 60 consecutive days, 90 consecutive days, 120 consecutive days, and 183 consecutive days were listed and ranked in ascending order of magnitude for the long-term stations on Eel River at Scotia, Calif. (sta. 4770), and Trinity River at Lewiston, Calif. (sta. 5255). The plotting position of each discharge was next computed by use of the formula

$$\text{Recurrence interval} = \frac{N+1}{M},$$

where N is the number of years of record (48 years), and M is the order number. These points were then plotted on logarithmic extreme-value probability paper and smooth curves were fitted to the points. The sets of curves for the two long-term stations are found on figures 10 and 11.

To obtain the ordinates of the points defining the low-flow frequency curves for the remaining 23 gaging stations, all of which have periods of record that are shorter than the 48-year base period, it was first necessary to extend these shorter records by correlation with the base stations at Scotia and Lewiston. It was found that minimum flows for all durations at 22 of the stations correlated well with concurrent flows at one or the other of the 2 base stations. The lone exception was the station on Sprague River near Chiloquin, Oreg. (sta. 5010). For this station low-flow frequency curves for the 48-year base period were obtained by extrapolation of the frequency curves for the 39 years of recorded flow (1921–60). The discharge figures obtained from this study are summarized in table 8; it provides the data needed for constructing long-term low-flow frequency curves for all 25 stations.

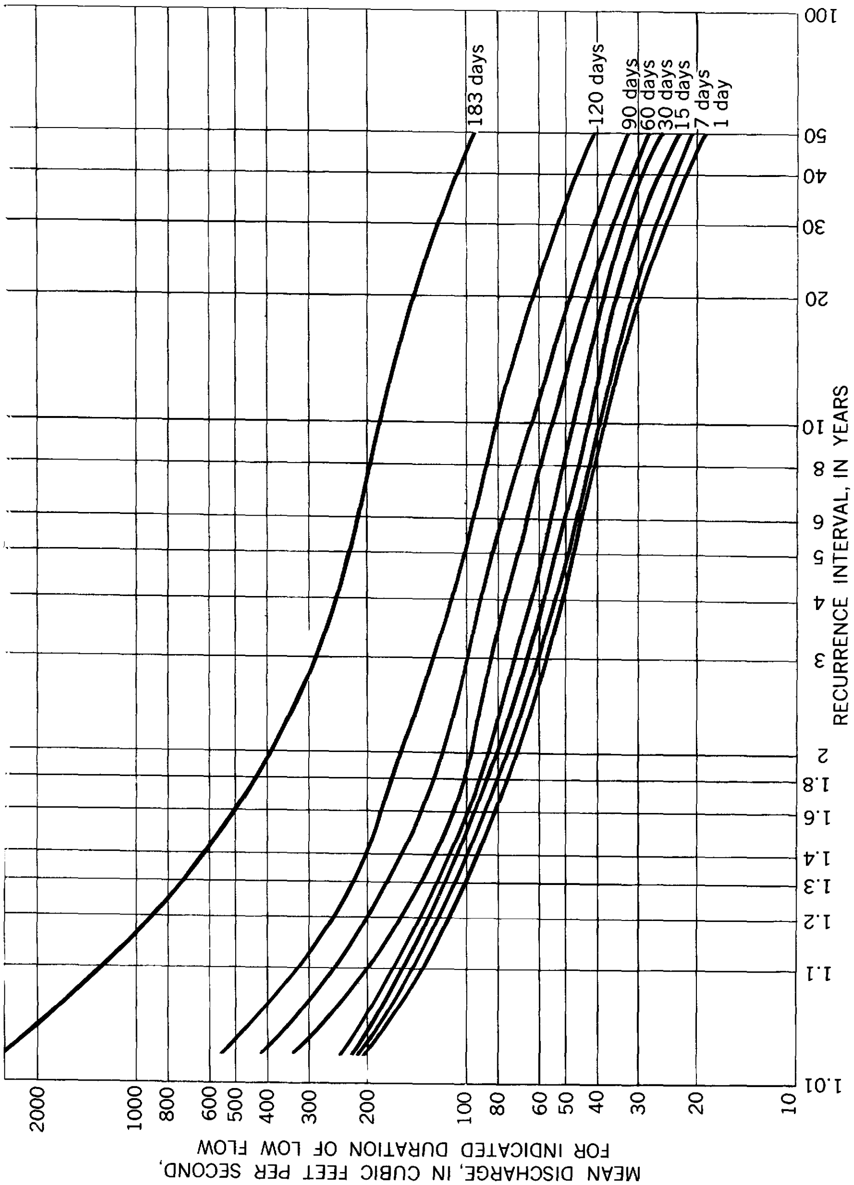


FIGURE 10.—Low-flow frequency curves for Eel River at Scotia, Calif. (sta. 4770). Curve based on recorded discharges during period from April 1, 1912, to March 31, 1960.

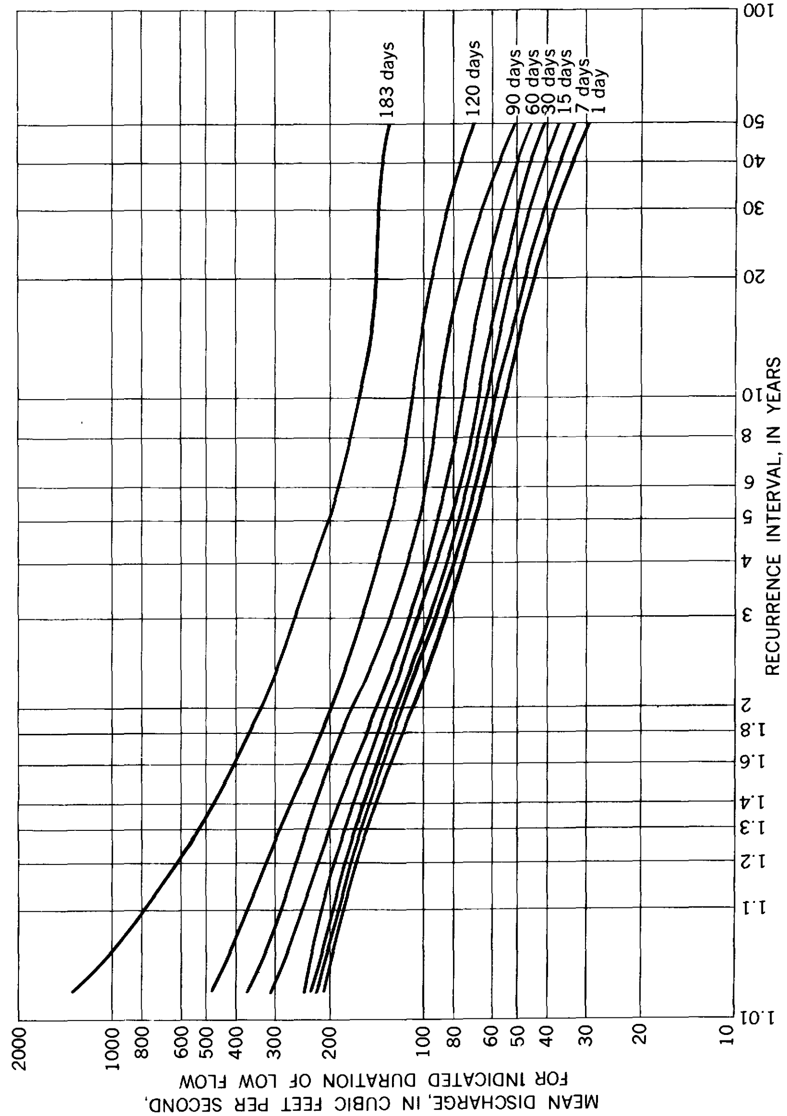


FIGURE 11.—Low-flow frequency curves for Trinity River at Lewiston, Calif. (sta. 5255). Based on the period from April 1, 1912, to March 31, 1960.

TABLE 8.—*Low-flow frequency table for selected stream-gaging stations*

[Discharge adjusted to base period April 1, 1912, to March 31, 1960]

Station No.	Gaging station	Number of consecutive days	Ordinates of low-flow frequency curves, in cubic feet per second, for indicated recurrence intervals, in years								
			1.02	1.10	1.3	2.0	5.0	10	20	30	50
4730	Middle Fork Eel River below Black Butte River near Covelo, Calif.	1	23.0	15.0	11.0	7.8	5.2	4.2	3.4	2.8	2.2
		7	23.5	16.0	11.5	8.2	5.5	4.4	3.5	3.0	2.3
		15	25.0	18.0	12	8.7	5.9	4.6	4.0	3.4	2.6
		30	27.5	19.5	13	9.4	6.6	5.2	4.3	3.8	3.0
		60	41	22	15	10.4	7.7	6.1	4.7	4.0	3.3
		90	56	30	19	12.7	9.0	7.0	5.4	4.5	3.6
		120	84	40	25	16.5	11	8.6	6.8	5.7	4.6
		183	463	235	121	51	25	19	15	13	10.2
4745	North Fork Eel River near Mina, Calif.	1	5.6	3.0	1.7	0.84	0.37	0.23	0.14	0.10	0.06
		7	5.9	3.2	1.9	.93	.40	.26	.16	.11	.07
		15	6.2	3.7	2.2	1.05	.46	.30	.20	.14	.09
		30	7.1	4.1	2.4	1.20	.56	.36	.24	.18	.11
		60	11.0	5.5	3.0	1.48	.79	.50	.30	.21	.13
		90	15.0	7.6	4.2	2.2	1.10	.66	.37	.26	.17
		120	21.5	10.8	6.2	3.6	1.70	1.02	.62	.43	.28
		183	133	57	29.5	13.9	6.3	4.6	3.10	2.30	1.42
4755	South Fork Eel River near Branscomb, Calif.	1	6.1	3.8	2.6	1.62	0.90	0.64	0.46	0.35	0.23
		7	6.3	4.1	2.8	1.75	.98	.71	.51	.38	.26
		15	6.6	4.5	3.1	1.90	1.08	.78	.60	.46	.31
		30	7.3	4.9	3.2	2.1	1.22	.90	.69	.55	.38
		60	10.0	6.1	3.8	2.4	1.55	1.12	.78	.62	.44
		80	12.5	7.7	5.0	3.1	1.96	1.36	.98	.73	.52
		120	15.5	10.0	6.6	4.5	2.60	1.88	1.32	1.05	.77
		183	44	26	18	11.8	6.6	5.4	3.90	3.15	2.30
4765	South Fork Eel River near Miranda, Calif.	1	76	53	39	27.0	17.0	13.0	10.0	8.0	5.8
		7	78	56	41	28.5	18.0	14.0	10.8	8.6	6.4
		15	81	60	45	30.5	19.5	15.0	12.3	10.0	7.4
		30	87	64	47	33.0	21.5	17.0	13.6	11.5	8.6
		60	112	76	53	36.5	26.0	20.0	15.0	12.5	9.7
		90	135	91	65	45	31.3	23.5	18.0	14.3	11.0
		120	165	111	81	60	39	30	23	19	14.8
		183	460	272	192	129	81	69	54	46	35.5
4770	Eel River at Scotia, Calif.	1	205	138	102	71	47	37	29.5	24.5	19.0
		7	210	146	108	75	49	39	31	26	20.5
		15	220	157	116	80	53	42	35	29	23
		30	240	168	122	86	58	47	38	33	26
		60	330	202	137	95	69	55	42	36	28
		90	420	253	172	117	82	63	48	40	32
		120	550	325	220	156	101	79	61	51	40
		183	2,400	1,220	705	390	223	182	141	120	93
4775	Van Duzen River near Dinsmores, Calif.	1	6.7	3.9	2.8	2.0	1.4	1.20	1.03	0.91	0.80
		7	7.0	4.3	3.0	2.1	1.5	1.25	1.07	.95	.83
		15	7.4	4.6	3.2	2.2	1.6	1.30	1.15	1.03	.87
		30	8.6	5.0	3.4	2.4	1.7	1.4	1.22	1.10	.95
		60	13.8	6.6	3.8	2.6	1.9	1.6	1.30	1.15	1.00
		90	19.5	9.5	5.2	3.2	2.2	1.8	1.44	1.25	1.09
		120	26.0	13.2	7.5	4.5	2.8	2.2	1.77	1.50	1.30
		183	117	58.0	33.0	17.2	7.6	5.6	4.00	3.30	2.55
4785	Van Duzen River near Bridgeville, Calif.	1	21	13.3	10.2	7.7	5.8	5.0	4.4	4.05	3.65
		7	22	14.2	10.8	8.0	6.0	5.2	4.6	4.20	3.75
		15	23	15.3	11.5	8.4	6.3	5.4	4.9	4.45	3.90
		30	26	16.5	12.0	8.8	6.7	5.8	5.1	4.70	4.20
		60	38	20.7	13.2	9.5	7.5	6.4	5.4	4.90	4.40
		90	50	28.0	17.0	11.5	8.5	7.1	5.9	5.25	4.63
		120	66	37.0	23.0	15.1	10.1	8.3	6.9	6.10	5.35
		183	280	142	83	46.0	23.5	18.0	13.8	11.8	9.4
4790	Yager Creek near Carlotta, Calif.	1	11.0	7.2	5.6	4.25	3.17	2.72	2.40	2.12	1.93
		7	11.4	7.8	6.0	4.40	3.30	2.80	2.45	2.20	1.98
		15	12.0	8.2	6.3	4.60	3.45	2.90	2.62	2.40	2.05
		30	13.2	8.8	6.6	4.75	3.70	3.17	2.77	2.52	2.20
		60	18.0	10.8	7.1	5.30	4.15	3.53	2.90	2.62	2.35
		90	23.6	14.0	9.0	6.3	4.70	3.90	3.20	2.80	2.50
		120	28.5	27.5	11.8	8.1	5.60	4.60	3.80	3.35	3.90
		183	110	56	34.5	21.0	12.0	9.60	7.50	6.50	5.20

TABLE 8.—*Low-flow frequency table for selected stream-gaging stations*—Continued

Station No.	Gaging station	Number of consecutive days	Ordinates of low-flow frequency curves, in cubic feet per second, for indicated recurrence intervals, in years								
			1.02	1.10	1.3	2.0	5.0	10	20	30	50
4805	Mad River near Forest Glen, Calif.	1	4.20	2.37	1.50	0.90	0.49	0.34	0.25	0.19	0.13
		7	4.35	2.55	1.66	.97	.52	.38	.27	.21	.14
		15	4.65	2.85	1.82	1.07	.59	.42	.31	.25	.17
		30	5.20	3.15	1.95	1.19	.67	.50	.36	.29	.20
		60	8.0	4.10	2.38	1.38	.86	.62	.42	.32	.23
		90	11.2	5.60	3.25	1.85	1.10	.75	.51	.39	.28
		120	16.3	7.90	4.65	2.80	1.50	1.04	.72	.56	.40
		183	96.0	44.0	22.0	10.2	4.65	3.55	2.41	1.90	1.32
4810	Mad River near Arcata, Calif.	1	47	33	26.0	19.7	14.7	12.8	11.0	10.1	9.0
		7	48	35	27.5	20.5	15.2	13.2	11.5	10.4	9.3
		15	50	37	29.0	21.7	16.0	13.7	12.2	11.0	9.8
		30	54	39	30	23.0	17.0	14.9	13.0	11.9	10.4
		60	73	46	33	24.8	19.4	16.3	13.7	12.3	10.9
		90	92	57	40	29.0	22.0	18.0	15.0	13.3	11.7
		120	120	71	50	36.5	26	21.4	17.6	15.5	13.5
		183	542	270	152	85	50	41.5	33.8	29.8	24.3
4815	Redwood Creek near Blue Lake, Calif.	1	13.5	9.6	7.4	6.0	4.5	3.80	3.25	2.80	2.30
		7	13.8	10.0	7.8	6.2	4.7	3.95	3.35	2.95	2.45
		15	14.3	10.4	8.3	6.4	4.9	4.15	3.65	3.25	2.65
		30	15.5	11.2	8.6	6.7	5.2	4.50	3.90	3.50	2.95
		60	20.0	13.2	9.4	7.2	5.8	5.0	4.15	3.70	3.15
		90	24.8	16.2	11.4	8.3	6.5	5.5	4.60	4.05	3.40
		120	31.5	19.5	14.3	10.4	7.4	6.4	5.4	4.75	4.10
		183	112	64.0	39.5	22.2	14.5	12.0	9.7	8.5	7.00
4825	Redwood Creek at Orick, Calif.	1	53.0	35.4	25	17.3	11.0	8.4	6.5	5.2	3.75
		7	54.5	37.5	27	18.3	11.7	9.0	6.9	5.6	4.1
		15	57	40	29	20.0	12.7	9.8	7.9	6.5	4.8
		30	62	43	31	21.4	14.0	11.0	8.8	7.4	5.6
		60	82	52	35	23.8	16.8	13.2	9.8	8.0	6.2
		90	100	65	44	29.8	20.3	15.2	11.4	9.3	7.1
		120	126	80	57	40	25	19.5	14.9	12.0	9.4
		183	423	242	154	95	58	47	36	30.5	23.2
4895	Antelope Creek near Tennant, Calif.	1	13.2	12.0	10.3	7.9	5.4	4.35	3.40	2.90	2.30
		7	13.7	12.3	10.5	8.6	5.6	4.60	3.65	3.15	2.55
		15	14.0	12.6	11.0	9.0	6.0	4.90	4.05	3.45	2.90
		30	14.3	13.2	11.7	9.3	6.1	5.15	4.35	3.85	3.15
		60	16.3	14.5	12.7	9.7	6.8	5.7	4.9	4.35	3.55
		90	17.5	15.9	14.3	11.4	7.8	6.7	5.7	4.95	4.05
		120	19.3	17.7	15.9	12.9	9.3	8.0	7.0	6.3	5.3
		183	25.0	21.0	19.8	17.0	13.1	11.0	9.8	9.5	9.3
5010	Sprague River near Chiloquin, Oreg.	1	350	260	203	150	110	103	89	80	68
		7	370	280	225	173	133	128	117	108	93
		15	380	295	240	189	148	140	128	115	100
		30	390	304	249	200	160	153	139	126	107
		60	400	313	260	212	176	163	149	139	124
		90	425	330	273	225	183	170	158	150	140
		120	450	350	284	240	190	180	164	158	150
		183	490	380	317	260	209	190	175	168	160
5120	Fall Creek at Copco, Calif.	1	31.0	30.2	29.5	28.0	26.0	24.9	23.7	22.8	21.7
		7	31.2	30.3	29.8	28.2	26.2	25.1	24.0	23.2	22.2
		15	31.3	30.5	30.0	28.6	26.4	25.3	24.5	23.7	22.8
		30	31.5	31.0	30.2	28.9	26.7	25.7	24.9	24.2	23.2
		60	32.5	31.7	30.5	29.2	27.2	26.2	25.3	24.9	23.8
		90	33.2	32.2	31.4	30.0	27.9	27.0	26.2	25.5	24.5
		120	34.4	33.3	32.2	30.8	28.9	28.0	27.2	26.9	25.9
		183	38.0	35.3	34.8	33.0	31.0	29.8	29.2	29.0	28.9
5195	Scott River near Fort Jones, Calif.	1	84	73	61	40	22.5	17.0	12.3	9.2	6.4
		7	89	76	63	43	25.0	18.2	13.5	11.0	7.6
		15	92	79	65	46	26.5	20.0	15.2	12.7	9.2
		30	96	84	71	49	27.5	21.5	17.0	14.5	11.0
		60	119	98	80	56	31.5	25.5	20.0	17.0	13.1
		90	137	112	95	69	38.0	31.3	25.5	20.7	15.3
		120	178	139	112	82	49	39.5	33.5	28.5	22.0
		183	495	282	195	128	83	65.0	56.0	53.0	49.0

TABLE 8.—*Low-flow frequency table for selected stream-gaging stations*—Continued

Station No.	Gaging station	Number of consecutive days	Ordinates of low-flow frequency curves, in cubic feet per second, for indicated recurrence intervals, in years								
			1.02	1.10	1.3	2.0	5.0	10	20	30	50
5225	Salmon River at Somesbar, Calif.	1	255	220	190	140	97	82	69	60	52
		7	270	230	195	150	103	85	72	65	56
		15	280	237	200	158	107	90	77	70	60
		30	295	255	215	163	110	94	82	75	65
		60	380	300	240	178	121	105	90	82	71
		90	440	355	290	210	137	120	105	91	77
		120	580	450	355	247	163	141	124	113	95
		183	1,450	910	640	410	252	200	178	172	163
5255	Trinity River at Lewiston, Calif.	1	210	180	152	109	70	56	44	37	30
		7	220	188	156	119	74	59	47	41	33
		15	230	195	162	124	78	63	52	45	37
		30	240	210	175	130	81	67	56	50	41
		60	310	245	197	142	91	75	63	56	46
		90	360	290	237	170	106	90	75	64	52
		120	480	370	290	202	130	110	94	84	69
		183	1,330	780	530	335	207	162	142	138	130
5260	Trinity River near Douglas City, Calif.	1	240	204	175	128	81	65	51	43	35
		7	246	212	179	139	85	68	54	48	38
		15	255	220	185	145	90	73	60	52	43
		30	265	240	200	150	93	78	65	58	48
		60	340	270	225	163	106	86	73	65	53
		90	390	315	260	193	125	105	86	74	60
		120	520	400	315	227	150	130	109	97	80
		183	1,520	845	570	365	232	185	164	160	150
5270	Trinity River near Burnt Ranch, Calif.	1	365	305	250	170	105	83	66	57	47
		7	380	320	260	187	111	88	70	62	51
		15	400	330	270	200	117	94	78	68	57
		30	422	415	295	209	122	99	83	75	62
		60	560	435	337	230	138	113	94	83	69
		90	655	520	417	283	165	136	113	95	78
		120	880	680	520	348	209	171	142	128	103
		183	2,400	1,450	980	610	355	269	231	226	209
5285	Hayfork Creek near Hyampom, Calif.	1	44	38	31	22.0	13.5	10.5	8.0	6.7	5.4
		7	46	39	32	24.0	14.3	11.1	8.7	7.4	5.8
		15	48	40	34	25.5	15.0	11.9	9.7	8.2	6.7
		30	51	44	36	26.5	16	13.0	10.5	9.2	7.4
		60	62	50	41	28.5	18	14.3	11.9	10.5	8.3
		90	70	58	48	35.0	21	17.5	14.3	12.2	9.7
		120	86	71	58	42	26	22.0	18.5	16.5	13.3
		183	223	133	94	66	43	34.0	29.0	28.0	26.5
5290	South Fork Trinity River near Salyer, Calif.	1	127	110	91	66	42	33	26	22.0	17.8
		7	132	113	94	71	44	35	28	24.0	19.5
		15	138	116	98	74	46	37	31	26.5	22.0
		30	142	127	105	77	48	40	33	29.5	24
		60	187	145	119	83	54	44	37	33.0	27
		90	215	172	140	102	63	53	44	38	31
		120	290	222	172	121	77	66	56	50	41
		183	850	475	320	200	125	98	84	82	77
5300	Trinity River near Hoopa, Calif.	1	680	580	480	347	217	173	135	113	91
		7	705	600	495	377	230	182	145	125	100
		15	740	620	515	395	243	195	160	138	113
		30	770	680	560	410	253	207	173	153	125
		60	1,010	790	635	445	285	235	195	173	142
		90	1,190	940	760	540	335	282	235	198	160
		120	1,600	1,220	940	645	410	350	295	262	215
		183	4,550	2,650	1,770	1,100	670	515	448	438	410
5320	South Fork Smith River near Crescent City, Calif.	1	187	160	137	107	82	76	70	66	62
		7	198	168	142	111	85	77	72	69	64
		15	202	173	145	117	89	79	73	71	66
		30	218	178	155	120	91	81	76	73	69
		60	290	220	173	132	95	86	79	76	71
		90	345	265	210	152	104	93	86	81	73
		120	470	355	265	180	120	106	97	90	81
		183	1,180	760	520	315	183	145	132	126	120
5325	Smith River near Crescent City, Calif.	1	375	325	285	230	183	168	155	148	140
		7	395	340	293	240	188	171	160	153	145
		15	405	350	300	248	195	175	163	157	148
		30	430	360	320	254	198	178	168	162	153
		60	560	435	350	275	208	190	175	168	158
		90	660	520	420	313	225	205	190	177	163
		120	890	675	520	362	254	228	210	199	180
		183	2,330	1,430	980	610	370	300	275	265	254

In the course of this analysis it became evident that for each gaging station there is a relation between the low-flow frequency curves and the flow-duration curve. This relation is more consistent for low-flow frequency curves for durations of 120 days or less than it is for the 183-day curves, because only base flow is involved in the discharges for the shorter durations. The paragraphs that follow present a generalized summary of the characteristics of the low-flow frequency curves for durations ranging from 1 day to 120 days and for recurrence intervals ranging from 2 to 50 years.

1. For recurrence intervals greater than 2 years, the graphs have only slight curvature when plotted on logarithmic extreme-value probability paper.
2. The graphs are roughly parallel for a particular station.
3. The relation between the low-flow frequency curve for 7 days duration at any station and the flow-duration curve for that same station is that shown in the upper part of table 9.
4. There is variation in the spacings between the roughly parallel low-flow frequency curves, but average values of the spacings at the 25 stations are as follows:
   a. 1-day discharges are approximately 6 percent smaller than 7-day discharges.
   b. 15-day discharges are approximately 9 percent larger than 7-day discharges.
   c. 30-day discharges are approximately 19 percent larger than 7-day discharges.
   d. 60-day discharges are approximately 34 percent larger than 7-day discharges.
   e. 90-day discharges are approximately 55 percent larger than 7-day discharges.
   f. 120-day discharges are approximately twice as large as 7-day discharges.

   Fall Creek, with its equable flow, shows wide departure from the percentages shown above. The 1-day discharge there is only 1 percent smaller than the 7-day discharge; the 120-day discharge is only 13 percent larger than the 7-day discharge.

The characteristics of the low-flow frequency curves for 183 days duration differ from those for the shorter durations, because fairly large quantities of surface runoff, particularly snowmelt, are included in the 183-day periods, whereas the shorter periods involve only base flow. It is to be expected, therefore, that relationships between the low-flow frequency and flow-duration curves will differ in the three physiographic sections, because of differences in runoff characteristics. The bottom part of table 9 shows the relations for the northern California Coast Ranges and the Klamath Mountains. The relations for the three gaging stations in the Southern Cascade Mountains showed considerable scatter, but their average was similar to that for Klamath Mountain stations.

The data in table 8 are in convenient form for use in studies of water supply, water power, and pollution control during periods of critically low flow, in those situations where the construction of storage facilities is not contemplated. Where the need for within-year storage is apparent and economic considerations govern the design of the storage facility, the data in these tables may be used to construct a frequency-mass curve that represents the total runoff available for a critical period of specified recurrence interval. The traditional mass-curve method of analyzing the storage required to maintain given draft rates may then be applied (Linsley and Franzini, 1955, p. 138–140). An example of this method of analysis, shown on figure 12, is self-explanatory. The curve of total runoff available, corresponding to a 20-year recurrence interval, is obtained by plotting the volume of runoff for various durations of minimum flow against the duration period.

TABLE 9.—*Relation of low-flow frequency and flow-duration curves for durations of 7 and 183 consecutive days*

Duration (days)	Physiographic section	Average recurrence interval, in years, of discharges corresponding to flow-duration curve percentiles indicated below										
		99.9	99.5	99	98	95	90	85	80	75	70	60
7	Entire region	50	20	11	6.0	2.65	1.55	----	----	----	----	----
183	Northern California Coast Ranges	----	----	----	----	----	46	27	14	6.5	3.3	1.45
	Klamath Mountains	----	----	----	----	----	46	10	6	3.7	2.6	1.55

FLOOD FREQUENCY

The magnitude and frequency of floods is an essential element in studies involving flood-control design or the economics of structures within the reach of flood waters. Accordingly, this section of the report provides regional flood-frequency graphs that may be used as guides in determining "design" flood flows for streams both gaged and ungaged, in the coastal basins of northern California. The application of these graphs is explained and the results are discussed in order to give some indication of the degree of reliability that may be expected from their use. The method of analysis used in deriving the regional graphs is only briefly described here; it is discussed in detail in a Geological Survey hydrology manual (Dalrymple, 1960). The regional concept of flood-frequency analysis has been adopted because flood-frequency curves for individual stations, particularly with the short

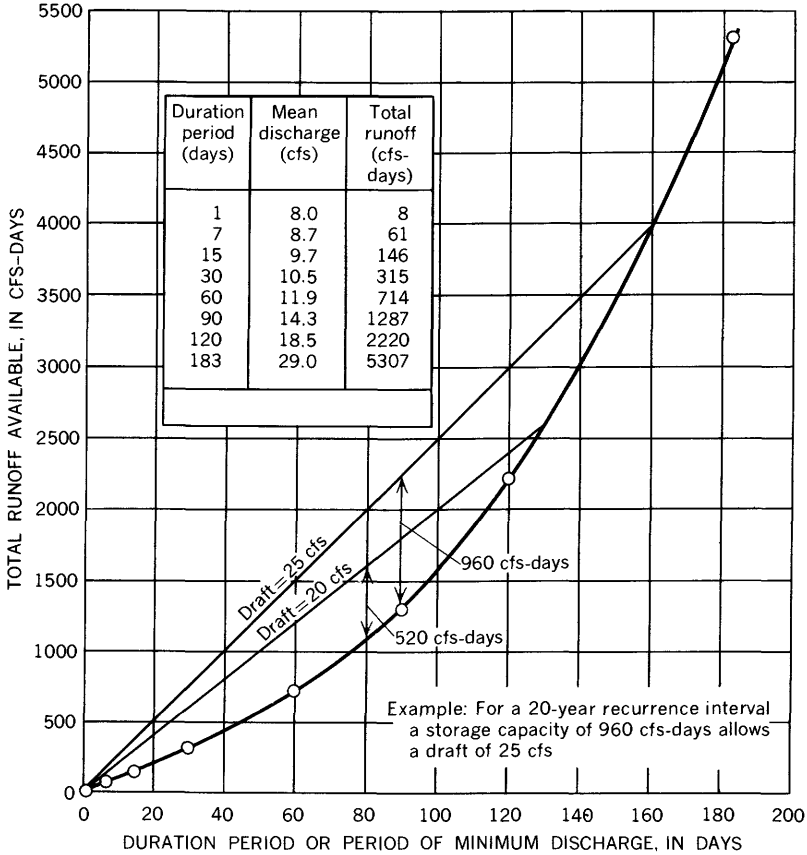


FIGURE 12.—Frequency-mass curve and storage-draft lines for Hayfork Creek near Hyampom, Calif. (sta. 5285) for 20-year recurrence interval. Mean discharge from table 8.

records available, are felt to be inadequate for establishing flood criteria for design purposes. The flood series for a single station is a random sample and therefore may not be representative of the long-term average distribution of flood events at the gaging station.

The streamflow records used in this study were those whose peak discharges were not seriously affected by storage or diversion. A common base period is required for all streamflow records used in the regional analysis, and the 28-year period October 1931, to September 1959 was selected; the dearth of long-term streamflow records precluded the use of a longer base period. It was possible to extrapolate the flood-frequency curves beyond the base period with considerable confidence because of the availability of historical records, both qualitative and quantitative, of major floods that occurred in years prior to 1931. It is known for example, that the flood peaks of December 1861–January 1862 were the greatest since at least 1854. Evidence also indicates that the peak discharges of December 1955 were roughly of the same magnitude as those of 1861–62. For the gaging station on Klamath River near Klamath, Calif., it has been possible to compute the peak discharge from floodmarks for all notable floods that occurred prior to 1932. For each of those years between 1932 and 1959 when this station was not in operation, annual flood peaks were computed by routing flows recorded at the gaging stations on Klamath River at Somesbar, Calif., and Trinity River near Hoopa, Calif. Because these computed flows do not appear in any Geological Survey publications, they are presented here in table 10. Notable peak discharges recorded prior to 1932, at the few other stations then in operation, were also used in the regional analysis.

TABLE 10.—*Annual peak discharges of Klamath River near Klamath, Calif. (sta. 5305)*

Water year	Date	Discharge (cfs)	Remarks
1862	Dec. 1861	[1] 450,000	Greatest flood in 106 years.
1881	Feb. 1881	[1] 360,000	Fourth highest in 106 years.
1890	Feb. 1890	[1] 425,000	Third highest in 106 years.
1927	Feb. 1927	[1] 300,000	Fifth highest in 106 years.
1932	Mar. 1932	[2] 96,400	
1933	Mar. 1933	[2] 46,200	
1934	Mar. 1934	[2] 51,100	
1935	Apr. 1935	[2] 60,000	
1936	Jan. 1936	[2] 162,000	
1937	Apr. 1937	[2] 121,000	
1938	Dec. 1937	[2] 218,000	
1939	Dec. 1938	[2] 71,000	
1940	Feb. 1940	[2] 237,000	
1941	Mar. 1941	[2] 124,000	
1942	Feb. 1942	[2] 151,000	
1943	Jan. 1943	[2] 162,000	
1944	Mar. 1944	[2] 32,000	
1945	Feb. 1945	[2] 102,000	
1946	Dec. 1945	[2] 209,000	
1947	Feb. 1947	[2] 73,900	
1948	Jan. 1948	[2] 202,000	
1949	Mar. 1949	[2] 95,000	
1950	Mar. 1950	[2] 92,600	
1951	Feb. 5, 1951	173,000	
1952	Feb 2, 1952	195,000	
1953	Jan. 18, 1953	297,000	Sixth highest in 106 years.
1954	Jan. 28, 1954	133,000	
1955	Dec. 31, 1954	74,200	
1956	Dec. 22, 1955	425,000	Second highest in 106 years.
1957	Feb. 26, 1957	160,000	
1958	Feb. 25, 1958	236,000	
1959	Jan. 12, 1959	175,000	

[1] Computed from floodmarks and hydraulic properties of channel.
[2] Computed by routing flows recorded at stations on Klamath River at Somesbar, Calif. and Trinity River near Hoopa, Calif.

METHOD OF ANALYSIS

The analysis of the peak-flow data was performed in two separate steps, in conformance with Geological Survey practice. Computation of the mean annual flood at each gaging station represented the first step. Geological Survey usage defines an annual flood as the maximum momentary discharge occurring in a water year; the mean annual flood is the discharge indicated for a recurrence interval of 2.33 years when the array of annual floods for a station is plotted on extreme-value probability paper. Plotting positions for annual floods in the array are computed by use of the formula:

$$\text{Recurrence interval}=\frac{N+1}{M},$$

where N is the number of years of record, and M is the order number of each flood when ranked in descending order of magnitude.

The magnitude of the mean annual flood was determined for each station that had 5 or more years of record of annual peak discharge within the base period 1932–59, providing these annual maximum discharges were not seriously affected by regulation or diversion. Correlation techniques were used in the determination of the mean annual flood for those stations whose records were shorter than the base period. Only one gaging station in the region, meeting the criterion of 5 or more years of record of essentially unregulated peak discharge, was omitted from the study. Station 4895, Antelope Creek near Tennant in the Southern Cascade Mountains, has 7 years of record but the peak-flow correlation with nearby stations is poor. Table 11 lists the stations used in the study and the station numbers that identify them on the location map (pl. 5). Referring to plate 5, it is seen that station 4615 in the Russian River basin in California and station 3770 in the Rogue River basin in Oregon lie just outside the region being studied. These two stations were used for verification of the flood characteristics of streams near the perimeter of the delineated area.

Preparation of dimensionless composite flood-frequency curves, each representative of a large area, constituted the second step in the analysis. All gaging stations in table 11 that had 10 or more years of record were used in this part of the analysis. For each of these selected stations flood-frequency curves were drawn on extreme-value probability paper with discharge expressed as a ratio to the mean annual flood. For Klamath River at Klamath, Calif. (sta. 5305), the magnitudes of all major flood peaks in the past 106 years are known and were used in the construction of the flood-frequency curve. For the other stations in California, where it was known only that the flood peaks of December 1955 were roughly equivalent to those of 1961–62, the magnitude of the 1955 peak was plotted with a recurrence interval of both 107 years and 53.5 years, indicating that this magnitude represented both the highest and second highest discharge

TABLE 11.—*Mean annual floods and associated hydrologic factors at selected stream-gaging stations*

[All mean annual discharges have been adjusted to the 28-year base period, 1932–59]

Station No.	Gaging station	Drainage area (sq mi)	Period of record	Mean annual flood (cfs)	Mean annual basinwide precipitation (in.)
	Northern California Coast Ranges				
[1] 3770	Illinois River at Kerby, Oreg	364	1928–59	27,000	----------
[1] 4615	East Fork Russian River near Calpella, Calif	93.0	1942–59	7,640	----------
4730	Middle Fork Eel River below Black Butte River, near Covelo, Calif	367	1952–59	30,000	60
4740	Eel River below Dos Rios, Calif	1,481	1912–13, 1952–59	88,000	53
4745	North Fork Eel River near Mina, Calif	251	1954–59	18,000	58
4755	South Fork Eel River near Branscomb, Calif	43.9	1947–59	6,500	79
4765	South Fork Eel River near Miranda, Calif	537	1941–59	47,300	70
4770	Eel River at Scotia, Calif	3,113	1911–15, 1917–59	180,000	59
4775	Van Duzen River near Dinsmores, Calif	80.2	1954–58	8,300	74
[2] 4785	Van Duzen River near Bridgeville, Calif	214	1912–13, 1940–59	18,600	72
4790	Yager Creek near Carlotta, Calif	127	1954–55, 1957–59	10,000	60
4800	Jacoby Creek near Freshwater, Calif	6.07	1955–59	540	54
4805	Mad River near Forest Glen, Calif	144	1954–59	10,000	60
4810	Mad River near Arcata, Calif	485	1911–13, 1951–59	32,000	64
4815	Redwood Creek near Blue Lake, Calif	67.5	1954–58	5,200	80
4825	Redwood Creek at Orick, Calif	278	1912–13, 1954–59	18,500	80
	Klamath Mountains				
5175	Shasta River near Yreka, Calif	[3] 657	1934–41, 1946–59	1,060	19
5195	Scott River near Fort Jones, Calif	662	1942–59	6,200	33
5225	Salmon River at Somesbar, Calif	746	1912–15, 1928–59	19,000	57
5255	Trinity River at Lewiston, Calif	726	1912–59	19,800	59
5260	Trinity River near Douglas City, Calif	1,017	1945–51	22,500	56
5270	Trinity River near Burnt Ranch, Calif	1,438	1932–40, 1957–59	37,400	57
5285	Hayfork Creek near Hyampom, Calif	379	1954–59	8,750	43
5290	South Fork Trinity River near Salyer, Calif	899	1951–59	22,000	50
5300	Trinity River near Hoopa, Calif	2,846	1912–14, 1917–18, 1932–59	65,300	55
5305	Klamath River near Klamath, Calif	12,100	1911–26, 1951–59 [4]	152,000	42
5320	South Fork Smith River near Crescent City, Calif	295	1955–59	38,000	116
5325	Smith River near Crescent City, Calif	613	1932–59	75,000	111
	Southern Cascade Mountains				
5010	Sprague River near Chiloquin, Oreg	1,580	1921–59	2,280	23
5025	Williamson River below Sprague River near Chiloquin, Oreg	3,000	1917–59	2,890	24
5120	Fall Creek at Copco, Calif	20	1929–59	174	24

[1] Outside the report region.
[2] Records for stations on Van Duzen River at and near Bridgeville, Calif. have been combined.
[3] Actual drainage area above gage is 796 sq mi, but 139 sq mi above Dwinnell Reservoir is non-contributing.
[4] Annual peak flows for period 1932-1950 computed by routing technique.

in 106 years. The well-defined portion of the flood-frequency curve for each station, generally a straight line or gentle curve, was extrapolated to the 100-year recurrence interval, with the provision that the extrapolation pass through one of these two plotted points or pass between them. A statistical test was then performed to define groups of stations that were homogeneous with respect to slope of the flood-frequency curve. Finally, a median curve was drawn for each group of homogeneous stations. Each median curve is considered to be the dimensionless flood-frequency curve for the subregion in which its group of stations lies.

The regional type of analysis described briefly in the preceding paragraphs is applicable to gaging stations in the northern California Coast Ranges and the Klamath Mountains, but could not be applied in the Southern Cascade Mountains (subregion 4 on pl. 5). Only three gaging stations with records unimpaired by regulation or diversion are available for regional analysis in that 8,000-square-mile lava area. Two of these stations, Sprague River near Chiloquin, Oreg. (sta. 5010), and Williamson River below Sprague River near Chiloquin, Oreg. (sta. 5025), can hardly be classed as independent, because the former station contributes more than 75 percent of the peak flow that passes the latter station. Both rivers drain extensive marsh areas that provide natural regulation for the high flows that result from snowmelt or rain on snow. No parallel can be drawn between these rivers and the California streams; far from being outstanding, the flood peaks of December 1955 on the two rivers were exceeded in the following April of 1956, and these peaks of April 1956, in turn, were exceeded in other years during the period of record. There is no information available concerning the floods of 1861–62 in subregion 4.

The third gaging station in the Southern Cascade Mountains, Fall Creek at Copco, Calif. (sta. 5120), is spring fed and normally has very steady flow. Winter rains, however, may cause sharp flood peaks, but these represent a low discharge per square mile of drainage area. As a matter of general interest, flood-frequency curves for each of the three stations, based on complete periods of record, are presented on figures 13 and 14. Because these stations could not be included in a regional type of analysis, the discussion that follows is confined to gaging stations in the northern California Coast Ranges and the Klamath Mountains.

MEAN ANNUAL FLOOD

The magnitude of the mean annual flood in basins in northwestern California is related primarily to the size of drainage area and to the magnitude of the mean annual storm. Mean annual precipitation is an excellent index of the relative magnitude of the mean annual

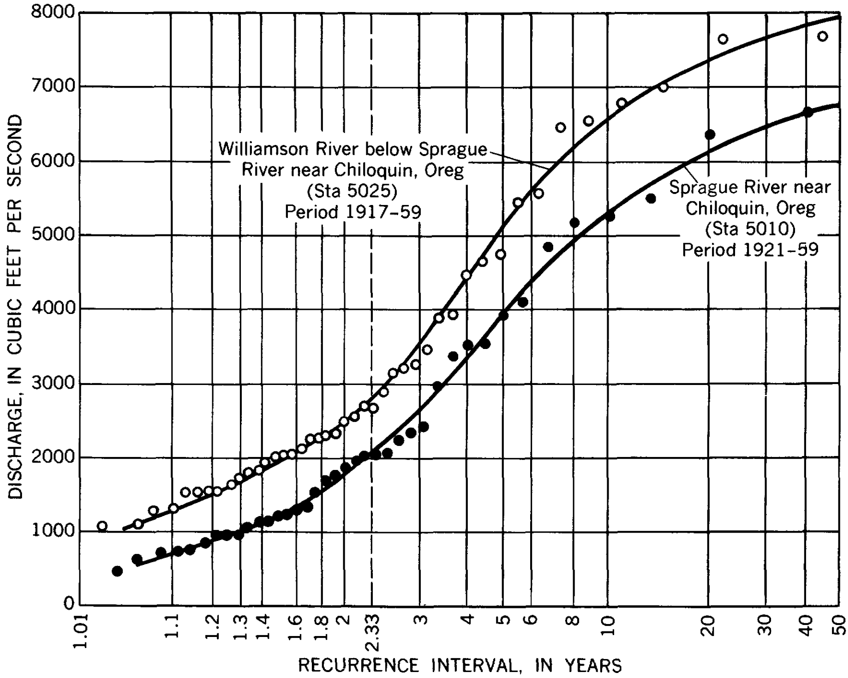


FIGURE 13.—Flood-frequency curves for Sprague River near Chiloquin, and for Williamson River below Sprague River near Chiloquin, Oreg.

storm because the bulk of the annual precipitation in the region occurs during several general storms each year, and all stations experience the same number of general storms in any given year. Subsurface storage also exerts a significant influence on the magnitude of the mean annual flood. Surface storage, on the other hand, is a negligible factor in this study, because there are no sizable lakes or reservoirs that are uncontrolled, and streams that are seriously affected by artificially regulated storage have been excluded from the analysis. Because subsurface storage is related to the infiltration capacity, or the permeability of the mantile rock, it is logical to expect the mean annual flood in the northern California Coast Ranges to differ from that in the Klamath Mountains, when all other factors are equal.

On figure 15 the mean annual floods for basins in the northern California Coast Ranges have been plotted against drainage area. Each point is labelled with (1) the number of the gaging station for identification purposes, and (2) the mean annual precipitation for the basin upstream from the station. The precipitation is seen to range from 53 inches to 80 inches, and within this relatively small

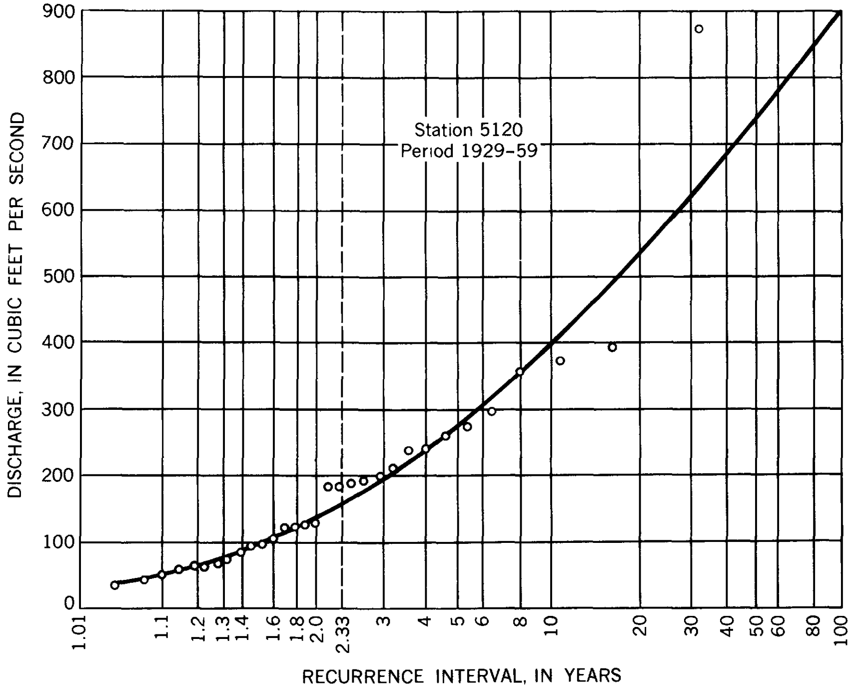


FIGURE 14.—Flood-frequency curve for Fall Creek at Copco, Calif.

range no correlation is apparent between mean annual flood and mean annual precipitation. A straight line averaging the plotted points has the equation

$$\text{Mean annual flood } (Q_{2.33})=130\ A^{0.91},$$

where A is drainage area in square miles.

Plate 6 is a similar plot for basins in the Klamath Mountains. The wide range in mean annual precipitation for this subregion, 19 inches to 116 inches, has a very pronounced effect on the magnitude of the mean annual flood. The equation of the family of curves on plate 6 is

$$Q_{2.33}=KA^{0.91}$$

where K is a variable that is related to the mean annual precipitation. This latter relation is shown graphically in the box on the right-hand side of plate 6. Comparing the graphs of figure 15 and plate 6, it is concluded that for the same size of drainage area and the same annual precipitation, mean annual floods are greater in the northern California Coast Ranges than in the Klamath Mountains. The basis for this conclusion is that the coefficient of 130 in the

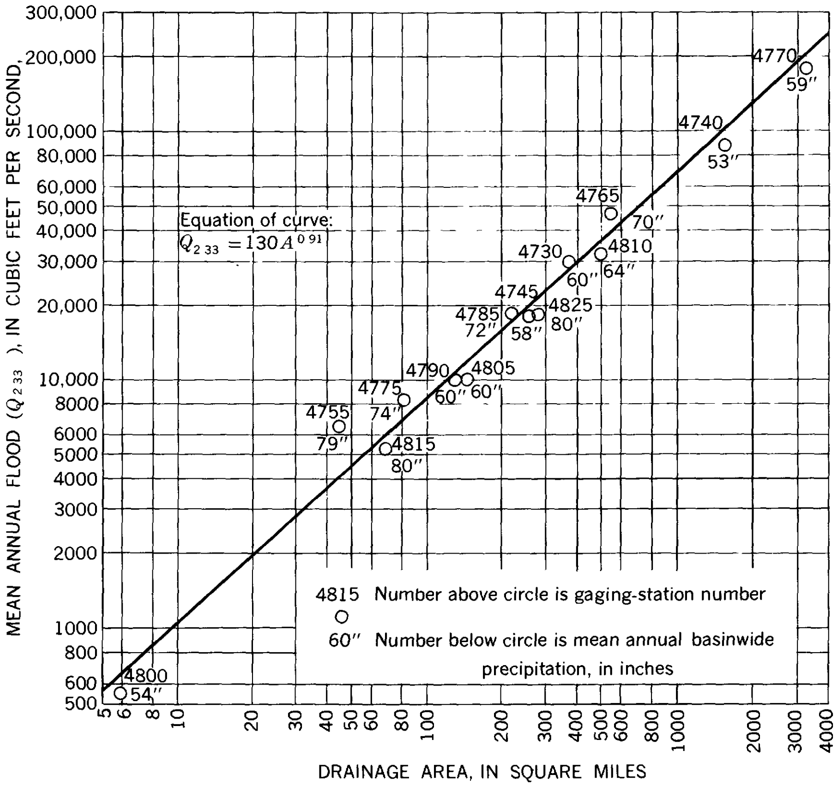
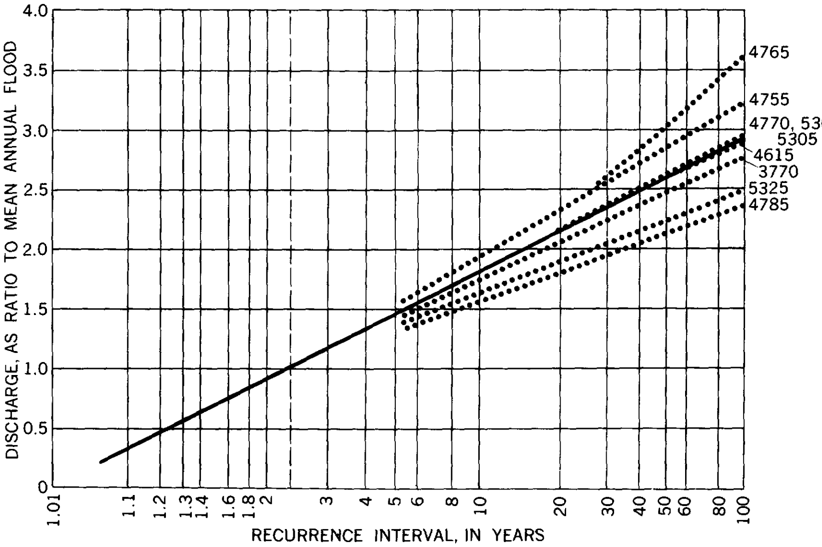


FIGURE 15.—Relation of mean annual flood to drainage area in the northern California Coast Ranges

Coast Ranges formula is equivalent to a K corresponding to about 90 inches of mean annual precipitation in the Klamath Mountains formula, yet the precipitation in the California Coast Ranges ranged from only 53 inches to 80 inches. This result is not surprising in view of the fact that the Klamath Mountains has the more permeable mantle rock.

DIMENSIONLESS FLOOD-FREQUENCY CURVE

The slope of the flood-frequency curve for northern California streams is influenced primarily by the difference in severity between the storms that cause the milder floods, such as the mean annual flood, and the storms that cause the infrequent major floods. The greater the disparity between these two types of storms, the greater the ratio of major flood peak to the mean annual flood peak, and therefore the steeper the slope of the flood-frequency curve. Furthermore, it is almost axiomatic that the more humid the area, the less variability there is in the precipitation. Consequently, the areas closest to



The solid line is the flood-frequency curve applicable for the entire subregion. This curve is the median of the flood-frequency curves for nine individual stations in the subregion. The curves for the individual stations are the dotted lines with identifying station numbers.

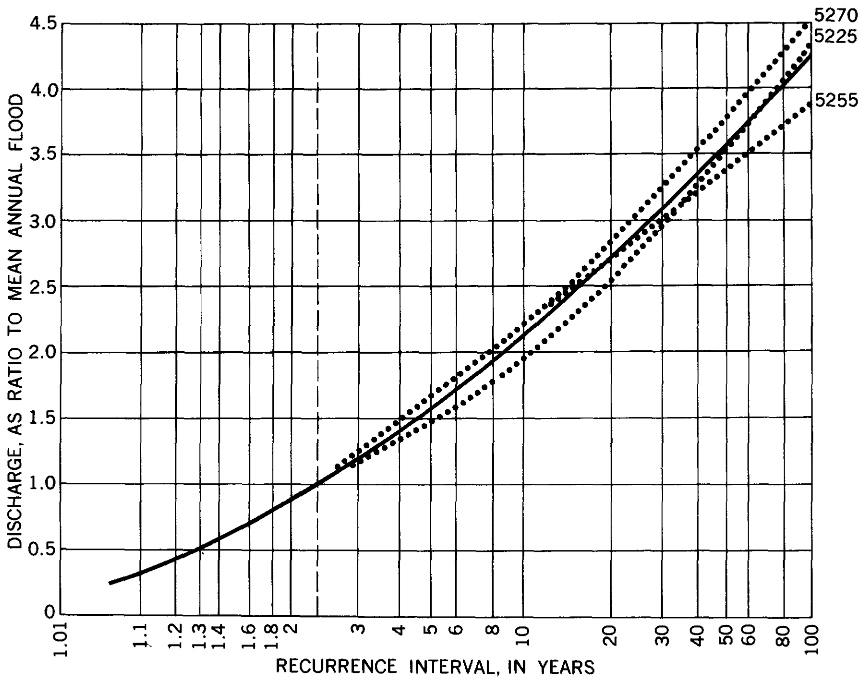
FIGURE 16.—Dimensionless flood-frequency curve for subregion 1.

the coast, because they in general, have the greatest precipitation, would be expected to have flood-frequency curves that show the flattest slopes. Infiltration capacity has little effect on the peak discharge during major floods, because these floods are generally associated with rains that last for many days, and as a consequence, the ground becomes well saturated and the infiltrating rain amounts to only a small percentage of the storm precipitation. Elevation may also be a factor because during these prolonged major storms there is generally some snowmelt which augments the runoff directly attributable to rainfall. Thus the flood-frequency curves for the basins of higher elevation in northwestern California tend to have steeper slopes.

The statistical tests for homogeneity of slope of the flood-frequency curves bear out these premises. These tests have resulted in the establishment of the areas of homogeneity shown on plate 5. Subregion 1 has the flattest flood-frequency curves; lying closest to the ocean, it is the most humid area and has the lowest elevations. Figure 16 shows the dimensionless flood-frequency curve for this subregion, based on the nine gaging stations in subregion 1 that had been in operation for at least 10 years. As an indication of the degree to which this flood-frequency curve is representative of the subregion, the individual flood-frequency curves for the nine stations have been included in figure 16. These individual curves, drawn as dotted lines, have a maximum departure of about 20 percent from the median curve for the subregion.

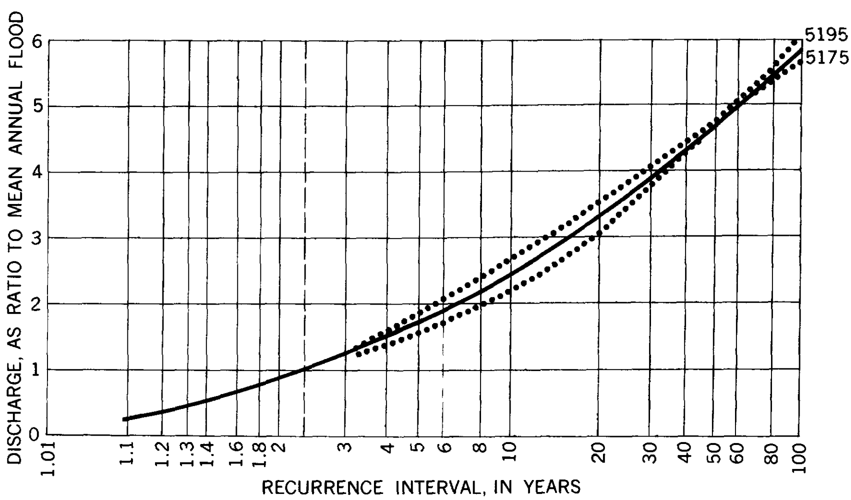
The slope of the flood-frequency curve for subregion 2, shown in figure 17, is steeper than that of the flood-frequency curve for subregion 1. This is attributed to the generally more variable storm precipitation and higher elevations found in subregion 2. There are only three stations with 10 or more years of record in subregion 2, and consequently the flood-frequency curve representative of the subregion lacks the high degree of confirmation obtainable from a large number of gaging stations. The flood-frequency curves for the 3 individual stations, drawn as dotted lines on figure 17, show a maximum departure of less than 10 percent from the median curve for the subregion.

The flood-frequency curve for subregion 3 is shown in figure 18. This curve has the steepest slope of the three regional curves, reflecting the fact that subregion 3 is the least humid of the three subregions. Only two stations in the subregion have the requisite 10 years or more of record, and one of those—Shasta River near Yreka, Calif.



The solid line is the flood-frequency curve applicable for the entire subregion. This curve is the median of the flood-frequency curves for three individual stations in the subregion. The curves for the individual stations are the dotted lines with identifying station numbers.

FIGURE 17.—Dimensionless flood-frequency curve for subregion 2.



The solid line is the flood-frequency curve applicable for the entire subregion. This curve is the median of the flood-frequency curves for two individual stations in the subregion. The curves for the individual stations are the dotted lines with identifying station numbers.

FIGURE 18.—Dimensionless flood-frequency curve for subregion 3.

(sta. 5175)—has flood flows from the upper 139 square miles of its drainage area completely controlled by Lake Dwinnell. It was possible, however, to include this station in the analysis because releases from the lake are negligible during flood peaks. The 139 square miles above Lake Dwinnell are therefore considered noncontributing area for the purpose of flood-frequency analysis. The flood-frequency curves for the 2 individual stations drawn as dotted lines on figure 18, show a maximum departure of less than 10 percent from the median curve for subregion 3.

APPLICATION OF REGIONAL FLOOD-FREQUENCY CURVES

The regional graphs may be used as guides in the construction of flood-frequency curves for ungaged sites in either the northern California Coast Ranges or the Klamath Mountains. The first step in the process is to determine the mean annual flood for the ungaged site. If the site lies in the northern California Coast Ranges this is accomplished by entering figure 15 with the drainage area above the site. If the site lies in the Klamath Mountains, it is first necessary to obtain the mean annual basinwide precipitation from plate 2. This precipitation value and the drainage area are then applied to plate 6 to obtain the mean annual flood. The next step is to apply the value of the mean annual flood to the appropriate dimensionless composite (median) curve found in figure 16, 17, or 18. By multiplying the mean annual flood by the ratios shown on the regional flood-frequency curve, the discharges corresponding to selected frequencies are obtained. A sufficient number of discharges are computed to define the flood-frequency curve for the ungaged site.

HIGH FLOW—MAGNITUDE, DURATION, AND FREQUENCY

Studies involving the storage of flood waters require a knowledge of the magnitude, duration, and frequency of high flows. To fill the need for this information, high-flow frequency curves were prepared for all but 5 of the 31 stations, listed in table 11, that were used in the previously described flood-frequency analysis. The stations omitted were:

No.	*Station*
3770	Illinois River at Kerby, Oreg.
4615	East Fork Russian River near Calpella, Calif.
4740	Eel River below Dos Rios, Calif.
4800	Jacoby Creek near Freshwater, Calif.
5175	Shasta River near Yreka, Calif.

Stations 3770 and 4615 both lie outside the report area; station 4800, which had 5 years of record of momentary peak discharge, did not meet the criterion of 5 complete years of daily discharge record; stations 4740 and 5175 are downstream from reservoirs whose operation does not impair an analysis of annual momentary flood peaks, but which may seriously affect a study involving average flow rates during periods of high discharge. The method of analysis described in the paragraphs that follow is most appropriate for use on streams having one major high-water period per year, and for use where large reductions in outflow are desired. The principal advantage of the method is that it allows estimates of required storage to be made for ungaged streams.

The high flows selected for analysis were the maximum average rates of discharge each year for the following intervals of time: 1 day, 3 consecutive days, 7 consecutive days, 15 consecutive days, 30 consecutive days, 60 consecutive days, 120 consecutive days, 183 consecutive days, 274 consecutive days, and 365 consecutive days. It was realized that maximum 24-hour flow would have been a great deal more significant than maximum flow for 1 calendar day. The users of Geological Survey streamflow data, however, do not generally have maximum 24-hour flow rates available to them, and in addition, the maximum flow for so short a time interval, is generally not a critical factor in reservoir design. For these reasons, the rather artificial duration period of 1 calendar day was adopted for use in this study. The results obtained for discharge of this duration were surprisingly consistent.

In analyzing the high-flow data, each of the 10 duration periods was studied separately, using a method of analysis that closely paralleled that described in the preceding flood-frequency section of this report.

The base period was again the 28 years between October 1931 and September 1959. For each station and each duration period the data were arrayed, the recurrence interval for each item was computed, and each array was plotted on extreme-value probability paper and fitted with a straight line or smooth curve. The plotted data were then analyzed on a regional basis, thereby minmizing the statistical sampling error that might be introduced by treating each station individually in a time series. Also, this had the effect of making the resulting regional frequency curves applicable as guides in determining design flows for storage projects on ungaged, as well as gaged streams in the coastal basins of northern California. The same subregions used in the flood-frequency study and delineated on plate 5 were used in this analysis. As before, the 3 gaging stations in subregion 4 could not be considered typical of the entire subregion, and therefore no regional analysis of the Southern Cascade Mountains was made. Individual magnitude-duration-frequency relations for these 3 stations, Sprague River near Chiloquin, Oreg. (5010), Williamson River below Sprague River near Chiloquin, Oreg. (5025), and Fall Creek at Copco, Calif. (5120) are presented on figures 19, 20, and 21, respectively. The plotted points are not shown to avoid cluttering the diagrams.

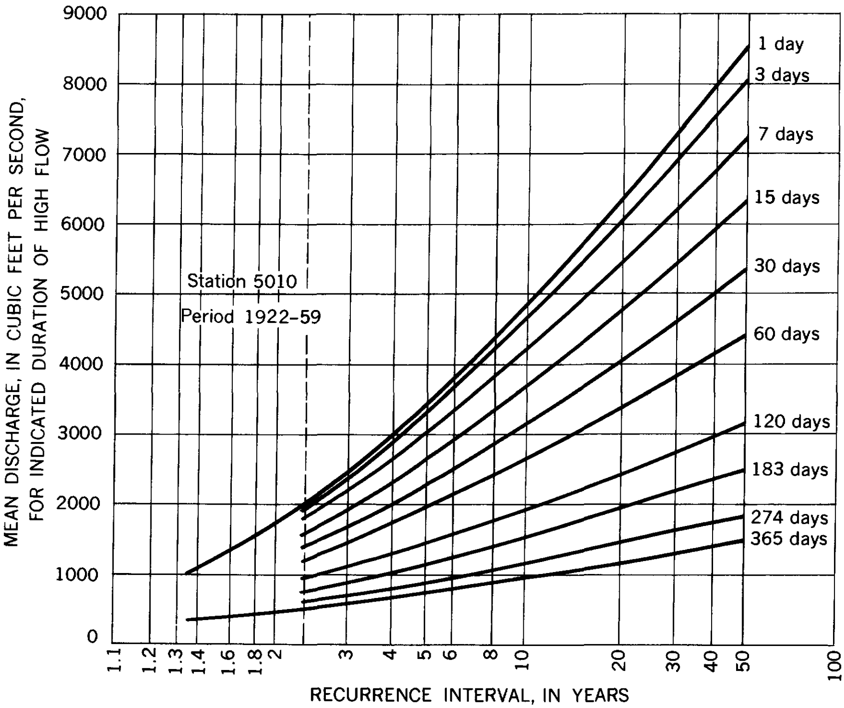


FIGURE 19.—High-flow frequency curves for Sprague River near Chiloquin, Oreg.

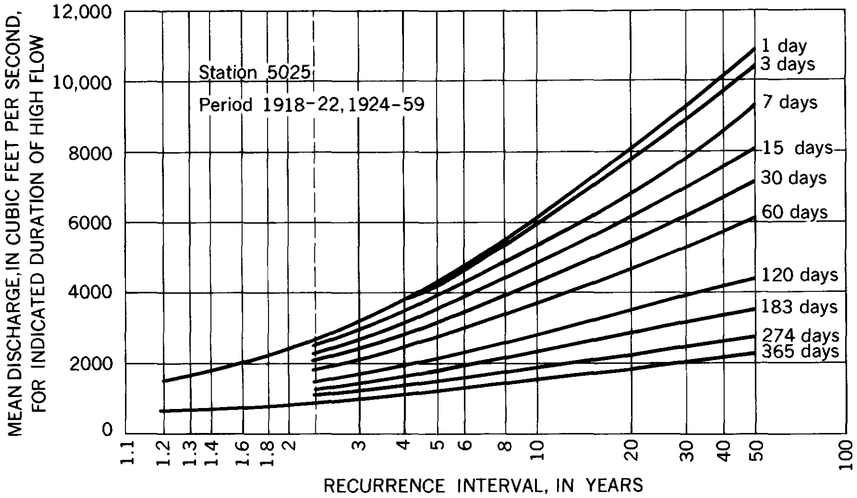


FIGURE 20.—High-flow frequency curves for Williamson River below Sprague River near Chiloquin, Oreg.

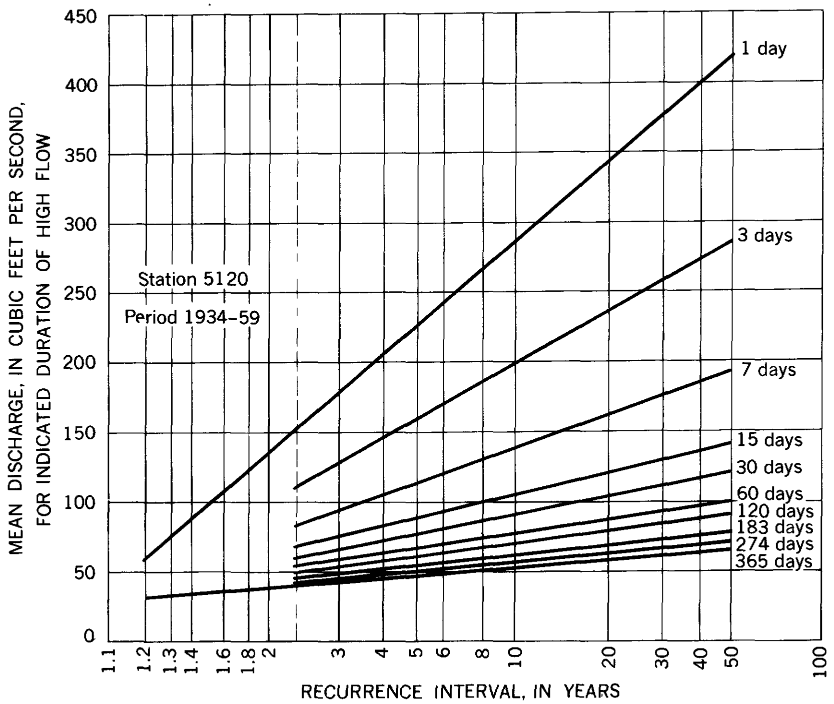


FIGURE 21.—High-flow frequency curves for Fall Creek at Copco, Calif.

The remaining 23 gaging stations used in this study are listed in table 12. The discharges shown for each duration are the graphic means for the individual arrays—that is, the discharge indicated for a recurrence interval of 2.33 years on each of the individual plots on extreme-value probability paper. These discharges, referred to hereafter as $Q_{2.33}$, were analyzed in precisely the same manner as were the mean annual floods in the preceding flood-frequency section of this report. $Q_{2.33}$ was found to be related to the size of drainage area and to the mean annual precipitation by the equation $Q=KA^{0.91}$. In this equation the parameter K varies with geologic characteristics, mean annual precipitation, and duration. With regard to geologic characteristics, the 23 stations lie in one or the other of two geologically homogeneous regions, the northern California Coast Ranges and the Klamath Mountains. In the northern California Coast Ranges, the basins investigated had a comparatively narrow range in mean annual precipitation (59–80 in.) and K was found to vary with duration alone. This is illustrated by figure 22. On this graph individual points have been plotted only for durations of 1 day, 30 days, and 365 days. Plotting the points for the other seven durations on this single diagram would have created a disorderly and obscuring effect.

In the Klamath Mountains, the wide range in mean annual precipitation, 33 inches to 116 inches, has a pronounced effect on the value of K. Figure 23 shows the variation of K with mean annual precipitation and duration of flow. To avoid cluttering the diagram the individual values of K have been plotted only for durations of 1 day, 30 days, and 365 days. It will be noted that 1 set of points, with mean annual precipitation equal to 42 inches, consistently plotted higher than the curves. This set of points represents the station on Klamath River near Klamath, Calif. (5305). Because of the complexity of the 12,100-square-mile area drained by the Klamath River, the lack of conformity of this station is not particularly surprising.

The values of K, as indicated by figures 22 and 23, may be compared by assuming the curves of figure 22 to represent an average annual precipitation of 70 inches. For durations of 120 days or more the values of K, corresponding to 70 inches of precipitation in each of the 2 physiographic provinces, are quite similar. As the duration periods decrease from 120 days, K values in the northern California Coast Ranges become increasingly larger than those in the Klamath Mountains. This development is not surprising. Because the Klamath Mountains have the more permeable mantle rock, a significantly larger percentage of the precipitation infiltrates into ground-water storage. Furthermore, some of the winter precipitation in the Klamath Mountains is retained for several months in the form of a mountain snowpack. The net result of these factors is a greater time

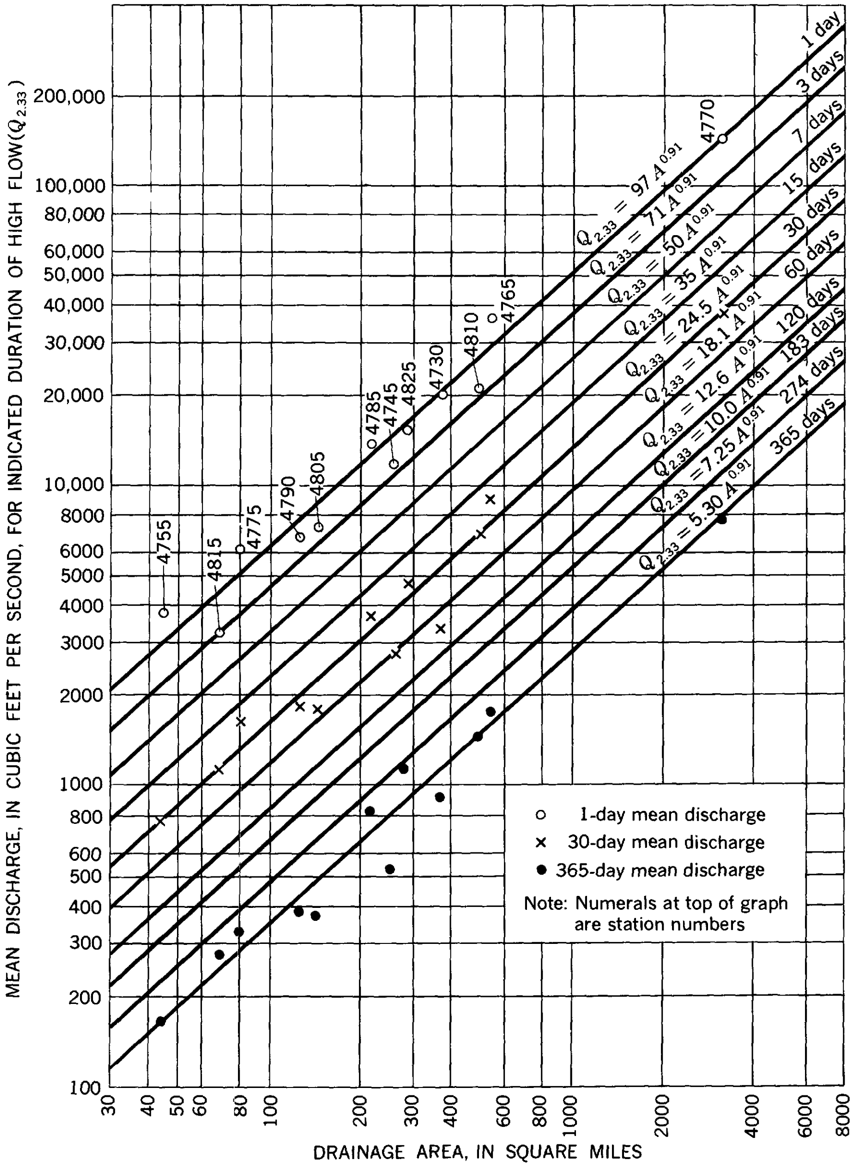


FIGURE 22.—Relation of $Q_{2.33}$, for high flows of various durations, to drainage area in northern California Coast Ranges.

TABLE 12.—*High flows, with recurrence interval of 2.33 years, for various durations at selected stream-gaging stations in California*

[Discharges for all stations have been adjusted to the 28-year base period, 1932–59]

Station No.	Gaging station	Drainage area (sq mi)	Period of record	Mean discharge ($Q_{2.33}$), in cubic feet per second, for indicated number of consecutive days										Mean annual basinwide precipitation (in.)
				1	3	7	15	30	60	120	183	274	365	
	California Coast Ranges													
4730	Middle Fork Eel River below Black Butte River, near Covelo	367	1952–59	20,200	13,100	9,200	6,000	3,330	2,500	2,160	1,680	1,140	910	60
4745	North Fork Eel River near Mina	251	1954–59	11,900	8,200	6,250	4,050	2,800	2,000	1,420	990	695	528	58
4755	South Fork Eel River near Branscomb	43.9	1947–59	3,750	2,420	1,730	1,090	770	570	420	312	220	167	79
4765	South Fork Eel River near Miranda	537	1941–59	36,000	26,000	18,000	12,300	8,900	6,850	4,850	3,450	2,330	1,780	70
4770	Eel River at Scotia	3,113	1911–15, 1917–59	146,000	107,000	78,000	55,000	39,000	27,700	19,500	14,400	10,100	7,700	59
4775	Van Duzen River near Dinsmores	80.2	1954–58	6,170	5,000	3,390	2,180	1,630	1,240	857	650	440	327	74
[1] 4785	Van Duzen River near Bridgeville	214	1912–13, 1940–59	13,700	11,200	7,700	5,050	3,670	2,780	2,010	1,540	1,060	820	72
4790	Yager Creek near Carlotta	127	1954–55, 1957–59	6,800	5,200	3,820	2,520	1,820	1,420	1,000	763	540	377	60
4805	Mad River near Forest Glen	144	1954–59	7,220	5,150	3,580	2,450	1,790	1,270	860	675	473	370	60
4810	Mad River near Arcata	485	1911–13, 1951–59	21,000	16,500	12,800	9,200	6,900	5,060	3,730	2,950	2,100	1,480	64
4815	Redwood Creek near Blue Lake	67.5	1954–58	3,200	2,700	1,800	1,430	1,100	745	615	513	365	274	80
4825	Redwood Creek at Orick	278	1912–13, 1954–59	15,000	11,900	9,200	6,280	4,750	3,290	2,650	2,100	1,520	1,120	80
	Klamath Mountains													
5195	Scott River near Fort Jones	662	1942–59	5,200	3,900	2,900	2,100	1,700	1,480	1,200	1,000	705	590	33
5225	Salmon River at Somesbar	746	1912–15, 1928–59	15,000	12,200	9,250	6,700	5,150	4,300	3,500	3,100	2,360	1,840	57
5255	Trinity River at Lewiston	726	1912–59	15,600	12,500	8,350	6,500	5,300	4,550	3,630	3,090	2,350	1,800	59
5260	Trinity River near Douglas City	1,017	1945–51	21,000	17,200	10,800	7,700	5,900	5,130	4,290	3,660	2,750	2,070	56
5270	Trinity River near Burnt Ranch	1,438	1932–40, 1957–59	30,000	23,000	15,800	11,500	9,400	7,500	6,250	5,100	3,750	2,970	57
5285	Hayfork Creek near Hyampom	379	1954–59	6,150	4,500	3,270	2,400	1,940	1,630	1,200	820	610	495	43
5290	South Fork Trinity River near Salyer	899	1951–59	18,300	14,600	11,000	8,400	6,400	5,200	3,780	2,940	2,050	1,650	50
5300	Trinity River near Hoopa	2,846	1912–14, 1917–18, 1932–59	56,000	46,000	34,000	24,600	18,900	15,600	12,400	10,500	7,850	5,950	55
5305	Klamath River near Klamath	12,100	1911–26, 1951–59	144,000	125,000	90,000	66,000	53,500	44,400	38,000	31,000	23,300	18,400	42
5320	South Fork Smith River near Crescent City	295	1955–59	28,000	20,300	14,200	9,700	6,780	5,300	4,000	3,300	2,500	1,900	116
5325	Smith River near Cresent City	613	1932–59	55,000	40,000	28,000	19,000	13,900	10,900	8,300	6,800	5,000	3,800	111

[1] Records for stations on Van Duzen River at and near Bridgeville have been combined.

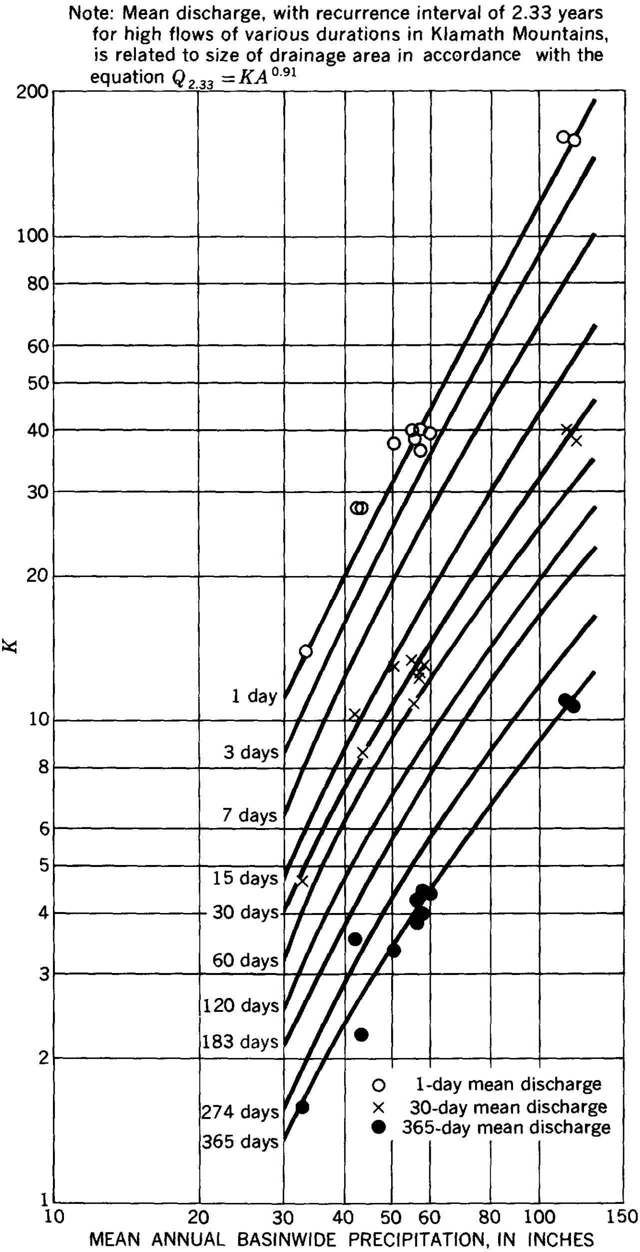


FIGURE 23.—Relation of *K*, for high flows of various durations, to mean annual precipitation in the Klamath Mountains.

lag between precipitation and runoff in the Klamath Mountains and, consequently, smaller K values for the durations of runoff shorter than 120 days.

The final step in the analysis of high flow was the construction of regional frequency curves for the various duration periods under consideration, using discharge expressed as a ratio of $Q_{2.33}$. All gaging stations in table 12 that had 10 or more years of record within the base period 1932–59 were used in this part of the analysis. These stations are listed in tables 13 and 14. It is seen that there is only one station, Scott River near Fort Jones, Calif. (5195), available for analysis in subregion 3. While the shapes of the high-flow frequency curves for this station are believed to be fairly representative of those for other basins in the subregion, it was felt that no generalizations concerning subregion 3 should be expressed until recently established gaging stations in the subregion have sufficient length of record to be included in the analysis. The magnitude-duration-frequency relations for the Fort Jones station are therefore presented in figure 24 without further comment.

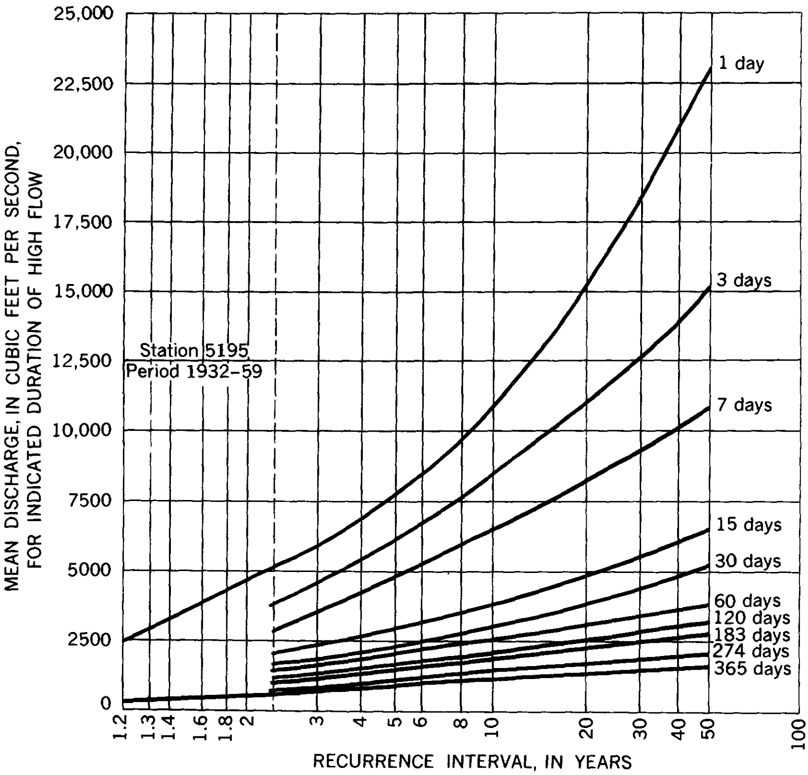


FIGURE 24.—High-flow frequency curves for Scott River near Fort Jones, Calif.

TABLE 13.—*High flows, with recurrence interval of 10 years, for various durations at selected stream-gaging stations in California*

[Ratio to the mean discharge shown in table 12]

Station No.	Gaging station and discharge units	Mean discharge for indicated number of consecutive days									
		1	3	7	15	30	60	120	183	274	365
	Subregion 1										
4755	South Fork Eel River near Branscomb, cubic feet per second	7,200	4,500	3,030	1,820	1,300	1,000	700	530	350	278
	ratio	1.92	1.86	1.75	1.67	1.69	1.75	1.67	1.70	1.59	1.66
4765	South Fork Eel River near Miranda, cubic feet per second	67,000	47,400	30,000	20,000	14,400	10,300	7,400	5,400	3,800	2,850
	ratio	1.86	1.82	1.67	1.63	1.62	1.50	1.53	1.53	1.63	1.60
4770	Eel River at Scotia, cubic feet per second	262,000	194,000	125,000	87,400	61,200	46,300	32,900	23,800	16,700	13,200
	ratio	1.79	1.81	1.60	1.59	1.57	1.67	1.69	1.65	1.65	1.71
[1]4785	Van Duzen River near Bridgeville, cubic feet per second	21,000	17,200	11,900	8,000	5,830	4,380	3,110	2,360	1,610	1,220
	ratio	1.53	1.54	1.55	1.58	1.59	1.58	1.55	1.53	1.52	1.49
5300	Trinity River near Hoopa, cubic feet per second	103,000	82,000	62,000	43,800	34,000	26,000	20,200	17,100	12,900	9,800
	ratio	1.84	1.78	1.82	1.78	1.80	1.67	1.63	1.63	1.64	1.65
5305	Klamath River near Klamath, cubic feet per second	261,000	215,000	156,000	122,000	94,500	72,000	56,500	48,000	37,300	29,400
	ratio	1.81	1.72	1.73	1.85	1.77	1.62	1.49	1.55	1.60	1.60
5325	Smith River near Crescent City, cubic feet per second	92,000	69,200	45,000	29,700	21,600	16,600	12,400	9,670	6,900	5,160
	ratio	1.67	1.73	1.61	1.56	1.55	1.52	1.49	1.42	1.38	1.36
	Subregion 2										
5225	Salmon River at Somesbar, cubic feet per second	27,000	23,100	16,500	11,200	8,300	6,700	5,430	4,800	3,700	2,850
	ratio	1.80	1.89	1.78	1.67	1.61	1.56	1.55	1.55	1.57	1.55
5255	Trinity River at Lewiston, cubic feet per second	30,000	22,400	13,900	10,200	8,450	7,000	5,700	5,000	3,830	3,020
	ratio	1.92	1.79	1.66	1.57	1.59	1.54	1.57	1.62	1.63	1.68
5270	Trinity River near Burnt Ranch, cubic feet per second	59,000	42,000	28,400	20,000	16,000	12,400	10,300	8,600	6,230	4,900
	ratio	1.97	1.83	1.80	1.74	1.70	1.65	1.65	1.69	1.66	1.65
	Subregion 3										
5195	Scott River near Fort Jones, cubic feet per second	10,900	8,500	6,500	3,840	3,000	2,570	2,150	1,890	1,290	1,100
	ratio	2.10	2.18	2.24	1.83	1.76	1.74	1.79	1.89	1.83	1.86

[1] Records for stations on Van Duzen River at and near Bridgeville have been combined.

TABLE 14.—*High flows, with recurrence interval of 50 years, for various durations at selected stream-gaging stations in California*

[Ratio to the mean discharge shown in table 12]

Station No.	Gaging station and discharge units	Mean discharge for indicated number of consecutive days									
		1	3	7	15	30	60	120	183	274	365
	Subregion 1										
4755	South Fork Eel River near Branscomb......cubic feet per second	10,600	6,600	4,300	2,530	1,830	1,420	970	745	476	388
	ratio	2.83	2.73	2.49	2.32	2.38	2.49	2.31	2.39	2.16	2.32
4765	South Fork Eel River near Miranda......cubic feet per second	98,000	69,000	42,300	26,500	18,600	13,100	9,250	6,900	5,220	3,900
	ratio	2.72	2.65	2.35	2.15	2.09	1.91	1.91	1.95	2.24	2.19
4770	Eel River at Scotia......cubic feet per second	377,000	280,000	170,000	110,000	83,000	65,000	44,700	33,300	23,200	18,600
	ratio	2.58	2.62	2.18	2.00	2.13	2.35	2.29	2.31	2.30	2.42
[1] 4785	Van Duzen River near Bridgeville......cubic feet per second	28,300	23,000	16,000	10,800	8,000	5,970	4,200	3,200	2,150	1,620
	ratio	2.07	2.05	2.08	2.14	2.18	2.15	2.09	2.08	2.03	1.98
5300	Trinity River near Hoopa......cubic feet per second	150,000	120,000	90,000	63,000	49,500	36,100	28,000	23,600	17,800	13,600
	ratio	2.68	2.61	2.65	2.56	2.62	2.31	2.26	2.25	2.27	2.29
5305	Klamath River near Klamath......cubic feet per second	378,000	305,000	225,000	177,000	136,000	100,000	75,000	62,000	49,800	39,400
	ratio	2.62	2.44	2.50	2.68	2.54	2.25	1.97	2.00	2.14	2.14
5325	Smith River near Crescent City......cubic feet per second	130,000	98,000	61,500	40,300	29,400	22,200	16,400	12,200	8,800	6,500
	ratio	2.36	2.45	2.20	2.12	2.12	2.04	1.98	1.79	1.76	1.71
	Subregion 2										
5225	Salmon River at Somesbar......cubic feet per second	39,000	34,000	23,600	15,800	11,500	9,100	7,400	6,500	5,040	3,860
	ratio	2.60	2.79	2.55	2.36	2.23	2.12	2.11	2.10	2.14	2.10
5255	Trinity River at Lewiston......cubic feet per second	44,300	32,500	19,500	14,000	11,600	9,400	7,800	6,920	5,200	4,250
	ratio	2.84	2.60	2.34	2.15	2.19	2.07	2.15	2.24	2.21	2.36
5270	Trinity River near Burnt Ranch......cubic feet per second	87,700	61,000	41,000	28,500	22,800	17,200	14,300	12,100	8,650	6,800
	ratio	2.92	2.65	2.59	2.48	2.43	2.29	2.29	2.37	2.31	2.29
	Subregion 3										
5195	Scott River near Fort Jones......cubic feet per second	23,200	15,100	10,800	6,500	5,250	3,750	3,210	2,750	2,030	1,620
	ratio	4.46	3.87	3.72	3.10	3.09	2.53	2.68	2.75	2.88	2.75

[1] Records for stations on Van Duzen River at end near Bridgeville have been combined.

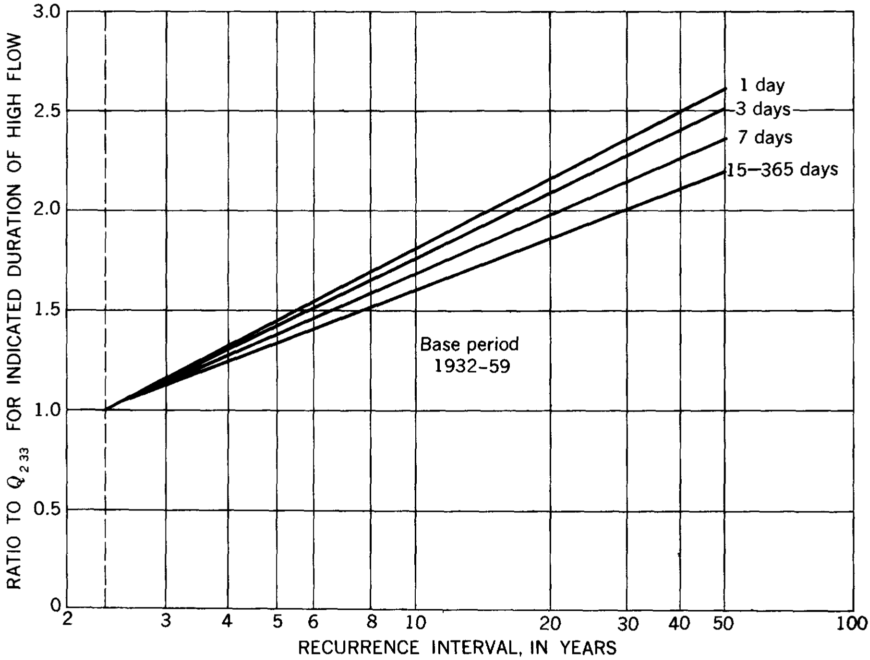


FIGURE 25.—Dimensionless curves of high-flow frequency for subregion 1.

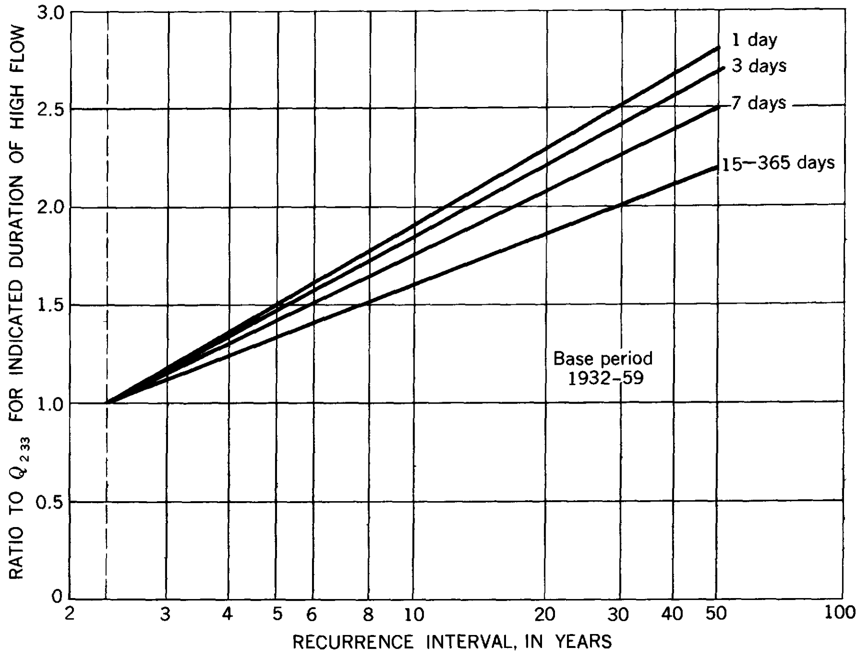


FIGURE 26.—Dimensionless curves of high-flow frequency for subregion 2.

The discharge figures in tables 13 and 14 were obtained from the individual frequency curves that had been drawn for each station and each duration period. With very few exceptions, each of these curves for stations in subregions 1 and 2 was linear. Discharges with indicated recurrence intervals of 10 years and 50 years were picked from the curves and then divided by $Q_{2.33}$, to give the ratios listed in tables 13 and 14. From these ratios the composite dimensionless high-flow frequency curves for subregions 1 and 2 were constructed. This was done by selecting the median ratios for the various duration periods (see listing in table 15), and plotting them on figures 25 and 26 to give

TABLE 15.—*Characteristics of frequency curves for high flows of various durations in subregions 1 and 2*

Recurrence interval	Ratio to $Q_{2.33}$ for indicated durations (days) of high flow			
	1	3	7	15 to 365
Subregion 1:				
10 years	1.81	1.77	1.68	1.60
50 years	2.60	2.50	2.35	2.20
Subregion 2:				
10 years	1.90	1.85	1.75	1.60
50 years	2.79	2.68	2.49	2.20

the desired curves. The maximum departure of any individual frequency curve from its appropriate regional curve was about 20 percent.

In accordance with the explanation given in the flood-frequency section of this report, it is to be expected that the slopes of the frequency curves for short duration periods would be steeper in subregion 2 than in subregion 1. This is primarily a result of the greater variability of storm precipitation in subregion 2. For durations of 15 days or more, the effect of differences in storm characteristics is less pronounced and the slopes of the frequency curves in the two subregions tend to be similar.

The regional graphs that were derived in this study may be used as guides in constructing frequency curves for various durations of high flow at ungaged sites in either subregion 1 or subregion 2. The procedure to be followed is similar to that previously described for constructing flood-frequency curves for ungaged sites.

The information furnished by these magnitude-duration-frequency graphs is useful in studying the hydrologic and economic aspects of reservoir design for flood control. Data picked from these curves would be used to construct a frequency-mass curve that represents the total flood volume produced, for some specified recurrence interval, during duration periods of various lengths. The traditional mass-curve method of analyzing the storage required to limit reservoir outflow rates to some given value would then be applied. This method of analysis is similar to the method explained and illustrated in the closing part of the low-flow analysis section of this report.

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