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TECHNICAL SUPPLEMENT
to the Hydrographic Atlas
Okanogan-Methow
River Basins Study Area

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TECHNICAL SUPPLEMENT
to the
HYDROGRAPHIC ATLAS

OKANOGAN-METHOW RIVER BASINS STUDY AREA
State Water Program

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State of Washington Water Research Center

for the

State of Washington Department of Ecology

December, 1973

Acknowledgments

The work upon which this publication and the Hydrographic Atlas are based was supported in part by funds provided by the State of Washington Department of Ecology through the State of Washington Water Research Center.

The numerous instances of assistance on the part of the U.S. Geological Survey in providing data, verficiations and reports are gratefully acknowledged.

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This Technical Supplement and the Hydrographic Atlas were prepared under State Water Program Contract Number SWP 20/P. Clark, Dept. of Ecology, Project W-7. Copies of these reports may be obtained from the Dept. of Ecology for $3 each.

ABSTRACT: This series of Technical Supplements has been prepared for use in conjunction with the Hydrographic Atlases of the Big Bend, Chehalis, Cowlitz, Lewis, Okanogan-Methow and Spokane River Basin Study Areas as part of the State Water Program of the Department of Ecology. The Hydrographic Atlases were prepared for use by the River Basin Committees and therefore present the surface water resources analyses of the basins in a graphical, layman's format (24 pages, 11 in. x 17 in.) with numerous pictures, diagrams and charts. The Atlases and Technical Supplements follow the same contents covering: Introduction, Sources of Information, Precipitation, Average Annual Flow, Water Balance, Floods, Low Flows, and Water Uses and Summary. The Technical Supplements provide more detailed information than the Atlases on: analytical methodology, variations in flow by basins, data acquisition and analysis problems, and water use in the Study Areas.

Key Words: Okanogan-Methow River Basins Study Area;* State Water Program;* river basin analysis; surface water resources; development of ungaged stream flow methodology;* hydrology.

--Orsborn, John F. and Sood, Mohinder N., "TECHNICAL SUPPLEMENT to the Hydrographic Atlas of the Okanogan-Methow River Basins Study Area," Albrook Hydraulic Laboratory, Washington State University, Dec., 1973.

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INTRODUCTION

During the preparation of the Hydrographic Atlases of the various river basin study areas which are part of the State Water Program, thousands of pieces of information had to be analyzed and summarized. In the process new methodologies for analyzing stream flows from ungaged drainage basins had to be developed, and a wide variety of information had to be acquired from numerous, diverse sources. Whereas the Atlases are primarily for use by citizen committees, it was felt that a separate supplement to each Hydrographic Atlas would provide information of use to agencies and consultants. For example, in the process of developing this information the low flow recurrence interval graphs for the various gaged and ungaged streams under investigation were sent to the consultant who was conducting the water quality management basin study.

The contents of the Technical Supplement parallel the contents of the Hydrographic Atlas so that cross reference can be easily accomplished. The emphasis in the Technical Supplement is on data, development of methodology, and details. Some of the figures and graphical relationships presented in the Atlases are repeated in the Supplements. Also, some of the technical terminology is defined in the text of the Supplements, whereas a glossary is provided in the Atlases.

In utilizing the information presented in each Atlas and Supplement, it is suggested that more detailed maps from the U.S. Geological Survey, the Department of Ecology, the Forest Service or some other source be used for the location of smaller streams. County maps prepared by the County Engineers' Office usually give good detail on drainages. To facilitate the graphical presentation of hydrological information developed on stream flow in this project, special base maps have been prepared which include the names of only the major streams as displayed on the line diagram at the back of the Atlas. Three maps are presented in the envelope on the inside back cover of this Technical Supplement:

(1) Study Area Map.--Includes basin outlines, names and numbers based on Water Resource Inventory Area numbers; major streams, lakes, reservoirs

and tributaries; and features such as mountains and cities. Emphasis is placed on the hydrographic features of the study area.

(2) Precipitation and Stream Gaging Station Map.--The location of the gaging stations that either are currently in use or have been discontinued after variable years of service are shown; also, special stations used to measure flood crest stages and low flows are included. Detailed information on gaging stations is presented in Table 5 in the next section on Sources of Information.

(3) Average Annual Precipitation Map.--Shows precipitation distribution over the basin.

These three maps are duplicates of the first three maps which appear in the Atlas. The rest of the stream flow information in the Supplement is presented in either graphical or tabular form for a larger number of streams and gages than are shown in the Atlas. For example, flood flows with recurrence intervals of 2-, 25- and 50-years are presented in Table 9 for all gages, including those with only published 2-year and 25-year flood flows.[1/] The 50-year values were determined by extrapolation of the flood flow-recurrence interval graphs for those gages without published 50-year flood flows.

Because of the transition which is occurring from the English Gravitational System (EGS) of measurement units to the Standard International System (SIS), commonly used water resources units and conversions have been included in Table 1. Equivalent measures of flow rate as used by different water practitioners are included in Table 1 (i.e., gallons per minute equivalent to cubic feet per second). This table is an expanded version of the one provided on page 1 of the Hydrographic Atlas. A nomograph is provided in Fig. 1 for rapid conversion from units of stream flow (as basic data in the center bar) to equivalent amounts of flow used in various fields of application. Considering the nomograph bars in Fig. 1, some of the more common uses for these units are (from left to right): pumping flow rate for municipal supply; daily rate of municipal supply (demand on the source); stream, canal or pipe flow rate; irrigation rates of application; and irrigation requirements per year or season, or amounts of storage in reservoirs and lakes.

[1/] Collings, M. R., "A Proposed Streamflow-Data Program for Washington State," U.S. Geol. Survey, Open-File Report, 1971.

Table 1. Round-Number Conversions, English and Metric Units
(Prepared by H. E. Thomas)

Length

	Symbol	*mm*	*m*	*km*	*in*	*ft*	*mi*
Millimeter	mm	1	0.001	----	0.039	0.003	------
Meter	m	1,000	1	0.001	39.4	3.28	------
Kilometer	km	----------	1,000	1	39,400	3,280	0.621
Inch	in	25.4	.0254	----	1	.083	------
Foot	ft	305.8	.305	----	12	1	------
Mile	mi	----------	1,610	1.61	63,360	5,280	1

Area

	Symbol	*m²*	*ha*	*km²*	*ft²*	*acre*	*mi²*
Square meter	m^2	1	--------	----	10.76	0.000247	------
Hectare	ha	10,000	1	----	107,600	2.47	0.00386
Square kilometer	km^2	1,000,000	100	1	10,760,000	247	.386
Square foot	ft^2	.093	--------	----	1	----------	------
Acre	acre	4,050	.405		43,560	1	.00156
Square mile	mi^2	2,590,000	259	2.59	----------	640	1

Volume

1 km^3 (cubic kilometer) = 811,000 acre-ft (acre-feet)
= 1,000,000,000 m^3 (cubic meters)

1 m^3 (cubic meter) = 35.3 ft^3 (cubic feet)
= 264. U.S. gallons
= 1,000 l (liters)

1 l (liter) = 0.0353 ft^3 (cubic foot)
= 0.264 U.S. gallon

1 mg (million U.S. gallons) = 3.07 acre-ft (acre-feet)

1 acre-ft (acre-foot) = 1,233 m^3 (cubic meters)
= 43,560 ft^3 (cubic feet)
= 325,900 U.S. gallons

1 ft^3 (cubic foot) = 0.0283 m^3 (cubic meters)
= 7.48 U.S. gallons
= 28.3 l (liters)

1 gal (U.S.) = 0.134 ft^3 (cubic foot)
= 3.78 l (liters)

1 inch of rain yields about 27,200 gallons per acre.
1 inch of rain yields about 100 tons per acre.
1 gallon of water weighs 8.34 pounds.
1 cubic foot of water weighs 62.43 pounds.
1 liter is nearly equivalent to 1¾ pints or ⅕ gallon.
1 imperial gallon (in the United Kingdom and Canada, for instance) = nearly 1⅕ U.S. gallon.
1 million gallons per day = 1.547 cubic feet per second.
1 cubic mile = 3,379,200 acre-feet = 1×10^{12} (1 followed by 12 zeros) gallons.
1 cubic foot per second = 1.85* (nearly 2) acre-feet per day.

Flow Rate

1 km^3/yr (cubic kilometer/year) = 811,000 acre-ft/yr (acre-feet/year)
= 723 mgd (million U.S. gallons/day)
= 31.7 m^3/s (cubic meters/second)

1 mgd (million U.S. gallons/day) = 694 gpm (U.S. gallons/minute)
= 1.55 cfs (cubic feet/second)
= 0.044 m^3/s (cubic meter/second)

1 gpm (U.S. gallon/minute) = 0.063 l/s (liter per second)

1 m^3/s (cubic meter/second) = 22.8 mgd (million U.S. gallons/day)
= 15,800 gpm (U.S. gallons/minute)
= 35.3 cfs (cubic feet/second)
= 1,000 l/s (liters/second)

1 cfs (cubic foot/second) = 0.645 mgd (million U.S. gallons/day)
= 449. gpm (U.S. gallons/minute)
= 0.0283 m^3/s (cubic meter/second)
= 28.3 l/s (liters/second)

1 l/s (liter/second) = 15.8 gpm (U.S. gallons/minute)
= 0.0353 cfs (cubic feet/second)

Ref.--Feth, J. H., "Water Facts and Figures for Planners and Managers," U.S. Geol. Surv., Circular 601-I, 1973.

*Should be 1.98.

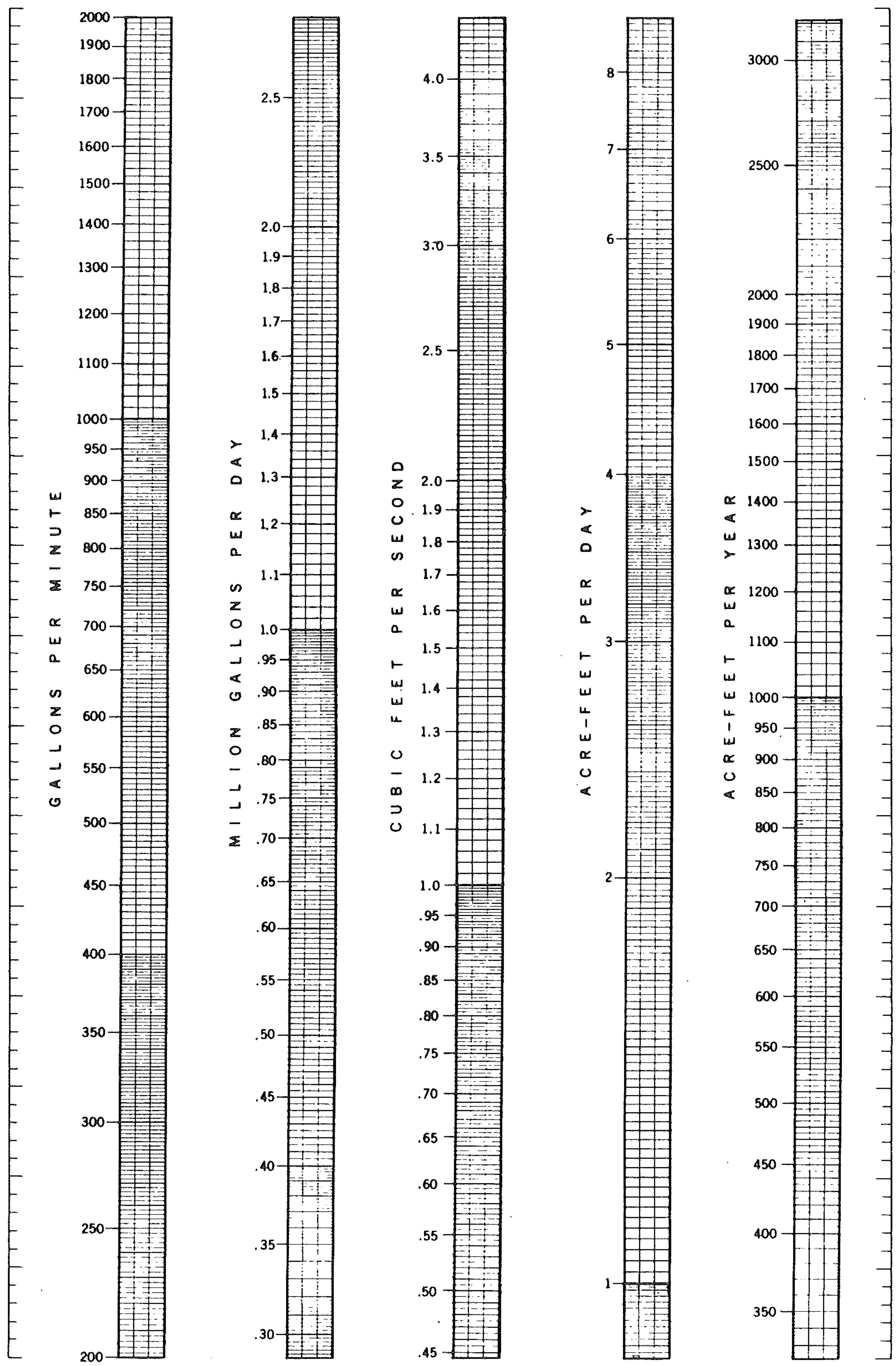

Figure 1. Nomograph for Converting Water-Measurement Units (by William Back).

Ref.--Feth, J. H., "Water Facts and Figures for Planners and Managers," U.S. Geol. Surv., Circular 601-I, 1973.

Methodologies for determining various ungaged stream flows developed as part of this study include:

(1) Average Annual Stream Flow--as a function of basin average annual precipitation and drainage area, based on a correlation graph for gaged stream flow values;

(2) Flood Flows--as a function of the average annual flow (QAA) and a geographic factor determined from flood flow records at the gages; includes recurrence interval graphs for ungaged streams; and

(3) Low Flows--as a function of drainage basin parameters using a method derived in an earlier study[2/] as a basis; refinements in the method were made where needed, depending on the area in the state and the availability of data; also includes the prediction of recurrence interval graphs for low flows in the ungaged streams of the Okanogan-Methow Study Area.

Descriptions of the types of information used in these analyses of gaged and ungaged stream flows are presented in the section on Sources of Information, after a brief description of the two basins which form the study area.

Summary of the Surface Water Resources of the Okanogan-Methow River Basins Study Area

The Okanogan and Methow River Basins would appear to be quite similar in hydrologic character if one were to examine them on a map. But a closer examination of their physical features, distribution of precipitation areally and seasonally, and their wide variations in amounts of stream flow during various times of the year, shows that the basins are hydrologically quite diverse.[3/] Therefore, the detailed material in the latter sections of this report has been arranged so that the Okanogan and Methow data appear in sequence. This study has been confined to those portions of the Okanogan Basin within the United States plus the Methow Basin. All gaged stream flows are for the period of record, and all ungaged stream flows are natural flows.

[2/] Orsborn, J. F., et al., "A Summary of Quantity, Quality and Economic Methodology for Establishing Minimum Flows," Vol. 1, Report No. 13, State of Washington Water Research Center, Pullman, June, 1973.

[3/] For a very comprehensive, but older reference, see International Columbia River Engineering Board, "Water Resources of the Columbia River Basin--Okanogan-Similkameen Basin," Appendix IV to Report to the Intl. Joint Commission, United States and Canada, 1955.

The Similkameen and Okanogan Rivers have almost the same drainage areas (3580 square miles at Nighthawk and 3210 square miles at Oroville, respectively), but the average annual flow of the Similkameen is almost four times that of the Okanogan (2132 and 640 cfs,* respectively). This divergence in flow is caused primarily by the effect of two mountain ranges which shield the upper Okanogan Basin and form its north-south elongated shape. This shape is displayed on the basin map in the envelope on the back cover. The Similkameen River Basin, by contrast, has much broader headwaters at generally higher elevations than those above Okanagan Lake in Canada.

The Lake, of course, exerts a very significant influence on the rate of flow in the Okanogan River in the United States. For example, in the 1948 flood season the Similkameen River flow at Nighthawk, Washington, rose and fell from 2000 to 4000 and back to 2000 cfs between May 1 and July 30. In that same time period the Okanagan River at Okanagan Falls, B.C., rose from 600 cfs to about 1400 cfs and stayed at almost that same value until well into October.

The diversity of the Similkameen and Okanogan River Basins is once again emphasized when one compares their seven-day average, 2-year recurrence low flows (Q7L2) of 360 and 321 cfs, respectively. The Similkameen River low flows only drop some 43 percent to 207 cfs about every 20 years on the average. On the other hand, even with the tremendous storage in its lakes, the Okanogan River low flow at Oroville, Washington, drops some 60 percent to 129 cfs once in about 20 years on the average. The high degree of variability in the low flows is indicative of the smaller amount of input (precipitation) to the Okanogan Basin and withdrawals for irrigation.

Although the majority of the information in this Technical Supplement deals with streams within the United States, in order to understand the hydrologic characteristics of the Okanogan River, the characteristics of its headwaters in Canada should be reviewed. The following summary of information of the Canadian part of the basin has been selected from one of the reports of the Study Committee, Canada-British Columbia Okanagan Basin Agreement.[4/]

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*cfs, cubic feet per second; flow rate.

[4/] Canada-British Columbia-Okanagan Basin Agreement, Preliminary Study Data--Bulletin No. 1, "Water Supply in the Okanagan Basin and Operation of the Okanagan Flood Control Works," Office of the Study Director, Penticton, B.C., June 15, 1972.

Table 2. Hydrologic Summary and Basin Data
for the Okanagan River and Okanagan Lake in British Columbia, Canada

Okanagan Basin Watershed	
Total Drainage Area	3100 sq. mi.
Okanagan Lake Basin	2340 sq. mi.
Okanagan Lake Surface	84000 acres
Total Arable Land	210000 acres
Irrigaged Lands	34000 acres
Climate	
Mean Annual Temperature	46° F
Mean Annual Precipitation	
Armstrong	17.2 in. (30 years)
Kelowna	12.2 in. (49 years)
Penticton	11.3 in. (49 years)
Oliver	10.8 in. (49 years)

Okanagan Lake Watershed--Average Annual Values

Component	Inches/Year	Acre-Feet/Year	Remarks
Precipitation	22.0		30-year average
Evapotranspiration	16.5		
Gross Inflow to Lake	5.5	690,000	
Consumptive Use	0.7	90,000	Irrigation, M & I Supply
Residual Inflow to Lake	4.8	600,000	
Evaporation from Lake		245,000	200,000 to 300,000 acre-ft. 2.4-3.6 ft. in depth.
Net Inflow to Lake	2.8	355,000	

By way of comparison, the average annual precipitation on the Similkameen River Basin is about 25 inches per year, although no complete determination has been made as yet. The influence of elevation on amounts of annual precipitation on the Similkameen Basin is shown in Table 3 for the few stations in that basin.

Summary data for the Stations at Princeton and Hedley show average annual precipitation values of 14.13 and 11.52 inches for the period 1941-1970. Therefore, the values in Table 3 can be considered representative of long-term Similkameen Basin precipitation.

Table 3. Precipitation Summary
Similkameen River Basin in British Columbia

Station	Elevation (ft)	Precipitation, Inches/Year Years	Mean	Max.	Min.	Snowfall Inches/Year Years	Mean
Princeton, B.C.	2289	12	14.24	21.06	7.90	44	47.1
Hedley	1700	44	11.52	21.31	5.76	40	30.1
Hedley (Nickel Plate)	5600	24	23.78	45.00	14.81	18	153.5
Keremos	1165	36	9.90	14.44	6.01	30	24.5

From Table 1, Ref. 3, through 1950.

The contribution to flow of the Okanogan River from the basin below its junction with the Similkameen is on the order of only 10 percent of the average annual flow at Malott. The Similkameen River usually contributes about 2300* cfs, the Okanogan River at Oroville about 600 cfs, and the total at Malott is usually about 3200 cfs. This net contribution from within the lower part of the basin (about 300 cfs) is of the same order of magnitude as the water rights on this reach of the river (150 cfs).

The Methow River Basin is quite similar in nature and physical characteristics to the Similkameen Basin, and their headwaters are intertwined along the border between Canada and the United States. Average annual precipitation on the Methow Basin is 31.4 inches per year. Although the Methow River Basin has a drainage area of only 1794 square miles, it has an average annual flow of 1555 cfs. The Similkameen River averages about 2300 cfs from 3550 square miles, the Okanogan River at Oroville 640 cfs from 3210 square miles and 3200 cfs from 8100 square miles at Malott. Average values of runoff per square mile of drainage area are (in cfs per square mile):

Similkameen at Nighthawk	Okanogan at Oroville	Okanogan at Malott	Methow at Pateros
0.65	0.20	0.40	0.87

By way of comparison the Columbia River at Bridgeport (Gage 12-4380) has a drainage area of 75,700 square miles and an average annual flow of 117,400 cfs (1.55 cfs per sq mi). Just downstream of its confluences with the Okanogan and Methow Rivers, the Columbia River at Wells Dam has a drainage area of

*Including the Sinlahekin Basin.

86,100 square miles and an average annual flow of 123,000 cfs (1.43 cfs per sq mi). Therefore, on the average the Okanogan River contributes about 2.7 percent of the flow to the Columbia River of which 1.8 percent (two-thirds) comes from the Similkameen Basin, and the Methow River contributes about 1.3 percent.

The main headwater streams in the Methow River Basin (Twisp, Methow Mainstem and Chewack Rivers) contribute about 40 percent of their annual precipitation to stream flow. The Chewack River contributes an average flow of 430 cfs, the Methow 700 cfs and the Twisp 300 cfs. Proceeding downstream from Twisp, all of the side streams from the rest of the basin contribute only about 230 cfs or about 15 percent of the average flow of 1555 at Pateros. For the total Methow River Basin, that portion above Twisp contributes 85 percent of the total flow from 72.5 percent of the drainage area. Between Twisp and Pateros, 27.5 percent of the total basin area contributes 15 percent of the total flow.

As is the case for the Okanogan River, the low flows in the streams of the central and lower Methow Basin are strongly influenced by diversions for irrigation. For an average year, the 7-day average low flow of the Methow River at Twisp is about 200 cfs, with 20 cfs coming from the Twisp River, 120 cfs from the Mainstem and 60 cfs from the Chewack. The same 7-day average low flow in the Methow at Pateros is about 300 cfs, so the lower 27.5 percent of the basin appears to contribute 30 percent of the low flow. But irrigation activities tend to distort the time distribution of this low flow through diversion and delayed return flow.

The Okanogan-Methow Basins are very complex geologic structures and are quite dissimilar in precipitation and runoff characteristics. The Methow Basin is characterized by bedrock exposures on the side hills and narrow, gravel filled valleys. These features tend to indicate high amounts of surface runoff and floods, and relatively small amounts of the precipitation appearing as low flow from ground-water storage. In contrast the lower Okanogan Basin shows considerable amounts of deposition and terraces in the valley, and a close linkage between ground water and stream flow. Some details on the ramifications of these physical basin features and stream flow components, such as floods and low flows, are discussed in subsequent sections of this Supplement.

SOURCES OF INFORMATION

The following sources of information were used for the stream flow analysis of the Okanogan-Methow River Basins Study Area:

- U.S. Geological Survey (USGS) Topographic Maps;
- U.S. Weather Bureau Average Annual Precipitation Map for the State of Washington, published by the Soil Conservation Service, March, 1965;
- Department of Ecology Water Resource Inventory Area (WRIA) Maps;
- U.S. Forest Service Maps;
- River Mile Index: Hydrology Subcommittee of the Columbia Basin Inter-agency Committee prepared Methow in 1964, and the Hydrology Subcommittee of Pacific Northwest River Basins Commission prepared Okanogan in 1968;
- U.S. Department of Commerce Precipitation Data;
- USGS Surface Water Supply Records (Water Supply Papers--WSP);
- USGS Open-File Reports;
- Miscellaneous Reports and those prepared by Canadian Agencies.

The following USGS 1:250,000-scale topographic maps were used for measuring the basin parameters such as the drainage area, A, basin length, L, and basin relief, H, and for preparation of the Okanogan-Methow River Basins Study Area base map (see envelope in back):

CONCRETE	NM 10-12	RITZVILLE	NL 11-1
OKANOGAN	NM 11-10	WENATCHEE	NL 10-3

The following Canadian maps, produced by the Department of Energy, Mines and Resources, were used for preparation of the base map: Vernon, 82L; Hope, 92H, and Penticton, 82E.

The base map was used for making the isohyetal map of average annual precipitation, the gaging station location map and other surface water flow charts (the average annual stream flow chart, the water balance chart, the flood flow chart and the 7-day average low flow chart). The study area map, the location map for the gaging stations, the precipitation map, and the surface water flow charts are included in the Hydrographic Atlas of the Okanogan-Methow Study Area. The Study Area Map and the Location Map for Gaging Stations and the Average Annual Precipitation Map are included in a folder in the back of this Technical Supplement. Other USGS topographic maps of 1:24,000, 1:62,500 and 1:125,000 scales were used to measure the lengths of the first and higher order streams, and to determine areas and reliefs of small basins. The maps in this series which cover the Okanogan-Methow Area can be determined from the USGS index.[5/] The 1:125,000 scale maps were used only where larger scale maps were not available. These stream lengths and other basin parameters were used in conjunction with stream flow records for the low flow analysis.

The U.S. Weather Bureau Precipitation Map for the State of Washington was enlarged to a 1:250,000 scale for preparation of an isohyetal analysis overlay for the basin base map. No precipitation analysis was made of the Canadian areas. The 1:125,000-scale WRIA maps of the Department of Ecology were used as work sheets for recording information during the initial analysis, and for the development of methodology.

The River Mile Index was used for determination of drainage areas above a stream gaging station or above any other location of interest on the stream. Also, the River Mile Index provided information about the location of stream gaging stations, the relative location of different streams and their tributaries, and man-made features such as bridges, diversions, outlets and dams.

U.S. Department of Commerce Precipitation Data Records were used for fixing the precipitation gaging station locations and for preparation of the isohyetal analysis overlay. The precipitation gaging stations in the Okanogan-Methow River Basins Study Area, along with their numbers and locations, are listed in Table 4.

USGS Surface Water Supply Records were used for locating the stream gaging stations, and for acquisition of other information about period of record, and the function of the stream gaging station (crest stage measurements, low flow measurements, continuous or partial record station). General descriptions about regulation and/or diversion of flow above the gaging stations were available from the Surface Water Supply Records. Table 5, at the end of this section, lists the stream gaging station numbers and names in the Study Area along with their periods of record, condition and function. Until 1961 stream flow records were published in USGS Water Supply Papers and the papers were published according to different geographic Parts (major basins) of the United States. Those Parts which apply to Washington (12, 13 and 14) are shown in Fig. 2. The Okanogan-Methow Study Area, for example, lies in Part 12 of the USGS Water Supply Papers. The Part number is also the two-digit prefix (i.e., 12-) to the gaging station numbers as they appear in the records.

[5/] U.S. Geological Survey, "Index to Topographic Maps of Washington," Current.

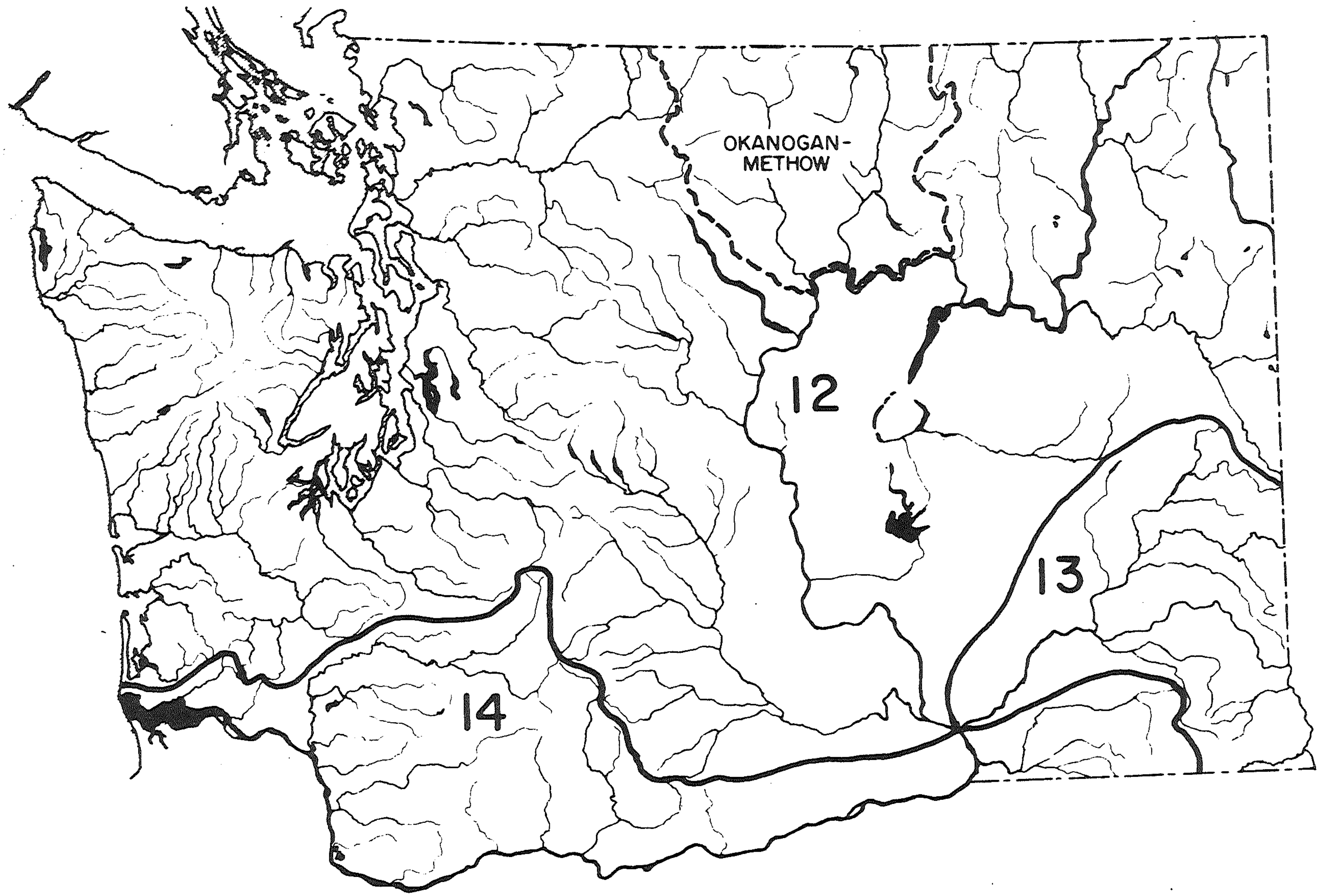

Figure 2. Map of Washington Showing the Part Numbers of USGS Stream Gaging Station Designations

Table 4. Precipitation Gaging Station Information
OKANOGAN-METHOW RIVER BASINS STUDY AREA

Number	Name and Location
1666	Conconully
3532	Harts Pass
5128	Mazama 6 SE*
5133	Mazama
5326	Methow 2 S
5327	Methow
6123	Omak 2 NW
7238	Rusty Creek
7287	Salmon Meadows
9376	Winthrop 1 WSW

*Example: Mazama 6 SE means that the precipitation gaging station is located 6 miles southeast of the town of Mazama. For location see chart in back.

Surface Water Supply Records are currently published annually by the USGS for each State with about a one-year lag between the end of the water year (water year is October 1 - September 30) and distribution. The annual records were called "Surface Water Records" from 1961-1964. Since 1965 they have been published as "Water Resources Data for Washington, Part 1, Surface Water Records." Part 2 is a separate volume covering Water Quality data. The Introduction to the yearly USGS surface water records provides more detailed information on conditions, terms and the history of the stream-gaging program.

For a quick summary analysis of gaging station descriptive information, one should refer to the most recent edition of the USGS "Catalog of Information on Water Data" for Water Resources Region 17 (Columbia-North Pacific).[6/]

[6/] USDI, Geological Survey, Office of Water Data Coordination, "Catalog of Information on Water Data;" Part A - Stream Flow and Stage, Part B - Quality of Surface Water, Part C - Quality of Ground Water; Water Resources Region 17 (CNP), Edition 1972.

USGS Surface Water Supply Records, USGS Open-File Reports and other miscellaneous reports provided surface water flow information such as: the average annual stream flow, QAA; the 2-year, 25-year and 50-year flood flows (QF2, QF25 and QF50, respectively); and the 2-year and 20-year, 7-day average low flows (Q7L2 and Q7L20, respectively). Also, these reports provided information related to the nature and quantity of the stream flow regulation or diversion out of the streams for flood control, low flow augmentation, irrigation or industrial and municipal use.

The surface water flow information available from these records, and the basin parameters and precipitation measured from the maps, were used to develop correlations for average annual stream flows, flood flows and low flows. The developed correlations were used for determining average annual stream flows, flood flows and low flows for ungaged drainage basins. Details on the development of methodology for determining average, flood and low flows for ungaged drainage basins are included in respective sections of this Technical Supplement.

For the headwaters of the Okanogan River Basin there were several references provided by the Study Director of the Canada-British Columbia-Okanagan Basin Agreement and the Water Investigations Branch of the Okanagan Study Committee. These reports assisted in the analysis of the Okanagan and Similkameen River flow and are included in the list of references at the end of this Technical Supplement.

Table 5. Stream Gaging Station Information

OKANOGAN-METHOW RIVER BASINS STUDY AREA

Number	Location	Period of Record	Operating or Discontinued	Function*
12-4385	Okanagan R. at Okanogan Falls, B.C. Canada (Int. G.S.)	Jan., 1915-Sept., 1965	D	SG
-4387	Okanagan R. at Oliver, B.C. Canada	March, 1944-1971	O	SGIR
-4390	Osoyoos L. near Oroville (Int. G.S.)	July, 1928-1971	O	LG
-4391.5	Okanogan R. at Bridge Street, Oroville (Int. G.S.)	1942-1971	O	GH only
-4392	Dry Cr. Tributary near Molson	1958-1971	O	CSPR
-4393	Tonasket Cr. at Oroville	March, 1967-1971	O	SG
-4394	Okanogan R. at Zosal Millpond at Oroville	Oct., 1942-1971	O	GH only
-4395	Okanogan R. at Oroville	Oct., 1942-1971	O	SG
-4400[a]	Sinlahekin Cr. above Blue L., near Loomis	May, 1924-Sept., 1930	D	CSPR
-4405[a]	Sinlahekin Cr. at Blue L., near Loomis	June-Oct., 1920	D	LFPR
-4410	Sinlahekin Cr. at Twin Bridges, near Loomis	May, 1921-Sept., 1923	D	SG
583**	Sinlahekin Cr. near Loomis	July, 1903-March, 1905	D	SG
-4417	Middle Fork Toats Coulee Cr. near Loomis	1965-1971	O	CSPR
-4418	Olie Cr. near Loomis	1961-1971	O	CSPR
-4420	Toats Coulee Cr. near Loomis	May, 1920-1971	O	CSPR

[a]*See explanation of abbreviations at end of Table.
**Gaging Station Number before revision in numbering system.

Table 5. (Continued)

Number	Location	Period of Record	Operating or Discontinued	Function
12-4422	Whitestone Irrigation Canal near Loomis	April, 1957-1971	O	SG
-4423	Sinlahekin Cr. above Chopaka Cr., near Loomis	April, 1957-Oct., 1965	D	SG
-4424	Palmer L. near Nighthawk	April, 1956-June, 1968	D	LG
-4425	Similkameen R. near Nighthawk (Int. G.S.)	May, 1911-1971	O	SG
-4435	Similkameen R. near Oroville	June, 1911-Sept., 1928	D	SG
-4437	Spectacle L. Tributary near Loomis	1961-1971	O	CSPR
-4438	Spectacle L. near Loomis	April, 1956-June, 1971	D	LGIR
-4440	Whitestone L. near Tonasket	Oct., 1958-June, 1971	D	LGIR
-4441	Whitestone Cr. near Tonasket	Oct., 1958-1971	O	SG
-4444	Siwash Cr. Tributary near Tonasket	1957-1971	O	CSPR
-4444.9	Bonaparte Cr. near Wauconda	Dec., 1967-1971	O	SG
588**	Bonaparte Cr. near Anglin	Oct., 1920-April, 1921	D	SG
-4447	Aeneas L. near Tonasket	Feb., 1964-1971	O	LG
-4450	Okanogan R. near Tonasket (Int. G.S.)	April, 1929-1971	O	SG
590**	Johnson Cr. near Riverside	June, 1903-Dec., 1907	D	SG
-4458	Omak Cr. Tributary near Disautel	1956-1971	O	CSPR
-4460	Okanogan R. at Okanogan	1911-1925	D	CSPR

Table 5. (Continued)

Number	Location	Period of Record	Operating or Discontinued	Function
12-4465	Salmon Cr. near Conconully	1911-1948	D	CSPRIR
-4470	Salmon Cr. near Okanogan	1903-1948	D	CSPRIR
-4471	Okanogan R. Tributary near Malott	1959-1971	O	CSPR
-4472	Okanogan R. at Malott	April, 1958-1971	O	SG
-4473	Okanogan R. near Malott	April, 1958-July, 1967	D	SG
-4473.8	Pine Cr. near Mazama	1966-1971	O	CSPR
-4473.9	Andrews Cr. near Mazama	June, 1968-1971	O	Hydrologic Benchmark Station
-4474	Doe Cr. near Winthrop	1957-1971	O	CSPR
-4474.3	Ortell Cr. near Winthrop	1965-1971	O	CSPR
-4475	Chewack R. below Boulder Cr., near Winthrop	April, 1920-Sept., 1921	D	SG
-4480	Chewack R. at Winthrop	May, 1912-Sept., 1913	D	SGIR
-4485	Methow R. near Winthrop	1971-	O	SG
-4487	Williams Cr. near Twisp	1965-1971	O	CSPR
-4489	Little Bridge Cr. near near Twisp	1965-1971	O	CSPR
-4495	Methow R. near Twisp	1919-1962	D	SG
-4496	Beaver Cr. below South Fork, near Twisp	April, 1960-1971	O	SG
-4497	Beaver Cr. near Twisp	May, 1956-Sept., 1961	D	SG
-4497.9	Rainy Cr. near Methow	1965-1971	O	CSPR

Table 5. (Continued)

Number	Location	Period of Record	Operating or Discontinued	Function
12-4499	Methow R. Tributary near Methow	1954-1969	D	CSPR
-4499.1	Methow R. Tributary No. 2, near Methow	1970-1971	O	CSPR
-4499.5	Methow R. near Pateros	April, 1959-1971	O	SG
-4500	Alta L. near Pateros	Nov., 1954-1971	O	LG
-4505	Methow R. at Pateros	1904-1920	D	CSPR

*Explanation for symbols used in Table 5 for stream gaging station information:

O	Operating Station
D	Discontinued Station
LFPR	Low Flow Partial Record Station
CSPR	Crest Stage Partial Record Station
SG	Stream Gaging Station
LG	Lake or Reservoir Gaging Station
WSR	Water Stage Recorder
GH	Gage Height
IR	Incomplete Fragmentary Records
R.	River
L.	Lake
Cr.	Creek

[a] USGS, Water Supply Paper 1687 lists 4400 as 4405 in error; and the River Mile Index on page 17 shows Palmer Creek which should be Sinlahekin as shown on page 15 of the RMI. Information from communication with USGS offices.

PRECIPITATION

Average annual precipitation and values for shorter periods of time, such as the seasons, were determined in several manners for the purposes described below. The average annual precipitation map for the State of Washington was used as a basic source of information in determining the average annual precipitation (P) on drainage basins.[7/] Values of (P) on basins above many of the stream gaging stations have been calculated and published by the Geological Survey.[1/] Where discrepancies between measured and published values were noted, they were checked with the Geological Survey. This policy was applied to all sources of data throughout the study. The Weather Bureau provided more detailed work sheet isohyetal charts for those portions of the State where they were available. The average annual precipitation isohyetal map for the United States portions of the Okanogan-Methow River Basins Study Area is in the envelope on the back cover.

Some precipitation gaging stations were selected to display variations in precipitation due to elevation and seasonal variations such as those shown in Fig. 3. Other stations, which have average annual precipitation values close to the published (P) values on basins above stream gages, were used to demonstrate monthly variations in precipitation and stream flow throughout a particular year of record.

The precipitation gaging stations which are located near or within the Area are listed by number and name in Table 4 in the previous section on Sources of Information and are shown on the gaging station map in the back envelope. The average annual precipitation (P) values for various gaged and ungaged basins are listed in Table 7 in the section on Water Balance and in Tables 18 and 19, the Line Diagram, in the last section on Water Uses and Summary.

After reconstruction of the isohyetal chart overlay, at a scale of 1:250,000 to agree with the Study Area base map, average annual precipitation values were determined for each subbasin. The precipitation values for each basin were determined using the standard averaging method of measuring the area within two isohyetal lines and the basin boundary, and then multiplying by the average value of precipitation between the two isohyetal lines. These (P·A) values

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[7/] U.S. Soil Cons. Svc. and Weather Bureau, "Isohyetal Chart of Mean Annual Precipitation, 1930-1957, State of Washington," March, 1965.

were accumulated for each basin, and then divided by the total basin drainage area to determine (P). The (P) values for basins above gaging stations were used to develop a correlation graph between average annual flow (QAA), (P) and drainage area (A). The graph was then used to determine (QAA) for ungaged areas using the measured values of (P) and (A). This methodology is discussed in the next section on Stream Flow.

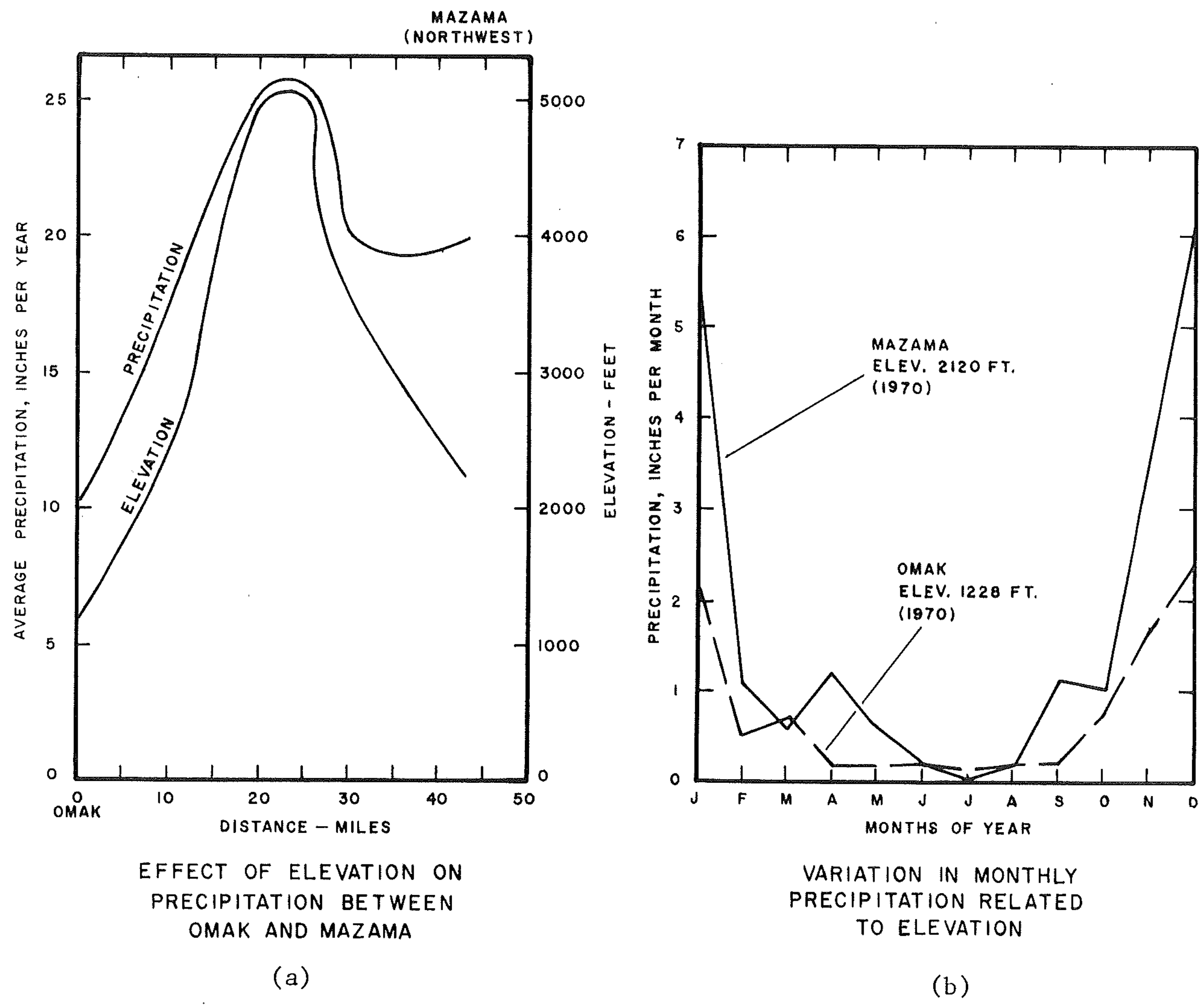


Figure 3. Variations in Precipitation Related to Elevation and Seasons for the Okanogan-Methow River Basins Study Area

STREAM FLOW

Data from reference (1) were used to develop correlations between average annual stream flow (QAA) for the period of record, and the average annual precipitation (P) and drainage area (A) for the stream gages in the Study Area. This relationship, as displayed in Figure 4, yielded the equation

$$QAA = 0.021\,(P \cdot A). \qquad (1)$$

Although there are some gaging station points which are a significant distance away from the average line, a closer inspection of the records for each station provides an explanation of the variability. The plotted (QAA) values are for different periods of record at each station, and this accounts for some of the variability between the individual data points and the graphical relationship.

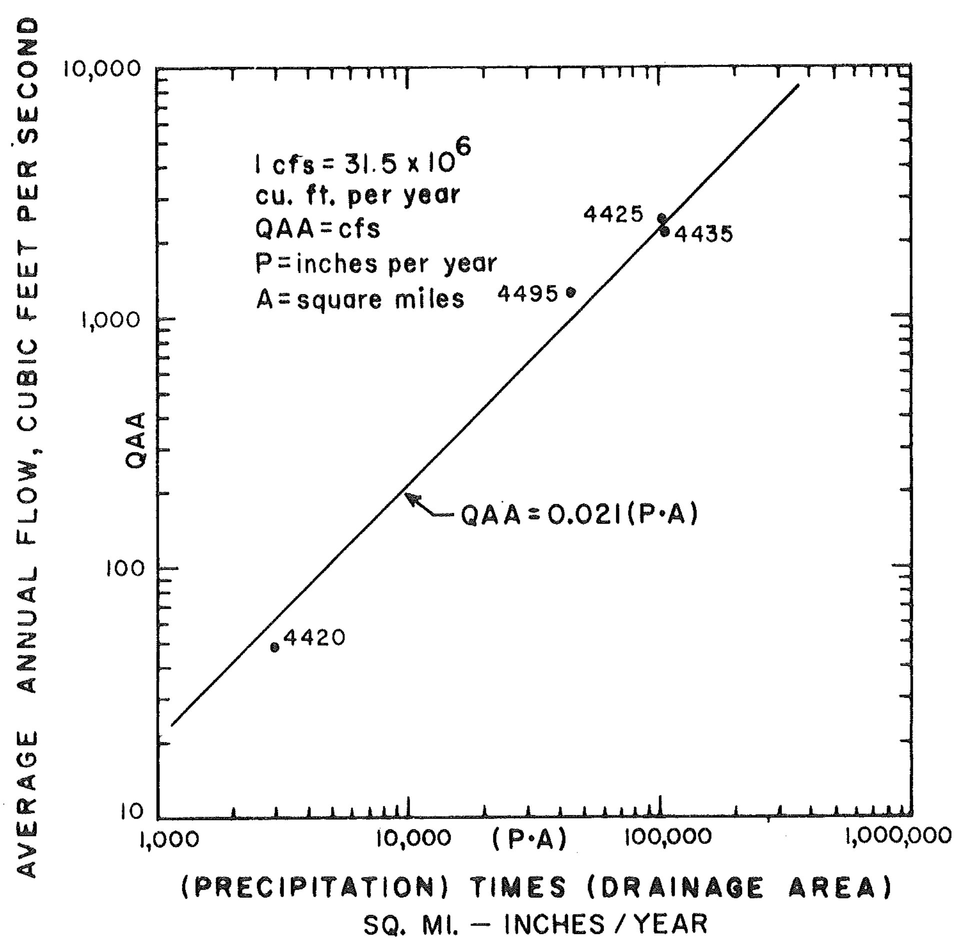


Figure 4. Gaged Average Annual Stream Flow Related to Average Annual Precipitation and Drainage Area for the Okanogan-Methow River Basins Study Area

Some of the variability in the relationship in Fig. 4 is probably due to inaccuracies in determination of the average annual precipitation from the isohyetal map of the entire state. A lack of precipitation data in remote areas and at higher elevations presents interpretation problems. More recent snow survey information has been applied successfully to the mountainous watersheds in Montana to update the average annual precipitation map.[8/] This change has resulted in much better average annual flow predictions in that state.

The U.S. Geological Survey has developed a series of average annual flow (QAA) equations for various geographic regions in the State.[9/] This information was developed in order to delineate streams with an average annual flow of 20 cfs and greater as part of the Shorelines Management Program. The regions, equations and variability for Central and Eastern Washington are listed below.

REGION	EQUATION	APPROXIMATE STANDARD ERROR (± percent)
Lower Yakima	$Q = (2.21 \times 10^{-4})A^{1.18}P^{1.98}$	28
Upper Yakima	$Q = (3.68 \times 10^{-3})A^{1.02}P^{1.60}$	20
Colville to Wenatchee	$Q = (1.13 \times 10^{-3})A^{1.04}P^{1.78}$	29
Pend Oreille	$Q = (1.46 \times 10^{-3})A^{1.30}P^{1.51}$	17
Columbia Basin to Palouse	$Q = (1.07 \times 10^{-5})A^{1.16}P^{3.01}$	29
Blue Mountains	$Q = (2.36 \times 10^{-7})A^{1.29}P^{4.04}$	21

Note: Q is average annual stream flow (QAA) in cfs; A is drainage area in sq mi; and P is average annual precipitation in in./yr on the basin.

The similarity between Eq. (1) and those in the list is obvious. The only differences are that Eq. (1) assumes (QAA) to vary as a function of (P) and (A) to the first power. An analysis on a larger, regional basis may show a better relationship if (P) and (A) are raised to a power other than one. If this is the case on a regional basis, of which the Study Area would be a part, then the coefficient in Eq. (1) would change from 0.021 to some other value.

8/ Farnes, P. E., "Preliminary Report-Hydrology of Mountain Watersheds," USDA-Soil Cons. Svc., Bozeman, Mont., April, 1971.

9/ U.S. Geological Survey, "Streams of Washington under the Requirements of the Shoreline Management Act of 1971," no date.

If one compares the results of applying Eq. (1) and the Colville to Wenatchee equation for gaging station 4435 (Similkameen River near Oroville), the following conditions apply: Area is 3580 sq mi; average annual precipitaiton (P) is 30 inches per year; and the gaged average annual flow (QAA) is 2132 cfs. The predicted flows are listed below.

	EQUATION	CALCULATED (QAA), cfs
Eq. (1):	$Q = 0.021\ (P \cdot A)$	2260
Colville to Wenatchee:	$Q = (1.13 \times 10^{-3})A^{1.04}P^{1.78}$	2400

The approximate standard errors for the Colville to Wenatchee equation is ±29 percent. It should be remembered that these average annual flow equations were derived on a regional basis for making safe estimates of streams having (QAA) values > 20 cfs. Therefore, one would not expect to compare these predicted (QAA) values very closely for small drainages with short, diverse periods of record. They are equations of "average" conditions and their variability can be analyzed due to such factors as different periods of record and geology.

Table 6 lists stream gages within the Okanogan-Methow Study Area, their drainage areas and average annual flows for the period of record at the gage, including the minimum, mean and maximum values.

Table 6. Summary of Stream Flow Variability for the Period of Record in Okanogan-Methow River Basins Study Area

Stream Gaging Station Number and Name		Drainage Area (sq mi)	Period of Record	Discharge for Period of Record* (cfs)		
				min	mean	max
12-4395	Okanogan R. at Oroville	3210	1943-72	227	674	1310
-4420	Toats Coulee Cr. near Loomis	130	1958-69	24	45	65
-4423	Sinlahekin Cr. above Chopaka Cr. near Loomis	256	1958-65	20	54	95
-4425	Similkameen R. near Nighthawk	3550	1929-72	1150	2424	4831
-4450	Okanogan R. near Tonasket	7280	1930-72	1140	2978	6019
-4470	Salmon Cr. near Okanogan	156	1904-09	35	49	80
-4473	Okanogan R. at Malott	8220	1959-72	2018	3194	6312
-4495	Methow R. at Twisp	1301	1919-62	1167	1327	2231
-4496	Beaver Cr. below South Fork, near Twisp	62	1960-72	10	19	46
-4499.5	Methow R. near Pateros	1772	1959-72	1037	1769	2963
-4505	Methow R. at Pateros	1794	1903-20	873	1655	2380

*Annual Average

WATER BALANCE

The average annual input-output values of precipitation (P) and stream flow (QAA) can be used to evaluate the general water balance of a drainage basin when they are converted to a common set of units such as cfs. Equation (2) shows the conversion of (P) in inches per year into an equivalent average flow value in cfs involving multiplication by the drainage area (A), conversion of inches to feet, square miles to square feet and years to seconds.

$$P \text{ (cfs)} = 0.0737 \; P \text{ (in./yr) } A \text{ (sq mi)} \qquad (2)$$

A summary of precipitation input and stream flow output for numerous gaged and ungaged drainage basins is presented in Table 7. In order to provide a quick estimate of how much of the average annual precipitation (P) appears as runoff at the gage or basin outlet, (QAA) (output) has been calculated as a percent of (0.0737 P•A) (input) in the last column. The range of values of 20 to 40 percent for the Okanogan-Methow Study Area indicate the Area has a relatively small amount of precipitation compared with the west side of the Cascade Mountains. Most of the precipitation falls during months when plants are dormant. Also, ground-water recharge and storage in the higher basins, where most of the precipitation originates, is a relatively small part of the total input (P). This is due to shallow soils of limited areal extent and narrow valleys with only small volumes of water-bearing deposits, and bedrock exposure especially in the Methow, Sinlahekin and lower Similkameen Basins. Also, the evaporation rates are higher in the Okanogan-Methow Study Area than they are along the Coast due to the generally warmer and drier climatic conditions during the growing season.

Two relative examples of monthly variations in precipitation and stream flow are shown in Figs. 5 and 6 for water year 1971 (October 1 through September 30). The precipitation stations have been selected at Mazama and Conconully, because the long-term average values at those stations are close to the average precipitation values over the Methow and Okanogan Basins, respectively. The records at the Mazama station were increased by 60 percent to more nearly reflect average conditions for the basin. These diagrams are merely for demonstrations of general water balance characteristics.

Table 7. Average Annual Water Balance for Gaged and Ungaged Streams
OKANOGAN-METHOW RIVER BASINS STUDY AREA

Stream Name and Gaging Station Number	P* (in./yr)	A* (sq mi)	QAA* (cu ft/sec)	P·A* (cu ft/sec)	QAA/(P·A)* (%)
Okanogan R. at Bridge Street, Oroville (-4391.5)	9.7	3150	640	2252	29
Dry Cr. Tributary near Molson (-4392)	24	1.7	1.2	3	40
Tonasket Cr. at Mouth	18.5	60.2	23.4	82	29
Okanogan R. at Zosal Millpond at Oroville (-4394)	9.7	3210	652	2288	29
Okanogan R. at Oroville (-4395)	9.7	3210	652	2288	29
Sinlahekin Cr. above Blue L. near Loomis (-4400)	21.8	41.7	19.1	67	29
Sinlahekin Cr. at Twin Bridges, near Loomis (-4410)	20.2	75.5	32	112	29
South Fork Toats Coulee at Mouth	26.6	34.1	19	67	29
Middle Fork Toats Coulee at Mouth	29.6	32.1	20	70	29
North Fork Toats Coulee at Mouth	29.1	52.3	32	112	29
Toats Coulee near Loomis (-4420)	24	130	47.4	237	20
Toats Coulee at Mouth	24	134	47.4	237	20
Sinlahekin Cr. above Chopaka Cr., near Loomis (-4423)	23.8	256	128	449	29
Palmer Cr. at Mouth	23.1	300	146	511	29
Similkameen R. near Nighthawk (-4425)	30	3550	2320	7849	29
Similkameen R. near Oroville (-4435)	30	3580	2132	7915	27

*See explanation of terms at end of Table.

Table 7. (Continued)

Stream Name and Gaging Station Number	P (in./yr)	A (sq mi)	QAA (cu ft/sec)	P·A (cu ft/sec)	QAA/(P·A) (%)
Similkameen R. at Mouth	30	3650	2320	8142	29
Spectacle L. Tributary near Loomis (-4437)	16.5	4.6	1.6	6	29
Whitestone Cr. near Tonasket (-4441)	16.5	55.4	19.2	67	29
Whitestone Cr. at Mouth	16.5	55.4	19.2	67	29
Siwash Cr. Tributary near Tonasket (-4444)	24	150	60	211	26
Bonaparte Cr. near Wauconda (-4444.9)	24.6	96.6	50	175	29
Bonaparte Cr. at Mouth	21.2	150	60	211	26
Okanogan R. near Tonasket (-4450)	19	7280	2905	10195	29
Omak Cr. Tributary near Disautel (-4458)	20	4.1	1.7	6	29
Omak Cr. at Mouth	16.3	251	83	290	27
Okanogan R. at Okanogan (-4460)	19	7900	3150	11062	29
Salmon Cr. near Conconully (-4465)	22.5	121	57.2	201	29
Salmon Cr. near Okanogan (-4470)	20.2	156	66.2	232	29
Salmon Cr. at Mouth	18.7	194	76	267	29
Okanogan R. at Malott (-4472)	19	8100	3232	11343	29
Okanogan R. near Malott (-4473)	19	8220	3420	11510	30
Okanogan R. at Mouth	19	8525	3543	12434	30
Early Winters Cr. at Mouth	61.7	79	102	359	28
Andrews Cr. near Mazama (-4473.9)	33.1	22	15.4	54	29
Doe Cr. near Winthrop (-4474)	30	3.8	2.4	8	29

Table 7. (Continued)

Stream Name and Gaging Station Number	P (in./yr)	A (sq mi)	QAA (cu ft/sec)	P•A (cu ft/sec)	QAA/(P•A) (%)
Chewack R. below Boulder Cr. near Winthrop (-4475)	27.9	465	272	956	28
Chewack R. at Winthrop (-4480)	26.7	544	433	1070	40
Chewack R. at Mouth	26.7	544	433	1070	40
Methow R. near Winthrop (-4485)	33.1	1007	700	2456	29
Williams Cr. near Twisp (-4487)	35	3.2	2.3	8	29
Little Bridge Cr. near Twisp (-4489)	37.9	24	19	67	29
Twisp R. at Mouth	38.8	265	306	759	40
Methow R. near Twisp (-4495)	35	1301	1327	3356	40
Beaver Cr. below South Fork near Twisp (-4496)	23.8	62	31	109	28
Beaver Cr. near Twisp (-4497)	26.2	68	37.4	131	29
Beaver Cr. at Mouth	22.7	111	58	205	31
Libby Cr. at Mouth	27.4	40	23	80	28
Gold Cr. at Mouth	35.8	93	71	248	29
Methow R. near Pateros (-4499.5)	31.4	1772	1555	4100	38
Methow R. at Pateros (-4505)	31.4	1794	1555	4151	37
Methow R. at Mouth	31.4	1794	1555	4151	37

*Explanation of terms:

- P — average annual precipitation on basin, inches per year.
- A — basin drainage area, square miles.
- QAA — average annual stream flow, cubic feet per second; based on period of record at gages or on QAA = 0.021(P•A) for ungaged basins (see Figure 4).
- (P•A) — cubic feet per second; conversion factor times (P•A).
- Note: Gaged values are for period of record.

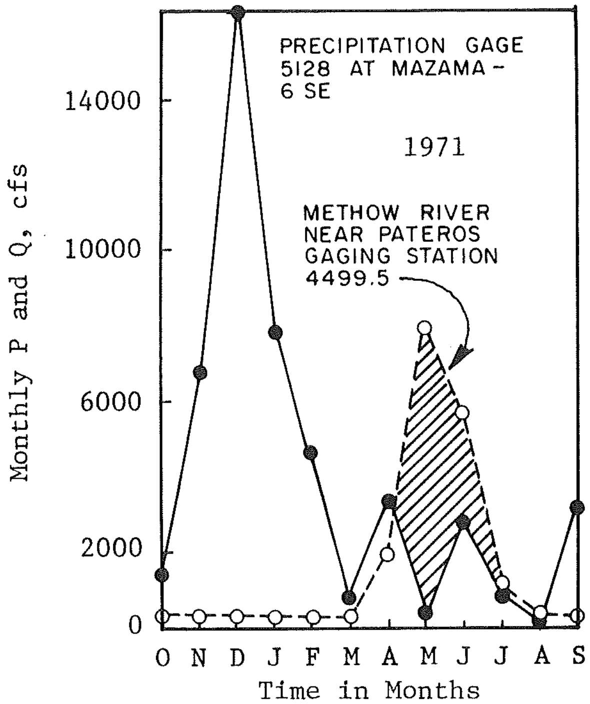


Fig. 5. Methow Basin Monthly Precipitation and Stream Flow

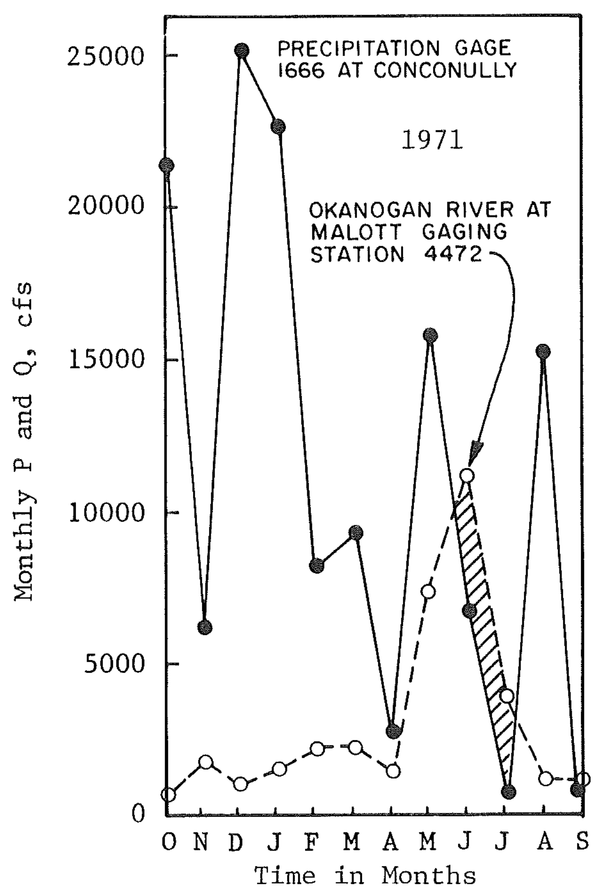


Fig. 6. Okanogan Basin Monthly Precipitation and Stream Flow

Seasonal precipitation patterns in the Methow Basin show a predominant amount of precipitation occurs between November and February (Fig. 5). The steady river discharge at Pateros would indicate that the precipitation was snow, and/or low intensity rains. Part of the snow appears as stream flow between April and July accompanied by portions of the precipitation which occurred during that same period. The summer period is characterized by a rapid recession in stream flow. The seasonal precipitation and stream flow characteristics of the Okanogan Basin are similar to those of the Methow Basin. Due to the large size of the Okanogan-Similkameen Basin, though, and the more mild climate of the Okanogan Valley, increased runoff appears in the winter months (Fig. 6). The units in the vertical scale of precipitation (P) appear to be much larger in Fig. 6 than in Fig. 5, even though the average precipitation at Mazama is larger than at Conconully. This is due to the much larger drainage area at Malott on the Okanogan River than at Pateros on the Methow River. When Eq.(2) is applied to both basins the precipitation at Mazama is 40 percent larger but the drainage area at Malott is 460 percent of the area at Pateros. Therefore, an equal amount of precipitation spread uniformly over both basins (annual average) would have a volume 3.27 times larger on the Okanogan Basin above Malott than on the Methow Basin above Pateros.

FLOODS

Numerous methods have been developed for estimating flood flows from ungaged drainage basins which require various degrees of sophistication in their application and data which is often difficult to obtain or is highly variable. For the purposes of this study it was felt that a method should be used which could be readily understood by the River Basin Committee, and which could be related easily to available stream flow records. After testing several approaches to the problem of predicting ungaged flood flows, a method was selected which establishes relationships between average annual flow (QAA) and flood flows of different recurrence intervals.[10/] The related values for the Okanogan-Methow Study Area geographic factors are tabulated in Table 8. The flood flows selected were the 2-year and 50-year recurrence interval flows, QF2 and QF50, respectively. Larger flood flows can be estimated by extending the recurrence interval graph for a particular stream. The 50-year flood flows were used as the largest floods in this analysis because very few stream gaging records are longer than 50 years.

Table 8. Flood Analysis Geographic Factors
OKANOGAN-METHOW RIVER BASINS STUDY AREA

Gage Number	QAA (cfs)	QF2 (cfs)	QF50 (cfs)	QF2/QAA*	QF50/QAA*
Sinlahekin Region					
12-4420	47.4	701	1750	15.0	37.5
Similkameen-Okanogan Region					
-4425	2320	16400	35000	7.1	15.1
-4458	1.7	7.3	17	4.3	10.0
Methow Region					
-4474	2.4	20	77	8.3	31.7
-4495	1327	12100	31400	9.0	23.2
-4499.5	1555	13200	34000	8.8	22.7

*Average values shown for each region in Fig. 7.

Average values of QF2/QAA and QF50/QAA were used to determine floods for ungaged streams in each of the regions. These average regional geographic factors are shown in Fig. 7.

10/ Conturk, H., "Mean Discharge as an Index to Mean Maximum Discharge," Proceedings of the Leningrad Symposium on Floods and Their Computation, IASH-UNESCO-WMO, August, 1967.

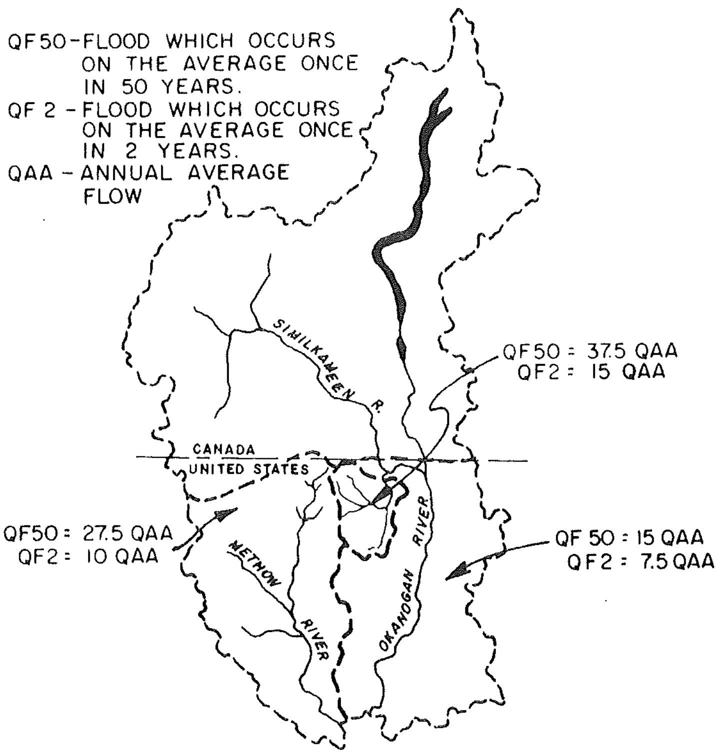


Figure 7. Flood Flow Relations Map OKANOGAN-METHOW RIVER BASINS STUDY AREA

The division of geographic regions was based on the ratio QF50/QAA rather than QF2/QAA because there was less variation in the larger flow ratios. After the ungaged flood flows were calculated and plotted on recurrence interval paper, the slopes of the recurrence interval plots were checked against those at gaging stations in that vicinity. In the southern region of the Okanogan Basin the 50-year flood flows are about twice as large as the 2-year flood flows, or QF50/QF2 = 2.0. In the Sinlahekin region of the Okanogan Basin QF50/QF2 = 2.5 and in the Methow Basin QF50/QF2 = 2.75. This higher ratio of flood flows in the Methow portion of the Study Area is due mostly to the shallow soils and narrow valleys. Also the large size and lake storage in the Okanogan would tend to reduce the flood ratio.

The 2-, 25- and 50-year flood flows for the gaged and ungaged streams in the Okanogan-Methow Study Areas are listed in Table 9. Following Table 9 are Figs. 8 through 14 which display the flood recurrence interval graphs for the same gaged and ungaged streams. Data points appearing on Figs. 8, 9 and 14 denote that the values have either been obtained from an open file-report or from records of the Geological Survey. The recurrence interval graphs with no data points are based on the analysis of limited records at a few gaging stations, or no records for ungaged streams, by using the geographic factor mentioned earlier. In order to provide an index to Figs. 8 through 14, the figure number on which the recurrence interval graph appears is typed after the stream gage number or stream name in Table 9.

Table 9. Gaged and Calculated Flood Flows
OKANOGAN-METHOW RIVER BASINS STUDY AREA

Stream Name, Gaging Station Number; Figure Number, (Basin Number)*	QF2* (cfs)	QF25* (cfs)	QF50* (cfs)
Okanogan R. at Bridge Street, Oroville (-4391.5); 8	4890	9000	9780
Dry Cr. Tributary near Molson (-4392); 14	8.5	97	150
Tonasket Cr. at Mouth; 12	176	320	351
Okanogan R. at Oroville (-4395); 9	4890	9000	9780
Sinlahekin Cr. above Blue L., near Loomis (-4400); 9	287	620	716
Sinlahekin Cr. at Twin Bridges, near Loomis (-4410); 9	480	1050	1200
South Fork Toats Coulee Cr. at Mouth; 10	285	630	713
Middle Fork Toats Coulee Cr. at Mouth; 10	300	660	750
North Fork Toats Coulee Cr. at Mouth; 10	480	1050	1250
Toats Coulee Cr. near Loomis (-4420); 9	701	1560	1750
Sinlahekin Cr. above Chopaka Cr., near Loomis (-4423); 8	1919	4250	4796
Palmer Cr. at Mouth; 12	2183	4900	5456
Similkameen R. near Nighthawk (-4425); 9	16400	31000	35000
Whitestone Cr. near Tonasket (-4441); 8	144	260	288
Siwash Cr. Tributary near Tonasket (-4444); 14	6.6	93	150
Bonaparte Cr. near Wauconda (-4444.9); 8	374	680	749
Bonaparte Cr. at Mouth; 12, (49-5)	452	820	903
Okanogan R. near Tonasket (-4450); 9	16000	31000	35000
Omak Cr. at Mouth; 12, (49-7)	620	1120	1240
Okanogan R. at Okanogan (-4460); 10	16100	33500	37000
Salmon Cr. near Conconully (-4465); 8	429	770	858
Salmon Cr. near Okanogan (-4470); 8	497	900	993

*See explanation of terms at end of Table.

Table 9. (Continued)

Stream Name, Gaging Station Number; Figure Number, (Basin Number)	QF2 (cfs)	QF25 (cfs)	QF50 (cfs)
Salmon Cr. at Mouth; 12, (49-8)	572	1030	1144
Okanogan R. at Malott (-4472); 8	16500	33000	38000
Okanogan R. at Mouth; 12	17360	34000	39720
Early Winters Cr. at Mouth; 11	1024	2450	2816
Andrews Cr. near Mazama (-4473.9); 11	154	370	424
Doe Cr. near Winthrop (-4474); 14	20	62	77
Chewack R. below Boulder Cr., near Winthrop (-4475); 11	2724	6450	7492
Chewack R. at Winthrop (-4480); 11	4070	9800	11193
Methow R. near Winthrop (-4485); 11	7000	16600	19250
Williams Cr. near Twisp (-4487); 14	23	54	63
Little Bridge Cr. near Twisp (-4489); 11	191	355	525
Twisp R. at Mouth; 13, (48-5)	2880	6800	7920
Methow R. near Twisp (-4495); 8	12100	27200	31400
Beaver Cr. below South Fork, near Twisp (-4496); 11	310	740	853
Beaver Cr. near Twisp (-4497); 11	374	900	1029
Beaver Cr. at Mouth; 13, (48-6)	543	1280	1493
Libby Cr. at Mouth; 13, (48-8)	210	500	577
Gold Cr. at Mouth; ;3, (48-9)	657	1560	1807
Methow R. near Pateros (-4499.5); 11	13200	30500	34000

*Explanation of terms:

QF2: Q(Flow), F(Flood), 2(Two-Year Recurrence Interval).

QF2, QF25 and QF50: flood flow values which can be expected to occur, once in any 2-, 25- or 50-year interval.

Gaged values are for period of record; ungaged values determined by analysis using geographic factors.

Figure number of Recurrence Interval Graph comes after semicolon. For stations not listed in Table 9, see Table 5. Ungaged basins are numbered by Water Resources Inventory Area numbers in parentheses, i.e., (49-8), as shown on base map.

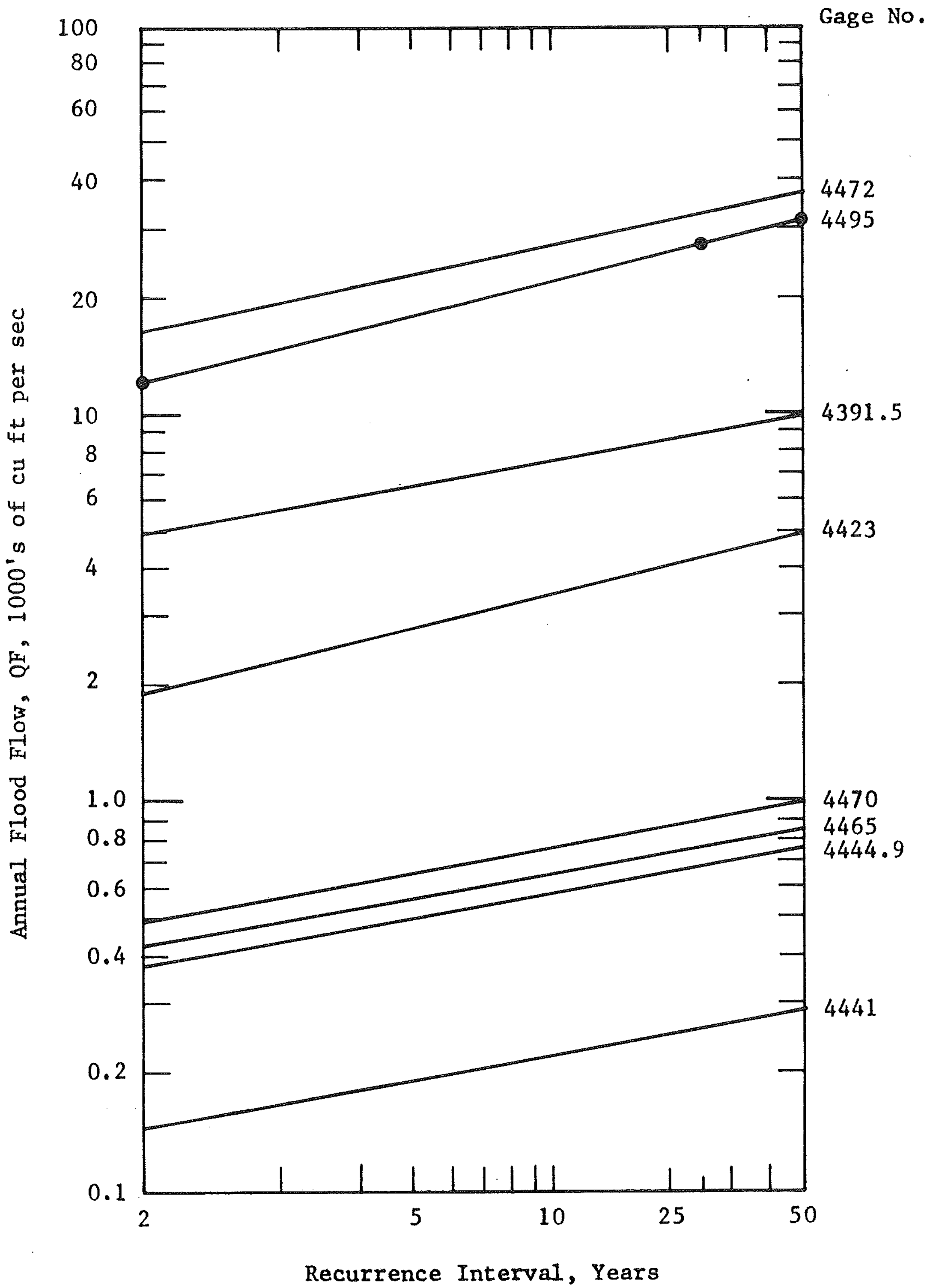


Figure 8. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors.

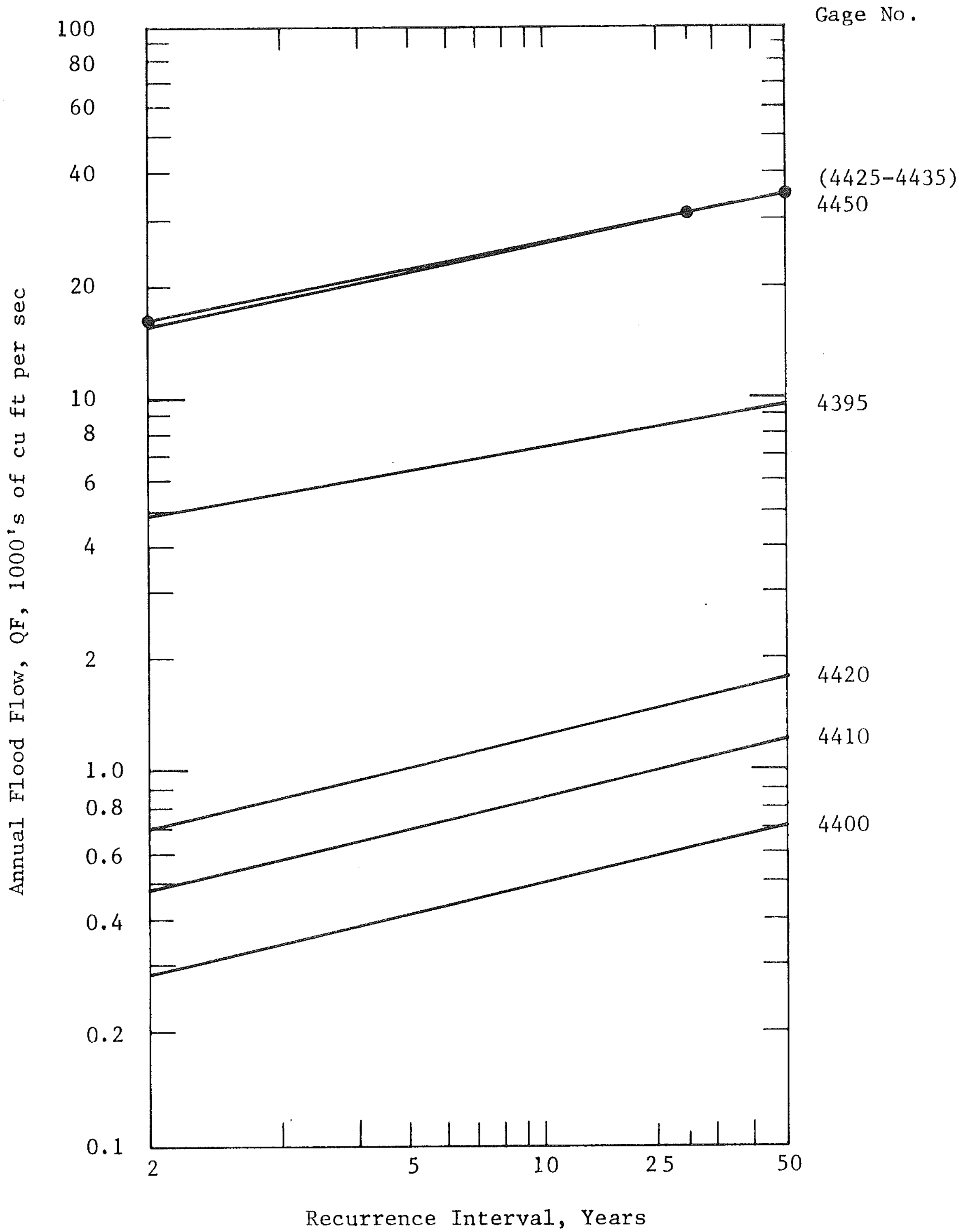


Figure 9. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors.

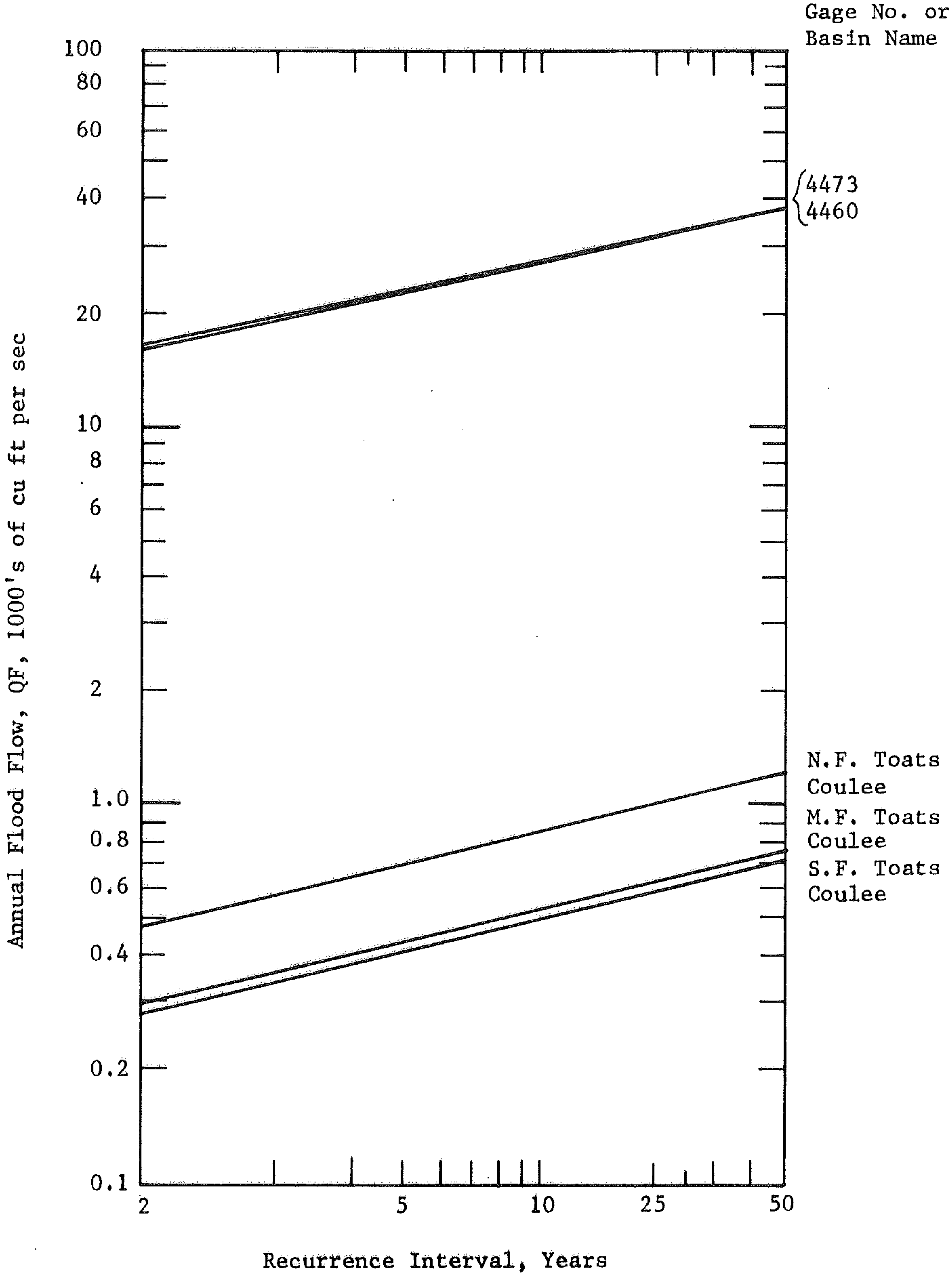


Figure 10. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors.

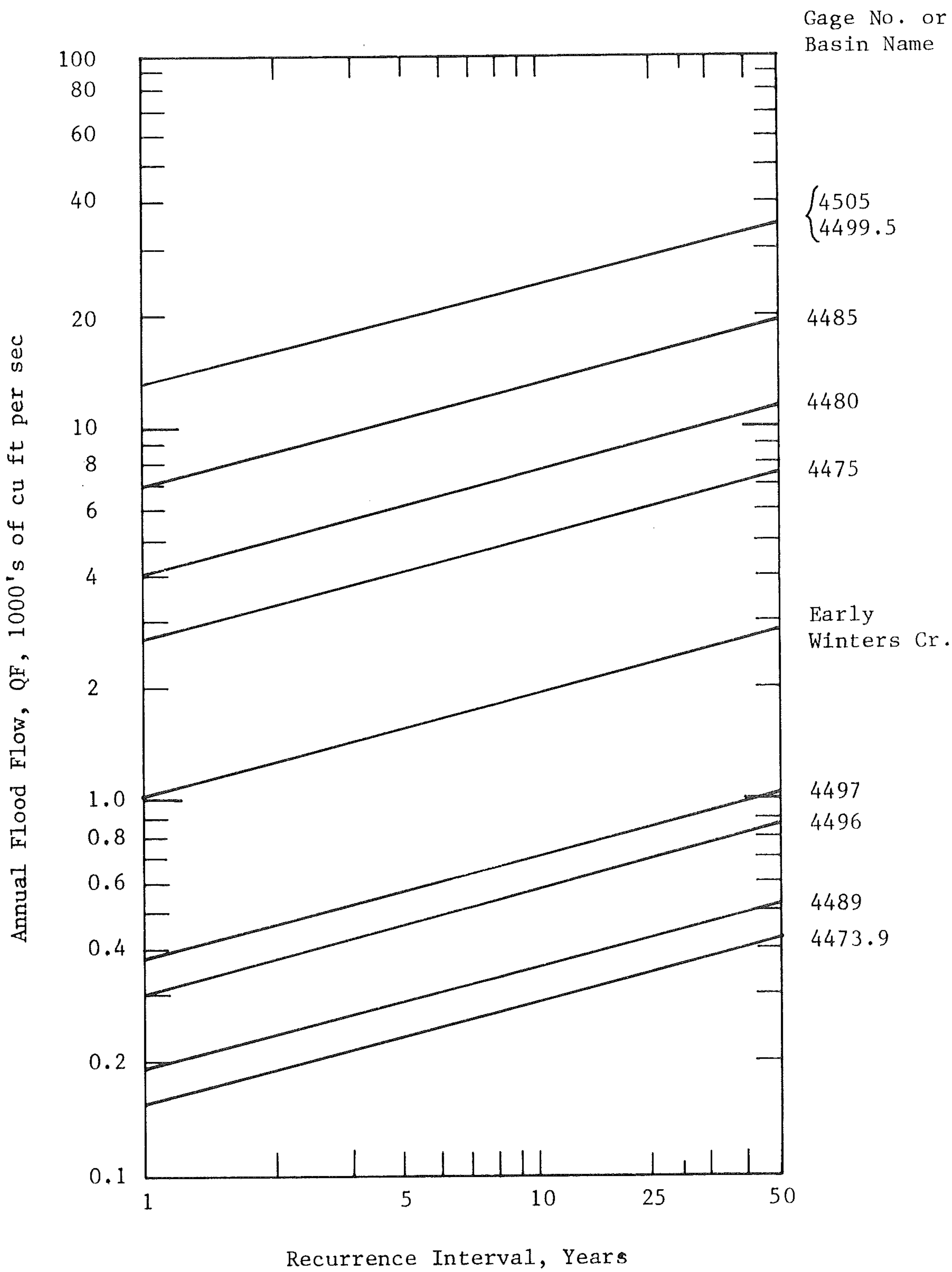


Figure 11. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors.

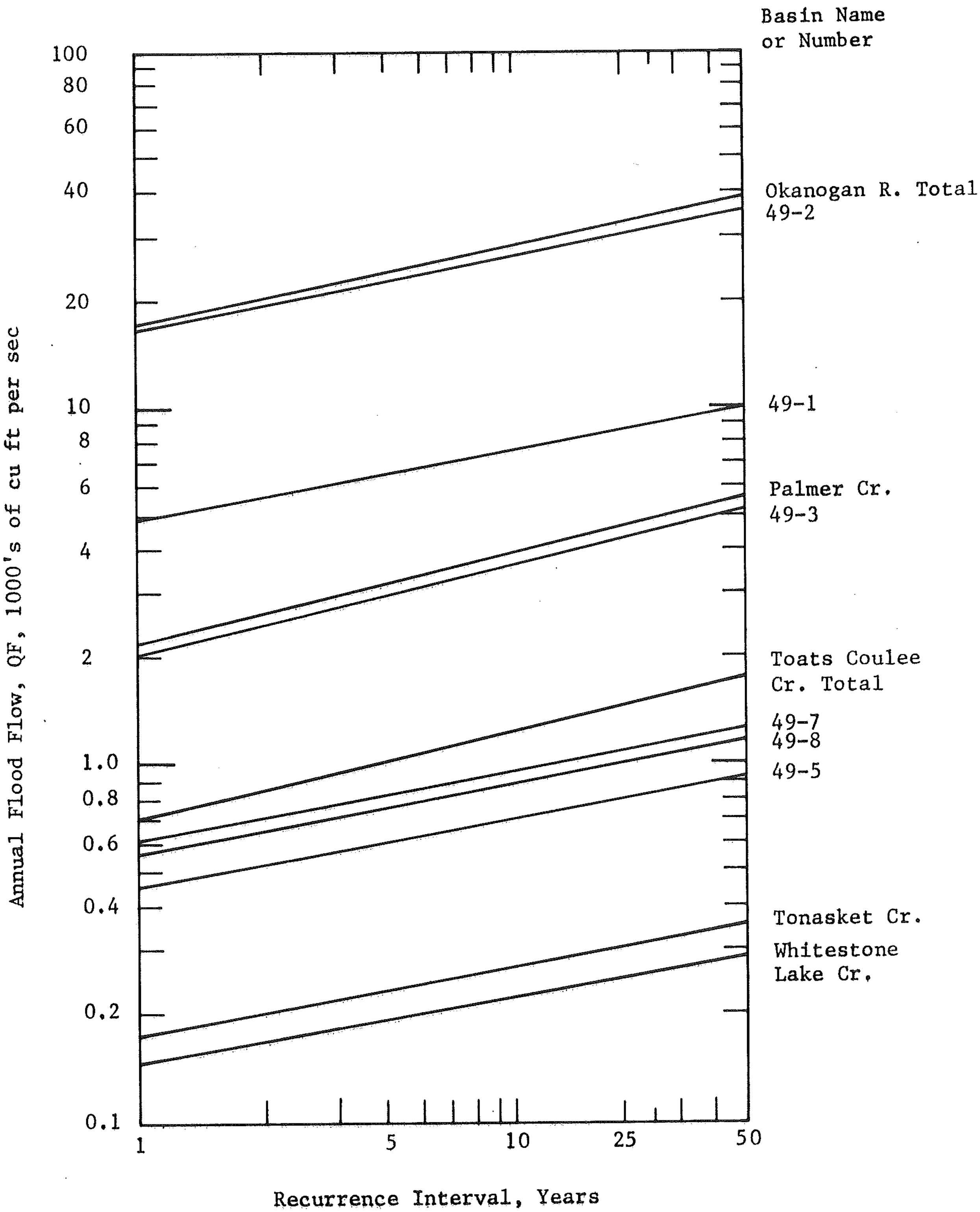


Figure 12. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors. Hyphenated numbers are basin numbers (i.e., 49-2). See Basin Map in envolope at back of Report.

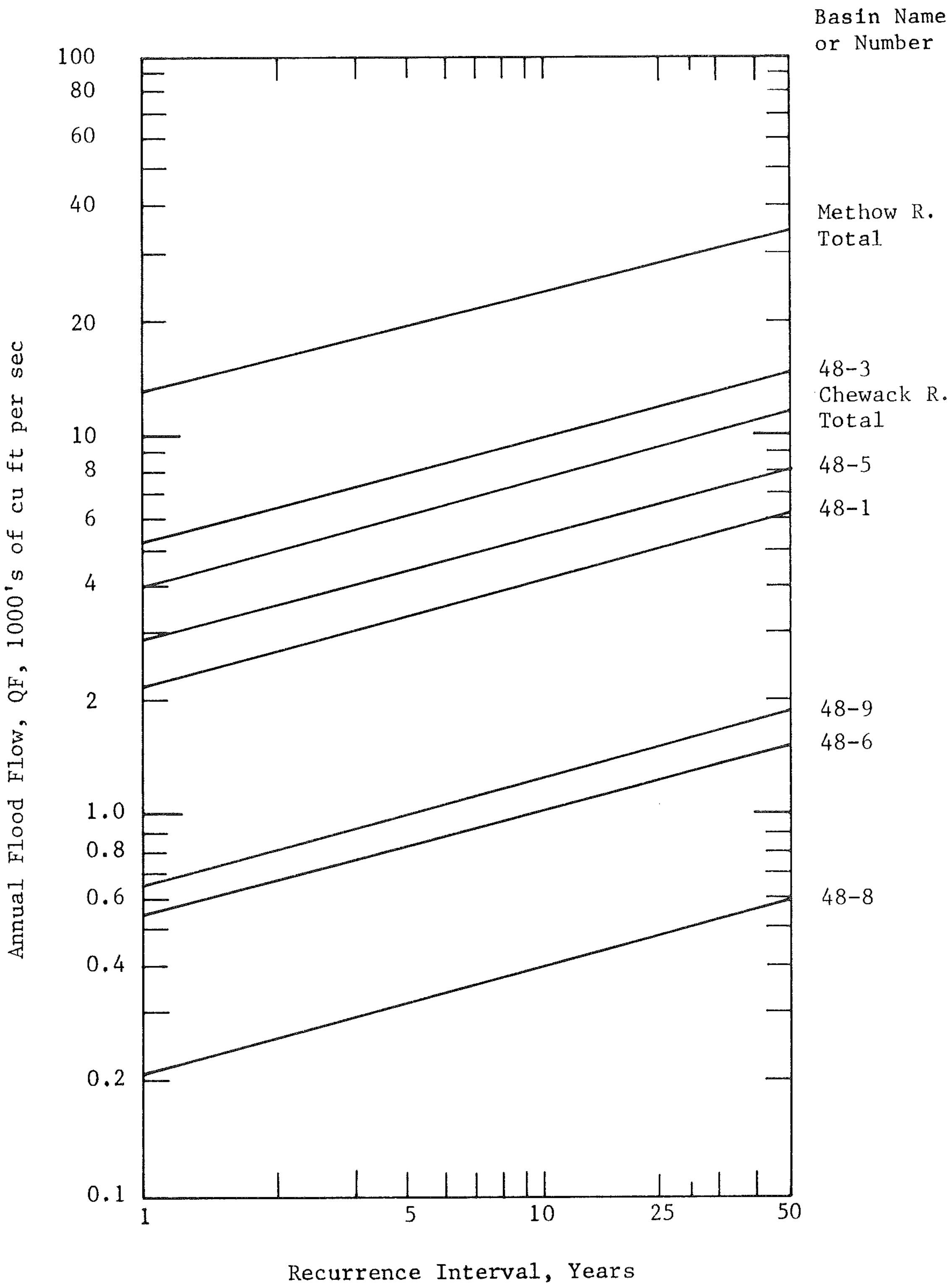


Figure 13. Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage numbers are from records. Other curves were calculated from geographic factors. Hyphenated numbers are basin numbers (i.e., 49-2). See Basin Map in envelope at back of Report.

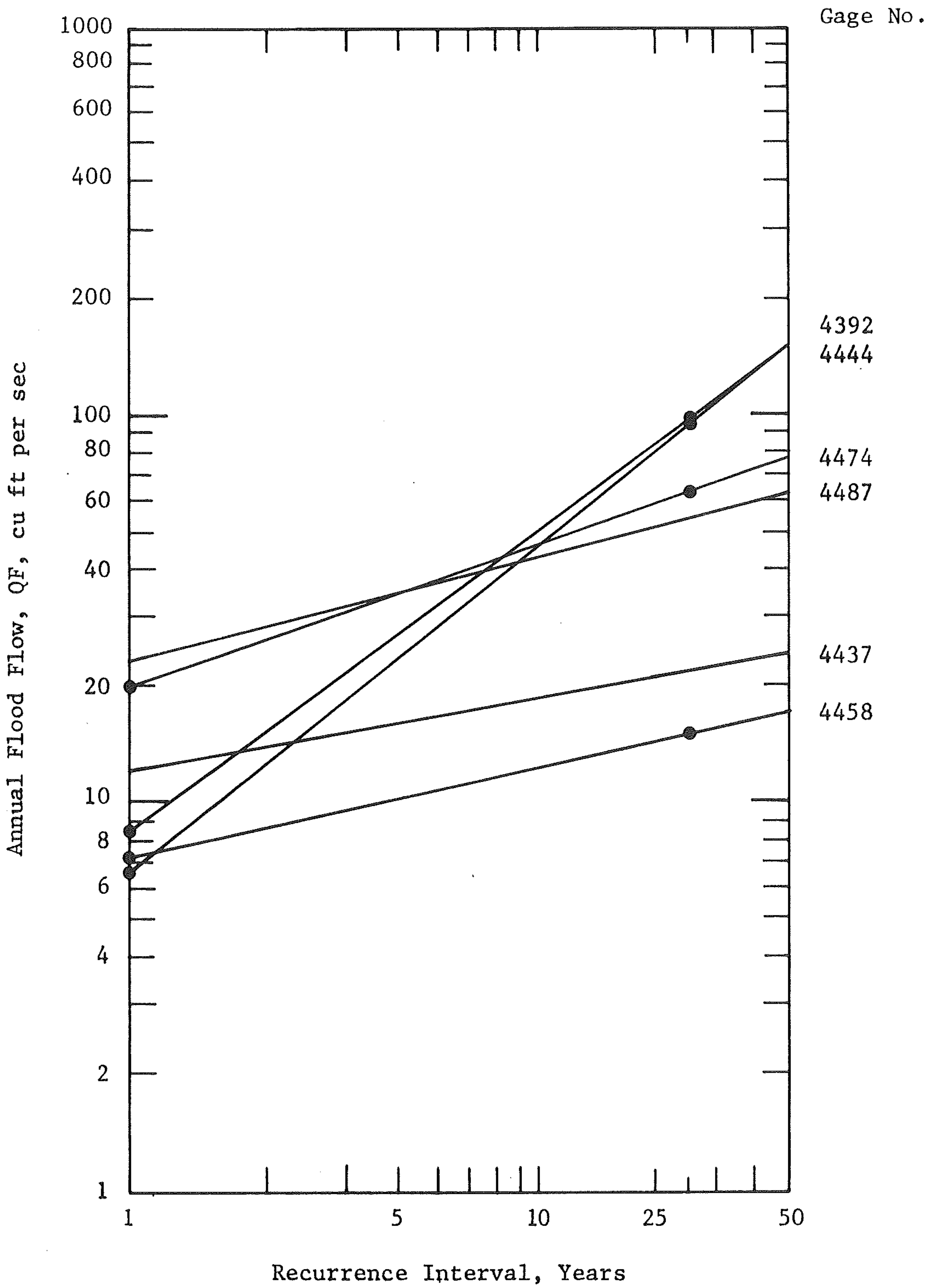


Figure 14. **Annual Flood Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area**

Note: Curves with data points and gage numbers are from records.

LOW FLOWS

The general methodology for determining natural low flows in ungaged streams is based on the low flow project conducted earlier for the Department of Ecology and as mentioned previously in the Introduction.[2/] This method is based on the reasoning that if a "characteristic" low flow for gaged streams, such as the 7-day average low flow with a 2-year recurrence interval (Q7L2), can be correlated against drainage basin characteristics, then the drainage basin characteristics of ungaged streams in the same region should be indicative of the (Q7L2) values of the ungaged streams on the correlation graph. This analytical process applies to other low flows as well, such as (Q7L20), the 7-day average low flow with a 20-year recurrence interval. With these two flows the major portion of the low flow, recurrence interval graph can be defined.

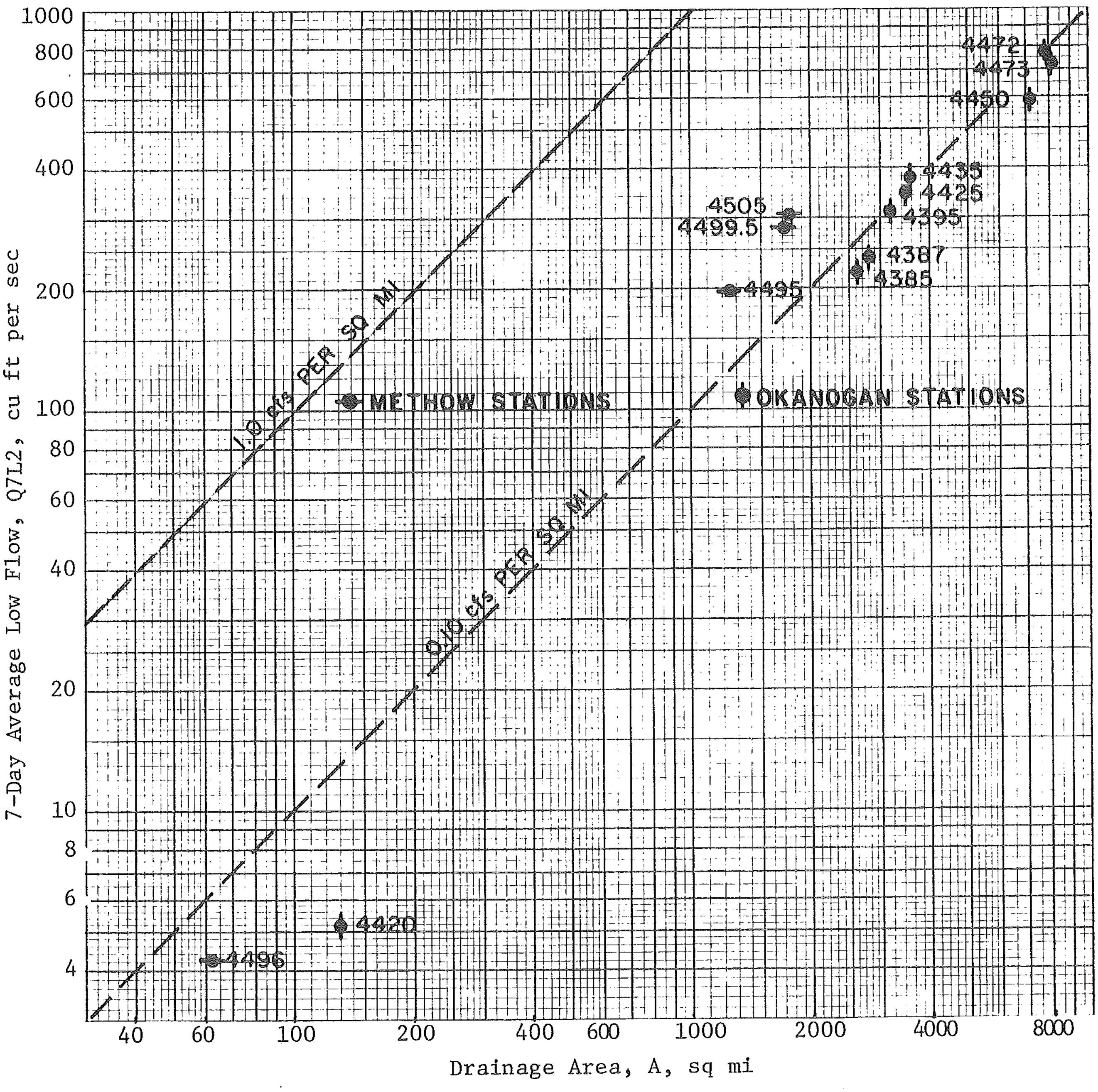
One of the major basin geomorphic characteristics which correlates with the low flow, but in a highly variable fashion, is drainage area (A).[11/] Part of this variability, as shown in Fig. 15, is due to the fact that all the projected surface area of a drainage basin does not contribute ground water to low flow in a stream. Therefore, the unit values of low flow in cfs per square mile of drainage basin (the low-flow-yield index)[12/] is an easy way to generally compare the low flows of different streams with geologically homogeneous drainage basins, but usually unit low flows do not correlate well with basin geomorphic parameters. Actual flow values provide better bases for comparison. Glaciers and high elevation snowpacks contribute melt to the low flows of some streams in the Area.

General Low Flow--Basin Parameter Methodology

By plotting the gaged low flow values of (Q7L2) and (Q7L20) against recurrence interval on log-log graph paper, the points can be connected in a straight line which is usually a curved line on regular recurrence interval (probability)

[11/] Thomas, D. M. and M. A. Benson, "Generalization of Streamflow Characteristics from Drainage-Basin Characteristics," Geological Survey Water Supply Paper 1975, U.S. Govt. Printing Office, Washington, D.C., 1970.

[12/] Nassar, E. G., "Low-Flow Characteristics of Streams in the Pacific Slope Basins and Lower Columbia River Basin, Washington," U.S. Geological Survey, Open-File Report, prepared in cooperation with the State of Washington, Department of Ecology, 1973.



Numbers are gaging stations; Okanogan-Methow River Basins Study Area

Figure 15. Seven-Day Average Low Flow Related to Drainage Area
(See Table 5 for Gaging Station Names)

paper. As shown in Fig. 16, extension of the straight line from (Q7L20) through (Q7L2) to an intersection with the 1-year recurrence interval line yields a projected 7-day average low flow value (Q7L1P) for each gaging station. Statistically, of course, this 1-year value cannot exist, but physically it represents a comparative measure of a maximum low flow that could be expected to occur in any particular stream. It provides a basis for comparison between streams as a measure of the relative basin-storage input. The slope of the recurrence interval graph (p) in Fig. 16 is a measure of low flow stability. This is analogous to the slope index which is defined by the ratio of (Q7L2)/(Q7L20).[12/]

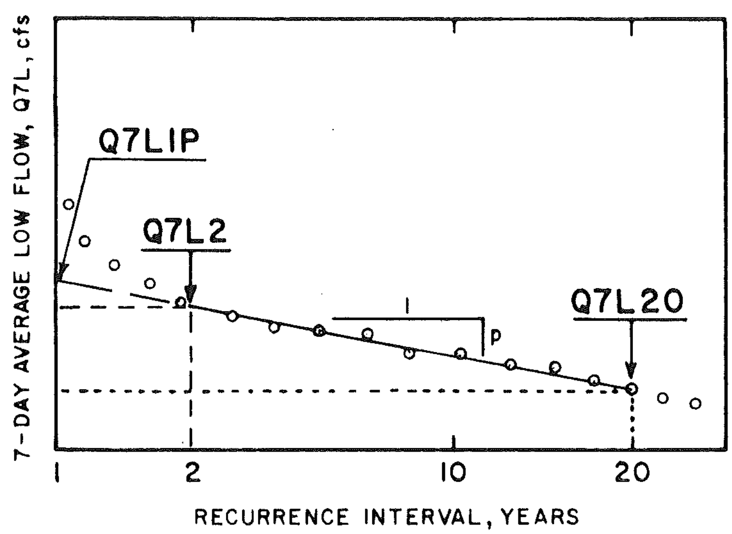


Fig. 16. Nomenclature Sketch for Low Flow Analysis

The basin relief (H), or differential elevation between the headwaters and outlet (or gage) of the basin, is introduced to account for the potential energy (driving force due to gravity) of the low flow (in the stream and in the groundwater source). The elevation at the headwaters of the basin is taken as the longest contour in the vicinity, not peak elevations which are isolated values. Combining the terms described above into a physical relationship yields

$$\chi = \frac{(AH)^{\frac{1}{2}}\ Q7L1P}{300p} . \qquad (3)$$

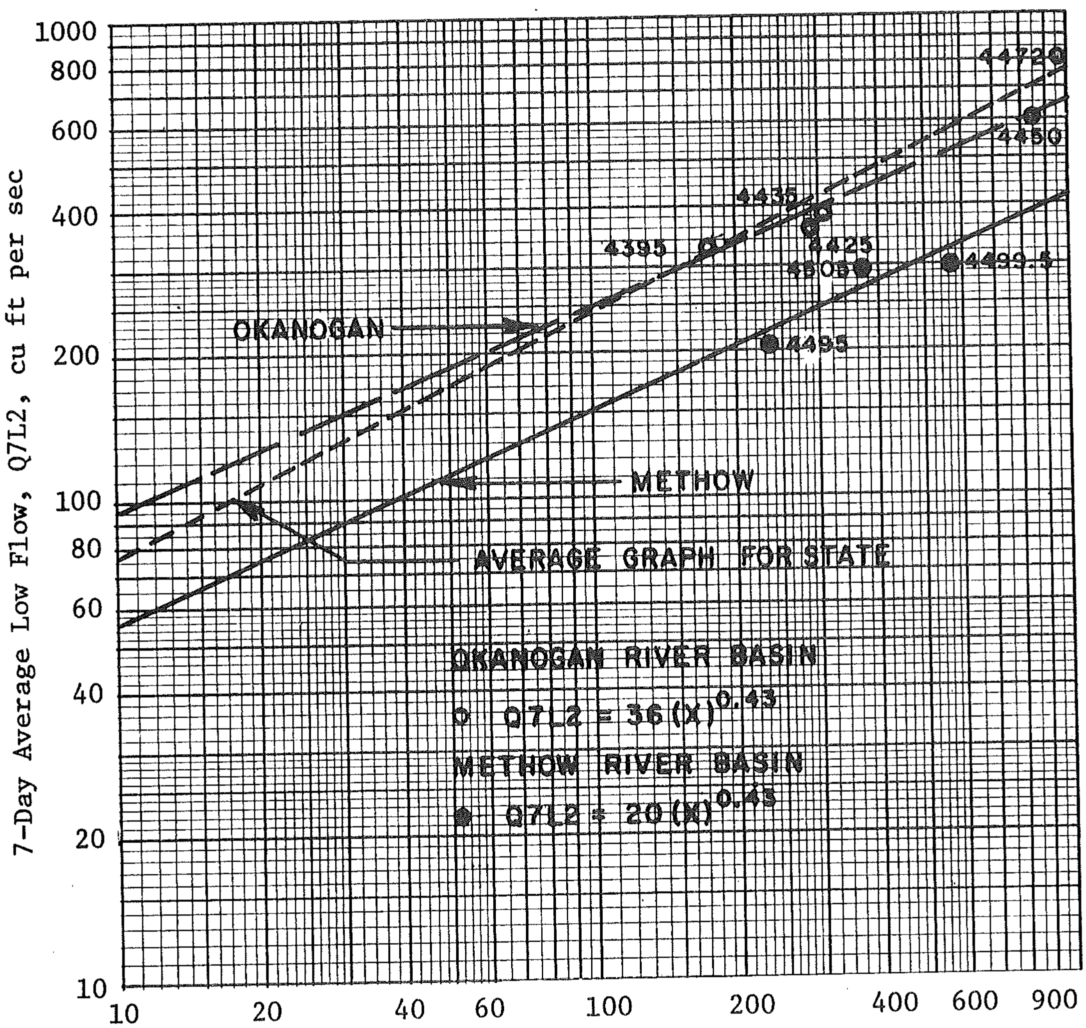
Data for the Okanogan-Methow general low flow analysis are presented in Table 10 and (Q7L2) is plotted against (χ) as shown in Fig. 17. This relationship yields the equation for the Okanogan Basin of

Table 10. Factors for Low Flow Analysis in the Okanogan-Methow River Basins Study Area

Stream Gaging Station Number	Location	Period of Record	Drainage Area, A (sq mi)	Elevation Relief, H (mi)	Low Flows Q7L2 (cfs)	Low Flows Q7L20 (cfs)	Low Flows Q7L1P (cfs)	Recurrence Interval Plot Slope, p	Basin Parameter χ*
12-4395	Okanogan River at Oroville	1943-69	3210	0.775	321.0	130.0	420.0	0.400	174.6
-4450	Okanogan River near Tonasket	1929-69	7280	0.780	610.0	370.0	710.0	0.210	849.2
-4472	Okanogan River at Malott	1958-71	8100	0.775	800.0	420.0	970.0	0.270	948.8
-4420	Toats Coulee Cr. near Loomis**	1920-71	130	0.970	5.2	3.3	6.0	0.200	1.1
-4425	Similkameen River near Nighthawk	1911-71	3550	0.730	360.0	207.0	420.0	0.240	297.0
-4435	Similkameen River near Oroville	1911-28	3580	0.775	380.0	215.0	420.0	0.240	307.3
-4495	Methow River at Twisp	1920-62	1301	1.216	205.0	150.0	220.0	0.125	233.3
-4496	Beaver Cr. below S.F., near Twisp**	1960-71	62	0.606	4.3	2.9	4.8	0.170	0.6
-4499.5	Methow River near Pateros	1959-71	1772	1.342	300.0	240.0	320.0	0.090	578.0
-4505	Methow River at Pateros	1904-20	1794	1.367	310.0	220.0	340.0	0.150	374.0

$$^{*}\chi = \frac{(AH)^{1/2}\,(Q7L1P)}{300p}$$

**Not included in Fig 17 to avoid excessive page size.



$$X = \frac{(AH)^{\frac{1}{2}}\ Q7L1P}{300p}$$

Figure 17. Correlation Graph for Low Flow Estimation (See Table 10 for Gaging Station Names)

$$(Q7L2) = 36.0\ (\chi)^{0.43}, \quad (4)$$

and for the Methow Basin

$$(Q7L2) = 20.0\ (\chi)^{0.43}. \quad (5)$$

The average equation developed for the whole State in the earlier low flow study,[2] and shown as a dashed line in Fig. 17, is

$$(Q7L2) = 23.0\ (\chi)^{0.50}. \quad (6)$$

It should be noted in Reference 2 that (Q7L2) is plotted as (Q_{72}) against (AH), whereas in Fig. 17 this set of terms is $(AH)^{\frac{1}{2}}$. Thus the coefficient in Eq. (6)

and Fig. 17 is 23.0, whereas in the earlier study (page 32, Fig. 4, Ref. 2) the coefficient was 7.5. It has been found that $(AH)^{\frac{1}{2}}$ reduces the amount of deviation from an average line for most of the basins tested.

The data points in Fig. 17 are based on the period of record for each gage. The average curve for the statewide analysis utilized (Q7L2) values for the longest period of record. In comparing the Okanogan and Methow River lines in Fig. 17, the lake storage and size effects of the Okanogan Basin are evident in the larger flows. Following a description of the general low flow procedure a special section on the Methow Basin will be presented.

In analyzing low flow values for the various Study Areas in the State, the following list of steps is suggested:

For Gaged Streams:

G1.* Set up a table for recording these values.

G2. Measure the following parameters for each gaged basin from maps of 1:24,000 and/or 1:62,500 scales: length of first-order (unbranched) streams (L1); total length of streams (LT); and basin relief (H). The map scales may be mixed. Do not include intermittent stream lengths.**

G3. Determine low flow values of (Q7L2) and (Q7L20) from the gage records or as analyzed in open-file reports or record analysis printout sheets from the USGS. Also find drainage area above gage from the records or River Mile Index.

G4. Calculate the following combinations of terms: 3/2(L1•H), (LT•H), $(LT)(H)^{\frac{1}{2}}$, and $\sqrt{DD}\cdot(L1)$, where DD is the drainage density, (LT)/A. These combinations are referred to as (BP) terms, for Basin Parameters, in later steps. These terms have been found to agree very closely with the (Q7L2) values for various parts of the

---

*"G" stands for Step in Gaged stream analysis procedure. "U" will represent Ungaged procedure Steps.

**A convenient way to do this is to trace the drainage networks off the topographic maps and work with the tracing. This avoids distraction by other features on the map. First order streams are numbered by geomorphic notation, starting from the headwaters, and are unbranched on the maps. Fisheries department ordering starts at the mouth of the stream as Order 1.

State on a 1:1 basis. They can be used also to develop correlations for (Q7L20) values.

G5. Evaluate which parameter(s) (called BP) best agree with the gaged (Q7L2) values for various subareas of the Study Area. Use these as the parameters for making first estimate of (Q7L2) for ungaged basins.

G6. Plot (Q7L2) and (Q7L20) for each gaging station on a log-log recurrence interval graph. Project each straight line graph from (Q7L20) through (Q7L2) to intersect a recurrence interval of 1-year and read (Q7L1P) from the graph.

G7. Measure the slope p = y/x with a scale directly from the low flow, recurrence interval plot.

G8. Calculate (χ) for each gaged basin (Eq. 3) and plot (Q7L2) versus (χ) as in Fig. 17 using log-log graph paper.

G9. Determine how much larger (Q7L1P) is than (Q7L2) for the various subareas in the Study Area. Use these ratios to estimate (Q7L1P) for the ungaged subareas later in Step U15.

G10. Determine the ratios of (Q7L2)/(Q7L20) (Slope Index) for gaged basins for later use in making first estimates of (Q7L20) for ungaged basins.

G11. Make two other log-log graphs of (Q7L2) and (Q7L20), each plotted against (BP)(Q7L1P)/1000p, where (BP) is the best predictor (consistently the closest) of (Q7L2) determined in Step G5 of the analysis. The 1000 and the 300 (in Step G8 and Fig. 17) are merely used for producing convenient-sized plotting numbers. Keep these graphs for future reference in checking predicted (Q7L2) and (Q7L20) values for ungaged streams.

<u>For Ungaged Streams</u>:

U12. Repeat Step G1 for ungaged streams.

U13. Repeat Step G2 for ungaged streams, and also measure the drainage area (A). As noted earlier you may find a tracing of the basin and its stream network much easier to work with than the original map.

U14. Using the best estimate basin parameters (BP) from Step G4 for ungaged basins, measure these parameters for the ungaged basins to make first estimates of (Q7L2).

U15. Estimate (Q7L1P) for each ungaged stream based on the relationships developed under Step G9.

U16. Determine $(\chi) = (AH)^{\frac{1}{2}}(Q7L1P)/300p$ from plot developed in Step G8 for each ungaged (Q7L2) value determined in Step U14. The only unknown in (χ) is (p), which is solved for by $(p) = (AH)^{\frac{1}{2}}(Q7L1P)/300(\chi)$, where (p) is the slope log-log, recurrence interval plot between (Q7L2) and (Q7L20) for the ungaged streams.

U17. Estimate the ungaged value of (Q7L20) based on the Slope Index of (Q7L2)/(Q7L20) determined in Step G10 for subareas.

U18. Plot (Q7L2) on log-log graph paper and project the slope of the line (p) towards (Q7L20). If the intercept of the projected line and the value of the ordinate (Q7L) at the 20-year recurrence interval line shows good agreement with the estimate value of (Q7L20) from Step U17, the solution is complete.

U19. If there is not good agreement, use the same values of (Q7L1P) and (p) found in Steps U15 and U16, and develop new estimates of (Q7L2) and (Q7L20) using the graphs developed in Step G11.

U20. Plot (Q7L2) and (Q7L20) on a log-log, recurrence interval graph, and compare the new slope (p) with those of gaged streams in the similar subareas from Step G6 to complete the analysis.

Miscellaneous measurements made by the Geological Survey at numerous stations on streams throughout the State provide a good source of information for comparing the magnitude of the predicted low flow values against actual conditions. Of course, upstream conditions such as regulation and diversion must be known to make an adequate comparison because the low flow methodology predicts natural flow conditions.

Low flow values of (Q7L2), (Q7L10) and (Q7L20) for gaged and ungaged streams in the Okanogan-Methow River Basins Study Area are summarized in Table 11. Figures 18, 19, 20, 21 and 22 are graphical plots of the gaged and ungaged 7-day average low flow recurrence interval analysis. After Fig. 22, two special sections are presented, one on the Methow Basin low flows, and one on the bank and basin storage in the Okanogan Valley.

Table 11. Gaged and Calculated 7-Day Average Low Flows

OKANOGAN-METHOW RIVER BASINS STUDY AREA

Stream Name, Gaging Station Number; Figure Number, (Basin Number)*	Q7L2* (cfs)	Q7L10* (cfs)	Q7L20* (cfs)
Okanogan R. at Bridge Street, Oroville (-4391.5); Fig. 19, (49-1)	321	170	129
Toats Coulee Cr. near Loomis (-4420); 22	5.2	3.8	3.3
Similkameen R. near Nighthawk (-4425); 19	360	245	207
Similkameen R. near Oroville (-4435); 19	360	245	207
Similkameen R. at Mouth; 18, (49-2)	360	245	207
Bonaparte Cr. at Mouth; 19, (49-5)	25	17	14.3
Okanogan R. near Tonasket (-4450); 19	780	470	380
Omak Cr. at Mouth; 22, (49-7)	28	11.5	7.8
Salmon Cr. at Mouth; 19, (49-8)	98	54	41.4
Okanogan R. at Malott (-4472); 19	858	520	418
Okanogan R. at Mouth; 18, (49)	891	530	425
Chewack R. at Winthrop (-4480); 21	61	48	43
Chewack R. at Mouth; 20, (48-1,2)	61	48	43
Twisp R. at Mouth; 20, (48-5)	18	14.5	13
Methow R. near Twisp (-4495); 21	205	166	153
Beaver Cr. below S. Fork, near Twisp (-4496); 20	4.3	3.3	2.9
Beaver Cr. at Mouth; 20, (48-6)	13.7	10.7	9.5
Libby Cr. at Mouth; none, (48-8)	1.3	1.0	0.9
Gold Cr. at Mouth; 20, (48-9)	8.0	6.1	5.4
Methow R. near Pateros (-4499.5); 21	300	255	240

*Explanation of terms:

Q7L2: Q(Flow), 7(Seven-Day Average), L(Low), 2(Recurrence Interval).

Q7L2, Q7L10 and Q7L20 are the 7-day average low flows which can be expected to occur once in any 2-, 10- or 20-year interval.

Gaged values are for period of record; ungaged values determined by analysis. For gaging station information see Table 5.

Figure number of Recurrence Interval Graph comes after semicolon. For stations not listed in Table 11, see Table 5. Ungaged basins are numbered by Water Resources Inventory Area numbers in parentheses, i.e., (49-8), as shown on base map.

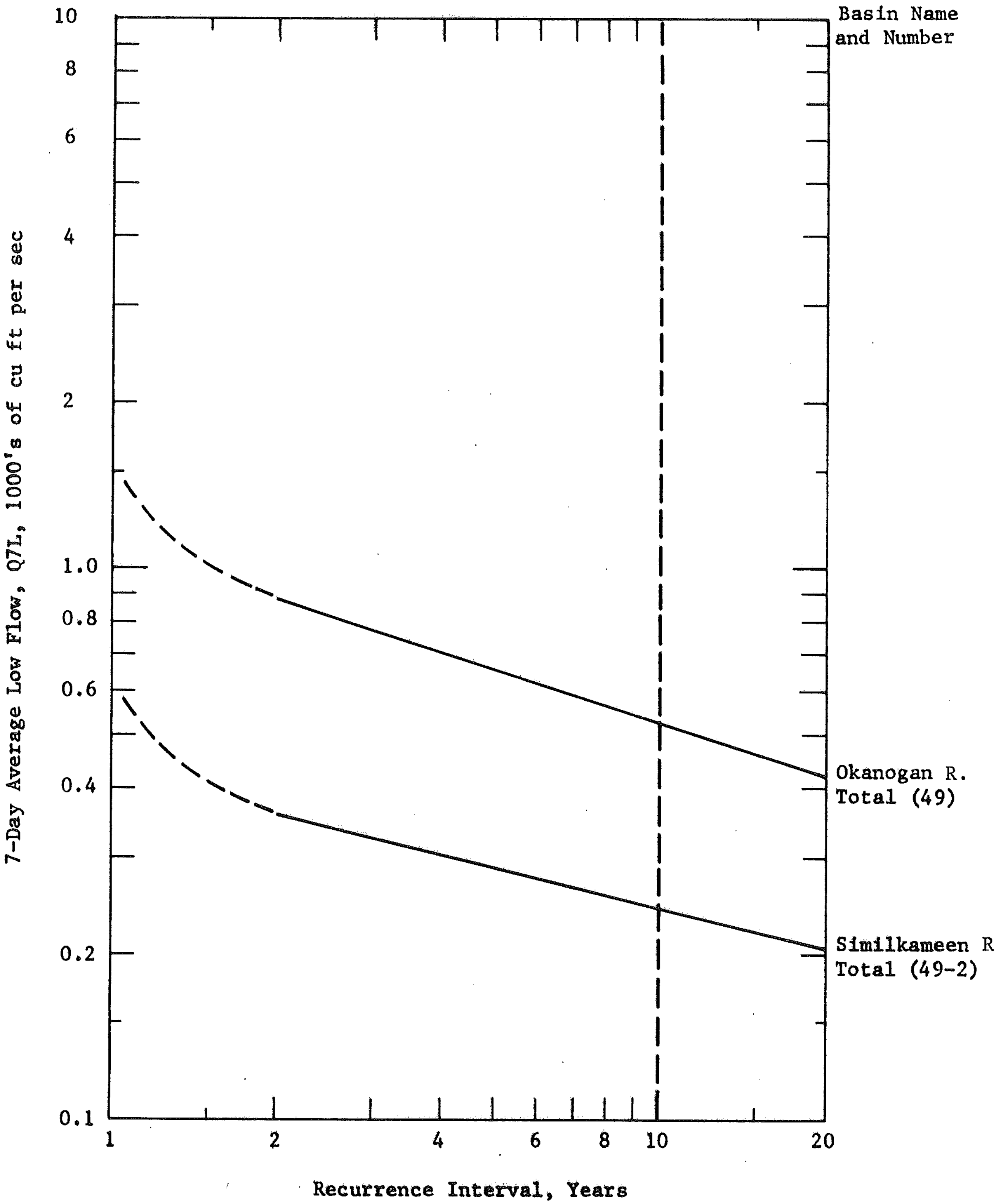


Figure 18. 7-Day Average Low Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage number are from records. Other curves are calculated from basin parameters.

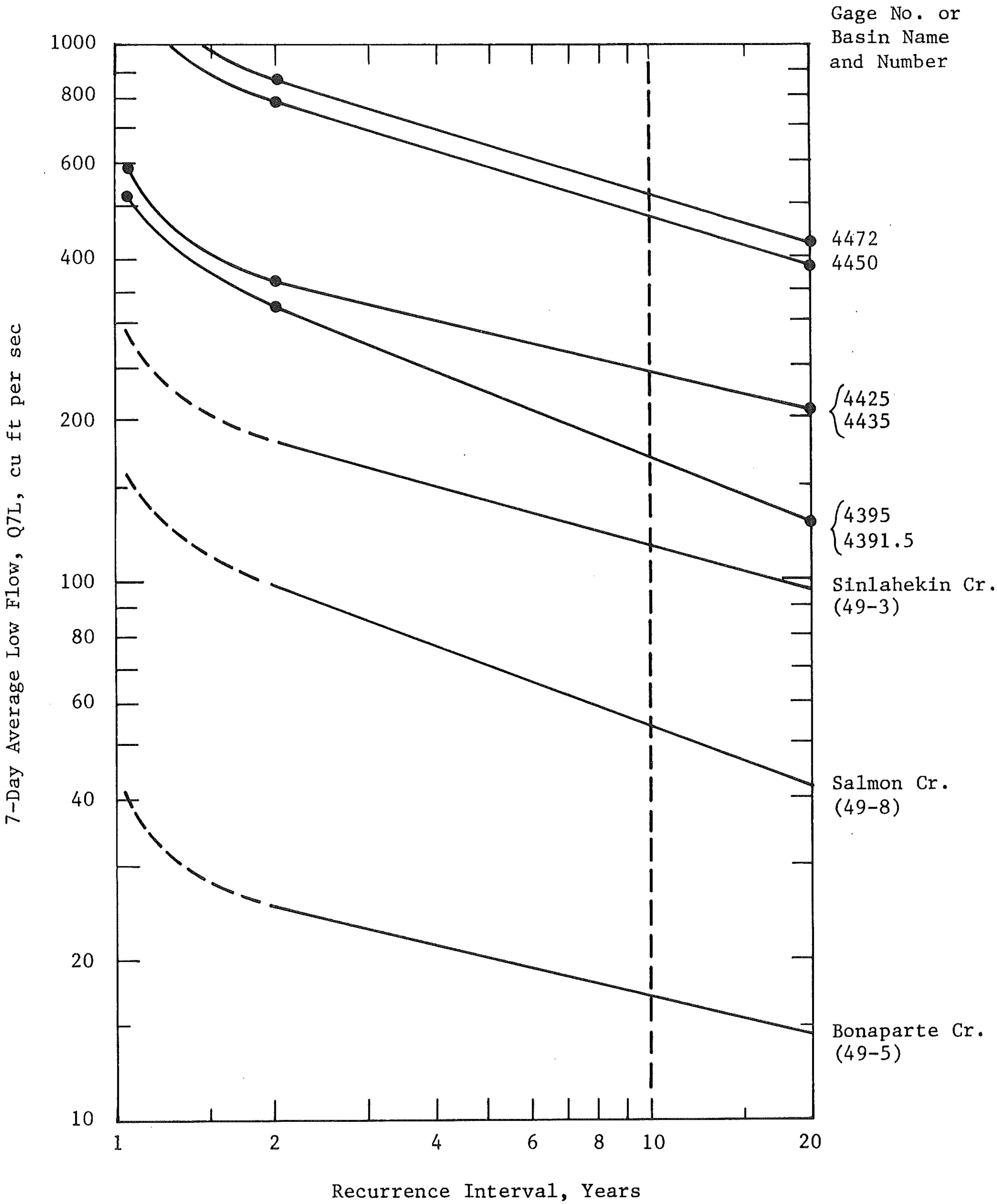


Figure 19. 7-Day Average Low Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage number are from records. Other curves are calculated from basin parameters.

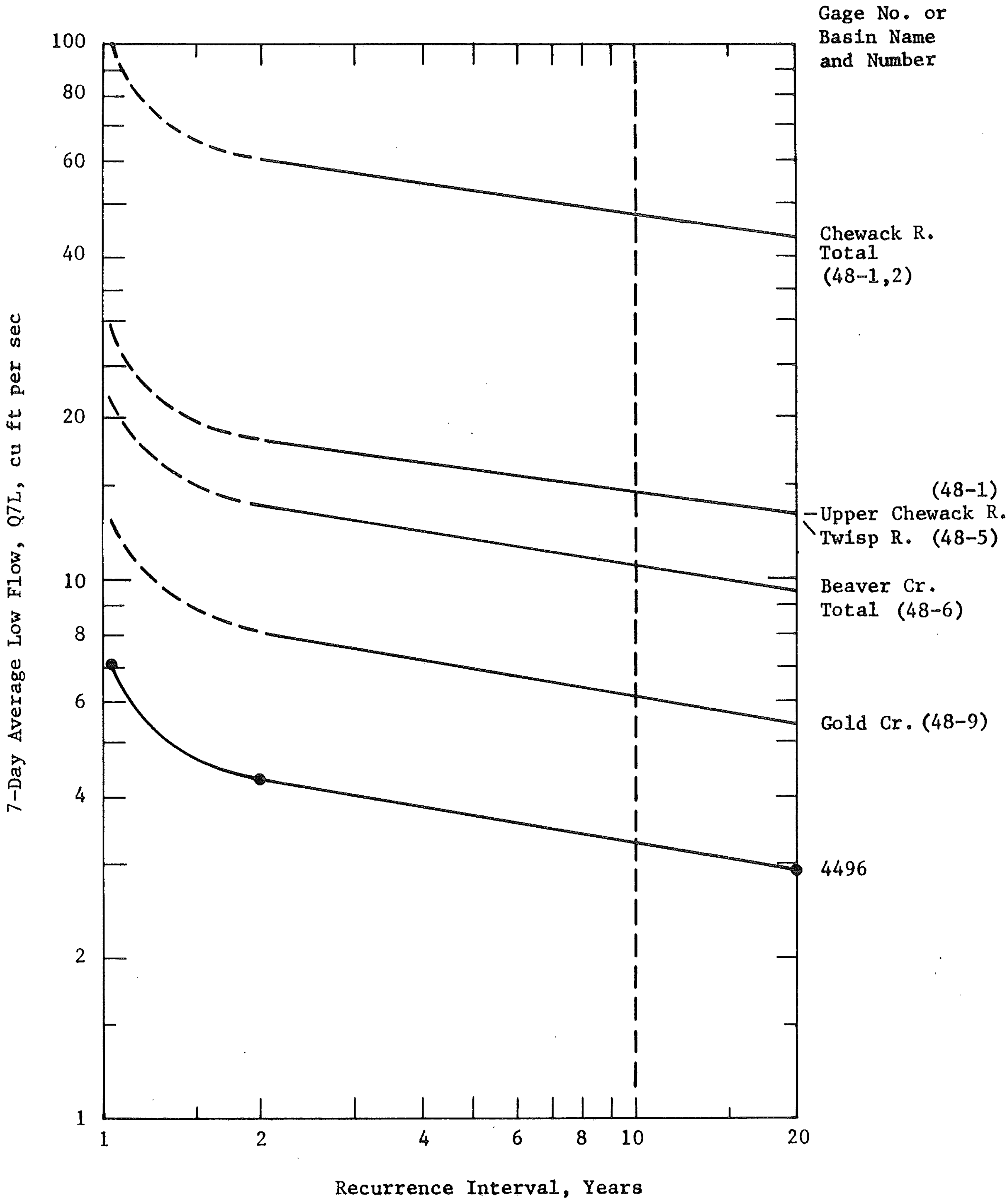


Figure 20. 7-Day Average Low Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage number are from records. Other curves are calculated from basin parameters.

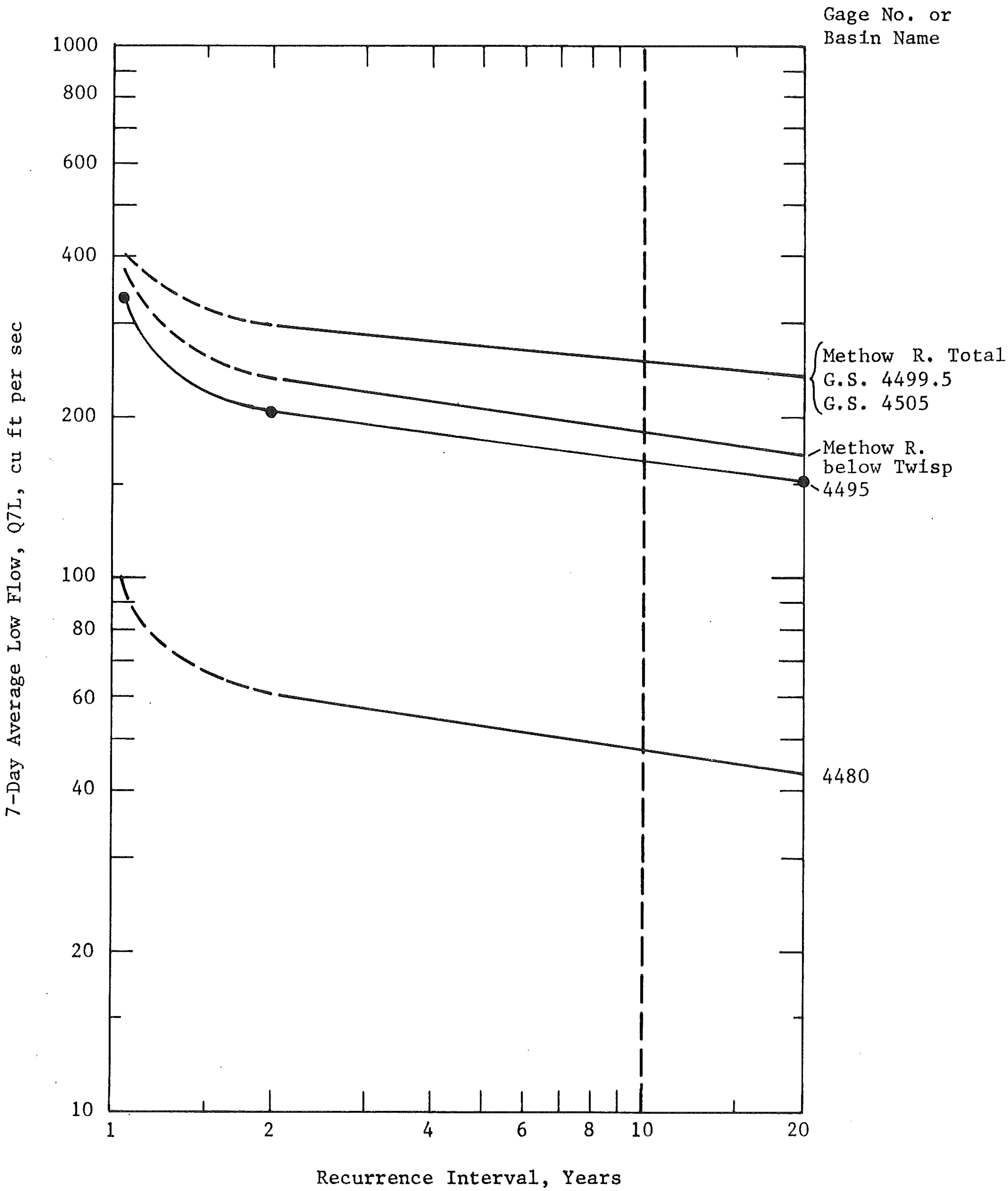


Figure 21. 7-Day Average Low Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage number are from records. Other curves are calculated from basin parameters.

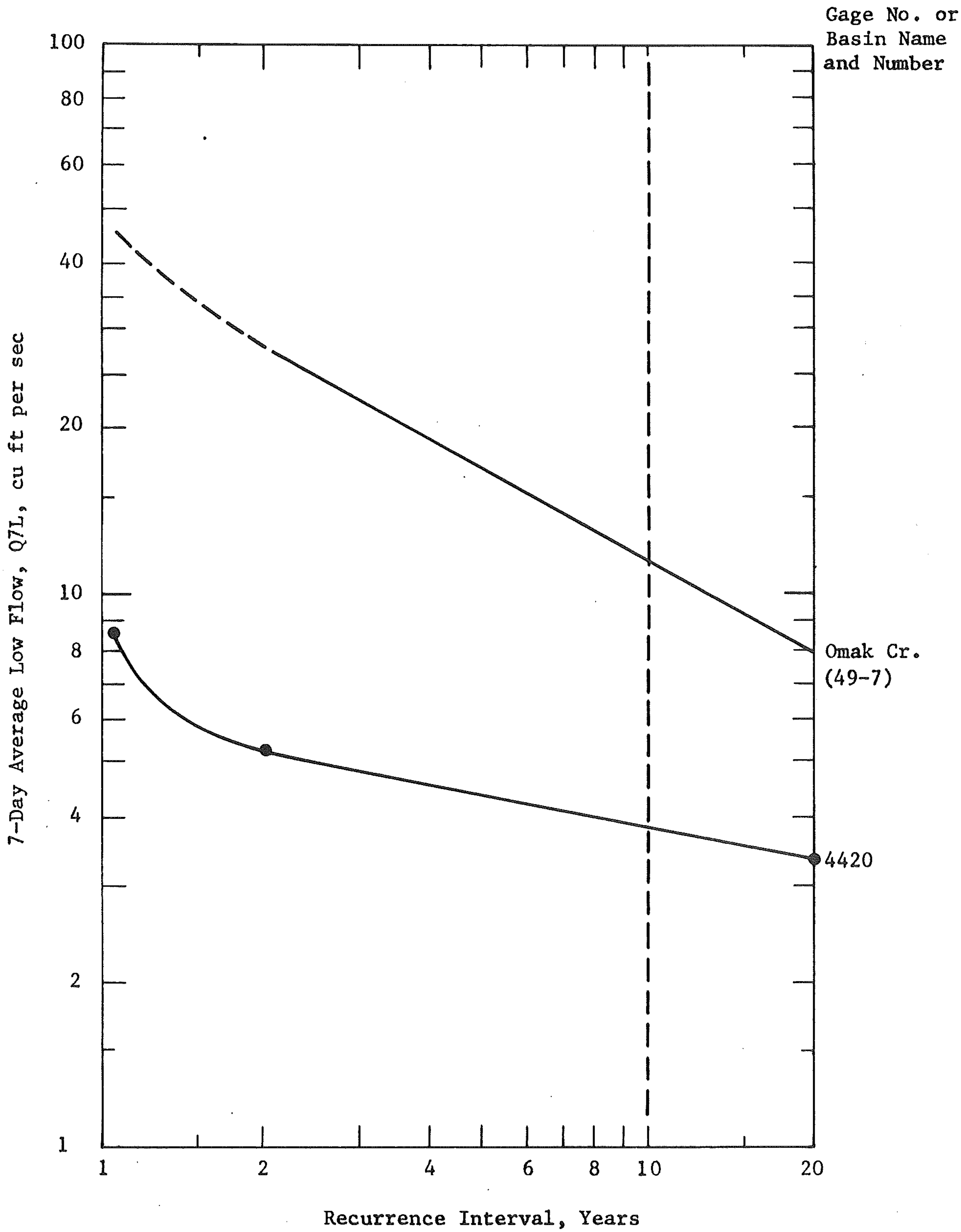


Figure 22. 7-Day Average Low Flow Recurrence Interval Graphs for Okanogan-Methow River Basins Study Area

Note: Curves with data points and gage number are from records. Other curves are calculated from basin parameters.

Low Flow Methodology for the Methow River Basin

A special analysis was conducted of the low flow conditions in the various streams of the Methow River Basin due to:

(1) the availability of only two long-term gaging station records still in operation;* and

(2) the "below average" characteristics of the low flows in the Methow Basin compared to the Statewide average and Okanogan River graphs as shown in Fig. 17.

In order to offset these conditions, relationships between miscellaneous low flow measurements and some of the geomorphic parameters for the Methow Basin were developed.[13/] Data for 1971 were selected because the low flow values that year at the two gages were very close to the 7-day average low flow with a 2-year recurrence interval. One-, three- and seven-day average low flows are usually very similar, and this was assumed to be the case for the miscellaneous stream gaging sites. The long-term and 1971 low flow values for the two gaging stations are presented in Table 12.

Table 12. Low Flow Gaged Records, Long Term Averages and for the Water Year 1971, at Two Stations in the Methow Basin

Stream Gaging Station Location and Number	Beaver Creek below South Fork near Twisp: 12-4496	Methow River near Pateros: 12-4499.5
7-Day Average, 2-Year Low Flow, Q7L2, cfs	4.3	300
7-Day Average, 20-Year Low Flow, Q7L20, cfs	2.9	240
Low Flow of 1971, QL(1971), cfs	4.8	311

The locations of the various miscellaneous stream gaging stations and the two long-term stations used in this analysis are shown in Fig. 23. The values shown in Table 12 are plotted in Fig. 24, and they suggest the following relationships for the Methow Basin:

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*One on a small branch of Beaver Creek (4496), and one near the outlet of the basin (4499.5) near Pateros. The Methow River gage (4495) at Twisp was discontinued in 1962.

13/ U.S. Geol. Survey, "Surface Water Records," Water Resources Data for Washington, 1971.

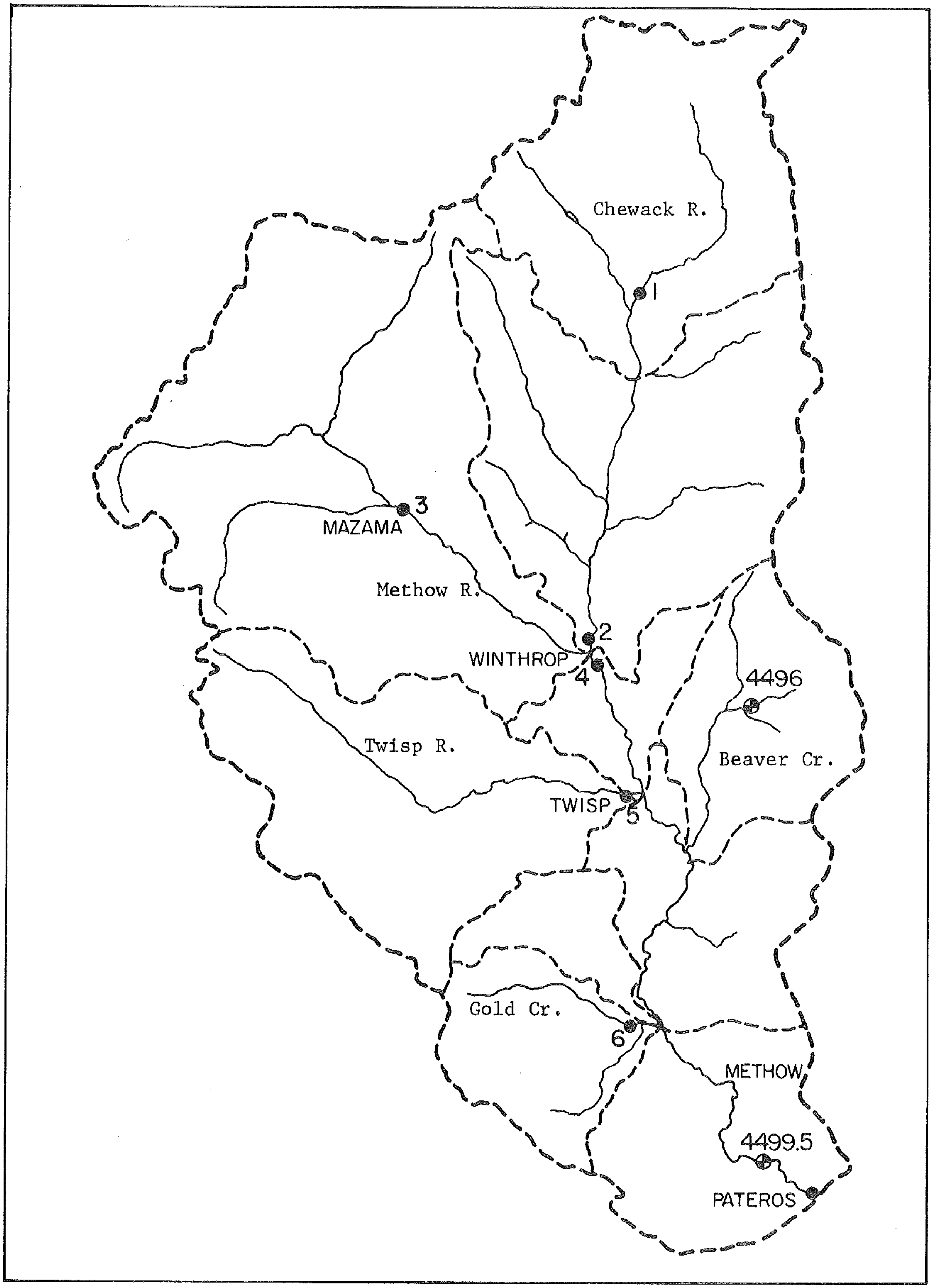

Figure 23. Location Map of Miscellaneous and Long-Term Gaging Stations Used in the Low Flow Analysis of the Methow River Basin

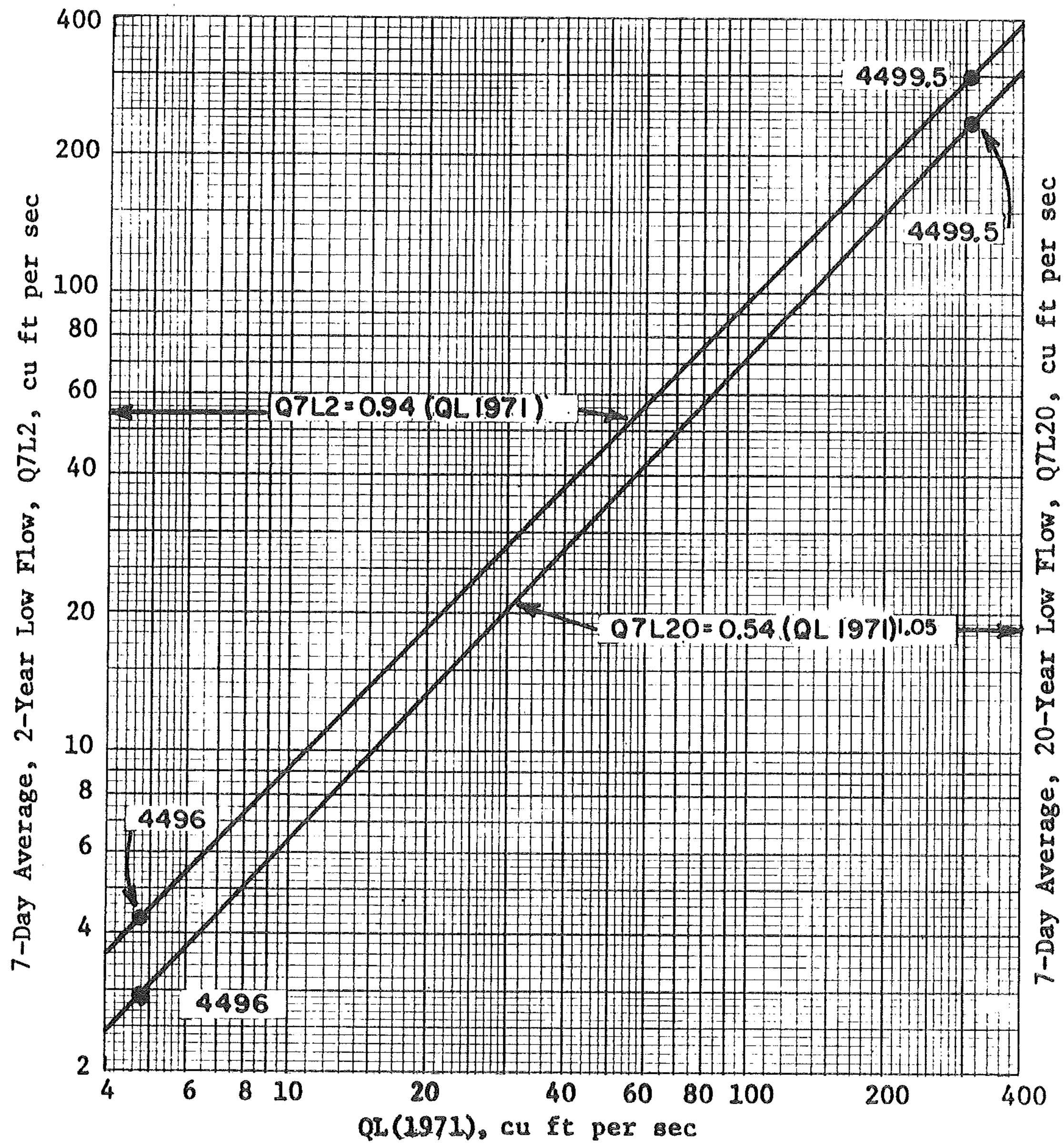

Figure 24. 2-Year and 20-Year 7-Day Average Low Flows Related to Low Flow of Water Year 1971, Methow River Basin

$$(Q7L2) = 0.94\ (QL1971) \quad (7)$$

$$(Q7L20) = 0.58\ (QL1971)^{1.05} \quad (8)$$

Information on the miscellaneous gaging stations is presented in Table 13. Also included are basin geomorphic characteristics such as first-order stream length (L1), total stream length (LT), and the combined terms of drainage density and first order stream length ($\sqrt{DD}\cdot L1$). The last column in Table 13 lists the 2-year and 20-year, 7-day average low flow values (Q7L2 and Q7L20) estimated for the six miscellaneous gaging stations using Fig. 24.

In order to develop a more general low flow-basin parameter correlation graph, the (Q7L2) and (Q7L20) values for the six miscellaneous stations in Table 13 were plotted against various basin parameters. The best correlation was achieved between the low flow values and ($\sqrt{DD}\cdot L1$) as displayed in Fig. 25. The graphical correlations developed are:

$$(Q7L2) = 0.13\ (\sqrt{DD}\cdot L1)^{1.22} \quad (9)$$

and

$$(Q7L20) = 0.07\ (\sqrt{DD}\cdot L1)^{1.27} \quad (10)$$

The 20-year low flows in Table 13 seem to be on the order of two-thirds of the 2-year low flow, which is typical of most basins in the state.

The plotted points 2 and ② for the Chewack River in Fig. 25 show positions considerably below the relationship defined by the graphs. If the water rights for irrigation on the Chewack River (on the order of 30 cfs) are added to the measured values, the plotted points would be at 2' and ②' inside the dashed area. Of course, 30 cfs is a rate, and when spread over the time period from first withdrawal until the date of measurements, and allowing for actual time of diversion, the actual rate to be added back would be less than 30 cfs. Therefore it would appear that the relationship would be applicable to the Chewack River as well.

At miscellaneous records station number 3, the measurements were made a month earlier than at the other stations, and therefore the flows would be normally higher at that time than in late September. Also, station 3 has a large drainage area and relatively little irrigation diversion above it, so diversions

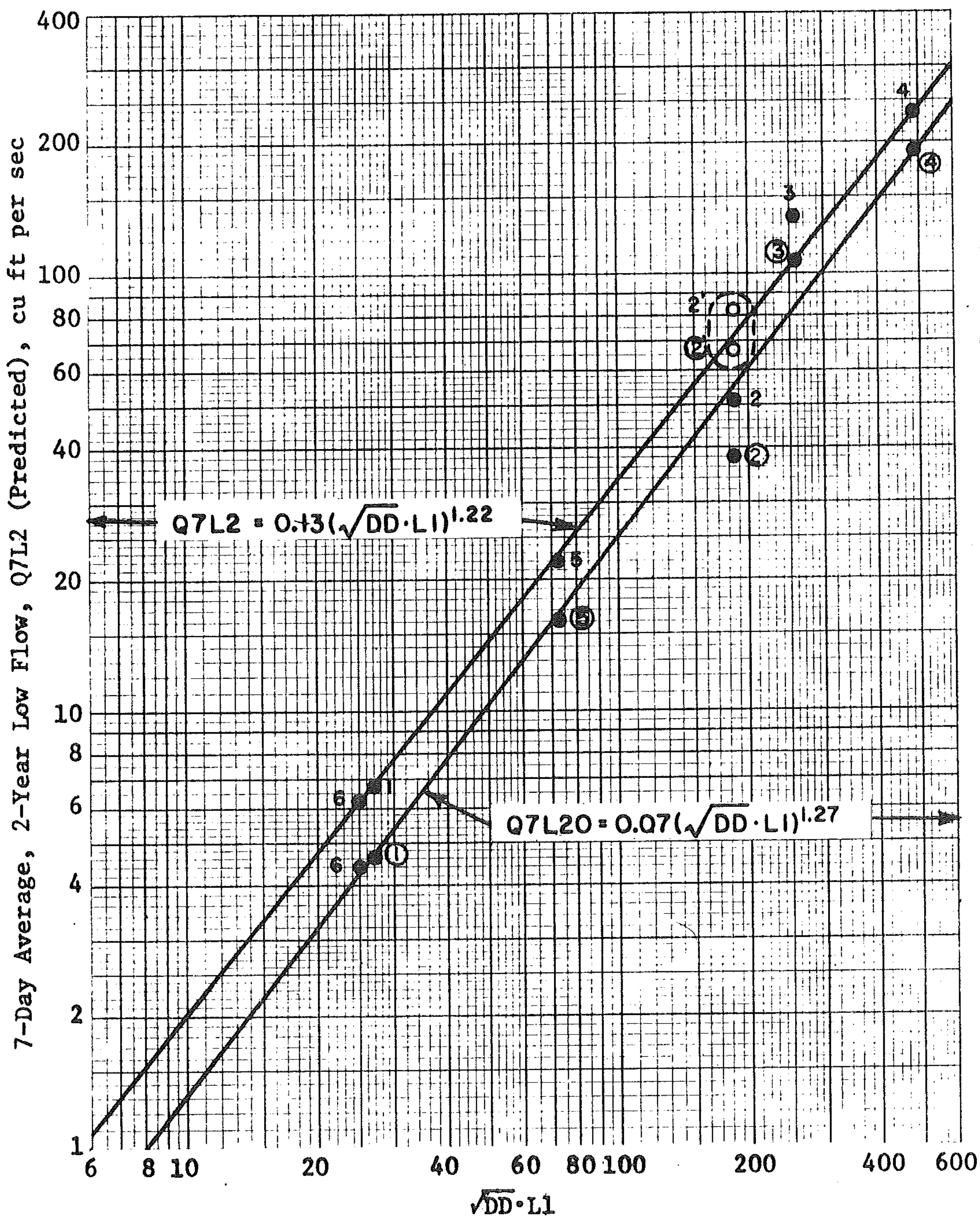

Figure 25. Predicted Low Flows Related to Basin Parameter √DD·L1
Methow River Basin

Table 13. Discharge Measurements Made at Miscellaneous Sites During Water Year 1971 and Drainage Basin Characteristics in Methow River Basin

Stream Name and Station Location (Plotting Point)	Drainage Area, A (sq mi)	Measurement Date	Discharge QL (1971) (cfs)*	Stream Lengths L1 (mi)	Stream Lengths LT (mi)	($\sqrt{DD} \cdot L1$)	Predicted** Q7L2 / Q7L20 (cfs/cfs)
Chewack River (1) Lat 48°47'37" Long 120°03'37"	126.0	9-24-71	7.2	34	77	27	6.8 / 4.6
Chewack River (2) Lat 48°28'38" Long 120°11'08"	525.0	9-25-71	53.8	223	358	184	51 / 38
Methow River (3) Lat 48°35'23" Long 120°24'13"	342.0	8-26-71	145.0	245	370	254	136 / 108
Methow River (4) below Chewack River	988.0	Estimated	250.0	534	828	489	235 / 191
Twisp River (5) Lat 48°22'06" Long 120°07'13"	247.0	9-22-71	23.8	80	198	72	22 / 16
Gold Creek (6) Lat 48°11'03" Long 120°07'03"	60.6	9-22-71	6.8	27	50	25	6.4 / 4.4

*From Miscellaneous Records Section, Ref. 13.

**2-year and 20-year, 7-day low flow values predicted from low flow measurements of Water Year 1971 using Fig. 24.

would not affect the records as much as in a smaller basin. The Methow River at Pateros (4499.5) registered an average discharge of 503 cfs on August 26 and an average of 368 cfs between September 22 and 25, 1971. Reduction of station 3 flows by a proportionate amount brings them very close to the graphical relationship in Fig. 25. The flow at station 4 was estimated on the basis of the flows at stations 2 and 3.

A more detailed analysis would require the monitoring of stream flows and diversions in a study basin to establish the effects on irrigation water usage on stream flow response. A few years of records throughout the irrigation season would determine the effects more accurately for planning purposes.

The estimates of 7-day average low flows with 2- and 20-year recurrence intervals were made using the relationships in Fig. 25. Basin characteristic $\sqrt{DD}\cdot L1$ was measured from USGS topographic maps for each ungaged subbasin listed in Table 11 and in the Line Diagram at the end of the report.

Consideration of Bank Storage in the Okanogan Valley

A brief description of the bank storage portion of base flow in the Okanogan River above Tonasket is presented in the section on low flow because the analytical methods are associated with ground-water temporary storage. In order to quantitatively evaluate bank-storage caused by floods and water surface rises within stream channels, detailed information on stream flows, ground-water levels and geology at each end of a river reach are needed.[14/][15/] A good method for approximating comparative bank storage values was presented by Kunkle based on the analysis of base-flow duration curves.[16/]

Using methods described by Kunkle, three years of record were investigated for the Okanogan River at Tonasket, 1943, 1965 and 1968. The average flows for those water years were 2980, 2934 and 2928 cfs, respectively. The long-term annual flow at Tonasket (1931-1968) was 2931 cfs. In this method daily flows for each year are plotted as annual hydrographs, separation* of the hydrographs is accomplished by the methods described by Kunkle, and duration curves are developed for the separated base flows as shown in Fig. 26.

Portions of the annual hydrographs have been reproduced in Fig. 27 for each year to demonstrate the flow characteristics during the high flow period between April 1 and July 31. The fluctuations are typical of springtime, snowmelt floods which are affected by temperature sequences. The response of ground-water storage to stream flow is very evident in the plot of water surface

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*Peaks are separated using the hydrograph regression slopes following each high flow period.

14/ Newcomb, R. C. and S. G. Brown, "Evaluation of Bank Storage Along the Columbia River Between Richland and China Bar, Washington," U.S. Geol. Survey, Water Supply Paper 1539-I, 1961.

15/ Cooper, H. H., Jr. and M. I. Rorabaugh, "Ground-Water Movements and Bank Storage Due to Flood Stages in Surface Streams," U.S. Geol. Survey, Water Supply Paper 1536-J, 1963.

16/ Kunkle, George R., "The Baseflow-Duration Curve, A Technique for the Study of Groundwater Discharge from a Drainage Basin," Journ. of Geophy. Res., V. 67(4), April, 1962.

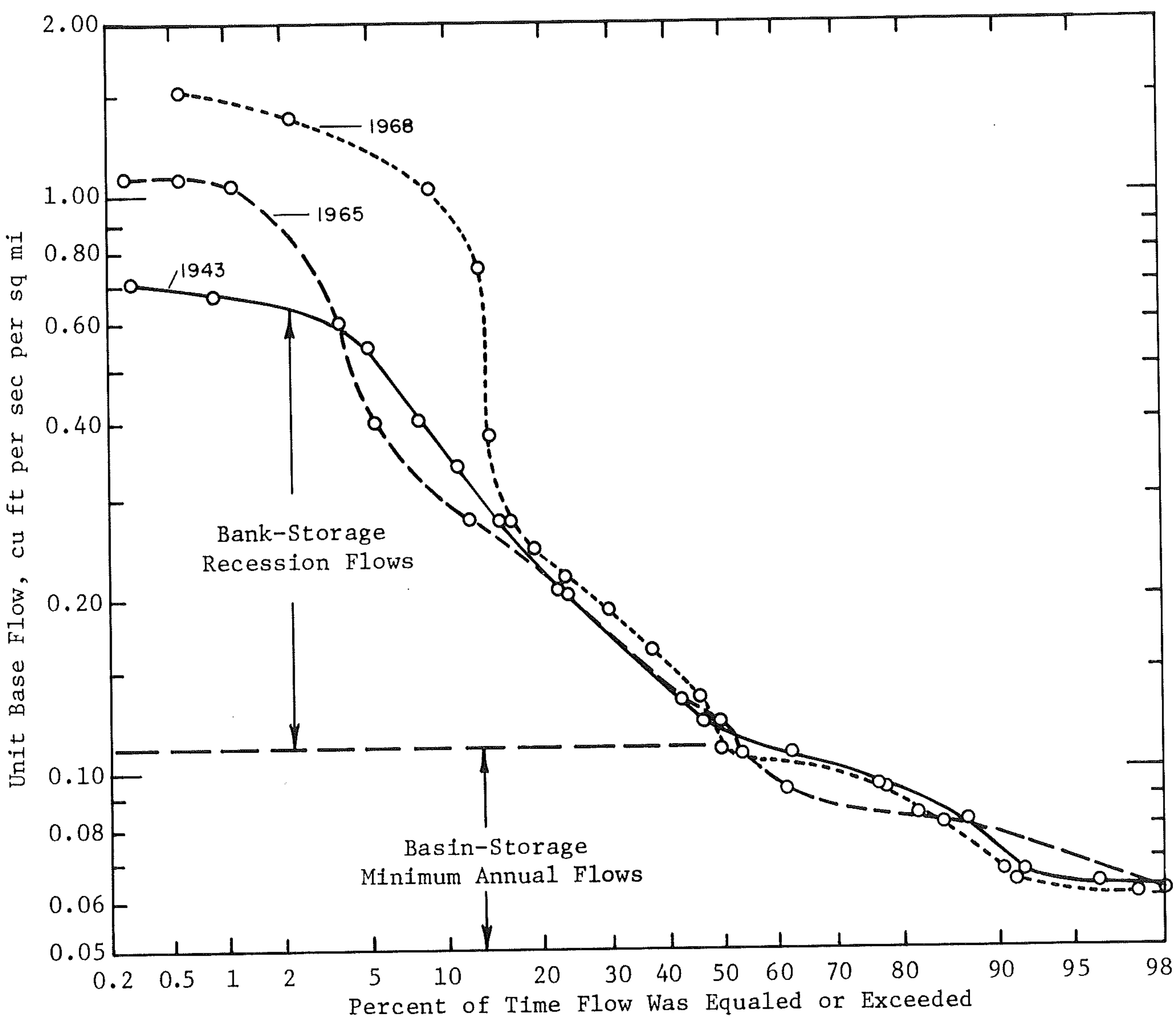

Figure 26. Base-flow Duration Curves for Okanogan River near Tonasket for Water Years 1943, 1965 and 1968 (Gaging Station 4450)

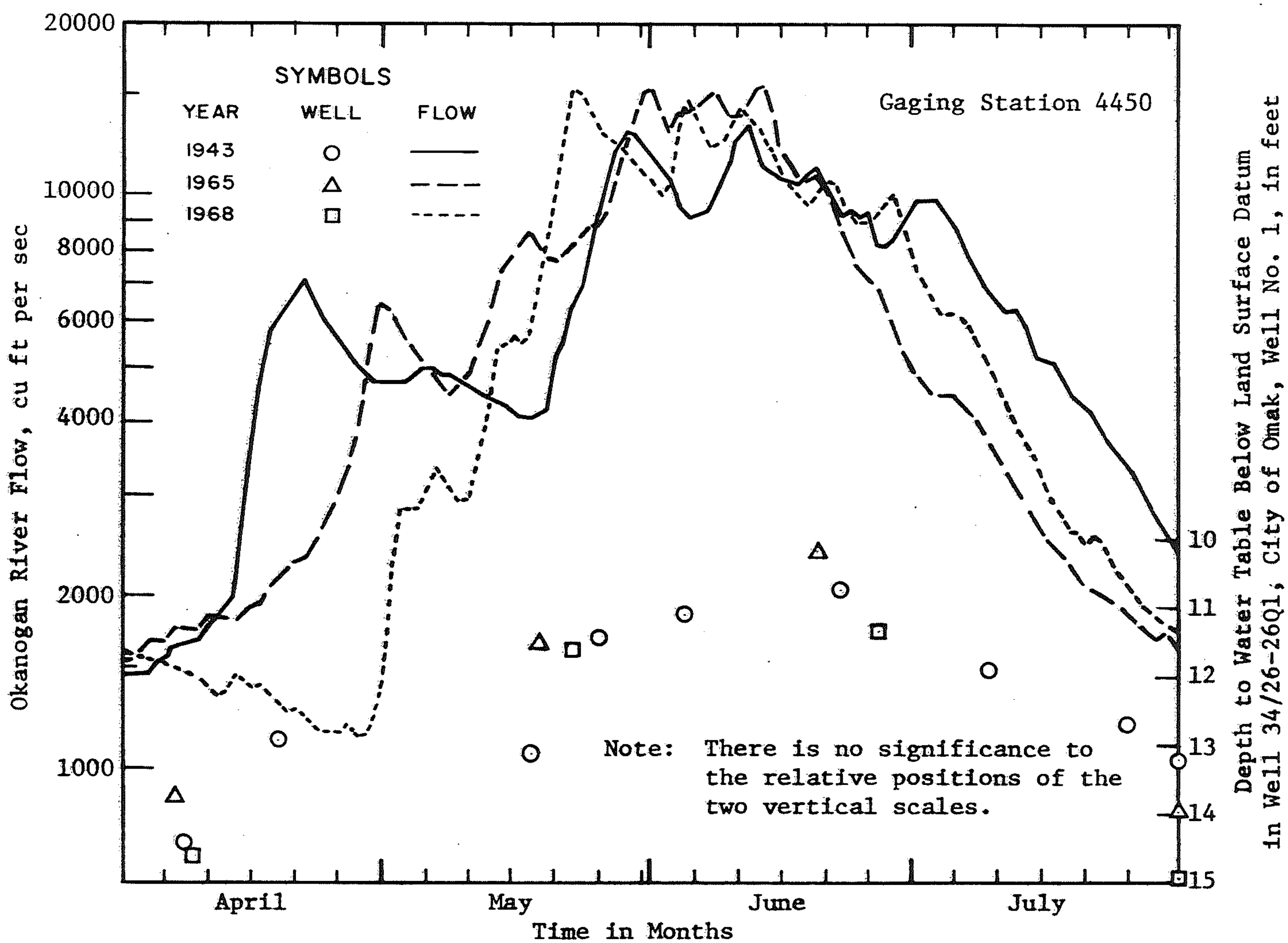

Figure 27. High Flow Season Hydrographs for the Okanogan River near Tonasket, Well Levels at Omak for 1943, 1963 and 1968

elevations in Omak City Well No. 1 (34/26-26Q1)[17/18/19] which is drilled in river bed gravels. The circles denoting 1943 well levels tend to follow the peaks and troughs of the Okanogan River hydrograph. The other two years had less frequently published data, but the highest point in the well in June, 1965 (triangle) was recorded following the highest, most continuous period of stream flow.

Referring once again to Fig. 26, estimates of base flow, including bank-storage (temporary) and basin-storage* components can be made by determining the areas underneath each part of the graphs as divided by the horizontal dashed line. The portion above the sharp break in the graph is from bank storage and that portion below the sharp break is from basin storage. The method used is as outlined by Searcy.[20] The basin-storage, minimum annual flows are about 780-800 cfs (0.105-0.110 cfs/sq mi), and very close to the 7-day average low flow with a 2-year recurrence interval (Q7L2).

The bank-storage component of base flow (above the horizontal line in Fig. 26) varied between 510, 580 and 1120 cfs for water years 1943, 1965 and 1968 during those days of bank discharge activity. Visual inspection of Fig. 26 shows the relative sizes of the flows by the shapes of the three curves. The reason 1968 had a much higher bank-storage than either 1943 or 1965 is because there were numerous periods of high flow between October, 1967 and April, 1968 which are not included in Fig. 27. Most of the bank storage activity during 1943 and 1965 took place between April and July, the period of the year displayed in Fig. 27.

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*Long term ground-water storage released to rivers during minimum flow periods.

17/ U.S. Geol. Survey, "Water Levels and Artesian Pressures in Observation Wells in the United States in 1943," Part 5, Northwestern States, Water Supply Paper 990, 1946.

18/ U.S. Geol. Survey, "Ground-Water Levels in the United States 1961-65," Northwestern States, Water Supply Paper 1845, 1968.

19/ U.S. Geol. Survey, "Ground-Water Levels in the United States 1966-70," Northwestern States, Water Supply Paper 1980, 1972.

20/ Searcy, James K., "Flow Duration Curves, Manual on Hydrology: Part 2. Low-Flow Techniques," U.S. Geol. Survey, Water Supply Paper 1542-A, 1959.

WATER USES AND SUMMARY

The primary use of surface waters in both the Okanogan and Methow River Basins is, of course, for irrigation. All registered municipal supplies are from ground water in Okanogan County. Some of these wells are near streams, and undoubtedly draw part of their supply indirectly from those streams. But, the municipal supplies are very small compared to even the minimum flows of the streams which they may be affecting.

Some irrigation water is drawn from wells in both basins, but a majority of it is supplied by direct pumpage from the streams in the Study Area. Surface water rights for the valley along the lower Okanogan River are summarized in Fig. 28.[21/] Although the water rights do not reflect the exact amounts of water used in an irrigation season, they do reflect the order of magnitude of the rate of diversion possible during minimum stream flow periods.

A similar diagram for the major irrigation diversions in the Methow River Basin is displayed in Fig. 29 and was derived from USGS records. This diagram shows the long-term average measured diversion where records are available, or the 1971 measurement at a few stations established during that year (in parentheses). The need for more detailed information on irrigation diversions in both basins is obvious if a more complete understanding of water availability and usage is to be achieved.

Tables 14, 15, 16 and 17 summarize the dependable yields of a sample of the gaging stations on the Similkameen, Okanagan and Methow Rivers.[22/] This type of summary provides a quick estimate of the variability which can be expected in average annual flows from year to year. The tables show also that planning for long-term water availability should not be based on mean annual flows which have a variability of 50 to 90 percent.

In the following subsection are instructions for use of the Line Diagram of the larger and/or more actively utilized subbasins within the Okanogan-Methow River Basins Study Area, followed by the Line Diagrams in Tables 18 and 19.

[21/] Communication with Dept. of Ecology, Water Rights Summary.

[22/] Pacific Northwest River Basins Comm., "Water Resources of the Columbia-North Pacific Region," Appendix V, Vol. 1, page 249, April, 1970.

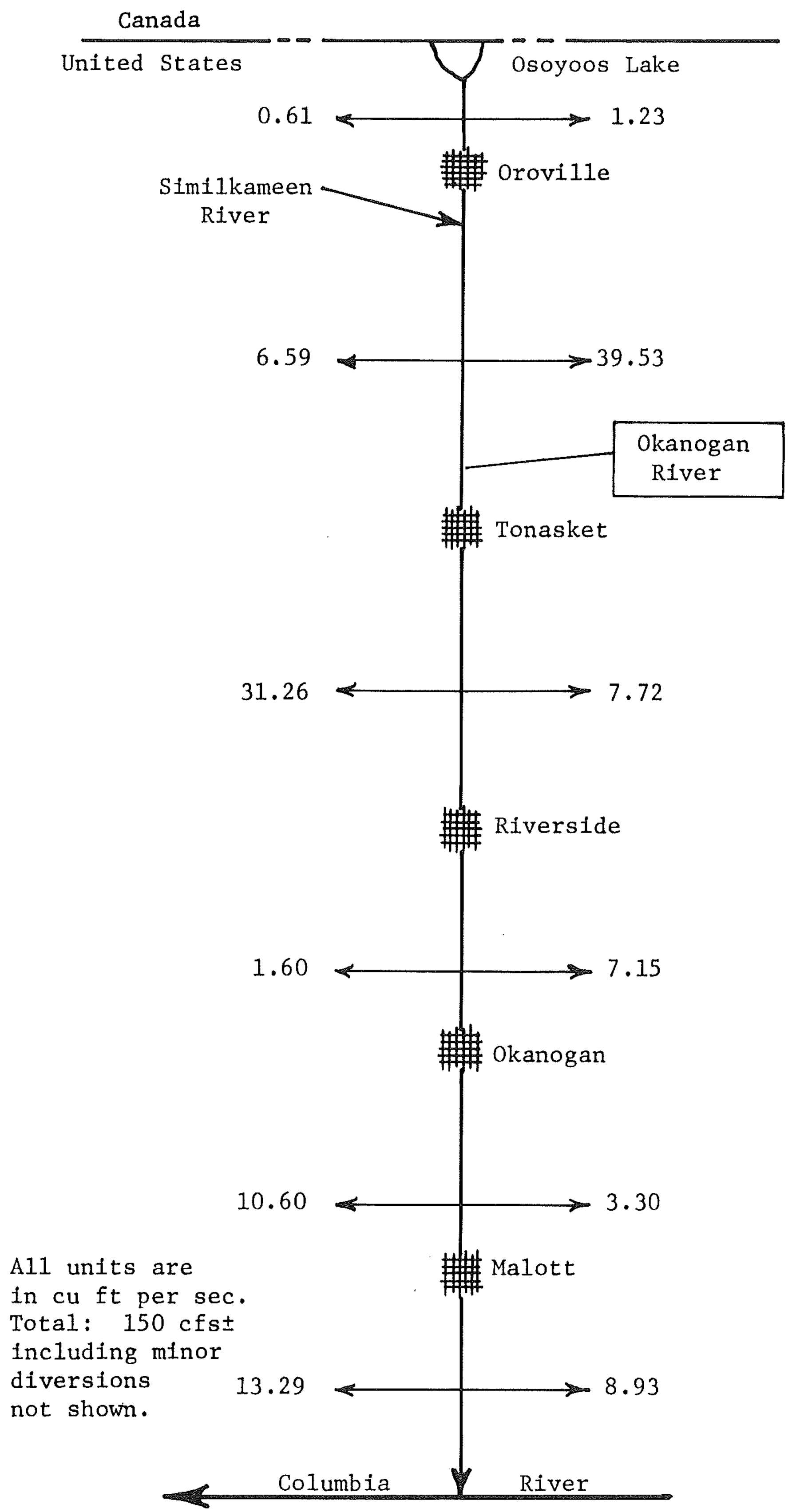
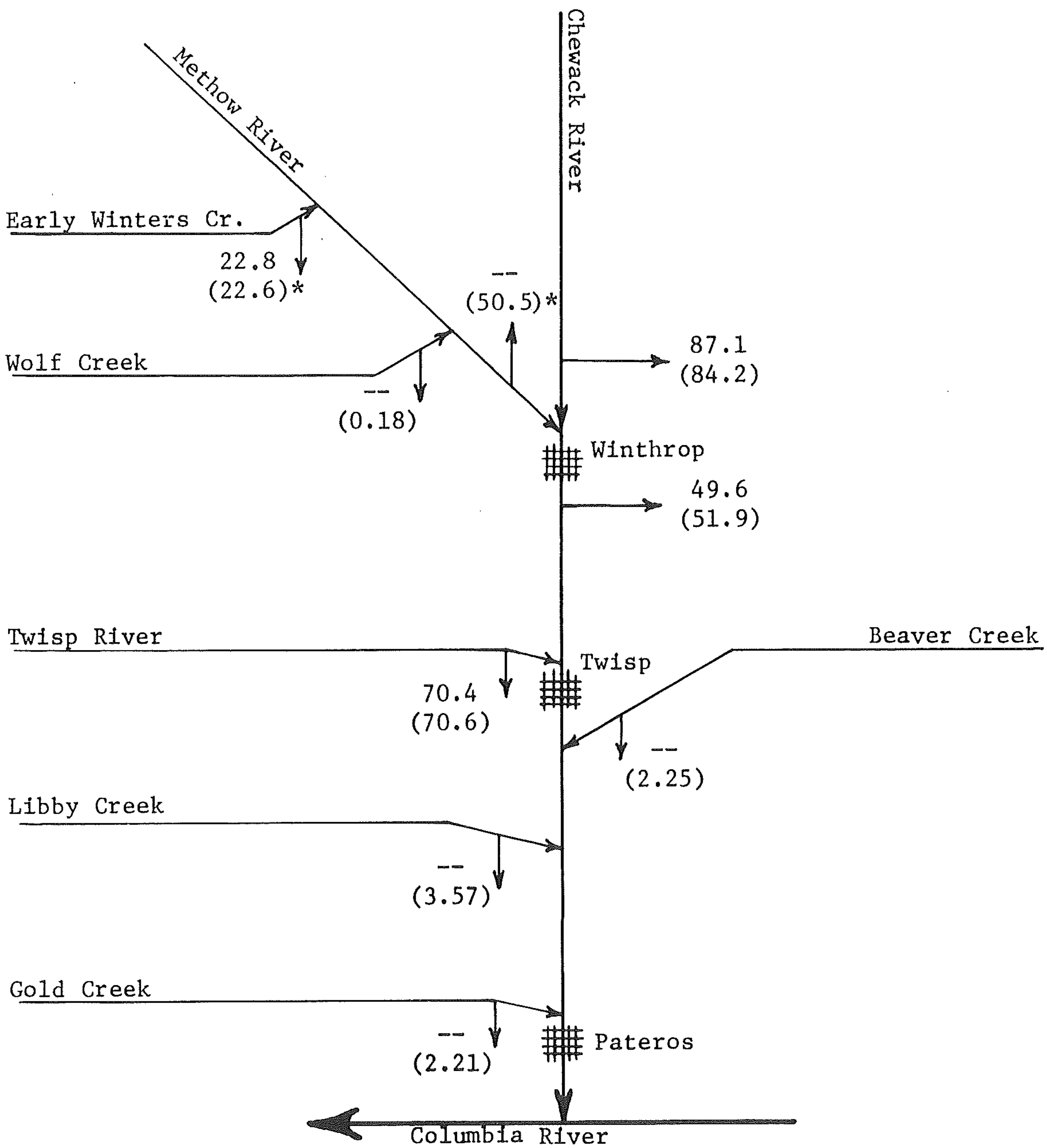


Figure 28. Summary of Water Rights by Reaches between Communities on the Okanogan River in Washington



*Numbers in parentheses are the 1971 flow rates in cubic feet per second, and other numbers are the average flow rates for the period of record. Dashes denote no long term average available.

Figure 29. Diversions in Methow River Basin Study Area into Irrigation Ditches and Canals; Averages and 1971 Miscellaneous Measurements

Ref. USGS Records.

Table 14. Dependable Yield, Okanagan River at Okanagan Falls, B.C.

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1931	52.2	9.5
2	1930-31	67.4	12.3
3	1930-32	150.7	27.4
4	1930-33	264.6	48.2
5	1929-33	345.9	63.0
6	1939-44	377.2	68.7
7	1939-45	393.9	71.7
8	1938-45	414.0	75.4
9	1937-45	429.0	78.1
10	1936-45	449.0	81.8
30	1929-58	549.0	100.0

Table 15. Dependable Yield, Similkameen River near Nighthawk, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1941	1,092.1	47.1
2	1940-41	1,216.2	52.5
3	1939-41	1,386.9	59.8
4	1939-42	1,634.8	70.5
5	1937-41	1,699.0	73.3
6	1939-44	1,744.2	75.3
7	1939-45	1,776.1	76.6
8	1937-44	1,850.0	79.8
9	1937-45	1,863.1	80.4
10	1936-45	1,877.4	81.0
29	1930-58	2,317.6	100.0

Table 16. Dependable Yield, Okanogan River near Tonasket, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1931	1,240.6	42.5
2	1930-31	1,399.2	47.9
3	1930-32	1,620.4	55.5
4	1930-33	1,932.4	66.2
5	1937-41	2,089.8	71.6
6	1939-44	2,173.9	74.5
7	1939-45	2.221.8	76.1
8	1938-45	2,345.4	80.3
9	1937-45	2,339.6	80.1
10	1936-45	2,374.4	81.3
29	1930-58	2,919.2	100.0

Table 17. Dependable Yield, Methow River at Twisp, Washington

Consecutive Years of Lowest Mean Flow	Inclusive Years	Lowest Mean Flow (cfs)	Percent of 1930-58 Mean
1	1929	681.0	49.5
2	1929-30	802.2	58.3
3	1929-31	799.6	58.1
4	1929-32	874.3	63.5
5	1929-33	954.1	69.3
6	1939-44	1,075.7	78.2
7	1939-45	1,071.0	77.8
8	1939-46	1,124.2	81.7
9	1937-45	1,126.9	81.9
10	1936-45	1,120.4	81.4
30	1929-58	1,375.9	100.0

Instructions for Use of the Line Diagram

SAMPLE HEADING FOR LINE DIAGRAM PAGE

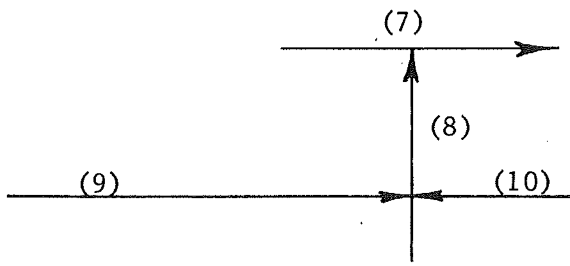
STATE WATER PROGRAM STUDY AREA ______ Note No. (1) ______ Page (5) of (6)

DRAINAGE BASIN ______ (2) ______

WATER RESOURCE INVENTORY AREA NUMBER ______ (3) ______

SUBBASIN ______ (4) ______

Explanation of notes (1) - (15) on page 55



P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
(11)	(12)	(13)	(14)	(15)

Explanatory Notes

Note No.

(1) The names and locations of these Study Areas are shown on the location map on the inside of the Hydrographic Atlas front cover. They are shown also on a small map on page 5 of the State Water Program Public Information Bulletin No. 2, February, 1973.

(2) Numerous major and minor drainage basins are located within the Study Area. The main streams within the Area have been analyzed and included in the Line Diagram and Summary Table.

(3) The Water Resource Inventory Area (WRIA) Number applies to the numbering system established by the former Department of Water Resources whereby the drainage basins in the State were assigned numbers for easy reference and data recall. These numbers include WRIA's 48 and 49 for the Okanogan-Methow Study Area and are noted on the maps in the back folder.

(4) Subbasins have been numbered beginning at the upper extremities of each WRIA, and apply to each major stream and its tributaries as shown on the maps in the folder.

(5) of (6): (5) is the consecutive number of the page in the Line Diagram and (6) is the total number of pages in the diagram. Five of 6 would mean page number 5 in a total of 6 pages. These page numbers are used to cross reference the pages on which details of tributary streams are located.

(7) Name of stream to which the diagramed stream is a tributary (i.e., the Columbia River receives the Lewis River as a tributary).

(8) The line representing the stream being diagramed which is named under Item (4), SUBBASIN. The arrow points in the direction of flow, so the top of the page is the downstream direction.

(9) and (10): Tributaries enter from either the left or right as indicated by the direction of the arrows on these lines. The name of the tributary or gaging station number appears as Item (9) and their distance from the mouth of the diagramed stream appears on the right in Item (10). Small tributaries and their gages (if available) appear sometimes in (9) or (10).

(11) through (15) are the average annual precipitation (P), drainage area (A) above the point in question in Item (9), and the various stream flow values which have been discussed in earlier sections of the Technical Supplement. A legend of symbols and definitions appears below.

The stream gaging station numbers have been abbreviated in the Line Diagram. Gaging stations 4473 is really 12-4473, where 12 refers to the part of the State as outlined in Fig. 2. An asterisk (*) near a flow value means it is available from the records, and all other values were calculated. All flows are given in cubic feet per second, and some information was left blank due to lack of availability and/or insufficient data for determination.

<u>Terms for Summary Table on Line Diagram</u>

P - Average Annual Precipitation, inches per year

A - Drainage Basin Area, square miles

QAA - Average Annual Flow, cubic feet per second (cfs)

QF2 - 2-Year Flood, cfs

QF50 - 50-Year Flood, cfs

Q7L2 - 7-Day Average, 2-Year Low Flow, cfs

Q7L20 - 7-Day Average, 20-Year Low Flow, cfs

<u>Legend for Line Diagram</u>

4473 - USGS Gaging Station Number*

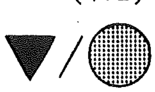
 - Continuous Gaging Station in Operation

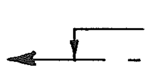
 - Discontinued Gaging Station

 - Crest Stage Partial Record Station

 - Low Flow Partial Record Station

(4.2) - Distance from Mouth of Stream to Gaging Station

 - Reservoir/Lake


Tributary
- Main Stream
60.1 - Distance from Mouth of River to Tributary

*See Table 5 and Gaging Station Map for details about stations.

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Okanogan River Mainstem

Columbia River

OKANOGAN RIVER
533.5 mi on Columbia River

Location	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	19.0	8525	3543	39720 / 17360	891 / 425
GAGING STATION 4473 near Malott	13.1 mi	19.0	8220*	3420	38300 / 16700	-
GAGING STATION 4472 at Malott	17.0 mi	19.0	8100*	3232	38000 / 16500	858 / 418
SALMON CREEK at Confluence Refer to page 3 of 7.	25.7 mi	18.7	194	76	1144 / 572	98.0 / 41.4
GAGING STATION 4460 at Okanogan	-	19.0	7900*	3150	37000 / 16100	-
OMAK CREEK at Confluence Refer to page 3 of 7.	32.01 mi	16.3	251	83	1240 / 620	28.0 / 7.8
GAGING STATION 4450 near Tonasket	50.8 mi	19.0	7280*	2905	35000 / 16000	780 / 380

Okanogan R. Cont'd

OKANOGAN RIVER MAINSTEM LINE DIAGRAM, Table 18-Cont'd

OKANOGAN RIVER
533.5 mi on Columbia River

Okanogan R. Cont'd

Location	River mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
BONAPARTE CREEK at Confluence. Refer to page 4 of 7.	56.7 mi	21.2	150.0	60.0	903 / 452	25.0 / 14.3
Siwash Creek GAGING STATION 4444 Tributary near Tonasket	57.3 mi	24.0*	0.6*	0.4	150.0 / 6.6*	-
WHITESTONE LAKE CREEK Refer to page 4 of 7.	62.4 mi	16.5	55.4	19.2	288 / 144	-
SIMILKAMEEN RIVER at Confluence Refer to page 5 of 7.	74.1 mi	30.0	3650.0	2320.0	35000 / 16400	360 / 207
GAGING STATION 4395 at Oroville	76.8 mi	22.0	3210.0*	652.0	9780 / 4890	321 / 129
Tonasket Creek GAGING STATION 4393 at Oroville (0.7)	77.8 mi	18.5	60.2*	23.4	351 / 176	-
GAGING STATION 4391.5 at Oroville	78.0 mi	9.7	3150.0*	640.0	9780 / 4890	321 / 129
CANADIAN BORDER**	82.5 mi					

**Data for the Canadian reach of Okanagan River not included.

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Salmon Creek (49-8)

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

Okanogan River

SALMON CREEK
25.7 mi on Okanogan River

Station	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	18.7	194	76.0	1144 / 572	98.0 / 41.4
GAGING STATION 4470 near Okanogan	3.5 mi	20.2	156*	66.2	993 / 497	-
GAGING STATION 4465 near Conconully	-	22.5	121*	57.2	858 / 429	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

WATER RESOURCES INVENTORY AREA NUMBER 49

SUBBASIN Omak Creek (49-7)

Okanogan River

OMAK CREEK
32.01 mi on Okanogan River

Station	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	16.3	251	83.0	1240 / 620	28.0 / 7.8
Tributary near Disautel GAGING STATION 4458 (-)	-	20.0*	4	1.7	17.0 / 7.3*	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Bonaparte Creek (49-5)

Okanogan River

BONAPARTE CREEK
56.7 mi on Okanogan River

Station	Mileage	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	21.2	150.0	60	903 / 452	25.0 / 14.3
GAGING STATION 4444.9 near Wauconda	13.8 mi	24.6	96.6*	50	749 / 374	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

WATER RESOURCES INVENTORY AREA NUMBER 49

SUBBASIN Whitestone Lake Creek (49-4)

Okanogan River

WHITESTONE LAKE CREEK
62.4 mi on Okanogan River

Station	Mileage	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
GAGING STATION 4441	1.5 mi	16.5	55.4*	19.2	288 / 144	-
GAGING STATION 4440L Whitestone Lake near Tonasket	3.01 mi					
GAGING STATION 4438L Spectacle Lake near Loomis	7.0 mi					
GAGING STATION 4437 near Loomis	-	16.5	4.6*	1.6	24 / 12	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN OKANOGAN RIVER

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Similkameen River (49-2)

Okanogan River →

SIMILKAMEEN RIVER
74.1 mi on Okanogan River

Location	River mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	30	3650	2320	35000 / 16400	360 / 207
GAGING STATION 4435 near Oroville	-	30*	3580*	2132*	35000 / 16400	360 / 207
GAGING STATION 4425 near Nighthawk	15.8 mi	30*	3550*	2320*	35000* / 16400*	360* / 207*
CANADIAN BORDER*	27.1 mi					

*Data for the Canadian reach of Okanagan River not included.

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN SIMILKAMEEN RIVER

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Sinlahekin Creek (49-3)

Similkameen River

PALMER CREEK on CHAMPNEYS SLOUGH 19.5 mi on Similkameen R.

Station	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
PALMER CREEK	0.0 mi	23.1	300.0	146	5456 / 2183	-
GAGING STATION 4423 above Copaka Cr. near Loomis	9.1 mi	23.8	256.0*	128	4796 / 1919	-
TOATS COULEE CREEK Refer to page 7 of 7.	10.1 mi	24.0	134.0	47	1750 / 701	5.2 / 3.3
GAGING STATION 4410 at Twin Bridges, near Loomis	18.5 mi	20.2	75.5*	32	1200 / 480	-
GAGING STATION 4405 at Blue Lake, near Loomis	-	-	42.9*	-	-	-
GAGING STATION 4400 above Blue Lake near Loomis	22.5 mi	21.8	41.7*	19	716 / 287	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN SIMILKAMEEN RIVER-CHAMPNEYS SLOUGH

LINE DIAGRAM
OKANOGAN BASIN
Table 18.

WATER RESOURCE INVENTORY AREA NUMBER 49

SUBBASIN Toats Coulee Creek (49-3)

Palmer Creek

TOATS COULEE CREEK
10.1 mi on Palmer Creek

Location	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
GAGING STATION 4420	2.2 mi	24.0*	130.0*	47.4*	1750 / 701*	5.2 / 3.3*
Olie Creek GAGING STATION 4418 near Loomis (-)	4.6 mi	-	1.4*	-	-	-
NORTH FORK TOATS COULEE CREEK	4.9 mi	29.1	52.3*	32.0	1200 / 480	-
Middle Fork Toats Coulee Creek GAGING STATION 4417 near Loomis (-)	7.1 mi	29.6	32.1*	20.0	750 / 300	-
SOUTH FORK TOATS COULEE CREEK	7.2 mi	26.6	34.1*	19.0	713 / 285	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN METHOW RIVER

LINE DIAGRAM
METHOW BASIN
Table 19.

WATER RESOURCE INVENTORY AREA NUMBER 48

SUBBASIN Methow River Mainstem

Columbia River

METHOW RIVER
523.9 mi on Columbia River

Location	Mile	P	A	QAA	QF50/QF2	Q7L2/Q7L20
GAGING STATION 4505 at Pateros	1.0 mi	31.4	1794*	1555	34000/13200	300/240
GAGING STATION 4499.5 near Pateros	6.7 mi	31.4	1772*	1555	34000/13200	300/240
GOLD CREEK	21.8 mi	35.8	93	71	1807/657	8.0/5.4
LIBBY CREEK	26.4 mi	27.4	40*	23	577/210	1.3/0.9
BEAVER CREEK at Confluence. Refer to page 2 of 4.	35.2 mi	22.7	111*	58	1493/543	13.7/9.5
GAGING STATION 4495 near Twisp	40.0 mi	35.0	1301*	1327	31400*/12100*	205/152*
TWISP RIVER at Confluence. Refer to page 3 of 4.	40.2 mi	38.8	265	306	7920/2880	18/13

Methow R. Cont'd

METHOW RIVER
523.9 mi on Columbia River

Methow R. Cont'd

Location	River mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
GAGING STATION 4485 near Winthrop	49.0 mi	33.1	1007*	700	19250 / 7000	-
CHEWACK RIVER at Confluence. Refer to page 4 of 4.	50.1 mi	26.7	544	433	11193 / 4070	61 / 43
Early Winters Creek	67.3 mi	61.7	79*	102	2816 / 1024	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN METHOW RIVER

WATER RESOURCES INVENTORY AREA NUMBER 48

SUBBASIN Beaver Creek (48-6)

Methow River

BEAVER CREEK
35.2 mi on Methow River

Location	River mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	22.7	111*	58.0	1493 / 543	13.7 / 9.5
GAGING STATION 4497	6.2 mi	26.2	68*	37.4	1029 / 374	-
GAGING STATION 4496	8.9 mi	23.8	62*	31.0	853 / 310	4.3 / 2.9

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN METHOW RIVER

LINE DIAGRAM
METHOW BASIN
Table 19.

WATER RESOURCE INVENTORY AREA NUMBER 48

SUBBASIN Twisp River (48-5)

Methow River

TWISP RIVER
40.2 mi on Methow River

Station	Mile	P	A	QAA	QF50 / QF2	Q7L2 / Q7L20
No Gaging Station	0.0 mi	38.8	265.0	306.0	7920 / 2880	18 / 13
Little Bridge Creek GAGING STATION 4489 near Twisp (-)	9.0 mi	37.9	24.0*	19.0	525 / 191	-
Williams Creek GAGING STATION 4487 near Twisp (0.1)	19.9 mi	35.0	3.2*	2.3	63 / 23	-

STATE WATER PROGRAM STUDY AREA OKANOGAN-METHOW

DRAINAGE BASIN METHOW RIVER

WATER RESOURCE INVENTORY AREA NUMBER 48

SUBBASIN Chewack River (48-1 and 48-2)

LINE DIAGRAM
METHOW BASIN
Table 19.

Methow River

CHEWACK RIVER
50.1 mi on Methow River

Station	Mi	P	A	QAA	QF50/QF2	Q7L2/Q7L20
GAGING STATION 4480 at Winthrop	0.2 mi	26.7	544.0*	433.0	11193/4070	61/43
GAGING STATION 4475 below Boulder Cr. near Winthrop	8.7 mi	27.9	465.0*	272.0	7492/2724	-
Doe Creek — GAGING STATION 4474 near Winthrop (-)	17.1 mi	30.0*	3.8*	2.4	77/20*	-
Andrews Creek — GAGING STATION 4473.9 near Mazama (3.5)	25.6 mi	33.1	22.1*	15.4	424/154	-

REFERENCES

Beck, R. W. and Associates, "Okanogan County, Washington, Comprehensive Water and Sewer Plan," Seattle, May, 1967.

Dept. of Agriculture, Province of British Columbia, "Climate of British Columbia, Tables of Temperature, Precipitation, and Sunshine," Report for 1971.

The Governments of the Dominion of Canada and the Province of British Columbia, "Report of the Joint Board of Engineers Okanagan Flood Control," Vol. 1.--Text, 1946.

Joint Planning Office, Wenatchee, Wash., "Comprehensive Plan for Okanogan County," 1964.

Joint Planning Office, Wenatchee, Wash., "Land Use in Okanogan County," 1963.

Meteorological Branch, Dept. of Transport, Canada, "Temperature and Precipitation Tables for British Columbia," 1967.

Obedkoff, W., "Inventory of Storage and Diversion and Their Effect on Flow Records in the Okanogan River Basin," Preliminary Report No. 6, Canada-British Columbia Okanagan Basin Agreements, Sept., 1972.

Obedkoff, W., "Regionalization of Sub-Basin Hydrology," Preliminary Report No. 38, Canada-British Columbia Okanagan Basin Agreements, March, 1973.

Okanagan Study Committee, Canada-British Columbia Okanagan Basin Agreement, "Annual Report," March 31, 1972.

U.S. Dept. of Agriculture, "The North Cascades Study Report," Oct., 1965.

U.S. Army Corps of Engineers, "Public Brochure, Alternatives and Their Pros and Cons, Okanogan River Basin Study," 3rd Draft, Dec., 1972.

U.S. Bureau of Reclamation, "Chief Joseph Dam Project, Washington, Methow Division, Reconnaissance Report," Nov., 1961.

U.S. Bureau of Reclamation, "Chief Joseph Dam Project, Washington, Okanogan-Similkameen Division--Okanogan Unit," Reasonability Report Review Copy, July, 1968.

U.S. Bureau of Reclamation, "Whitestone Coulee Unit, Okanogan-Similkameen Chief Joseph Dam Project, Washington," House Document No. 201, 1964.

U.S. Environmental Protection Agency, Office of Water Programs, "Municipal Waste Facilities, A Cooperative State Report," 1968.

U.S. Geological Survey, "Potential Transport of Sediment from Enloe Reservoir by the Similkameen and Okanogan Rivers, Washington," by Leonard M. Nelson, Open-File Report, 1972.

U.S. Dept. of Health, Education, and Welfare, "Municipal Waste Facilities, A Cooperative State-Federal Report," 1962.

U.S. Dept. of Health, Education, and Welfare, "Municipal Water Facilities, Inventory," 1958, 1963.

Washington (State) Dept. of Agriculture, "Okanogan County Agriculture," Olympia, 1958.

Washington (State) Dept. of Commerce and Economic Development, "Counties: Chelan, Douglas, Okanogan: Upper Columbia Region," Olympia, 1972.

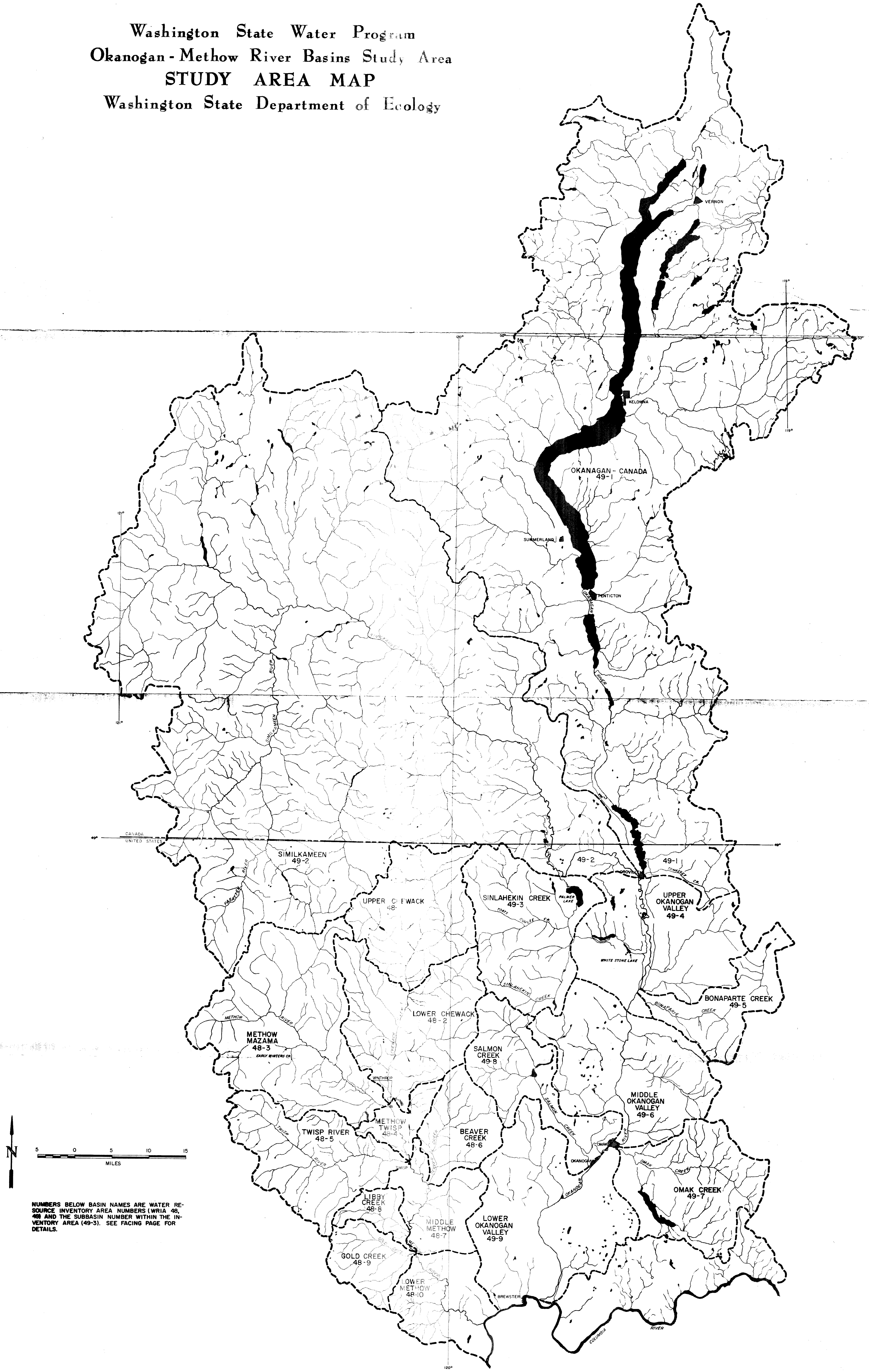
Washington (State) Dept. of Ecology, "Methow-Okanogan River Basin Bibliography," Basin Bibliography No. 2, Dec., 1972.

Washington (State) Division of Mines and Geology, "Mineral and Water Resources of Washington," Reprint 9, 1966.

Washington (State) Pollution Control Commission, Public Hearing on Proposed Water Quality Standards for Okanogan River, Similkameen River, Columbia River from Grand Coulee to Priest Rapids, Information Bulletin, Wenatchee, Wash., Nov. 21, 1966.

Washington (State) Water Research Center, "Bibliography of Water Resources Studies and Data Sources in Washington," Part D, North Central Washington, Report 14, June 30, 1973.

Washington State Water Program
Okanogan - Methow River Basins Study Area
STUDY AREA MAP
Washington State Department of Ecology



NUMBERS BELOW BASIN NAMES ARE WATER RESOURCE INVENTORY AREA NUMBERS (WRIA 48, 49) AND THE SUBBASIN NUMBER WITHIN THE INVENTORY AREA (49-3). SEE FACING PAGE FOR DETAILS.

Washington State Water Program
Okanogan-Methow River Basins Study Area

AVERAGE ANNUAL PRECIPITATION

Washington State Department of Ecology