86-68530 July 5, 2006
PRJ-13.00

MEMORANDUM

TO: Manager, Sedimentation and River Hydraulics Group
Attention: 86-68540 (J. Bountry)

FROM: David E. Sutley, Hydraulic Engineer
Flood Hydrology and Meteorology Group
Technical Service Center

SUBJECT: Methow River Drainage Basin, Hydrology Data and GIS for the Methow River, In-Stream Habitat Restoration Project

This report documents hydrology data and a GIS database developed for the Methow River In-Stream Habitat Restoration Project (MIHRP) being accomplished by the Technical Service Center for the Pacific Northwest Region of the Bureau of Reclamation. The report contains the following information:

- Basin characteristics.
- Historical flood accounts.
- Flood frequency computations for peak flows at USGS gage station locations.
- Flood frequency computations with GIS integration for ungaged locations based on two methods.
- Maximum, average, and minimum daily flow values at gaging stations for the period of record.
- Flow duration curves for mean daily flows for USGS gage station locations.
- Summary of the effects of PDO on Pacific Northwest salmon production.

This report was peer reviewed by Robert E. Swain (86-68530). If you have any further questions about the contents of this memorandum, please contact David Sutley at (303) 445-2464.

Attachments

cc: Greg Knott, U.S. Geological Survey, 1201 Pacific Av., Suite 600, Twisp WA 98856 (5)

PN-1710 (G. Dailey)
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PN-3616 (E. Lyon, T. Maguire, R. McAffee)
PN-3913 (K. Swoboda)
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WBR:SUTLEY : 7-5-06 : JH/2536
[30/Methow_Hydro Data & GIS.MDS]

Methow River Drainage Basin
Hydrology Data and GIS

July 5, 2006

Prepared by: David E. Sutley
Hydraulic Engineer

Introduction:
This report documents hydrology data and a GIS database developed for the Methow River In-Stream Habitat Restoration Project (MIHRP) being accomplished by the Technical Service Center for the Pacific Northwest Region of the Bureau of Reclamation. The report contains the following information:

- Basin characteristics.
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- Flow duration curves for mean daily flows for USGS gage station locations.
- Summary of the effects of PDO on Pacific Northwest salmon production.

Basin Characteristics:
The Methow River drainage basin is located in western Okanogan County, Washington. The drainage basin above the mouth of the Methow River is 1,814 mi^2 which accounts for 35% of the total area of Okanogan County. Within the basin, there are two major sub-drainages that contribute runoff to the Methow River. These include the Twisp River basin and the Chewuch River basin. The areas of each are 245 mi^2 and 525 mi^2, respectively. All runoff generated from the Methow River Drainage basin empties into the Columbia River near Pateros, Washington.

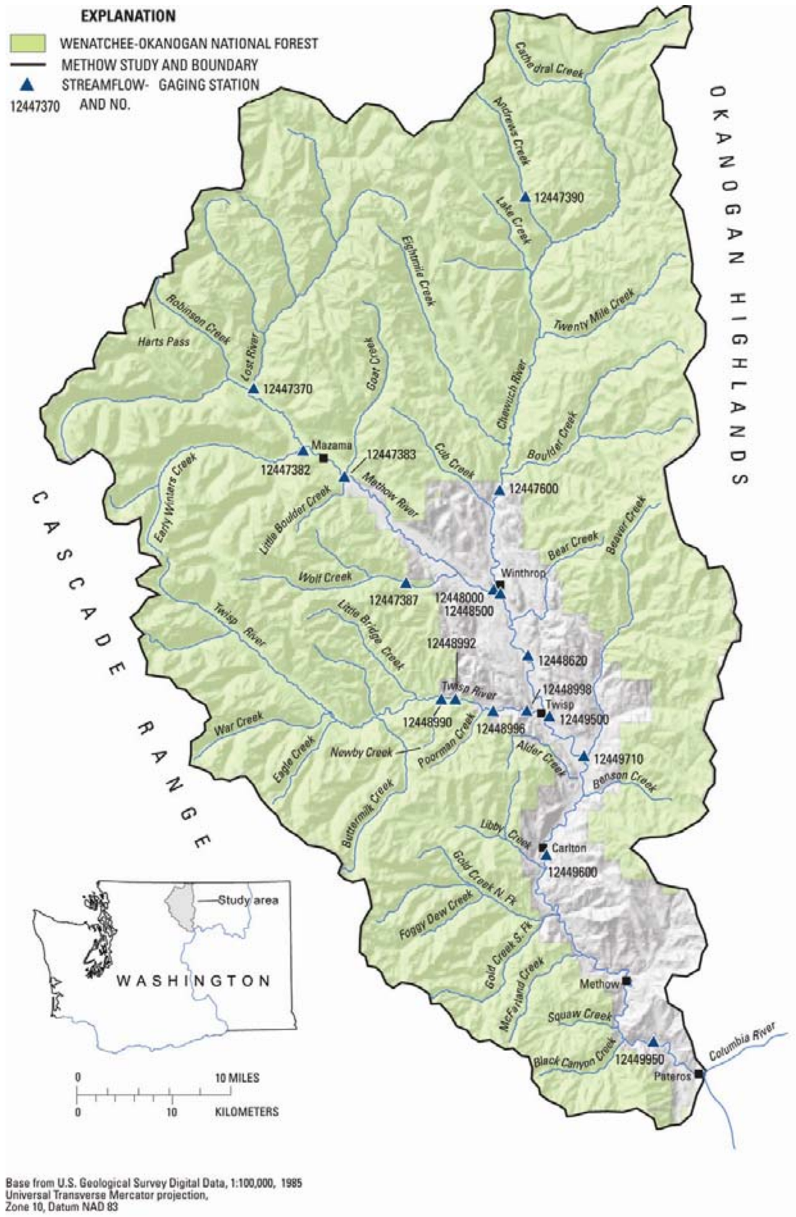


Figure 1 – Methow River drainage basin vicinity map.

The topography of the basin varies significantly. The mouth of the Methow River is approximately 780 ft above sea level. The highest point at elevation 8,500 is located just above the headwaters of the Lost River.

The USGS maintains stream gage stations throughout the Methow River drainage basin which provide mean daily flow data and instantaneous annual peak flow data (Figure 1). Of the nineteen gages, eight have greater than 10 years of record (Table 1).

Table 1 – USGS stream gage information for gages with more than 10 years of record in the Methow River basin.

USGS Gage No.	Description	Date of Peak Discharge	Years of Record	Drainage Area (mi2)
12449950	METHOW RIVER NEAR PATEROS, WA	5/29/1948	47	1772
12449600	BEAVER CREEK BELOW SOUTH FORK NEAR TWISP, WA	5/29/1972	20	62
12449500	METHOW RIVER AT TWISP, WA	5/29/1948	52	1301
12448998	TWISP RIVER NEAR TWISP, WA	5/29/1948	19	245
12448500	METHOW RIVER AT WINTHROP, WA	5/31/1972	16	1007
12448000	CHEWUCH RIVER AT WINTHROP, WA	6/16/1999	13	525
12447390	ANDREWS CREEK NEAR MAZAMA, WA	6/10/1972	36	22
12447383	METHOW RIVER ABOVE GOAT CREEK NEAR MAZAMA, WA	6/17/1999	14	373

Historical Flood Accounts:

Based on the annual trends for each gage, the basin is subject to large late spring and early summer floods. Major floods have occurred in the valley in 1894, 1948, and 1972 [1]. The flood of 1894 occurred prior to the establishment of stream flow records, but high water marks were used to estimate a peak discharge of 50,000 ft^3/s [1]. The dollar value of the damage caused by the 1894 flood was not great in comparison with subsequent floods because of the minimal development in the river valley at that time. The largest flood of record occurred on May 29, 1948 at the Pateros, WA gage (12449950). The magnitude of this flow was 46,700 cfs. Figures 2 and 3 display the annual peak flow data available at the two USGS stream gages in the Methow basin with the longest period of record.

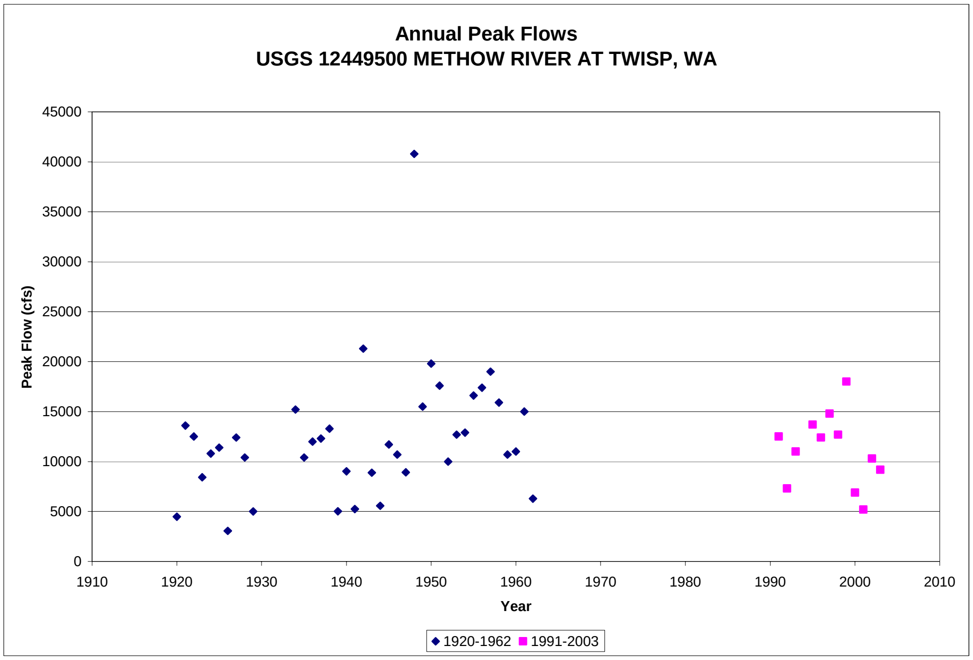


Figure 2 – Annual peak flow data for the Methow River at Twisp, WA.

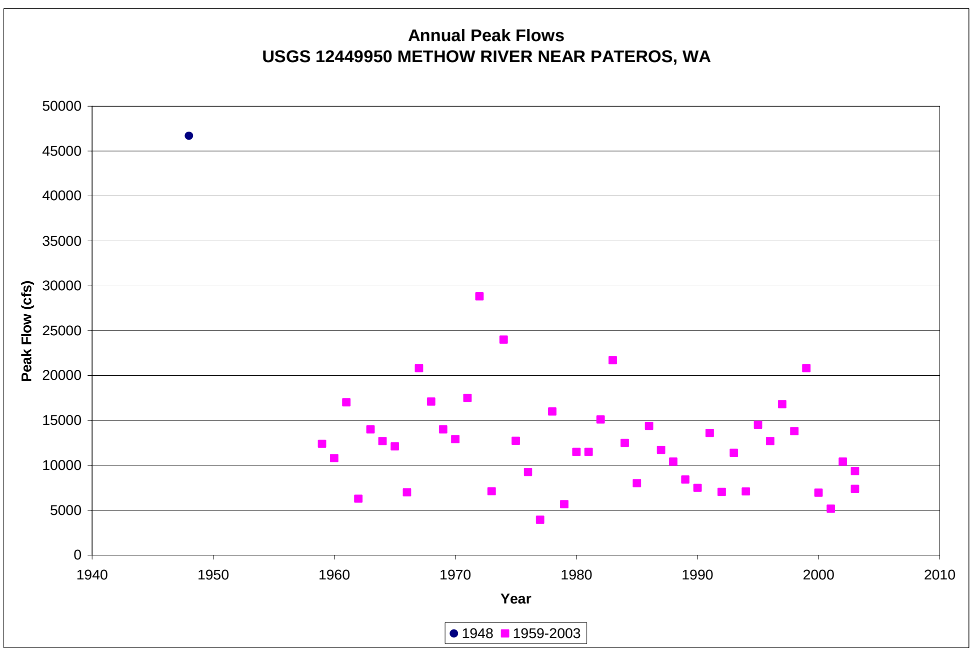


Figure 3 – Annual peak flow data for the Methow River at Pateros, WA.

R.W. Beck and Associates (1973) notes the following regarding the 1948 flood:

"…occurred in 1948 at a time when severe flooding occurred throughout Columbia River basin. The snowpack accumulated during the winter was 19 percent above normal on the first of April and was augmented by unusually heavy precipitation and cool temperatures until mid-May when the temperatures rose to unseasonably high readings. Above average rainfall began in mid-May which accelerated the rate of snowmelt resulting in a rapid rise in the river discharge…. This flood destroyed roads and bridges, caused severe erosion of agricultural lands and inundated homes and thousands of acres of land. The estimated damage caused by this flood was $2,250,000 based on 1948 prices."

The peak discharge of 46,700 ft^3/s was recorded at the Pateros gage near the mouth of the Methow River on May 29, 1948.

Regarding the 1972 flood, R.W. Beck and Associates (1973) notes the following:

"The flood was initiated from a snow accumulation averaging approximately 175 percent of normal from an unusually cool, long, and stormy winter. Near the end of May the weather cleared bringing two periods of high temperatures which caused rapid snowmelt and rapid rise of the discharge of the river….A short period of cool temperatures caused the river crest to recede, however, a subsequent period of high temperatures resulted in second river crest approximately two weeks later….Widespread erosional damage and large inundated areas resulted from this flood…Damages resulting from this flood had an estimated magnitude of $420,000 consisting mostly of bank erosion and crop loss due to inundation of farm lands."

The peak discharge of 28,800 ft^3/s was recorded at the Pateros gage near the mouth of the Methow River on May 31, 1972.

Peak Flow Calculations at USGS Gage Station Locations:

The annual flow data for the eight selected USGS stream gages were sought from the USGS NWIS web site. A Log-Pearson III distribution was fit to the gaged record of peak flows using the method of moments to develop the 2-, 5-, 10-, 25-, 50-, and 100-year flood frequency values. This process is consistent with the procedure described in the Guidelines for Determining Flood Flow Frequency, *Bulletin 17B* [2]. A Regional skew value was not included in the calculations because it was determined to be approximately equal to zero. Table 3 and figure 2 provide the results of the statistical analysis for each gage. The ranked data statistics and flood frequency results for each gage are shown in more detail in the Appendix.

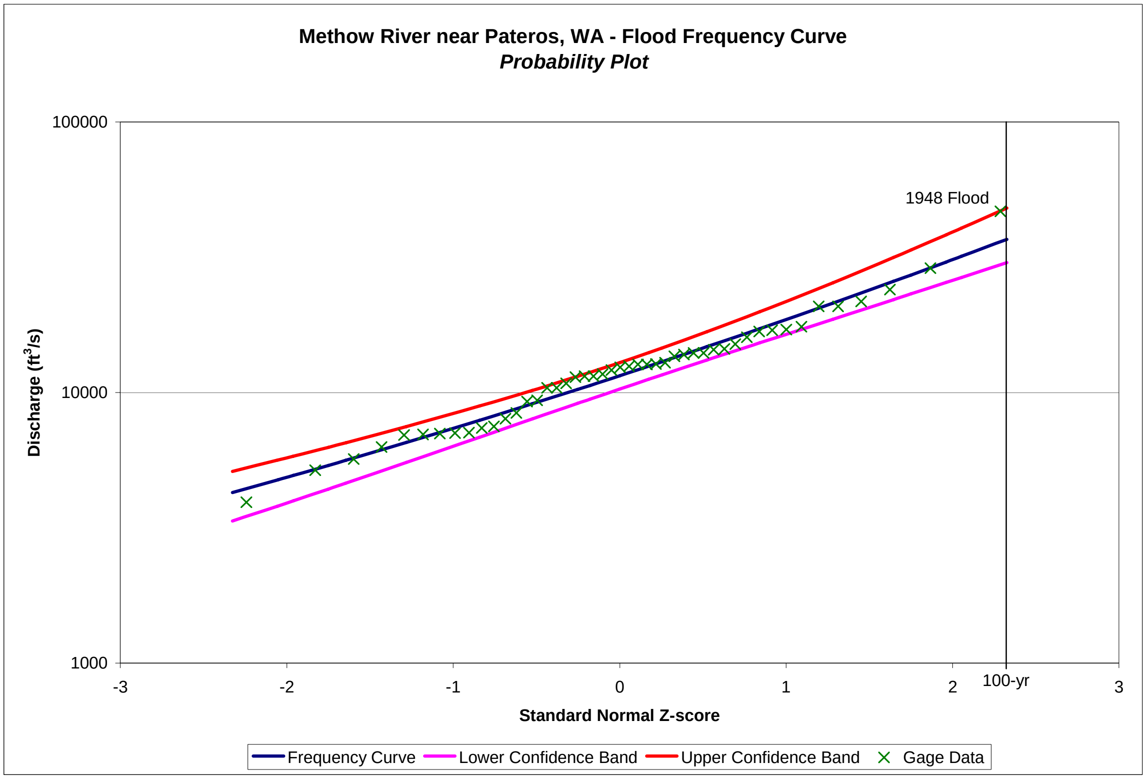


Figure 4 – Methow River Flood Frequency Curve – Probability Plot (to AEP 0.01)

Table 3 – Peak flow data computed for USGS stream gages in the Methow basin.

USGS Gage No.	Description	Q2_cfs	Q5_cfs	Q10_cfs	Q25_cfs	Q50_cfs	Q100_cfs
12449950	METHOW RIVER NEAR PATEROS, WA	11500	17200	21400	27200	31900	36800
12449600	SOUTH FORK NEAR TWISP, WA	136	267	367	506	615	727
12449500	METHOW RIVER AT TWISP, WA	11100	16000	19200	23000	25700	28300
12448998	TWISP RIVER NEAR TWISP, WA	2120	3160	3890	4860	5610	6390
12448500	METHOW RIVER AT WINTHROP, WA	9020	13300	16600	21400	25400	29700
12448000	CHEWUCH RIVER AT WINTHROP, WA	3240	4980	6100	7470	8450	9390
12447390	ANDREWS CREEK NEAR MAZAMA, WA	362	508	619	778	911	1060
12447383	GOAT CREEK NEAR MAZAMA, WA	5250	6900	7890	9040	9840	10600

Peak Flow Calculations at Ungaged Sites with GIS Integration:
Because a stream channel restoration project site could potentially be located along any reach within the Methow basin, peak flow calculations were also computed over the entire basin and incorporated into a geographic information system. The user of the Methow GIS database can easily acquire the desired peak flow information by simply clicking on a potential project site within the basin. This system was created using the

watershed processing tools in ESRI's ArcHydro and the USGS publication: *Methods for Estimating Flood Magnitude and Frequency in Washington, 2001* [3]. Two independent methods were used for computing peak flow computations at ungaged locations which will be described in further detail below. The results from each computation method can vary at individual sites and should be considered tools to represent a range of possible flood frequency values.

A geographic information system was created, in order to quickly access specific peak flow information associated with potential project sites. This system incorporates digital elevation models (DEM's) of the topography, aerial photography, precipitation isohyetal maps, existing stream networks, existing project locations, and a graphical database that contains the peak flow information for the Methow River drainage basin's individual watersheds or sub-basins. Once the DEM of the basin is imported into the GIS, ArcHydro delineated all of the sub-basins. For this system, a minimum sub-basin size of 3.5 mi^2 was selected because most stream channel restoration projects have watersheds greater than this size. After the watershed processing was complete, ArcHydro had created 519 sub-basins within the entire Methow basin. For each of these sub-basins peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals were calculated based on a local gage data analysis and a regional gage data analysis.

Peak Flows at Ungaged Locations Based on Local Gage Data Analysis

Using the guidelines specified in the USGS publication [3], the peak flows at the USGS gages were used to compute the flows for the appropriate sub-basins. These guidelines state that the ungaged location must be on the same stream as the gaged location and the ungaged watershed area must not exceed +/- 50 percent of the gaged watershed area. The following expression was used to estimate the ungaged peak flows at the ungaged sub-basin outlets,

$$Q_u = Q_g \left(\frac{A_u}{A_g} \right)^{0.97} ,$$

where Q_u is the peak discharge, in cfs, at the ungaged site for a specific recurrence interval, Q_g is the peak discharge, in cfs, at the gaged site for a specific recurrence interval, A_u is the contributing drainage area, in mi^2, at the ungaged site, A_g is the contributing drainage area, in mi^2, at the gaged site, and, 0.97 is the regional exponent for Okanogan County, Washington. Of the 519 sub-basins, 81 basins' peak flows were computed using this method. If a sub-basin happens to fall in range of two gages, then the closest gage is used to compute the peak flows. For this method, only the gages listed in Table 1 were used to estimate peak flows. Below, Figure 4 highlights the sub-basins with peak flows computed using local gage data.

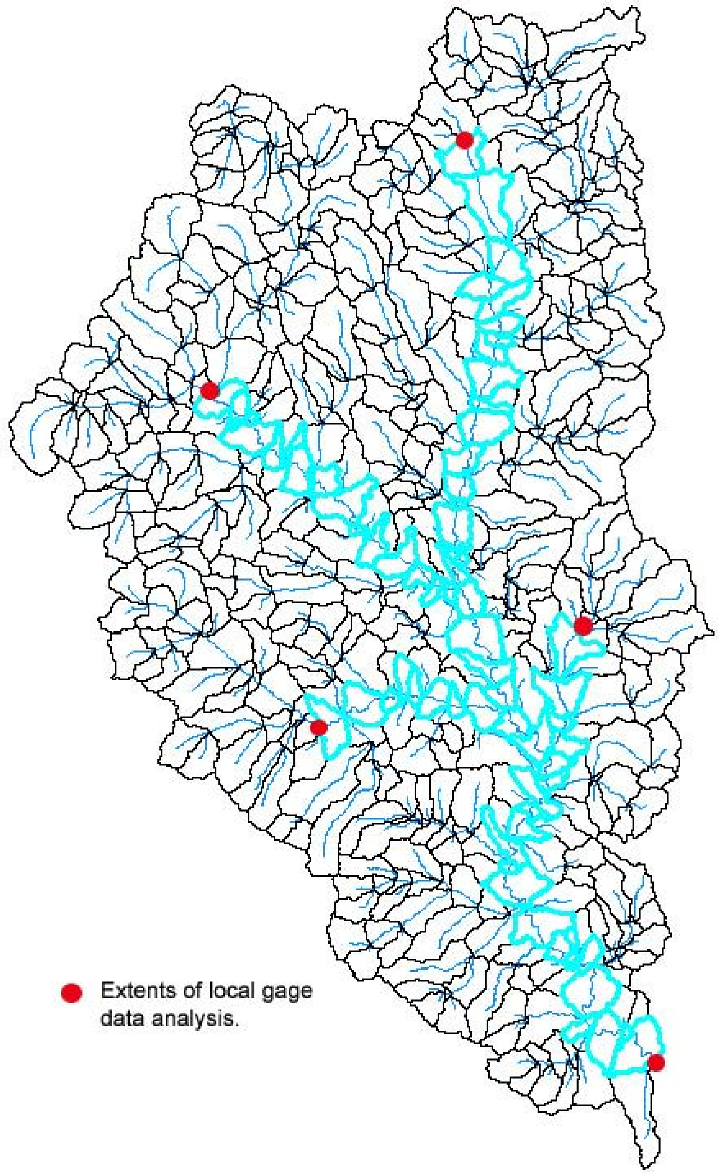


Figure 5 – Highlighted sub-basins within the Methow River watershed with peak flows computed using local gage data.

Peak Flows at Ungaged Locations Based Regional Gage Data Analysis

Because only 81 of the 519 sub-basins met the criteria above, a regional gage data analysis was implemented to fill the gaps. Using annual peak flow data from the eight USGS gage stations within the Methow basin, regional parameters for the log skewness and log variance were computed. Then a linear trendline was added to the regional log mean flow versus log area data. This yielded the following equation which had a correlation coefficient of 0.8532.

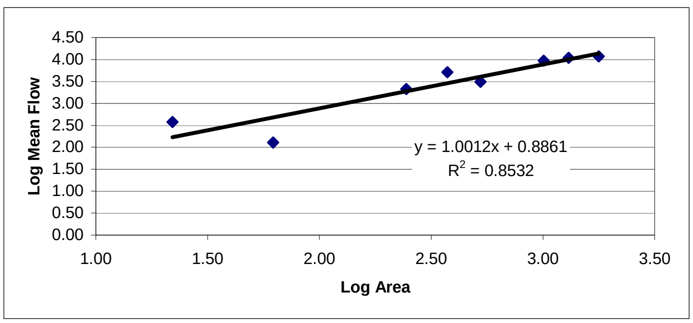
$$\log \text{mean flow} = 1.0012*(\log \text{area}) + 0.8861$$

The log mean flows for the remaining sub-basins were computed using the above equation, and finally a Log Pearson III analysis was performed to compute the peak flows for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals.

Table 4 – Example Regional Gage Data Analysis for a 50 mi^2 sub-basin.

Site ID	Area (mi^2)	LogArea	LogMean	N	LogSkew	N*LogSkew	LogVar	n*LogVar
12447383	373.0	2.57	3.71	14	-0.28	-3.974	0.148	2.065
12447390	22.0	1.34	2.57	36	0.57	20.549	0.165	5.922
12448000	525.0	2.72	3.50	13	-0.41	-5.269	0.236	3.065
12448500	1007.0	3.00	3.97	16	0.43	6.824	0.191	3.063
12448998	245.0	2.39	3.33	19	0.02	0.329	0.205	3.889
12449500	1301.0	3.11	4.04	52	-0.32	-16.635	0.200	10.380
12449600	62.0	1.79	2.11	20	-0.39	-7.799	0.369	7.375
12449950	1772.0	3.25	4.07	47	0.20	9.409	0.204	9.580
					Sum	**3.435**		**45.339**

LogSkew	0.0158			
LogVar	0.2089			
			Regional Analysis	
Slope	1.001	**Return Period**	**Probability**	**Peak Flow**
Intercept	0.886	2	0.5	386
Effective N	27	5	0.2	579
		10	0.1	716
Sub-basin Area	50	25	0.04	900
LogArea	1.6990	50	0.02	1042
LogMean	2.5871	100	0.01	1190



Using the GIS Database

Once the computations for all of the sub-basins were completed, they were integrated in the GIS. The following figure is an example of the output from the GIS for a specific sub-basin. It contains the information listed in the table below. Note: If the Ref_Gage field is 0, then the regional gage data analysis was used to calculate the peak flows for the selected sub-basin.

Table 5 – GIS output description.

Field	**Description**
Area_mi2	Sub-basin area in square miles
Q2_cfs	2 year peak flow in cubic feet per second
Q5_cfs	5 year peak flow in cubic feet per second
Q10_cfs	10 year peak flow in cubic feet per second
Q25_cfs	25 year peak flow in cubic feet per second
Q50_cfs	50 year peak flow in cubic feet per second
Q100_cfs	100 year peak flow in cubic feet per second
Ref_Gage	Gage used to estimate peak flows (used for local analysis only)

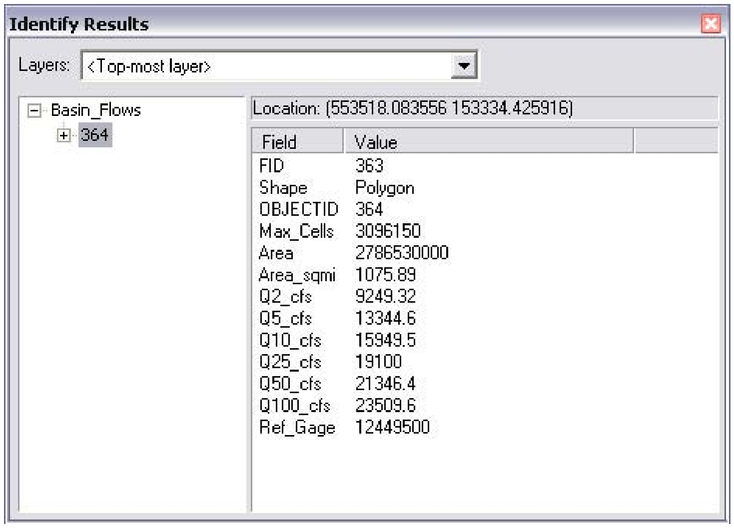


Figure 6 – Output summary example for an ungaged sub-basin.

Maximum, Average, and Minimum Daily Flows:
Figures 7 through 11 represent a summary hydrograph analysis of the mean daily flows for five major USGS gages in the Methow River drainage basin. Maximum, mean, median, minimum and the upper and lower quartiles of daily flow values are presented for each day. A simple routine was developed in Microsoft Excel's Visual Basic editor to compute the above statistics for each calendar day of a gage's period of record and output them in a graphical format.

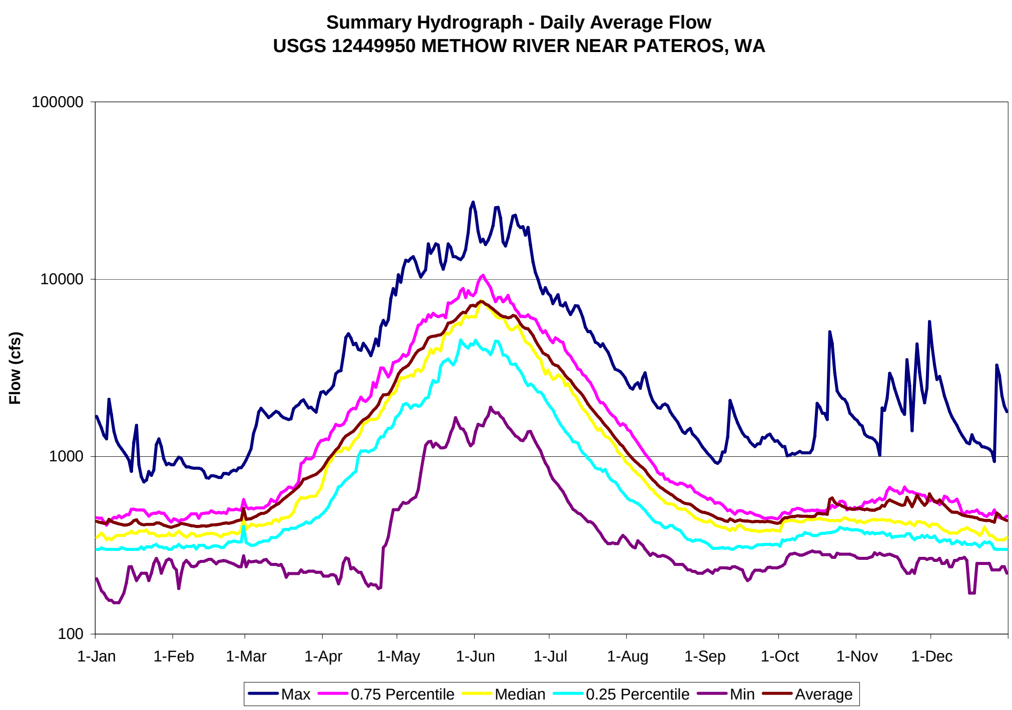


Figure 7 – Mean daily flow statistics for Methow River near Pateros, WA.

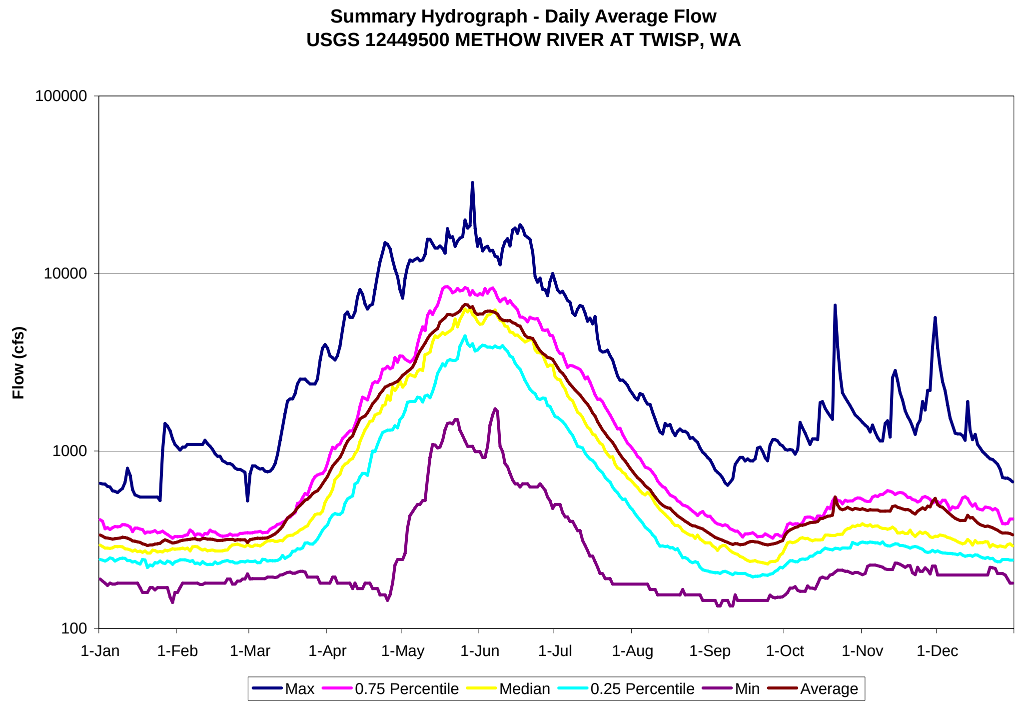


Figure 8 – Mean daily flow statistics for Methow River at Twisp, WA.

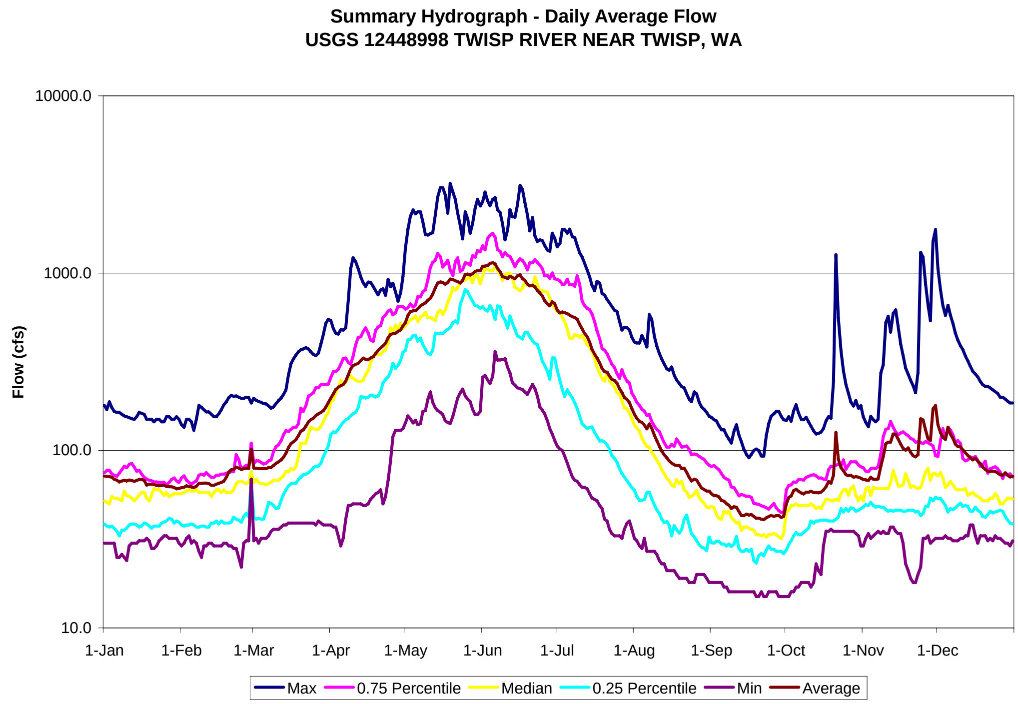


Figure 9 – Mean daily flow statistics for Twisp River near Twisp, WA.

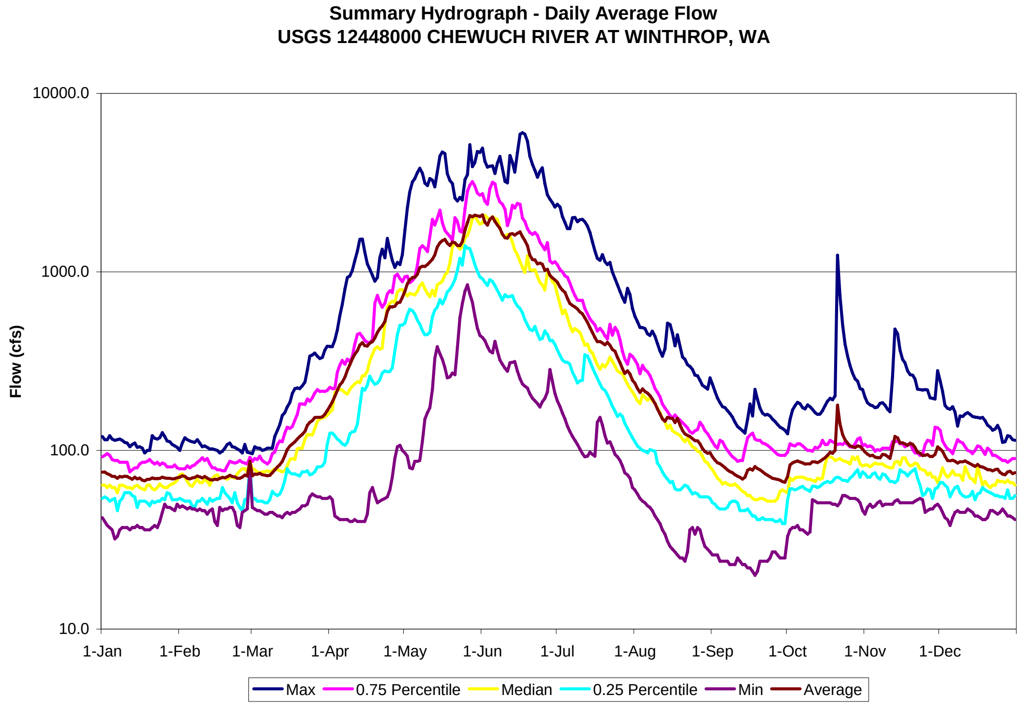


Figure 10 – Mean daily flow statistics for Chewuch River at Winthrop, WA.

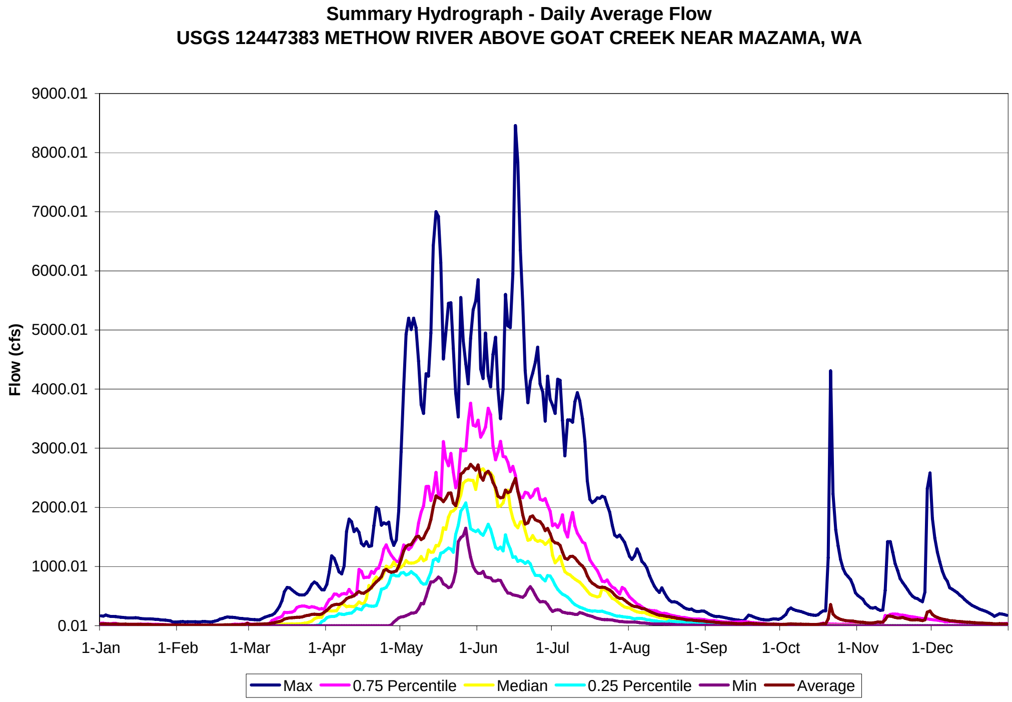


Figure 11 – Mean daily flow statistics for Methow River above Goat Creek near Mazama, WA.

Flow-Duration Curves:
Analysis of the mean daily flow data was performed to produce standard flow duration curves that depict the fraction of time that the river flows are below a specific flow. In addition to the curve, bins have been created that represent estimates of the volume of water for a specific discharge and duration. This volume is then used to estimate sediment loads at the selected discharge. The height of the bin is the discharge (ft^3/s) and the width of the bin is the duration displayed as a fraction of a year (365.25 days). The gage records were used to estimate the duration for each desired discharge. For each of the five gages analyzed, the 1-, 2-, 5-, and 10-year discharges have bins. There are also bins representing recurrence intervals between 1 and 2 years. Figures 12 - 16 display these curves.

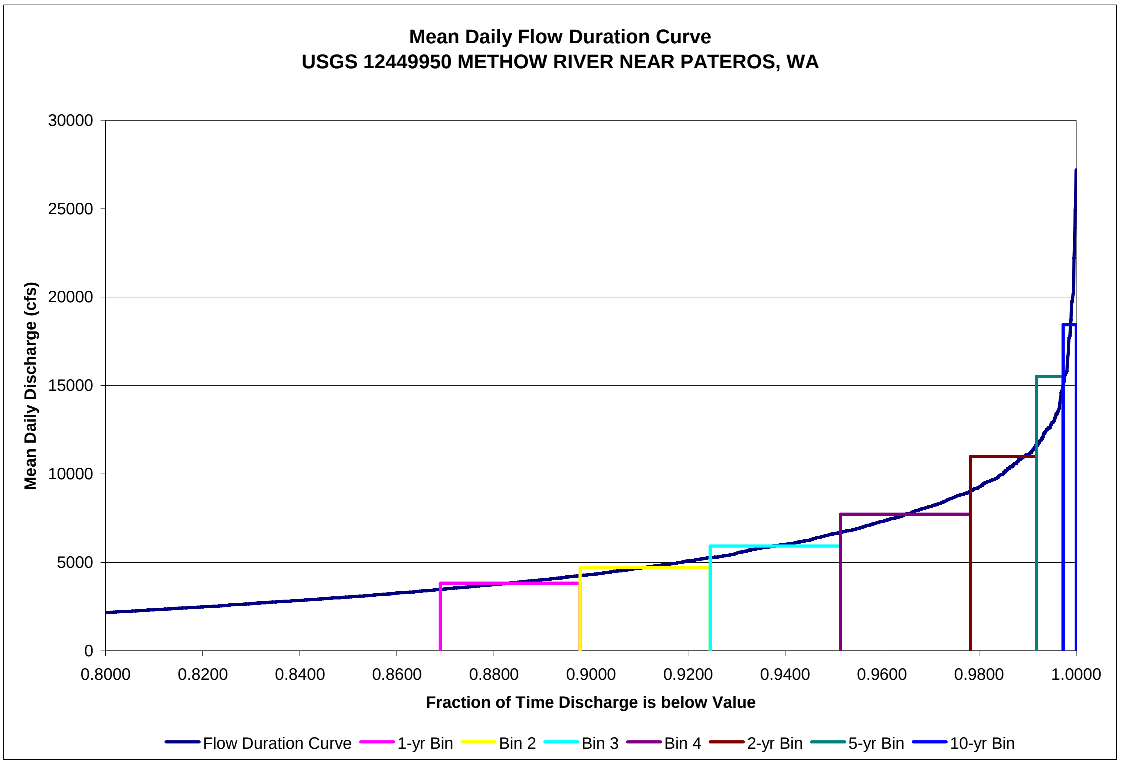


Figure 12 – Mean daily flow duration curve for Methow River near Pateros, WA.

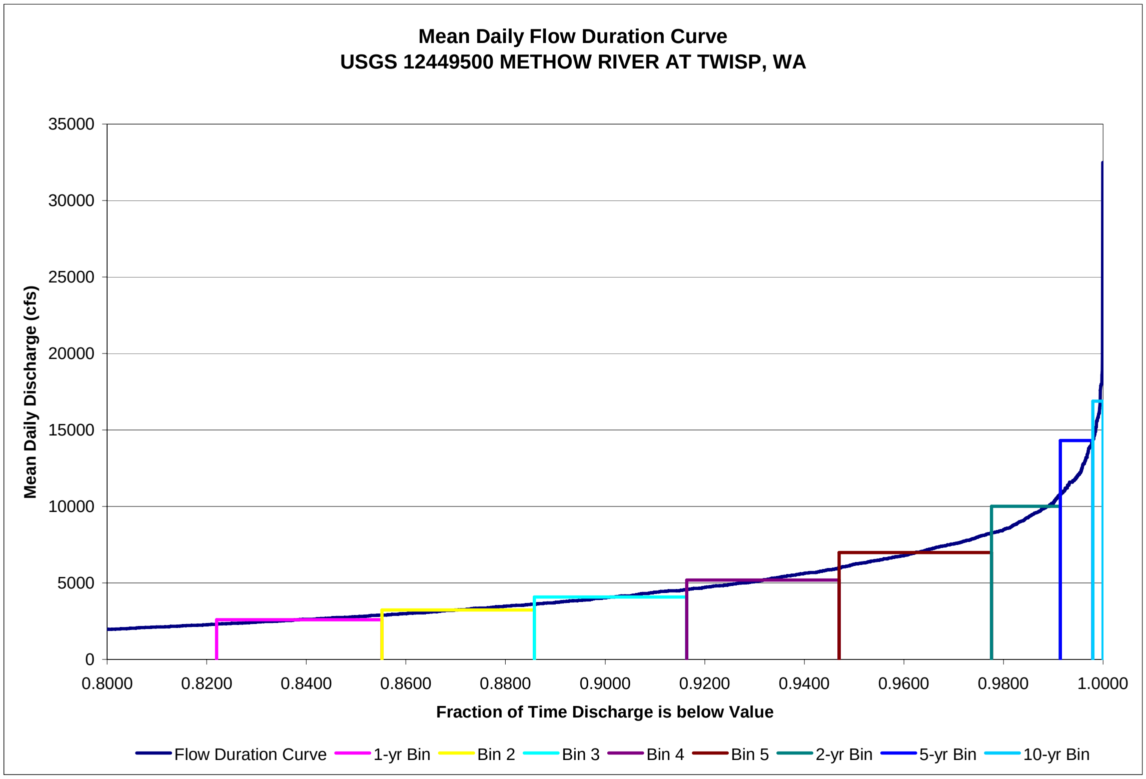


Figure 13 – Mean daily flow duration curve for Methow River at Twisp, WA.

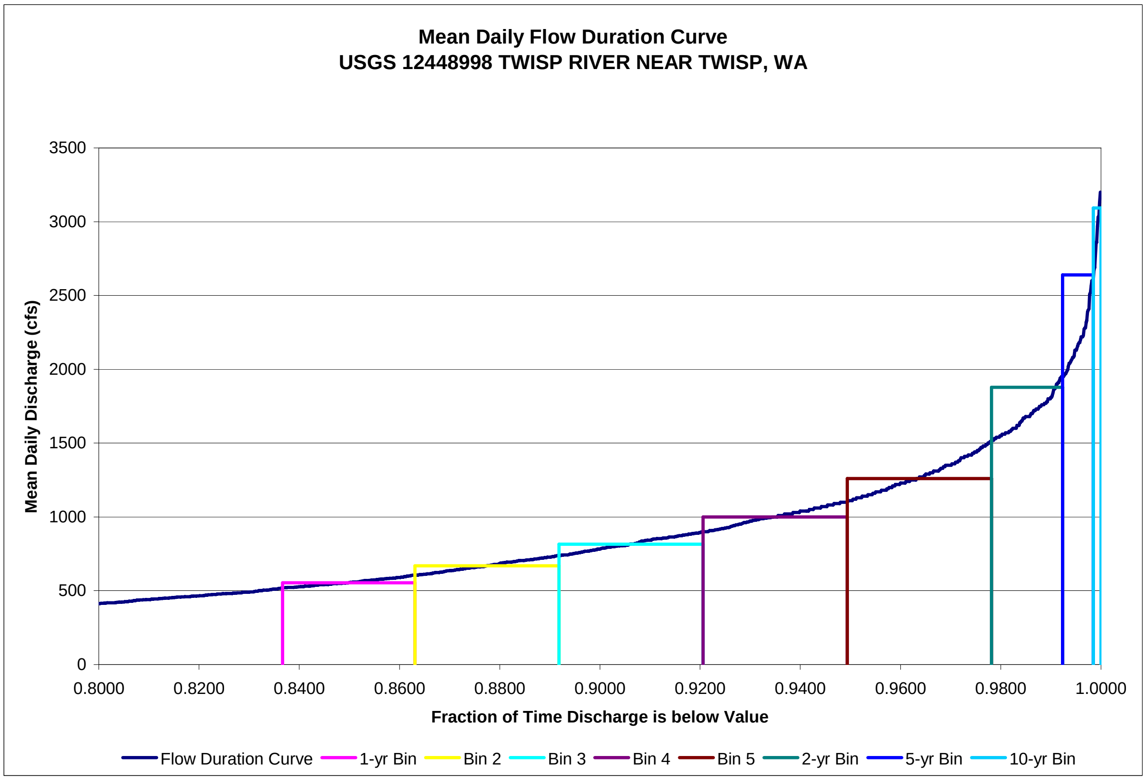


Figure 14 – Mean daily flow duration curve for Twisp River near Twisp, WA.

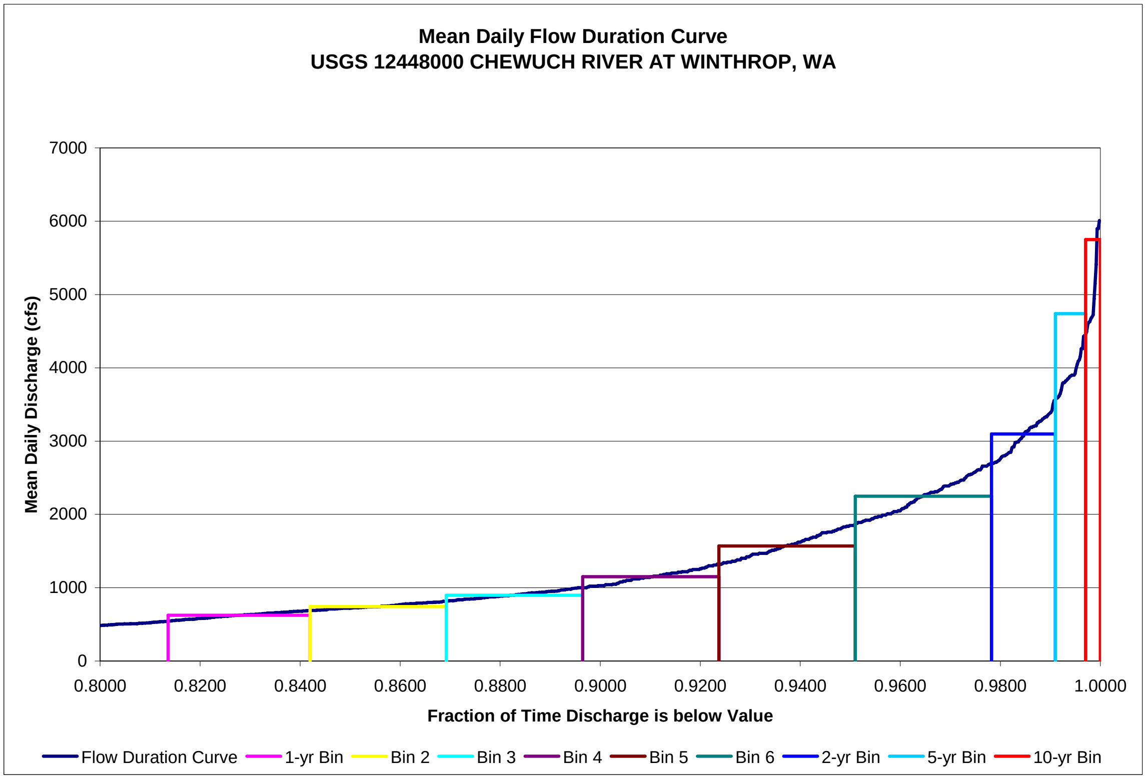


Figure 15 – Mean daily flow duration curve for Chewuch River at Winthrop, WA.

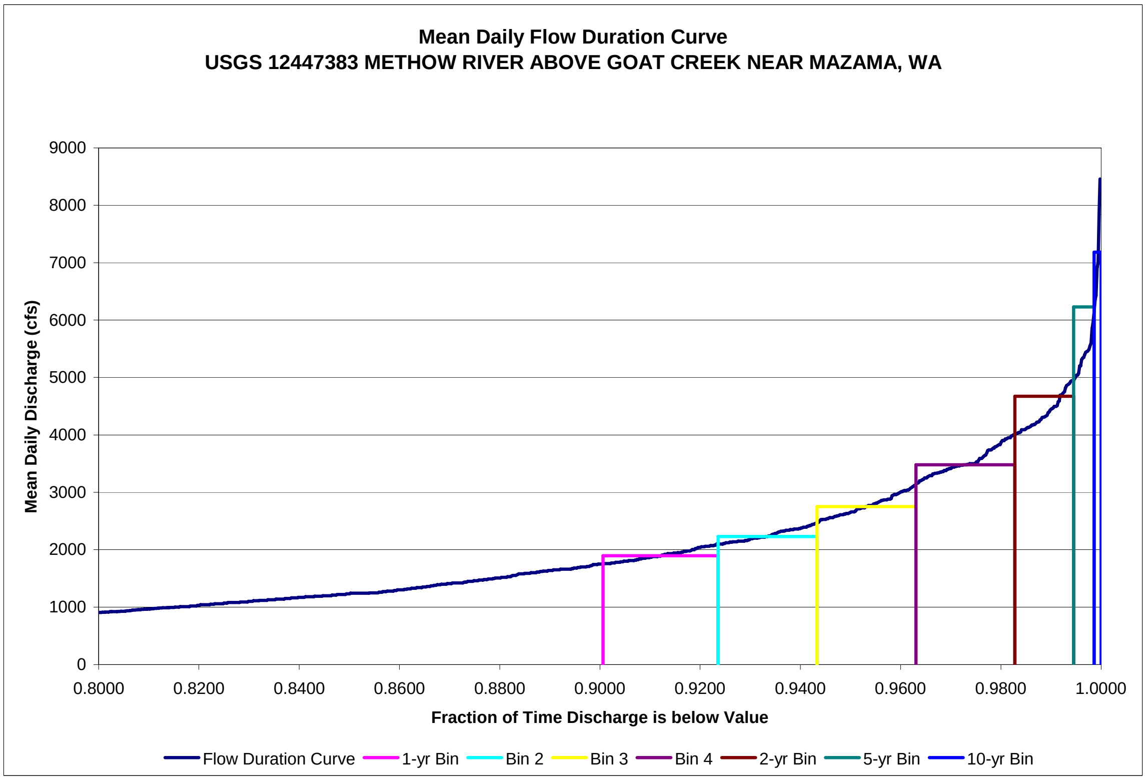


Figure 16 – Mean daily flow duration curve for Methow River above Goat Creek near Mazama, WA.

The Effects of PDO on Pacific Northwest Salmon Production:

"Pacific Decadal Oscillation" (PDO) is a term that has been created to describe the climate variability in the North Pacific and North American sector. During the 20th century PDO events persisted for 20 to 30 years. A specific PDO event is assigned a polarity. In the last century the North Pacific PDO was predominantly positive between 1925 and 1946, negative between 1947 and 1976, and positive since 1977. Table 6 summarizes the climate anomalies associated with positive and negative PDO phases [4].

Table 6 – Summary of Pacific and North American climate anomalies associated with extreme phases of PDO [4].

Climate Anomalies	Positive PDO (warm phase)	Negative PDO (cool phase)
Ocean surface temperatures in the northeastern and tropical pacific	Above average	Below average
October-March northwestern North American air temperatures	Above average	Below average
October-March Southeastern US air temperatures	Below average	Above average
October-March southern US/Northern Mexico precipitation	Above average	Below average
October-March Northwestern North America and Great Lakes precipitation	Below average	Above average
Northwestern North American spring time snow pack and water year (October-September) stream flow	Below average	Above average
Winter and spring time flood risk in the Pacific Northwest	Below average	Above average

During negative or cool phases of PDO, climate conditions are the most favorable for salmon production in the Pacific Northwest. Relatively cool winter air temperatures and high precipitation yield increased snowpack. As a result, the annual water year discharge in the Skeena, Fraser, and Columbia Rivers is on average 8%, 8%, and 14% higher, respectively. For Pacific Northwest salmon, the typical negative PDO year brings enhanced streamflows and nearshore ocean mixed-layer conditions favorable to high biological productivity [5].

References:

[1] Beck, R.W. and Associates, 1973. Floodplain information Methow River, Mazama to Twisp, Okanogan County, Washington: WA Department of Ecology, Olympia, WA.

[2] Guidelines for Determining Flood Flow Frequency, *Bulletin #17B of the Hydrology Committee*, U.S. Department of the Interior, United States Water Resources Council, 1981.

[3] USGS, 2001. *Methods for Estimating Flood Magnitude and Frequency in Washington, 2001*, U.S. Geological Survey Fact Sheet 016-01.

[4] Mantua, Nathan, 1999: The Pacific Decadal Oscillation. Joint Institute for the Study of the Atmosphere and Oceans University of Washington, Seattle, Washington, USA.

[5] Mantua, N.J., S. R. Hare, Y. Zhang, J. M. Wallace, and R. C. Francis, 1997: A Pacific Interdecadal Climate Oscillation with Impacts on Salmon Production. *Bulletin of the American Meteorological Society,* Vol. 78, pp 1069-1079.

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