WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Open File Technical Report

Washougal River Fish Habitat Analysis Using the Instream Flow Incremental Methodology and the Toe-Width Method for WRIAs 25, 26, 28, and 29

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Washougal River Fish Habitat Analysis Using the Instream Flow Incremental Methodology and the Toe-Width Method for WRIAs 25, 26, 28, and 29

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SUMMARY

The Washington State Department of Ecology (Ecology) conducted an instream flow study on the Washougal River using the Instream Flow Incremental Methodology (IFIM). In addition, we collected Toe-Width information on 33 streams in WRIAs 25, 26, 28, and 29. These WRIAs are the Grays/Elochoman, the Cowlitz, the Salmon/Washougal, and the Wind/White Salmon, respectively. These studies provide information about the relationship between streamflows and fish habitat which can be used in developing minimum instream flow requirements for fish in the Washougal River and the 33 chosen streams in WRIAs 25, 26, 28, and 29. For the IFIM study on the Washougal River one site, composed of eight transects, was chosen. The site was located at approximate River Mile 3.5 at Hathaway Park. Streamflow measurements and substrate information were recorded at high, medium, medium-low, and low flow. This information was entered into the IFG4 hydraulic model to simulate the distribution of water depths and velocities with respect to substrate and cover under a variety of flows. Using the HABTAT model, the simulated information was then used to generate an index of change in available habitat relative to changes in flow; this index is referred to as "weighted usable area" (WUA).

Determination of a minimum instream flows for WRIAs 25, 26, 28, and 29 will require setting priorities for river reaches, fish species and lifestages. Different fish species and lifestages exist simultaneously in the river and each has a different flow requirement. There is no single flow that will simultaneously provide optimum habitat for all fish species and lifestages.

In addition, minimum instream flows must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding fry and juveniles. Other variables to be considered include water temperature, water quality, and sediment load. These variables were not addressed in this study.

No instream flow recommendations were made in this report. Those recommendations would be the next step after this study. Instream flow determinations would require an evaluation of the environmental variables listed above combined with the long-range fishery management objectives of the state and federal natural resource agencies and affected Tribes. Some results of the IFIM study are portrayed in the table below:

Flow and Habitat Relationships for the Washougal River

Species	Instream Flow Which Provides Maximum Spawning Habitat	Instream Flow Which Provides Maximum Juvenile Habitat
Chinook	425 cfs	225 cfs
Steelhead	375 cfs	525 cfs
Coho	225 cfs	N/A

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I want to thank Joshua Husseman (Ecology), Jeff Marti (Ecology), Clay Keown (Ecology), and Cynthia Pratt (Fish and Wildlife) for having provided valuable assistance in gathering field data.

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Introduction

The Washington State Department of Ecology (Ecology) is mandated by the 1971 Water Resources Act (Chapter 90.54 RCW) to maintain instream flows necessary to provide for preservation of wildlife, fish, scenic, aesthetic and other environmental values. As part of Ecology's commitment to the Lower Columbia Steelhead Conservation Initiative to provide more protection for salmonids after the listing of steelhead as a threatened species in the lower Columbia River in March 1998, Ecology agreed to conduct instream flow studies to provide information for determining instream flows. To determine appropriate minimum instream flows for fish habitat, one tool Ecology often uses is the Instream Flow Incremental Methodology (IFIM) to generate some of the necessary information. Another tool is the Toe-Width Method to generate streamflows needed by fish. The minimum flows determined by Ecology cannot take away any existing water rights and serve to protect existing water right users by restricting new upstream diversions if the river is already experiencing low flows. This information may be used by Ecology to determine the impact of future water appropriations on fish habitat or to condition new water rights to protect instream flows for fish habitat.

Study participants included staff from Ecology and Washington State Department of Fish and Wildlife (WDFW).

Project Background: Location and Description

The Washougal River is located in southwest Washington in Skamania and Clark counties originating in the south Washington Cascade mountain range. The Washougal River flows southwesterly approximately 33 miles to its confluence with the Columbia River at River Mile (RM) 121 at the city of Camas. The Washougal River watershed encompasses about 240 square miles in a geographical region known as the Willamette-Puget trough (WDF, 1990). The lower two miles of the river are in the Columbia River valley. A narrow, shallow valley characterizes the next eleven miles upstream. Beyond this valley is a narrow, deep canyon extending into the Yacolt burn area (WDF et al., 1993). The major tributaries to the Washougal River include the Little Washougal River, Cougar Creek, Canyon Creek, West Fork Washougal River, and Dougan Creek among other numerous smaller tributaries.

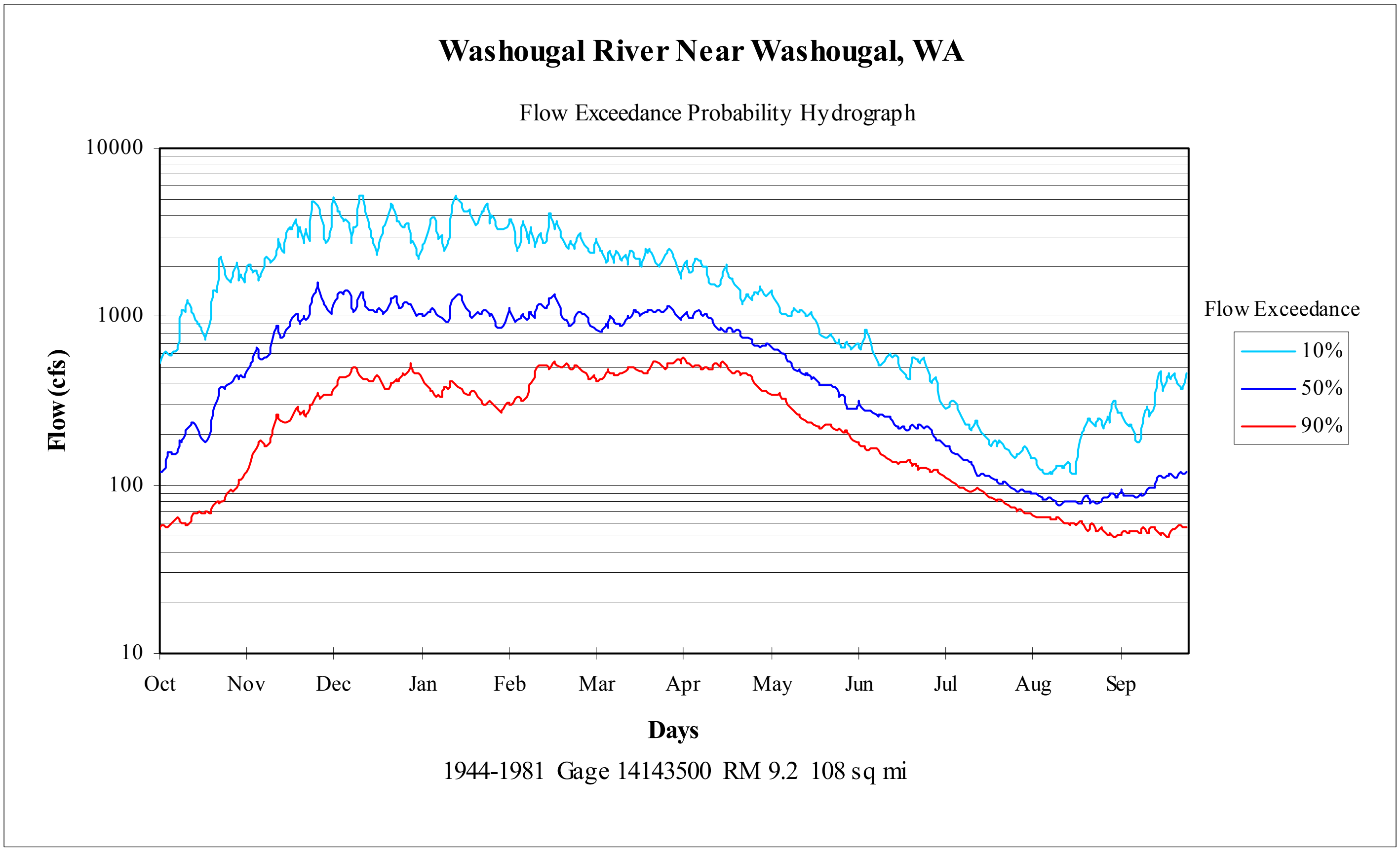
The major population concentration of the Washougal basin is centered on the cities of Washougal and Camas located on the short confined floodplain at the mouth of the river. Private residential developments are dispersed along State Route 140, which follows the river upstream from Washougal. Agricultural development in the area has been limited primarily to the lower reaches of the watershed due to more rugged topography upstream (WDF, 1990).

The climate of the watershed is characterized by warm, dry summers and cool, wet winters. Annual rainfall varies throughout the drainage area due to elevation differences. The lower portion of the watershed averages about 50 inches of rainfall per year while the upper elevations of the watershed receive an average of 110 inches annually. There are no permanent snow packs or reservoirs on the river so stream flow is mainly a result of precipitation runoff and groundwater recharge (WDF, 1990)

Hydrology

The daily exceedence flows for the Washougal River are portrayed in Figure 1. This graph is based upon daily averages from a 1944-81 period of record obtained from the USGS gage near Washougal at RM 9.2. The

Figure 1. Hydrograph of the Washougal River.



exceedence graph is useful in assessing variances in streamflows at certain times of the year rather than relying on a single number such as mean monthly flow. The exceedence graph shows the range of flows one might expect on a given day or during a particular time period.

When a single number is used to describe the flow in a stream, such as average monthly flow, it gives a very distorted idea of the normal flow in the stream. A range, such as the 10% to 90% flow exceedence values, best describes streamflow. This flow range describes the flow one would expect to see 80% of the time in the stream. The 10% exceedence value can be viewed as the quantity of flow in the stream on a specific day that reaches that flow level or higher one out of every 10 years. The 50% exceedence flow value is the median flow: over all the years of record, half of the time on that day the flow was higher and half of the time the flow was lower. The 90% exceedence level means the flow is that level or higher in 9 out of 10 years on that day.

The 10% exceedence flow level is not an unusual flow in the stream. Streamflow in a certain year in not at the 10%, 50%, or 90% level on a consistent basis. Rather, flow normally jumps back and forth on a daily or weekly basis from the 10% to 90% exceedence level and sometimes from the 5% to 95% exceedence levels. Usually the reason for this flow behavior is either it's raining and streamflows are very high, or it has stopped raining for a week and streamflows are now very low.

Hydrographs for Abernathy Creek, Coweeman River, Elochoman River, Grays River, Jim Crow Creek, Little Washougal River, Mill Creek, Salmon Creek, and the Wind River are in Appendix A. These were the streams and rivers for which there were enough years of USGS flow data to generate hydrographs in WRIAs 25, 26, 28, and 29 that also included the Evolutionary Significant Unit (ESU) areas for lower Columbia River chinook, steelhead, and chum. All hydrographs do not include water diverted for irrigation or other purposes and used consumptively. This diverted water would need to be added to the hydrographs to determine the natural flow in the stream. Additional spot measurements of flow for the 33 Toe-Width measured streams were taken by Ecology and are in Tables 6 to 9.

Water Quality Standards

The major water quality concern on the Washougal River is effluent from the pulp mill in Camas. Treated municipal waters from Washougal and Camas discharge to the Columbia River rather than to the Washougal River (WDF, 1990). Monitoring of water quality has been conducted on the Washougal River by the Department of Ecology recently at monitoring station 28B070 (RM 3.0 at bridge on Highway 140 at 17th street). One out of nine water samples taken exceeded state water quality standards for water temperature. This single excursion did not meet the criteria for listing on Ecology's 303(d) list of water bodies that fail to meet state water quality standards (Ecology, 1996).

Fish Use and Status

The Washougal River basin is in the area for three different fish species listed as threatened under the Endangered Species Act: steelhead were listed in March, 1998 for the Lower Columbia River ESU; chinook salmon were listed in March, 1999 for the Lower Columbia River ESU; and chum salmon were listed in March, 1999 for the Columbia River ESU. Maps of these ESU areas are in Appendix B.

As part of the 1992 Salmon and Steelhead Stock Inventory (SASSI), the Washington State Department of Fish and Wildlife identified coho stocks as being "depressed" (WDFW, 1993). The rating "depressed" means a stock of fish whose production is below expected levels based on available habitat and natural variations in survival rates, but above the level where permanent damage to the stock is likely.

Chinook

There is no natural spring chinook salmon production in the Washougal River. Returning fall chinook are primarily hatchery fish. Native fall chinook have been reported in the Washougal River (identified as hatchery strays), but a distinct stock no longer exists (WDF, 1990). Spawning fall chinook enter the river in early August and spawn slightly later than other lower Columbia River fall chinook: typically in October and November. There does not seem to be any unique biological characteristics distinguishing these fall spawners from other Columbia River fall chinook spawners. Washougal fall chinook spawn primarily in a 4-mile stretch of the Washougal River from Salmon Falls downstream to the Wildlife Access. The SASSI report of 1993 lists the status of naturally spawning stock as healthy. Escapements between 1967 and 1970 averaged 120 fish, but between 1971 and 1991 escapements averaged 2,157 fish (WDF et al., 1993).

Summer Steelhead

Summer steelhead are a native and distinct stock of the Washougal River. Run sizes have fluctuated historically due to natural events (i.e. large forest fires and Mt. St. Helens eruption) and human activities within the watershed. Slow recovery from habitat degradation have limited production. Logging activities, gravel mining, passage constraints due to dams (these have since been removed), effluent from the Camas paper mill, predation of outmigrating smolts, harvest and hatchery management, as well as changes in marine habitat have all influenced summer steelhead production. Removal of the dams on the Washougal River and construction of a fishway over Salmon Falls has made available more of the mainstem river as well as smaller tributaries to summer steelhead spawners (WDF, 1990 and WDF et al., 1993). Adult upmigration is typically May through November with spawning taking place from early March through early June. The status of the stock is unknown because of a lack of survey data according to the SASSI Report. The escapement goal for the mainstem Washougal is 1,210 wild adults (WDF et al., 1993).

Winter Steelhead

Like summer steelhead, Washougal winter steelhead are a native stock based on the geographic isolation of the spawning population, although there may be some genetic influence from hatchery introduced fish. Winter steelhead utilize spawning and rearing habitat throughout the Washougal River mainstem as well as the West Fork Washougal River, Stebbins Creek, Cougar Creek and the Little Washougal River. Spawners generally migrate upriver from December through April and spawn from early March to early June. Juveniles outmigrate in April and May at two years of age (WDF, 1990). The SASSI Report indicates the status of the stock as unknown although helicopter survey data show very few redds per mile were observed. The spawning escapement goal is 841 fish (WDF et al., 1993).

Coho

Coho salmon natural spawning is believed to be low and juvenile production below its potential. Limiting factors for Washougal River coho include low summer flows, high stream temperatures and low quality and quantity of gravel substrate. Logging, agriculture, and suburban development have impacted fish habitat in

Washougal River tributaries. Sport and commercial fisheries in the ocean and the Columbia River are also thought to be a limiting factor of fish production. Smolt outmigration may be affected by pollution in the Columbia River (WDF et al., 1993). Coho returning to the Washougal River are comprised of two major stocks: returning three-year-olds with some two-year-old jacks. The first stock migrates upriver at the beginning of September through November and spawns from mid-October through November. Incubation occurs from late October through January with fry emerging in late January and early February. The later stock migrates upriver from the first of November through December. Spawning takes place from mid-December through January. Incubation is complete by the end of March and fry emerge in April. Coho salmon juveniles usually spend their first year in freshwater before outmigration (WDF, 1990). Coho are thought to spawn in all available Washougal tributaries; particularly below the falls in the Little Washougal, Winkler Creek and the West Fork Washougal River. Washougal coho stock status is depressed according to the 1993 SASSI Report (WDF et al., 1993).

Study Methods

Instream Flow Incremental Methodology (IFIM)

IFIM was selected as the best available method for predicting how the quantity of available fish habitat changes in response to incremental changes in streamflow. The U.S. Fish and Wildlife Service in the late 1970s (Bovee, 1982) developed this methodology. The IFIM involves putting site-specific streamflow and habitat data into a group of models collectively called PHABSIM (physical habitat simulation). The most common model is IFG4, which uses multiple transects to predict depths and velocities in a river over a range of flows. IFG4 creates a cell for each measured point along the transect or cross-section. Each cell has an average water depth and water velocity associated with a type of substrate or cover for a particular flow. The cell's area is measured in square feet. Fish habitat is defined in the computer model by the variables of velocity, depth, substrate, and/or cover. These are important habitat variables that can be measured, quantified, and predicted.

The IFIM is used nationwide and is accepted by most resource managers as the best available tool for determining the relationship between flows and fish habitat. However, the methodology only uses four variables in hydraulic simulation. At certain flows, such as extreme low flows, other variables such as fish passage, food supply (aquatic insects), competition between fish species, and predators (birds, larger fish, etc.) may be of overriding importance. In addition to the PHABSIM models, IFIM may include reviewing water quality, sediment, channel stability, temperature, hydrology, and other variables that affect fish production. These additional variables are not analyzed in this report.

After the IFG4 model is calibrated and run, its output is entered into another model (HABTAT) with data describing fish habitat preferences in terms of depth, velocity, substrate, and cover. These preferences vary according to fish species and life-stage (adult spawning and juvenile rearing).

The output of the HABTAT model is an index of fish habitat known as Weighted Useable Area (WUA). The preference factor for each variable at a cell is multiplied by the other variables to arrive at a composite, weighted preference factor for that cell. For example: a velocity preference of 1.0 multiplied by a depth preference of 0.9, then multiplied by a substrate preference of 0.8 equals a composite factor of 0.72 for that cell. This composite-preference factor is multiplied by the number of square feet of area in that cell.

A summation of all the transect cells' areas results in the total number of square feet of preferred habitat available at a specified flow. This quantity is normalized to 1,000 feet of stream or river. The final model result is a listing of fish habitat values (WUA) in units of square feet per 1,000 feet of stream. The WUA values are listed with their corresponding flows (given in cubic feet per second).

Study Site and Transect Selection

A preliminary study site was selected for the IFIM study by reviewing topographic maps. Actual site selection was done during field visits. Eight transects were chosen around RM 3.5 (see Figure 2) to represent the lower river. These transect sites are shown in the table below.

Washougal River Transects

Transect #	Location
1	River Mile 3.5
2	103 feet upstream of Transect 1
3	96 feet upstream of Transect 2
4	55 feet upstream of Transect 3
5	125 feet upstream of Transect 4
6	93 feet upstream of Transect 5
7	100 feet upstream of Transect 6
8	73 feet upstream of Transect 7

Field Procedures

IFIM measurements were taken on 6-8-98, 5-11-98, 7-30-98, and 9-15-98. We measured flows on the Washougal River at 440, 255, 153 and 72 cfs, respectively.

A temporary gage at each site was used to verify that streamflow at each transect remained steady during measurement. Transects were marked using survey hubs and flagging. Water velocity was measured using standard USGS methods with a calibrated Swoffer velocity meter mounted on a top-set wading rod.

Water surface elevations and stream-bank profiles were surveyed with a survey level and stadia rod. These points were referenced to an arbitrary, fixed benchmark. Substrate composition and cover were assessed by visually estimating the percent of the two main particle size classes and type of cover according to a scale recommended by the Washington Departments of Fisheries and Wildlife. This scale is included as Appendix E.

Hydraulic Model

Calibration Philosophy

Calibration of the hydraulic model involved checking the velocities and depths predicted by the model against velocities and depths measured in the field. This included examining indicators of the model's accuracy such as

mean error and Velocity Adjustment Factor (VAF). The calibration philosophy was to change data or to manipulate data using a computer calibration option only when doing so would improve the model's ability to extrapolate without reducing the accuracy of predicted depths and velocities at the measured calibration flows.

Calibration of the IFG4 model was done cell by cell for each transect to decide whether the predicted cell velocities adequately represented measured velocities. Generally, if the predicted cell velocity at the calibration flow was within 0.2 feet per second (fps) of the measured cell velocity, the predicted velocity was considered adequate. Any change to a calibration velocity was limited to a change of 0.2 fps. The 0.2-fps change limit was thought to be reasonable considering the normal range of velocity measurement error. All cell velocities were reviewed at the highest and lowest extrapolated flows to ensure that extreme cell velocities were not predicted.

Indicators of Model Accuracy

Two indicators of the IFG4 model's accuracy in predicting depths and velocities are the mean error and the Velocity Adjustment Factor (VAF). See Appendix C for mean errors and VAFS for each transect at each site.

The mean error is the ratio of the calculated flow (from depths and velocities at the measured flows) to the predicted flow (from depth and velocity regressions). As a rule of thumb, the mean error for the calculated discharge should be less than 10 percent.

The Velocity Adjustment Factor (VAF) for a three-flow IFG4 hydraulic model indicates whether the flow predicted from the velocity/discharge regressions matches the flow predicted from the stage/discharge regressions. The velocities predicted from the velocity/discharge regressions for a transect are all multiplied by the same VAF to achieve the flow predicted from the stage/discharge regression. Calculating and comparing the flows predicted from two different regressions gives an indication as to whether or not some of the model's assumptions are being met.

A range in the VAF value of 0.9 to 1.1 is considered good, 0.85 to 0.9 and 1.1 to 1.15 fair, 0.8 to 0.85 and 1.15 to 1.20 marginal, and less than 0.8 and more than 1.2 poor (Milhous, 1984). The standard extrapolation range is 0.4 times the low calibration flow and 2.5 times the high calibration flow. The extrapolation range of the model is usually limited when two or more transects have VAFs which fall below 0.8 or above 1.2.

Options in IFG4 Model

Several options are available in the IFG4 hydraulic model (Milhous, 1989). Ecology's standard method is to set all the options to zero except for option 8 which is set at 2, and option 13 to 1 to get a summary of the velocity adjustment factors. The standard options were used for the models in this study.

Site Specific Calibration

A three-flow IFG4 model with eight transects was run for the Washougal River site. The IFG4 input file, a summary of the calibration details, data changes, and the velocity adjustment factors are included as Appendix C. The velocity adjustment factors range from 0.80 to 1.05 allowing an extrapolation range from 50 to 1100 cfs.

Transect Weighting

The table below lists the percent weighting each transect received relative to the whole site. Transect weighting is determined one of two ways: either the model automatically determines weighting for each transect by using the distance between the transects or transect weight is set to predetermined levels by specifying distances between transects and upstream weighting (referred to as composite weighting). Composite weighting is done when the transects are located far apart and the distances between the transects would create incorrect weighing, or the investigator wants to increase the weight of a particular type of fish habitat for that site. Transect weighting for the Washougal River site was done using the distances between transects.

Transect Weighting for the Washougal River Site

Transect #	1	2	3	4	5	6	7	8
Percent of Total Site	7.98	15.43	11.71	13.95	16.90	14.96	13.41	5.66

Agency Approval of the Hydraulic Model

Brad Caldwell of the Department of Ecology and Hal Beecher of the Department of Fish and Wildlife met December 3, 1998 and after reviewing the calibration details decided the hydraulic models were adequate for the extrapolation range listed above.

Habitat Use Model (HABTAT)

Options Used in HABTAT

The HABTAT program combines the depths and velocities predicted from the IFG4 hydraulic model with the depths, velocities, cover, and substrate preferences from the habitat-use curves. The HABTAT program calculates WUA for each flow modeled. The IOC options used in HABTAT were IOC 00000 00101 00000 000.

Habitat Preference Curves

Fish preference curves for the Washougal River were agreed to by Brad Caldwell for the Department of Ecology and by Hal Beecher for the Department of Fish and Wildlife at a December 3, 1998 meeting. Existing agency preference curves were used for chinook, coho, and steelhead. These preference curves are listed in Appendix D. The substrate and cover code is listed in Appendix E.

Results and Discussion

The results are the fish habitat versus flow curves in Figure 3. Figure 4 shows how the wetted area changes with flow. The total area number can be divided by 1,000 to calculate the average wetted width for any flow from 50 to 1100 cfs. Table 1 shows what percent of optimum habitat is available for each species at a given flow.

These results can be interpreted by biologists to determine a minimum flow regime to protect and preserve instream flow for fish under Washington State law.

Toe-Width Method

The Toe-Width Method was developed by the Department of Fisheries (WDF), the Department of Game (WDG), and the U.S. Geological Service (USGS) in the 1970s at the request of the state legislature in response to the need to determine minimum instream flows for fish. After the legislature passed the Minimum Water Flows and Levels law in 1969 and the Water Resources Act of 1971, USGS collected water depths and velocities along transects over known spawning areas. WDF and WDG provided the criteria for salmon and steelhead spawning and rearing and the locations of the known spawning areas. After 9 years of data collection, USGS had measured 28 streams and rivers in eastern and western Washington. They had 84 study reaches with each reach consisting of 4 transects. They measured each transect at 8 to 10 different flows. USGS used the data from these 336 transects to calculate spawning and rearing flows for salmon and steelhead. Criteria for the needed spawning and rearing depths and velocities for each fish species and lifestage were used to calculate the square feet of habitat at each measured flow. These points of habitat quantity at different flows were connected to create a fish habitat versus streamflow relationship. Next, these fish habitat relationships were compared to many different variables in the watershed to determine if there were any correlations that could be used to avoid having to do so many flow measurements to calculate a spawning or rearing flow for a certain fish species. The toe-width was the only variable found to have a high correlation. The toe-width is the distance from the toe of one streambank to the toe of the other streambank across the stream channel. This width of the stream is used in a power function equation to derive the flow needed for spawning and rearing salmon and steelhead (Swift, 1976 and 1979).

Field Procedure

Toe-Width measurements were gathered on September 9, 10, 16, 22, 23, and 24 for the 33 streams chosen in WRIAs 25, 26, 28, and 29. A fiberglass tape was used by Brad Caldwell (Ecology) and Hal Beecher and Cynthia Pratt (WDFW). Usually 4 toe-widths were measured at each site and then averaged.

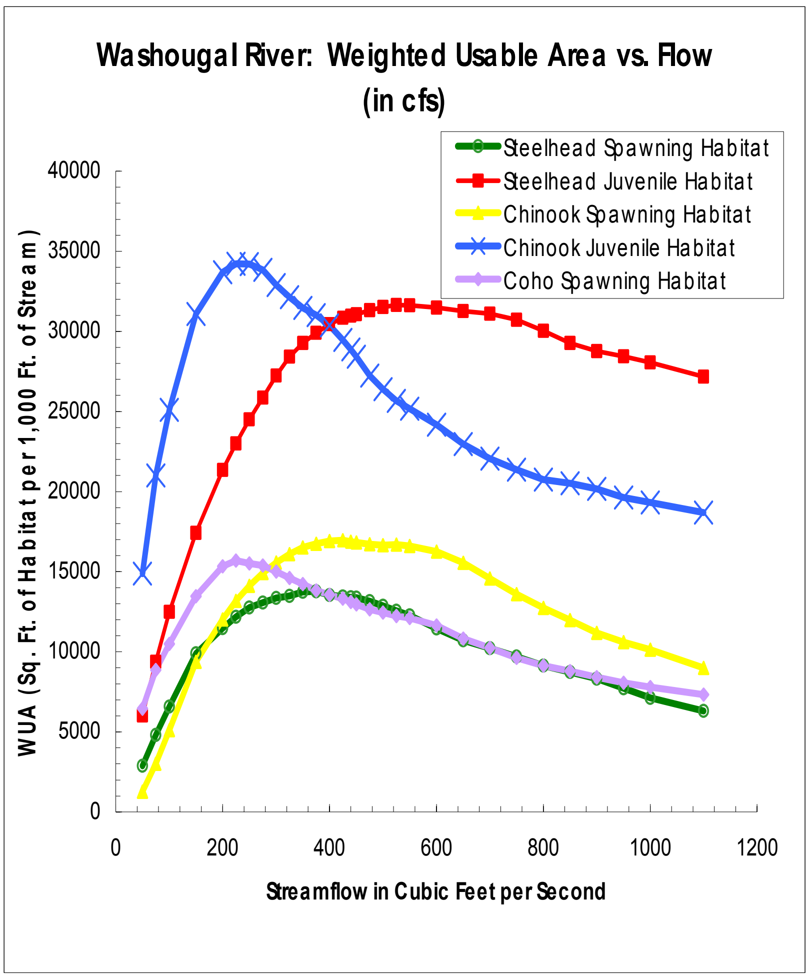
Jim Shedd (Ecology) gathered additional flow data on the 33 streams by collecting flows measurements in August, September, October, and November to facilitate synthesizing hydrographs.

Results and Discussion

The toe-width data is summarized in Tables 2 to 5. The additional spot flow measurements are summarized in Tables 6 to 9. These results are ready to be interpreted by biologists to determine a minimum flow regime to protect and preserve instream flow for fish under Washington State law.

Figure 3. WUA vs Flow for Washougal River.

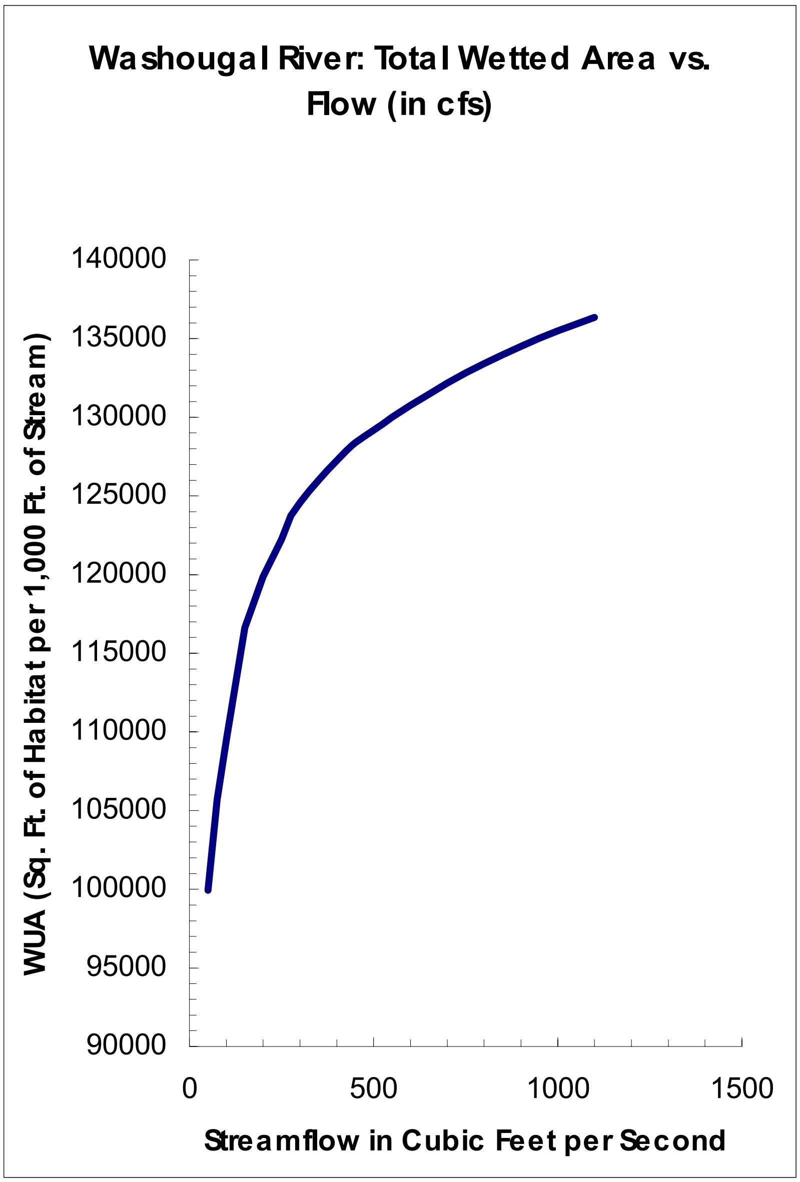
Washougal River Fish Habitat: Weighted Usable Area vs. Flow (in cfs)



Flow (in cfs)	Steelhead Spawning Habitat	Steelhead Juvenile Habitat	Chinook Spawning Habitat	Chinook Juvenile Habitat	Coho Spawning Habitat
1100	6300	27171	8982	18695	7326
1000	7122	28064	10134	19329	7794
950	7716	28432	10606	19637	8061
900	8320	28765	11192	20165	8415
850	8738	29272	11981	20512	8785
800	9132	30036	12746	20744	9143
750	9700	30721	13599	21376	9630
700	10220	31095	14565	22066	10239
650	10710	31271	15553	22965	10818
600	11449	31487	16250	24173	11632
550	12272	31631	16595	25170	12099
525	12559	31636	16686	25662	12233
500	12871	31510	16656	26393	12452
475	13157	31320	16708	27246	12653
450	13376	31063	16824	28420	12963
440	13395	30980	16883	28873	13101
425	13442	30854	16970	29476	13313
400	13532	30442	16901	30368	13566
375	13776	29903	16755	31018	13834
350	13732	29278	16512	31459	14225
325	13491	28413	16087	32131	14615
300	13353	27243	15570	32896	15002
275	13071	25866	14925	33845	15386
250	12765	24508	14125	34207	15509
225	12173	22995	13173	34225	15698
200	11473	21345	12024	33695	15328
150	9903	17426	9368	31087	13459
100	6575	12490	5112	25110	10491
75	4799	9371	3012	21006	8869
50	2873	6010	1275	14882	6445

Figure 4. Wetted Area vs Flow.

Washougal River: Total Wetted Area vs. Flow (in cfs)



Flow in cfs	Total Area
1100	136357
1000	135486
950	135019
900	134513
850	133973
800	133410
750	132820
700	132177
650	131472
600	130751
550	129993
525	129595
500	129183
475	128781
450	128396
440	128197
425	127855
400	127260
375	126643
350	125986
325	125294
300	124566
275	123753
250	122233
225	121065
200	119853
150	116614
100	109500
75	105691
50	99925

Table 1. Habitat as a percent of optimum.

Flow (in cfs)	Steelhead Spawning Habitat	Steelhead Juvenile Habitat	Chinook Spawning Habitat	Chinook Juvenile Habitat	Coho Spawning Habitat
1100	46%	86%	53%	55%	47%
1000	52%	89%	60%	56%	50%
950	56%	90%	62%	57%	51%
900	60%	91%	66%	59%	54%
850	63%	93%	71%	60%	56%
800	66%	95%	75%	61%	58%
750	70%	97%	80%	62%	61%
700	74%	98%	86%	64%	65%
650	78%	99%	92%	67%	69%
600	83%	100%	96%	71%	74%
550	89%	100%	98%	74%	77%
525	91%	100%	98%	75%	78%
500	93%	100%	98%	77%	79%
475	96%	99%	98%	80%	81%
450	97%	98%	99%	83%	83%
440	97%	98%	99%	84%	83%
425	98%	98%	100%	86%	85%
400	98%	96%	100%	89%	86%
375	100%	95%	99%	91%	88%
350	100%	93%	97%	92%	91%
325	98%	90%	95%	94%	93%
300	97%	86%	92%	96%	96%
275	95%	82%	88%	99%	98%
250	93%	77%	83%	100%	99%
225	88%	73%	78%	100%	100%
200	83%	67%	71%	98%	98%
150	72%	55%	55%	91%	86%
100	48%	39%	30%	73%	67%
75	35%	30%	18%	61%	56%
50	21%	19%	8%	43%	41%

Table 2. Toe-Width Flows for WRIA 25, Grays/Elochoman.

Stream Name	Tributary to	Average Toe Width (in feet)	Toe-Width Flow for Fish Spawning and Rearing (in cfs)					
			Chinook Spawning	*Coho Spawning*	*Chum Spawning*	*Steelhead Spawning*	*Steelhead Rearing*	*Salmon Rearing*
Grays River (@ HWY 4 Bridge Crossing)	Columbia River	120.3	516.5	292.1	516.5	401.3	147.5	137.6
Elochoman River (@ Steel Bridge)	Columbia River	89	355.5	196.8	355.5	282.9	96.2	89.2
Coal Creek (@ Harmony Rd)	Columbia River	35.7	114.5	59.5	114.5	98.0	26.3	23.9
Germany Creek (@ Germany Creek Rd)	Columbia River	37.4	121.3	63.2	121.3	103.5	28.1	25.6
Abernathy Creek (@ Abernathy Rd)	Columbia River	43.3	145.5	76.6	145.5	122.6	34.6	31.6
Mill Creek (@ Mill Creek Rd past bridge)	Columbia River	46	156.8	82.9	156.8	131.6	37.7	34.5
Crooked Creek (nr Eden Ln @ Rd crossing)	Columbia River	8.5	19.3	9.1	19.3	18.6	3.4	3.0
Wilson Creek (@ East Valley Rd)	Columbia River	18	49.0	24.3	49.0	44.3	9.9	8.9

Table 2. Toe-Width Flows for WRIA 26, Cowlitz.

Stream Name	**Tributary to**	**Average Toe Width (in feet)**	**Toe-Width Flow for Fish Spawning and Rearing (in cfs)**					
			Chinook Spawning	*Coho Spawning*	*Chum Spawning*	*Steelhead Spawning*	*Steelhead Rearing*	*Salmon Rearing*
Coweeman River (@Rose Valley Rd Crossing)	Cowlitz River	75.5	289.9	158.7	289.9	233.7	76.1	70.3
Ostrander Creek (@ Ostrander Rd)	Cowlitz River	33	103.9	53.7	103.9	89.5	23.5	21.4
Leckler Creek (@ Hazel Dell Rd)	Cowlitz River	8.3	18.8	8.8	18.8	18.0	3.3	2.9
Olequa Creek (@ Kollock Rd bridge)	Cowlitz River	54.3	192.6	103.0	192.6	159.5	47.7	43.8
Lacamas Creek (@ HWY 506 bridge)	Cowlitz River	42	140.1	73.6	140.1	118.4	33.1	30.2
Salmon Creek (@ Jackson Hwy)	Cowlitz River	59.8	217.1	116.9	217.1	178.4	54.7	50.3
Cedar Creek (@ Hwy 505 crossing)	Salmon Creek to Cowlitz River	26.8	80.2	40.9	80.2	70.3	17.5	15.8
Mill Creek (@ Cowlitz Salmon Hatchery)	Cowlitz River	29.8	91.5	46.9	91.5	79.5	20.3	18.4
Winston Creek (@ Hadaller Rd)	Mayfield Lake to Cowlitz River	41.5	138.0	72.4	138.0	116.8	32.5	29.7

Table 4. Toe-Width Flows for WRIA 28, Salmon/Washougal.

Stream Name	Tributary to	Average Toe Width (in feet)	Toe-Width Flow for Fish Spawning and Rearing (in cfs)					
			Chinook Spawning	*Coho Spawning*	*Chum Spawning*	*Steelhead Spawning*	*Steelhead Rearing*	*Salmon Rearing*
Weaver Creek (@ 199th Rd crossing)	Salmon Cr to Lake River to Columbia River	10.3	24.5	11.7	24.5	23.2	4.5	4.0
Gibbons Creek (@ Frontage Rd crossing)	Columbia River	19.5	54.1	26.9	54.1	48.6	11.1	10.0
Whipple Creek (@ 179th st. crossing)	Lake River to Columbia River	20.3	56.9	28.4	56.9	50.9	11.8	10.6
Mill Creek (@ North Salmon Creek Rd)	Salmon Cr to Lake River to Columbia River	19.8	55.1	27.5	55.1	49.5	11.4	10.2
Morgan Creek (@ 182nd st. crossing)	Salmon Cr to Lake River to Columbia River	14	35.9	17.4	35.9	33.1	7.0	6.2
Rock Creek (nr 213th Rd)	Salmon Cr to Lake River to Columbia River	24.3	71.1	35.9	71.1	62.8	15.2	13.7
Little Washougal River (@ HWY 140 crossing)	Washougal River	54.3	192.6	103.0	192.6	159.5	47.7	43.8
W.F. Washougal River (@ Skamania Hatchery)	Washougal River	57	204.6	109.8	204.6	168.7	51.1	46.9
Lawton Creek (@ HWY 14 crossing)	Columbia River	18	49.0	24.3	49.0	44.3	9.9	8.9
Duncan Creek (@ HWY 14 crossing)	Columbia River	16	42.3	20.8	42.3	38.6	8.4	7.5
Woodward Creek (@ Beacon Rock State Park Rd crossing	Columbia River	27.5	82.9	42.3	82.9	72.4	18.1	16.4
Hardy Creek (@ HWY 14 crossing)	Columbia River	26.3	78.4	39.9	78.4	68.8	17.0	15.4
Hamilton Creek (nr North Bonneville)	Greenleaf Slough to Columbia River	41.5	138.0	72.4	138.0	116.8	32.5	29.7
Greenleaf Creek (@ Cascade Drive crossing)	Greenleaf Slough to Columbia River	21.7	61.8	31.0	61.8	55.0	13.0	11.7

Table 5. Toe-Width Flows for WRIA 29, Wind/White Salmon.

Stream Name	**Tributary to**	**Average Toe Width (in feet)**	**Toe-Width Flow for Fish Spawning and Rearing (in cfs)**					
			Chinook Spawning	*Coho Spawning*	*Chum Spawning*	*Steelhead Spawning*	*Steelhead Rearing*	*Salmon Rearing*
Rock Creek (@ Stevenson/ Attwell rd. bridge crossing)	Columbia River	84.3	332.3	183.3	332.3	265.6	89.0	82.5
Carson Creek (@ Carson Depot Rd crossing)	Columbia River	15	39.1	19.1	39.1	35.9	7.7	6.9

Table 6. WRIA 25, Grays/Elochoman, Spot Flow Measurements by Ecology.

WRIA 25 Measured Flows (in cfs)

Date	10/1/97	11/1/97	12/1/97	1/1/98	3/1/98	6/1/98	7/1/98	8/1/98
Columbia River Tributaries								
Grays River (@ HWY 4 Bridge Crossing)	**206.6**	**1738.2**	**832.9**	**1183.3**	**1297.7**	**116.8**	**54.5**	**29.1**
Elochoman River (@ Steel Bridge)	**141.1**	**694.1**	**503.3**			**91.7**	**45**	

WRIA 25 Measured Flows (Continued)

Date	9/15/98	10/13/98	11/9/98
Columbia River Tributaries			
Coal Creek (@ Harmony Rd)	**3.8**	**41.2**	**24.1**
Germany Creek (@ Germany Creek Rd)	**3.7**	**6.6**	**16.1**
Abernathy Creek (@ Abernathy Rd)	**8.3**	**11.5**	**22.6**
Mill Creek (@ Mill Creek Rd past bridge)	**9.5**	**11.5**	**16.7**
Crooked Creek (nr Eden Ln @ Rd crossing)	**0.6**	**2.4**	**8.9**
Wilson Creek (@ East Valley Rd)	**7.9**	**8.7**	**15.3**

Table 7. WRIA 26, Cowlitz, Spot Flow Measurements by Ecology.

WRIA 26 Measured Flows (in cfs)

Date	10/1/97	11/1/97	12/1/97	1/1/98	3/1/98	7/1/98
Cowlitz River Tributary						
Coweeman River (@Rose Valley Rd Crossing)	**121.5**	**874.1**	**275.2**	**713.8**	**398.3**	**52.2**

WRIA 26 Measured Flows (continued)

Date	8/31/98	10/1/98	11/10/98
Salmon Cr. To Cowlitz River Tributary			
Cedar Creek (@ Hwy 505 crossing)	**0.2**	**0.5**	**5.8**
Cowlitz River Tributaries			
Ostrander Creek (@ Ostrander Rd)	**3.2**	**2.4**	**16.6**
Leckler Creek (@ Hazel Dell Rd)	**0.4**	**0.5**	**3.0**
Olequa Creek (@ Kollock Rd bridge)	**12.1**	**12.1**	**31.0**
Lacamas Creek (@ HWY 506 bridge)	**3.3**	**4.4**	**7.6**
Salmon Creek (@ Jackson Hwy)	**0.9**	**2.8**	**14.0**
Mill Creek (@ Cowlitz Salmon Hatchery)	**2.7**	**3.0**	**10.0**
Winston Creek (@ Hadaller Rd)	**3.6**	**3.8**	**21.0**
Arkansas Creek (nr Castlerock)	**5.97**	**5.98**	**35.4**

Table 8. WRIA 28, Salmon/Washougal, Spot Flow Measurements by Ecology.

WRIA 28 Measured Flows (in cfs)			
Date	9/3/98	10/3/98	11/3/98
Columbia River Tributaries			
Gibbons Creek (@ Frontage Rd crossing)	**3.1**	**2.1**	**3.6**
Lawton Creek (@ HWY 14 crossing)	**1.8**	**2.9**	**2.8**
Duncan Creek (@ HWY 14 crossing)	**0.0**	**0.0**	**0.0**
Woodward Creek (@ Beacon Rock State Park Rd crossing	**2.7**	**5.2**	**7.9**
Hardy Creek (@ HWY 14 crossing)	**0.8**	**2.1**	**3**
Washougal River Tributaries			
Little Washougal River (@ HWY 140 crossing)	**8.2**	**9.3**	**26.0**
W.F. Washougal River (@ Skamania Hatchery)	**18.8**	**45.8**	
Salmon Creek Tributaries			
Weaver Creek (@ 199th Rd crossing)	**0.3**	**1.3**	**2.6**
Mill Creek (@ North Salmon Creek Rd)	**0.5**	**0.8**	**1.4**
Morgan Creek (@ 182nd st. crossing)	**0.6**	**1.2**	**2.1**
Rock Creek (nr 213th Rd)	**0.4**	**1.7**	**7.6**
Greenleaf Slough Tributaries			
Greenleaf Creek (@ Cascade Drive crossing)	**1.7**	**1.87**	**1.85**
Hamilton Creek (nr North Bonneville)			**13.3**
Lake River Tributary			
Whipple Creek (@ 179th st. crossing)	**2.05**	**2.7**	**3.9**

Table 9. WRIA 29, Wind/White Salmon, Spot Flow Measurements by Ecology.

WRIA 29 Measured Flows (in cfs)			
Date	8/26/98	10/5/98	11/2/98
Columbia River Tributaries			
Rock Creek (@ Stevenson/ Attwell rd. bridge crossing)	**9.2**	**57.2**	**34.9**
Carson Creek (@ Carson Depot Rd crossing)	**0.3**	**0.5**	**0.9**

Tennant Method

Another method is the Tennant Method. It gives a point estimate of the flow that maximizes habitat. This method only needs the mean annual flow to use in calculating a flow for fish habitat. This method was developed by Don Tennant of the U.S. Fish and Wildlife Service in the 1970s (Tennant, 1976a and b). He photographed a large number of streams from the same place at several different flows, then compared his rating of habitat quality and quantity at different flows. From this evaluation he concluded that optimal habitat is achieved at 60% of the mean annual flow (MAF). He also rated other (lower) percentages of MAF as fair to poor habitat. Based on the standards implied in the Wild Salmonid Policy (WDFW, 1997), WDF uses the optimal rating.

> "In streams or basins that provide useable wild salmonid habitat, and where stream flows have been adopted or are being revised, the performance measure will be the stream flow as adopted by rule. Where review is requested the objective will be to establish or revise stream flows to optimize habitat conditions for migration, spawning, incubation, and rearing of wild salmonids and their prey."
>
> --WDFW Wild Salmonid Policy 1997, Basin Hydrology and Stream Flow Performance Measure 1.

In the Wind River, MAF is about 1,200 cfs at USGS gauge 14128500, so *the recommended flow is **720 cfs***. Between 1934 and 1977 low flow at river mile 1.9 (at the gauge) was about 170 cfs with the lowest flow 123 cfs. The mean September (lowest flow month) flow was 235 cfs. Mean flow in June was 741 cfs and mean flow in November was 1388 cfs. Thus, with a recommended instream flow of 720 cfs, no new consumptive diversion would be allowed during July through October in most years. In one year (1954) during the period of record mean July flow exceeded 720 cfs. Mean October flow exceeded 720 cfs in six years (1947, 1950, 1951, 1955, 1959, and 1968).

To determine a minimum instream flow at a control point near the mouth, we opted to use the Tennant method for the Wind River. To collect the IFIM/PHABSIM measurements that would represent the lower Wind River would have jeopardized the safety of my crew. IFIM flow measurements were not possible without major equipment and staffing expense (e.g., special boats equipped for both white water and flow measurement, rock climbing equipment and expertise) due to vertical bedrock walls, cascades, and high velocities. The Wind River only has access at the mouth for the lower 17 miles and shortly upriver there is a riffle so long and shallow that even a jet boat could not pass upstream. Most of the lower 17 miles of river are in a vertical rock wall canyon with flows high enough even in summer to have standing waves in the pools between the boulder cascades. Avoiding these conditions would have been possible, but we would not have adequately modeled the river's habitat.

Another possibility is to set a control point 17 miles upstream where the stream flattens and is no longer in a very steep canyon. When Swift measured streams in the 1970's and created the Toe-Width Method, one of the rivers he measured was the Wind River. He measured three sites at RM s 21.6, 19.1, and 17.0. He recommended a flow at RM 17 of 330 cfs for coho spawning, and found 380 cfs to be the flow for spawning chinook. He also calculated a salmon rearing flow of 60 cfs. Results for steelhead were not determined. The toe-width was 84 feet. At RM 17 the river drains 95.3 square miles compared to its mouth, which drains 225 square miles.

Factors To Consider When Developing A Minimum Insteam Flow

Determining a minimum instream flow for a river or stream requires more than choosing the peak WUA flow for one lifestage of one species at one reach from the IFIM study. Because multiple lifestages existing simultaneously in a river, no specific flow will provide an optimum flow for all lifestages and species. Setting a minimum instream flow requires ranking the importance of each fish species and lifestage. This ranking requires considering long-range management plans for the fishery resources as determined by the state and federal natural resource agencies and the affected Tribes.

In addition, minimum instream flows must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding of fry and juveniles. Other variables, which have to be considered, include water temperature, water quality, and sediment load. None of these variables were measured in this IFIM study. Therefore, reaching a conclusion about an appropriate minimum instream flow involves integrating the results of the IFIM study with consideration of these additional variables.

It's important to know that under a minimum instream flow under Washington State's laws is not the minimum flow that must be in the stream. No one has to stop using an existing water right to meet the minimum instream flow set by rule. The minimum instream flow only applies to new water rights issued after the date the rule was adopted. The minimum instream flow is the flow at which water is unneeded for the protection and preservation of fish and therefore new water rights can be given to anyone who requests since there is surplus water available.

Setting the minimum instream flow at the monthly mean during the low flow month sounds reasonable, but under State law it means that one-half of the flow during the low flow month is now available for new diversions. This is because the flow in the stream is higher than the mean about 50% of the time.

Stream flows vary seasonally. The more we learn about flow and fish, the more we learn that, in most cases, we haven't learned how to improve on nature. Our instream flow methods give numbers that provide some protection for fish, but if streams are regulated to only those flows, without the greater variation we see in nature, fish production declines. Natural systems function naturally, with variation.

High flows during spring melt form the channels, move and clean gravel, and control the distribution of new riparian vegetation and large woody debris. They also transport smolts to sea in streams that are still accessible to anadromous fish. Our models do not address these flows.

Monitoring of flows and fish production over a series of years yields evidence of the importance of instream flows. We have evidence from several different types of monitoring studies showing that fish production responds favorably to favorable instream flows. We have validated many of the assumptions of our instream flow methods and models, but we are learning more all the time.

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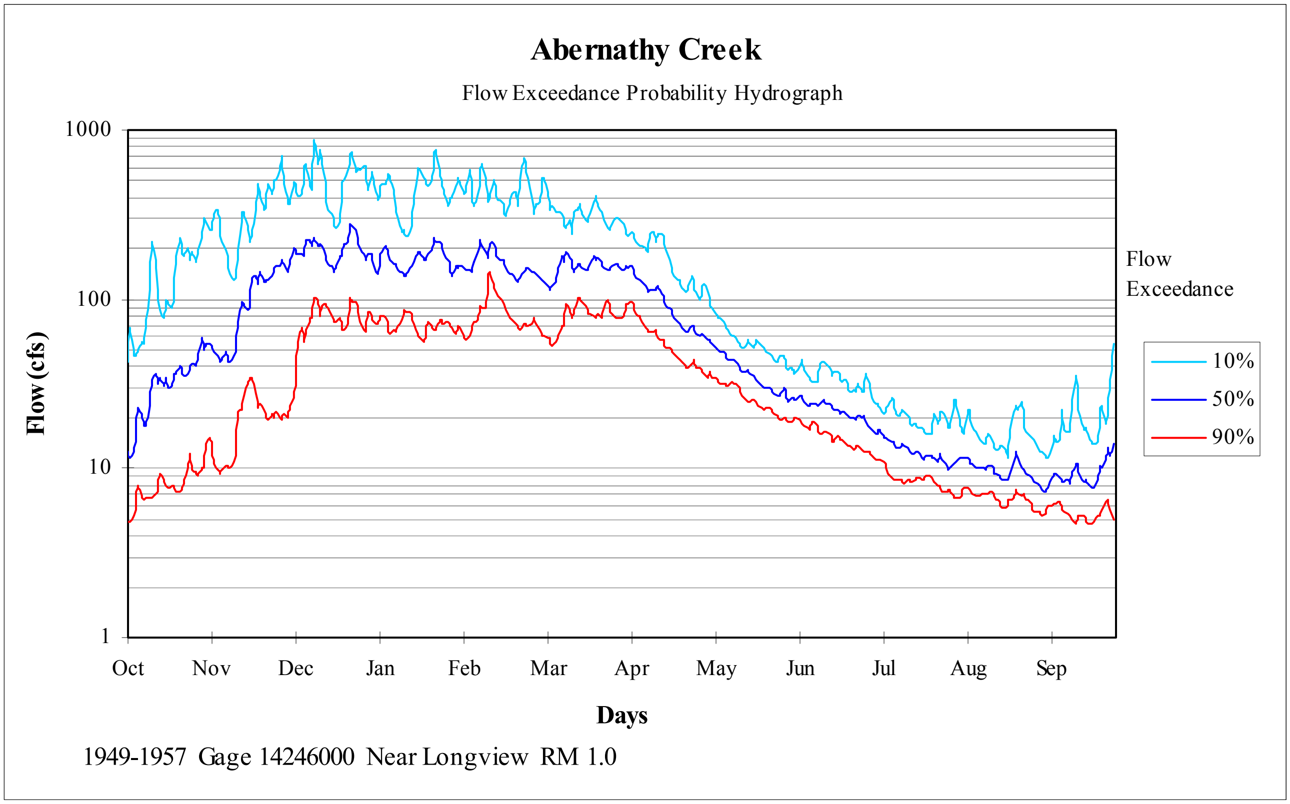
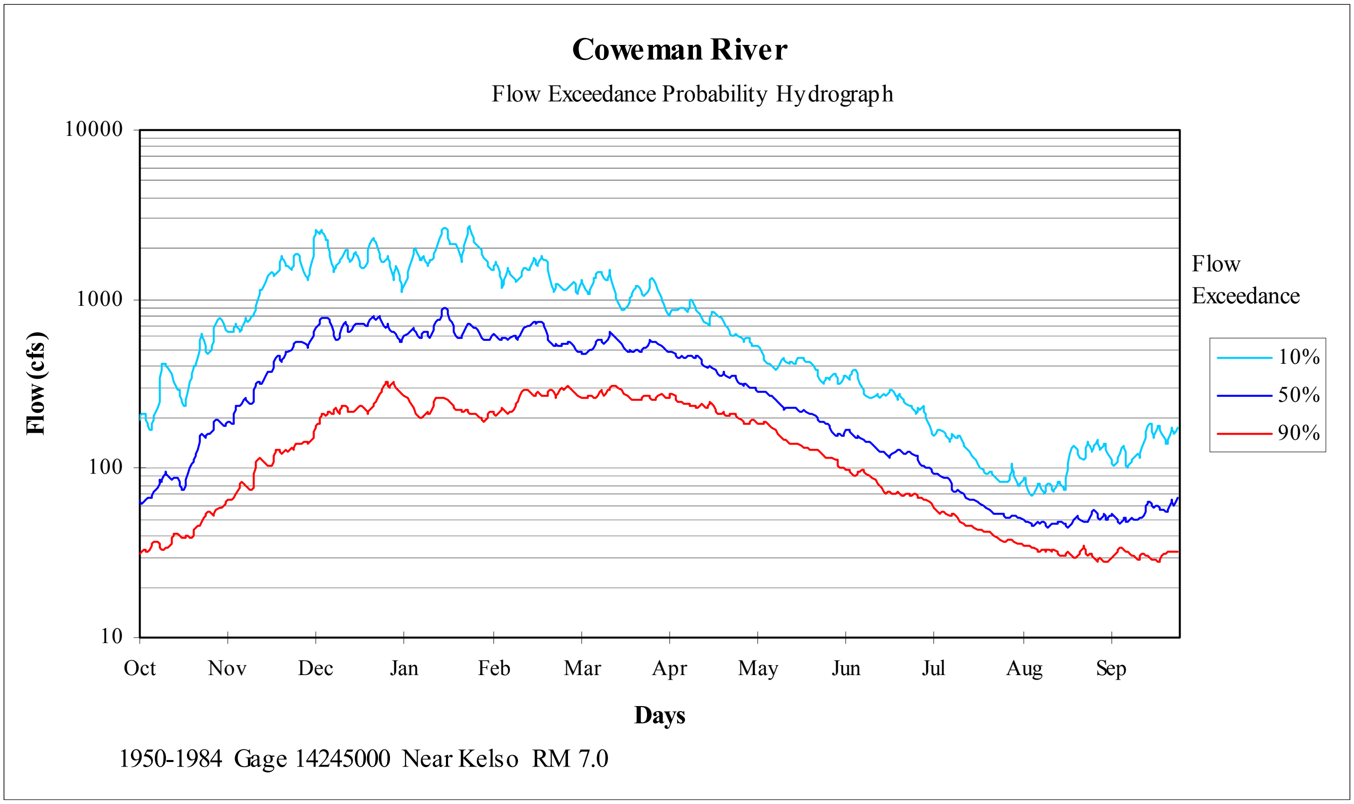
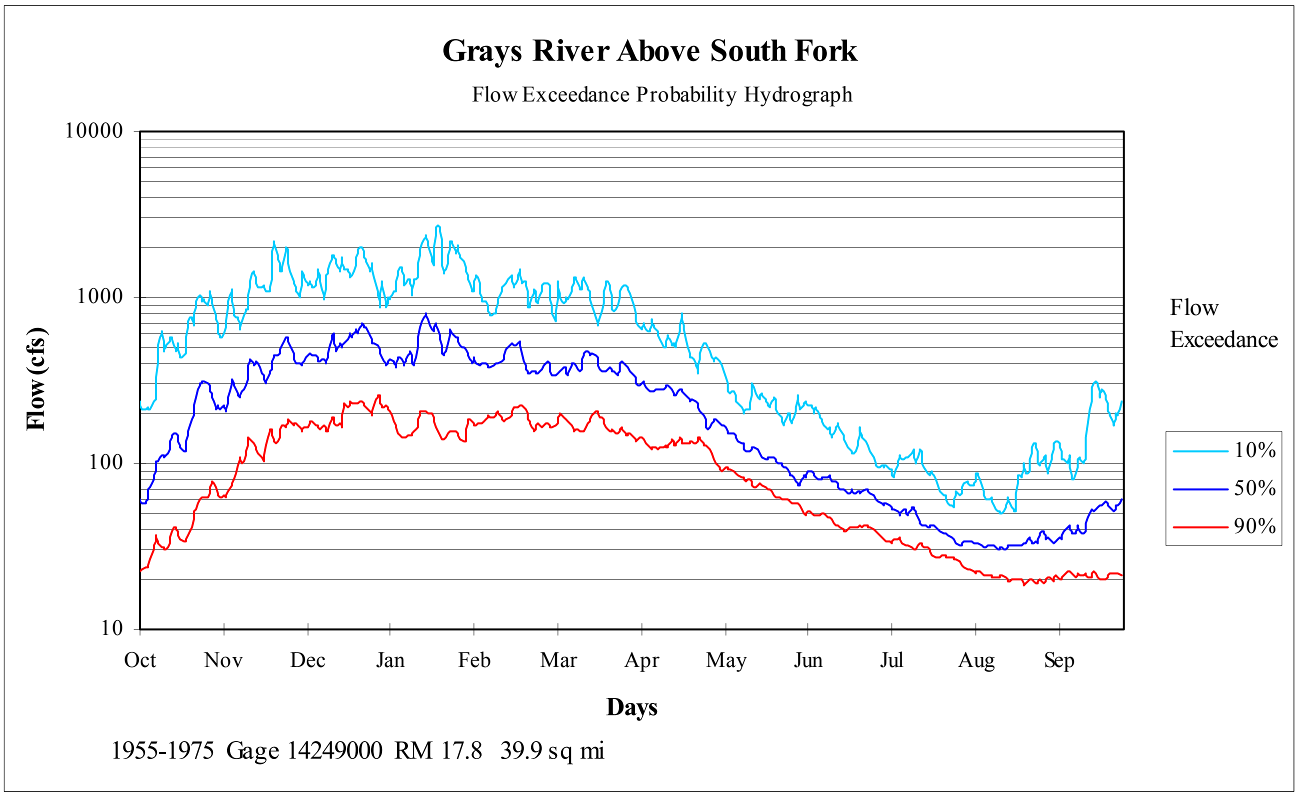
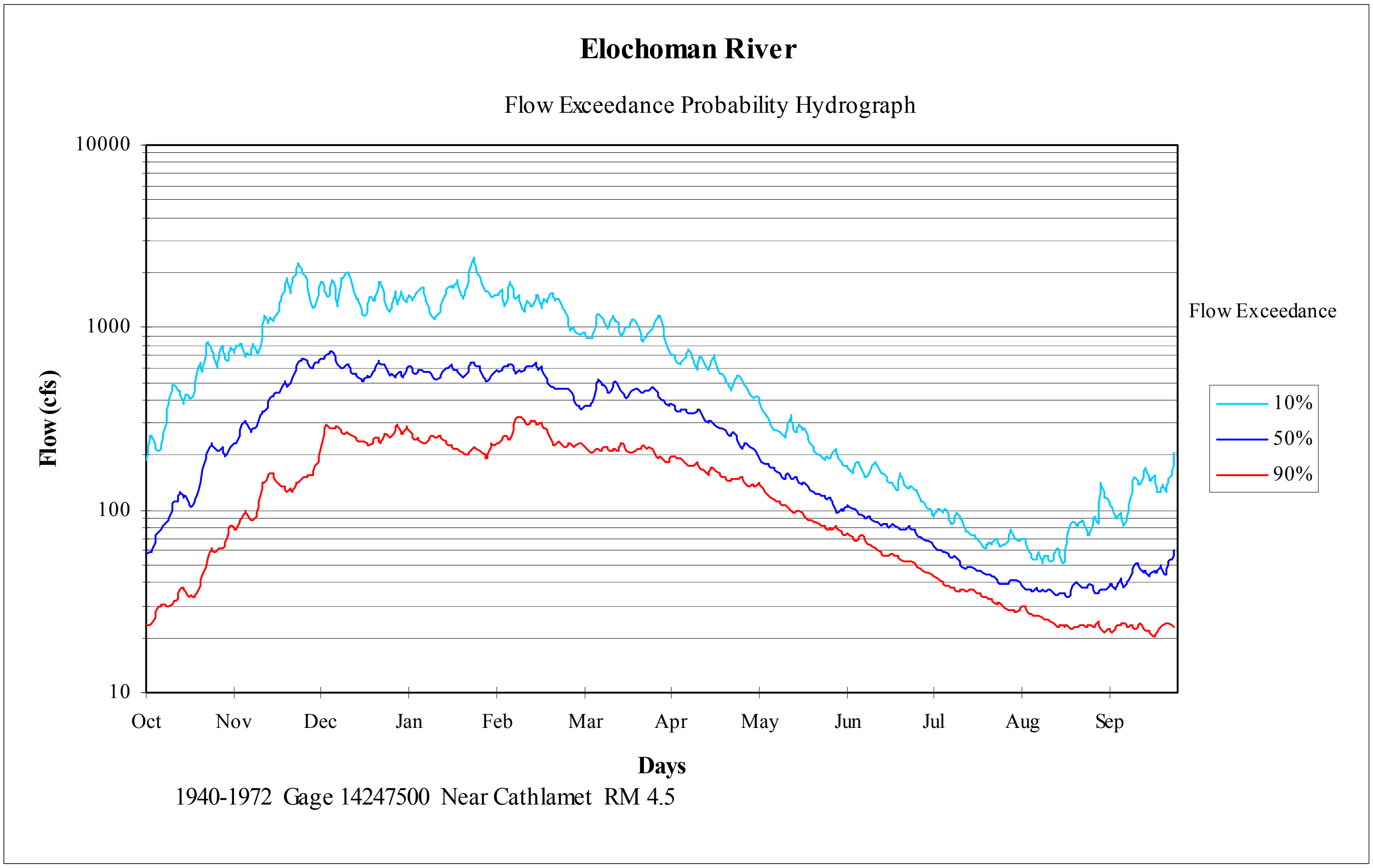
Appendix A. Hydrographs of 9 Stream and Rivers in WRIAs 25, 26, 28, and 29.

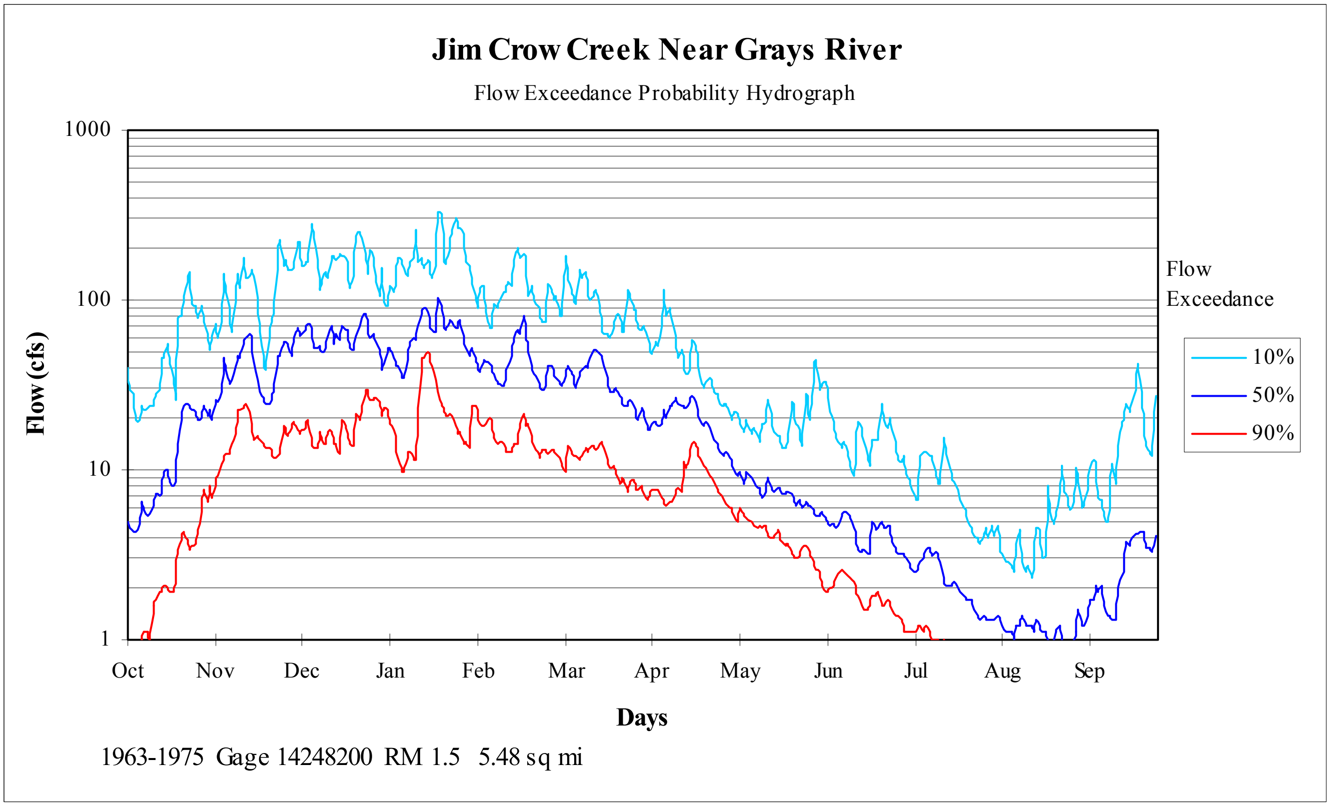

Abernathy Creek
Flow Exceedance Probability Hydrograph
1000
100
10
1
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1949-1957 Gage 14246000 Near Longview RM 1.0



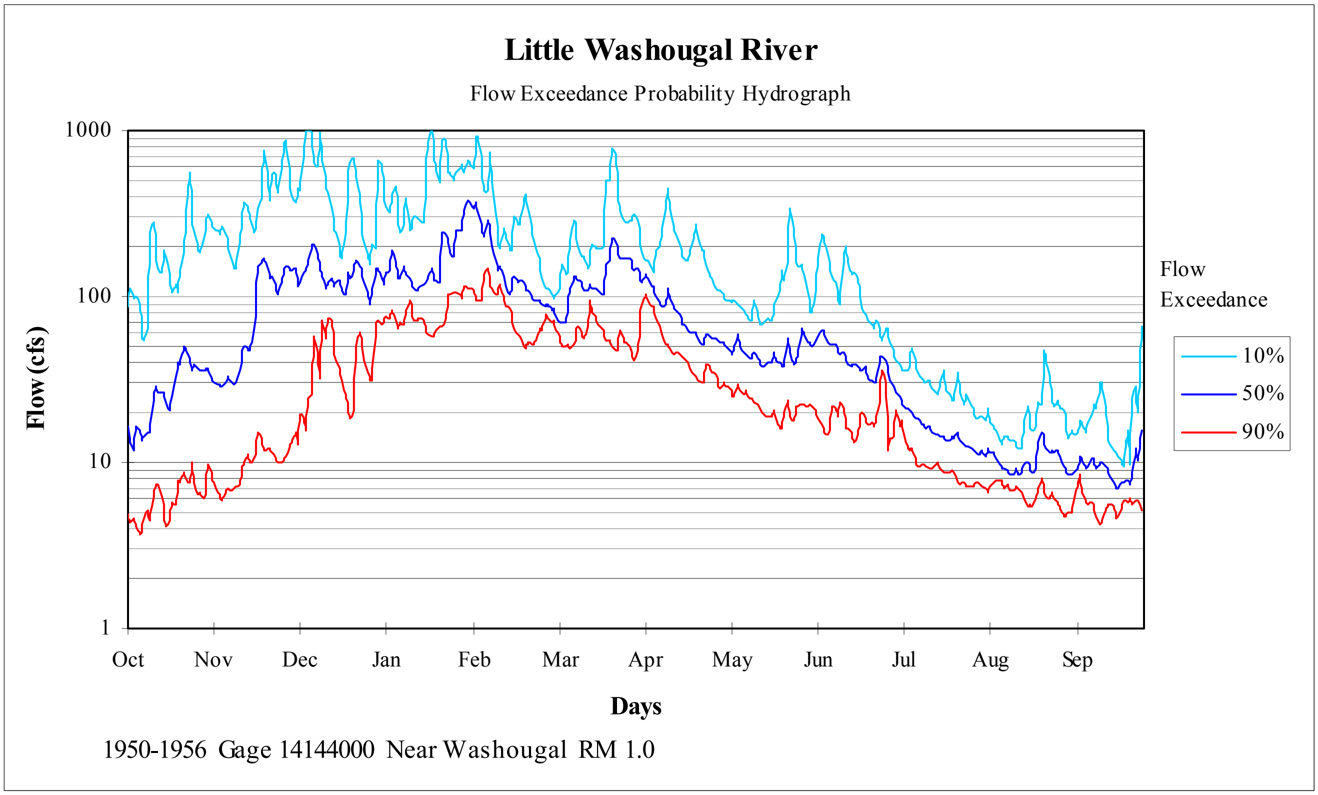
Coweman River
Flow Exceedance Probability Hydrograph
10000
1000
100
10
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1950-1984 Gage 14245000 Near Kelso RM 7.0


Grays River Above South Fork
Flow Exceedance Probability Hydrograph
10000
1000
100
10
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1955-1975 Gage 14249000 RM 17.8 39.9 sq mi

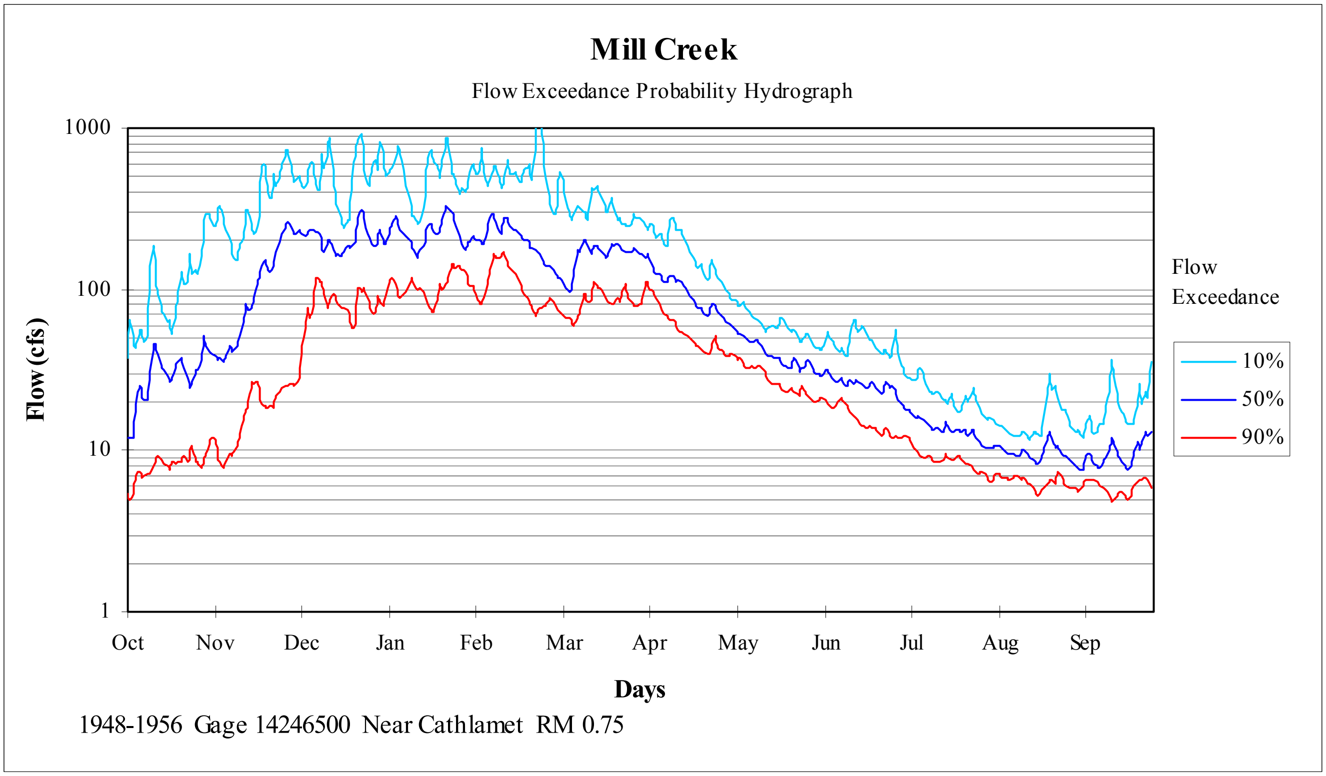

Elochoman River
Flow Exceedance Probability Hydrograph
10000
1000
100
10
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1940-1972 Gage 14247500 Near Cathlamet RM 4.5

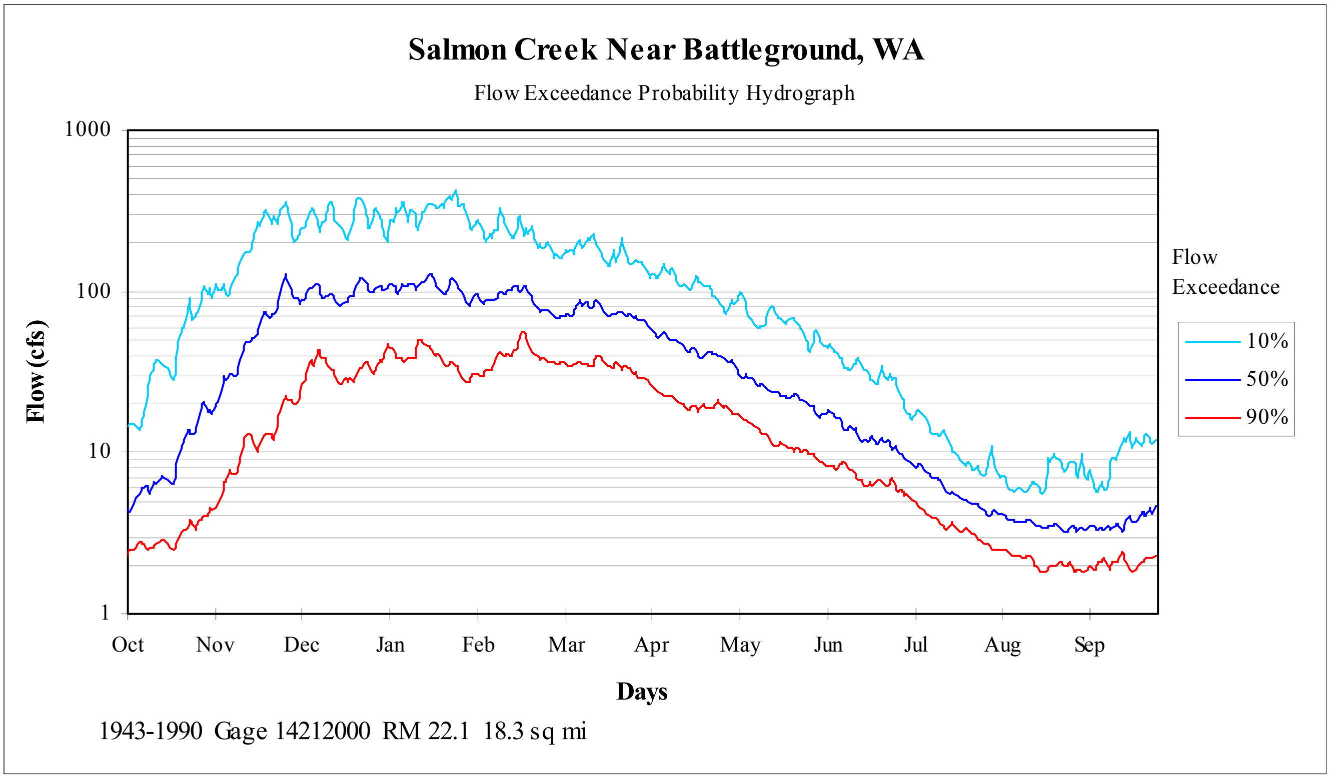


Jim Crow Creek Near Grays River
Flow Exceedance Probability Hydrograph
1000
100
10
1
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1963-1975 Gage 14248200 RM 1.5 5.48 sq mi

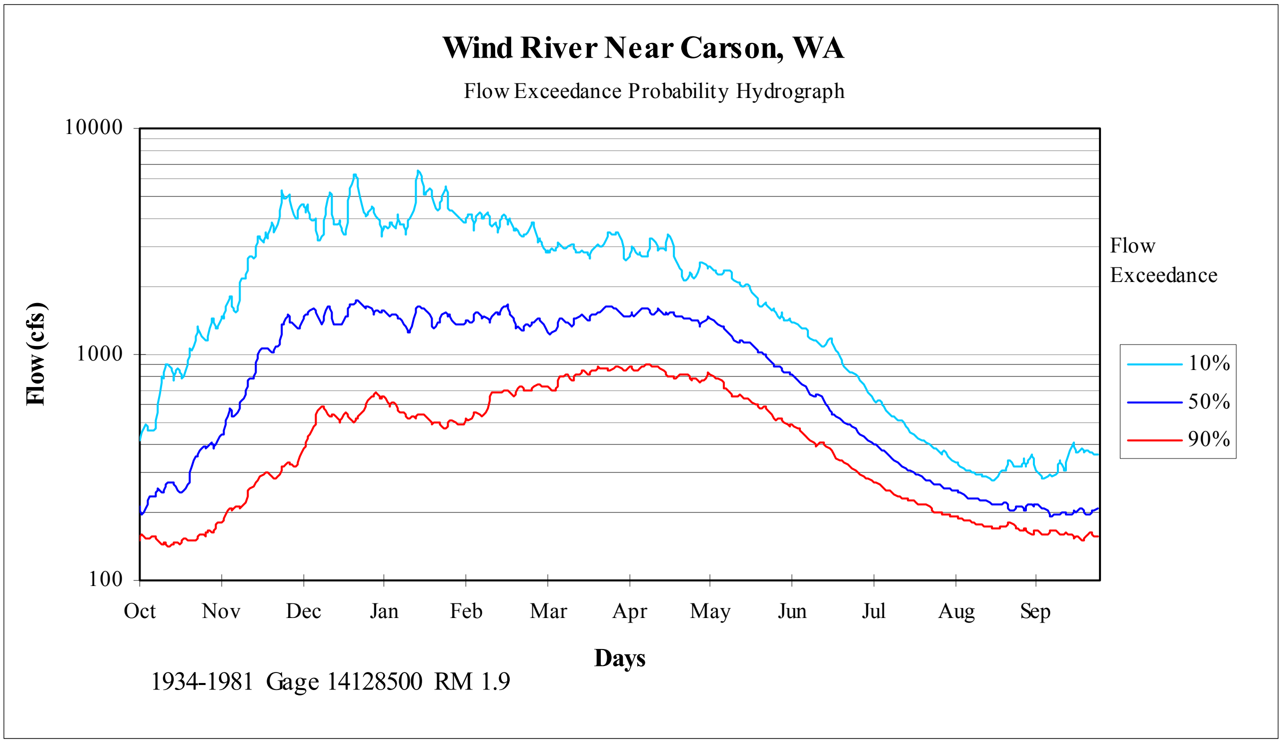


Little Washougal River
Flow Exceedance Probability Hydrograph
1000
100
10
1
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1950-1956 Gage 14144000 Near Washougal RM 1.0


Mill Creek
Flow Exceedance Probability Hydrograph
1000
100
10
1
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1948-1956 Gage 14246500 Near Cathlamet RM 0.75



Salmon Creek Near Battleground, WA
Flow Exceedance Probability Hydrograph
1000
100
10
1
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1943-1990 Gage 14212000 RM 22.1 18.3 sq mi



Wind River Near Carson, WA
Flow Exceedance Probability Hydrograph
10000
1000
100
Flow (cfs)
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Days
Flow Exceedance
10%
50%
90%
1934-1981 Gage 14128500 RM 1.9

Appendix B. Maps of Chinook, Steelhead, and Chum ESUs for WRIAs 25, 26, 28, and 29.

Appendix C. Calibration Information for the IFIM Computer Model.

Appendix C1. IFG4 Input File

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Washougal River at Hathaway Park:  Measured 440 cfs on 6-8-98, 255 cfs on
5-11-98, 153 cfs on 7-30-98, and 72 cfs on 9-15-98.
IOC      11000002000010000 10 1
QARD1100.0
QARD1000.0
QARD 950.0
QARD 900.0
QARD 850.0
QARD 800.0
QARD 750.0
QARD 700.0
QARD 650.0
QARD 600.0
QARD 550.0
QARD 525.0
QARD 500.0
QARD 475.0
QARD 450.0
QARD 440.0
QARD 425.0
QARD 400.0
QARD 375.0
QARD 350.0
QARD 325.0
QARD 300.0
QARD 275.0
QARD 250.0
QARD 225.0
QARD 200.0
QARD 150.0
QARD 100.0
QARD  75.0
QARD  50.0
XSEC   1.0      0.0 .50     91.58    .00250
     1.0   .597.68 11.694.86 13.194.61 15.294.19 17.093.33 20.593.03
     1.0 24.092.16 27.591.77 31.091.92 34.591.58 38.091.79 41.591.84
     1.0 45.092.78 48.592.96 52.093.56 56.593.04 60.092.77 63.592.89
     1.0 67.092.48 70.593.03 74.092.39 78.592.14 82.092.18 85.592.37
     1.0 89.092.57 92.592.62 96.092.68 99.592.61103.592.56107.092.56
     1.0110.092.58114.092.49117.592.41121.092.81124.592.92128.094.28
     1.0128.594.28135.596.98
NS     1.0      .80     88.90     88.90     88.90     88.90     88.90
NS     1.0    87.90     87.50     87.50     87.50     88.90     88.90
NS     1.0    88.90     88.90     88.90     88.90     87.90     87.80
```

```
NS     1.0     87.80     83.80     87.50     87.50     67.50     67.60
NS     1.0     67.60     76.50     68.70     76.50     86.70     85.90
NS     1.0     76.80     78.50     87.50     85.90     81.50     81.50
NS     1.0       .80       .80
CAL1   1.0     94.86    440.00
VEL1   1.0      0.00 0.00       .38  .63 1.04  .78 1.08 1.08  .65  .38
VEL1   1.0  .07  .39  .34  .55  .82 1.09 1.20  .98 2.07 1.27 3.41 2.42
VEL1   1.0 2.93 2.22 2.96 3.20 2.76 3.09 2.65 2.27 1.96  .71  .12 0.00
VEL1   1.0
CAL2   1.0     94.42    255.00
VEL2   1.0           0.00       .13  .29  .65  .56  .46  .60  .75  .53
VEL2   1.0  .02  .09 0.00  .13 1.02 1.01  .97 1.14 1.57 1.10 2.68 1.96
VEL2   1.0 2.57 1.80 1.85 2.38 2.17 2.34 2.04 1.73 1.89  .63  .06 0.00
VEL2   1.0
CAL3   1.0     94.11    153.00
VEL3   1.0                0.00 0.00 0.00 0.00  .51  .18  .45  .34  .13
VEL3   1.0 0.00  .14 0.00 -.09  .53  .52  .93  .94 1.19  .37 2.12  .92
VEL3   1.0  .92 1.52  .96 1.41 2.01 1.57 1.50 1.36 1.38 1.81 1.32 0.00
VEL3   1.0
CAL4   1.0     93.79     72.00
VEL4   1.0                0.00 0.00 0.00 0.00 0.00 0.00  .37  .06  .05
VEL4   1.0  .05  .08 0.00  .32  .11  .36  .45  .75  .90  .16 1.59 1.11
VEL4   1.0 1.15 0.00  .88 1.31 1.36 1.15  .54  .33  .97  .32  .20 0.00
VEL4   1.0
XSEC   2.0     103.0 .50     93.00     .00250
       2.0  4.1100.8 24.795.34 26.0 94.7 32.094.15 37.094.18 42.094.22
       2.0 47.093.62 52.093.36 57.093.09 62.093.91 67.095.34 72.095.04
       2.0 77.094.96 82.094.57 87.094.34 92.093.97 97.093.77102.0 93.0
       2.0104.593.77107.093.69109.5 93.5112.093.37114.593.27117.093.27
       2.0119.593.27122.093.22127.093.22132.093.15137.0 93.2142.093.65
       2.0143.995.02146.094.98149.097.98
NS     2.0     81.90     81.90     86.90     86.80     86.90     88.90
NS     2.0     86.80     86.90     87.80     87.90     81.90     88.90
NS     2.0     85.90     81.90     87.50     85.90     87.80     75.70
NS     2.0     86.90     68.50     86.50     68.50     87.50     76.80
NS     2.0     78.70     78.80     78.80     87.50     87.90     81.50
NS     2.0       .30       .80       .80
CAL1   2.0     95.34    440.00
VEL1   2.0                .59 1.75 2.14 1.97 1.57 1.59 1.30      0.00
VEL1   2.0  .56  .89  .53 3.30 3.21 3.12 4.18 5.68 4.40 4.17 4.69 5.29
VEL1   2.0 4.62 4.73 4.47 3.28 1.07  .20
CAL2   2.0     94.98    255.00
VEL2   2.0                .52 1.43 1.50 1.39  .16 1.21  .06
VEL2   2.0 0.00  .70  .99  .48 1.40 1.97 2.01 5.58 5.76 4.21 4.92 4.41
VEL2   2.0 3.21 3.55 4.28 1.66 1.39  .05
CAL3   2.0     94.70    153.00
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VEL3   2.0          0.00  .38  .77  .07 1.16  .67 1.07  .30
VEL3   2.0     0.00 -.03  .83  .08 1.81  .53 4.01 3.91 3.41 3.32 3.31
VEL3   2.0 2.54 2.41 2.70  .80  .72  .02
CAL4   2.0     94.39     72.00
VEL4   2.0               .09  .33  .42  .28  .17  .60  .38
VEL4   2.0          .09 0.00  .46 1.58 1.25 2.71 1.09 1.89 1.80 2.05
VEL4   2.0 1.79 2.42 1.56 0.00  .68
XSEC   3.0     96.0 .50     94.74    .00250
     3.0  3.898.88  5.896.88 12.096.36 17.096.16 22.096.62 27.095.64
     3.0 32.096.05 37.096.12 42.096.07 47.095.64 52.0 95.7 57.095.47
     3.0 62.095.55 67.095.97 72.095.45 77.095.42 82.095.42 87.095.34
     3.0 92.095.49 97.095.29102.095.64107.095.34112.095.24117.095.24
     3.0122.095.22127.095.19132.094.87137.094.74142.094.87147.095.13
     3.0152.095.69154.496.07161.297.82181.299.82
NS     3.0       .80       .80     87.80     87.90     88.90     84.80
NS     3.0     85.90     87.90     86.80     87.90     87.90     78.50
NS     3.0     48.50     86.50     86.80     78.50     87.80     87.50
NS     3.0     68.50     78.50     87.70     78.60     78.50     68.50
NS     3.0     68.60     68.50     68.50     76.80     87.80     78.70
NS     3.0     74.70     87.50       .20       .80
CAL1   3.0     96.62    440.00
VEL1   3.0          .91  .36       .31 1.01 1.23 1.55 1.60 3.37  .69
VEL1   3.0 1.27 1.08  .88 2.67 2.47 4.02  .84 1.89 1.57 2.63 5.32 3.03
VEL1   3.0 4.89 6.56 4.58 2.37 4.89 2.66 1.76  .03
CAL2   3.0     96.40    255.00
VEL2   3.0          0.00  .93       .28  .89      1.85  .89 5.08 1.47
VEL2   3.0  .34  .50 1.02  .54 1.77 1.94 2.27 2.20  .25 2.41 2.22 2.10
VEL2   3.0 3.93 6.34 4.19 4.13 3.48 3.03  .40 0.00
CAL3   3.0     96.10    153.00
VEL3   3.0                         .13 0.00      0.00 0.00 0.00 0.00
VEL3   3.0  .72 0.00 1.24 2.20  .65 1.07 0.00 3.00 1.36 1.72  .57 2.30
VEL3   3.0 1.86 4.78 3.73 2.31 2.91 2.42
CAL4   3.0     95.95     72.00
VEL4   3.0                    0.00                      .50 1.23
VEL4   3.0  .06 0.00 1.29 1.44 0.00  .42 1.71 1.78 1.17  .36 1.56 3.15
VEL4   3.0 0.00 3.82  .72 1.40 1.53 0.00 1.61  .90
XSEC   4.0     55.0 .50     95.69    .00250
     4.0-15.7101.0  5.797.98  9.096.75 14.097.07 19.096.65 24.096.91
     4.0 29.096.46 34.096.28 39.095.91 44.096.38 49.095.71 54.096.39
     4.0 59.0 97.0 64.097.25 69.097.09 74.096.33 79.096.24 84.096.53
     4.0 89.0 96.8 94.096.09 99.096.11104.095.69109.096.38114.096.26
     4.0119.095.86124.095.88129.0 95.9134.096.04139.095.99144.096.35
     4.0149.096.59154.0 96.8159.097.51161.097.68181.099.68
NS     4.0       .80     81.90     88.90     87.90     87.90     86.90
NS     4.0     87.90     87.90     86.90     86.90     87.80     78.50
NS     4.0     86.90     87.50     87.90     87.80     87.50     86.50
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NS     4.0     87.90     87.80     78.50     87.50     78.50     86.80
NS     4.0     87.50     78.50     58.50     87.50     74.90     84.80
NS     4.0     68.50     86.70     67.50     67.50       .80
CAL1   4.0     97.75    440.00
VEL1   4.0           .87  .63 1.10 2.01 1.84 2.38 1.50 1.88  .97 2.06
VEL1   4.0 2.01 1.69 1.87 3.82 3.59  .91 1.86 1.41  .93  .75 4.65 4.06
VEL1   4.0 4.98 3.88  .76 4.62 3.91 2.64 2.74  .22 0.00
CAL2   4.0     97.42    255.00
VEL2   4.0          0.00 0.00 0.00 1.32 1.12 1.25 1.50 1.51  .92  .50
VEL2   4.0  .81 0.00      2.03 2.54 3.07 0.00  .59 2.74  .33 3.11  .30
VEL2   4.0 4.26 3.00 3.98 1.58 2.06 2.30 2.44  .06 0.00
CAL3   4.0     97.20    153.00
VEL3   4.0          0.00 0.00  .43  .75 1.28 1.34 1.79  .66  .09 1.04
VEL3   4.0 1.28  .63  .55 1.52 2.07  .98 1.97 2.12  .69 1.94 2.94  .84
VEL3   4.0 3.41 2.49 2.53 1.17 2.13 2.10 2.12  .10
CAL4   4.0     96.89     72.00
VEL4   4.0          0.00       .71  .24  .36 1.32  .45  .63  .30  .70
VEL4   4.0               1.51 1.07 0.00       .35  .53  .39 2.10 1.15
VEL4   4.0 2.59 2.97  .20 0.00 2.41 1.23 1.04
XSEC   5.0     125.0 .50     96.18     .00250
       5.0 -3.0100.9  2.097.94  7.097.16 12.096.45 17.096.49 22.0 96.3
       5.0 27.096.18 32.096.34 37.097.37 42.096.38 47.096.77 49.5 96.6
       5.0 52.096.45 57.0 97.1 62.0 97.1 62.597.03 67.596.68 72.596.87
       5.0 75.097.03 77.5 97.4 80.096.22 82.596.52 84.596.47 87.096.64
       5.0 90.0 97.0 95.097.14100.0 97.2105.097.44110.097.22115.097.45
       5.0120.096.88125.097.27130.097.19135.097.27139.3 98.2148.399.25
       5.0158.3101.5168.3103.8
NS     5.0     81.90     81.90     86.90     87.90     85.90     87.90
NS     5.0     87.90     87.90     88.90     84.90     87.90     86.90
NS     5.0     87.90     84.90     87.60     87.80     87.90     87.90
NS     5.0     87.90     88.90     87.70     78.50     87.50     87.80
NS     5.0     87.80     86.80     68.50     86.70     75.50     75.50
NS     5.0     86.50     86.50     74.80     85.50     65.50     76.50
NS     5.0       .80       .80
CAL1   5.0     98.68    440.00
VEL1   5.0      0.00      1.40 1.65 1.95 1.31 1.69 1.30 1.44 1.12 1.71
VEL1   5.0 2.13 1.64  .84 1.03 1.45  .78 2.75 3.39 2.41 3.42 3.50 2.81
VEL1   5.0 2.00 1.23 1.81 3.35 1.03 2.90 2.41 2.01 2.29  .61  .40 0.00
VEL1   5.0
CAL2   5.0     98.33    255.00
VEL2   5.0      0.00  .37 1.53 1.84 1.30 1.00 1.17  .84 1.23 2.17 1.81
VEL2   5.0 1.95 1.08  .73 2.24  .91  .53 2.27 3.35 2.34 2.84 2.41 2.03
VEL2   5.0 1.56  .79  .71  .26 1.54 1.33 1.69 2.01 1.19  .62 0.00
VEL2   5.0
CAL3   5.0     98.01    153.00
VEL3   5.0          0.00  .77 1.55 1.19  .87  .40  .62  .85 1.16  .43
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VEL3   5.0  .91 1.03 1.57  .77  .37  .22 2.88 3.44 3.05 3.12 2.80 2.60
VEL3   5.0 3.31 2.28-2.00-1.04 2.75 2.73 2.83 2.69 1.78 1.08
VEL3   5.0
CAL4   5.0     97.70     72.00
VEL4   5.0      0.00  .28  .34  .67 1.15  .51  .25  .04  .19  .75  .82
VEL4   5.0  .49  .77  .08 0.00  .39  .24 1.65  .69 1.90 1.04 1.24  .84
VEL4   5.0 1.51 1.98  .16  .20 1.79 0.00  .99 0.00  .52  .63
VEL4   5.0
XSEC   6.0      93.0 .50     96.18    .00250
      6.0 -6.3101.8  1.7100.1  6.0 98.3 10.098.08 14.0 97.9 18.098.23
      6.0 22.098.21 26.097.14 30.096.12 34.096.72 38.096.54 42.097.49
      6.0 46.097.24 50.0 96.4 54.096.22 58.097.22 62.096.75 66.096.49
      6.0 70.096.04 74.096.53 78.096.64 82.096.73 86.097.08 90.097.35
      6.0 94.0 97.5 98.097.68102.097.72106.097.84110.098.17114.098.27
      6.0117.098.43121.098.68136.9100.3146.9100.3155.9103.3
NS     6.0       .80     81.80     86.60     86.90     86.90     86.90
NS     6.0     86.90     87.70     86.90     86.90     87.90     85.90
NS     6.0     86.90     87.90     86.70     86.90     78.50     86.90
NS     6.0     78.50     78.50     75.80     67.50     67.50     75.50
NS     6.0     75.50     75.50     57.60     67.70     75.70     75.80
NS     6.0     75.80     75.80     75.80     57.50     76.50
CAL1   6.0     99.07    440.00
VEL1   6.0            .02  .53  .26  .86 1.47  .40 1.55 2.09 2.34 3.16
VEL1   6.0 2.67 2.65 2.30 3.15 2.76 2.73 2.69 3.08 2.62 3.05 3.39 3.07
VEL1   6.0 2.60 2.73 2.81 2.21 1.53 1.36  .34
CAL2   6.0     98.68    255.00
VEL2   6.0           0.00  .82  .32  .76  .48  .34  .83  .82  .69 1.58
VEL2   6.0 2.38 1.03 1.63 1.56 2.42 1.66 1.73 1.64 1.92 2.21 2.87 2.35
VEL2   6.0 2.42 2.16 1.95 1.02  .98  .53 0.00 0.00
CAL3   6.0     98.35    153.00
VEL3   6.0           0.00 0.00  .04 0.00  .16  .22  .32  .83  .68  .76
VEL3   6.0 1.63  .75 1.20  .23 1.37  .86 1.23 1.52 1.63 1.67 1.59 1.52
VEL3   6.0 1.61  .95 1.21 1.00 0.00 0.00
CAL4   6.0     98.07     72.00
VEL4   6.0                     0.00 0.00 0.00 0.00  .31  .62 0.00 1.10
VEL4   6.0 1.32  .71  .64 1.58 1.00  .72  .95  .85 1.36 1.13  .55  .92
VEL4   6.0 0.00 0.00  .40 0.00
XSEC   7.0     100.0 .50     96.18    .00250
      7.0 -5.7101.4  3.3100.8  8.4 98.8 11.098.41 14.098.12 17.097.87
      7.0 20.097.29 23.096.76 26.097.74 29.097.06 32.097.13 35.096.72
      7.0 38.096.96 41.097.64 44.096.77 47.096.82 50.096.51 53.096.28
      7.0 56.095.65 59.095.98 62.095.98 65.096.24 68.096.19 71.096.07
      7.0 74.096.23 77.096.49 80.096.57 83.096.81 86.097.11 89.097.26
      7.0 92.097.97 95.098.36 98.098.46101.098.66104.098.86107.099.37
      7.0120.0100.1140.0101.6160.0103.7175.5102.6
NS     7.0       .80       .80     81.50     84.90     87.50     87.70
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NS     7.0     87.70     86.80     88.90     87.70     87.90     87.70
NS     7.0     87.80     86.80     86.70     87.90     87.90     88.90
NS     7.0     87.90     87.50     87.80     87.90     87.50     87.50
NS     7.0     76.50     68.50     67.50     67.80     67.80     67.80
NS     7.0     57.50     74.80     74.50     86.50     85.50     85.50
NS     7.0     75.80     75.70     56.50     75.50
CAL1   7.0     99.37    440.00
VEL1   7.0                .74  .66  .12 1.67  .91 1.41  .75 1.14 1.74
VEL1   7.0 1.38 1.71 1.98 2.47 3.08 2.51 3.29 3.03 2.92 2.97 2.81 2.45
VEL1   7.0 2.32 1.68 2.30 2.12 1.94 1.74 1.61 1.61 1.09 1.10  .01
VEL1   7.0
CAL2   7.0     98.80    255.00
VEL2   7.0                .36  .27  .41 1.02  .61  .88  .41  .72  .78
VEL2   7.0  .46  .10  .52 1.73 2.28 2.04 2.38 1.30 1.69 2.06 1.09 1.30
VEL2   7.0 1.58 1.52 1.72 1.56 1.62  .94  .93  .85  .43 0.00 0.00
VEL2   7.0
CAL3   7.0     98.51    153.00
VEL3   7.0               0.00 0.00  .17  .46  .35  .62  .18  .37  .73
VEL3   7.0  .27  .77  .47 1.18 1.33 1.18 1.51 1.56 1.05 1.74  .26  .96
VEL3   7.0 1.23  .88 1.96  .91  .91 1.04  .61 0.00 0.00
VEL3   7.0
CAL4   7.0     98.20     72.00
VEL4   7.0                    0.00  .16  .14  .23 0.00 0.00  .16  .45
VEL4   7.0  .29 0.00 0.00  .58  .81  .74 1.05 1.17  .45 1.13  .82  .94
VEL4   7.0  .88  .76  .64  .48  .46  .39 0.00
VEL4   7.0
XSEC   8.0      73.0 .50     96.18     .00250
       8.0  2.6101.4  4.799.46 12.096.94 15.096.98 18.098.05 21.098.08
       8.0 24.097.13 27.097.35 30.096.96 33.097.36 36.097.74 39.096.88
       8.0 42.096.23 45.095.89 48.096.46 51.095.52 54.095.62 57.095.69
       8.0 60.095.76 63.096.11 66.096.16 69.096.23 72.096.18 75.096.72
       8.0 78.097.11 81.097.71 84.097.99 87.098.29 90.098.49 93.098.64
       8.0 96.098.76 99.398.89120.0100.5140.0101.7150.0102.5163.8103.6
NS     8.0     88.90     88.90     88.90     88.90     88.90     88.90
NS     8.0     88.90     88.90     87.90     87.80     87.90     87.90
NS     8.0     87.90     87.90     87.90     87.90     87.90     87.70
NS     8.0     87.70     87.70     87.50     87.50     87.50     85.90
NS     8.0     76.70     76.50     75.90     75.90     76.50     87.50
NS     8.0     76.70     76.80     75.90     75.70     75.70       .80
CAL1   8.0     99.46    440.00
VEL1   8.0      0.00  .21  .20 1.61 1.91  .97  .77 1.39 2.85 2.16 1.36
VEL1   8.0 2.37 3.42 3.43 2.92 2.83 3.20 3.24 1.98 1.92 1.86 2.60 1.84
VEL1   8.0 1.02  .85 1.17  .79  .78  .23  .51  .11
CAL2   8.0     98.82    255.00
VEL2   8.0           .50  .24  .77 1.00  .07  .61  .30 1.80 1.69  .90
VEL2   8.0  .66 3.08 3.07 2.46 2.58 2.70 2.16 1.71 1.53  .94 1.39  .99
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VEL2   8.0  .72  .24  .45  .52 0.00 0.00 0.00 0.00
CAL3   8.0     98.54    153.00
VEL3   8.0            .18  .01  .52  .42  .03  .08  .12 1.14 1.40  .35
VEL3   8.0  .39 1.64 1.81 1.65 1.80 2.19 2.10 1.40  .86  .83  .74  .47
VEL3   8.0  .56  .54  .14 0.00      0.00
CAL4   8.0     98.21     72.00
VEL4   8.0            .17  .04 0.00 0.00  .03  .12 0.00 0.00  .48 0.00
VEL4   8.0  .27 1.17 1.38 1.09 1.25 1.22 1.08  .95  .41  .48  .71  .48
VEL4   8.0  .33  .23 0.00
ENDJ
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Appendix C2. Summary of Calibration Details

Washougal River

Calibration Information for Calculated Discharges

Transect Number	1	2	3	4	5	6	7	8
Discharge	383.79 242.19 139.29 65.82	453.51 268.05 145.81 68.65	422.92 297.50 148.20 78.43	477.01 262.70 191.59 78.07	420.12 268.69 196.38 70.39	482.85 247.96 127.00 71.95	447.46 213.19 131.07 68.37	431.69 238.13 141.35 73.76
Stage	94.86 94.42 94.11 93.79	95.34 94.98 94.70 94.39	96.62 96.40 96.10 95.95	97.75 97.42 97.20 96.89	98.68 98.33 98.01 97.70	99.07 98.68 98.35 98.07	99.37 98.80 98.51 98.20	99.46 98.82 98.54 98.21
Plotting Stage	3.28 2.84 2.53 2.21	2.34 1.98 1.70 1.39	1.88 1.66 1.36 1.21	2.06 1.73 1.51 1.20	2.50 2.15 1.83 1.52	2.89 2.50 2.17 1.89	3.19 2.62 2.33 2.02	3.28 2.64 2.36 2.03
Ratio of Measured vs. Predicted Discharge								
	0.92 1.11 1.07 0.92	0.97 1.05 1.00 0.98	0.94 1.05 1.11 0.91	0.98 0.96 1.10 0.96	0.92 0.99 1.27 0.86	1.01 1.00 0.97 1.02	0.97 1.04 1.03 0.97	0.93 1.14 1.02 0.93
Mean Error of Stage/Discharge Relationship for Calculated Q								
	8.22	2.54	7.82	4.75	11.57	1.69	3.27	7.46
Mean Error of Stage/Discharge Relationship for Given Q								
	6.22	2.23	9.17	1.64	2.74	5.89	10.53	11.42
Stage/Discharge Relationship (S vs. Q) S=A*QB+SZF**								
A=	0.8532	0.4358	0.3705	0.3160	0.4267	0.7357	0.7141	0.6208
B=	0.2231	0.2732	0.2657	0.3031	0.2887	0.2218	0.2440	0.2709
SZF=	91.58	93.00	94.74	95.69	96.18	96.18	96.18	96.18
Beta Coefficient Log/Log Discharge/Stage Relationship								
	4.57	3.47	3.84	3.38	3.60	4.19	3.94	3.75

Appendix C3. Summary of Data Changes

Data changes for calibration, Washougal River at Hathaway Park

Transect	Vertical	Vel	Change
1	7	1	1.24 to 1.04
1	8	1	0.88 to 0.78
1	9	1	1.28 to 1.08
1	26	1	2.42 to 2.22
1	31	1	2.85 to 2.65
1	32	1	2.47 to 2.27
1	6	2	0.09 to 0.29
1	15	2	0.01 to 0.00
1	7	3	0.18 to 0.00
1	26	3	1.72 to 1.52
1	31	3	1.70 to 1.50
1	32	3	1.56 to 1.36
1	8	4	0.04 to 0.00
1	9	4	0.05 to 0.00
1	26	4	0.26 to 0.00
1	35	4	0.00 to 0.20
2	14	3	0.01 to 0.00
2	28	3	0.60 to 0.80
2	16	4	0.04 to 0.00
2	21	4	0.89 to 1.09
2	28	4	0.16 to 0.00
3	10	1	1.80 to 1.60
3	15	1	0.68 to 0.88
3	17	1	2.87 to 2.47
3	18	1	4.42 to 4.02
3	22	1	2.83 to 2.63
3	24	1	3.23 to 3.03
3	25	1	5.29 to 4.89
3	26	1	6.76 to 6.56
3	27	1	4.98 to 4.58
3	10	2	0.69 to 0.89
3	11	2	5.28 to 5.08
3	15	2	1.22 to 1.02
3	17	2	1.97 to 1.77
3	19	2	2.47 to 2.27
3	20	2	2.40 to 2.20
3	24	2	1.90 to 2.10

3	30	2	3.23 to 3.03
3	15	3	1.44 to 1.24
3	17	3	0.25 to 0.65
3	20	3	3.20 to 3.00
3	24	3	2.50 to 2.30
3	27	3	3.93 to 3.73
3	30	3	2.62 to 2.42
3	11	4	0.30 to 0.50
3	15	4	1.49 to 1.29
3	17	4	0.02 to 0.00
3	19	4	1.91 to 1.71
3	20	4	1.98 to 1.78
3	24	4	3.35 to 3.15
3	26	4	4.02 to 3.82
3	27	4	0.52 to 0.72
3	30	4	0.26 to 0.00
4	3	2	0.09 to 0.00
4	15	3	0.35 to 0.55
4	18	4	0.03 to 0.00
4	27	4	0.00 to 0.20
4	28	4	0.23 to 0.00
5	29	1	0.83 to 1.03
5	32	1	1.71 to 2.01
5	32	2	2.21 to 2.01
5	29	3	2.95 to 2.75
5	32	3	3.09 to 2.69
5	16	4	0.05 to 0.00
5	20	4	0.49 to 0.69
5	28	4	0.00 to 0.20
5	30	4	0.02 to 0.00
5	32	4	0.06 to 0.00
6	8	1	0.20 to 0.40
6	30	2	0.33 to 0.53
6	8	3	0.42 to 0.22
6	21	3	1.83 to 1.63
6	25	3	1.81 to 1.61
6	11	4	0.11 to 0.00
6	13	4	1.52 to 1.32
6	25	4	0.23 to 0.00
6	26	4	0.07 to 0.00
7	17	1	3.28 to 3.08
7	19	1	3.49 to 3.29
7	34	2	0.09 to 0.00
7	9	4	0.04 to 0.00
7	15	4	0.10 to 0.00
7	31	4	0.01 to 0.00

8	6	1	2.11 to 1.91
8	9	1	1.59 to 1.39
8	14	1	0.00 to 3.42
8	15	1	0.00 to 3.43
8	16	1	0.00 to 2.92
8	17	1	0.00 to 2.83
8	18	1	0.00 to 3.20
8	28	1	0.99 to 0.79
8	29	1	0.98 to 0.78
8	15	2	3.27 to 3.07
8	29	2	0.08 to 0.00
8	30	2	0.02 to 0.00
8	6	3	0.22 to 0.42
8	10	3	0.94 to 1.14
8	15	3	2.01 to 1.81
8	28	3	0.02 to 0.00
8	5	4	0.04 to 0.00
8	9	4	0.05 to 0.00
8	10	4	0.25 to 0.00
8	12	4	0.05 to 0.00
8	14	4	0.97 to 1.17
8	15	4	1.58 to 1.38
8	17	4	1.45 to 1.25
8	18	4	1.42 to 1.22
8	19	4	1.28 to 1.08

Appendix C4. Velocity Adjustment Factors

Washougal River at Hathaway Park: Measured 440 cfs on 6-8-98, 255 cfs on 5-11-98, 153 cfs on 7-30-98, and 72 cfs on 9-15-98.

1.00	1100.0	0.932
1.00	1000.0	0.946
1.00	950.0	0.952
1.00	900.0	0.959
1.00	850.0	0.965
1.00	800.0	0.972
1.00	750.0	0.978
1.00	700.0	0.984
1.00	650.0	0.989
1.00	600.0	0.994
1.00	550.0	0.999
1.00	525.0	1.001
1.00	500.0	1.003
1.00	475.0	1.004
1.00	450.0	1.006
1.00	440.0	1.006
1.00	425.0	1.007
1.00	400.0	1.008
1.00	375.0	1.008
1.00	350.0	1.008
1.00	325.0	1.008
1.00	300.0	1.007
1.00	275.0	1.005
1.00	250.0	1.002
1.00	225.0	0.999
1.00	200.0	0.994
1.00	150.0	0.980
1.00	100.0	0.954
1.00	75.0	0.935
1.00	50.0	0.910
2.00	1100.0	0.959
2.00	1000.0	0.971
2.00	950.0	0.977
2.00	900.0	0.983
2.00	850.0	0.989
2.00	800.0	0.995
2.00	750.0	1.002
2.00	700.0	1.008
2.00	650.0	1.014
2.00	600.0	1.021
2.00	550.0	1.027

2.00	525.0	1.030
2.00	500.0	1.033
2.00	475.0	1.036
2.00	450.0	1.039
2.00	440.0	1.040
2.00	425.0	1.041
2.00	400.0	1.044
2.00	375.0	1.045
2.00	350.0	1.047
2.00	325.0	1.048
2.00	300.0	1.049
2.00	275.0	1.049
2.00	250.0	1.049
2.00	225.0	1.047
2.00	200.0	1.044
2.00	150.0	1.033
2.00	100.0	1.010
2.00	75.0	0.987
2.00	50.0	0.951
3.00	1100.0	0.845
3.00	1000.0	0.869
3.00	950.0	0.882
3.00	900.0	0.894
3.00	850.0	0.907
3.00	800.0	0.920
3.00	750.0	0.933
3.00	700.0	0.946
3.00	650.0	0.959
3.00	600.0	0.971
3.00	550.0	0.983
3.00	525.0	0.989
3.00	500.0	0.995
3.00	475.0	1.000
3.00	450.0	1.005
3.00	440.0	1.006
3.00	425.0	1.009
3.00	400.0	1.013
3.00	375.0	1.016
3.00	350.0	1.018
3.00	325.0	1.019
3.00	300.0	1.019
3.00	275.0	1.017
3.00	250.0	1.014
3.00	225.0	1.009
3.00	200.0	1.000
3.00	150.0	0.972

3.00	100.0	0.927
3.00	75.0	0.875
3.00	50.0	0.802
4.00	1100.0	0.967
4.00	1000.0	0.981
4.00	950.0	0.988
4.00	900.0	0.995
4.00	850.0	1.002
4.00	800.0	1.009
4.00	750.0	1.016
4.00	700.0	1.022
4.00	650.0	1.029
4.00	600.0	1.034
4.00	550.0	1.039
4.00	525.0	1.042
4.00	500.0	1.044
4.00	475.0	1.046
4.00	450.0	1.047
4.00	440.0	1.048
4.00	425.0	1.048
4.00	400.0	1.049
4.00	375.0	1.050
4.00	350.0	1.050
4.00	325.0	1.049
4.00	300.0	1.048
4.00	275.0	1.046
4.00	250.0	1.043
4.00	225.0	1.039
4.00	200.0	1.033
4.00	150.0	1.017
4.00	100.0	0.987
4.00	75.0	0.969
4.00	50.0	0.973
5.00	1100.0	0.934
5.00	1000.0	0.951
5.00	950.0	0.959
5.00	900.0	0.967
5.00	850.0	0.974
5.00	800.0	0.981
5.00	750.0	0.988
5.00	700.0	0.995
5.00	650.0	1.000
5.00	600.0	1.005
5.00	550.0	1.010
5.00	525.0	1.011
5.00	500.0	1.013

5.00	475.0	1.014
5.00	450.0	1.015
5.00	440.0	1.015
5.00	425.0	1.015
5.00	400.0	1.015
5.00	375.0	1.014
5.00	350.0	1.013
5.00	325.0	1.011
5.00	300.0	1.008
5.00	275.0	1.004
5.00	250.0	1.000
5.00	225.0	0.993
5.00	200.0	0.986
5.00	150.0	0.964
5.00	100.0	0.929
5.00	75.0	0.906
5.00	50.0	0.883
6.00	1100.0	1.013
6.00	1000.0	1.017
6.00	950.0	1.019
6.00	900.0	1.020
6.00	850.0	1.021
6.00	800.0	1.023
6.00	750.0	1.023
6.00	700.0	1.024
6.00	650.0	1.024
6.00	600.0	1.024
6.00	550.0	1.023
6.00	525.0	1.023
6.00	500.0	1.022
6.00	475.0	1.021
6.00	450.0	1.020
6.00	440.0	1.020
6.00	425.0	1.019
6.00	400.0	1.018
6.00	375.0	1.016
6.00	350.0	1.014
6.00	325.0	1.012
6.00	300.0	1.009
6.00	275.0	1.006
6.00	250.0	1.002
6.00	225.0	0.998
6.00	200.0	0.994
6.00	150.0	0.983
6.00	100.0	0.974
6.00	75.0	0.969

6.00	50.0	0.951
7.00	1100.0	0.958
7.00	1000.0	0.966
7.00	950.0	0.970
7.00	900.0	0.973
7.00	850.0	0.977
7.00	800.0	0.981
7.00	750.0	0.986
7.00	700.0	0.990
7.00	650.0	0.994
7.00	600.0	0.998
7.00	550.0	1.002
7.00	525.0	1.004
7.00	500.0	1.006
7.00	475.0	1.008
7.00	450.0	1.010
7.00	440.0	1.011
7.00	425.0	1.012
7.00	400.0	1.014
7.00	375.0	1.016
7.00	350.0	1.017
7.00	325.0	1.019
7.00	300.0	1.020
7.00	275.0	1.021
7.00	250.0	1.022
7.00	225.0	1.022
7.00	200.0	1.022
7.00	150.0	1.016
7.00	100.0	1.001
7.00	75.0	0.984
7.00	50.0	0.957
8.00	1100.0	0.887
8.00	1000.0	0.906
8.00	950.0	0.916
8.00	900.0	0.926
8.00	850.0	0.936
8.00	800.0	0.945
8.00	750.0	0.955
8.00	700.0	0.965
8.00	650.0	0.974
8.00	600.0	0.983
8.00	550.0	0.992
8.00	525.0	0.996
8.00	500.0	1.000
8.00	475.0	1.004
8.00	450.0	1.008

8.00	440.0	1.009
8.00	425.0	1.011
8.00	400.0	1.015
8.00	375.0	1.018
8.00	350.0	1.020
8.00	325.0	1.022
8.00	300.0	1.024
8.00	275.0	1.025
8.00	250.0	1.025
8.00	225.0	1.024
8.00	200.0	1.021
8.00	150.0	1.009
8.00	100.0	0.982
8.00	75.0	0.956
8.00	50.0	0.916

Appendix D. Fish Habitat Preference Curves

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Fishcrv for Washougal approved by Hal Beecher 12-3-98
H   101  9  7 75  0 Chinook                          Spawning
V   101  0.00  0.00  0.50  0.00  1.00  0.10  1.30  0.70  1.75  1.00  3.00  1.00
V   101  3.50  0.70  4.00  0.00 99.90  0.00
D   101  0.00  0.00  0.50  0.00  1.00  0.75  1.20  1.00  3.40  1.00  5.00  0.00
D   101 99.90  0.00
S   101  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S   101 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S   101 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   101 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S   101 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
S   101 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   101 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   101 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   101 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   101 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   101 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S   101 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   101 87.90  0.03 88.50  0.00 99.90  0.00
H   102 12  8 87  0 Chinook                          Juvenile
V   102  0.00  0.09  0.20  0.20  0.30  0.26  0.40  0.93  0.60  1.00  1.10  0.90
V   102  1.30  0.75  2.00  0.50  2.20  0.08  2.70  0.03  3.60  0.00 99.00  0.00
D   102  0.00  0.00  0.40  0.00  0.50  0.05  1.00  0.33  1.20  0.50  1.50  0.80
D   102  2.20  1.00 99.00  1.00
S   102  0.10  1.00  0.40  1.00  0.50  0.80  0.80  0.10 12.50  0.10 14.80  0.14
S   102 15.50  0.20 15.80  0.14 16.50  0.30 17.50  0.40 17.90  0.16 18.50  0.55
S   102 18.70  0.37 22.50  0.10 23.90  0.10 24.50  0.20 24.80  0.14 25.50  0.20
S   102 25.60  0.18 26.50  0.30 26.90  0.14 27.50  0.40 27.80  0.22 28.60  0.46
S   102 29.50  0.20 31.70  0.10 34.80  0.14 42.50  0.20 42.80  0.26 43.50  0.20
S   102 45.50  0.30 45.90  0.30 46.60  0.38 46.80  0.34 48.50  0.65 51.50  0.20
S   102 51.80  0.26 52.50  0.20 52.80  0.26 54.50  0.30 54.80  0.30 56.50  0.40
S   102 56.80  0.34 57.50  0.50 57.80  0.38 58.50  0.65 58.60  0.58 61.50  0.30
S   102 61.90  0.46 62.50  0.30 62.90  0.46 64.60  0.42 64.90  0.48 65.50  0.40
S   102 65.90  0.48 67.50  0.60 67.90  0.52 68.50  0.75 68.80  0.60 71.50  0.40
S   102 71.80  0.58 72.50  0.40 72.90  0.64 74.50  0.50 74.90  0.66 75.50  0.50
S   102 75.90  0.66 76.50  0.60 76.90  0.68 78.50  0.85 78.80  0.76 81.50  0.55
S   102 81.90  0.91 82.50  0.55 82.70  0.73 83.80  0.82 84.80  0.86 84.90  0.93
S   102 85.50  0.65 85.90  0.93 86.50  0.75 86.90  0.95 87.50  0.85 87.90  0.97
S   102 88.50  1.00 88.90  1.00 99.90  0.30
H   201 11  9 75  0 Steelhead                        Spawning
V   201  0.00  0.00  1.10  0.45  2.10  0.97  2.90  1.00  3.20  1.00  3.30  0.62
V   201  3.60  0.40  4.00  0.20  4.50  0.10  5.00  0.00 99.00  0.00
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D   201  0.00  0.00  0.60  0.00  0.70  0.50  1.00  1.00  1.50  1.00  1.60  0.75
D   201  2.20  0.60  2.40  0.50 99.00  0.50
S   201  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.80 16.50  0.50
S   201 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.25 23.90  0.05
S   201 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   201 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.35 34.80  0.60
S   201 42.50  0.50 42.80  0.80 43.50  0.75 45.50  1.00 46.80  1.00 48.50  0.50
S   201 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   201 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   201 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   201 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   201 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   201 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.10 84.80  0.20
S   201 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   201 87.90  0.03 88.50  0.00 99.90  0.00
H   202 13 14 87  0 Steelhead                         Juvenile
V   202  0.00  0.23  0.20  0.30  0.50  0.50  0.90  0.80  1.30  1.00  1.50  0.97
V   202  2.40  0.80  3.00  0.35  3.60  0.22  3.70  0.19  5.00  0.16  6.00  0.00
V   202 99.00  0.00
D   202  0.00  0.00  0.50  0.03  0.70  0.07  0.90  0.11  1.10  0.25  1.60  0.35
D   202  1.90  0.40  2.10  0.65  2.20  0.85  2.50  0.90  2.60  1.00  3.40  0.86
D   202  4.50  0.64 99.00  0.64
S   202  0.10  1.00  0.40  1.00  0.50  0.80  0.80  0.10 12.50  0.10 14.80  0.14
S   202 15.50  0.20 15.80  0.14 16.50  0.30 17.50  0.40 17.90  0.16 18.50  0.55
S   202 18.70  0.37 22.50  0.10 23.90  0.10 24.50  0.20 24.80  0.14 25.50  0.20
S   202 25.60  0.18 26.50  0.30 26.90  0.14 27.50  0.40 27.80  0.22 28.60  0.46
S   202 29.50  0.20 31.70  0.10 34.80  0.14 42.50  0.20 42.80  0.26 43.50  0.20
S   202 45.50  0.30 45.90  0.30 46.60  0.38 46.80  0.34 48.50  0.65 51.50  0.20
S   202 51.80  0.26 52.50  0.20 52.80  0.26 54.50  0.30 54.80  0.30 56.50  0.40
S   202 56.80  0.34 57.50  0.50 57.80  0.38 58.50  0.65 58.60  0.58 61.50  0.30
S   202 61.90  0.46 62.50  0.30 62.90  0.46 64.60  0.42 64.90  0.48 65.50  0.40
S   202 65.90  0.48 67.50  0.60 67.90  0.52 68.50  0.75 68.80  0.60 71.50  0.40
S   202 71.80  0.58 72.50  0.40 72.90  0.64 74.50  0.50 74.90  0.66 75.50  0.50
S   202 75.90  0.66 76.50  0.60 76.90  0.68 78.50  0.85 78.80  0.76 81.50  0.55
S   202 81.90  0.91 82.50  0.55 82.70  0.73 83.80  0.82 84.80  0.86 84.90  0.93
S   202 85.50  0.65 85.90  0.93 86.50  0.75 86.90  0.95 87.50  0.85 87.90  0.97
S   202 88.50  1.00 88.90  1.00 99.90  0.30
H   301 13 11 75  0 Coho                              Spawning
V   301  0.00  0.00  0.20  0.00  0.25  0.40  0.40  0.59  0.75  0.80  1.00  0.92
V   301  1.10  0.98  1.20  1.00  2.00  1.00  2.25  0.42  3.40  0.16  4.20  0.00
V   301 99.00  0.00
D   301  0.00  0.00  0.20  0.00  0.40  0.04  0.55  0.08  0.65  0.16  0.75  0.40
D   301  0.95  0.80  1.00  1.00  3.40  1.00  4.00  0.10 99.00  0.00
S   301  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S   301 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S   301 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
```

```
S   301 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S   301 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
S   301 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   301 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   301 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   301 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   301 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   301 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S   301 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   301 87.90  0.03 88.50  0.00 99.90  0.00
H   401 12  8 75  0 Chum                        Spawning
V   401  0.00  0.09  0.20  0.10  0.40  0.20  0.80  0.40  1.90  1.00  2.20  1.00
V   401  2.70  0.80  3.20  0.70  3.50  0.35  3.70  0.10  5.00  0.00 99.00  0.00
D   401  0.00  0.00  0.40  0.17  0.70  1.00  1.50  1.00  1.80  0.44  2.50  0.23
D   401  5.00  0.00 99.00  0.00
S   401  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S   401 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S   401 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   401 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S   401 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
S   401 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   401 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   401 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   401 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   401 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   401 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S   401 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   401 87.90  0.03 88.50  0.00 99.90  0.00
```

Appendix E. Substrate and Cover Codes

Instream Flow Studies Substrate and Cover Code Application

November 23, 1987

The three-digit code used describes the dominant substrate (the first number, the subdominant substrate (the second number), and the percent of <u>only</u> the dominant substrate (the third number). The percent of the sulxiominant substrate can be determined by subtraction. Dominant substrate is determined by the largest quantity of a certain substrate not the size of the substrate. The sum of the percent dominant and the percent sulxiominant will total 100 percent. The coding will not allow the dominant percent to be less than 50 percent, or greater than 90 percent. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate, and the product is added to the product of the subdominant substrate times the percent of subdominant substrate. The sum of all the codes observed times their preference value will be a value between 0.0 and 1.0. The coding should also give a preference value of zero for the entire substrate observation when the code is class zero, one, or two, and is 50 percent or more of the observation. Where there is a situation where addition of two values could equal more than 1.0, the value will default to 1.0. Overhanging vegetation should be counted as cover if it is within 3 to 4 feet of the water surface. Cover values should be incorporated with the substrate values for both salmon and steelhead juvenile life stages and for Chinook and steelhead adult holding.

Life Stage and Value of Substrate

			Salmon			Steelhead and Trout			
						Spawning		Rearing/Holding	
Code	**Substrate Size In Inches**		**Juvenile Rearing**	**Spawning**	**Adult Holding**	**Steelhead**	**Trout**	**Juvenile & Adult**	**Steelh Adult**
0	**Detritus**		**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
1	**Silt, Clay**		**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
2	**Sand**		**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
3	**Small Gravel**	**.1-0.5**	**.1**	**.3**	**.1**	**.5**	**1**	**.1**	**.1**
4	**Medium Gravel**	**.5-1.5**	**.3**	**1**	**.3**	**1.0**	**1**	**.3**	**.3**
5	**Large Gravel.**	**1.5-3.0**	**.3**	**1**	**.3**	**1.0**	**1**	**.3**	**.3**
6	**Small Cobble**	**3.0-6.0**	**.5**	**1**	**.3**	**1.0**	**.5**	**.5**	**.3**
7	**Large Cobble**	**6.0-12.0**	**.7**	**.3***	**.3**	**.3**	**.0**	**.7**	**.3**
8	**Boulder**		**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
9	**Bedrock**		**.3**	**0**	**.3**	**0**	**0**	**.3**	**.3**
0.1	**Undercut Bank**		**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.2	**Overhanging Vegetation**		**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.3	**Root Wad**		**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.4	**Log Jam**		**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.5	**Log Instream**		**.8**	**0**	**.8**	**0**	**0**	**.8**	**.3**
0.6	**Submerged Vegetation**		**1.0**	**0**	**.8**	**0**	**0**	**1.0**	**.8**
0.8	**Grass/Bushes Up on Bank**		**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
0.9	**Fine Organic Substrate**		**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**

(*0.6 for chinook spawning can be used, depending on river size)