WRIA 44 and 50

Watershed Instream Flow Study
Grant No. G0200263
(Step C – Draft Flow Recommendations)

Prepared for:

The Foster Creek Conservation District
and
The WRIAs 44 and 50 Planning Unit

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1. INTRODUCTION

This document provides a description of the methods and results of an instream flow study completed for Rock Island and Douglas Creeks in WRIA 44 and Foster Creek in WRIA 50 under the State of Washington Department of Ecology Grant No. G0200263 with the Foster Creek Conservation District. The objectives of this phase were to: (1) gather and summarize appropriate site-specific field data; (2) to use various techniques to model the appropriate nature of flow regimes in each creek per the Step A Scope of Work; (3) to review the findings with the WRIAs 44 and 50 Planning Unit (PU) in accordance with their instream flow setting objectives and (4) to make preliminary recommendations of the minimum instream flows needed in each creek.

During the fall of 2002, the WRIAs 44 and 50 Planning Unit (PU) submitted, and Ecology approved, the instream flow scope of work as the first phase of the grant (Step A) to establish minimum stream flows for priority streams in the watershed under the watershed planning program, HB 2514 (R2 Resource Consultants 2002). The priority streams for this assessment were determined to be Foster, Rock Island, and Douglas creeks. This report provides the results of the second and third phases (Steps B and C) of the Ecology grant, related to development of minimum instream flows for the priority streams.

This document is separated into five major sections that include in addition to Section 1 – INTRODUCTION; Section 2 – BACKGROUND INFORMATION: presenting an overview of stream specific hydrology, fish use/status, and water quality conditions; Section 3 – METHODS: describing procedures used in completing the study; Section 4 –RESULTS: presenting results by study element; and Section 5 – RECOMMENDATIONS. The recommended action section presents draft minimum monthly instream flows for each of the priority streams per R2's assessment of site-specific hydrological, morphological, and biological considerations. The report contains five appendices including Appendix A – Hydrology Data; Appendix B – Water Temperature Records; Appendix C – Copy of field data; Appendix D – Habitat Suitability Curves; Appendix E – Hydraulic Calibration Output; and Appendix F – Riparian Assessment of Stream Channel Transects.

Biological assessments including spring and fall adult spawning surveys and late spring and late summer juvenile snorkel surveys were conducted in the priority creeks. The results of these efforts have been presented in separate documents and summarized in this assessment in Section 2.3. The biological assessment results were used to improve the understanding of the periodicity of species use in the creeks under current conditions and to facilitate the use of habitat suitability criteria for various life history stages on a monthly basis.

2. BACKGROUND INFORMATION

2.1 WATER QUALITY

Ecology classifies all of the streams included in the WRIAs 44 and 50 study as Class A; Excellent. Per recent changes in state water quality standards (WAC 173-201A), the priority streams offer beneficial uses including non-core anadromous fish habitat in Foster and Rock Island creeks and interior trout habitat in Douglas Creek (Ecology 2003).

Since the summer of 2001, a suite of water quality parameters has been monitored in the priority streams under the watershed planning process in WRIAs 44 and 50 to provide a screening level assessment. Water quality parameters included surface water temperature, dissolved oxygen (DO), percent DO saturation, pH, and conductivity. A summary of results of water quality testing completed between 2001 and 2003 on priority streams is provided in Table 2-1. A detailed discussion of the methods and results of water quality testing on all WRIAs 44 and 50 streams can be found in the WRIA 44 and 50 basin assessment report (PGG 2003).

Table 2-1. Results of water quality testing completed in 2001 through 2003 on priority streams in WRIAs 44 and 50.

Water Quality Parameter	**Priority Streams**		
	Rock Island Creek	**Douglas Creek**	**Foster Creek**
Temperature	C	F	O
DO	O	O	O
pH	C	C	C

C= complied continuously with state standards
F= frequently exceeded state standards during late spring and summer months
O= occasionally failed to meet state standards in mid-to late summer

2.2 HYDROLOGY

As described in the Washington Conservation Commission Habitat Limiting Factor Assessment (Bartu and Andonaegui 2001), most streams in WRIAs 44 and 50 are intermittent, fed by spring runoff or groundwater. All three of the priority streams (Foster, Douglas, and Rock Island creeks) are known to have stream reaches with perennial flows under normal hydrological conditions since they are groundwater fed. The perennial flowing sections of Foster and Rock Island creeks are connected to the Columbia River and offer access to anadromous salmonid fishes. Streams in the WRIAs are susceptible to infrequent, large flood events associated with summer thunderstorms and warm rain-on-snow events. Existing stream channels have been shaped by these high flow events and the streambeds are dynamic. Major floods have occurred about every 10 years, although smaller storms are more frequent (Bartu and Andonaegui 2001). Stream discharge the balance of the year is a fraction of the storm flow.

Groundwater springs support surface water flow during the low-flow summer season in all three of the perennial flowing stream reaches included as part of this study. Without the springs, surface stream flows in all of these streams would be intermittent during most years. Surface water flow in Rock Island Creek has been artificially enhanced via mechanical excavation of an artesian spring in the late 1950s. This groundwater to surface water connection has been maintained such that water generally flows year-round. Surface water stream flow would not persist in the lower most reach of Rock Island Creek without the artificial spring. The artificial spring flow was removed from the hydrograph in this analysis to approximate natural stream flows in lower Rock Island Creek.

Historic stream flow records generally do not exist for streams within the WRIAs 44 and 50. Douglas Creek is the only stream with historic stream flow data. The period of record for that gage is from 1949 to 1955 and 1963 to 1968. Because of the paucity of data, a streamflow monitoring program was initiated to obtain hydrologic data on streams in WRIAs 44 and 50. Stream flow monitoring stations were installed on the priority streams in June 2001. Following installation, the gaging stations have been serviced monthly by Conservation District staff. The April 2003 WRIAs 44 and 50 Basin Assessment contains detailed discussion of gage data collection and surface water analyses (PGG et al. 2003). Results through September 2003 are shown in Figure 2-1 and the details are included in Appendix A.

Hydrologic data obtained from these sites were used to produce daily exceedence flow values for each of the priority streams. Exceedence flow statistics are the stream flow values expected to be exceeded a specific period of time (e.g., the 50 percent exceedence flow would be exceeded 50 percent of the time). Data from three priority stream gages within WRIAs 44 and 50 are graphed in Figure 2-1. These graphs show the range of flows expected throughout the year based on recorded data. The period of flow record used to develop the exceedence values for each of the three streams is extremely short (<3 years) and, therefore, may not represent the entire range of flows experience by the priority streams. Furthermore, the natural or historic flow levels are unknown. Since less than 1 percent of the total water yield upstream of the flow gages is used in any of the basins (PGG et al. 2003), it is assumed the measured flows approximate natural flow levels.

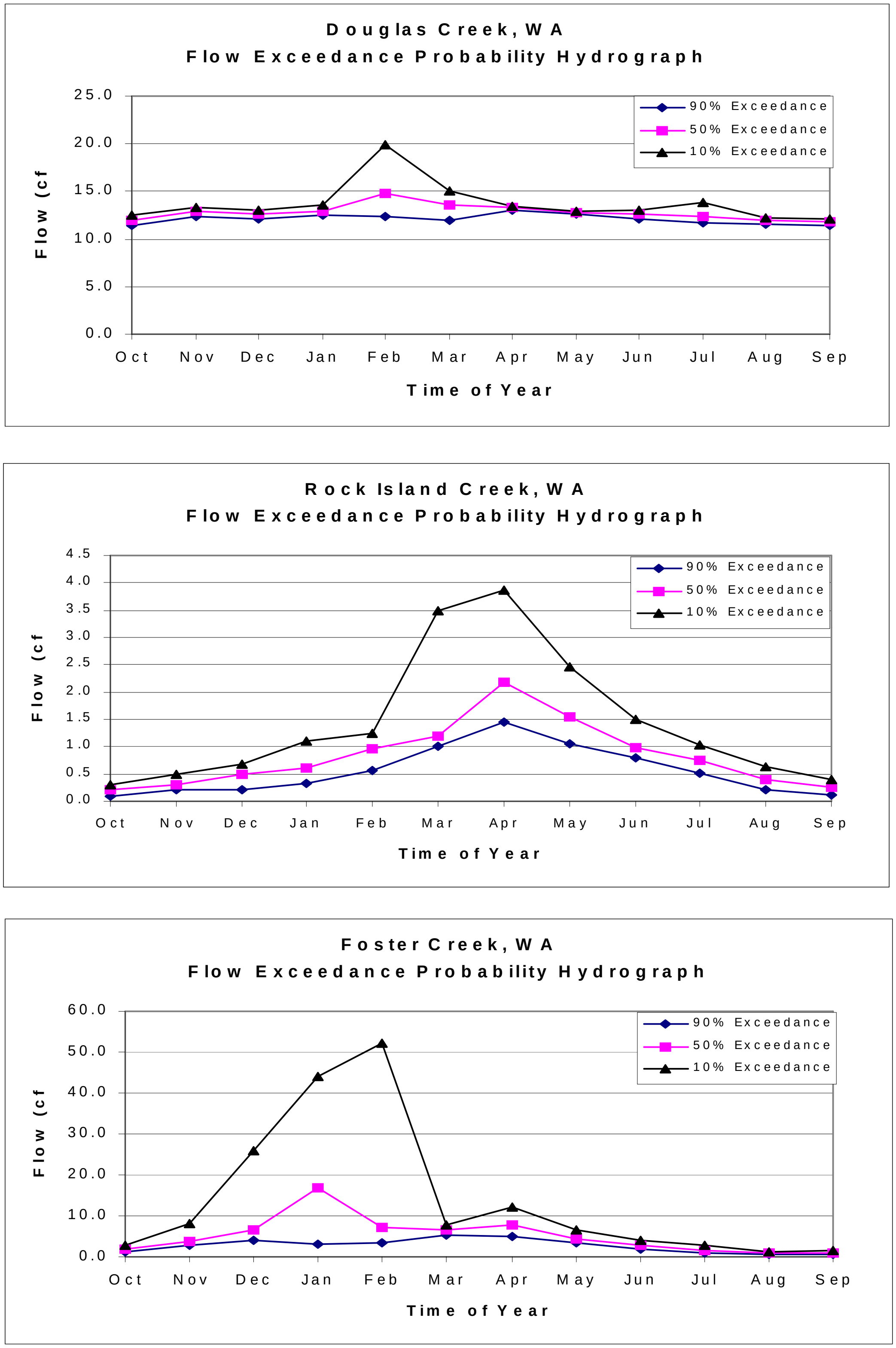


Figure 2-1. Stream flow exceedence curves developed from site-specific gage data collected over the period of record 2001 to 2003 for each of the priority streams in WRIAs 44 and 50, WA.

Average monthly and average annual stream flows were estimated for the three priority streams using site-specific gage data collected from June 2001 to September 2003 (Appendix A). Due to the limited amount of gage data and the somewhat drier than normal precipitation pattern during this period, estimated stream flows should be considered conservative and used with caution. The estimated mean monthly flow values for each of the priority streams is presented in Table 2-2. The artificially enhanced spring flow discharging into Rock Island Creek was removed from the hydrograph in Table 2-2 to approximate natural stream flow conditions for the lowermost reach of Rock Island Creek.

Table 2-2. Estimated mean monthly stream flow (cfs) based on available flow records for each of the priority streams (Appendix A).

Month	Mean Monthly Stream Flow (cfs)		
	Rock Island	**Foster**	**Douglas**
October	0.0	2.0	11.9
November	0.1	3.9	12.9
December	0.1	6.5	12.7
January	0.1	16.9	12.9
February	0.2	7.1	14.8
March	0.3	6.6	13.6
April	0.0	7.8	13.3
May	0.0	4.4	12.8
June	0.0	2.9	12.6
July	0.2	1.7	12.3
August	0.2	0.9	11.9
September	0.1	0.9	11.8

2.3 FISHERY RESOURCE

Several types of anadromous and resident fish, including summer steelhead (rainbow) trout [*Oncorhynchus mykiss*], Chinook salmon [*O. tshawytscha*], and coho salmon [*O. kisutch*] are known to utilize portions of the priority streams during one or more of their life history stages. Results of snorkel surveys conducted during late spring and summer of 2003 in WRIAs 44 and 50 priority streams indicate the presence of juvenile rearing salmonid fishes including steelhead (rainbow) trout and Chinook salmon in Foster Creek, Chinook and coho salmon and rainbow trout in Rock Island Creek and resident rainbow trout in Douglas Creek (R2 Resource Consultants 2003). Current fish distribution in the WRIAs is summarized in Table 2-3 and shown in Figures 2-2 through 2-4.

Spawning of adult steelhead trout has been previously documented in Foster Creek and confirmed during spring 2003 and 2004 spawning surveys conducted under Step B of this Grant. A total of 11 redds and 5 redds were recorded during the 2003 and 2004 spawning periods, respectively. The first redds of the year were observed during surveys the third week of April and the latest redd development occurred during the first week of June. As such, the summer steelhead spawning period in Foster Creek is assumed to extend from April 15th to June 15th. Given the water temperatures experienced in Foster Creek (Appendix B), it is anticipated fry emergence would peak in late June and could continue into mid-July. Summer steelhead trout rearing was established between June and November based on water temperature data. From December through March water temperatures in Foster Creek are generally below 5°C. This season represents a period of winter refuge behavior in salmonid fishes with diminished metabolic activity and swimming capabilities.

Table 2-3. Known salmonid distribution by life stage for each of the WRIAs 44 and 50 priority streams (adapted from Bartu and Andonaegue 2001 and R2 Resource Consultants 2003) (see Figures 2-2 through 2-4).

	Fish Species			
Stream	**Chinook**	**Coho**	**Summer Steelhead**	**Rainbow Trout**
Foster Creek	F	NP	S, J, F	ALL
Rock Island Creek	F	J, F	NP	ALL
Douglas Creek	NP	NP	NP	ALL

S-spawning, J-juvenile, F-fry, A-adult, NP-not present, All-all life stages present

Fall and winter spawning surveys were conducted in 2003 and they are currently in progress in the priority streams during fall 2004. There have been no observations of adult anadromous salmon species in either Foster or Rock Island creeks (T. Behne, FCCD pers. comm. April 2004). These surveys will continue through the end of February 2005. Given the lack of sightings and the typical low stream levels during the fall spawning seasons, it is assumed salmon spawning does not occur on a routine basis in the priority streams. It is further assumed that observations of juvenile Chinook salmon in Foster and Rock Island creeks and coho salmon in Rock Island

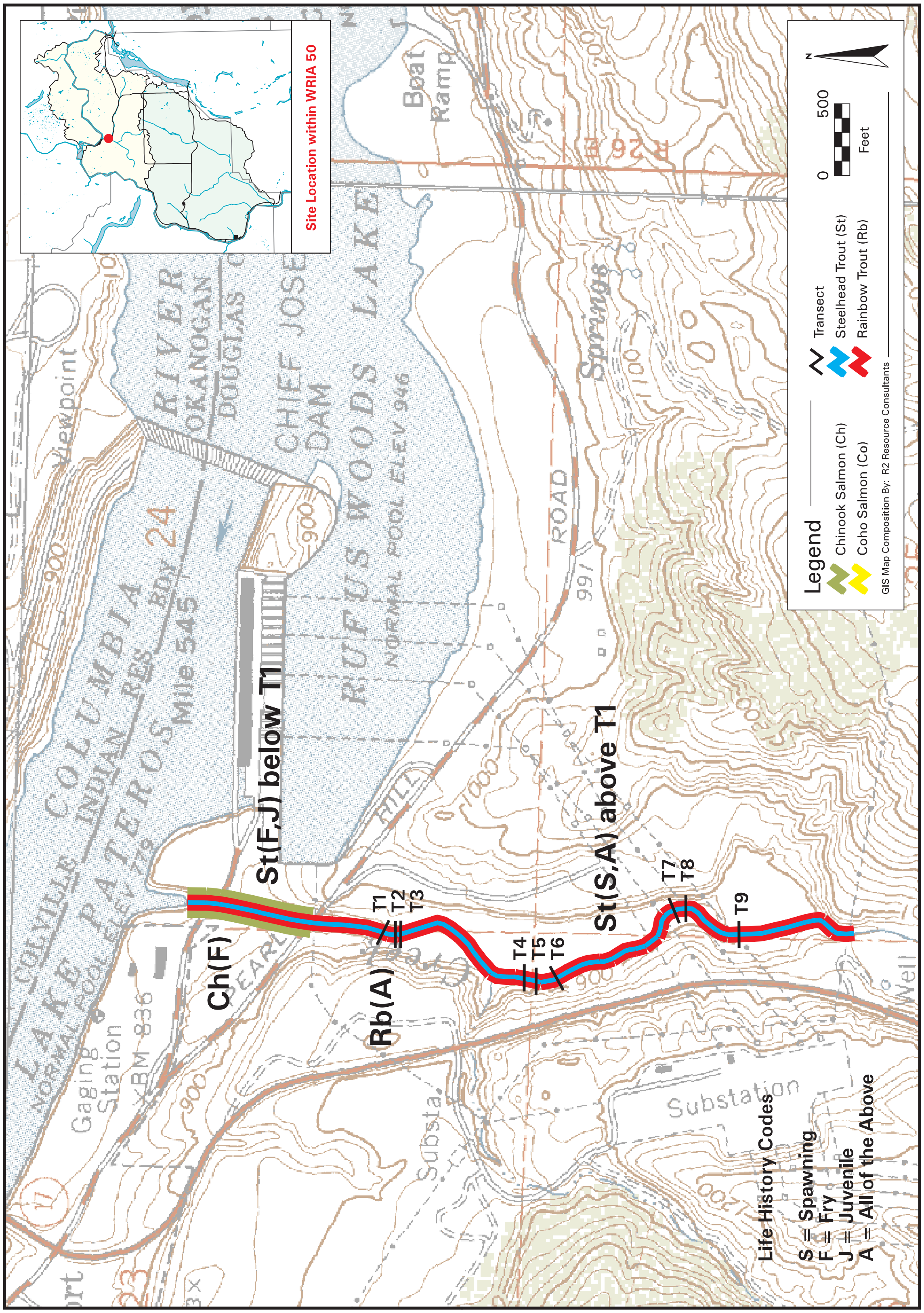


Figure 2-2. Fish species and distribution of life history stages in Foster Creek.

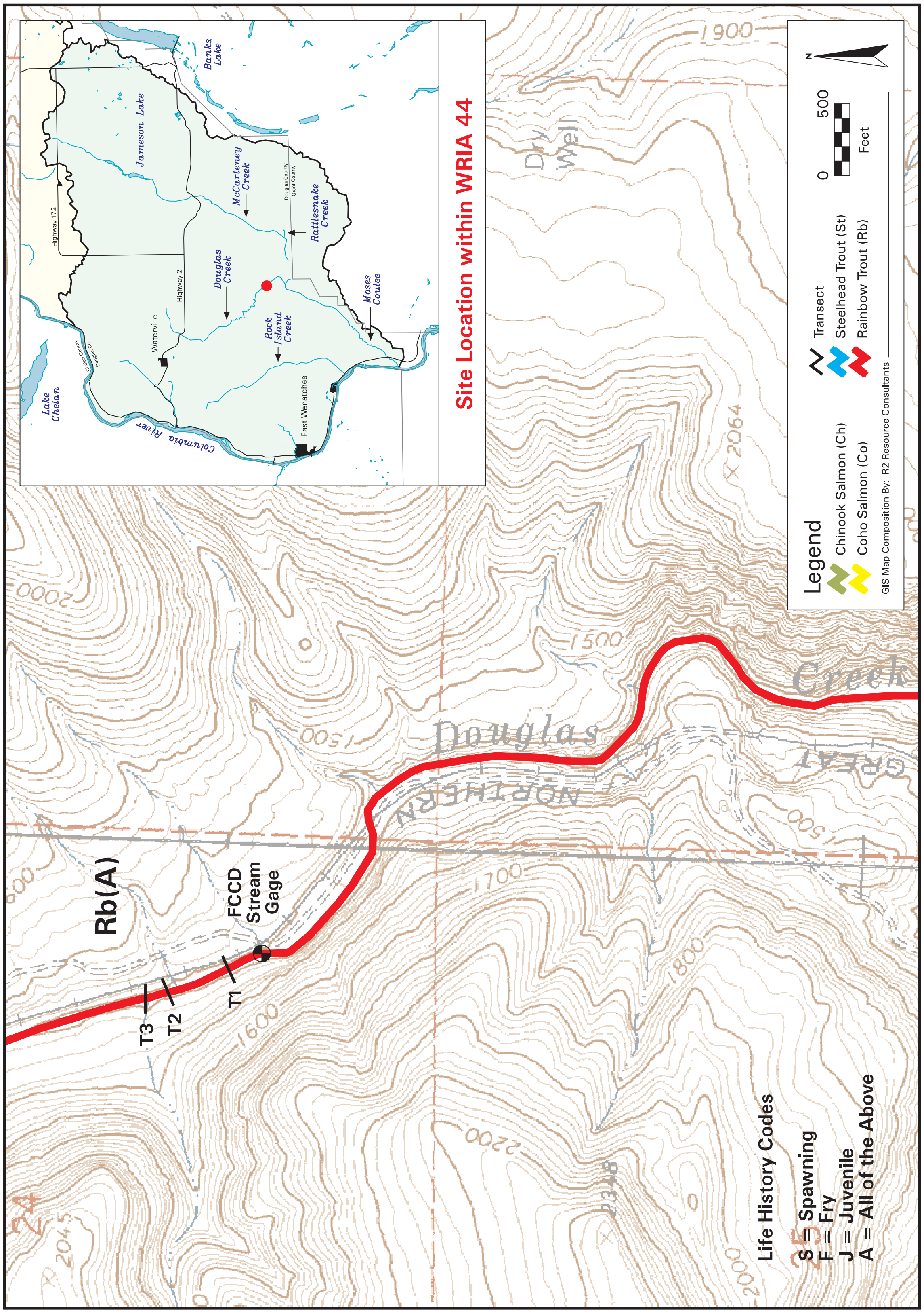


Figure 2–3. Fish species and distribution of life history stages in Douglas Creek.

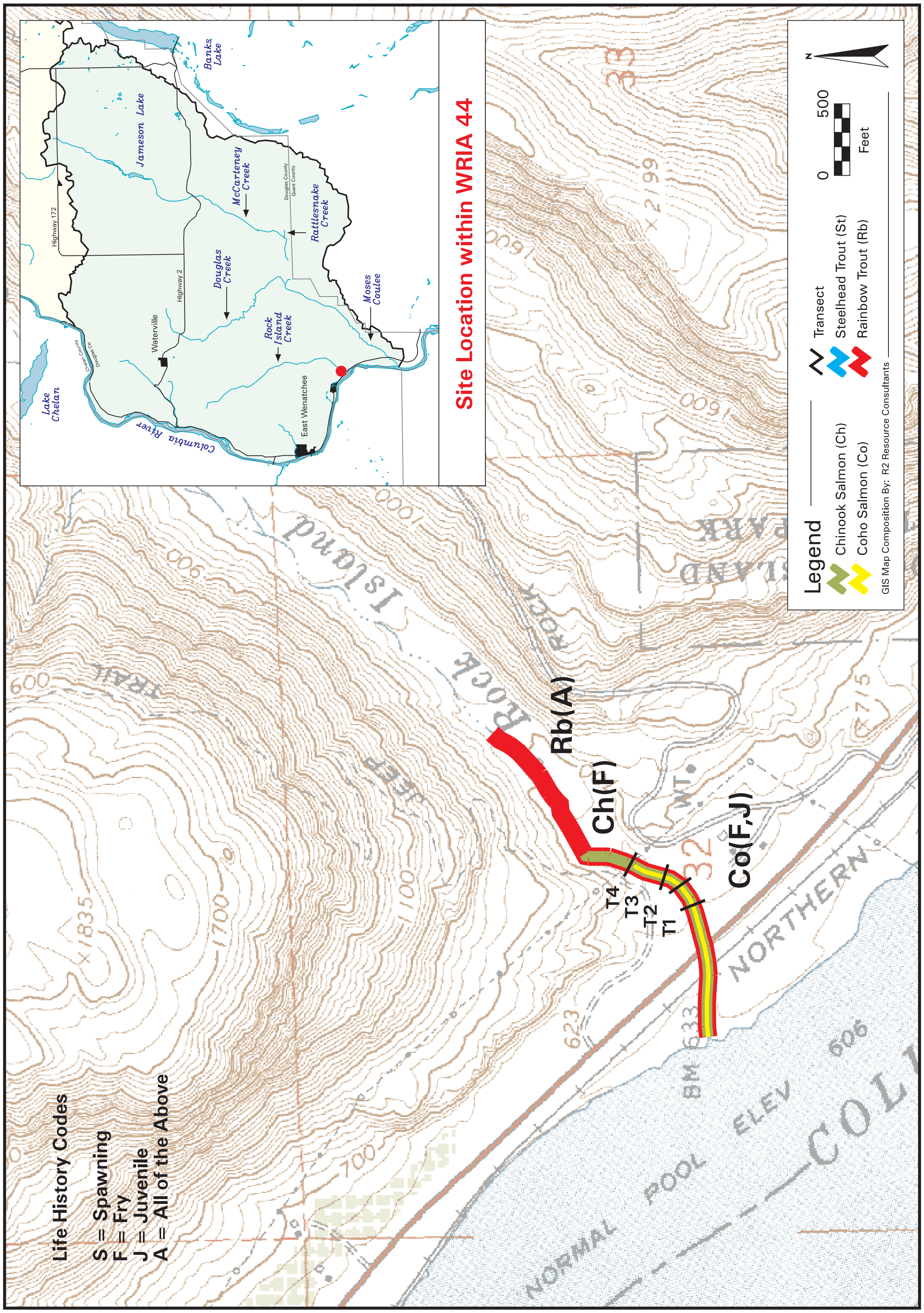


Figure 2-4. Fish species and distribution of life history stages in Rock Island Creek.

Creek are the result of Columbia River fish taking advantage of seasonal rearing opportunities in these tributary streams.

The various size classes of fish, their seasonal presence and water temperature data were used in determining the life-history stage periodicity charts for these species in the priority streams as shown in Tables 2-4 through 2-6. The periodicity table developed for each of the priority streams was used to focus the assessment of monthly instream flow needs on the particular species and life stages that are expected to utilize the stream during each monthly time-step.

Table 2-4. Life-history stage periodicity chart for species of interest in Rock Island Creek.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout												
Spawning			X	X	X							
Incubation					X	X						
Summer Rearing						X	X	X	X	X	X	
Winter Rearing	X	X	X								X	X
Chinook Salmon												
Summer Rearing				X	X	X	X	X	X	X	X	
Winter Rearing	X	X	X								X	X
Juvenile outmigration				X	X	X						
Coho Salmon												
Summer Rearing				X	X	X	X	X	X	X	X	
Winter Rearing	X	X	X								X	X
Juvenile outmigration					X	X						

Table 2-5. Life-history stage periodicity chart for species of interest in Foster Creek.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout												
Spawning				X	X	X						
Incubation					X	X	X					
Summer Rearing						X	X	X	X	X	X	
Winter Rearing	X	X	X								X	X
Summer Steelhead Trout												
Adult migration				X	X	X	X					
Spawning				X	X	X						
Incubation				X	X	X	X					
Summer Rearing						X	X	X	X	X	X	X
Winter Rearing	X	X	X								X	X
Juvenile outmigration				X	X							
Chinook Salmon												
Summer Rearing				X	X	X	X	X	X	X	X	X
Winter Rearing	X	X	X								X	X
Juvenile outmigration				X	X	X						

Table 2-6. Life-history stage periodicity chart for species of interest in Douglas Creek.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainbow Trout												
Spawning			X	X	X							
Incubation			X	X	X	X						
Summer Rearing	X	X	X	X	X	X	X	X	X	X	X	X

The recommended seasonal flow regimes address the critical or priority species and life-history stages for any given month for each stream using the site-specific life history information. A hierarchical listing of each of the species and life stages known to use the study streams was developed as follows:

Stream	Time Period	Priority Life-history Phase
Foster Creek	April to June	Steelhead Spawning
	July to November	Summer Rearing
	December to March	Winter Rearing
Rock Island Creek	March to May	Trout Spawning/Chinook Rearing
	June to October	Summer Rearing
	November to February	Winter Rearing
Douglas Creek	March to May	Trout Spawning
	June to February	Trout Rearing

3. METHODS

The methods used for assessing instream flow needs depended on the channel characteristics, flow regime and species utilization in for each stream. Methodologies for determining instream flow requirements can generally be grouped into three general categories: 1) hydrology-based methods; 2) hydraulic rating methods; and 3) habitat rating methods. Within these categories, three different but interconnected methodologies including Tennant/Tessman Method and flow exceedence metrics (hydrology), wetted perimeter (stream channel morphology), and PHABSIM (habitat) were the primary methods used to assess minimum instream flow needs for the priority streams. These methods are included as potential instream flow methods used in Washington State (Ecology 2002) and their use was approved by the State of Washington (WDFW and Ecology) for establishing minimum instream flows for this project (Watershed Instream Flow Recommendations Step A – Scope of Work, R2 Resource Consultants 2002). Comparisons of the results of these methods with the anticipated monthly frequency of water availability in the streams based on hydrologic exceedence flow levels occurred to help put the results in context. Additionally, an evaluation of the relationship between riparian vegetation and water quality was also completed to assist with determining instream flow needs. An overview of the major components and procedures followed in each of the methodologies is described below.

3.1 HYDROLOGIC ASSESSMENT (TENNANT/TESSMAN)

The Tennant Method was developed by Donald Tennant in 1975 and has been applied widely to establishing instream flows in broad scale studies and regional planning efforts (Tennant 1975). The method can be used with limited or extensive hydrological and fisheries data. The Tennant Method is considered one of the simplest techniques evaluating instream flows for fish. The method relies on eight flow classifications established by Tennant after analyzing a series of field measurements and observations (Table 3-1). Each classification is assigned a percentage or percentage range of the average annual flow (QAA). The percentages are applied to specific times of year with the year divided into two six-month periods, April through September and October through March.

The QAA was estimated from existing flow records (Appendix A). Habitat quality is then expressed as a percent of QAA ranging from less than 10 percent (Severe Degradation) to 60-100 percent (Optimal Range). Per the study objectives, an instream flow level that provides “good” flow conditions (20 to 40 percent of QAA), was used to approximate a minimum flow level for maintaining existing habitat conditions.

Table 3-1. Habitat quality as expressed as a percentage of QAA (Tennant 1975)

Narrative Descriptions of Flows	**Recommended Base Flow Regimes (QAA)**	
	Oct. – Mar.	**Apr. – Sept.**
Flushing Flow	200%	200%
Optimal Range	60 – 100%	60 – 100%
Outstanding	40%	60%
Excellent	30%	50%
Good	20%	40%
Fair	10%	30%
Poor or Minimum	10%	10%
Severe Degradation	<10%	<10%

The Tessman modification of the Tennant Method (*in* Wesche and Rechard 1980) is designed to account for the importance of flow cycles and stream productivity on ecosystems. It is based on the following assumptions:

- The best flow model is one that mimics nature. Hence, minimum flow values should parallel the natural flow regime during the yearly cycle.
- Living components of the stream ecosystem are adapted to the natural flow regime and depend both on high flows and periods of low or even zero flow to satisfy all requirements of their life cycles.

The Tessman method accommodates fluctuation in periodicity by calculating minimum flows on a monthly basis rather than on an annual or bi-annual basis. The recommended minimum is calculated as a percent of the mean monthly flow (MMF) rather than the average annual flow (QAA). Tessman modified Tennants' seasonal flow recommendations using the following guidelines:

- Monthly minimum flow equals the MMF, if MMF <40 percent of average annual flow (QAA);
- If MMF >40 percent QAA, then monthly minimum equals 40 percent QAA;

- If 40 percent MMF >40 percent QAA, then monthly minimum equals 40 percent QAA.

The approach used a mean value of 40 percent of the mean monthly flow as mid-way between the 30 percent and 50 percent values Tennant used to represent excellent habitat during the two periods of the year.

Modifications to the Tennant method that address flows as a function of MMF are more appropriate for WRIAs 44 and 50 streams than the original Tennant method due to the ability to take monthly flows into consideration. Hydrologic data provided by the Montgomery Water Group was used to calculate the percent of average annual and mean monthly flow values required as part of this method (Appendix A). These values were used for comparison with result of the PHABSIM analysis.

3.2 CHANNEL MORPHOLOGY (WETTED PERIMETER)

The wetted perimeter method provides a graphic representation of the channels' wetted perimeter versus discharge and uses the relationship as a surrogate for physical habitat. This method is widely used an alternative or supplemental approach to PHABSIM and involves a cross-sectional hydraulic measurement as a way to approximate available aquatic habitats. The distance from water's edge to water's edge along the bottom of the channel is defined as the wetted channel perimeter. This hydraulic variable changes with flow and a variety of biological benefits have been ascribed to increasing the amount of wetted perimeter. In this approach, a desired low-flow value is chosen based on the shape of the wetted perimeter-flow curve.

The wetted perimeter analysis was applied to all transects as an indicator of habitat conditions throughout the stream. The analysis procedure selected the break or "inflection point" in the streams wetted perimeter versus discharge relationship as a surrogate for minimally acceptable habitat. The inflection point represents the flow where the rate of wetted perimeter change begins to slow with increasing discharge.

The channel cross sectional data were used and combined with the hydrologic data to produce graphical figures displaying the relationship between flow and wetted perimeter for each of the channel transects. The results of this effort were subsequently compared to results of the PHABSIM and Tessman analysis to provide additional perspective into the setting of minimum instream flow levels.

In the case of Douglas Creek, it was one of the major methods utilized for the fish habitat assessment. Transects were placed across suitable spawning areas for resident fish and areas important for invertebrate production. Data collection occurred during a range of seasonal flow conditions to allow an assessment of changes in wetted perimeter of the channel with stream flow.

3.3 FISH HABITAT; PHYSICAL HABITAT SIMULATION (PHABSIM)

The major steps in quantifying how the amount of available fish habitat changes in response to incremental changes in stream flow are briefly described below.

3.3.1 Sampling Site and Transect Selection

The number and location of instream flow transects within each segment was based on the habitat composition within the segment and through consultation with the resource agencies during a January 31, 2003 site visit. Only run, riffle, and pool, habitat types comprising greater than 10 percent of the channel type length were sampled. Individual transects were placed in representative units of the particular habitat type. The number and distribution of instream flow transects for each of the study streams in presented in Table 3-2.

Table 3-2. Location and number of instream flow sampling transects used as part of the instream assessment of WRIAs 44 and 50 priority streams.

Stream	Channel Type	Habitat Composition (%)				Total # of Transects
		Cascade	Pool	Riffle	Run	
Foster Creek	Step-pool	53	20	20	5	
	# of Transects	0	2	2	0	4
	Pool-Riffle	0	16	56	28	
	# of Transects	0	1	3	1	5
Rock Island Creek	Pool-Riffle	0	25	74	1	
	# of Transects	0	2	2	0	4
Douglas Creek[1]	No Habitat Data					
	# of Transects		1	2		3
Total		0	5	7	1	16

[1]Habitat surveys were not completed on Douglas during the Phase 1 Assessment. The number of transects was based on an assessment of habitat conditions during the site surveillance and the uniform habitat features present.

Each transect extended across the stream up to approximately the 20- and 100-year flood elevations on both banks, depending on local morphological conditions. This approach, ensured the transect survey data could be integrated as part of the wetted perimeter and riparian vegetation assessments. Each transect location was marked on topographic maps and GPS coordinates were recorded (Figures 3-1, 3-2, and 3-3).

3.3.2 Field Procedures/Data Collection

Field measurements were taken over a range of stream flows to allow PHABSIM modeling of habitat conditions over the extent of flow conditions experienced in Foster, Rock Island, and Douglas creeks (Table 3-3) (Appendix C). All three streams were surveyed under three flow conditions. The first survey was conducted in February 2003, the second in June 2003, and the third in August 2003. The collection of physical and hydraulic measurements at each transect was completed following the procedures for PHABSIM studies outlined by Bovee and Milhous (1978), Bovee (1982), and Trihey and Wegner (1984). Field data were collected by a field crew of 2 to 3 individuals (depending upon flow conditions) with experience in both the field and office components of PHABSIM measurements and hydrologic modeling.

The establishment of cross channel transects at each sampling location included securing transect benchmarks, working pins and surveying headpin elevations. Transect water surface elevations, depth, velocity, and substrate measurements were measured at each transect under all three stream discharges.

The following data were recorded at each transect: (1) segment and transect number; (2) habitat type – classified as run, riffle, or pool; (3) flow – information regarding the timing and under what flow conditions the data were collected; (4) local longitudinal bed profile and water surface elevations (WSEs) – measured to the nearest 0.01 ft.; and (5) photographs of each transect taken during each of the three flow samplings.

Data were also collected at set intervals across each transect. Sampling intervals were established so the flow between any two intervals (cells) did not exceed 10 percent of the total flow in the channel. The following data were collected at measurement points (verticals) across each transect: (1) bed elevations (to nearest 0.01 ft); (2) water depth (to nearest 0.1 ft); (3) mean column water velocity (to nearest 0.1 ft/sec); (4) substrate characteristics (dominant and subdominant); and (5) cover at each measurement point.

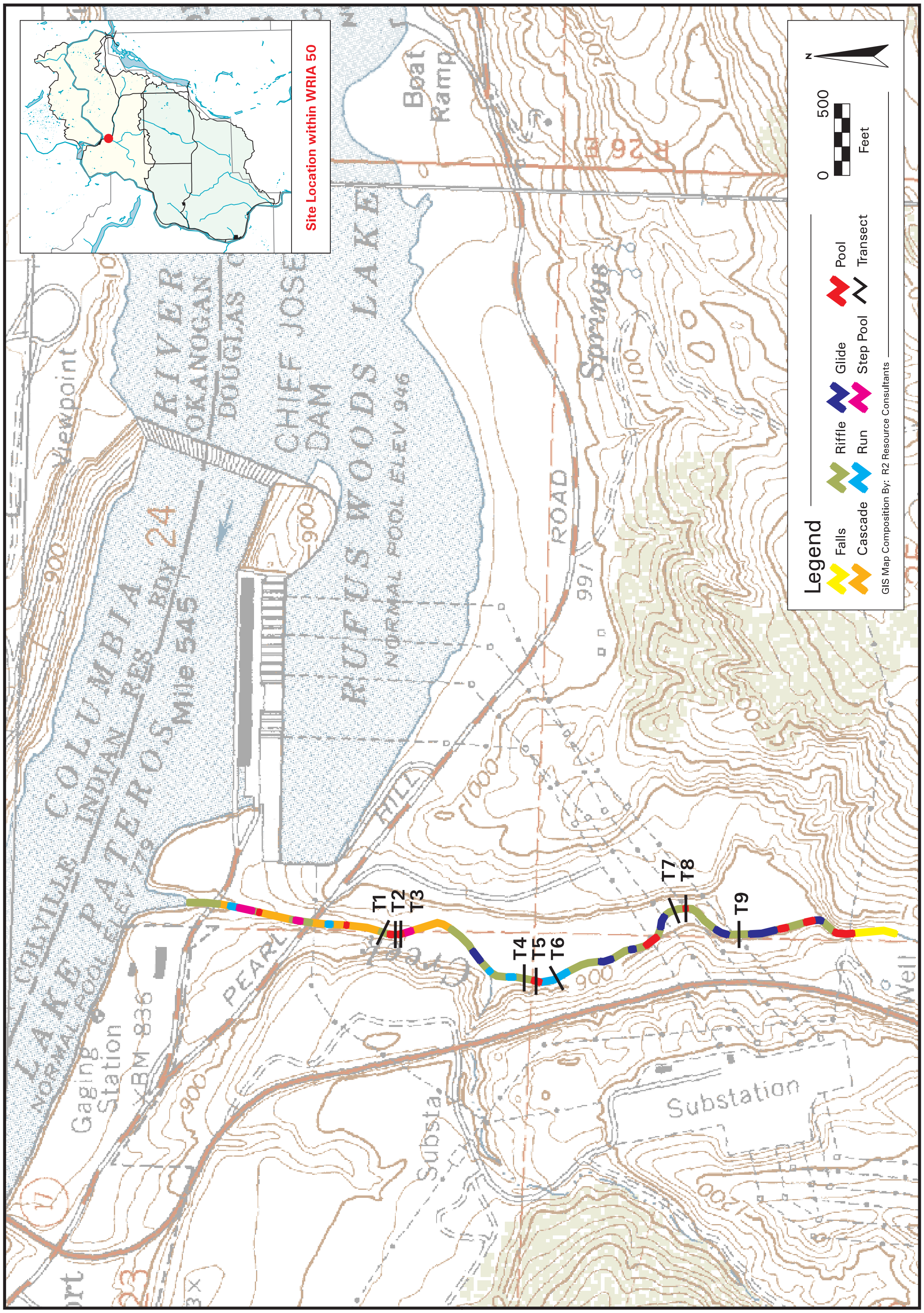


Figure 3-1. Location of habitat types in Foster Creek and instream flow study transects.

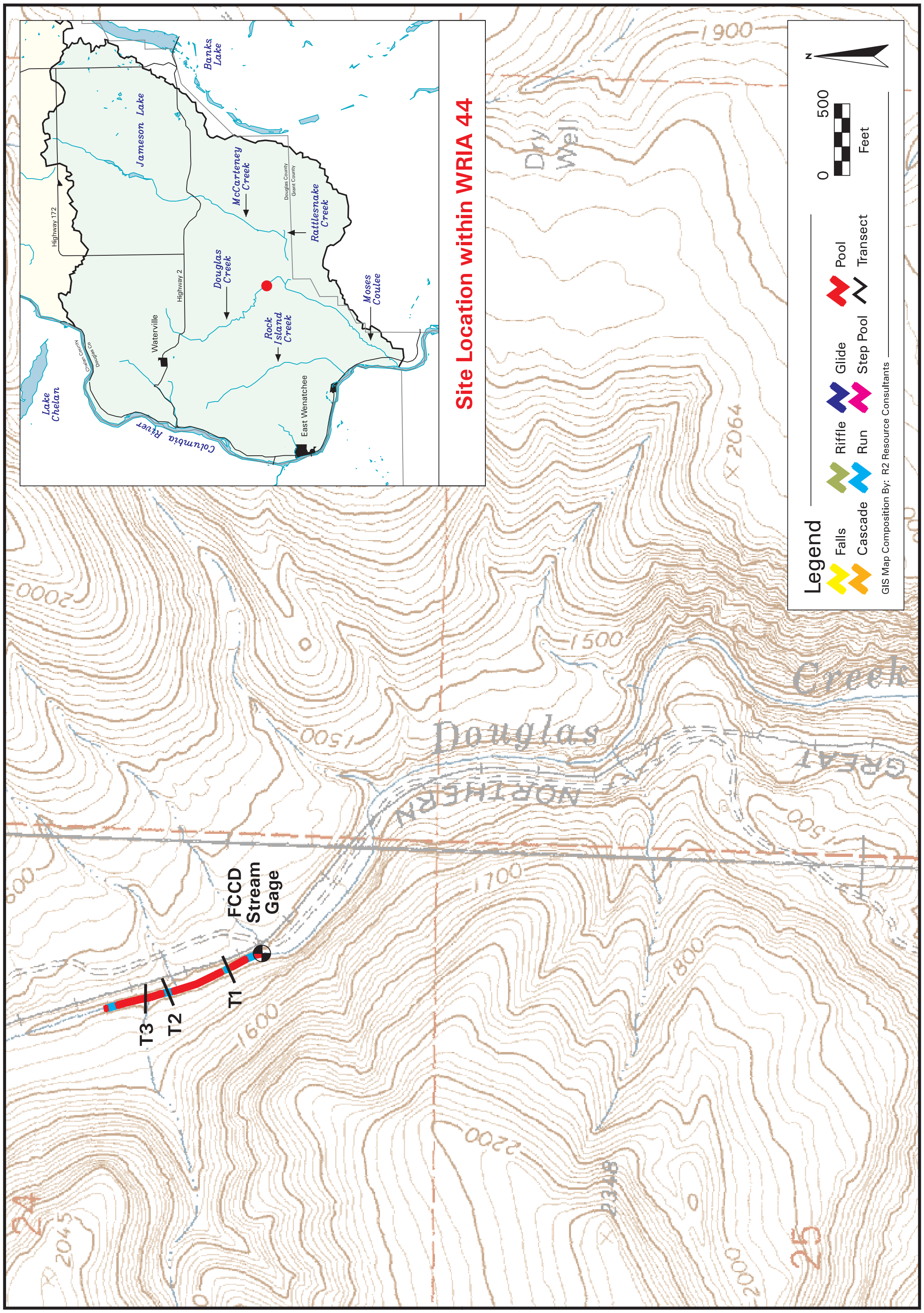


Figure 3-2. Location of habitat types in Douglas Creek and instream flow study transects.

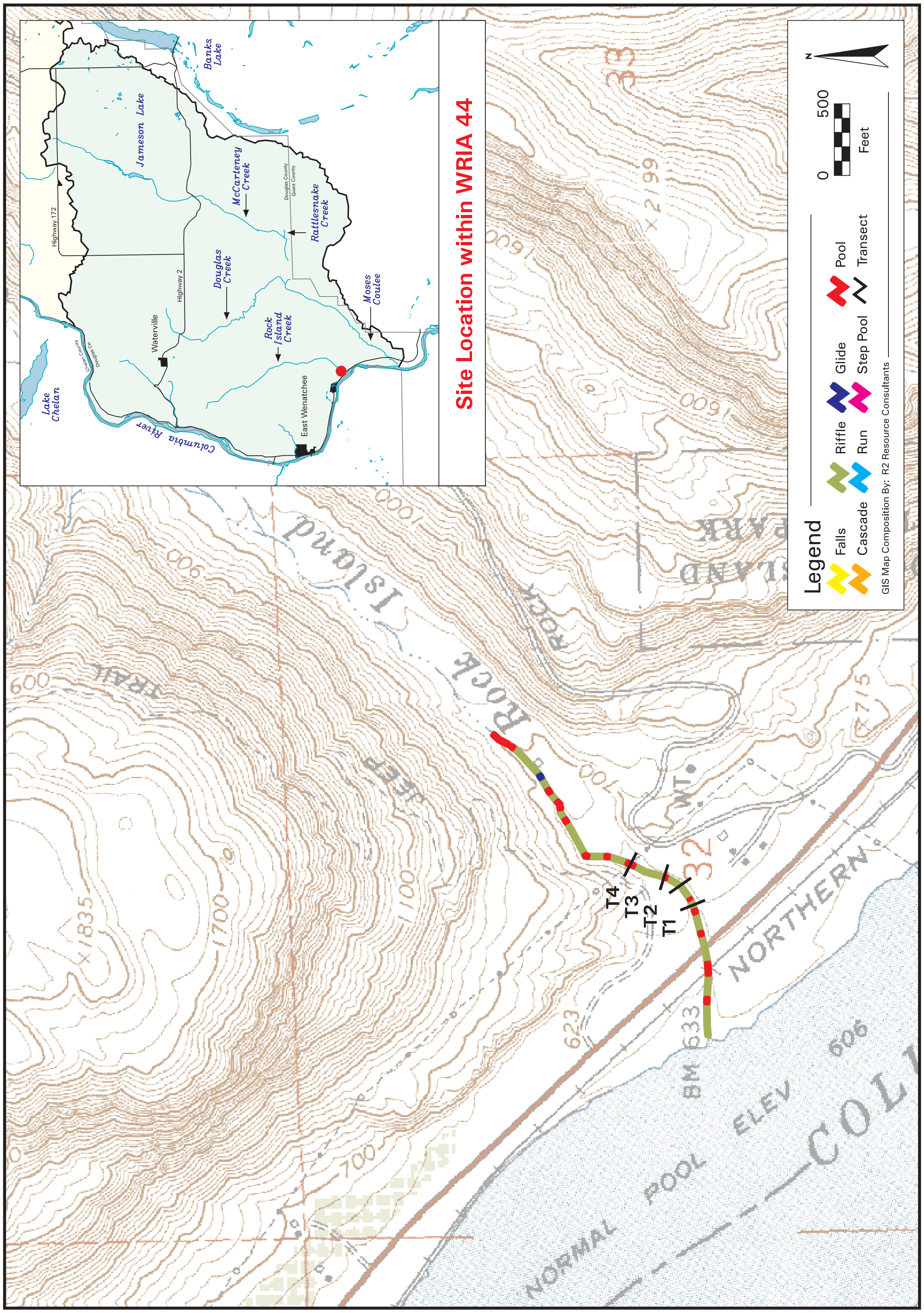


Figure 3–3. Location of habitat types in Rock Island Creek and instream flow study transects.

Table 3-3. Summary of survey dates and stream discharges during field data collection for each of the priority streams.

	High Flow		Medium Flow		Low Flow	
Stream	Date	Discharge (cfs)	Date	Discharge (cfs)	Date	Discharge (cfs)
Foster Creek	02/27/03	11.7	06/05/03	3.7	08/26/03	1.5
Rock Island Creek[1]	06/03/03	2.4	02/28/03	1.7	08/26/03	0.30
Douglas Creek	02/27/03	14.5	06/04/03	11.6	08/27/03	11.1

[1] Due to late runoff, the high and mid flow events occurred opposite to the other two streams. An additional sampling (at 0.6 cfs) was conducted on Rock Island Creek in early August 2003 to ensure sufficient water depth to accurately measure channel hydraulics.

3.3.3 Hydraulic and Habitat Modeling

Hydraulic Modeling

Hydraulic and habitat simulation modeling were conducted using PHABSIM Version II computer software (Milhous et al. 1989). Hydraulic simulations modeling included the following steps: (1) raw field data were entered into Excel spreadsheets, (2) the data were reviewed and reduced into a form ready for creation of hydraulic data decks; (3) hydraulic data input files were generated for the PHABSIM hydraulic simulation program; (4) stage-discharge relationships were developed using the IFG4 hydraulic simulation procedure; and (5) velocities across each transect were calibrated to provide a realistic distribution of mean column velocities across the stream channel for the entire range of flows employed in habitat simulations.

Transect Weighting

Two levels of habitat weighting were employed in the instream flow study: transect and reach. A habitat mapping approach was used in determining the weighting factors for individual transects and reaches. Individual transects were provided weighting factors based upon the amount of habitat represented by each transect within a specific reach. For example, if pools constituted 10 percent of the length of a reach, pools were assigned a weighting factor of 10 percent in PHABSIM habitat simulation runs conducted for that transect.

Individual reaches were weighted according to the amount of linear habitat they represented in the entire study section. The length of channel represented by each reach was determined from channel condition observations made by R2 during habitat surveys completed in May of 2001. An exception to this method was made for steelhead spawning in Foster Creek. Since most (10 out of 11 redds) steelhead spawning occurs within Reach 3 of Foster Creek a reach weighting of 0.9 for spawning was used for transects located within Reach 3 and a weighting factor of 0.1 was used for transects located in Reach 2. For all other species and life stages, reach weighting was based on reach length.

The percent weighting of each transect relative to the length of stream reach are presented in Tables 3-4 and 3-5. Since habitat mapping was not completed on Douglas Creek, transect weighting was equally distributed between the three transects. Each transect was assigned a weighting of 33.3 percent.

Habitat Suitability Criteria

Habitat suitability index (HSI) curves reflect species and life stage use and preference for selected habitat parameters, including depth, velocity, and substrate (cover is also used in some models) (Bovee 1982). Depending on the extent of data available, HSI curves can be developed from the literature (Category I curves), or from physical and hydraulic measurements made in the field over species microhabitats (Category II curves). These latter curves, when adjusted for availability (i.e., the quantity of habitat present within a given study reach) may more accurately reflect species preference (Category III curves) (Bovee 1986).

Site specific suitability curves were not available for the project streams and it was not possible to collect site-specific habitat suitability data as part of this study. For these reasons, habitat suitability index curves (HSI) were obtained from existing literature sources. The WDFW Fallback HSI curve set (WDFW and Ecology June 2003) were initially evaluated for applicability to the habitat conditions found in the project streams. Due to the small size and extreme low flow conditions experienced by streams in the project area, the State Fallback curves did not represent the range of suitable depth and velocity conditions available to salmonid fishes in the project streams under all situations.

Table 3-4 Individual transect and reach weighting employed in the Foster Creek, Washington, PHABSIM habitat simulations. Values based upon results of Foster Creek habitat mapping completed by R2 during the spring of 2001.

	Reach Habitat Composition					Transect Weighting			
Reach	**Habitat Type**	**Length (ft)**	**Percent of Total**	**Number of Transects**	**Transect Number(s)**	**Length (ft)**	**Percent of Total**	**Transect Weighting**	**Reach Weighting**
1	Pool	0	0	0	-	0	0	-	
Alluvial	Riffle	125	100%	0	-	0	0	-	
Fan	Glide	0	0	0	-	0	0	-	
	Cascade	0	0	0	-	0	0	-	
	Total	**125**	**100%**	**0**		**0**	**0**		**2%**
2	Step-Pool	350	20%	1	3	350	53%	53%	
Step-Pool	Riffle	315	18%	2	1, 2	315	47%	23.5%	
	Glide	105	6%	0	-	0	0	-	
	Cascade	981	56%	0	-	0	0	-	
	Total	**1752**	**100%**	**3**		**665**	**100%**		**34%**
3	Pool	459	14%	2	5, 8	459	17%	8.5%	
Pool-Riffle	Riffle	1837	56%	3	4, 7, 9	1837	69%	23%	
	Glide	384	30%	1	6	384	14%	14%	
	Cascade	0	0	0	-	0	0	-	
	Total	**3280**	**100%**	**6**		**2680**	**100%**		**64%**

Table 3-5 Individual transect and reach weighting employed in the Rock Island Creek, Washington, PHABSIM habitat simulations. Values based upon results of habitat mapping completed by R2 during the spring of 2001.

	Reach Habitat Composition					Transect Weighting			
Reach	**Habitat Type**	**Length (ft)**	**Percent of Total**	**Number of Transects**	**Transect Number(s)**	**Length (ft)**	**Percent of Total**	**Transect Weighting**	**Reach Weighting**
1	Riffle	2206	76.0%	2	1, 2	2206	23%	11.5%	
Pool-Riffle	Step-Pool	660	22.8%	2	3, 4	660	77%	38.5%	
	Glide	35	1.2%	0	-	0.0	0	-	
	Cascade	0.0	0.0%	0	-	0.0	0	-	
	Total	**2901**	**100%**	**4**		**2866**	**100%**		**100%**

As an example, the range of depth and velocities measured during each of the three samplings for two transects (actual steelhead spawning locations) on Foster Creek are plotted in Figure 3-4 with State fallback and recommended HSI curves for steelhead trout spawning. The recommended HSI curves were selected from small rivers and streams in Idaho, Oregon, and Washington states, especially those in low-gradient, semi-arid locations and spring or groundwater dominated sources. If the State fallback curves were used to predict the flow versus habitat relationship for spawning steelhead trout, only flows as high or higher than the highest measured flow (11.7 cfs) would produce suitable habitat conditions. Since we know from spawning surveys conducted on Foster Creek that successful steelhead spawning occurred at flows of 3.0 cfs or less, the State fallback curves did not appear to adequately represent spawning habitat conditions in this system. Per guidance from WDFW, the final HSI curve for steelhead trout spawning in this assessment used the leading edge of the recommended curves in Figure 3-4 and the trailing edge of the State fallback curves to account for site-specific observations of spawning in shallow, slow water.

For all spawning life stages, the State fallback curves for substrate suitability were combined with depth and velocity criteria from the blended HSI curves to form a composite curve set. The final curves sets used as part of this study, with the concurrence of the WDFW, are presented in Appendix D.

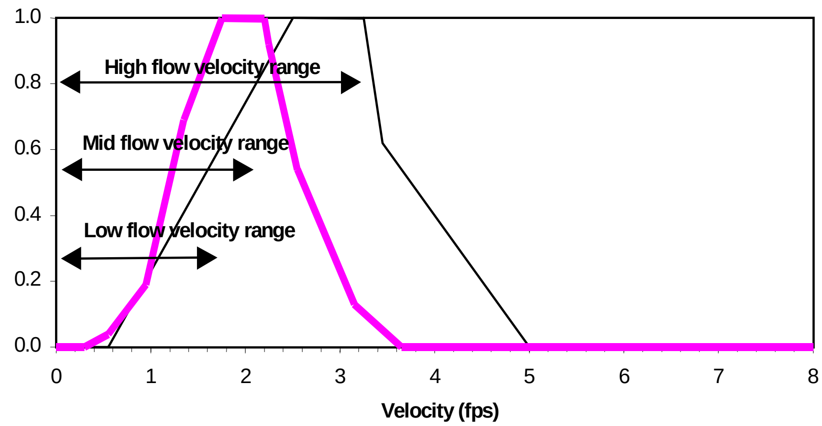
Habitat Simulation Modeling

Output from the hydraulic simulation modeling was used in conjunction with HSI curves to simulate habitat conditions for each target species and life stage over a wide range of flows. Habitat simulations were conducted using the HABTAT simulation modeling program. HABTAT averages velocity values between adjacent verticals for use in habitat area calculations.

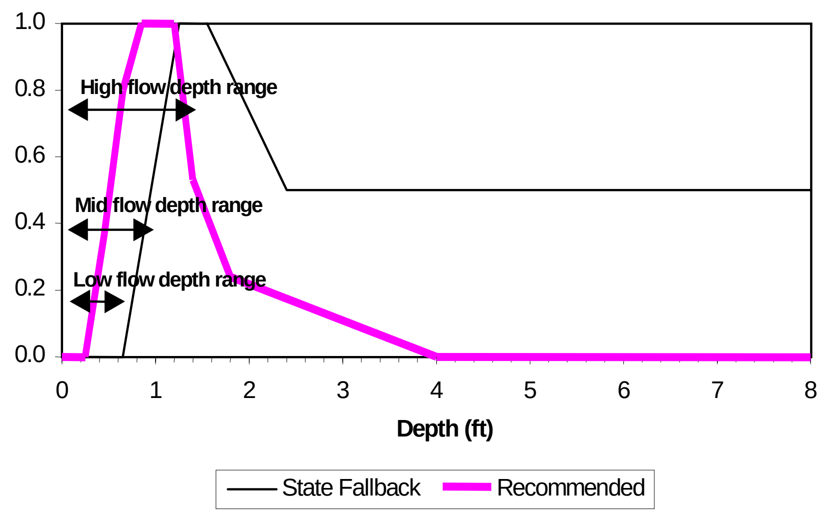
Weighted Usable Area Curves

Weighted usable area (WUA) habitat versus discharge curves were calculated for each target fish species and life stage for all transects and reaches. WUA is a habitat index that combines the quantity and quality of that habitat provided by alternative flows. WUA is expressed in units of square feet of habitat area per 1,000 linear ft of stream (sq-ft per 1,000 ft); (Bovee 1982, Milhous et al. 1989). The WUA versus flow curves for each transect were combined (using the appropriate transect weighting) to determine the amount of WUA provided by each of the modeled flows.

State Fallback Velocity		Recommended Velocity	
X	Y	X	Y
0.00	0.00	0.00	0.00
0.55	0.00	0.30	0.00
2.50	1.00	0.55	0.04
3.25	1.00	0.95	0.19
3.45	0.62	1.35	0.69
5.00	0.00	1.75	1.00
8.00	0.00	2.20	1.00
		2.25	0.92
		2.55	0.54
		3.15	0.13
		3.65	0.00
		8.00	0.00



State Fallback Depth		Recommended Depth	
X	Y	X	Y
0.00	0.00	0.00	0.00
0.65	0.00	0.25	0.00
1.25	1.00	0.45	0.37
1.55	1.00	0.65	0.80
2.40	0.50	0.85	1.00
5.00	0.50	1.20	1.00
8.00	0.50	1.40	0.53
		1.80	0.24
		4.00	0.00
		8.00	0.00



High Flow = 11.1 cfs
Mid Flow = 3.7 cfs
Low Flow = 1.7

Species: Steelhead Trout
Lifestage: Spawning

Source: Washington State Fallback Curves
Source: Reiser et al. 1989, Idaho

Figure 3-4. Comparison of Habitat Suitability Criteria for spawning steelhead trout with measured stream depths and velocities at transects with known spawning activity in Foster Creek during the spring of 2003.

3.4 ANALYSIS OF RIPARIAN VEGETATION

Given the importance of riparian plant communities to the proper functioning of stream ecosystems, and specifically to the maintenance of desirable fish populations, an understanding of how stream flow levels maintain riparian resources is an important component in establishing an instream flow water right. As part of the Step B instream flow assessment data gathering process for the study streams, a characterization of the riparian plant communities along each transect and an analysis of their relationship to current flow regimes was conducted.

There were three steps to the approach for understanding the relationship of riparian resources and flows in the Foster, Rock Island and Douglas creek systems. The first step consisted of characterizing the distribution (vertical and horizontal) of riparian plant communities along each transects. The second step entailed an analysis of the stream cross section, distribution of vegetation, and hydraulic characteristics (e.g., water surface elevations and flow exceedence) along each of the channel transects. The hydraulic analyses conducted for the PHABSIM component of the study was extended to the floodplain to determine water surface elevations and flow exceedence statistics for flows within the riparian zone. The elevation of dominant species or vegetation types was related to specific discharges, flood frequencies and seasonal groundwater tables, providing specific flow attributes associated with common riparian vegetation types found in the study reach.

In the final step, using the flow and geomorphic characteristics associated with each vegetation type, the recommended and alternative flow regimes were evaluated for how the distribution of riparian vegetation types may be altered. This approach entailed interpreting how changes in duration or timing of water will affect each riparian vegetation type within a specified geomorphic setting and predicting possible changes.

3.5 WATER QUALITY

Water quality and water quantity need to be managed together, since actions affecting one will affect the other. Water temperatures were evaluated using SSTEMP – Stream Segment Temperature Model developed by USGS/BRD Fort Collins Science Center. SSTEMP simulates downstream water temperature in a flowing river segment over a 24-hour day given inputs of meteorology, stream geometry, and hydrology (Bartholow, J.M. 2002).

The input parameters into SSTEMP for the three creeks are outlined in Tables 3-6 and 3-7. The variable input parameters are summarized in Table 3-6, while the constant parameters are summarized in Table 3-7. Most meteorological data including air temperature, relative humidity, wind speed, and solar radiation, were obtained from the Western Regional Climate Center webpage for the Douglas, Washington RAWS site (http://www.wrcc.dri.edu/cgi-bin/rawMAIN.pl?waWDOU). The model was set up to simulate both extreme and average weather events during the summer months. The 7-day moving average air temperature was calculated for the months of July and August for the period of record (1990-2003) and the maximum value was used in the model to represent an extreme event. The maximum air temperature, relative humidity, and wind speed over the period of record were also used in the extreme weather event model. The average of the daily average and maximum air temperatures, wind speed, and relative humidity were used in the average weather event model.

Using the input parameters outlined in Tables 3-6 and 3-7, stream flows between the 10 percent and 90 percent exceedence levels were input into the model and the predicted mean, estimated maximum, and approximate minimum water temperatures were estimated. A relationship between stream temperature and stream discharge was subsequently established with the modeling effort. The model was used to evaluate the effect of minimum instream flows on surface water temperature and subsequently to other water quality parameters. Temperature results were extrapolated in a qualitative manner to anticipated changes in dissolved oxygen (DO) and percent oxygen saturation levels.

Table 3-6. Variable SSTEMP Input Parameters for Extreme and Average Weather Events

Input Parameter	**Douglas Creek (Extreme/Average)**	**Foster Creek (Extreme/Average)**	**Rock Island Creek (Extreme/Average)**
Segment Inflow (cfs)	6.0-40.0 cfs	0.7-30.0 cfs	0.1-6.0
Inflow Temperature (C)	18.3/17.8	16.1/14.8	17.1/16.9
Segment Outflow (cfs)	Same as segment inflow	Same as segment inflow	Same as segment inflow
Accretion Temp (C)	17.8	14.8	16.9
Segment Length (mi)	0.5	0.5	0.5
Upstream Elevation (ft)	1,350	1,000	1,500
Downstream Elevation (ft)	1,331	970	1,431
Width’s A Term	20.5	9.6	10.9
B Term	0.01	0.09	0.09
Manning’s n	0.04	0.04	0.04
Total Shade (%)	30	30	32.5

Table 3-7 Constant SSTEMP Input Parameters for Extreme and Average Weather Events

Parameter	Value (Extreme/Average)	Calculation (Extreme/Average)	Source
Air Temperature (F)	82.9/69.0	Maximum/Average of 7-day moving average series	July and August daily air temperature data for 1990-2003 from the Douglas RAWS site.
Maximum Air Temperature (F)	94.2/83.2	7-day average for the same days having the maximum 7-day moving average air temperature/Average	July and August maximum daily air temperature data for 1990-2003 from the Douglas RAWS site.
Relative Humidity (%)	29.6/39.0	7-day average for the same days having the maximum 7-day moving average air temperature/Average	July and August average daily relative humidity data for 1990-2003 from the Douglas RAWS site.
Wind Speed (mph)	6.5/9.2	7-day average for the same days having the maximum 7-day moving average air temperature/Average	July and August average daily wind speed data for 1990-2003 from the Douglas RAWS site.
Ground Temperature (F)	80.0/69.0	Two week average air temperature for the days prior to the maximum 7-day moving average air temperature/Average Air Temperature	July and August daily air temperature data for 1990-2003 from the Douglas RAWS site.
Thermal Gradient	1.65	Default value given in SSTEMP manual	Default value given in SSTEMP manual
Possible Sun (%)	70.0	Monthly Average Cloud Cover data for Yakima	Monthly Average Cloud Cover data for Yakima
Solar Radiation (langleys/day)	550/588	7-day average for date with a similar 7-day moving average air temperature/ Average	July and August total solar radiation data for 1998-2003 from the Douglas RAWS site.
Latitude (degrees)	40	Washington State Atlas	Washington State Atlas
Month/day	August 15		

4. RESULTS

This section presents the results of the instream flow study and includes specific sections on hydrologic, channel, and biological habitat assessments. Additional discussion is included for riparian and water quality assessments completed for Rock Island, Douglas, and Foster creeks.

4.1 HYDROLOGIC ASSESSMENT

4.1.1 Tennant Method

Using average annual flow (QAA) estimates developed from existing stream flow records (Appendix A) an assessment of habitat quality expressed as a percentage of average flow conditions was completed for each of the priority streams (Table 4-1 to 4-3). Following Tennant Method procedures, habitat quality was expressed as a percentage of QAA ranging from less than 10 percent (necessary to sustain short-term survival) to 60 percent - 100 percent (considered to provide excellent and optimal conditions, respectively). In accordance with study objectives, the assessment focused on flow levels in the good habitat, 20 to 40 percent of QAA, range. This range of flow is considered to provide average or satisfactory flow conditions for fish (Stalnaker and Arnette 1976). The percentages were assigned to a specific time of year with the year divided into six-month periods (Section 3.1).

Foster Creek

The average annual flow in Foster Creek is estimated to be 7.2 cfs (Appendix A). Applying the Tennant Method criteria for “good” conditions of 20 and 40 percent of the average annual flow produce a flow range from 1.4 cfs to 2.9 cfs in Foster Creek (Table 4-1). For comparison, flows in the “outstanding” category would range from 2.9 cfs in the fall and winter months to 4.3 cfs during the spring and summer, based on the Tennant methodology.

Douglas Creek

The average annual flow in Douglas Creek is estimated to be 12.8 cfs (Appendix A). Applying the criteria for “good” conditions of 20 and 40 percent of the average annual flow would produce a flow range from 2.6 cfs to 5.1 cfs in Douglas Creek (Table 4-2). For comparison, flows in the “outstanding” category would range from 5.1 cfs in the fall and winter months to 7.7 cfs during the spring and summer, based on the Tennant methodology.

Table 4-1. Foster Creek habitat quality as expressed as a percentage of average annual flow using the Tennant Method (1975).

Narrative Descriptions of Flow	Oct – Mar Flow Regimes (cfs)	Apr – Sept Flow Regimes (cfs)
Optimal Range	4.3 – 7.2	4.3 – 7.2
Outstanding	2.9	4.3
Excellent	2.2	3.6
Good	1.4	2.9
Fair	0.7	2.2
Poor or Minimum	0.7	0.7

Table 4-2. Douglas Creek habitat quality as expressed as a percentage of average annual flow using the Tennant Method (1975).

Narrative Descriptions of Flow	Oct – Mar Flow Regimes (cfs)	Apr – Sept Flow Regimes (cfs)
Optimal Range	7.7 – 12.8	7.7 – 12.8
Outstanding	5.1	7.7
Excellent	3.8	6.4
Good	2.6	5.1
Fair	1.3	3.8
Poor or Minimum	1.3	1.3

Table 4-3. Rock Island Creek habitat quality as expressed as a percentage of average annual flow using the Tennant Method (1975).

Narrative Descriptions of Flow	Oct – Mar Flow Regimes (cfs)	Apr – Sept Flow Regimes (cfs)
Optimal Range	0.11	0.11
Outstanding	0.04	0.06
Excellent	0.03	0.05
Good	0.02	0.04
Fair	0.01	0.03
Poor or Minimum	0.01	0.01

Rock Island Creek

The average annual flow in Rock Island Creek is estimated to be 0.9 cfs (Appendix A). The low average annual flow in Rock Island Creek results in an extremely low flow range of 0.2 cfs to 0.4 cfs to produce “good” conditions (Table 4-3). Likewise, flows in the “outstanding” category range from 0.5 cfs in the fall and winter months to 0.6 cfs during the spring and summer.

Because Tennant’s (1975) method is based on mean annual flow percentages, the reliability of recommendations may be less valid when applied to streams with stable flows (i.e., spring-dominated systems like Rock Island and Douglas creeks). The approach seems best suited for streams with fluctuating flow regimes (i.e., Foster Creek).

4.1.2 Tessman Method

The Tessman modification of the Tennant Method was used to accommodate annual fluctuations in flow levels by calculating minimum flows on a monthly basis rather than on an annual or bi-annual basis. The recommended minimum flows were calculated as a percent of the mean monthly flow (MMF) rather than the QAA as recommended by Tennant. Mean or average monthly flows were derived from the 50 percent exceedence values that were calculated from site specific flow data collected since the summer of 2001 at each of the priority streams (Appendix A).

Following the Tessman modified guidelines, the criteria listed below were used to develop monthly minimum instream flows:

- Monthly minimum flow equals the MMF, if MMF <40% of average annual flow (QAA);
- If MMF >40% QAA, then monthly minimum equals 40% QAA;
- If 40% MMF >40% QAA, then monthly minimum equals 40% QAA.

This approach uses the mean value of 40 percent of the mean monthly flow as mid-way between the 30 percent and 50 percent values Tennant used to represent excellent habitat during the two periods of the year. Results of the Tessman Method are presented below for each of the priority streams.

Foster Creek

Monthly average flows in Foster Creek ranged from a low of 0.9 cfs in the fall months to a high of 6.8 cfs during the winter (Table 4-4). Applying the Tessman criteria produces a range of flows from 0.9 cfs in August and September to a high of 6.8 cfs in January. The recommended flow range, using this method, appears to adequately represent the natural flow variability experienced in Foster Creek.

Douglas Creek

The range of monthly average flows calculated for Douglas Creek is narrow with a monthly high of 14.8 cfs in February and a low of 11.8 in September (Table 4-5). The variation of only 3 cfs between the high and low average monthly flows is reflected in the restricted range of monthly flows produced using the Tessman criteria. Applying the Tessman criteria produces a range of recommended flows from 4.7 cfs to 5.9 cfs (Table 4-5). The range of flows produced using this method appears to be extremely limited (1.2 cfs) and does not represent the natural flow variability experience in Douglas Creek (Figure 2-1).

Rock Island Creek

Monthly average natural stream flows in Rock Island Creek ranged from a low of 0.0 cfs in April, May, and October to a high of 0.3 cfs in March (Table 4-6). Like Douglas Creek, the limited variation in monthly stream flows results in a restricted range of flows produced using the Tessman criteria. Monthly flows produced using this method ranged from 0.0 cfs to a high of 0.1 cfs in March (Table 4-6).

The results of the Tessman modification to the Tennant Method resulted in considerably more variation on a monthly basis than the Tennant Method. Mean or average monthly flow conditions varied the most in Foster Creek and were more restricted in Douglas Creek and Rock Island Creek which have more consistent spring-fed stream flows.

Table 4-4. Recommended monthly instream flows developed for Foster Creek using the Tessman Method.

Month	Mean Flow (cfs)	40% of Mean Flow (cfs)	Tessman Flow (cfs)
October	2.0	0.8	2.0
November	3.9	1.6	1.6
December	6.5	2.6	2.6
January	16.9	6.8	6.8
February	7.1	2.8	2.8
March	6.6	2.6	2.6
April	7.8	3.1	3.1
May	4.4	1.8	1.8
June	2.9	1.2	1.2
July	1.7	0.7	1.7
August	0.9	0.4	0.9
September	0.9	0.4	0.9

Table 4-5. Recommended monthly instream flows developed for Douglas Creek using the Tessman Method.

Month	Mean Flow (cfs)	40% of Mean Flow (cfs)	Tessman Flow (cfs)
October	11.9	4.8	4.8
November	12.9	5.2	5.2
December	12.7	5.1	5.1
January	12.9	5.2	5.2
February	14.8	5.9	5.9
March	13.6	5.4	5.4
April	13.3	5.3	5.3
May	12.8	5.1	5.1
June	12.7	5.1	5.1
July	12.3	4.9	4.9
August	11.9	4.8	4.8
September	11.8	4.7	4.7

Table 4-6. Recommended monthly instream flows developed for Rock Island Creek using the Tessman Method.

Month	Mean Flow (cfs)	40% of Mean Flow (cfs)	Tessman Flow (cfs)
October	0.00	0.00	0.00
November	0.13	0.05	0.05
December	0.12	0.05	0.05
January	0.10	0.04	0.04
February	0.17	0.07	0.07
March	0.26	0.10	0.10
April	0.00	0.00	0.00
May	0.00	0.00	0.00
June	0.01	0.00	0.01
July	0.15	0.06	0.06
August	0.18	0.07	0.07
September	0.14	0.06	0.06

4.2 CHANNEL ASSESSMENT - WETTED PERIMETER

Field data for the wetted perimeter (WP) analysis were collected at the same time as data for the PHASIM analysis were collected. The field efforts were timed to correspond to high (February 27 and 28, 2003), average (June 4 and 5, 2003) and low (August 26 and 27, 2003) flow conditions in each of the priority streams. Data necessary for completion of the wetted perimeter analysis were collected from each of the PHABSIM transects in each stream during the three surveys. One additional survey was conducted on Rock Island Creek on August 1, 2003 to ensure late season stream flow did not restrict the measurement of channel hydraulics; especially water velocities.

4.2.1 Foster Creek

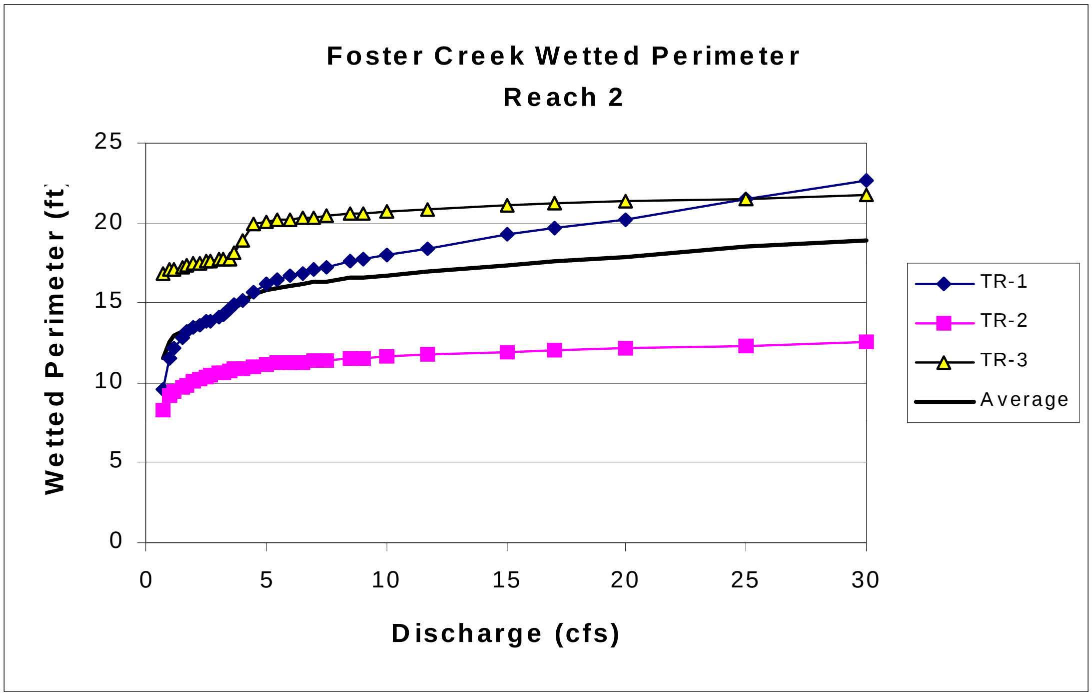
A total of nine transects were used as part of the WP assessment of Foster Creek. Cross-sectional plots of each transect are displayed in Appendix E. These figures also depict the water surface elevations occurring under flow conditions ranging from the low to high flows measured during the field surveys. Inspection of these figures and associated channel morphologies suggest there would be only slight to moderate changes in wetted perimeter for a relatively wide range of flows. This result is confirmed graphically via plots of WP versus discharge for the nine transects (Figure 4-1). To enhance the view of each individual transect, the transects have been split into two separate plots; one plot for the step-pool reach (Transects 1 – 3) and one plot for the pool-riffle reach (Transects 4 – 9). For all transects, except Transect 4, there is little change in WP for flows over 5 cfs. This finding is likewise true for the combined plot of all transects. A slight inflection point occurs at 4 cfs for Transects 1 – 3. Transects 5 – 9 are relatively flat displaying a gradual increase in WP as flows increase. For Transect 4, the gain in WP is dramatic as flows increase from approximately 7 cfs to 30 cfs. The loss in WP is more gradual as flows drop below 7 cfs. There is no noticeable inflection point for Transects 8 and 9.

The results of the WP analysis suggest that a minimum instream flow of approximately 5 cfs would provide nearly the same quantity of wetted channel area as high flow conditions while still maintaining sufficient pool and riffle areas.

4.2.2 Douglas Creek

Flow conditions in Douglas Creek were similar during each of the three field samplings (14.5, 11.6, and 11.1 cfs). Cross-sectional profiles and water surface elevations surveyed during the sampling are displayed in Appendix E. Inspection of the WP versus discharge plots confirms two slight inflection points at 12 and 14 cfs for both Transects 2 and 3 (Figure 4-2). This inflection is also present in the combined plot. There is approximately a one-foot gain in WP between the two flows. The WP versus flow relationship produced for Transect 1 displays a gradual incline from the lowest (6 cfs) to highest (40 cfs) modeled flows, with no apparent inflection point. Like Foster Creek, review of these figures and associated channel morphologies suggested that for a relatively wide range of flows, there would be only slight to moderate changes in wetted perimeter.

The results of the WP analysis for Douglas Creek are somewhat inconclusive. The confined, parabolic channel type in the survey reach displays only limited change in WP as a result of flow variation. A slight inflection occurs in rate of change in WP at flows of approximately 14.0 cfs. Above this flow level, the rate of change is very gradual with only small gains in WP over a large range of flows. This finding suggests a minimum instream flow of approximately 14.0 cfs would provide nearly the same quantity of wetted channel area as high flow conditions while still maintaining sufficient pool and riffle areas.



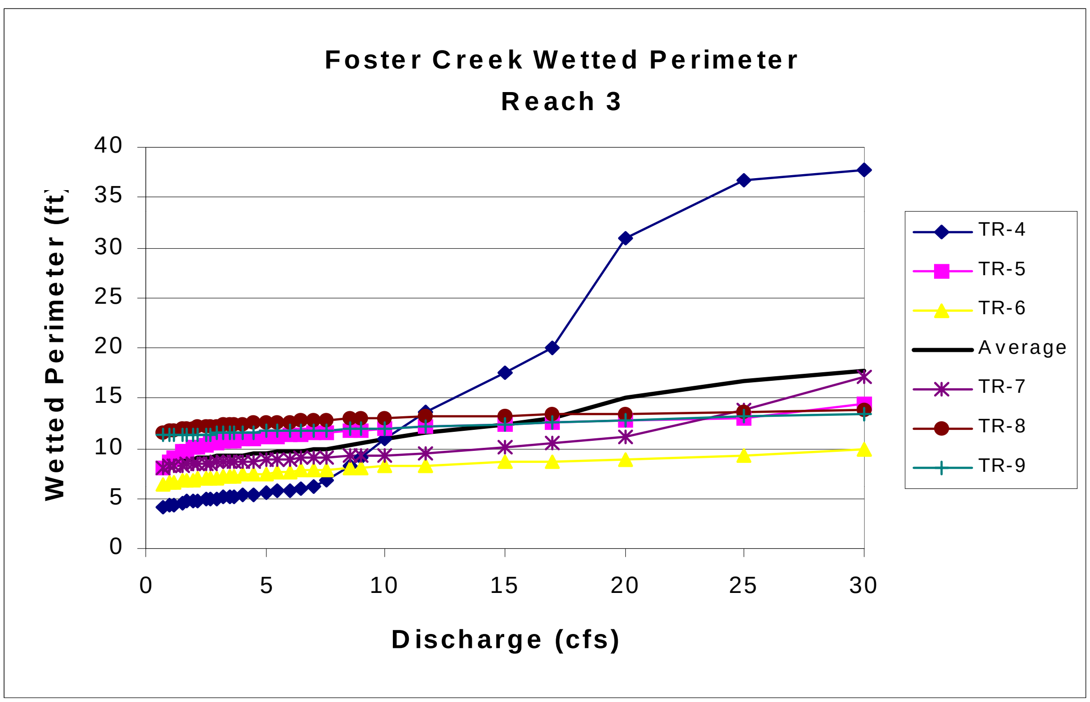


Figure 4-1. Wetted perimeter versus discharge relationship for each of the nine transects on Foster Creek, and for all transects combined.

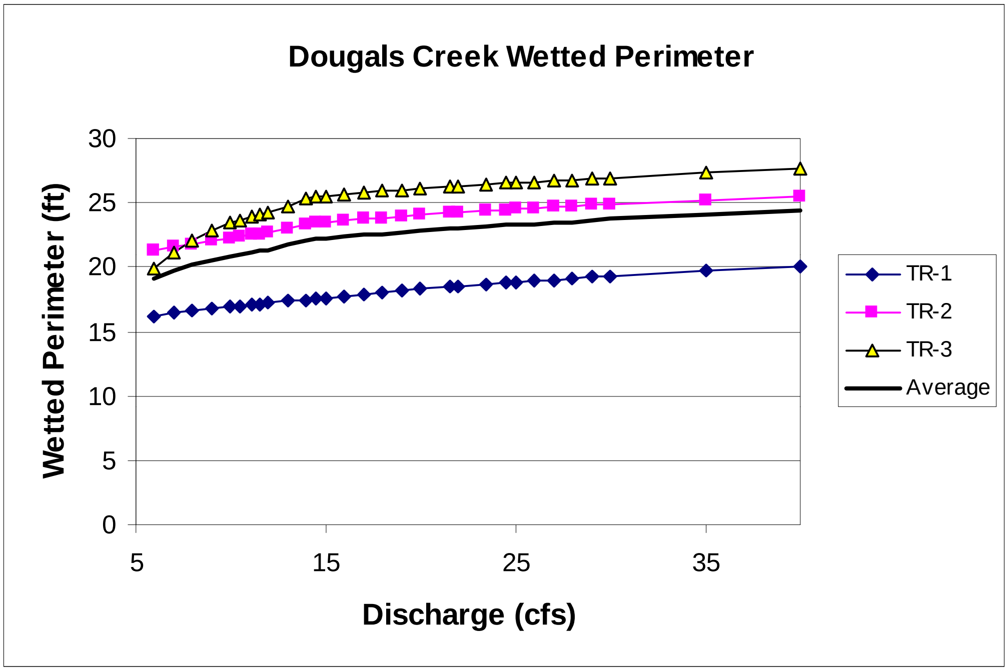


Figure 4-2. WP versus discharge relationship for Douglas Creek.

4.2.3 Rock Island Creek

Flow conditions in Rock Island Creek ranged from a low of 0.3 cfs to a high of 2.4 cfs during the four field samplings. Cross-sectional profiles and water surface elevations surveyed during the sampling are displayed in Appendix E. Review of the WP versus discharge plots confirms a distinct difference in the change in WP as a result of a change in flow between the two riffle (Transects 1 and 2) and two pool (Transect 3 and 4) transects (Figure 4-3). The pool Transects 3 and 4 display a gradual increase in WP from the lowest (0.1 cfs) to highest (6.0 cfs) modeled flows, with no apparent inflection point. Transect 1 has two distinct inflection points, one at 0.4 cfs and the other at 2.0 cfs with approximately 4-feet of gain in WP between the two points. Transect 2 has only one pronounced inflection point occurring at 1.4 cfs. For both Transects 1 and 2 the gain in WP is minimal for flows greater than 2.0 cfs and 1.4 cfs, respectively.

The results of the WP analysis suggest that a minimum instream flow of approximately 1.4 cfs provides nearly the same quantity of wetted channel area as high flow conditions while still maintaining sufficient pool and riffle areas.

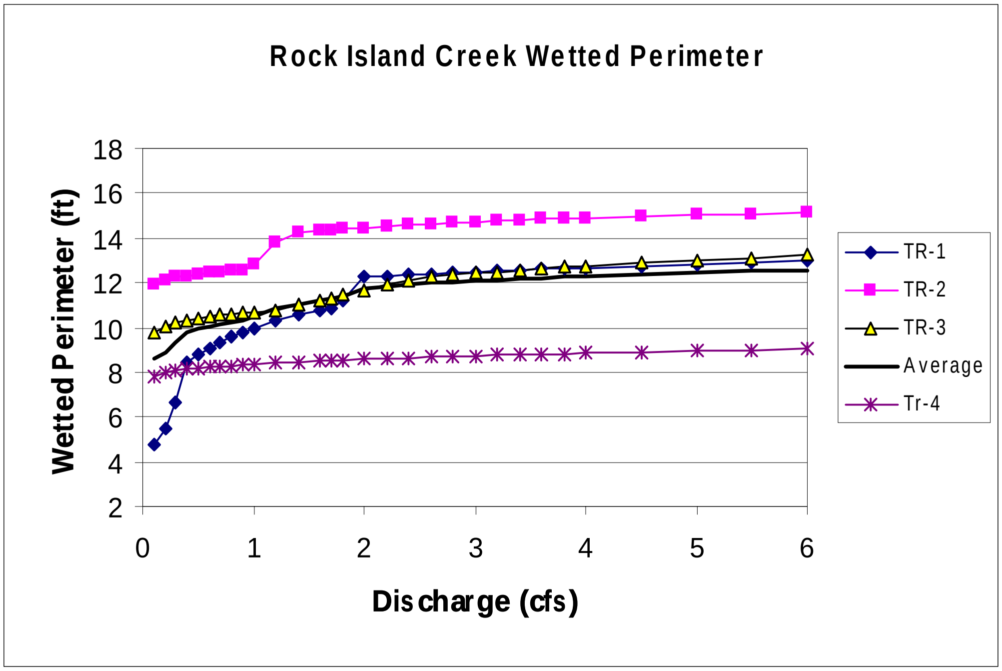


Figure 4-3. WP versus discharge relationship for Rock Island Creek.

4.3 HABITAT ASSESSMENT (PHABSIM)

As previously mentioned, field data collection for the PHABSIM analysis was timed to correspond to high (February 27 and 28, 2003), average (June 4 and 5, 2003) and low (August 26 and 27, 2003) flow conditions in each of the priority streams. Data necessary for completion of the PHABSIM analysis were collected from each of the cross channel transects during each field sampling effort.

Based upon results of the hydraulic and habitat modeling, habitat versus flow relationships (i.e., WUA curve) were developed for individual life stages of steelhead and rainbow trout, Chinook, and coho salmon. Habitat versus flow relationships were initially calculated as WUA for each transect for each priority stream. These WUA curves were then combined using the transect weighting described in the methods section (Section 3.0).

4.3.1 Interpretation of WUA Curves

The shape of the WUA curves reflect changes in hydraulic conditions with increasing flow, and the suitability of the microhabitat conditions provided by these hydraulic conditions to each fish life history stage. Major differences in the shape of each WUA curve are a result of the individual microhabitat preferences (depth, velocity, and substrate) specific to each species and life stage.

Starting with the lowest simulated flow, WUA curves typically increase with increasing flow as a result of substantial increases in wetted width. Increases in WUA values are most rapid in areas with narrow widths during low flow conditions, but increase greatly with increasing discharge as the result of a wide active channel. This situation is most likely to occur in unconfined channel types.

Increases in WUA with discharge can also result from increases in depth. Greater depths are often more suitable for juvenile and particularly the adult life stages, especially in areas where shallow water is abundant at low flows (e.g., riffles). Depth can become a limiting factor to fish at low flows, especially when a majority of habitat areas possess depths less than 1.0 ft. Water depth less than 0.3 feet become limiting to spawning resident and anadromous species in this study. Depth is typically not a limiting factor during high flows and so the depth suitability curves for the juvenile and adult rearing life stages were left “open ended.”

Increases in velocity with discharge can also result in greater WUA values for many life stages. Velocity is the microhabitat variable is most often limiting to a particular life stage. Most reductions in WUA values with increasing flow are a consequence of increasing velocity values becoming progressively less suitable (either behaviorally or physiologically) to fish. The threshold discharge where velocities effectively begin to reduce WUA values is much higher for adult fish because of the preference or tolerance of this life stage for higher velocity regimes than for small fish.

To facilitate analysis and comparison of results, three flow values are presented for each stream including: the flow resulting in the maximum WUA value (i.e., peak of curve), the flow providing 80 percent of maximum, and the flow resulting in 50 percent of the maximum WUA value. The maximum WUA value represents the flow offering 100 percent (peak of the curve) of the maximum habitat for a given species and life stage, while the 80 and 50 percent of maximum are provisional target values providing “good” and “average” habitat conditions to the same species and life stage. It should be noted the WUA curves reflect only the hydraulic and habitat conditions provided by various stream flow conditions and do not reflect the availability of flow within any given time period. For example, a WUA curve may predict that a certain flow provides the maximum habitat for a given species and life stage, but that flow may never (or very seldom) occur naturally. In that case, fish habitat would be limited by flow availability and not a combination of channel hydraulics and/or habitat preferences.

Results of the PHABSIM analysis are described separately for each of the priority streams.

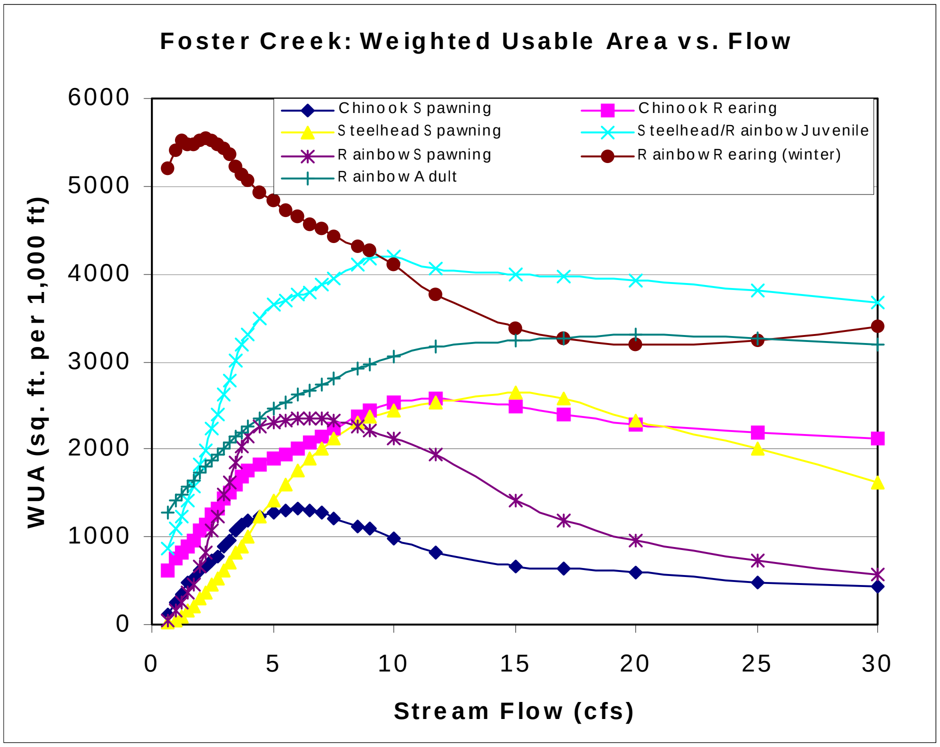
4.3.2 Foster Creek

Flow conditions in Foster Creek during data collection were approximately 11.7 cfs (high flow), 3.7 cfs (average flow), and 1.5 cfs (low flow). Following the general guidelines for extrapolation of PHABSIM modeling results (2.5 times the highest measured flow and 0.5 times the lowest measured flow), the lowest modeled flow was equal to 0.7 cfs and the highest modeled flow was 30.0 cfs. Habitat types sampled in Foster Creek included pools (Transects 3, 5, and 8), runs (Transect 6), and riffles (Transects 1, 2, 4, 7, and 9).

Steelhead/rainbow trout were the primary focus in Foster Creek with spawning occurring from April through June, summer rearing extending from July through November, and winter rearing from December through March (R2 Resource Consultants 2003). Chinook salmon rearing and steelhead trout incubation were the secondary life stages of concern in the basin.

Steelhead Trout

The shape of the WUA versus discharge cures for steelhead trout spawning in Foster Creek is highly influenced by the availability of water depth greater than 0.5 feet and velocities in the 1.75 to 2.25 feet per second range. Stream flow of 15.0 cubic feet per second produces the maximum amount of spawning habitat for steelhead trout in Foster Creek (Figure 4-4). The availability of suitable spawning habitat falls off quickly at flows greater than 11.7 cubic feet per second. Flow levels necessary to produce maximum spawning habitat are generally not available in any of the three spawning months (Figure 2-1). Stream flows that produce both 80 percent (7.5 cfs) and 50 percent (4.7 cfs) of maximum habitat are routinely available during the spawning period.



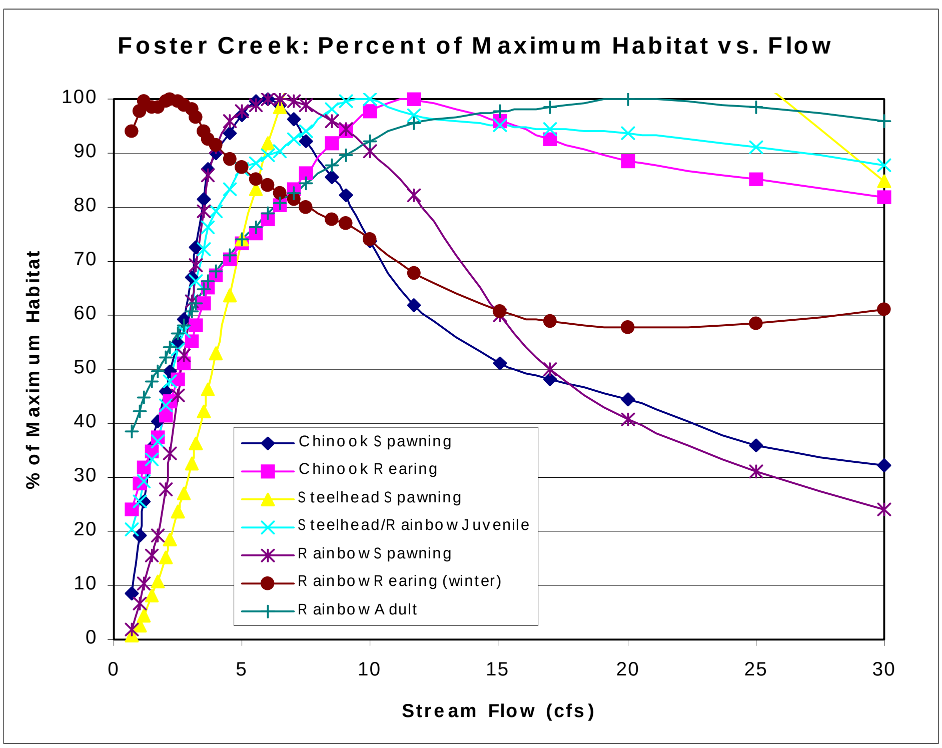


Figure 4-4. Weighted usable area and percent of maximum habitat versus discharge curves for Foster Creek.

Maximum WUA for juvenile steelhead/rainbow trout is provided at a flow of +30.0 cfs (Figure 4-4). The amount of WUA for juvenile steelhead increases continuously from the lowest modeled flow to the maximum extrapolated flow of 30 cfs. The lack of a defined peak for the juvenile WUA curves is attributed to the broad range of suitable depths and the unconfined nature of Foster Creek (Appendices D and E). The steep ascending limb of the juvenile WUA curve results in significant gains in predicted habitat with only a modest increase in flow (Figure 4-4). A flow of 7.0 cfs provides 50 percent of the maximum WUA while a flow of 13.5 cfs provides approximately 80 percent of maximum habitat. It is apparent such flows are not usually available in Foster Creek until November or December, annually (Figure 2.1; Table 5-1).

Flow levels required for winter rearing of salmonid fishes were significantly lower than flow needs predicted for all other life stages. The maximum winter habitat condition was provided with a flow of 2.2 cfs in Foster Creek. This result is due to the increased suitability of low water depth and velocity conditions during the inactive winter refuge period (Appendix D).

Chinook Salmon

The WUA curve for Chinook salmon rearing is relatively broad with a poorly defined peak resulting in modest changes in quantity of suitable habitat over a large range of flow conditions (Figure 4-4). Like juvenile steelhead trout, the lack of a defined peak for Chinook salmon rearing is attributed to the broad range of suitable depths and the unconfined nature of Foster Creek. Peak or maximum WUA for Chinook rearing in Foster Creek occurs at a flow of 20.0 cfs (Figure 4-4). Flows of 6.5 cfs and 2.6 cfs provide 80 and 50 percent of the maximum WUA value for juvenile Chinook salmon, respectively.

The priority for Chinook salmon rearing in Foster Creek occurs between the months of July through December, annually. Mean monthly flows greater than 2.6 cfs are available only during the months of November and December during normal water years (Figure 2-1).

4.3.3 Douglas Creek

Flow conditions in Douglas Creek during data collection were approximately 14.5 cfs (high flow), 11.6 cfs (average flow), and 11.1 cfs (low flow). Following the general guidelines for extrapolation of PHABSIM modeling results, the lowest modeled flow was equal to 6.0 cfs and the highest modeled flow was 40.0 cfs. Habitat types sampled in Douglas Creek included a pool (Transects 2) and two riffles (Transects 1 and 3).

Resident rainbow trout were the only priority species observed in and with access to Douglas Creek. Spawning was estimated to occur from March through May with summer rearing conditions available the remainder of the year due to warm stream temperatures (R2 Resource Consultants 2003).

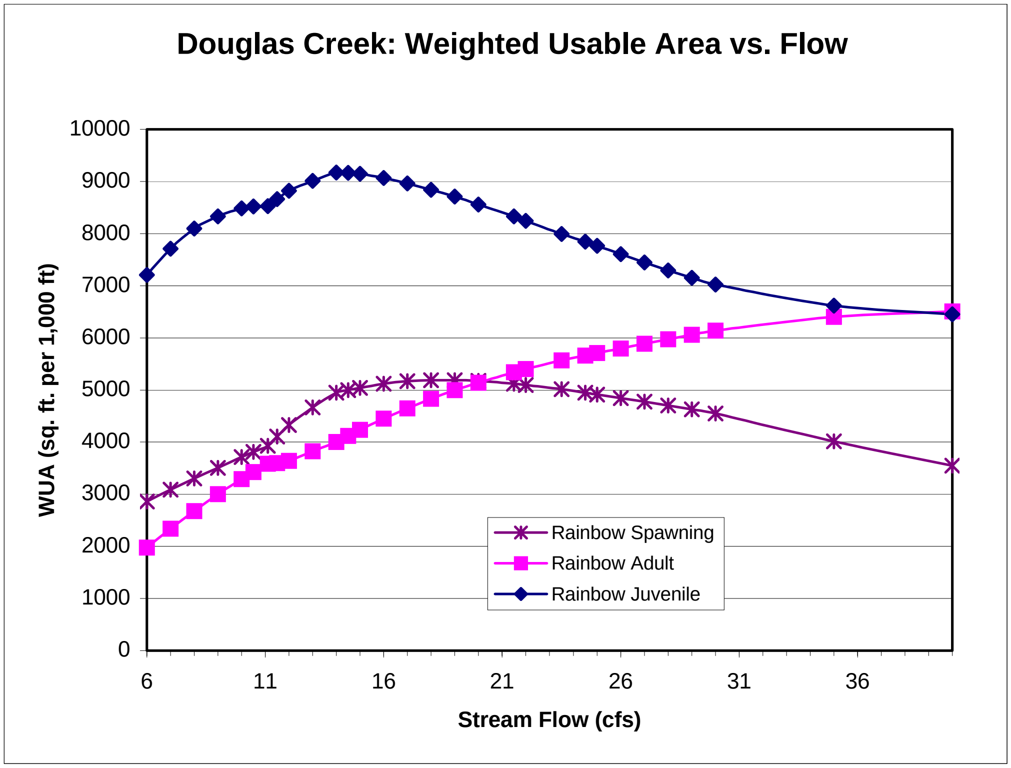
Rainbow Trout

The WUA curves produced as part of the PHABSIM analysis for Douglas Creek are poorly defined with broad peaks or gradually increasing shape. The stable stream flow conditions observed in Douglas Creek limit the extent of predicted change in either depth or water velocity over the range of modeled flows. Without a significant change in one or both of these parameters the quantity of WUA predicted by the PHABSIM models displays very little variation in response to changing flow levels.

The maximum WUA value for rainbow trout spawning in Douglas Creek occurs at a flow of 18 cfs (Figure 4-5). For the period of flow record, the highest 10 percent exceedence flow during the rainbow trout spawning period was 15.1 cfs (Figure 2-1). Stream flow that produces 80 percent (11.7 cfs) of maximum habitat is comparable to the predicted 50 percent exceedence flow (Figure 2-1). A flow of 6.0 cfs provides 50 percent of the maximum WUA value for spawning rainbow trout and this discharge is predicted to be continuously available during the spawning period.

The quantity of WUA for rainbow trout adult rearing progressively increases from the lowest modeled flow to the highest modeled flow with no clear peak or inflection point. This result is likely due to the broad range of suitable velocities and unlimited depth used in the HSI curves and the stable flow conditions found in Douglas Creek. Maximum WUA for rainbow adult occurs at a flow greater than the highest modeled flow of 40 cfs (Figure 4-5). Flows of 21.0 cfs and 10.0 cfs provide 80 and 50 percent of the habitat quantity provided by the highest modeled flow, respectively.

The WUA curve for juvenile rainbow trout shows a modest peak at flows of approximately 14 cfs (Figure 4-5). This flow level corresponds well with results of the wetted perimeter analysis that shows a slight inflection in the quantity of wetted perimeter produced by a flow of 14 cfs (Figure 4-2). Due to the small body size, reduced swimming ability and predator avoidance behavior of juvenile fish, it is expected that shallow, slow velocity water would be more suitable



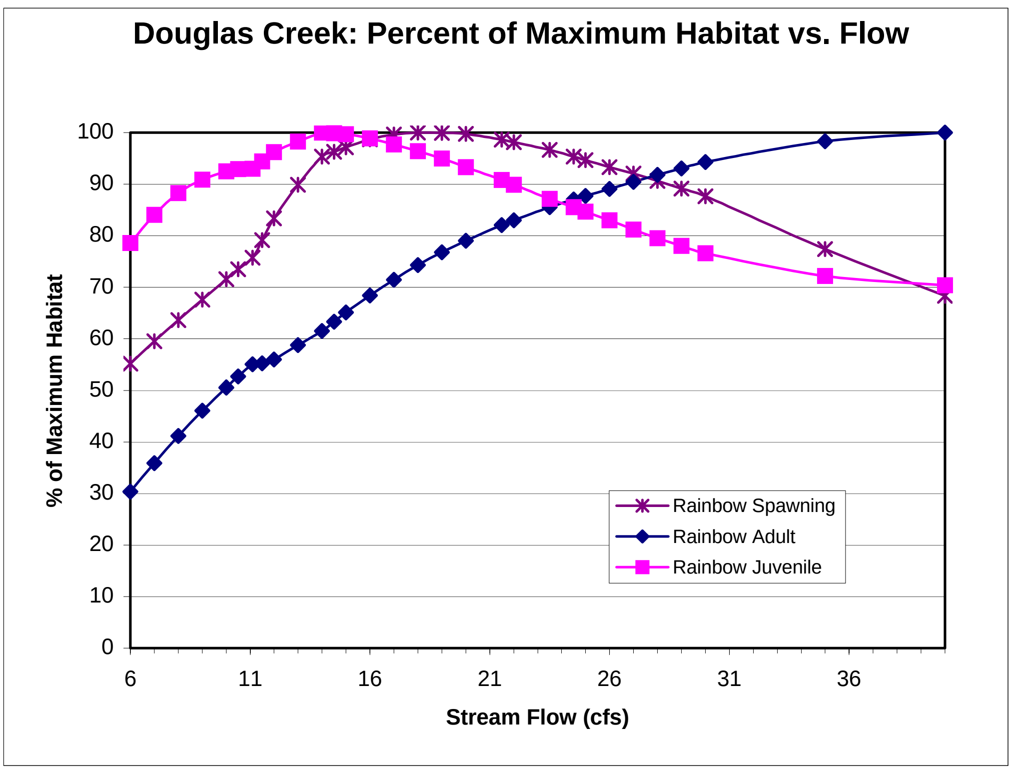


Figure 4-5. Weighted usable area and percent of maximum habitat versus discharge curves for Douglas Creek.

to this life stage compared to adult trout. A flow level of 6.5 cfs is predicted to provide 80 percent of maximum habitat. This flow is much lower than the lowest 90 percent exceedence flow level (Figure 2-1). As a result, under the current flow regime, the 80 percent maximum habitat flow level of 6.5 cfs is readily available during the rearing period.

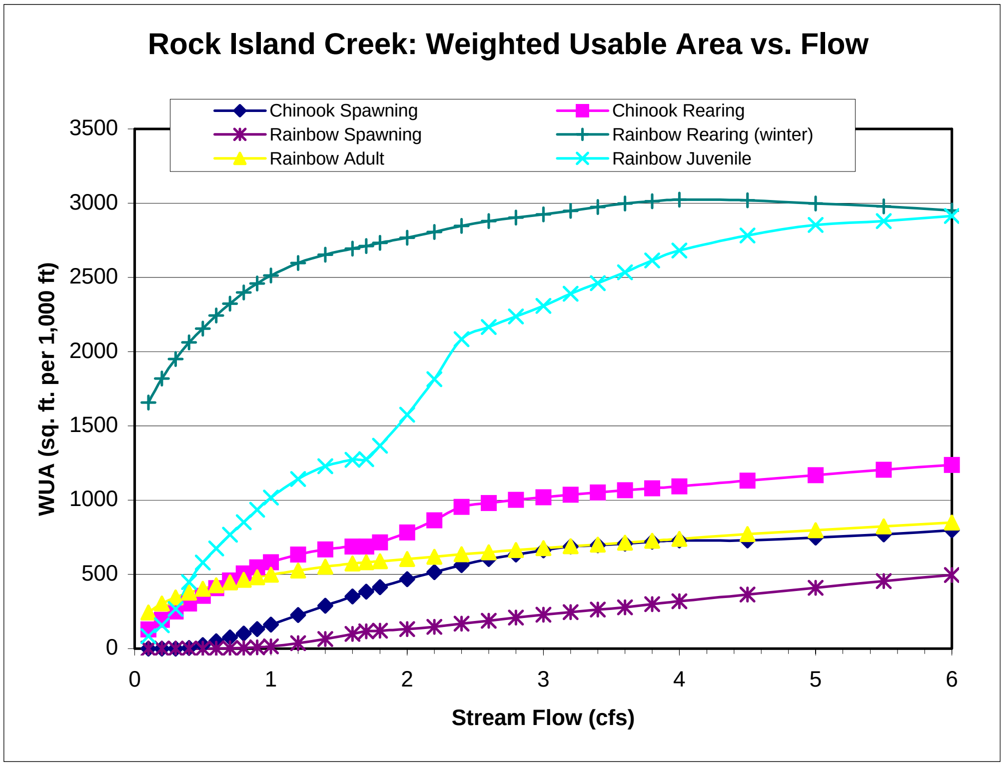
4.3.4 Rock Island Creek

Flow conditions in Rock Island Creek during data collection at the instream flow study site were approximately 2.4 cfs (high flow), 1.7 cfs (average flow), 0.6 cfs (low flow), and 0.3 (extreme low flow). These flows included the addition of the Rock Island spring. Following the general guidelines for extrapolation of PHABSIM modeling results, the lowest modeled flow was equal to 0.1 cfs and the highest modeled flow was 6.0 cfs. Habitat types sampled in Rock Island Creek included pools (Transects 3 and 4) and riffles (Transects 1 and 2).

Rainbow trout and Chinook salmon were the primary focus in Rock Island Creek with rainbow spawning assumed to occur from March through May, summer rearing for juvenile Chinook extending from June through October, and winter rearing for all salmonids from November through February (R2 Resource Consultants 2003). Juvenile rainbow trout rearing and incubation were the secondary life stages of concern in Rock Island Creek.

Rainbow Trout

The extremely shallow water depth experienced during all measured (and modeled) flows in Rock Island Creek severely limited the suitability of this stream for spawning and adult salmonid fishes. The WUA curves for all life stages, except for juvenile rainbow trout, display a gradual increase in the amount of predicted WUA as flow increases from the lowest to highest modeled flows. None of the curves display a distinctive peak. The maximum WUA value for rainbow trout spawning in Rock Island Creek is assumed to occur at a flow greater than 6.0 cfs, which is the upper extent of the modeling range (Figure 4-6). The highest available flow (10% exceedence), including the artificial spring water, during the rainbow spawning period is 3.9 cfs. Stream flows that produce 80 percent (4.7 cfs) of maximum habitat are also higher than the 10 percent exceedence flow. A flow of 3.3 cfs provides 50 percent of the maximum WUA value for spawning rainbow trout and is approximately equal to the 10 percent exceedence flows experienced during the spawning period. The available spawning area produced by the highest modeled flow of 6.0 cfs provides just slighter under 500 square feet per 1,000 feet of stream, indicating a system that is somewhat spawning area limited.



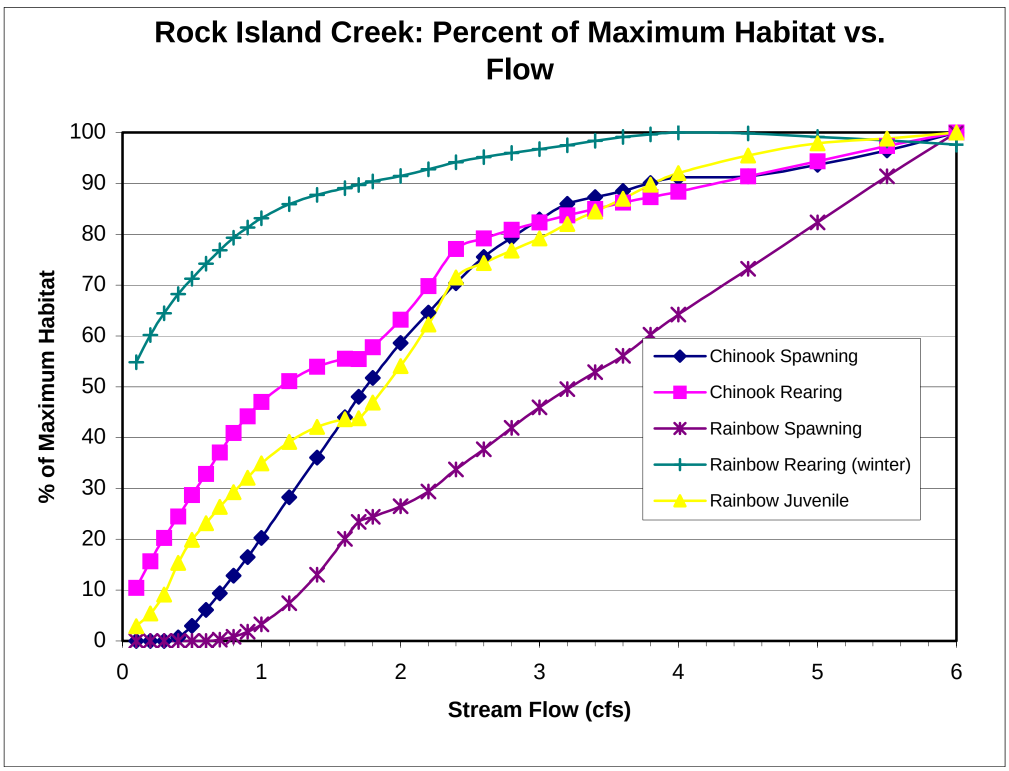


Figure 4-6. Weighted usable area and maximum habitat area versus discharge curves for Rock Island Creek.

Maximum WUA values for juvenile rainbow trout in Rock Island Creek also occurred at flows greater than 6.0 cfs (Figure 4-6). Flows of 3.1 cfs and 1.9 cfs provided 80 and 50 percent of maximum rainbow rearing habitat, respectively. Flow levels required for winter rearing of rainbow trout were somewhat lower than those predicted for the other life stages with maximum habitat provided by a flow of 4.0 cfs. Again, this result is due to the increased suitability of low water depth and velocity conditions during the winter period when fish activity is generally limited.

Chinook Salmon

The WUA curves for Chinook salmon are very similar to the rainbow trout curves in that they are continuously increasing with no defined peak within the modeled flow range (Figure 4-6). Maximum WUA for Chinook salmon rearing in Rock Island Creek occurs at a flow greater than 6.0 cfs (Figure 4-6). Flows of 2.7 cfs and 1.1 cfs provide 80 and 50 percent of the habitat produced by the highest modeled flow, respectively.

Flow levels in Rock Island Creek during the Chinook salmon rearing period of June through October average (50% exceedance) less than 1.0 cfs and drop as low as 0.2 cfs. The limited amount (<600 sq ft per 1,000 ft) of WUA predicted at these flow levels indicates that Chinook salmon rearing in Rock Island Creek is limited and probably occurs on an opportunistic basis only.

4.4 RIPARIAN VEGETATION

Surveys of the composition and distribution of riparian vegetation along each of the cross channel transects were conducted during the June 2 and 3, 2003 field data collection effort. This sampling period was selected to increase the likelihood of positive identification of riparian species by allowing plants to leaf out and for development of flowers in flowering species. This analysis is based on the horizontal and vertical distribution of riparian plant species in relationship to the June water surface elevation, geomorphic surface, and interpreted hydrologic regime of each priority stream. Assessment of the riparian vegetation-hydrologic relationships for Foster, Douglas, and Rock Island creeks is presented below in a narrative format. When known, scientific names are presented with the common name for each plant species, otherwise common names are used.

4.4.1 Foster Creek

Riparian vegetation surveys were completed on six (TR 1-4, 6 and 7) of the nine Foster Creek transects. The composition and distribution of riparian species at the remaining three transects (Transects 5, 8, and 9) were believed to be adequately represented by other sampled transects. The streamside zone along Foster Creek appears to be wet in early season and stays moist through the growing season (March – September), as indicated by Baltic rush (*Juncus balticus*), horsetail, and reed canarygrass (*Phalaris arundinacea*). In winter or early spring, surface water occurs at elevations up to 3 ft above the June water surface elevation (WSE) (Appendix F). The presence of water smartweed (probably *Polygonum amphibium*) indicates ponding persists following the flooding, but only into the early part of the growing season in Transects 4 and 7. The presence of cheat grass (*Bromus tectorum*) and Indian rice grass (*Oryzopsis hymenoides*) indicate that surface soils at 2+ feet elevation mostly dry out during summer.

In Transects 1, 2, and 6, however, the occurrence of goldenrod (*Solidago* sp.), cudweed (probably *Gnaphalium chilense*), and horsetail at high elevations (+2-3 ft) indicates that soil moisture stays relatively high during the growing season, so soil moisture from winter/spring flooding seems to persist. Willows and other riparian shrubs do not appear abundant, suggesting the alluvial aquifer is too deep to maintain their presence immediately adjacent to the stream channel. Some sandbar willow (*S. exigua*) seems to survive at 2+ ft, suggesting a higher degree of soil moisture through the growing season. Silver sage (*Artemesia cana*) also indicates higher water availability in the soils at 2 ft elevation above the stream compared to uplands.

In general, the riparian vegetation on Foster Creek does not seem as productive and diverse as Rock Island or Douglas creeks, and away from the channel edge it is more dependent on moisture from winter-spring runoff than on seasonal peak stream flows or alluvial groundwater. Since the stream dependent component of the riparian vegetation along Foster Creek is confined to areas adjacent to the stream, a 50 percent exceedence flow as defined under the 3-year baseline conditions that ranges between 1 cfs in August and September to 17 cfs in January should be sufficient for maintenance of the existing riparian vegetation (D. Chapin, personal communication 2003).

4.4.2 Douglas Creek

Riparian vegetation surveys were completed on all three of the Douglas Creek transects. Douglas Creek has a streamside plant community (water cress, reed canarygrass, horsetail), indicative of wet soils early in the season and at least moist soils through the summer. It also has a rich riparian shrub community of water birch (*Betula occidentalis*), peach-leaf (*S. amygdaloides*) and sandbar willow, Woods rose, red osier dogwood, and mockorange (*Philadelphus lewisii*), indicate the availability of high soil moisture levels throughout the riparian zone up to 4 ft above the June, 2003 WSE (Appendix F). With the exception of willow and red osier dogwood, the shrub community does not suggest major recent flooding has occurred.

The dominance of spring flow upstream of the transects, and a lack of persistent annual flooding has resulted in a current riparian vegetation that is associated with relatively constant surface water in the channel and a shallow alluvial aquifer. The elevational limit of riparian species around Douglas Creek is likely determined by the depth of the alluvial aquifer in relation to the rooting depths of individual species. The 50 percent monthly exceedence flow as defined under the 3-year baseline conditions that ranges between 12 and 15 cfs per month should approximate the current flow regime and alluvial aquifer depth of Douglas Creek and should maintain current riparian vegetation patterns.

4.4.3 Rock Island Creek

Riparian vegetation surveys were completed on all four of the Rock Island Creek transects. The streamside area within about 1 ft elevation of the June 2003 WSE (with water cress [*Rorippa nasturtium-aquaticum*] and horsetail [*Equisetum arvense*]) appears to be wet in the early part of the growing season and stays moist through the growing season (Appendix F). Willows (*Salix. amygdaloides*, *S. exigua*) occur up to about 4.5 ft above the June 2003 water surface elevation (Appendix F). Establishment of willows is typically associated with flood disturbance and is dependent on bare mineral soil that often results from deposition of sediment during flooding. Since flooding occurs episodically (occurring over periods of multiple decades) in Rock Island Creek these willows are now dependent on the alluvial aquifer associated with Rock Island Creek. Assuming the alluvial aquifer near the stream is approximately equal to the stream water surface at Rock Island Creek, the distribution of willows along the creek is consistent with other surveys that show a maximum 3 to 4 ft depth of willow root growth to the water table in semiarid environments in the western United States. The presence of other riparian shrubs (red osier dogwood [*Cornus sericea*], rose [*Rosa woodsii*]) at 3 to 4 ft elevation above the stream water surface also indicate that these species can tap soils with higher moisture levels than surrounding uplands through most of the growing season.

The main source of Rock Island Creek surface water appears to be the man-made spring located upstream from the sampled transects. In contrast to vegetation typical of this area (sage), the riparian vegetation along the creek is undoubtedly dependent on the groundwater associated with the man-made spring and the creek. If this water source were to be reduced, it is assumed that an associated reduction in the extent of the riparian vegetation in the vicinity of the creek would occur. Although a quantitative relationship between surface flow and the extent and quality of riparian vegetation can not readily be determined from the data available at Rock Island Creek, it seems reasonable to assume that maintenance of a 50 percent exceedence flow during the growing season (April – September) as defined under the 3-year baseline conditions that ranges between 0.3 and 2.2 cfs per month is probably sufficient to support the existing riparian community along the sampled transects.

4.5 WATER QUALITY

4.5.1 Surface Water Temperature

The SSTEMP instream flow model was used to compare the recommended minimum instream flow regime with the baseline hydrology to estimate potential incremental changes in water temperature. The discharge-temperature relationships for the extreme and average events are shown in Figures 4-7 through 4-9 for Douglas, Foster, and Rock Island creeks, respectively. As expected, these relationships show decreasing water temperatures with increasing flow. The plots also show lower water temperatures for the average event with a smaller change in temperature over the evaluated flows compared to the extreme event.

The influence of the 10, 50, and 90 percent July exceedence flows on water temperature are summarized in Tables 4-7 and 4-8 for the extreme and average weather events. The 1-day maximum temperature as modeled and an approximation of the highest 7-day average of the daily maximum temperature values (7-day maximum) are provided in the tables.

Both the plots and tables show a minimal change in water temperature for Douglas Creek between the 10 and 90 percent exceedence flows, while both Foster and Rock Island Creek show a change between 1.3 - 2.0°C degrees for the extreme event and between 0.3 - 1.0°C for an average event.

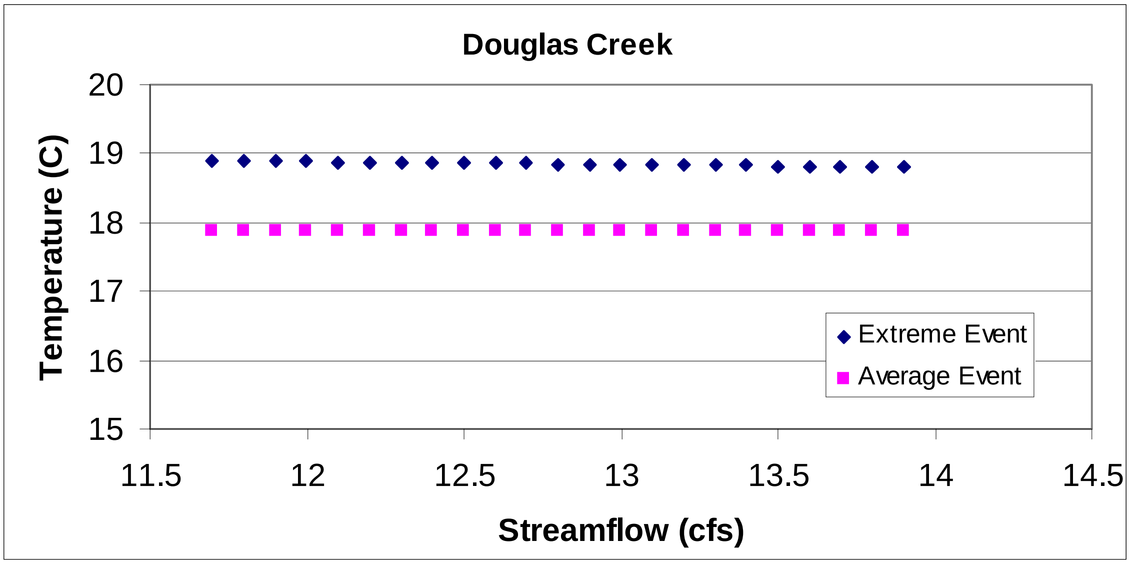


Figure 4-7. Discharge and temperature relationships for Douglas Creek established using SSTEMP.

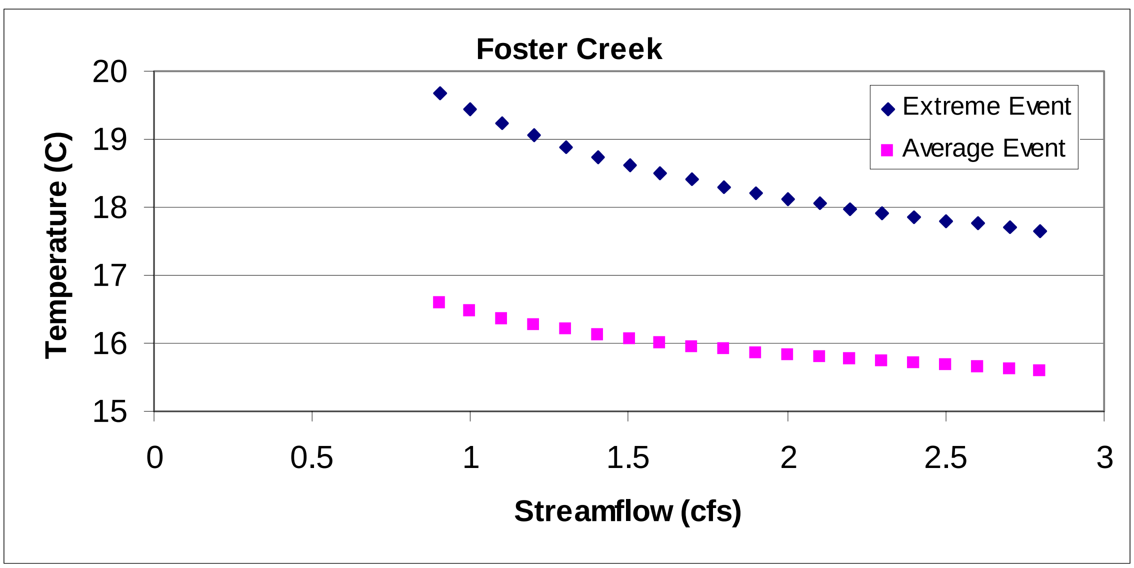


Figure 4-8. Discharge and temperature relationships for Foster Creek established using SSTEMP.

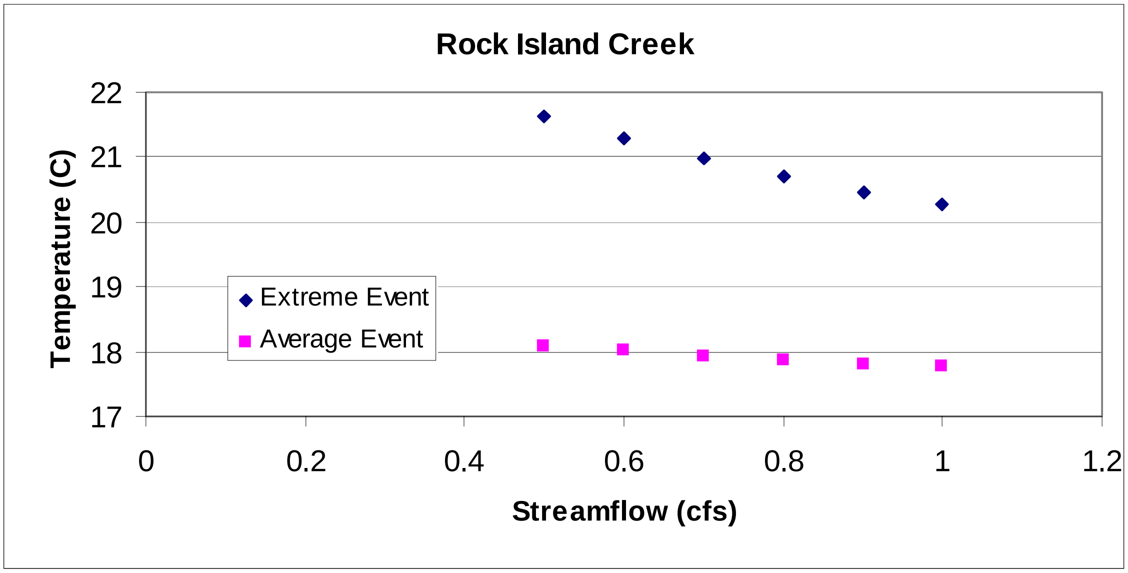


Figure 4-9. Discharge and temperature relationships for Rock Island Creek established using SSTEMP.

Table 4-7. Summary of Influence of July Exceedence Flows on Temperature[1/] in Douglas, Foster, and Rock Island Creek for an Extreme Weather Event.[2/]

	Douglas Creek			Foster Creek			Rock Island Creek		
Flow Exceedence	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**
10%	13.9	18.8	17.9	2.8	17.7	16.8	1.0	20.3	19.3
50%	12.3	18.9	18.0	1.7	18.4	17.5	0.7	21.0	20.0
90%	11.7	18.9	18.0	0.9	19.7	18.8	0.5	21.6	20.6

1) Temperatures are reported as the 7-Day maximum in accordance with the new state water quality standards by converting the 1-Day maximum modeled temperatures (after Plum Creek 2001, WF Timber Co. 2004) given the highest recorded daily input temperatures measured in each creek during the continuous stream gage placement, 2001 – 2003, as follows:

7-Day Max. = (0.96 * 1-Day Max) – 0.15C

2) Extreme weather event is highest 7-day air temperature between 1990 and 2003 in combination with the corresponding 7-day average relative humidity, wind speed, ground temperature and solar radiation occurring during the extreme air temperature event. Such an event has a return frequency of 1 in 14 years.

Table 4-8. Summary of Impacts of July Exeedence Flows on Temperature[1/] in Douglas, Foster, and Rock Island Creek for an Average Weather Event.[2/]

	Douglas Creek			Foster Creek			Rock Island Creek		
Flow Exceedence	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**	**Q (cfs)**	**T°C (1-Dmax)**	**T°C (7-Dmax)**
10%	13.9	17.9	17.0	2.8	15.6	14.8	1.0	17.8	16.9
50%	12.3	17.9	17.0	1.7	16.0	15.2	0.7	17.9	17.0
90%	11.7	17.9	17.0	0.9	16.6	15.8	0.5	18.1	17.2

1) Temperatures are reported as the 7-Day maximum in accordance with the new state water quality standards by converting the 1-Day maximum modeled temperatures

(after Plum Creek 2001, WF Timber Co. 2004) given the highest recorded daily input temperatures measured in each creek during the continuous stream

gage placement, 2001 – 2003, as follows:

7-Day Max. = (0.96 * 1-Day Max) – 0.15C

2) Average weather event is the mean of the 7-day running averages during the months of July and August between 1990 – 2003 in combination with the 7-day average relative humidity, wind speed, ground temperature and solar radiation occurring over the period of record, 1990 – 2003.

The anticipated annual 7-day average of the daily maximum temperatures comply with state criteria for anadromous salmon and trout spawning in Foster Creek of 16°C and for anadromous salmon and trout rearing of 17.5°C in Foster, Rock Island and Douglas creeks. During an extreme climatic event (calculated as a 1-in-14 year event), Douglas Creek is estimated to maintain 7-day maximum temperature regime of ≤18.0°C. This temperature level is regarded as appropriate for resident trout rearing. Under an extreme weather event, Foster Creek is projected to support anadromous fish rearing of 17.5°C, 7-day max. at stream flows above 1.7 cfs. The SSTEMP model suggests Rock Island Creek under the extreme weather conditions will not support a coldwater fishery under any flow conditions.

New State Water Temperature Standards (WAC 173-201(a))

Aquatic Use Category	7-DADmax	Dissolved Oxygen
Native Char	12.0°C	9.5 mg/l
Core Salmon and Trout Spawning	16.0°C	9.5 mg/l
Non-core Salmon and Trout Spawning	17.5°C	8.0 mg/l
Salmon and Trout rearing and migration, only	17.5°C	6.5 mg/l
Non-anadromous Interior (Resident) Trout	18.0°C	8.0 mg/l
Warmwater species	20.0°C	6.5 mg/l

4.5.2 Dissolved Oxygen

The partial pressure of dissolved gases in water is indirectly influenced by water temperature. As water temperatures increase, the percent saturation of dissolved oxygen will decrease, lowering the oxygen concentrations in streams. As such, no change in DO levels are anticipated in Douglas Creek with decreasing stream flows; while DO levels may decrease a small fraction as flows are incrementally decreased between the 90 and 10 percent exceedence flows in late summer in both Rock Island and Foster Creeks.

Douglas Creek

Complete oxygen (O_2) saturation at the annual average 7-day maximum temperatures of 17.0°C equates to a DO concentration of 9.6 mg/l. The worst-case extreme event is anticipated to have fully-saturated DO levels of 9.4 mg/l. Since there are no anticipated temperature changes with stream flows between the 10 and 90 percent exceedence levels, there is no projected change in dissolved oxygen levels in Douglas Creek.

DO monitoring during warm summer months of 2003 indicate dissolved oxygen levels between 9.4 and 9.9 mg/l. These fully-saturated oxygen levels are appropriate for all aquatic use categories and are in compliance with state water quality standards.

Foster Creek

Complete oxygen (O_2) saturation at the annual average 7-day maximum temperatures between 14.8°C and 15.8°C equates to DO concentrations between 10.1 and 9.9 mg/l. The worst-case extreme event is anticipated to have fully-saturated DO levels between 9.7 and 9.3 mg/l. The data imply flow level changes between the 10 and 90 percent July exceedence flows would reduce DO levels on average by approximately 0.2 mg/l and by 0.4 mg/l under the extreme event or approximately 4 percent. On average, the relationship is approximately 0.1 mg dissolved O_2 /l for each cfs of flow change.

DO monitoring during warm summer months of 2003 indicate dissolved oxygen levels between 8.7 and 9.5 mg/l. The data suggest oxygen levels are not fully saturated in Foster Creek and may be influenced by organic loading in the creek. However, the current levels remain appropriate for most aquatic use categories and are in compliance with state water quality standards for the aquatic use categories present in Foster Creek.

Rock Island Creek

Complete oxygen (O_2) saturation at the annual average 7-day maximum temperatures between 16.9°C and 17.2°C equates to DO concentrations between 9.6 and 9.7 mg/l. The worst-case extreme event is anticipated to have fully saturated DO levels between 9.0 and 9.2 mg/l. The data imply flow level changes between the 10 and 90 percent July exceedence flows would reduce DO levels on average by approximately 0.1 mg/l and under the extreme event by 0.2 mg/l or approximately 1 to 2 percent. On average, the relationship is approximately 0.2 mg dissolved O_2/l for each cfs of flow change.

DO monitoring during warm summer months of 2003 indicate dissolved oxygen levels between 9.1 and 10.6 mg/l. The data suggest oxygen levels are near full saturation in Rock Island Creek.

The current levels remain appropriate for most aquatic use categories and are in compliance with state water quality standards for the aquatic use categories present in Rock Island Creek.

4.5.3 Water Quality Conclusion

The water quality-flow assessment indicates that anticipated changes in water temperatures, dissolved oxygen levels and percent O_2 saturation with changes in late summer stream flows are very low. Under average conditions, the highest annual 7-day mean surface water temperatures and associated dissolved oxygen levels should comply with state water quality standards for appropriate aquatic use categories at the 90 percent flow levels in all of the priority streams during the month of July as shown below:

	90% Exceedence Flow
Douglas Creek	
Discharge	11.7 cfs
Range of flows 10-90% Exceedence	2.2 cfs
Water Temperature (7-DADmax)	17.0°C
Temperature Change Rate	0.0°C per cfs
Dissolved Oxygen-saturated	9.6 mg/l
DO Change Rate	0.0 mg/l per cfs
Foster Creek	
Discharge	0.9 cfs
Range of flows 10-90% Exceedence	1.9 cfs
Water Temperature (7-DADmax)	15.8°C
Temperature Change Rate	0.5°C per cfs
Dissolved Oxygen-saturated	9.9 mg/l
DO Change Rate	0.1 mg/l per cfs
Rock Island Creek	
Discharge	0.5 cfs
Range of flows 10-90% Exceedence	0.5 cfs
Water Temperature (7-DADmax)	17.2°C
Temperature Change Rate	0.6°C per cfs
Dissolved Oxygen-saturated	9.6 mg/l
DO Change Rate	0.2 mg/l per cfs

5. RECOMMENDATIONS

The recommendations offered herein are consistent with the Planning Units stated objectives to provide a minimum flow regime that maintains current levels of habitat and species use (Step A; Scope of Work). The flow recommendations are also intended to provide for ongoing riparian and water quality maintenance.

A series of tools have been used to assist the Planning Unit in approximating the minimum instream flow needs for WRIAs 44 and 50 priority streams. Individually, the tools each have inherent strengths and weaknesses. Combined the tools help provide the boundaries of the assessment.

Each stream is unique with respect to land use, channel morphology, flow pattern, species composition and biological use. A number of the flow-setting approaches appear to work well in some streams, while they do not work well in others. It is important to understand there is no one methodology that will provide a flow recommendation to explicitly determine the minimum flow necessary to meet the objectives.

Three approaches were used to assess minimum instream flows including, a hydrological-based approach (Tennant/Tessman); a physical channel-based approach (Wetted Perimeter) and a biological-based approach (PHABSIM) to help define the range of flows needed. All of the results were put in context with the available stream flows and were compared with the exceedence curves for each stream on a monthly basis.

Development of minimum instream flow recommendations for the WRIAs 44 and 50 priority streams required examination and consideration of several pieces of information including stream flow availability, fish species and life stage use, and the relationship between stream flow and wetted channel area, an index of fish habitat as weighted usable are (WUA), riparian vegetation, and water quality. Each of these factors were evaluated and the results assessed according to their applicability and relative importance or influence on aquatic conditions in Foster, Douglas, and Rock Island creeks.

The requirements of instream flows vary according to seasonal needs of specific life history stages and seasonal stream flows. As such, the minimum instream flow recommendations provided herein respond to changing needs on a monthly basis. The integration of the instream flow needs was intrinsically tied to the life cycle history and growth periods of the target species and life stages. This approach allows the stream flow recommendations to be tailored to the unique physical and biological aspects of each of the priority streams.

5.1 FLOW RECOMMENDATION

To integrate the various methods in making a preliminary flow recommendation for a stream, the following life history stages and seasons were prioritized. The prioritization occurred within certain biological and physical constraints, while evaluating the physical habitat characteristics of a stream. Flow recommendations were generally based on the following guidelines:

- The Planning Units stated objectives for this process were to establish minimum stream flows that maintain current habitat levels and species use, as well as to provide for the ongoing maintenance of riparian and water quality conditions.

- The winter season is a period of dormant growth for vegetation and low metabolic activity for aquatic species. Flow needs during winter are minimal and thus, winter rearing life history stages received a low priority. The wetted perimeter approach was used to ensure the channel bottom remained wet during winter months.

- The spring season is related to renewed vegetation growth and is an active period of trout spawning and incubation. Instream flow needs are highest in the spring for maintaining both riparian and aquatic habitats. Sufficient levels of flow are needed for spring spawning trout to provide adequate recruitment to the adult population on a long-term basis. As such, spring flows received a high priority.

- The recommended instream flow level each month following the initiation of spawning has at least two-thirds of the recommended flow of the prior month for sufficient incubation of embryos. The lowest 2-day flow during the incubation period was assessed to determine the potential risk to redd de-watering. Site-specific water surface elevations were evaluated along known spawning transects in Foster Creek to assess the level of incubation flows available to support spawning.

- Stream flows during the summer and fall low flow seasons are often limiting to riparian communities, water quality conditions and the rearing carrying capacity of a stream to support aquatic species. The low flow season received a high priority.

- If stream flows come up during late fall they might offer additional salmon spawning and rearing habitat capacity. However, such stream flows are inconsistent in WRIA 44 and 50 streams on an annual basis. The instream flow regimes during late fall are regarded as a habitat opportunity rather than maintenance of existing conditions. Late fall flows received a moderate priority.

- If recommended instream flows provided by any of the modeling methods are greater than the 10 percent exceedence levels experienced in the streams, other techniques are given a higher priority. Conversely, methods providing flow less than the 90 percent exceedence levels experienced in the streams are similarly disregarded. In this manner, the recommended flows stay consistent with the objective to maintain existing habitat and species use levels.
- The instream flow levels are initially recommended according to the species life history stage designated as primary. The life stage prioritized as secondary as well as riparian and water quality needs were reviewed to ensure flow levels were adequate to maintain such habitat features over a long-term basis.

Monthly minimum instream flow recommendations for each of the priority streams are presented in Tables 5-1 to 5-3. Shaded sections in the tables indicate which methods were given top priority each month to generate or verify the recommended flows.

Table 5-1. Review and recommendation of minimum instream flows for Foster Creek, WA.

Evaluation Parameter	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Priority Species Life Stage:												
Primary	STH-wr	STH-wr	STH-wr	STH-s	STH-s	STH-s	STH-j	STH-j	STH-j	STH-j	STH-j	STH-j
Secondary	-	-	-	STH-i	STH-i	STH-i	STH-i	CH-r	CH-r	CH-r	CH-r	CH-r
Hydrology Based												
10% Exceedence	44.0	52.3	7.9	12.1	6.6	4.2	2.8	1.3	1.5	2.7	8.0	26.0
50% Exceedence	16.9	7.1	6.6	7.8	4.4	2.9	1.7	0.9	0.9	2.0	3.9	6.5
90% Exceedence	3.0	3.5	5.3	5.0	3.3	1.9	0.9	0.7	0.7	1.2	2.9	4.1
Tennant	1.3	1.3	1.3	2.6	2.6	2.6	2.6	2.6	2.6	1.3	1.3	1.3
Tessman	6.8	2.8	2.6	3.1	1.8	1.2	1.7	0.9	0.9	2.0	1.6	2.6
Channel Based												
Wetted Perimeter	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Habitat Based												
Primary												
Max. Habitat	2.2	2.2	2.2	15.0	15.0	15.0	30.0	30.0	30.0	30.0	30.0	30.0
80% of Max.	-	-	-	7.5	7.5	7.5	13.5	13.5	13.5	13.5	13.5	13.5
50% of Max.	-	-	-	4.7	4.7	4.7	7.0	7.0	7.0	7.0	7.0	7.0
Secondary												
Max. Habitat	-	-	-	10.0a	10.0a	10.0a	10.0a	20.0	20.0	20.0	20.0	20.0
80% of Max.	-	-	-	5.0a	5.0a	5.0a	5.0a	6.5	6.5	6.5	6.5	6.5
50% of Max.	-	-	-	3.1a	3.1a	3.1a	3.1a	2.6	2.6	2.6	2.6	2.6
PU Recommended Minimum Flow	5.0	5.0	5.3	9.5#	6.3#	4.2	2.8	1.3	1.5	2.7	3.9	5.0

STH = steelhead trout, CH = Chinook salmon; s = spawning; r = rearing; wr = winter rearing; i = incubation
a – value represents 2/3 of primary species spawning flow for incubation
- Flow recommendation of 10% exceedence value reduced to account for available incubation habitat the subsequent month.

Table 5-2. Review and recommendation of minimum instream flows for Douglas Creek, WA.

Evaluation Parameter	Month											
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Priority Species Life Stage:												
Primary	RBT-a	RBT-a	RBT-s	RBT-s	RBT-s	RBT-r	RBT-a	RBT-a	RBT-a	RBT-a	RBT-a	RBT-a
Secondary	RBT-j	RBT-j	RBT-i	RBT-i	RBT-i	RBT-I	RBT-j	RBT-j	RBT-j	RBT-j	RBT-j	RBT-j
Hydrology Based												
10% Exceedence	13.6	19.9	15.1	13.5	12.9	13.1	13.9	12.2	12.1	12.5	13.3	13.1
50% Exceedence	12.9	14.8	13.6	13.3	12.8	12.7	12.3	11.9	11.8	11.9	12.9	12.7
90% Exceedence	12.5	12.3	11.9	13.0	12.6	12.2	11.7	11.5	11.4	11.4	12.3	12.1
Tennant	2.6	2.6	2.6	5.1	5.1	5.1	5.1	5.1	5.1	2.6	2.6	2.6
Tessman	5.2	5.9	5.4	5.3	5.1	5.0	4.9	4.8	4.7	4.8	5.2	5.1
Channel Based												
Wetted Perimeter	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Habitat Based												
Primary												
Max. Habitat	40.0	40.0	25.0	25.0	25.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
80% of Max.	24.0	24.0	16.5	16.5	16.5	24.0	24.0	24.0	24.0	24.0	24.0	24.0
50% of Max.	12.0	12.0	11.2	11.2	11.2	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Secondary												
Max. Habitat	14.0	14.0	16.7a	16.7a	16.7a	16.7a	14.0	14.0	14.0	14.0	14.0	14.0
80% of Max.	6.5	6.5	11.0a	11.0a	11.0a	11.0a	6.5	6.5	6.5	6.5	6.5	6.5
50% of Max.			7.5a	7.5a	7.5a	7.5a						
PU Recommended Minimum Flow	13.0	15.0	15.0	13.3	13.0	13.0	12.0	12.0	12.0	12.0	13.0	13.0

STH = steelhead trout, CH = Chinook salmon; s = spawning; r = rearing; wr = winter rearing; i = incubation

A – value represents 2/3 of primary species spawning flow for incubation

Table 5-3. Review and recommendation of minimum instream flows for Rock Island Creek, WA.

Evaluation Parameter	Month											
	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Priority Species Life Stage:												
Primary	RBT-wr	RBT-wr	RBT-s	RBT-s	RBT-s	CH-r	CH-r	CH-r	CH-r	CH-r	RBT-wr	RBT-wr
Secondary	-	-	RBT- i	RBT-I	RBT-i	RBT-I	RBT – j	RBT – j	RBT – j	RBT – j	RBT – j	RBT – j
Hydrology Based												
10% Exceedence	0.7	0.7	1.5	2.0	1.1	0.6	0.5	0.4	0.3	0.2	0.3	0.4
50% Exceedence	0.1	0.2	0.3	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.1	0.1
90% Exceedence	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tennant	0.2	0.2	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2
Tessman	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1
Channel Based												
Wetted Perimeter	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Habitat Based												
Primary												
Max. Habitat	4.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	4.0	4.0
80% of Max.	0.9	0.9	4.7	4.7	4.7	3.5	3.5	3.5	3.5	3.5	0.9	0.9
50% of Max.	-	-	3.3	3.3	3.3	1.3	1.3	1.3	1.3	1.3	-	-
Secondary												
Max. Habitat			4.0a	4.0a	4.0a	4.0a	6.0	6.0	6.0	6.0	6.0	6.0
80% of Max.			3.1a	3.1a	3.1a	3.1a	3.1	3.1	3.1	3.1	3.1	3.1
50% of Max.			2.2a	2.2a	2.2a	2.2a	1.9	1.9	1.9	1.9	1.9	1.9
PU Recommended Minimum Flow	0.7	0.7	1.5	2.0	1.1	0.6	0.5	0.4	0.3	0.2	0.3	0.4

STH = steelhead trout, CH = Chinook salmon; s = spawning; r = rearing; wr = winter rearing; i = incubation
a – value represents 2/3 of primary species spawning flow for incubation

5.2 FLOW RECOMMENDATION RATIONALE

5.2.1 Foster Creek

Foster Creek stream temperatures indicate a strong winter season and the establishment of a winter flow regime from December through March is appropriate. Biological suitability criteria for winter trout rearing used in the PHASIM modeling suggest the maximum habitat in Foster Creek is achieved at 2.2 cfs. This flow rate is less than the available water levels during winter months. To remain consistent with the Planning Unit objectives to maintain existing habitat levels, the inflection point of the wetted perimeter approach resulting in 5.0 cfs is recommended as the winter minimum flow level. This approach is designed to keep sufficient water in the channel cross section to cover the stream bottom. During the month of March, the 90 percent exceedence level of 5.3 cfs is recommended. This value is slightly higher than the inflection point of the wetted perimeter.

Spawning and incubation is initiated in mid-April and carries through the month of July. Spawning flow requirements are needed to provide suitable depths and velocities for redd construction, to provide proper stream velocities to deliver oxygen to embryos and carry away waste products during incubation and to provide proper flow elevations for the inundation and annual soil water recharge of riparian vegetation.

Biological modeling (PHABSIM) with blended habitat suitability criteria from small, semi-arid interior streams and from the State fallback curves (Appendix D) suggests steelhead trout spawning flows between 4.7 and 15.0 cfs and incubation flows between 3.1 and 10.0 cfs would be commensurate with 50 and 100 percent of the maximum WUA habitat flow levels, respectively. The modeled maximum habitat WUA spawning flow of 15.0 cfs is generally not available for the spawning season. For these months, the 10 percent flow exceedence level each month is an appropriate flow recommendation since it maintains existing riparian and aquatic habitat levels and water quality conditions during the highest priority spring growth period. One of the important guidelines in establishing spawning flow is to ensure sufficient water is available in each subsequent month to support the incubation of redds constructed one month earlier. As a general rule-of-thumb, two-thirds of previous months' flow is recommended to support subsequent incubation. For example, the 10 percent exceedence flow in July of approximately 2.8 cfs, would readily support spawning at a 10 percent exceedence flow of 4.2 cfs in June. The incubation flow of 4.2 cfs in June supports a flow of 6.3 cfs in May, just slightly below the monthly 10 percent exceedence flow of 6.6 cfs. As such, the recommended May spawning flow was lowered slightly to 6.3 cfs. As an incubation flow, the 6.3 cfs would support 9.5 cfs spawning flow recommended for the month of April.

During the summer and fall low flow rearing season of August through November, the PHABSIM modeling for steelhead and Chinook juveniles indicates 50 to 100 percent of the maximum WUA habitat occurs between 2.6 and 30.0 cfs. Such stream flows are not available in the creek until perhaps December. The Planning Unit's (PUs) minimum flow setting objective was to establish flows for fish that maintain current levels of habitat and species use. Using the hydrology-based 10 percent exceedence flows from August through October will ensure existing riparian communities and aquatic habitat conditions are maintained. Water quality conditions as a function of stream discharge are estimated to comply with the new state standards at the 90 percent exceedence flow level. Water quality will readily be maintained at the recommended 10 percent exceedence flow level during the low stream flow period of the year.

November is a transition month where the behavior of the rearing fish is tending toward winter refuge with a decrease in daylight hours and cooler water temperatures than the prior three-month season. This period in WRIA 44 and 50 is one where stream flows could come up with a rainstorm, but often remain very low. Given the large spread in measured stream flows for this season, use of the 50 percent exceedence level of 3.9 cfs is recommended. The recommended November flow regime transition is consistent with the biological transition and compatible with the flow recommendations for October and December.

5.2.2 Douglas Creek

Douglas Creek offers very stable and consistent stream flows on a year-round basis. As such, neither the Tennant nor the Tessman hydrology-based methods are inappropriate for use on this stream.

Given the warm, stable water temperature regime and single species use, it is also a stream that can be separated into 2 basic life history periods; spawning (March through May) and rearing (June through February). A winter refuge period is non-existent for aquatic species, since water temperatures remain sufficiently high year-round for feeding, growth and other metabolic activities.

Using the state default HSI criteria, PHABSIM modeling suggests 50 to 100 percent of the maximum spawning habitat occurs between 11.2 and 25.0 cfs. The available water in Douglas

Creek, as recorded between the 10 and 90 percent exceedence levels during the spring spawning period, will not support 100 percent of the maximum, modeled WUA spawning habitat. As a high priority season for establishing riparian habitat and providing for annual recruitment to the fish populations, the 10 percent monthly exceedence flow level is recommended as the minimum instream flow for March. This flow level is reduced to the 50 percent monthly exceedence flow level to accommodate ongoing spawning and incubation in April and May. In round numbers this flow level changes from 15 cfs in March to 13 cfs in May. Each subsequent month offers sufficient incubation flow to support spawning at these discharge levels.

For trout rearing conditions during the balance of the year (June through February), PHABSIM output suggests stream flows between 12 and 40 cfs provide from 50 to 100 percent of maximum adult fish habitat. Similarly, the PHABSIM model suggests flows between 6.5 and 14 cfs provide 80 and 100 percent of the maximum habitat for rearing juvenile trout. There is insufficient water in Douglas Creek, as recorded between the 10 and 90 percent exceedence levels, to support 100 percent of the maximum, modeled WUA rearing habitat for either adult or juvenile life history stages. As a moderate priority season for maintaining riparian and aquatic habitat and, the 50 percent monthly exceedence flow level is recommended as the minimum instream flow for June through February. In round numbers this flow level changes from 12 cfs in July to 15 cfs in February. These recommendations bracket the wetted perimeter value and should maintain current aquatic, riparian and water quality conditions.

Rock Island Creek

Multiple fish species and three life history stages are present in Rock Island Creek. The following biological seasons have been established: (1) winter resident rainbow trout and coho salmon rearing from November through February, (2) resident rainbow trout spawning (March – May) and (3) Chinook and coho salmon and rainbow trout summer rearing from June through October.

Winter is a period of low biological activity and dormant vegetative growth. Winter rearing criteria provide WUA estimates that peak at 4 cfs. These flow levels are generally not available in Rock Island Creek from November through February. Use of the 10 percent exceedence values of the estimated natural flows in Rock Island Creek from 0.3 in November increasing monthly to 0.7 cfs in February is recommended.

Based on stream flow temperature regimes, rainbow trout spawning should be initiated in March annually. PHABSIM modeling results suggest 50 to 100 percent of the maximum spawning habitat levels fall between 3.3 and 6.0 cfs, respectively. The WUA vs Q curves do not peak within the recorded range of hydrology data for the creek. Therefore, to be consistent with the study objectives of maintaining existing fish, riparian and water quality conditions, use of the monthly 10 percent flow exceedence levels of the natural flow regime, ranging between 1.5 and 2.0 cfs, are recommended for the spawning period. Subsequent monthly flows are sufficient for incubation in each case through the month of June where the 10 percent exceedence flow level of 0.6 cfs will support the prior monthly spawning flows.

PHABSIM results for summer salmon and trout rearing are similar to the spawning season in that 50 to 100 percent of maximum WUA ranges between 1 and 6 cfs depending upon the species. These flow levels are generally unavailable instream. Use of the 10 percent flow exceedence level beginning at 0.5 cfs in July and gradually decreasing to 0.2 cfs in October is recommended. These flow levels should maintain existing fish, riparian and water quality conditions in Rock Island Creek.

The PHABSIM modeling results indicate the stream would benefit from more flow than currently is available on a monthly basis in the stream. This stream would be a good candidate for consideration of a low flow augmentation project in WRIAs 44 and 50.

5.3 STUDY LIMITATIONS

The confidence in using any one of the methodologies for recommending instream flows is low. The hydrological assessment is based on less than three years of stream flow data. It provides a good understanding of low flows, but does not fully represent the possible range of flow values. Efforts to simulate a long-term record based on stream flow information from the Crab Creek gage have been unreliable. Efforts to develop both hydrologic and habitat time series as stated in the scope of work could not be accomplished at this time.

The wetted perimeter approach allows an assessment of points in the channel above which additional water does not add as much wetted perimeter per incremental increase in stream flow. The method does not allow an assessment of seasonal changes and it only indirectly implies a benefit to aquatic habitat. Use of the wetted perimeter in combination with other approaches as a reference point is recommended.

The PHABSIM approach is tailored to life history stage suitability of flows in relation to incremental changes in streamflow as it interacts with physical channel characteristics. Since the state's suitability criteria for small streams evaluated in this analysis, were too restrictive in relation to the size of streams in WRIAs 44 and 50, additional HSI criteria from small semi-arid interior streams were used for steelhead trout spawning (Appendix D). This approach improved our confidence in the PHABSIM model to provide reasonable recommendations for the species and life stages of interest in Foster Creek. Nevertheless, model confidence would increase with the development of site-specific habitat suitability criteria. Our confidence in the PHABSIM recommendations for Douglas and Rock Island creeks remains low with use of the State's fallback HSI criteria.

The riparian assessment indicates stream flows near the present day 50 percent exceedence level on a monthly basis during the growing season should maintain the current riparian vegetation patterns. The riparian assessment concludes a flow regime that provides mean monthly stream flows should maintain riparian habitat conditions. Water quality modeling was performed to ensure the minimum flow regime will not adversely influence concentrations of target water quality parameters. This effort indicates recommended stream flows should not preclude compliance with the new state water quality standards.

5.4 FLOW SETTING RISK FACTORS

It is important to recognize the dynamic nature of stream channels and hydrological flow regimes in WRIAs 44 and 50. Establishing stream flows on hydrology-based methods are at some risk to future flow-related changes. Since all of the perennial flowing streams in WRIAs 44 and 50 are groundwater dominated, the surface water expression of this groundwater is the existing baseflow. The variation in baseflow has been low during the 3-year monitoring period to date. However, flow changes over a long period cannot be predicted. Changes in water yield, groundwater recharge and land use practices will likely have an influence on the gage sites in each of Foster, Douglas and Rock Island Creeks.

Similarly, storm events can have a dramatic influence on stream channel characteristics altering channel hydraulics. Flow recommendations from channel-based methods like wetted perimeter and from hydraulic modeling like PHABSIM can vary widely when channel conditions change.

It is also likely that future population growth and development in Douglas County will alter land use, groundwater recharge and water needs. However, existing water withdrawals upstream of the gage sites have had a negligible effect on surface water stream flows in Foster, Douglas and

Rock Island creeks. Less than 1 percent of the subbasins upstream of the gages are consuming surface or groundwater (refer to the specific details of each subbasin Table 8.1 of the WRIA 44 and 50 Watershed Assessment Report PGG et al. 2003). It would take a substantial amount of future water withdrawals to alter surface water in the priority streams for setting instream flows.

5.5 FUTURE ACTIONS

To improve the confidence in the instream flow recommendations, it is recommended to continue stream flow data collection in each of the priority streams to improve the prediction of monthly flow exceedence values. It is also recommended to continue the effort to develop a long-term 10 to 20-yr simulated flow record by correlating with the Crab Creek stream flow gage. The PHABSIM modeling effort would benefit from the development of site-specific habitat suitability data to refine the HSI curves to improve the model's representation of microhabitat use and preference of target species. Continued biological surveys to refine estimates of the extent and timing of habitat use by each of the target species and life stages would also be of value.

Given the hydrologic record, it is clear abundant surface water in Foster and Rock Island creeks is only sporadically available during the winter and early spring periods. It is recommended the Planning Unit consider water storage by means of either surface or groundwater storage for low flow supplementation purposes in Rock Island and Foster creeks. Without rainfall, the perennial nature of these streams is supported solely by groundwater inputs during the low flow season. The annual surface water expression in these streams is a function of groundwater recharge. Low seasonal baseflows for these streams have been estimated to lie in the range of 0.1 cfs in Rock Island Creek and 1.2 cfs in Foster Creek. Additional groundwater recharge should increase base flow conditions and, based on instream flow assessment, increased recharge should have a corollary improvement in stream habitat conditions. Douglas Creek has a very consistent flow pattern based on groundwater flow with minimal seasonal fluctuation. The fisheries and riparian conditions in Douglas Creek have responded well to the stable flow regime. Further study effort in Douglas Creek is not recommended, although continuation of the ongoing flow monitoring is suggested to ensure the current flow trends remain consistent.

Due to the short record of hydrologic data collection and lack of site-specific validation of HSI curves, it is recommended a minimum flow regime for the creeks be established on an interim basis. The flow regime should be reviewed following additional data collection and updated per new information.

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