

Woods Creek Watershed Habitat Conditions Report



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Acknowledgements

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I. EXECUTIVE SUMMARY

The Woods Creek Watershed Habitat Conditions Report documents current habitat and stream temperature conditions in the Woods Creek basin and suggests a suite of possible restoration and preservation actions. This project was completed by Snohomish County Surface Water Management to provide a better understanding of habitat limitations for ESA listed salmonids in this watershed, including Chinook (threatened), steelhead (threatened), and coho (species of concern).

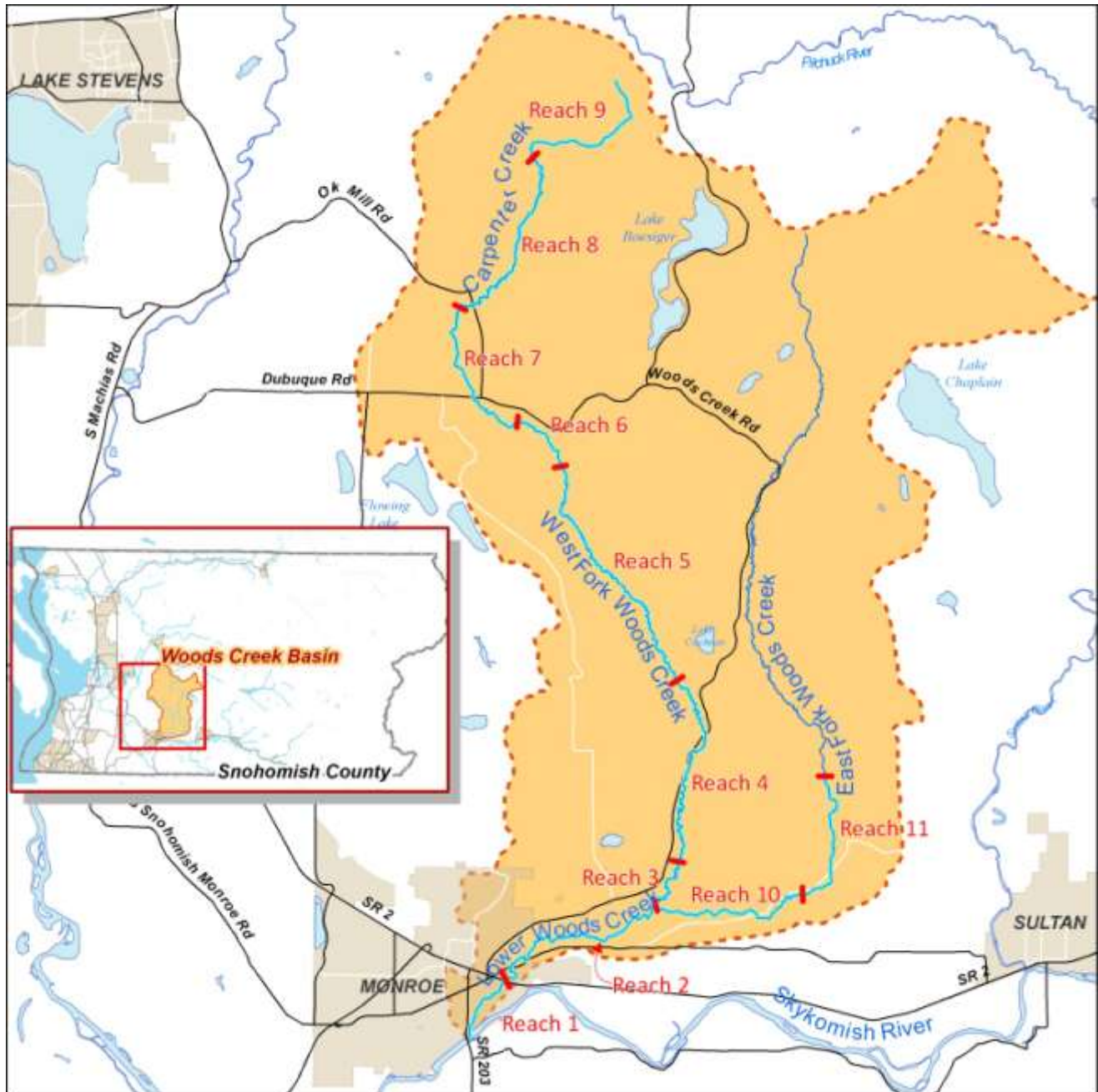


Figure 1. Woods Creek watershed and analysis reach breaks. The Woods Creek watershed is highlighted in orange. The mainstem of Woods Creek (includes Lower, West Fork, Carpenter, and East Fork) was subdivided into 11 analysis reaches.

Woods Creek is a tributary to the lower Skykomish River, and it is created by the combined flow of West Fork Woods Creek and East Fork Woods Creek. West Fork Woods Creek Sub-basin is identified in the *Snohomish River Basin Salmon Conservation Plan* (2005) as having particularly high value among lowland tributary streams for supporting Chinook and coho salmon viability (SBSRF, 2005). The Salmon Conservation Plan highlights the importance of preserving and restoring hydrologic and sediment processes in both the West Fork and Lower Woods Creek sub-basins. The more recent listing of steelhead salmon reinforces the importance of Woods Creek, historically a significant steelhead producing watershed.

To assess the habitat conditions of Woods Creek, the mainstem and forks were divided into eleven analysis reaches (Figure 1). Data were collected in the field and through analysis of remote-sensing data. These data included: channel gradient, riparian land-cover, canopy cover, substrate size characteristics, bank conditions, woody debris presence, pool conditions, and water temperature. Potential actions were identified that are intended to help address habitat limitations within each reach.

Data analysis revealed that the primary limitations to salmon habitat include elevated stream temperatures, fine sediments, lack of large woody debris (LWD) in the channel, and infrequent, low quality pools. These degraded conditions may have been caused by a loss of forest and wetland functions throughout the watershed. Therefore, long-term salmon recovery prescriptions include preservation of remaining forests and wetlands throughout the basin and restoration of riparian forests (SBSRF, 2005). Short-term recovery prescriptions include the addition of large woody debris to the channel to scour deep pools, retain fine sediment, and create cover for rearing salmonids (SBSRF, 2005).

Table 1 summarizes the primary habitat limitations for each of the eleven analysis reaches as well as potential actions that could help address these limitations.

Table 1. Summary of results by analysis reach. Primary habitat limitations and potential next steps are given for each analysis reach. A more detailed description of this information can be found in section VI: Reach Descriptions.

Reach	Habitat Limitations	Next Steps
Lower		
1	• High fine sediment • Low wood volume & frequency • Unstable banks • Shallow pools	• Possible LWD installation with additional sediment transport study • Riparian enhancement
2	• Low pool area & frequency • Low wood frequency • Degraded riparian vegetation • Lack of canopy cover • Unstable banks	• Riparian re-vegetation • LWD installation to scour pools
West Fork/Carpenter		
3	• High fine sediment • Low wood volume & frequency • Degraded riparian vegetation	• Riparian re-vegetation • LWD installations to trap fine sediment, scour pools & sort gravels
4	• Low pool frequency • Highly erosive soils • Unstable banks • Degraded riparian vegetation • Lack of canopy cover	• Riparian re-vegetation • LWD installation to sediment, scour pools, and sort gravels • Bio-engineered bank stabilization where appropriate
5	• High fine sediment	• Preservation of existing habitat
6	• High fine sediment • Low wood volume & frequency • Degraded riparian vegetation • Lack of pools	• Riparian re-vegetation • LWD installation to scour pools & sort gravels
7	• Degraded riparian vegetation • High fine sediment • Low wood volume & frequency • Unstable banks	• Riparian re-vegetation • Livestock exclusion & other agricultural BMPs • Bio-engineered bank stabilization where appropriate
8	• Degraded riparian vegetation • Lack of canopy cover	• Preservation of existing habitat
9	• Degraded riparian vegetation	• Preservation of existing habitat • Riparian re-vegetation
East Fork		
10	• Low wood volume • Lack of deep pools • Small wood dominated	• Preservation of existing habitat • LWD installation to scour pools
11	• High fine sediment • Lack of deep pools • Degraded riparian vegetation	• Riparian re-vegetation • LWD installation to scour pools & sort gravels

II. BACKGROUND

A. Purpose

The *Snohomish River Basin Salmon Conservation Plan* (2005) identifies the West Fork Woods Creek sub-basin as an important part of the Chinook recovery strategy in the Snohomish River watershed. The Woods Creek Habitat Conditions Project was initiated to develop a detailed recovery approach for all of Woods Creek. Through analysis of current habitat and stream temperature conditions in the basin, this project suggests a framework for restoration and preservation actions to improve the abundance, health, and distribution of Chinook, steelhead, and coho.

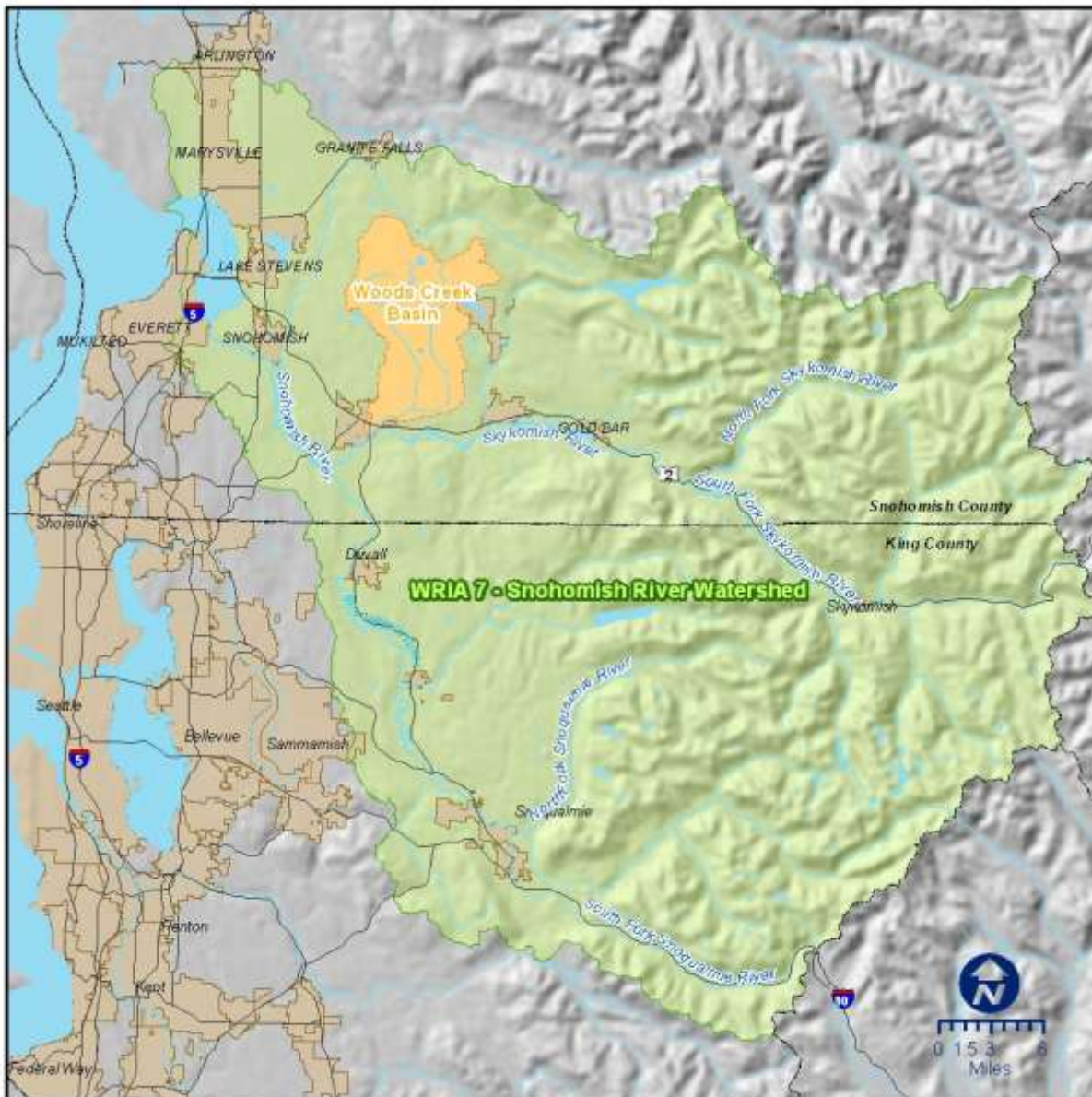


Figure 2. Snohomish River watershed. The Snohomish River watershed (WRIA 07) is highlighted in green and the Woods Creek sub-basin is highlighted in orange.

B. Overview of Woods Creek

Woods Creek (Figure 2) is the largest lowland tributary of the Skykomish River, draining an area of nearly 61 mi². Small peaks in the upper watershed reach an elevation of 2,370 feet and the stream drains to an elevation of 40 feet at the mouth. Woods Creek enters the Skykomish River at river mile 24 at the east end of the City of Monroe, about 16 miles east of Everett.

The Woods Creek watershed is divided into the Lower, West Fork, and East Fork Woods Creek sub-basins. At river mile 3.9, the two nearly equal sized sub-basins of the West and East Forks come together to form Lower Woods Creek (Figure 3).

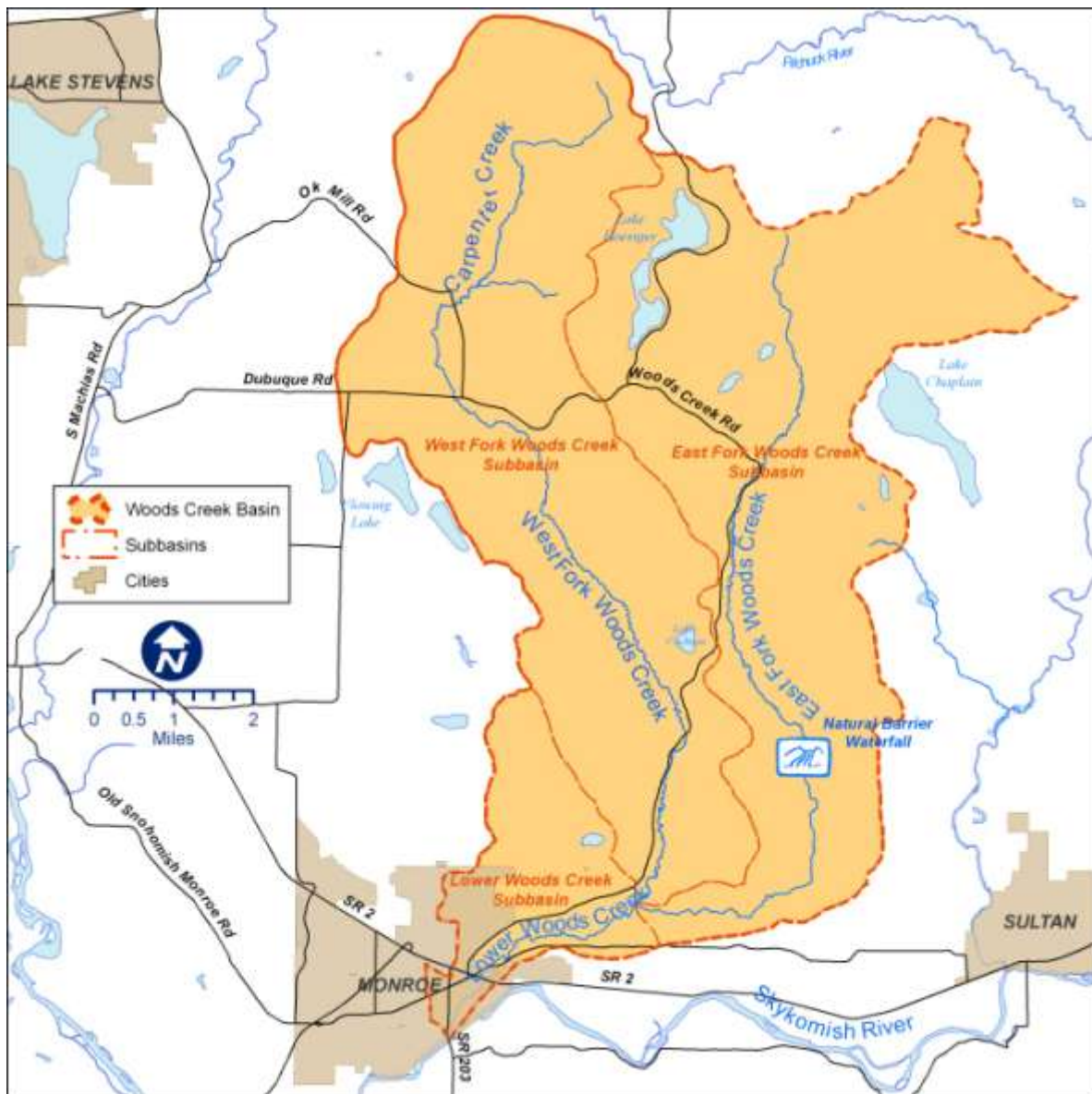


Figure 3. Woods Creek watershed. The Woods Creek watershed is highlighted in orange with boundaries shown for the three sub-basins: Lower, West Fork, and East Fork of Woods Creek.

Land-use

The primary land uses in the upper reaches of Woods Creek are forestry and rural residential, while the lower reaches are dominated by small non-commercial farms and several equestrian centers (Thornburgh and Williams, 2000). The basin is currently zoned 48% rural residential (5 acres parcels) and 45% forestry (Figure 4). Many non-commercial farms are present as part of the area's agricultural legacy. The population in the basin has increased by 34% from 8,655 in 2000 to 11,595 in 2007.

Land cover

Historical aerial photos (1947) indicate the watershed was originally a mix of evergreen and deciduous forest with much of the floodplain converted to agriculture. Current land cover still primarily consists of vegetation, with a mixture of evergreen forest, deciduous forest, shrubs and small trees, grass and crops. Impervious surface covers less than 1% of the East and West Fork sub-basins, however, the Lower Woods Creek sub-basin has approximately 8% impervious from the urban and rural development in and around the City of Monroe.

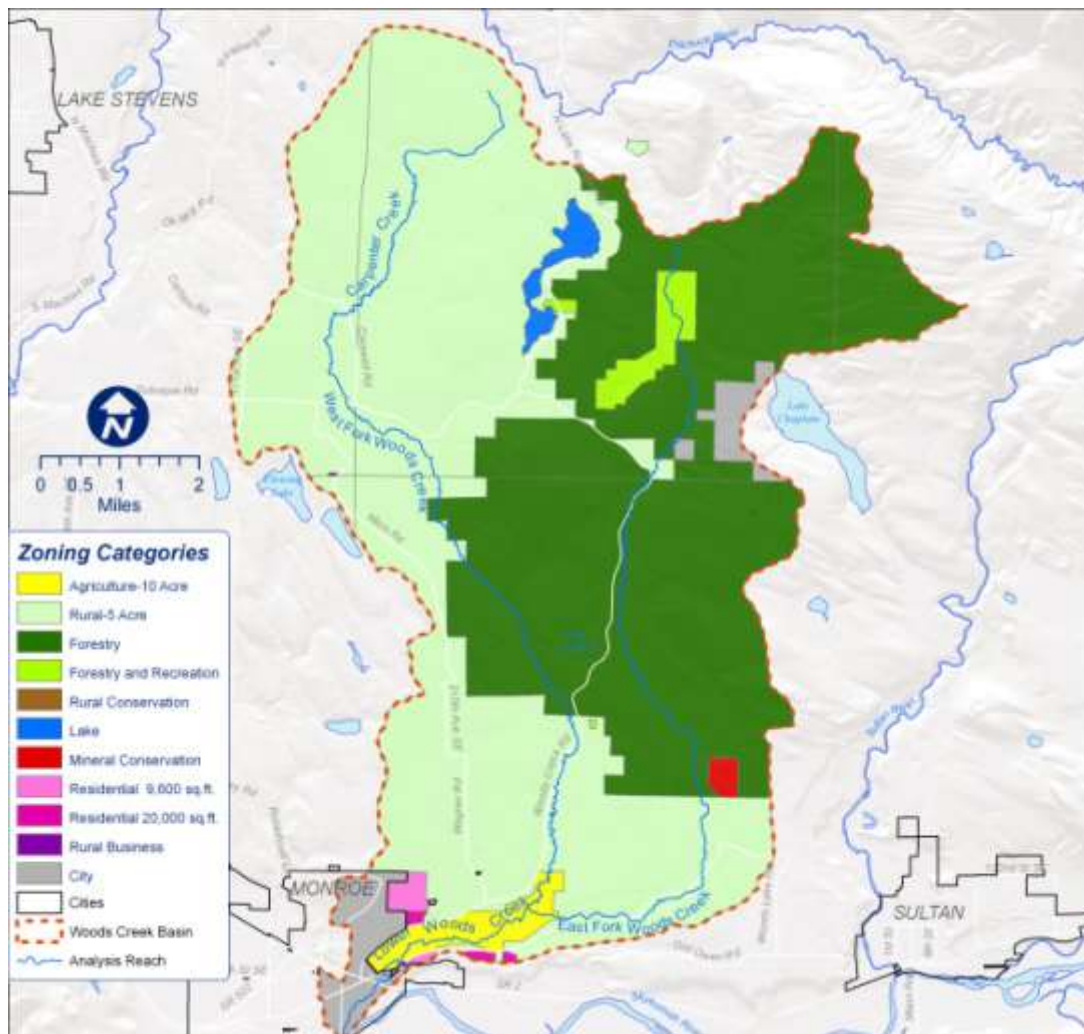


Figure 4. Land use zoning. Land use zoning designations in the Woods Creek basin.

Climate

The climate in this watershed is fairly mild. In the City of Monroe, the lowest elevation in the watershed, average monthly temperatures range between 39°F and 64°F (WRCC, 1929-2009). Average yearly precipitation is 48 in with a yearly snowfall of 8 in (WRCC, 1929-2009). Snowfall is likely greater in the upper watershed where the elevation reaches 2,370 ft.

Geology and soils

The Woods Creek watershed is underlain by glacial deposits. In most of the basin, parent material is comprised of Vashon till and recessional outwash. Soils formed from this material are often shallow and well-draining above the compacted till layer at approximately 0.8 m (33 in). These properties make soils susceptible to erosion by surface water and can lead to high stream migration and sediment transport.

Hydrology

Flow was gauged at river mile 3.4 in Lower Woods Creek between 1947 and 1978 (USGS 12141000). Average flow at this point was 155 cfs with an average yearly peak flow of 1,375 cfs.

Fish use

At river mile 3.9, the stream branches into two nearly equally sized drainage basins (Figure 3). The West Fork becomes Carpenter Creek in the upper watershed and nearly all 17 mi of this fork are accessible to salmonids. Fish migration in the East Fork, however, is blocked 4.2 mi from the confluence of the forks by a natural waterfall that is approximately 50 ft high. Above this natural blockage, resident salmonids (kokanee: *Oncorhynchus nerka*) are present in the streams draining to and from Lake Roesiger.

Chinook, coho, chum, and pink salmon, as well as steelhead and presumably bull trout, all live in Woods Creek (WDFW, 2010). The approximate distribution of Chinook, coho, and steelhead are shown in Figure 5.

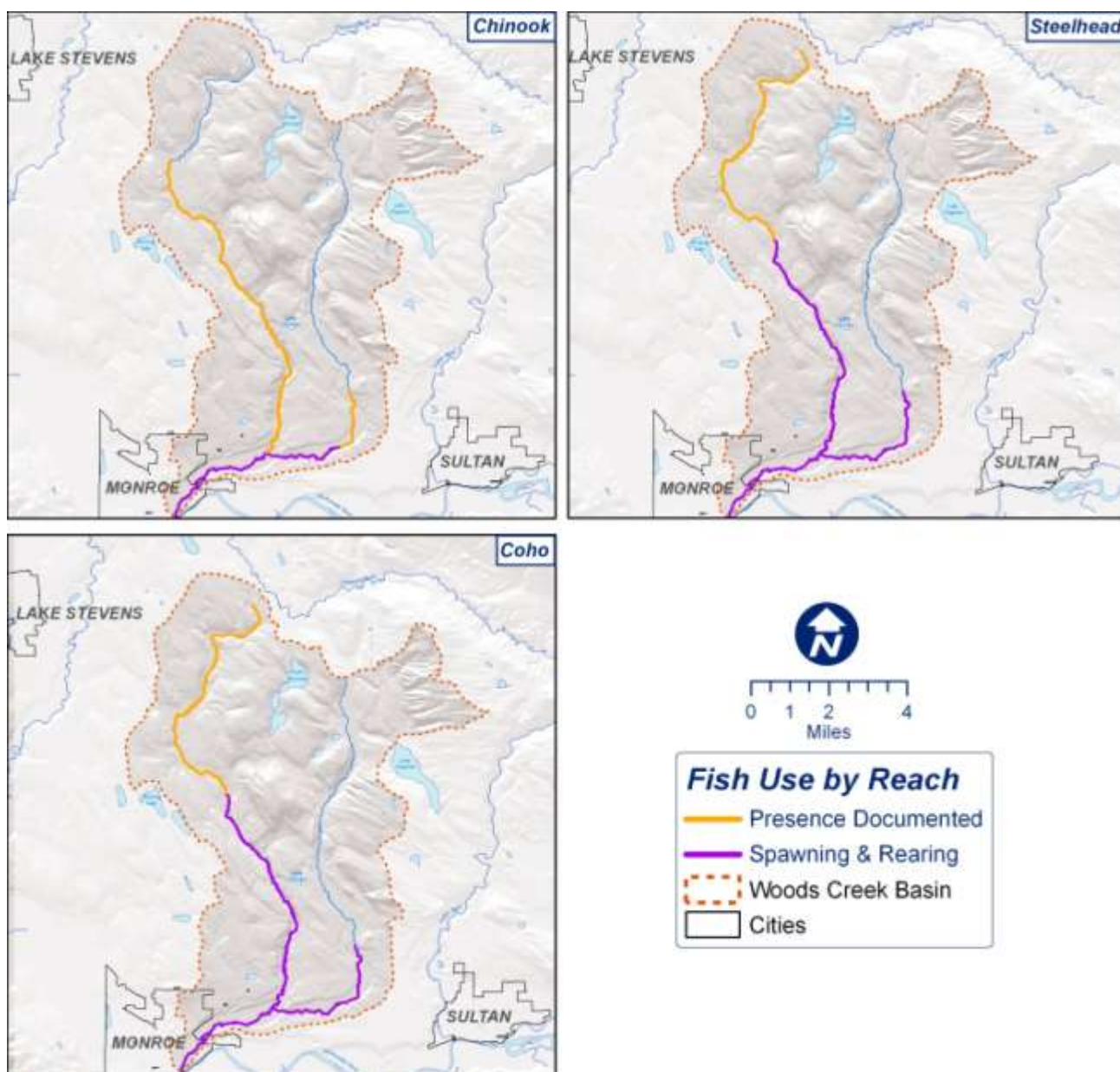


Figure 5. Fish use. Data from WDFW's Salmonscape database are represented here for approximated Chinook, steelhead, and coho salmon distributions.

C. State of the Watershed

Residential development is expanding throughout much of the Woods Creek watershed and is threatening both forestry and agricultural land-uses (SBSRF, 2005). In general, as areas develop, there is a loss of forest cover and an increase in impervious surfaces. This can result in changes to the hydrology of the system and can potentially contribute to increases in flooding and erosion.

Prior to this study, available data and field observations indicated the major problems related to aquatic habitat in Woods Creek were unstable streambanks, lack of riparian vegetation, and elevated stream temperatures (Leonetti et al., 2008). Lack of riparian vegetation and unstable streambanks can cause channel enlargement that may increase sediment yield (from channel erosion) and elevate temperatures (from increased solar radiation) (Spence et

al., 1996; Knutson and Naef, 1997). Livestock access in some locations likely contributes to bank erosion.

D. Regional Salmon Planning

The West Fork of Woods Creek is recognized as having particularly high potential among lowland tributary streams to support Chinook and coho salmon (SBSRF, 2005). In 1999, the federal Endangered Species Act listed Puget Sound Chinook and bull trout as threatened species. These listings mandated the creation of a cohesive *Snohomish River Basin Salmon Conservation Plan* (SBSRF, 2005). This work was undertaken by the Snohomish Basin Salmon Recovery Forum in conjunction with NOAA Fisheries, the U.S. Fish and Wildlife Service, and the Shared Strategy for Puget Sound (SBSRF, 2005; 3.5). Since the creation of the recovery plan, steelhead trout have additionally been listed as a threatened species.

The Salmon Conservation Plan divides the whole of the Snohomish River Basin into sub-basin strategy groups. These groups are categorized by certain identifying features which call for the implementation of a specific recovery strategy. The Lower Woods Creek sub-basin is classified into the *Mainstem Secondary Restoration* strategy group and the West Fork of Woods Creek sub-basin is classified into the *Rural Streams Primary Restoration* strategy group (SBSRF, 2005;11.56). Both of these sub-basins strategy groups are important if populations are to recover to the target levels identified in the recovery plan, particularly with regard to restoration of spatial structure and diversity of Chinook populations (SBSRTC, 2005). The plan cites the highest priority (first-tier) ecological recovery needs in both of these sub-basin strategy groups as being the preservation and restoration of hydrologic and sediment processes. Other important (second-tier) actions include preserving and enhancing riparian areas, removing human-made barriers blocking salmonid access, and restoring shoreline conditions. Additional (third-tier) actions include addressing water quality impacts and enhancing in-stream structural composition (SBSRF, 2005; 11.58). Actions that contain development and increase forest cover are recommended to maintain and restore habitat forming processes in the basin (SBSRF, 2005; 11.55).

E. Water Quality

While the assessment of impacts to water quality for this report is focused on stream temperature, existing water quality data was reviewed for fecal coliform and dissolved oxygen.

Washington State Administrative Code (WAC173-201A) requires that Woods Creek meet fecal coliform bacteria standards for primary contact recreation. Seasonal or annual geometric mean values must not exceed 100 colonies/100 ml of sample, and no more than 10 percent of samples used to calculate a geometric mean can exceed 200 colonies/100 ml.

As required by section 303(d) of the Clean Water Act, the Department of Ecology's 2008 assessment of Snohomish County data gathered in the Woods Creek basin resulted in segments of Woods Creek being listed as impaired for fecal coliform bacteria, and one segment on the West Fork of Woods Creek listed as impaired for dissolved oxygen.

To address the bacteria impairment, the Department of Ecology published a total maximum daily load (TMDL) clean-up plan for the Lower Snohomish River Tributaries (including Woods Creek) outlining the actions needed to reduce high bacteria concentrations found in impaired

waters (Svrjcek, 2003). The established TMDL states that “probable sources of contaminants include agriculture, pasture land, confined animals, tree harvesting, forest management, road construction, channelization, removal of riparian vegetation, and streambank modification (Svrjcek, 2003).” Failing septic systems are also likely contributors (Svrjcek, 2003).

Snohomish County’s analysis of fecal coliform bacteria data gathered monthly during 2010 from two established long-term stations on Woods Creek suggests that both are meeting the geometric mean and 10 percent criteria. These data will be provided to the Department of Ecology for the 2012 303(d) list assessment.

In accordance with the Washington State Administrative Code (WAC 173-201A), dissolved oxygen in Woods Creek and its tributaries must not fall below 9.5 mg/l. The Department of Ecology based its 2008 assessment of dissolved oxygen impairment in the West Fork of Woods Creek on grab samples collected by Snohomish County between 2004 and 2006. A review of Snohomish County dissolved oxygen data gathered from 2004-2009 for the listed segment suggests that 6 of 60 single grab measurements over the five year period fell below 9.5 mg/l. The lowest one day measurement was 7.27 mg/l, observed in February of 2004. In 2004 and again in 2009, greater than 10 percent of single grab sample values fell below the criteria.

III. METHODS

The approach to this habitat conditions project consisted of quantifying salmon habitat limitations (primarily for Chinook, steelhead and coho), identifying the potential causes of this habitat degradation, and then synthesizing this information into conclusions and next steps for restoration and preservation of the basin. The following is a summary of the methodology. For a more complete description of methods used, see Appendix A.

A. Reach delineation

This study includes Lower Woods Creek from the mouth to the confluence of forks, the East Fork of Woods Creek to the natural barrier (waterfall) at river mile 4.2, and the West Fork of Woods Creek (including Carpenter Creek). These reaches, henceforth referred to as the mainstem of Woods Creek, were further divided into 11 analysis reaches (see Appendix A: Methods). Data used to subdivide reaches included channel gradient (Figure 6), valley width, channel size, and land-use zoning boundaries (Figure 4). Reach delineation for the watershed is shown in Figure 7.

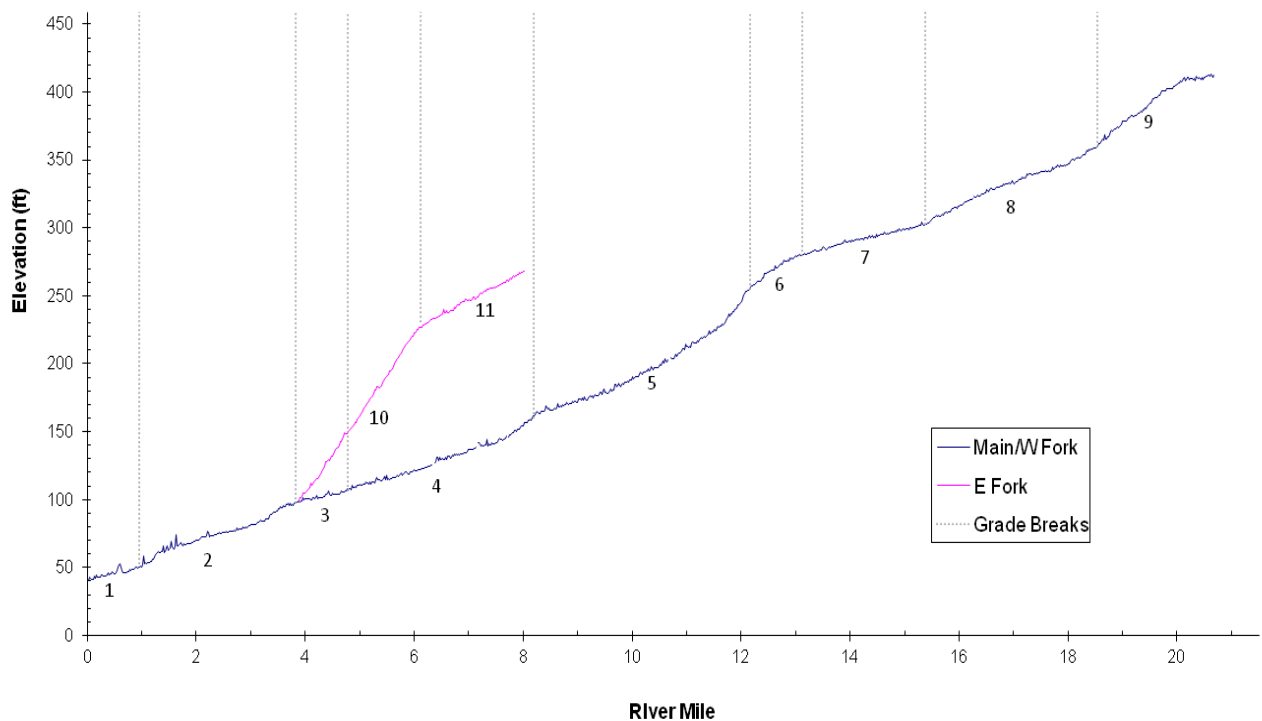


Figure 6. Channel profile. Channel slopes every 100 ft were calculated using LiDAR elevation data. Slope was one criterion used to break out the eleven analysis reaches as shown. The blue line represents channel elevations for Lower Woods Creek from the mouth to the West Fork and then Carpenter Creek. The orange line represents the East Fork of Woods Creek to the natural barrier waterfall.

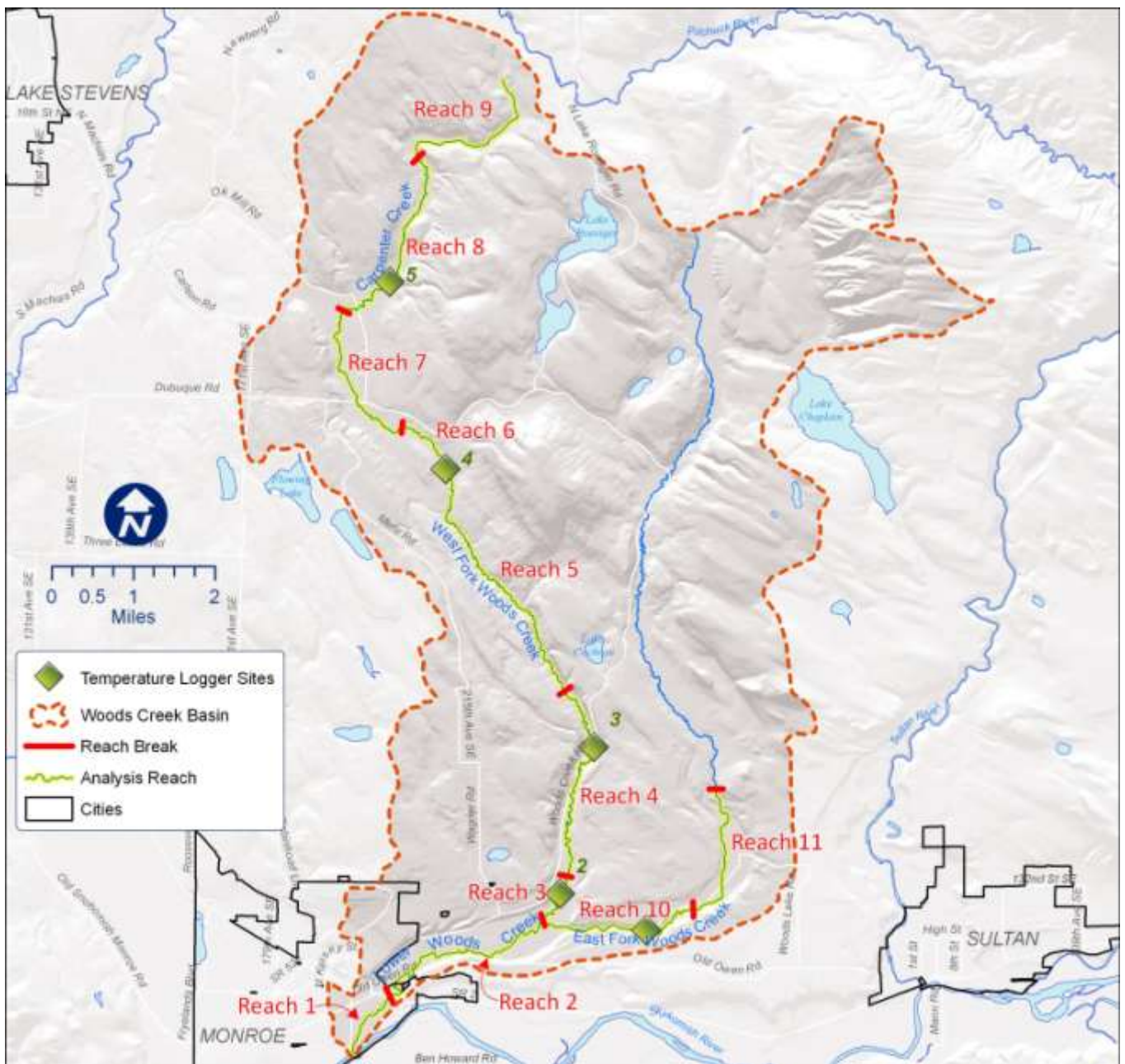


Figure 7. Analysis reach delineation. The mainstem of Woods Creek was subdivided into 11 analysis reaches using LiDAR data for channel gradient, valley width, channel size, and land-use zoning.

B. Land cover analysis

As part of Snohomish County's Critical Area Regulations monitoring program, 2007 high-resolution multi-spectral satellite imagery, was used to classify land cover into the following categories: emergent wetland, grass/pasture/crops, scrub/shrub, deciduous forest, evergreen forest, impervious surface, bare earth, gravel bar, and open water (Appendix A: Methods). Data for this report came from preliminary datasets and have not been subject to a final accuracy assessment. The analysis was done for the entire watershed, within a riparian buffer of 150 ft from the edge of the channel, and within the core re-vegetation zone of 50 ft from the edge of the channel. The percent of deciduous and evergreen forest combined was

used to analyze riparian condition relative to all analysis reaches and provide riparian enhancement goals.

C. Stream Temperature

Continuous temperature data was gathered from five locations (Figure 8) during the summer critical period (June 15th through September 15th), following the Department of Ecology's guidance for continuous temperature monitoring (WA DOE, 2003). All data analyzed for comparison with Washington State Water Quality Standards (WAC173-201A) is considered valid. Additional details on methodology are found in Appendix A, while results of the monitoring efforts are summarized in Table 6.

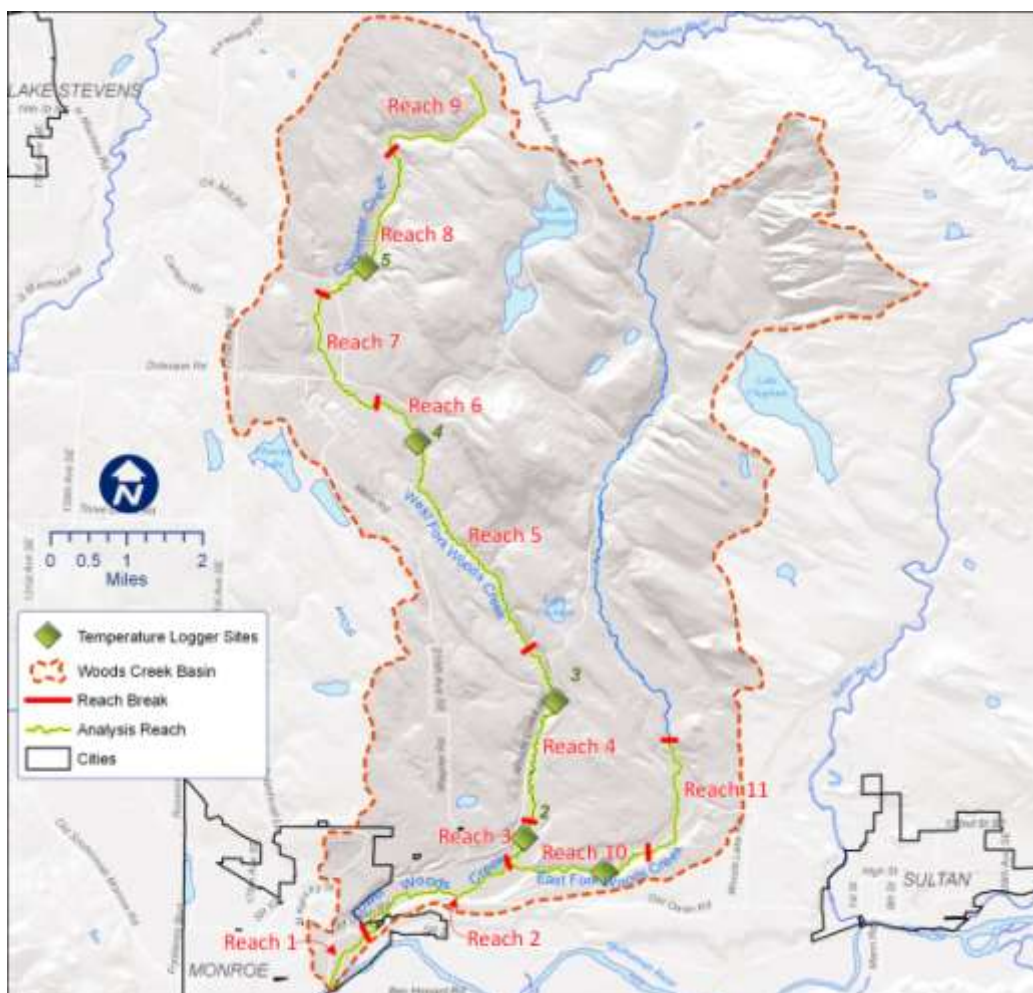


Figure 8. Location of temperature loggers. Green triangles represent the 5 locations where temperature loggers collected data the summers of 2009 and 2010.

D. Habitat Conditions

In-stream habitat data was collected using Snohomish County's *Wadeable Stream Habitat Survey Protocol* (Rustay et al., 2008; Appendix A: Methods). Surveys in the basin from 2007 were compiled and additional surveys to supplement this data were conducted the summer of 2009. Depending on length and assumed variability of each reach, one to three habitat surveys were completed in each of the 11 analysis reaches. Data from habitat surveys was summarized and extrapolated to the analysis reach level. Available data is intended to guide

general analysis of each analysis reach and prescribe broad restoration actions. Before implementing some types of in-stream projects, it is suggested that additional data be collected on the project site scale.

E. Sediment inputs and erosion potential

Three methods were used to determine the potential for sediment inputs to the stream: quantification of unpaved road area within 150 ft of the channel edge, classification of the erosion potential within 300 ft of the channel edge based on soil type, and land cover analysis of the riparian zone as described above (Appendix A: Methods).

IV. RESULTS

A. Reach Delineation and Physical Characteristics

Reach delineation was based on channel gradient (Figure 6), valley width, channel size (substituting for flow), and land-use zoning boundaries (Figure 4). The gradient throughout the system is low, ranging from 0.4 to 1.1% (Table 2).

Table 2. Reach delineation and physical characteristics.

Reach	Location	Length (mi)	Confinement	Land Use	Channel gradient (%)	Bankfull width (ft)	Width/Depth Ratio
1	Lower	0.9	Un-confined*	Urban & Public Park	0.6	50.1	11
2	Lower	2.9	Un-confined	Ag	0.6	48.9	12
3	West Fork	0.9	Un-confined/ moderately confined	Ag	0.4	23.0	7
4	West Fork	3.4	Moderately confined	Rural	0.6	24.6	9
5	West Fork	3.9	Confined	Forestry	0.7	21.7	9
6	West Fork	0.9	Moderately confined	Rural	0.6	26.9	15
7	West Fork	2.3	Un-confined	Rural - Ag	0.4	16.4	4
8	West Fork/ Carpenter	3.2	Un-confined	Rural	0.5	28.5	7
9	Carpenter	2.2	Moderately confined	Rural	0.7	11.8	6
10	East Fork	2.3	Moderately confined	Rural - Ag	1.1	37.4	17
11	East Fork	1.9	Un-confined	Rural	0.6	36.1	15

*Within the Skykomish River floodplain.

Reaches 1 and 2 in Lower Woods Creek are downstream of the confluence of the two major forks and therefore have the highest bankfull widths averaging 49 ft (Table 2). Reaches 3 through 9 continue up the West Fork and then Carpenter Creek (the main channel of this fork). Average bankfull widths for these reaches range from 23 to 26 ft in the lower reaches to 12 ft in the headwater reach. Reaches 10 and 11 are the East Fork, a larger fork than the West, and have average bankfull widths of 37 and 36 ft respectfully.

The width-to-depth ratio indicates that reaches 3, 7, 8, and 9 may be incised. Incision can occur naturally or through the impact of human alterations to the landscape. In both cases, this downward erosion can scour out spawning gravels, disconnect the stream from its floodplain, and introduce fine sediment to the system.

B. Land cover and canopy cover

A detailed analysis of 2007 high-resolution multi-spectral satellite imagery indicates the basin was comprised of approximately 37% evergreen forest, 24% deciduous forest, 18% shrubs and small trees, 12% grass and crops, and 3% impervious surface (Table 3). While the East and West Fork sub-basins have less than 1% impervious surface, the Lower Woods Creek sub-basin has approximately 8%, a likely result of development pressures facing the basin from the City of Monroe and surrounding area. The city is currently 6.1 mi² in area with the potential to grow an additional 1.6 mi² if Monroe annexes the property currently within the Urban Growth Area.

Table 3. Land cover (%). Percent area of land cover type was summarized for the entire Woods Creek basin*. (Percent values do not sum to 100% due to rounding.)

Land cover type	%
Grass/Pasture/Crops	12
Scrub/Shrub	18
Deciduous Forest	24
Evergreen Forest	37
Emergent Wetland	2
Bare Earth	2
Open Water	1
Gravel Bar	0
Impervious Surface	3
Unclassified	0

*These data were derived from preliminary land cover layer produced as part of Snohomish County's Critical Areas Monitoring Program (2012). Though accuracy tests were performed throughout the land cover classification a final formal accuracy assessment has not yet been completed for this product.

The percent of forest cover (deciduous and evergreen) within 150 ft of the edge of the channel and the canopy cover at the channel center were used to determine the riparian condition for each analysis reach (Table 4). Canopy cover at the center of the channel was used (as opposed to the canopy cover at the edge of the bank) because this value was more likely to exclude cover by shorter, non-native grass and shrub species. Our analysis of data suggests that reaches 2, 3, and 7 have the poorest riparian condition.

A comparison of the measured canopy cover to the measure of the potential, or expected, canopy cover for a healthy stream of a given bankfull width (Cristea and Janisch, 2007), show that Lower Woods Creek and the lower West Fork (reaches 2 and 3) and reach 7 in the upper West Fork have the greatest shade deficit overall (Figure 9). This data corresponds to the riparian condition data which shows that reaches 2, 3, and 7 have severely degraded riparian zones.

Table 4. Riparian condition and land cover*

Reach	% Forested (150 ft buffer)	Canopy Cover: Bank (%)	Canopy Cover: Center (%)	% Impervious (150 ft buffer)	% Impervious Surface in Contributing Area**
1	65	96	41	8	3
2	42	88	34	6	3
3	35	99	41	10	3
4	55	89	51	4	2
5	88	88	67	1	2
6	61	91	76	3	2
7	32	93	54	2	2
8	60	91	59	2	1
9	53	89	78	1	1
10	73	87	61	4	2
11	63	93	58	5	2

*Values for % forested and % impervious land cover were derived from a preliminary land cover layer produced as part of Snohomish County's Critical Areas Monitoring Program (2012). Though accuracy tests were performed throughout the land cover classification a final formal accuracy assessment has not yet been completed

**Contributing area for the downstream habitat survey in each analysis reach.

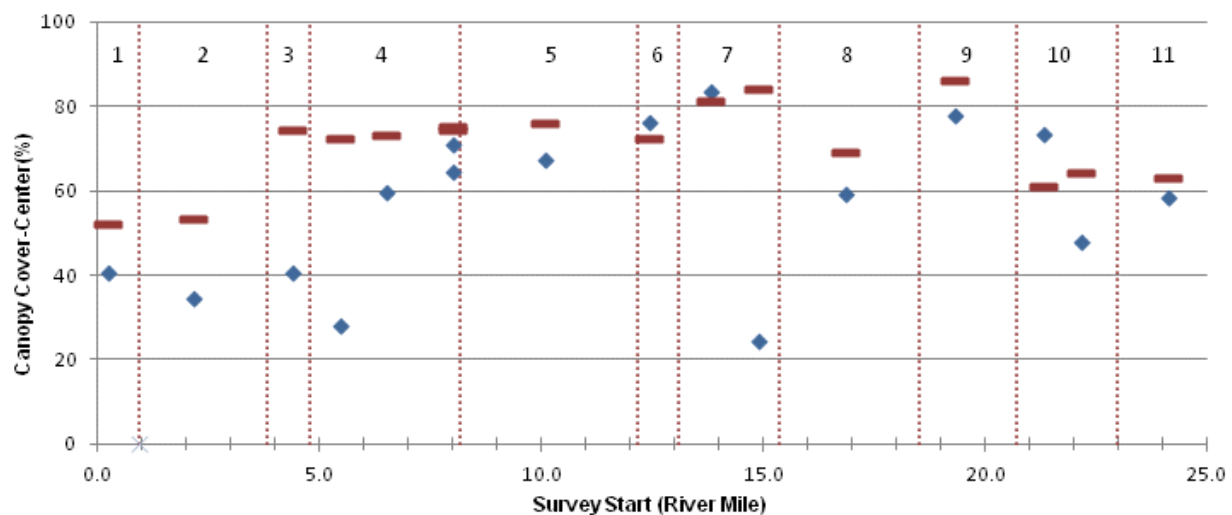


Figure 9. Canopy cover and shade potential. Woods Creek channel center percent canopy cover (diamonds) are shown for sample locations surveyed in 2007 and 2009. Solid horizontal dash marks for each sample location represent the canopy cover values expected for a healthy stream given the bankfull width for each reach (Cristea and Janisch, 2007). Reach numbers are shown at top.

To determine priority reaches for riparian enhancement actions, an analysis of the percent of forest cover (deciduous and evergreen) within 50 ft and 150 ft of the edge of the channel was completed. Although scientific literature indicates a wider buffer is necessary for maintaining the ecological functions of a riparian zone (Pollock & Kennard, 1998), 50 and 150 ft values give a range of potential restoration widths and were chosen for this initial goal setting exercise. Table 5 gives riparian conditions of each analysis reach and restoration acreage goals given the percentage of forest cover desired.

Table 5. Riparian buffer enhancement targets. Land cover data for a buffer width of 50 ft and 150 ft from the edge of the channel were analyzed for percent forest cover (deciduous and evergreen). Acres of additional riparian forest within this buffer zone were calculated for various targets of total forest cover.

Reach	Within a 50ft Buffer						Within a 150 ft buffer					
	Current Condition	Acres needed to achieve forested cover of:					Current Condition	Acres needed to achieve forested cover of:				
	% forested	75%	80%	85%	90%	95%	% forested	75%	80%	85%	90%	95%
1	85%	0.0	0.0	0.0	0.6	1.2	65%	3.4	5.1	6.8	8.6	10.3
2	66%	3.2	4.9	6.7	8.4	10.2	42%	34.6	39.8	45.1	50.3	55.6
3	53%	2.5	3.0	3.6	4.2	4.8	35%	13.9	15.6	17.3	19.1	20.8
4	67%	3.1	5.2	7.2	9.3	11.4	55%	25.2	31.4	37.6	43.8	50.0
5	93%	0.0	0.0	0.0	0.0	1.0	88%	-18.1	-10.9	-3.6	3.6	10.8
6	72%	0.4	1.0	1.5	2.1	2.7	61%	4.9	6.7	8.4	10.1	11.8
7	43%	8.9	10.3	11.6	13.0	14.4	32%	35.7	39.8	44.0	48.1	52.2
8	75%	0.0	2.0	4.0	5.9	7.8	60%	17.2	23.0	28.7	34.5	40.2
9	56%	4.9	6.3	7.6	8.9	10.2	53%	17.0	21.0	24.9	28.9	32.8
10	85%	0.0	0.0	0.0	1.4	2.8	73%	1.6	5.7	9.8	14.0	18.1
11	77%	0.0	0.7	1.9	3.1	4.3	63%	8.3	11.9	15.4	18.9	22.5
	Total	22.9	33.4	44.1	56.9	70.6	Total	143.8	189.1	234.4	279.8	325.1

C. Stream Temperature

According to Washington State Water Quality Standards (WAC173-201A), the Woods Creek temperature threshold of 16°C for core summer habitat is not to be exceeded more than once every ten years on average. None of the five sampling sites met this requirement as they all exceeded the standard multiple times during the data collection period (June 15th – September 15th) in 2009 and 2010. At Site 1 (Figure 8), the lower end of the East Fork, 67% of the seven day average of the daily maximum (7DAD Max) temperatures exceeded the threshold in 2009, and at Site 2, the lower end of the West Fork, 85% of the 7DAD Max temperatures exceeded the standard in 2009 (Table 6). The variability seen between sampling sites could indicate that local conditions highly affect the temperature at each site. For example, at Site 4, located just above Reach 5 in the West Fork, the daily maximum temperature exceeded the threshold 78% of the time in 2009 while downstream of Reach 5 at Site 3, the threshold was exceeded only 30% of the time. This pattern holds for 2010 as well. Reach 5 has the highest percentage of forested riparian area of all the analysis reaches and it is likely that this cover helps mitigate upstream high temperatures. Though little is known about potential cold water inputs in this reach, the data suggests that localized riparian reforestation efforts could have a positive impact on reducing stream temperatures.

Table 6. Water temperature (2009-2010). The highest seven day average of the daily maximum (7DADMax), number of days the 7DADMax exceeded the WA DOE threshold (16°C) for the Woods Creek basin, and the percent of days the 7DADMax exceeded this threshold are shown for June 15th - September 15th, 2009 & 2010 for each of the five temperature logger locations (Figure 8).

	Site 1		Site 2		Site 3		Site 4		Site 5	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Maximum 7DAD Max (°C)	21.6	18.8	22.6	19.1	19	17.5	22	18.6	19.6	19.2
Days 7DAD Max exceeded 16°C	62	46	79	50	28	21	73	43	53	46
% of days 16°C exceeded	67%	49%	85%	54%	30%	23%	78%	46%	57%	49%

D. Physical Characteristics and Habitat Conditions

i. Substrate

Fine sediments (sand and fines <0.1 in) were high throughout the basin (Table 7). Since substrate size data were collected at transects evenly distributed throughout each habitat survey, many of these sample locations were located in slow moving water making them a poor indicator of the condition of spawning gravels. Separate percent fines data collected at spawnable pool tailouts are a better indicator, therefore, of conditions where fish are likely to spawn (Table 7). Bjornn (1969) and McCuddin (1977) found that when fine sediments < 6.4 mm (0.25 in) exceed 20-25%, Chinook and steelhead embryo survival is negatively impacted. Reaches 2, 5, 6, 7 and 11 have high percentages of fines in pool tailouts and likely have impaired spawning potential. The D_{50} , median diameter of substrate data collected at transects, is also low in reaches 1, 3, 7, 8 and 9. This is to be expected in reach 1 due to the proximity to the river, and in reaches 8 and 9 due to the frequency of beaver created pools. The low D_{50} in reaches 3 and 7, however, indicates compromised habitat quality.

ii. Large wood

Large woody debris (LWD)/channel width, LWD volume, and the calculated percent of LWD expected (Fox and Bolton, 2007) give an indication of which reaches are lacking sufficient wood to create habitat (Table 7). Reaches 1, 2, 3, 6, 7, and 10 have much lower than expected wood frequency. Furthermore, it should be noted that the wood present in all reaches is primarily small (<1 ft diameter and <25 ft long) so the habitat forming potential is less than the historical potential. In reaches that do not have sufficient pools, pool depths, or sediment sorting, the installation of large wood could be beneficial.

iii. Pools

Pool condition was assessed using both the percent pool area of the channel and the pool frequency. Analysis reaches with the poorest pool condition are reaches 2, 4, 10 and 11. Except for reaches 3 and 8, pools throughout the basin are shallow and do not meet the regional performance standard of 1 m (3.28 ft) in depth for anadromous salmon (NMFS, 1996).

Table 7. Habitat conditions. Habitat condition is given for characterization of fine sediments, LWD abundance, and pool quality as collected during in-stream habitat surveys (2007 and 2009). The percent of wood expected was calculated using the average bankfull width for each reach (Fox and Bolton, 2007.)

Reach	% Fines*	% <0.25 in (pool tailouts)	D50 (in)**	LWD/Channel Width	LWD Volume (yd ³ / 100 yd)	% of wood expected	Small/Large Wood Ratio	% Pools	Channel widths/ pool	Avg Residual Depth (m)
1	54.3	45%	0.1	3.0	4.8	39	1.0	69	9	0.79
2	31.4	19%	0.6	3.6	19.3	50	0.9	50	3	0.78
3	55.2	no data	0.1	0.9	5.6	35	1.0	76	7	0.97
4	44.4	18%	0.3	2.9	27.7	102	0.9	72	3	0.56
5	47.6	26%	0.2	3.8	23.7	162	1.0	82	3	0.60
6	36.2	35%	0.5	1.5	9.1	48	0.9	41	7	0.39
7	76.2	32%	0.1	1.0	5.9	69	1.0	85	8	0.73
8	77.1	n/a	<0.1	2.6	16.1	76	0.9	100	6	1.24
9	71.4	n/a	0.1	1.1	6.0	109	1.0	75	4	0.33
10	17.4	8%	3.3	2.8	13.9	56	1.0	43	4	0.53
11	39.0	42%	0.8	3.5	10.2	75	1.0	25	5	0.48

*Data collected at transects in all habitat unit types over-represent fines in areas suitable for salmon spawning.

**Median bed-sediment size, such that 50 percent of the particles are finer.

E. Sediment inputs and erosion potential

The percent of unstable banks in the survey reaches indicate highly erodible banks throughout the watershed (Table 8). Reaches 1 and 7 have the highest percentage of unstable banks at 66% and 94% respectively.

The area of unpaved roads within 150 feet of the channel was also calculated to determine the potential for sediment contributions to the stream. While unpaved road area is low in all reaches, the highest value is 0.6 ac/mi in Reach 3.

Table 8. Substrate and fine sediment.

Reach	% Unstable Banks	High Erosion Potential within 300 ft (ac/mi)*	Unpaved road area within 150 ft (ac/mi)	D50 (in)**
1	66	0.0	0.20	0.1
2	56	0.0	0.23	0.6
3	9	1.7	0.60	0.1
4	35	7.1	0.08	0.3
5	39	10.6	0.03	0.2
6	16	2.3	0.25	0.5
7	94	0.0	0.20	0.1
8	0	2.1	0.15	<0.1
9	7	7.2	0.09	0.1
10	5	12.0	0.15	3.3
11	14	4.1	0.09	0.8

*From Dept. of Natural Resources erosion potential data. Acres of high erosion potential per km within 300 ft of channel.

**Median bed-sediment size, such that 50 percent of the particles are finer.

F. Summary of Results

The following is a summary of the major findings of this project.

- Lower Woods Creek (specifically reaches 2 & 3) and reach 7 in the West Fork have the lowest percent riparian forest cover and greatest shade deficit.
- Summer stream temperatures at all five sampling sites during 2009 and 2010 exceeded the water quality standard established by Washington State. Reaches with less riparian forest cover generally had higher water temperatures.
- Surface fine sediment levels in spawning areas are high throughout the basin. The most degraded reaches with potential for increased spawning value through the reduction of fine sediment inputs included in reaches 3, 6, 7, and 11.
- Stream bank data indicates highly eroded banks throughout the watershed, with the highest percentage of eroding banks occurring in reaches 1 and 7.

- The size and abundance of large wood in the channel are low throughout the basin relative to regional performance standards for functioning habitat. Over 90 percent of wood in the system is small (<1 ft diameter and <25 ft long), which limits its function in a stream the size of Woods Creek.
- Pool quality, a determination based on pool area and frequency, was lowest in reaches 2, 4, 10, and 11. Throughout most of the basin, pool depth did not meet regional performance standards for anadromous salmon.

V. CONCLUSIONS

Synthesis of results led to the following conclusions and suggestions for next steps:

- Preservation of remaining habitat is a critical component of a recovery strategy in Woods Creek. Buffering against further hydrological alteration through protection of remaining forests and wetlands is necessary if habitat gains are to be achieved through restoration. Next steps include preserving wetland function in the upper watershed and restoring and protecting riparian habitat in the lower watershed near development pressure from the south.
- Long-term riparian enhancement is needed throughout the basin to address elevated stream temperatures, control sediment sources, and provide a long-term supply of LWD. Planting efforts are most needed in reach 2 in Lower Woods Creek and reaches 3 & 7 in the West Fork.
- In the short-term, fish presence data indicates that Chinook salmon populations would benefit most from in-stream restoration actions in Lower Woods Creek (reaches 1 & 2) and the East Fork (reaches 10 & 11). Restoration efforts in the West Fork would benefit coho and steelhead populations.
- Fine sediment levels in the system are high enough that they are likely reducing egg-to-fry survival for all salmon and impacting rearing habitat for steelhead. Projects in the lower West Fork (reach 3), the upper West Fork (reaches 6 and 7), and the East Fork (reach 11) that result in gravel sorting and reduce fine sediment input would be beneficial. Addressing the causes of altered hydrology and unstable banks through actions such as preservation of forests and riparian planting can help remediate this problem over the long-term.
- A shortage of large wood limits the quantity and quality of pools. Projects that increase pool frequency, depth and cover for rearing juvenile salmon and holding adult salmon should be considered in Lower Woods Creek (reach 2), the lower West Fork (reach 4), and the East Fork (reaches 10 & 11).
- Understanding habitat forming processes such as aggradation and degradation are critical to siting in-stream habitat improvement projects. A detailed sediment transport analysis at the site scale is advised to inform project design.

VI. REACH DESCRIPTIONS

The following pages contain descriptions of each of the eleven analysis reaches. This discussion synthesizes the data and conclusions from the overall report in the context of each reach and provides suggested conclusions and next steps. These descriptions are meant for use in determining the relative importance of each reach in terms of restoration or preservation actions as well as suggest the types of actions that will most likely address the habitat limitations given the geomorphologic processes and constraints.

Reach 1: Lower Woods Creek

Reach Description

Reach 1 (1.0 mi) extends from the mouth of Woods Creek at the Skykomish River upstream to US Highway 2. It is completely within the City of Monroe and is buffered along the entire length of the left bank by a forested city park (known as Buck Island/Al Borlin Park). At the upstream end of the reach there is an abandoned railroad trestle that collects woody debris during flood events as does the current railroad bridge (Reach 1 Map). Reach 1 has an average bankfull width of 51 ft and is connected to the Skykomish River at the upstream end by a side-channel that contributes flow to the creek. For this reason, the reach is affected by the flows of the river, especially during floods, and is essentially an inactive low slope (0.6% gradient) side-channel/slough of the Skykomish River. As such, this reach is a repository of finer sand and silt that presumably accumulates from the mainstem Skykomish River during flooding. Sediments are fine with a D_{50} of < 0.1 inch and spawnable pool tailout areas contain 45% fine substrate (< 0.25 in).

In-channel woody debris volume and frequency is very low ($4.8 \text{ yd}^3/100 \text{ yd}$; 39% of expected), potentially due to the lack of upstream or local recruitment, the movement of wood out of this reach during high flows, or the removal of wood by humans. The City of Monroe park on the left-bank of this reach is maintained as a passive-use park. As such, the 150 ft wide riparian buffer zone is well vegetated at 65% (average of both banks). However, 66% of the banks are unstable with a higher instability rate on the left bank. Pools are frequent, totaling 69% of the wetted channel area at low flow, but the average residual depth (2.6 ft) is relatively shallow for the size of the channel. The lack of deep pools could be due to the abundance of fine sediment, the absence of large wood jams that would form scour pools, or a backwatering effect in larger flood events that could dampen local stream power.

Importance of Reach

Reach 1 provides low gradient, off-channel rearing habitat for juveniles from both Woods Creek and the Skykomish River. In addition, the Washington Department of Fish and Wildlife (WDFW) has data as recent as 2008 confirming Chinook spawning in Lower Woods Creek (Reaches 1 and 2). The reach also supports steelhead, coho, chum and pink salmon (WDFW, 2010). Bull trout use is presumed (WDFW, 2010).

Summary of Habitat Limitations

- High fine sediments (45% < 0.25 inches in pool tailouts; D_{50} of < 0.1 in)
- Low wood volume and frequency ($4.8 \text{ yd}^3/100 \text{ yd}$; 39% of expected)
- Unstable banks (66%)
- Shallow pools, but high pool area (69%)

Conclusions and Next Steps

Relative to the other analysis reaches, there are limited opportunities for restoration work in Reach 1 due primarily to sediment dynamics and the potential for high flows. The creation of deep pools through the placement of wood may be hindered by the input and amount of fine sediment in the reach, although placement of large wood jams or flood fencing to trap wood could help dissipate the force of high flows, create more and better in-channel complexity, and sort gravels. Wood placement, however, should be preceded by a more detailed

sediment transport study. Due to the high flows and public use, structures would need to be highly engineered and stable.

The functions and values of the riparian forest along Reach 1 could be improved by removal of knotweed and planting of conifers.

The land between Woods Creek, the Skykomish River, and the side-channel that connects the two (known as Buck Island) is eroding from the Skykomish River side. Evaluation of the avulsion risk and re-occupancy of Reach 1 by the Skykomish River mainstem seems warranted prior to consideration of any action other than riparian enhancement or bank stabilization.

Reach 2: Lower Woods Creek

Reach Description

Reach 2 (2.9 mi) extends from Hwy 2 at the downstream end to the confluence of the East and West Forks of Woods Creek at the upstream end. The reach runs through a wide floodplain that is primarily in agricultural production (zoned Agriculture – 10 acre). This reach is an unconfined pool-riffle channel with a mean bankfull width of 49 ft, a width-to-depth ratio of 11.9 and a slope of 0.6%. There is less fine sediment in this reach relative to other reaches in the study, with a D_{50} of 0.6 in, and spawnable pool tailouts consisting of 19% fines (<0.25 in). Wood frequency is low at approximately 50% of expected. This result likely overestimates the natural LWD abundance because this randomly selected survey reach contained an engineered large wood placement project. The naturally recruited wood present is primarily small (<1 ft diameter and <25 ft long) so the habitat forming potential of the wood in a channel of this width is less than the historical potential. Pools total 50% of the wetted channel area during summer low flows with an average residual depth of 2.6 ft. Seven out of the nine pools were formed by wood. This suggests that the addition of wood could create additional pools and possibly encourage deposition of fine sediments and sorting of gravels.

Reach 2 has a highly degraded riparian buffer zone (42% forested within 150 ft of channel) and a high percentage of unstable banks (56%). The canopy cover in the center of the channel is the lowest in the basin (34%). This could be due, in part, to the width of the channel but also corresponds to the lack of forest in the riparian zone.

Importance of Reach

The Washington Department of Fish and Wildlife (WDFW) has data as recent as 2008 confirming Chinook spawning in Lower Woods Creek (reaches 1 and 2). The reach also supports steelhead, coho, chum and pink salmon (WDFW, 2010). Periodic bull trout use is presumed (WDFW, 2010).

Summary of Habitat Limitations

- Low pool area and frequency (50% channel area; 3 channel widths/pool)
- Low wood frequency (50% of expected)
- Lack of large wood, but abundant smaller pieces
- Degraded riparian vegetation (42% forested within 150 ft of channel)
- Low canopy cover (34% cover in channel center)
- Unstable banks (56%)

Conclusions and Next Steps

Riparian re-vegetation is the primary recommended action in this reach to improve bank stability, increase shading and cover for salmonids, and provide a long-term source of large wood to the channel. A secondary recommendation is the addition of large woody debris to the channel to create pools.

Given the amount of existing bank instability, projects that incorporate bank protection with riparian planting are recommended. Engineered bank stabilization, however, would be limited in extent and long-term effectiveness relative to larger-scale planting.

Reach 3: West Fork Woods Creek

Reach Description

Reach 3 (0.9 mi in length) is the West Fork of Woods Creek just upstream from the confluence of the East and West Forks. This is a short reach that still flows through the wider floodplain valley that characterizes Lower Woods Creek. Because this reach is above the confluence of the East and West Forks, Reach 3 is much narrower (a bankfull width of 23 ft) than Reach 2. This reach is moderately confined, with a width-to-depth ratio of 6.9. Because the channel has incised in deep glacial deposits, has a low slope (0.4%) and a lower stream power than Lower Woods Creek, it has not migrated extensively within the floodplain but carries and stores a high sediment load. Substrate size is fine with a D_{50} of 0.1 in and fine sediment at transects totaling 55% (sediment data in pool tailouts was not available for Reach 3). In-channel wood frequency is very low with 5.6 yd³/100 yd and 0.9 pieces/channel width; this is the lowest wood frequency in the basin reaching only 35% of the expected rate. Despite the low frequency of wood, pools total 76% of the wetted area during summer low flows and have an average residual depth of 3.2 ft. This reach has a highly degraded riparian buffer zone (35% forested within 150 ft of channel) yet a low percentage of unstable banks (9%). The canopy cover is also very low at 41% cover in the center of the channel.

Within the entire basin, the contributing areas to each analysis reach have less than 3.5% impervious surface indicating a relatively low impact on the hydrology. Reach 3, however, has the highest percent impervious surface within 150 ft of the channel (10% impervious), consisting primarily of residential and agricultural building, roads, and driveways. This may have an impact on hydrology although more likely represents a pathway for polluted surface water to reach the channel. The area of unpaved roads within a 150 ft buffer is also the highest in the basin at 0.60 ac/mi. These roads may contribute fine sediment where they have direct drainage connections to Woods Creek.

Importance of Reach

Reach 3 supports use by steelhead, coho, chum and pink salmon (WDFW, 2010). Bull trout use is presumed (WDFW, 2010) and there is limited Chinook use (Snohomish County observation). Overall, this reach appears to be most suitable for coho and pink spawning and rearing and less suitable for Chinook spawning due to the smaller size of the channel and substrate.

Summary of Habitat Limitations

- High fine sediment (55% total; D_{50} of 0.1 in)
- Low wood volume and frequency (5.6 yd³/100 yd; 0.9 pieces/channel width; 35% of expected)
- Degraded riparian vegetation (35% forest within 150 ft of channel)

Conclusions and Next Steps

Riparian re-vegetation is recommended to filter out fine sediments reaching the stream through surface runoff, increase canopy cover, and provide a long-term source of large wood to the channel.

Wood volume is low and benefits to in-stream habitat would likely be achieved through placement of large woody debris to trap sediment and sort gravels. The accumulation of fine

sediment in this reach, however, could limit the creation of pools. Sediment transport analysis is advised before structures are added to the channel for pool creation as the supply of fines may quickly fill any pools created through additional channel roughness.

Reach 4: West Fork Woods Creek

Reach Description

Reach 4 (3.4 mi long) is the West Fork of Woods Creek where the valley becomes moderately confined and runs through highly erosive soils (7.1 ac/mi within 300 ft of the channel). Parcels are zoned Rural – 5 acre and include small farms and equestrian centers. Reach 4 has a pool-riffle and forced pool-riffle channel classification with a bankfull width of 25 ft, a width-to-depth ratio of 8.8, and a slope of 0.6%. Thirty-five percent of banks are unstable and visual observation confirms that these unstable banks are contributing fine sediment to the water through extensive erosion. Substrate is characterized by a D_{50} of 0.3 in and spawnable pool tailouts consisted of 18% fines (<0.25 in). In-channel wood frequency is relatively high within Woods Creek at 2.9 pieces/channel width and 102% of the expected amount given the bankfull width. Pool habitat quality is low with a frequency of 3 channel widths/pool and an average residual pool depth of 1.8 ft, although the total area of pools during the summer low flows is fairly high at 72%. Within the surveyed area, 20 out of 29 pools are formed by woody debris, suggesting that wood, where present, is effective at scouring pools. This reach has a degraded riparian buffer zone (55% forested within 150 ft of channel) and the canopy cover is low at 51% cover in the center of the channel.

Importance of Reach

Reach 4 supports use by steelhead, coho, chum and pink salmon (WDFW, 2010). Bull trout use is presumed (WDFW, 2010) and there is limited Chinook use (Snohomish County observation).

Summary of Habitat Limitations

- Low pool frequency (3 channel widths/pool)
- Highly erosive soils (7.1 ac/mi within 300 ft of channel)
- Unstable banks (35%)
- Degraded riparian vegetation (55% forest within 150 ft of channel)
- Low canopy cover (51% cover in channel center)

Conclusions and Next Steps

Riparian re-vegetation is recommended to control bank erosion in these highly erosive soils, increase canopy cover, and provide a long-term source of large wood to the channel. In-stream wood installation is recommended to encourage sediment deposition where incision is present, form scour pools where pool spacing is low, and sort gravels. In some areas, bio-engineered bank armoring may be appropriate although the design should incorporate methods for slowing water down so as not to exacerbate erosion problems downstream.

Reach 5: West Fork Woods Creek

Reach Description

Reach 5 (4.0 mi long) is mainly in forest production (zoned Forestry) with the primary land holder being the Washington State Department of Natural Resources. This reach is in a confined valley but has a relatively un-confined pool-riffle channel classification with a bankfull width of 22 ft, a width-to-depth ratio of 9.5 and a slope of 0.7%. Substrate size is small with a D_{50} of 0.2 in and spawnable pool tailouts consist of 26.4% fines (<0.25 in). This reach has the highest wood frequency (3.8 pieces/channel width) of all the analysis reaches and 162% of the expected wood given the channel width. Pool area is high totaling 82% of the wetted area during summer low flows with an average residual depth of 0.60 m. Due to land use, Reach 5 has the highest percentage of forested riparian habitat (88%) with a canopy cover of 67% in the channel center. Water temperatures during summer months are higher upstream of this reach than they are downstream (Table 6) suggesting cool water input from groundwater or hyporheic sources is better protected by the forest cover and/or that shade over the channel may cool water temperatures. Although fine sediments in the pool tailouts are high and banks are unstable, this reach appears to have higher functionality than other reaches especially considering the amount of highly erosive soils within 300 ft of the channel (10.6 ac/mi).

Importance of Reach

Reach 5 supports use by steelhead, coho, chum and pink salmon (WDFW, 2010). Bull trout use is presumed (WDFW, 2010). Water temperature data suggests this reach is important for maintaining cold water during summer months.

Summary of Habitat Limitations

- High fine sediment (26% <0.25 inches in pool tailouts)

Conclusions and Next Steps

Recommendations include preservation of existing habitat through protection of riparian forest corridor, wetlands, and groundwater or hyporheic sources of cold water.

Reach 6: West Fork Woods Creek

Summary

Reach 6 (0.9 mi long) is zoned for Rural 5-acre parcels and consists primarily of small farms and rural-residential land uses. It is an unconfined pool riffle (and forced pool-riffle) channel with a bankfull width of 27 ft, a width-to-depth ratio of 15 and a slope of 0.6%. At the survey location, the channel type is plane-bed and slightly confined. Substrate is characterized by a relatively larger D_{50} of 0.5, in yet pool tailout spawning areas are high in fine sediment (35% <0.25 in). In-channel wood volume and frequency are very low with 9.1 yd³/100 yd and 1.5 pieces/channel width; this represents 48% of the expected wood given the channel width. Pools total only 41% of the wetted area during summer low flows, and have an average residual depth of 1.3 ft. Only one of five pools was formed by woody debris which is expected given the low abundance of wood. This reach has a degraded riparian buffer zone (61% forest within 150 ft of channel) although canopy cover in the center of the surveyed channel is high relative to other reaches (76%). The percentage of unstable banks is low at 16% of the total reach.

Importance of Reach

Reach 6 supports use by steelhead, coho, chum and pink salmon (WDFW, 2010). Bull trout use is presumed (WDFW, 2010). This reach is close to the upper limit of Chinook salmon distribution in Woods Creek.

Summary of Habitat Limitations

- High fine sediment (35% <0.25 inches in pool tailouts)
- Low wood volume and frequency (9.1 yd³/100 yd; 1.5 pieces/channel width; 48% of expected)
- Degraded riparian vegetation (61% forest within 150 ft of channel)
- Low pool area (41% channel area) and depth (1.3 ft)

Conclusions and Next Steps

This reach appears to be an ideal location for installation of large woody debris that may help scour additional pools and sort gravels. Riparian re-vegetation is also recommended to increase canopy cover, filter sediment from surface runoff and provide a long-term source of large wood to the channel.

Reach 7: West Fork Woods Creek

Summary

Reach 7 (2.3 mi long) is zoned for Rural 5-acre parcels and consists primarily of small farms with livestock operations. It is an unconfined channel within a wide valley with low channel gradient (0.4%) and active beaver use. It therefore exhibits inconsistent channel planform (pool-riffle and deep sand bedded). The bankfull width is 16 ft and the width-to-depth ratio is 4.4. Several sections of the channel appear to have been straightened and it was likely dredged historically. Substrate is very fine with an overall D_{50} of 0.1 in and 32% fines (<0.25 in) in spawnable pool tailouts. In-channel wood volume and frequency are very low at 5.9 $\text{yd}^3/100$ yd and 1 piece/channel width respectively. The reach is approximately 85% pools (average residual depth of 2.4 ft) which could account for the abundance of fine sediment. Beaver dams account for 50% (5/10 pools) of pool formation, and over 70% of all beaver formed pools in Woods Creek were observed in and upstream of this reach. The riparian buffer zone is highly degraded with the lowest forest cover in the basin (32% forest within 150 ft and 54% canopy cover in the channel center). Water temperature data for 2009 and 2010 indicates more frequent exceedances of the temperature standard above reach 7 than below.

The width-to-depth ratio of 4.4 indicates that this reach may be incised, but further data collection is needed to confirm this. The high percentage of unstable banks (94%) suggests the reach is laterally adjusting to channel incision and/or the banks are degraded from adjacent land uses. Livestock operations along portions of this reach may be contributing to the high sediment load and also affecting water quality.

Importance of Reach

Reach 7 supports use by steelhead, coho, chum and pink salmon (WDFW, 2010).

Summary of Habitat Limitations

- Degraded riparian vegetation (32% forest within 150 ft of channel; 54% cover in channel center)
- High fine sediments (32% <0.25 inches in pool tailouts)
- Low wood volume and frequency (5.9 $\text{yd}^3/100$ yd; 1 piece/channel width)
- Unstable banks (94%)

Conclusions and Next Steps

A focus on re-vegetating the riparian corridor, fencing to manage livestock access, and promoting implementation of agricultural best management practices (BMPs) is prescribed. The goals of these practices will be to decrease sediment inputs to the stream, reduce bank erosion, and increase canopy cover to address elevated stream temperatures. Non-engineered bank stabilization such as fascine bundles, willow staking, and erosion control fabric, may be appropriate in some locations.

Reach 8: West Fork Woods/Carpenter Creek

Summary

Reach 8 (3.2 mi long) is zoned for Rural 5-acre parcels and consists primarily of small farms and rural-residential uses. It is an unconfined channel with variable channel classification owing to the abundance of beaver ponds. The bankfull channel width is 29 ft, and the reach has a width-to-depth ratio of 6.9 and a slope of 0.5%. Reach 8 is high in the watershed and dominated by beaver ponds (100% of surveyed habitat is pools and 100% of pools are formed by beaver). Pools are deep, averaging 4.1 ft residual depth. This appears to explain the high fine substrate content as the reach is characterized by a D_{50} of <0.1 in and 77% total fine sediments at transects. In-channel wood volume and frequency are low at 16.1 yd³/100 ft and 2.6 pieces/channel width respectively. This reach has a degraded riparian buffer zone (60% forest within 150 ft of channel) and canopy cover in the channel center is 59%.

Importance of Reach

Reach 8 primarily provides rearing habitat and passage to smaller tributaries where coho and steelhead spawn. Beaver ponds in this reach help maintain stable hydrology, trap fine sediments, maintain cool water temperatures and provide wildlife habitat.

Summary of Habitat Limitations

- Degraded riparian vegetation (60% forest within 150 ft of channel)
- Low canopy cover (59% cover in channel center)

Conclusions and Next Steps

The primary recommended actions in this reach are to preserve the existing riparian and wetland habitat and protect beaver ponds through landowner education.

Reach 9: Carpenter Creek

Summary

Reach 9 (2.2 mi long) is the headwater reach for the West Fork of Woods Creek/Carpenter Creek. It is zoned for Rural 5-acre parcels although the land is primarily in forest production with only a small amount of rural residential development concentrated near the stream. It is an unconfined former glacial meltwater channel with a bankfull width of 12 ft, a width-to-depth ratio of 6.2, and a slope of 0.7%. Fine sediments dominate with a D_{50} of 0.1 in and 71% total fine sediments at transects (sediment data in pool tailouts was not collected as no pool tailouts were spawnable). In-channel wood volume is low at 6.0 yd³/100 yd, although frequency is at 109% of expected given the narrow channel width. Pools comprise 75% of the wetted area at summer low flow with an average residual depth of 1.1 ft. Unlike Reach 8 where 100% of pools were formed by beaver, only one in nine of the pools the survey area were beaver formed. It is not clear why beaver presence seems to be lower in reach 9 than in reach 8 although it may be due to local land-use at the specific survey location. Aerial images show that both reaches are largely ponded throughout. Reach 9 has a degraded riparian buffer zone (53% forest within 150 ft of channel) and although the canopy cover in the channel center is high (78%), this is due, in part, to the presence of tall Reed Canary grass (*Phalaris arundinacea*) in several areas.

Importance of Reach

Reach 9 includes a spawning survey index reach for the WA Department of Fish and Wildlife. Data indicate the presence of coho in the main channel as well as a small tributary (WDFW, 2010). In this headwater reach for the West Fork of Woods Creek, integrity of the riparian forest and protection of beaver ponds are important for sediment control, hydrologic control, wildlife habitat, and groundwater recharge.

Summary of Habitat Limitations

- Degraded riparian vegetation (53% forest within 150 ft of channel)
- Abundance of Reed Canary grass (*Phalaris arundinacea*)

Conclusions and Next Steps

The primary recommended actions in this reach are to preserve the existing riparian and wetland habitat and protect beaver ponds through education to landowners.

In addition, re-vegetating areas where the riparian zone is degraded will help preserve the integrity of this headwater reach and shade out Reed Canary grass.

Reach 10: East Fork Woods Creek

Summary

Reach 10 (2.3 mi long) is the East Fork of Woods Creek just above the confluence of the East and West Forks. The downstream portion has a lower gradient than the rest of the reach as it is still within the floodplain of Lower Woods Creek. The habitat survey was located upstream of this floodplain and as such, conditions in this lower portion of reach 10 are likely more similar to reaches 2 and 3. The riparian buffer is highly degraded in the lower portion of the analysis reach (near the confluence), where it is zoned Agriculture – 10 acre. The upper portion of reach 10 is zoned Rural – 5 acre and consists of small farms.

Reach 10 is an unconfined channel with pool riffle and forced-pool-riffle morphology, a bankfull width of 37.4 ft, a width-to-depth ratio of 17 and a slope of 1.1%. Sediment is characterized by a D_{50} of 3.3 in and with only 8% fines (<0.25 in) in spawnable pool tailouts. Despite having highly erosive soils within 300 ft of the channel (12.0 ac/mi), fine sediment did not appear to be a problem in this reach. This could be due to a somewhat intact riparian zone (70% forested within 150 m of channel; 61% canopy cover in channel center) and a low percentage of unstable banks (5% of total length). In-channel wood volume is low with 13.9 yd³/100 yd and a frequency of 2.8 pieces/channel width. Compared to reference conditions, woody debris frequency is about one-half of the expected value. Pools total 43% of the wetted area during summer low flows with an average residual depth of 1.7 ft. Wood formed only 1 out of the 14 pools surveyed.

Importance of Reach

Data from the Washington Department of Fish and Wildlife confirms Chinook spawning in reach 10 in 1991 (most recent survey conducted). This reach has a larger gravel size than elsewhere (and smaller amounts of fine sediment) and is suitable for steelhead spawning due to the higher gradient. This reach also supports coho, pink, chum and bull trout use (WDFW, 2010).

Summary of Habitat Limitations

- Low wood volume (13.9 yd³/100 yd; 56% of expected)
- Lack of pools (43% channel area; 4 channel widths/pool)
- Shallow pools (1.7 ft average residual depth)
- Small wood dominated (100% <1 ft diameter and <25 ft in length)

Conclusions and Next Steps

Since the East Fork is a larger channel and has larger gravels than the West Fork, reaches 10 and 11 have a high potential for restoration and preservation of Chinook habitat.

Preservation of existing habitat is the primary recommendation for this reach. It should also provide a good location for installation of large woody debris to scour pools and provide cover for salmonids.

Reach 11: East Fork Woods Creek

Summary

Reach 11 (1.9 mi in length) is the uppermost reach of the East Fork of Woods Creek included in this study and extends to the natural waterfall marking the extent of anadromous fish migration. This reach runs through land zoned Rural – 5 acre and consists primarily of small farms. Reach 11 is an unconfined, pool riffle channel with a bankfull width of 36 ft, a width-to-depth ratio of 15 and a slope of 0.6%. Although the D_{50} is relatively high compared to the other analysis reaches (0.8 in), there is a high percentage of fine sediment (< 0.25 in) in spawnable pool tailout areas (42%). In-channel wood volume and frequency are low at 10.2 $\text{yd}^3/100$ yd and 3.5 pieces/channel width. At 75% of expected wood frequency, however, this reach has one of the higher wood frequencies in the basin. Pools are infrequently spaced and total only 25% of the wetted area during summer low flows with an average residual depth of 1.6 ft. This reach has a degraded riparian buffer zone (63% forested within 150 ft of channel; 58% canopy cover in channel center) and 14% unstable banks.

Importance of Reach

The larger gravel size in this reach makes it suitable habitat for Chinook. This reach also supports use by steelhead, coho, pink, chum, and bull trout (WDFW, 2010).

Summary of Habitat Limitations

- High fine sediment (42% < 0.25 inches in pool tailouts)
- Lack of pools (25% channel area)
- Shallow pools (1.6 ft average residual depth)
- Degraded riparian vegetation (63% forest within 150 ft of channel)

Conclusions and Next Steps

Since the East Fork is a larger channel with larger gravels than the West Fork, reaches 10 and 11 have a high potential for restoration of Chinook habitat. Of these two reaches, reach 11 has poorer habitat quality and a greater need for restoration work.

The primary recommendations for this reach are riparian re-vegetation and installation of large woody debris. Re-vegetation will be important for filtering sediment from surface runoff and providing a long-term source of in-stream wood to the channel. This reach should also provide a good location for installation of large woody debris to create deep scour pools and sort gravels in spawning areas.

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Appendix A: Methods

A. Reach delineation

This assessment includes Lower Woods Creek from the mouth to the confluence of forks, the East Fork of Woods Creek to the natural barrier (waterfall) at river kilometer 6.8 (RM 4.2 from confluence of forks) and the West Fork of Woods Creek (including Carpenter Creek). These reaches, henceforth referred to as the mainstem of Woods Creek, were further divided into 11 analysis reaches. Data used to subdivide reaches included channel gradient (Figure 6), valley width, channel size, and land-use zoning boundaries (Figure 4). Reach delineation for the watershed is shown in Figure 7.

- i. Channel gradient
Elevation using LiDAR data was extracted every 100 ft and then average slope was calculated every 1,000 ft).
- ii. Valley width
The width of the valley was calculated manually every 0.6 mi using LiDAR data.
- iii. Channel size
Limited flow data exists for this basin and was not used in the analysis. Channel size and the location of major tributaries were taken into account when determining reach delineation.
- iv. Land-use zoning
Current zoning boundaries for Snohomish County were used.

B. Land cover analysis

Multi-spectral high-resolution satellite imagery was used to identify and classify land cover (Snohomish County, 2012). Land cover in the basin was classified into the following categories: emergent wetland, grass/pasture/crops, scrub/shrub, deciduous forest, evergreen forest, impervious surface, bare earth, gravel bar, and open water. Land cover values in this report are derived from a preliminary dataset developed as part of the larger Critical Area Regulation monitoring program. The data reported have not undergone a final accuracy assessment.

Land cover in the riparian zone was characterized within a buffer of 150 ft from the edge of the channel and summarized for each analysis reach. This buffer width was chosen as it is consistent with buffers for salmon bearing streams in Snohomish County's Critical Area Regulations. The percent of deciduous and evergreen forest combined was used to analyze riparian condition relative to all analysis reaches.

For each of the 15 individual habitat surveys that were conducted within the analysis reaches, the land cover data for the entire contributing area to the upstream end of the survey was summarized. Differences in these values were to be analyzed for any correlations with habitat conditions data.

To establish riparian planting goals upon completion of the analysis of habitat conditions for each reach, a narrow riparian buffer of 50 ft was characterized along with a standard buffer of 150 ft. The 50 ft buffer is less than recommended buffer width necessary for maintaining the ecological functions of a riparian zone (Pollock & Kennard, 1998), but it was chosen along with the standard 150ft buffer to provide a range for initial goal setting.

Stream Temperature

Onset™ Pro V II water temperature data loggers, having 0.2°C accuracy were used to collect data from June 15th -September 15th, 2009 and 2010. Logger calibration, set up, placement and retrieval followed protocols established by the WA State Department of Ecology (WA DOE, 2003). The seven day average of the daily maximum temperature (7DADMax) was calculated on verified and valid data for this period. These values were then compared to the aquatic life criteria of 16°C for core summer salmonid habitat for this basin according to the Washington State Water Quality Standards (WAC173-201A). The 7DADMax is not to exceed this threshold more than once every 10 years on average (WAC173-201A).

C. Habitat Conditions

In-stream habitat data was collected using Snohomish County's Wadeable Stream Habitat Survey Protocol (Rustay et al., 2008). Surveys collected using this protocol from 2007 were compiled and additional surveys to supplement this data were conducted the summer of 2009. Depending on length and assumed variability of each reach, one to three individual surveys were conducted in each of the 11 analysis reaches. The length of each survey varied between 328 ft long in the headwaters of the West Fork and 1300 ft in Lower Woods Creek depending on the average bankfull width of the channel. The bankfull width was also used to determine the minimum size of functioning pools for each survey. Bankfull width and bankfull depth were measured at three locations along each survey and averaged.

i. Transects

Eleven transects and ten half transects were evenly spaced within the survey. Data collected at transects were as follows:

- Canopy cover - At each full transect, a total of six cover measurements were made using a convex spherical densitometer modified as described in Lazorchak et al. (1998) where the number of grid points are reduced from 96 to 17. Four readings were taken from the center of the channel facing toward the right bank, upstream, the left bank and downstream. Next, readings at the left and right streambanks were made facing perpendicular to the stream bank. Cover readings did not distinguish between native and non-native vegetation. Measured canopy cover was compared against a calculation of the potential, or expected, canopy cover for a healthy stream based on the bankfull width (Cristea and Janisch, 2007).
- Substrate size - Five sediment samples were collected across the wetted width of the stream channel at each of 11 transects and 10 half-transects, for a total of 105 samples recorded for each survey. At each transect and half-transect, the wetted width was divided into four equal sections in order to sample at the wetted edge, at 25%, 50%, and 75% of the wetted width, and at the opposite wetted edge. Beginning at the wetted edge, the first substrate particle touched in front of the surveyor's boot toe was picked up. Using a caliper, the intermediate axis (the dimension by which the particle would pass through a sieve) of the particle was recorded. For this part of the study,

sediment <2 mm (0.08 in) was considered fine sediment. The D_{50} was calculated as the median substrate size for each survey using measurements from the whole and half transects, as opposed to the pool tailouts (discussed below).

ii. Continuous Habitat Parameters

In addition to data collected at transects, data was also collected continuously along the survey.

- Bank condition – The percentage of banks classified as unstable was measured along both banks of each survey length. Criteria from Bauer and Burton (1993) were used to determine bank stability.
- Side channel habitat - Side channel total length, wetted length, and mean total width were measured. Side channels are defined as channels that are separated from the main channel by a stable island and contain the smaller portion of the total flow. A stable island in a forested stream is defined by USFS (1999) as supporting woody vegetation (excluding willow) that is estimated to be at least 5 years old and covers at least 50% of the island surface at or above bankfull elevation.
- Woody debris – Wood was measured continuously and assigned to one of the following diameter and length classes: diameter (<30 cm, 30-60 cm, 60-90 cm, >90 cm [(<1 ft, 1-2 ft, 2-3 ft, >3 ft)] and length (1.5-7.6 m, 7.6-15 m, >15 m [5 ft - 25 ft, 25 - 50 ft, >50 ft]). The minimum size for a qualifying piece of wood was 1.5 m long and at least 10 cm (4 in) in diameter. For pieces that were less than 7.6 m long, the average diameter over the length of the piece was used. For pieces that were greater than 7.6 m long, the diameter was measured at 7.6 m from the large end. Only downed wood that intercepts the bankfull flow was counted. The total volume of large woody debris (LWD) was estimated using the median values of length and diameter to calculate LWD piece volume for each size class range multiplied by the number of pieces counted with each class. The predicted mean number of pieces of LWD/channel width was calculated using the equation $Y = 0.22x^{1.26}$, where Y is the predicted number of LWD and x is the bankfull width in meters (Fox and Bolton, 2007). This expected value was compared to the actual value obtained from the reach and used to indicate which reaches were lacking sufficient wood.
- Riffle and Other habitat – The summer low flow wetted channel area was categorized into habitat units (pool, riffle, or other). The average wetted width and wetted length of riffles and other channel types were measured to determine the most accurate representation of area.
- Pool habitat – The pool tailout depth and maximum depth were measured using a stadia rod to calculate the residual pool depth (maximum depth less tailout depth). For a habitat unit to qualify as a pool it met minimum wetted area and residual depth requirements determined for the average bankfull width of the survey length (see Rustay et al., 2008).
- Fines in pool tailouts – Measures of fine sediment were performed in cross-sectional transects perpendicular to flow at all spawnable (ocular estimation) pool tailouts. Each transect was divided into 5 equal sections and measurements were taken at the four points along the transect dividing those sections. A grid with 25 cross-sections was placed at each of the four points and the number of points underlain by substrate <6.3 mm in diameter were counted and converted to a percent value. These values were averaged across each survey reach.

D. Sediment inputs and erosion potential

Three methods were used to determine the potential for sediment inputs to the stream: quantification of unpaved road area near the stream, classification of erosion potential based on soil type, and land cover analysis of the riparian zone.

Unpaved roads and parking areas within 45 m (150 ft) of the channel edge were digitized manually from 0.3 m (1 ft) resolution aerial photos (2007). A value of hectares/km (ac/mi) was calculated for each analysis reach.

Soil erosion potential maps from the WA State Department of Natural Resources (DNR) were used to determine the area (ha/km) of high erosion potential within 90 m (300 ft) of the channel edge. This analysis was originally done using a 45 m (150 ft) buffer, but was doubled to account for the low resolution and accuracy of the soils data. Ultimately, the soils map was deemed of limited use when attempting to determine the erosivity of the banks at the site scale and the results were not reported. A detailed sediment transport analysis is recommended for feasibility and design of in-stream projects.