Salmon Habitat Limiting Factors

Report

for the

PUYALLUP RIVER BASIN
(Water Resource Inventory Area 10)

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Executive Summary

The Puyallup River Basin was one of the earliest areas settled in the Puget Sound area. Arriving Euro-American immigrants prized this basin for its deep-water embayment, large tracts of pristine old growth forests, fertile river valley soils and abundant runs of salmon. Homesteads and settlements began appearing as early as 1850 and the new arrivals initiated a series of actions to modify the landscape to fit their needs. The dredging and filing of the estuary, started in the late 1800's, was largely completed by 1930. Two hydroelectric dams that are impassable to salmonids were completed shortly after 1900. An extensive system of levees, dikes and revetments were started in the early 1900's and continue to be maintained today. In 1906 the White River was diverted into the Puyallup River Basin almost doubling the flows in the lower Puyallup River.

All of these actions have impacted the biological processes necessary for the natural production of salmonids in the Puyallup River Basin. Commencement Bay, once a highly productive estuarine environment, has lost in excess of 98% of its historical intertidal and subtidal habitat. The remaining habitat is separated and in places contaminated with chemicals that further reduces its value to organisms and their biological processes. The Puyallup, White and Carbon Rivers are all contained within a revetment and levee system for their lower 26, 8 and 5 miles respectively. These channel containment structures have removed the natural sinuosity of the rivers and the spawning and rearing habitats that were once present. The two hydroelectric dams, and later a flood control project on the White River, have blocked salmon from their historical habitat and reduced their geographical distribution. Numerous other impassable barriers exist on smaller tributary stream that further reduce available spawning and rearing habitats. Land use practices have eliminated the opportunities for large and small woody debris recruitment and heavily impacted riparian buffers.

This report examines these process changes and their associated functional implications in the Puyallup River Basin. Four fundamental lessons are evident within this basin. First, the methods employed for mitigating the biological and hydrologic functions in the surface water systems have been ineffective. There has been dramatic loss of estuarine, riverine and wetland habitat processes and their associated functions. Second, the cost associated preserving the remaining functioning habitats and attempting to restore portions of lost habitats will be substantial. Third, the biological functions historically present in the Puyallup River basin cannot be fully restored. Fourth, fundamental changes in land use will be necessary to restore self-sustaining populations of salmonids in this basin. Finally, while the Puyallup River basin is faced with many critical issues, it is the opinion of the Technical Advisory Group that it is still capable of naturally producing self-sustaining runs of salmonids.

Acknowledgements

The following individuals participated in the development of this project:

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Purpose of Report

The 1998 Washington State Legislature passed Engrossed Substitute House Bill (ESHB) 2496 popularly called “An Act Relating to Salmon Recovery”. As a portion of the Conservation Commission responsibilities set forth ESHB 2496 the agency was directed to form regional technical advisory groups to complete a statewide salmon habitat limiting factors project. Under ESHB 2496, limiting factors were defined to mean, “conditions that limit the ability of habitat to fully sustain populations of salmon. These factors are primarily fish passage barriers and degraded estuarine areas, riparian corridors, stream channels and wetlands.” Completion of this project will provide a consistent approach for identifying habitat functions that require protection and restoration to maintain and increase naturally spawning and self-sustaining populations of salmonids. This report meets the legislative requirement for the Puyallup River Watershed (Water Resource Inventory Area 10).

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1.0 INTRODUCTION

The Puyallup Basin, Water Resource Inventory Area 10, (Figure 1) drains an area of approximately 1,065 square miles, has over 728 miles of rivers and streams which flow over 1,287 linear miles. Included in the watershed are more than a dozen cities and towns, including the state's third largest city, Tacoma.

Salmonid habitat in the Puyallup River basin, WRIA 10, is controlled by basin-scale characteristics including water quality and quantity, sediment sources and associated transport, aggradation and deposition, nutrient supply, and hydromodifications. For purposes of this report, the Puyallup watershed has been divided into six subbasins:

(1) Commencement Bay and Puget Sound Nearshore
(2) Lower Puyallup, (RM 0.0 to RM 41.7)
(3) Upper Puyallup, (RM 41.7 to Headwaters)
(4) Carbon River (RM 0.0 to Headwaters
(5) White River (RM 0.0 to Headwaters)
(6) Independent Tributaries to Puget Sound

Annual average rainfall in the basin ranges from 40 inches at the city of Puyallup to 70 inches at Electron Dam. Mountain snowpack has been recorded at up to 150 inches. Eighty percent of this precipitation occurs in the fall and winter months. Sixty percent of the Puyallup basin lies at an elevation between 1,000 and 4,000 feet, an area where neither rain nor snow predominates. This topographical feature often leads to moisture conditions that are capable of generating tremendous amounts of runoff. These flood events normally occur in the winter months and are followed by less severe spring runoffs generated by snowmelt.

The Puyallup River basin was one of the first watersheds in Puget Sound to experience the full impacts of industrial, urban and agricultural development. This development has had negative impact on natural spawning salmonid populations in the Puyallup River basin.

The Puyallup River basin has been substantially altered from its historic condition. In particular, the lower river bears little resemblance to its historic past (Figures 2 and 3). Extensive urban growth, heavy industry, a large modern marine port, an extended revetment and levee system and agriculture have combined to significantly alter the natural landscape. Table 1 illustrates a chronology of events that provide some detail into how the habitats within the basin were impacted by events. Table 2 depicts the habitat limiting factors to individual bodies of water within the Puyallup River Basin (WRIA 10).

In spite of widespread habitat degradation within WRIA 10, there still exist functioning and productive areas. The South Prairie Creek subbasin continues to be the backbone of natural salmonid production for WRIA 10. Steelhead trout, chinook, pink, coho and chum salmon all successfully reproduce within this subbasin. The middle and upper reaches of the White River and associated tributaries have the potential to be highly productive if significant passage problems associated with the Lake Tapps Diversion Dam and Tacoma Water Pipeline in the lower reaches can be successfully addressed and riparian areas are allowed to recover. The upper Puyallup River subbasin has the potential to naturally produce significant numbers of coho, steelhead and potentially a reintroduced spring chinook run if passage problems at the Electron Dam can be successfully addressed. Both the upper Puyallup and White rivers are predominantly within US Forest Service and private commercial timberlands and they have been afforded a certain amount of protection from the ravages of urbanization and development compared to urban areas in Puget Sound lowlands. However, both the upper Puyallup and upper White River watersheds suffer from present and past timber harvest practices that reduce the ability for riparian areas to provide wood and shade to the river and stream channels and continue to contribute fine sediments from road construction and landslides. All of these continue to adversely impact natural salmonid production.

Table 1: Puyallup River Basin Chronology of Events

Date	Event	Impact(s)
1792	First European description of the Puyallup River mouth	Initial description of attributes of Commencement Bay as a possible port
1850	Donation Land Claim Law	Encouraged settlement of Oregon and Wash.
1851	Initial European settlers arrive in vicinity of Tacoma	Land clearing and farming begins
1852	Pierce County organized	First citizen based government formed
1852	First commercial lumber mill constructed	Timber harvest begins.
1853	First railroad surveys conducted	First mapping attempts of historical habitat
1854	Medicine Creek Treaty signed	Large tracts of land are given up by the Puyallup Tribe
1858	Laws permitting draining passed	Wetlands drainage begins.
	Coal discovered in upper Carbon River subbasin	Mining was initiated in 1873.
1870	Irrigation of agricultural lands begins	Water withdrawals from surface waters
1873	First railroad into Puyallup R. valley	Allows easy access into and out of Tacoma and Puyallup River valley
1874	Initial railroad construction across Commencement Bay tidal marshes	First filling of tidal marshes and tideflats in Commencement Bay
1883	First report of RR bridge across White River	Railroad is constructed east/west in the then White/Green river valley
1890's	Tacoma Land Co. began dredging of western channel of Puyallup River	Significant loss of estuarine environment and function in Commencement Bay
1899	Mt. Rainier National Park established	Headwaters of Puyallup and White rivers preserved.
1903	Electron Power Project construction started.	26 miles of spawning and rearing habitat lost and 10 miles of mainstem river habitat impacted due to reduced flows.
1906	Flood event (probably a 10 year flood event)	Log jam on White R. diverts White into Stuck River and Puyallup River basin

Table 1: Puyallup River Basin Chronology of Events (continued)

Date	Event	Impact(s)
1907	Washington State Legislature grants county governments authority to do flood protection work	Pierce County River Improvement District (PCRI) formed and channelization efforts begin between White River and Puyallup River mouth.
1908	Channel realignment, bank stabilization and diking projects started in Puyallup, Carbon and White rivers	Instream habitat losses associated with each project.
1911	Debris barrier constructed in White R. upstream of the 1906 diversion	Removed LWD from portions of the White and lower Puyallup Rivers
1913	State Legislation passed permitting Inter-County River Improvement District to be formed (1914)	Pierce and King counties work together to perform flood control projects
1914	Concrete Diversion constructed at Auburn permanently diverting White River into Stuck River	Increased Puyallup River flows by approximately 50% at confluence with Stuck River.
1917	Puyallup River Relocation Project complete	Channel relocation, diking alterations to salt/freshwater mixing, erosion and changes to the estuarine environment. 1,800 acres of tidal marsh lost.
1930's	Work on St. Paul, Wapato (Blair) and Hylebos waterways	Estimated 570 acres of mudflats and 121 acres of salt marsh were filled in.
1939	Mud Mountain Dam construction begins	Barrier to anadromous fish migration.
1946	Army Corps of Engineers' channelization and diking projects	Lower three (3) river miles of Puyallup River diked
1940's – 70's	Major logging activities in the upper watersheds	Logging road construction and impacts to riparian buffers and habitat
By 1970's	Major channelization projects completed.	45 miles of the three rivers had been channelized (14.7 miles of dikes with concrete armoring, 57.3 miles of dikes and river banks with rock riprap.
1974	County gravel removal projects started	Rivers maintained by lowering of riverbed instead of raising heights of dikes.
1988	Puyallup Land Claims Settlement	Major property ownership issues settled.
1999	Puget Sound Chinook Listed as Threatened under the Endangered Species Act	

Table 2: Identified habitat limiting factors in WRIA 10

Subbasin/ Stream Name	WRIA Stream Index Number	Fish Passage	Floodplain Connectivity	Bank Stability	LWD	Pools	Side Channel Habitat	Substrate Fines	Riparian	Water Quality	Water Quantity	Sediment Contamination	Lakes	Estuarine
Commencement Bay Subbasin														
	10.CB				**X**				**X**	**X**		**X**		**X**
Puyallup River Subbasin														
Puyallup River	**10.0021**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Clear Creek	**10.0022**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Swan Creek	**10.0023**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Squally Creek	**10.0024**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Canyon Creek	**10.0026**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Clarks Creek	**10.0027**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Rody Creek	**10.0028**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**					
Diru Creek	**10.0029**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Meeker Ditch	**unnumbered**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Unnamed Tributary	**10.0402**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**UC**				
Fennel Creek	**10.0406**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**UC**		
Canyon Falls Ck	**10.0410.**			**X**	**X**	**X**	**X**	**X**	**X**	**X**				
Horsehaven Ck	**10.0589**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**				
Fiske Ck	**10.0596**	**UC**		**X**	**X**	**X**	**X**	**UC**	**X**					
Unnamed Tributary	**10.0595**		**X**		**X**	**X**		**X**	**X**					
Kapowsin Ck	**10.0600.**		**X**		**X**	**X**	**X**		**X**				**X**	
Ohop Ck	**10.6000.**			**X**	**X**	**X**		**X**						
NF Ohop Creek	**10.0605**	**X**			**X**	**X**			**X**					
Fox Ck	**10.0608**				**X**	**X**	**X**	**X**	**X**					
Kings Creek	**10.0613**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**					
LeDout Creek	**10.0620.**	**X**			**X**	**X**			**X**	**UC**				
Kellogg Creek	**10.0621**	**X**			**X**	**X**			**X**	**UC**				
Niesson Creek	**10.0622**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**					
Mowich River	**10.0624**	**X**			**X**	**X**								
Rushingwater Ck	**10.0625**	**X**	**X**	**X**	**X**	**X**	**X**	**X**						
Deer Creek	**10.0685**	**X**		**X**	**X**	**X**			**X**					
Swift Creek	**10.0697**	**X**			**X**	**X**								

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Table 2: Identified habitat limiting factors in WRIA 10 (continued)														
Subbasin/	**WRIA Stream**	**Fish**	**Floodplain**	**Bank**			**Side Channel**	**Substrate**		**Water**	**Water**	**Sediment**		
Stream Name	**Index Number**	**Passage**	**Connectivity**	**Stability**	**LWD**	**Pools**	**Habitat**	**Fines**	**Riparian**	**Quality**	**Quantity**	**Contamination**	**Lakes**	**Estuarine**
White River Subbasin														
White River	**10.0031**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**			
Jovita Creek	**10.0033**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Strawberry Creek	**10.0035**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Jones Creek	**10.0039**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**UC**				
Bowman Creek	**10.0042**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**UC**	**X**			
Unnamed Tributary	**10.0048**		**X**		**X**	**X**	**X**	**X**	**X**	**UC**				
Unnamed Tributary	**10.0049**		**X**		**X**	**X**	**X**	**X**	**X**	**UC**				
Boise Creek	**10.0057**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			
Unnamed Tributary	**10.0059**	**X**	**X**		**X**	**X**	**X**		**X**					
Scatter Creek	**10.0073**			**X**	**X**	**X**			**X**					
Canyon Creek	**10.0077**				**X**	**X**			**X**					
Clearwater R.	**10.0080.**		**X**	**X**	**X**	**X**	**X**		**X**	**X**				
Camp Creek	**10.0112**				**X**	**X**			**X**					
Rocky Run Ck	**10.0117**			**X**	**X**	**X**		**X**	**X**					
Slippery Creek	**10.0118**	**X**		**X**	**X**	**X**			**X**					
Greenwater R	**10.0122**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**				
Unnamed Tributary	**10.0125**		**X**	**X**	**X**	**X**	**X**	**X**	**X**					
Forest Creek	**10.0134**	**X**			**X**	**X**		**X**	**X**				**X**	
Whistler Creek	**10.0136**			**X**	**X**	**X**		**UC**	**X**	**X**				
Pyramid Creek	**10.0143**	**X**		**X**	**X**	**X**		**X**	**X**	**X**				
George Creek	**10.0150**								**X**					
W.F. White River	**10.0186**		**X**	**X**	**X**	**X**	**X**		**X**					
Unnamed Tributary	**10.0187**				**X**	**X**			**X**					
Thirsty Creek	**10.0192**													
Dinner Creek	**10.0190.**													
Pinochle Creek	**10.0198**	**X**		**X**	**X**	**X**	**X**		**X**					
Viola Creek	**10.0199**	**X**		**X**	**X**		**X**		**X**					
Huckleberrey Ck	**10.0253**	**X**	**X**	**X**	**X**	**X**	**X**		**X**					
Eleanor Creek	**10.0258**	**X**			**X**			**X**	**X**					
Midnight Creek	**10.0126**				**X**	**X**			**X**					
Foss Creek	**10.0128**			**X**	**X**	**X**		**X**	**X**					
Twenty-Eight Mi Ck	**10.0129**			**X**	**X**	**X**	**X**		**X**					
Slide Creek	**10.0130.**	**X**	**X**		**X**	**X**			**X**					
Straight Creek	**10.0132**				**X**	**X**			**X**	**X**				

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Table 2: Identified habitat limiting factors in WRIA 10 (continued)														
	WRIA Stream	**Fish**	**Floodplain**	**Bank**			**Side Channel**	**Substrate**		**Water**	**Water**	**Sediment**		
Stream Name	**Index Number**	**Passage**	**Connectivity**	**Stability**	**LWD**	**Pools**	**Habitat**	**Fines**	**Riparian**	**Quality**	**Quantity**	**Contamination**	**Lakes**	**Estuarine**
Wrong Creek	**10.0205**				**X**	**X**			**X**					
Cripple Creek	**10.0204A**				**X**	**X**		**X**	**X**					
Lightning Creek	**10.0252**			**X**	**X**	**X**		**X**	**X**					
Minnehaha Creek	**10.0300**	**X**		**X**							**X**			
Ranger Creek	**10.0308**	**X**												
Deep Creek	**10.0311**	**X**												
Silver Creek	**10.0313**	**X**		**X**	**X**			**X**						
Goat Creek	**10.0314**				**X**									
Silver Spring Ck	**10.0322A**				**X**	**X**								
W. Twin Creek	**10.0107**				**X**	**X**			**X**					
E. Twin Creek	**10.0109**	**X**		**X**	**X**	**X**			**X**					
Carbon River Subbasin														
Carbon River	**10.0413**		**X**	**X**	**X**	**X**	**X**		**X**					
Voight Creek	**10.0414**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**				
Coplar Creek	**10.0417**			**X**	**X**	**X**		**X**	**X**					
Unnamed Tributary	**10.0415**		**X**		**X**	**X**	**X**	**X**	**X**	**UC**				
Unnamed Tributary	**10.0416**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**UC**				
Page Creek	**10.0455**				**X**	**X**			**X**					
S. Prairie Creek	**10.0429**		**X**	**X**	**X**	**X**	**X**		**X**	**UC**				
Wilkeson Creek	**10.0432**		**X**	**X**	**X**	**X**	**X**		**X**					
Spiketon Creek	**10.0449**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**UC**				
Page Creek	**10.0455**													
Beaver Creek	**10.0461**	**UC**	**X**	**X**	**X**	**X**	**X**	**X**	**X**					
Independent Tributaries Subbasin														
Joes Creek	**10.0001**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
E.F. Hylebos Creek	**10.0015**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	
M.F. Hylebos Creek	**10.0013**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
W.F. Hylebos Creek	**10.0014**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	
Wapato Creek	**10.0017**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Simmons Creek	**10.0020.**			**X**	**X**	**X**	**X**	**X**	**X**		**X**			
Dash Creek	**10.0003**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Lakota Creek	**10.0002**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Puget Creek		**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Mason Creek		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**
Day Island Creek		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**			**X**

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2.0 HISTORIC CONDITIONS OF NATURAL SPAWNING SALMONID POPULATIONS IN THE PUYALLUP RIVER BASIN

There is no reliable historical source of information on salmonid species abundance in the Puyallup River basin of record. Historically, runs of chinook (fall and spring stocks), pink, coho, chum salmon, winter steelhead and cutthroat trout were present in the Puyallup River system. There is limited evidence that sockeye salmon also spawn in the Puyallup system. Adult sockeye are reported spawning annually but there is no information that suggests these fish are successful in their reproduction. Because the Puyallup River is glacial in origin, the associated colder water temperatures and high sediment load pose significant hurdles that sockeye would have overcome to successfully reproduce. Riverine rearing stocks of sockeye are known to exist (Gustafson 1997) but there are no reported captures of juvenile sockeye in this river system (R. Ladley, 1999).

Since 1967, run sizes of fall chinook, coho, pink, chum and winter steelhead have been highly variable. Escapement trends for fall chinook and chum have trended upwards while coho have decreased significantly. Winter steelhead run sizes decreased throughout the 1980's and have not recovered since that time (SASSI, 1994). Pink salmon have remained relatively stable and their stock status is considered healthy (SASSI, 1994). The White River spring chinook population have been in a rebuilding process for much of this period with run sizes increasing from historic low levels of the late 1970's (Muckleshoot Indian Tribe, 1996). There is very little data available, for any life history stage, for anadromous cutthroat trout.

In a natural ecosystem, salmonids exhibit great variability with respect to the duration and types of habitats used for rearing. Juvenile chinook can spend anywhere from several days to a year in freshwater prior to migrating to the estuary (Healey 1991). These life histories or trajectories (in the terminology of Lichatowich and Mobrand 1995) vary most markedly with respect to timing and length of residency in the estuary.

For ocean-type chinook, juvenile rearing is a transition in size and habitat use by which an individual grows from a newly emerged fry to an osmoregulating saltwater-tolerant juvenile without necessarily exhibiting a distinct smolt phase. Rearing occurs in one or more of the following habitat types: freshwater, estuarine, or marine shoreline. The different life history trajectories are expressed through the duration of use of these habitats. For migrating juvenile Puget Sound chinook this rearing phase is followed by a period of several months residence in the greater Puget Sound Estuary. All of these rearing trajectories, regardless of species, yield the same results, a fish of appropriate size that has successfully moved from freshwater existence to pelagic existence in Puget Sound, the Pacific Ocean and a returning mature adult salmon. Due to the importance of size, behavior, and physiology, this life history section presents discussions on feeding, growth, behavior and physiology to provide a context for the rearing trajectories described elsewhere in this report.

Because of their recent Endangered Species Act listing as Threatened, the possible rearing trajectories of chinook salmon are discussed at this point in detail. Other species and stocks of Puyallup River origin salmonids have different rearing trajectories but a functioning estuarine environment is important to the survival of the salmonid species and stocks of the Puyallup River basin.

Immediately after emergence, ocean type chinook fry move to low velocity habitats, usually along stream margins before dispersing or migrating to rearing habitats in higher velocity water. This migration can taken them to relatively close freshwater habitats, the estuary (Congleton et al. 1981; Levy and Northcote 1981; 1982; Levings 1982; Hayman et al. 1996), or high salinity shoreline habitats (Healey 1991). In streams and tidal channels of estuaries, fry are located at the margins in low water velocities (Congleton et al. 1981; Healey 1991; Hayman et al. 1996).

Feeding and growth are functions of fish size and the habitat occupied. Insects dominate the diet of fry (<40 millimeters (mm)) whether the fish is rearing in a stream or in a tidal channel of an estuarine marsh (Dunford 1972; Levy and Northcote 1981; Meyer et al. 1981; Levings et al. 1995). The diet of fingerlings (55-70mm) is very dependent upon the habitat occupied. Fingerlings in freshwater feed on insects, while those in more saline areas feed on epibenthic crustaceans (Dunford 1972; Levy and Northcote 1981; Meyer et al. 1981; Levings et al. 1995), while taking insects opportunistically (Meyer et al. 1981; Levings et al. 1995). In altered estuaries, the diet can be dominated by pelagic species such as calanoid copepods (Weitkamp and Schadt 1982). Growth is typically higher in estuarine habitats than in freshwater habitats (Healey 1991).

For ocean-type chinook, there is a convergence of rearing habitat needs as they reach a length of about 70 mm. At 70 mm juvenile chinook are physiologically capable of osmoregulating in full strength seawater (Clarke and Shelbourn 1985) and are large enough to feed on larger prey including larval and juvenile fish (Healey 1991). Ocean-type juvenile chinook that have been using estuarine or marine shoreline habitats will have typically migrated offshore at about this length.

Chinook residing within upstream freshwater habitats (or hatcheries) can be in excess of 70 mm when they reach the estuary. These fish are capable of moving offshore very soon after migrating from the river. In Commencement Bay, chinook longer than 70 mm have been captured along estuarine and marine shorelines, but they are likely facultative rather than obligate residents of these habitats relative to feeding and physiology. It is possible these fish are not behaviorally ready to leave the shoreline although they are morphologically and physiologically ready. A similar behavioral staging has been noted for coho salmon smolts in the lower Chehalis River (Moser et al. 1991). Individual growth rates of juvenile fish can be dependent upon a variety of factors such as dominant/submissive behaviors, wild vs. hatchery interactions, etc.).

Chinook >70 mm that reside in saltwater typically feed on pelagic prey of variable sizes including pelagic crustaceans, and juvenile fish (Healey 1991). These fish will also take smaller prey such as calanoids. Typically these large fish are no longer tied to either freshwater food webs (drifting chironomids) or detritus-based food webs (epibenthic zooplankton and crustaceans) of the estuary, but they will take these organisms opportunistically. Instead, they prefer the pelagic habitats and prey offered by the greater Puget Sound estuary.

In contrast, stream type chinook rearing occurs in freshwater habitats for one year or longer, dictated by their growth rate. This growth rate is often a function of water temperature and food supply.

Recently emerged chinook fry can tolerate high salinity as can newly emerged pink and chum fry (Wagner et al. 1969). However, chinook fry (< 40 mm) cope by tolerating elevated blood chloride levels, while pink and chum regulate blood chloride levels. Therefore, newly emerged chinook fry are not actually fully adapted to osmoregulate in seawater. Exposure to increasing salinity yields fry that regulate blood chloride levels sooner than if direct transfer to seawater occurs (Wagner et al. 1969). It is possible that some stocks of chinook fry are genetically adapted to regulate blood chloride levels in a manner similar to juvenile pink and chum salmon. The marine rearing chinook reported by Lister and Genoe (1970) are one possible example of this rearing trajectory.

The relationship of elevated blood chloride to fitness is unknown but would be expected to be adverse. Clarke et al. (1989) suggests that ocean-type chinook fry exploit estuarine habitat by seeking out lower salinity regions of the estuary, rather than through greater salinity tolerance. This may explain why fry (particularly those that are <45 mm) that rear in estuaries are typically concentrated in areas with very low salinity (<5 ppt), though high quality, habitats with high salinity, exist in adjacent areas. Older and larger chinook fry and fingerlings have greater tolerance to salt water than do younger and smaller fish (Taylor 1990). The growth rate is also important with faster growing fish at any length being more tolerant of higher salinities than slower growing fish (Wagner et al. 1969). The salinity tolerance benefit of rapid growth is more noticeable in smaller fish than in larger fish.

Once fingerlings achieve a length of 55-60 mm, salinity tolerance increases rapidly, and survival upon direct transfer to seawater is high (Wagner et al. 1969). By 65 mm chinook can fully osmoregulate and maintain blood chloride levels below a threshold of 170 meq/l (Wagner et al. 1969, Clarke and Shelbourn 1985, Clarke et al. 1989). Environmental factors (photoperiod and temperature) also influence seawater tolerance and other endocrine mediated changes involved in smoltification. Overall, increasing salinity tolerance creates a cascade of effects in response to both environmental and physiological events that support continued salinity resistance and growth (Wedemeyer 1980). The process of smoltification is a prerequisite for juvenile salmon to continue rapid growth after adapting to seawater (Wedemeyer 1980). Based on physiological studies, smoltification of ocean-type chinook appears to be complete at a length of 65-70mm.

The previous discussion is useful in understanding salmonid, and particularly, chinook utilization in Commencement Bay. Numerous sampling efforts have been conducted in the Bay over the last twenty years to determine the distribution of juvenile salmonids. The Puyallup Tribe of Indians has conducted the longest term sampling effort. These efforts started in 1980 and continued through 1995 (results are reported in Miyamoto 1980; Port of Tacoma and Puyallup Tribe of Indians 1998). Sampling intensity was greatest during the early to mid 1980's. An important aspect of the study is that the sampling locations were selected based on the efficacy of beach seining. These sites typically have low gradients with fine grained substrates and represent higher quality habitat in the bay. The Fisheries Research Institute of the University of Washington (results are reported in Duker et al. 1989) conducted an intensive beach seine juvenile salmonid sampling effort in 1983 at many of the same beach seine sampled locations as the tribe's efforts plus tow net sampling to investigate distribution in the open water habitats of Commencement Bay.

In addition to the above mentioned efforts, sampling of salmonid distribution has also been conducted at a number of sites within the waterways during the course of impact assessment and/or mitigation site planning. These sampling activities have been conducted at a number of locations within the waterways, and include a range of highly altered habitat types (e.g., steep riprap slopes and habitat under piers). Those studies provide a base of knowledge on the utilization and productivity of altered habitats.

Overall, the sampling that has been conducted provides a complete picture of the timing and use of the bay by juvenile salmonids. General conclusions from these studies relative to chinook salmon include:

- Juvenile chinook are present in very low numbers in March, peak catches occur in late May or early June and drop to essentially zero by July 1. The timing of the peak is determined by releases from hatcheries.

- The progeny of naturally spawned chinook arrive in the estuary throughout this period at a variety of lengths.

- The timing of use of shorelines in the waterways and along the Brown's Point and Ruston shorelines is similar to that at the mouth of the river.

- All shorelines are used but catches are typically higher near the mouths of the waterways than near the heads.

- After arrival of the hatchery fish, juvenile chinook are found in shoreline and open water habitats.

- Offshore catches of chinook peak about 2 weeks later than shoreline catches.

Table 3 presents juvenile chinook catch data for three areas in Commencement Bay sampled in 1982 by staff of the Puyallup Tribe of Indians. The year 1982 was selected as an example from the fifteen-year record to illustrate catches trends. Sampling results from the early 1980's are instructive due to the extensive temporal coverage from late winter to mid summer and the overall high level of sampling effort. The figures express catch data as "percent cumulative catch." The slopes of these lines reflect the broad or peaked nature of the migration (broad run timings yield flatter slopes). This graphic form was selected to allow a visual comparison of run timing in different habitats. Generally, the distance between two "percent cumulative catch" lines is an indication of timing differences in the peak of utilization of different areas. The duration of use by the population is indicated by the overall season over which substantial catches occur. Mean length of captured fish and the timing and magnitude of hatchery releases are plotted to decipher life history trajectories and the contribution of hatchery fish. Table 3 also demonstrates the dominance of larger chinook migrants in the Commencement Bay population. This result is expected due to the numerical dominance of the hatchery origin chinook.

Four rearing trajectories (Table 4) may occur in the Puyallup River for juvenile chinook as defined along the lines of Hayman et al. (1996), and are based on the timing of entrance to the estuary:

Emergent Fry: Emergent chinook fry migrate to estuarine rearing habitats immediately after emergence at a length of approximately 40 mm. This trajectory can include fry that rear in essentially freshwater habitats (typically marshes and tidal sloughs) (Hayman et. Al 1996; Healey 1980; Levings et al. 1995) and to those that are rearing in moderate salinity (Levings et at. 1986; Macdonald et al. 1988). Of the two types, the freshwater rearing fry are more common.

The behavior, feeding habitats, and physiological state of emergent fry are very similar to chinook fry in freshwater. They are found in shallow water and at habitat margins, particularly tidal channels within salt marshes, and are closely associated with shorelines (Levy and Northcote 1981; Hayman et al. 1996). A high proportion of the diet of these emergent fry is composed of insects, although euryhaline species are also taken. These fry can tolerate salinity up to 15-20 ppt (Healey 1991). However, the bulk of the emergent fry occupy either low salinity habitats such as the marsh of the Fraser River (Levy and Northcote 1982) or low salinity strata of the water column (Healey 1991) which tends to be the surface waters.

This life history trajectory can be best understood as an adaptation for utilization of high quality estuarine rearing habitats that have few salmonid competitors. The use of these habitats are dictated either by density, where excess fry are displaced from upstream freshwater rearing habitats due to competition, or genetics.

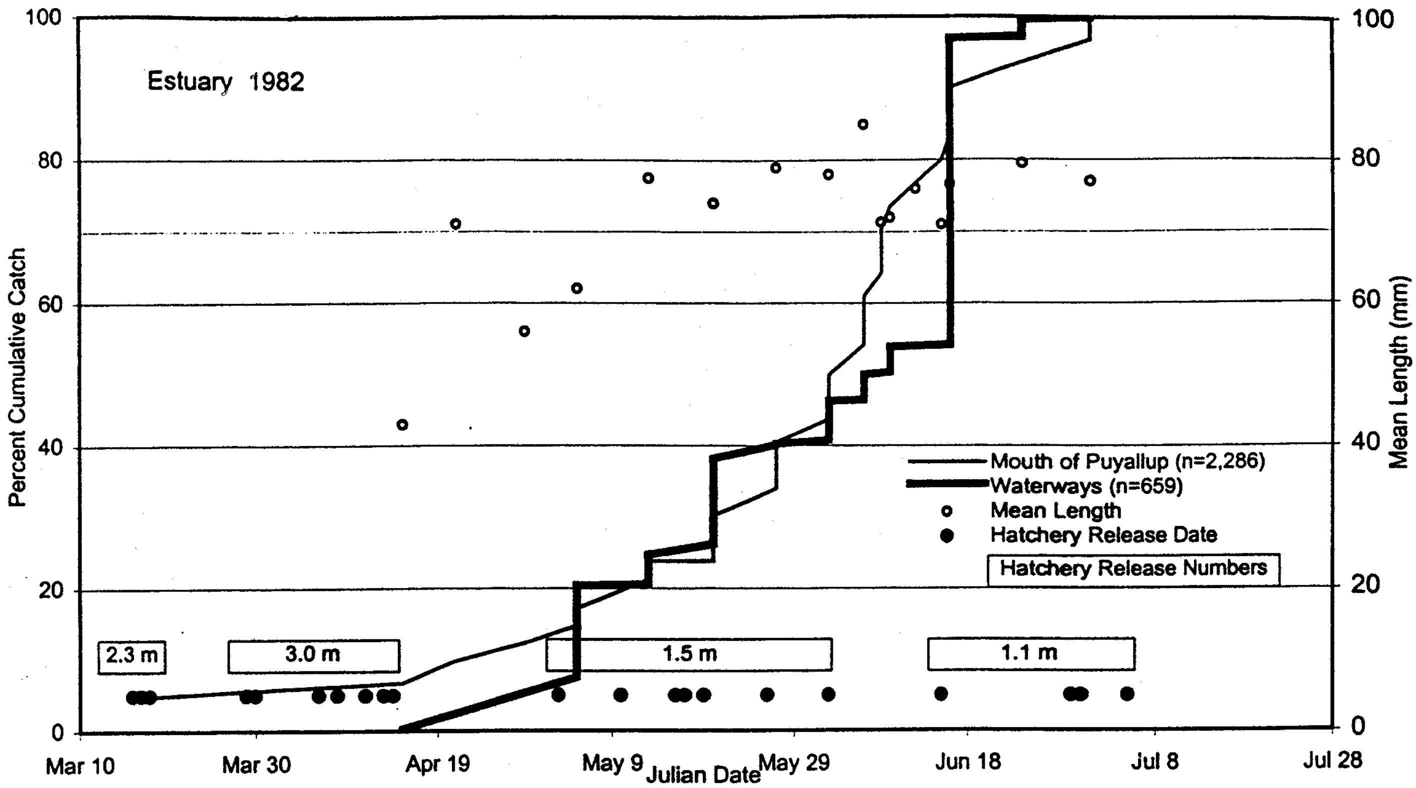
Based on extensive sampling in Commencement Bay (Duker et al 1989, Port of Tacoma and Puyallup Tribe of Indians 1998) very few emergent fry are found in Commencement Bay. This size group comprises a very small percentage of the total catch of juvenile chinook. The low catches may be due to the relative high salinity of the habitats present. Those fry that do attempt to migrate to Commencement Bay may find an unsuitable environment not conducive to their survival, as most habitats in the bay have salinity of 10 – 25 ppt rather than 5 ppt that would be more optimal for their survival.

Fry/Fingerlings: For chinook, fry/fingerlings are fish that migrate to estuarine or marine shoreline habitats at a length of approximately 45 – 70 mm. This trajectory could be represented by an array of sub-trajectories defined by the length of entry into the estuary. These fish rear in the upstream habitats for a variable number of days or weeks prior to migrating downstream. They reach the estuary with much greater saltwater tolerance than do fry. Insects in the stream drift would dominate chinook fry/fingerlings diets in upstream freshwater habitats. These fish may have limited territorial behavior and their downstream migration may involve a slow migration with continuous feeding. In the estuary, epibenthic zooplankton and crustaceans likely dominate diets, but these fish may also show an early shift to calanoid copepods (a pelagic species) if the latter are abundant relative to the former.

This fingerling size group of fish makes up a much larger percentage of the catch in Commencement Bay than do the emergent fry, but catches are still small relative to the more populous hatchery dominated chinook fingerling group.

Fingerlings: Chinook fingerlings migrate to estuarine or marine shoreline habitats at a length of approximately 70 mm or more. This group includes naturally spawned and hatchery produced chinook. Prior to reaching this size, these fish would be expected to exhibit territorial behavior dependent on the length of their time period of rearing in freshwater (Taylor 1990). Insects in the stream drift would dominate diets in upstream freshwater habitats. This group likely undergoes smoltification comparable to coho, steelhead, or stream-type chinook while in freshwater. Based on their size it is reasonable to expect that they would have full osmoregulation capability when they reach the estuary.

The bulk of migration to the estuary occurs during May and early June and the duration of the peak of migration is narrow (Duker et al. 1989). This observed pattern is determined primarily by the timing of hatchery fingerling releases in May. These fish arrive in all portions of the Bay at once and are present on the estuarine shorelines, although the peaks of the runs differ slightly in each area.



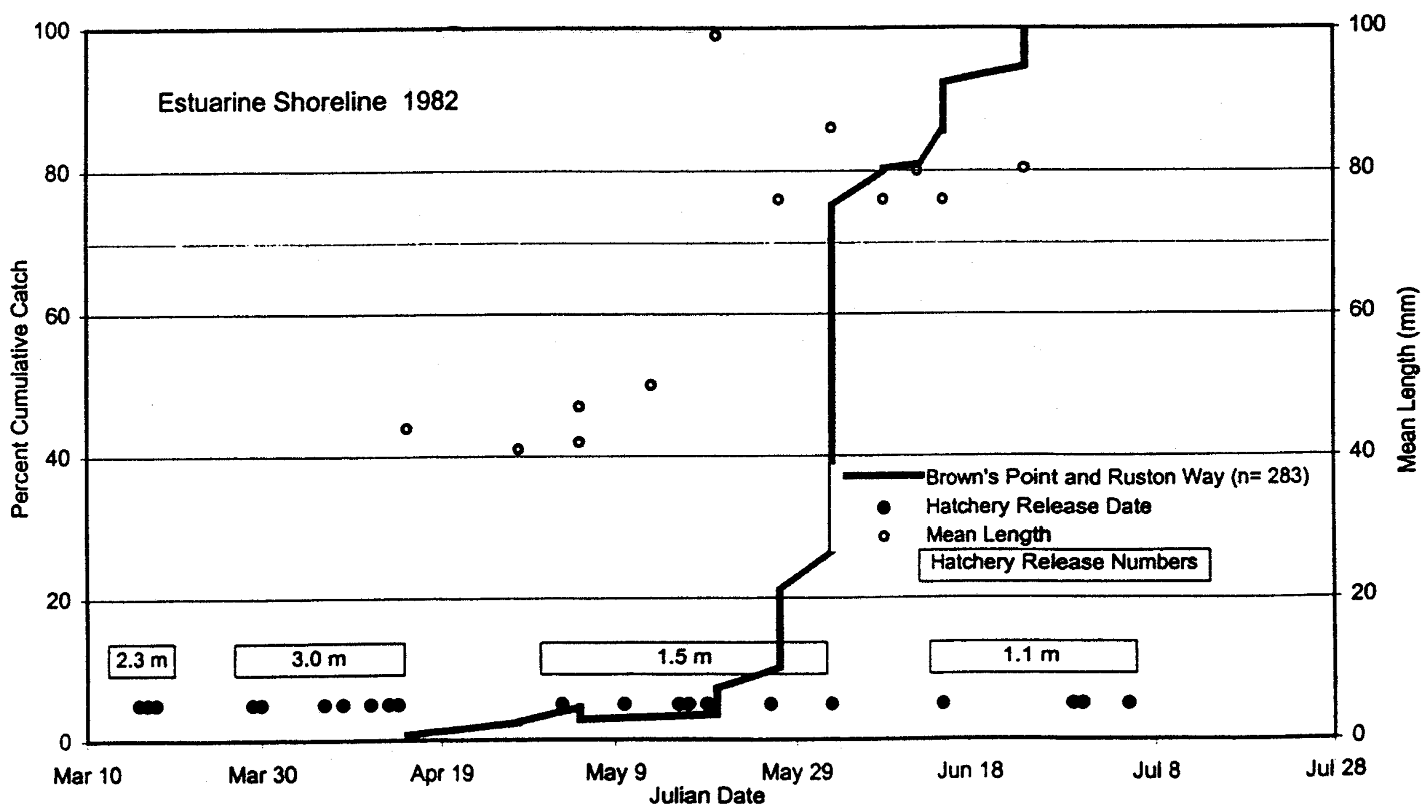


Table 3: Lengths and percent cumulative catch of beach seine caught juvenile chinook at Commencement Bay locations, 1982

Table 4: Puyallup River Basin Rearing Trajectories for Naturally Spawning and Hatchery Chinook (WRIA 10)

Chinook Rearing Trajectory (1)	Abundance in the Puyallup River (2)	Freshwater Rearing Duration (3)	Freshwater Rearing Season (4)	Estuarine Rearing Season (3)	Estuarine Rearing Season (4)	Bay Rearing Duration (3)	Bay Rearing Season (4)
Emergent Fry (< 40-45 mm)	Uncommon	Days	Late February thru March	Months	March to late May	Several weeks to months	May and June (5)
Fry/Fingerling (45-70 mm)	Present	Days to Months	Late February thru April	Several days to months	Early April to late May	Several weeks to months	May and June (5)
Fingerling (>70 mm)	Abundant	Months	Late February thru early June	Several days to two weeks	Late April to mid June	Several days to two weeks	May and June (5)
Yearling	Present	~14 months	Year-round	Brief	----	----	----

(1) Defined based upon timing of entrance to estuary.
(2) Based on sampling conducted in Commencement Bay estuary during the 1980's and 1990's.
(3) Individual residence
(4) Population residence
(5) Chinook may be present in small numbers through July.

Yearling chinook: These fish generally are the product of natural spawning in the Puyallup River and are likely produced predominantly in the White River subbasin. Dunstan (1955) reported that approximately 20 percent of the juvenile outmigrants from the White River were yearlings. Recent information suggests that very few naturally spawned yearlings are produced in the White River. In addition to the naturally produced yearling chinook, hatchery releases occur annually in the White River. Yearling chinook are not considered to linger in estuarine and marine shoreline habitats.

3.0 CURRENT SALMONID POPULATION CONDITIONS IN THE PUYALLUP RIVER BASIN

The 1992 Washington State Salmon and Steelhead Inventory (SASSI) (WDFW and WWTIT, 1994) listed the White River spring chinook as critical and Puyallup River coho as depressed. A summary of salmon and steelhead usage in major subbasins is presented in Table 5. The White River spring chinook are defined as a native stock while Puyallup River coho are of a mixed native and hatchery origin. The stock status for Puyallup summer/fall chinook are unknown but the national Marine Fisheries Service (NMFS) includes this population in the Puget

Sound Ecological Significant Unit (ESU) and has listed that ESU as Threatened under the Endangered Species Act. Nelson et al. (1991) considered Puyallup River spring chinook extinct while White River spring chinook were considered at a moderate extinction risk. There have been occasional observations of adult spring chinook in the Carbon River through the 1980's. It is not known if these adult chinook are strays from the White River or remnants of a Puyallup River spring chinook stock. Nelson et al (1991) also considered Puyallup River fall chinook as a stock of special concern. Higgins et al (1992) and Nickelson et al. (1992) did not list any species or stocks in the Puyallup River basin at risk of extinction or of concern. Puyallup River and White River summer/fall stocks are included in the ONRC and NAWA ESA petition dated 31 January 1995. The stock status of White River spring chinook and Puyallup River summer/fall chinook have been reviewed by NMFS and is still under active review.

Table 5: Profiles of Puyallup River Basin Salmon and Steelhead stocks (SASSI 1994)

Stock	Major Subbasin(s)	Stock Status	Stock Origin
White River Spring Chinook	White River Clearwater River W Fork White River Greenwater River	Critical	Native
White (Puyallup) River Summer/Fall Chinook	White River Clearwater River Greenwater River	Unknown	Unknown
Puyallup River Summer/Fall Chinook	Puyallup River Carbon River South Prairie Creek	Unknown	Unknown
Puyallup/Carbon Fall Chum	Carbon River South Prairie Creek	Unknown	Mixed
Puyallup River Coho	Puyallup River Carbon River South Prairie Creek Voight Creek	Depressed	Mixed
White River Coho	White River Clearwater River Greenwater River W.Fork White River	Healthy	Mixed
Puyallup River Pink	Puyallup River South Prairie Creek	Healthy	Native
Puyallup River Winter Steelhead	Puyallup River Carbon River South Prairie Creek Voight Creek	Healthy	Native
White (Puyallup) Winter Steelhead	White River Clearwater River Greenwater River	Healthy	Native

The earliest return records for White River spring chinook are from the Buckley fish trap in 1941 (Miyamoto 1986). Adult returns from 1942 to 1950 averaged 2,953. Declines in returns were lowest in the 1970's when approximately 50 fish returned in 1977. Currently White River spring chinook escapement numbers have increased primarily because of hatchery intervention programs initiated in the late 1970's. Between 1985 and 1996 naturally spawning fish have been steadily increasing and averaged 263 adults.

The naturally spawning chinook population in the Puyallup River is comprised of an unknown mixture of natural and hatchery origin fish. The magnitude of adult hatchery fish that contribute to the natural spawning population has not been determined. There is the strong likelihood of exchange between natural and hatchery stocks. If the numbers hatchery strays are included in SASSI escapement estimates, the SASSI status designations for this population could be optimistic.

Three fall chum stocks, Puyallup/Carbon, Fennel Creek and Hylebos were listed in SASSI (WDFW and WWTIT, 1994) and only the Puyallup/Carbon are considered native. Fennel and Hylebos Creeks chum stocks are of unknown origin and only Fennel Creek is considered healthy, the others having an unknown stock status. Fennel Creek chum probably consist of a mixture of Hood Canal hatchery origin and native Puyallup River gene pools (L. LeClair 1999). The Puyallup Tribe considers the Fennel Creek chum stock to be of Hood Canal (Hoodsport State Fish Hatchery) origin (R. Ladley pers. comm. 1999).

Puyallup River pink salmon (SASSI 1994) have been considered native and healthy, as are both (Puyallup and White rivers) steelhead stocks. However, population trends within the past five years are not as optimistic. These stocks are considered as native in their origin.

The stock status for all three native populations of bull trout in the basin is unknown. Only limited data exists from sporadic electrofishing and angler catch reports to verify their presence in all three river subbasins. During 1993, the staff from Mt. Rainier National Park conducted some limited sampling in the Upper White River to Fryingpan Creek (USFS 1995) and they were able to determine the presence of native char in this area. No effort was made to determine if the fish they found were dolly varden or bull trout. Survey work conducted by Mt Baker-Snoqualmie National Forest and Muckleshoot Tribal biologists has confirmed the presence of native char in Silver, Dry and Goat creeks (USFS 1995). There is some additional data from the Buckley Trap showing native char catches from the Puget Energy diversion dam trap on the White River at Buckley. Mature dolly varden/bull trout have been found by WDFW in the upper Carbon River downstream from the USFS Bridge 7820.

The current known distribution of anadromous salmonids within the Puyallup River basin and independent tributaries to Puget Sound in WRIA 10 is illustrated in Figures 4 through 10. Information for the known distribution was obtained from tribal, state, county and federal fishery professionals and published databases (SASSI, WDFW Spawning Ground Survey Database, StreamNet). Individuals participating in the mapping of known distribution included: John Kerwin, Project Coordinator (Conservation Commission), Russ Ladley, Blake Smith and Travis Nelson (Puyallup Tribe of Indians), Rob Fritz (Muckleshoot Indian Tribe), Don Nauer and Chuck Baranski (WDFW), Tyler Patterson (US Forest Service), Jennifer Cutler (Northwest Indian Fish Commission), and Tom Demming (former Puyallup Tribal biologist).

The current known distribution underestimates actual distribution because it does not include the presumed distribution. The presumed distribution of salmonids is being addressed through efforts by the Northwest Indian Fish Commission Salmon and Steelhead Habitat Inventory Project (SSHIAP). In many cases the smaller tributaries have not been surveyed. Often times, private landowners deny survey crews access to creeks. Some reaches of streams and rivers are not survey due to difficult access caused by natural terrain. Stream gradient break points are being established and a presumed distribution map should be available later in 1999.

The Washington Department of Natural Resources water typing system does not accurately reflect the actual and potential distribution of salmonids. During 1996 and 1997, staff from the Muckleshoot Indian Tribe surveyed 118 stream reaches in the Green (WRIA 9) and White (WRIA 10) river basins for the presence of salmonids. Sixty-eight of the 118 stream reaches surveyed categorized as Type 4 or 5 stream contained salmonids and need reclassification into Type 3 streams. Nine of these streams had been previously surveyed by others and were reported to contain no salmonids (Fox 1997). Twenty-five stream reaches that contained salmonids had stream gradients greater than 16% and twenty-one had gradients greater than 20%.

Forest seral stage for the Puyallup River Watershed Administrative Units (WAU) are depicted in Table 6. Of particular interest is the absence, or minimal presence, of late seral stage forests in the lower Puyallup River, lower White River and Electron WAUs.

Table 6. Forest seral stage in WRIA 10 WAUs. Data from Cosentino et. al. 1997.

SUB-BASIN (WAU)	Percent Seral Stage*					
	LATE SERAL	MID-SERAL	EARLY SERAL	OTHER	WATER	NON-FORESTED
PUYALLUP, LOWER	0.0	6.4	1.7	23.2	1.8	66.9
LOWLAND WHITE	0.0	8.6	6.3	28.4	6.3	50.4
MUD MTN	3.3	38.8	3.7	41.1	0.1	13.0
WHITE, MIDDLE	7.3	52.7	1.3	38.6	0.0	0.2
GREENWATER	45.0	11.8	0.3	41.6	0.3	1.0
WHITE, UPPER	43.7	19.4	0.4	31.5	0.0	5.0
HUCKLEBERRY	52.5	11.3	0.3	29.1	0.1	6.7
WHITE, WF	41.2	22.6	0.4	33.1	0.3	2.5
CLEARWATER	35.3	34.0	0.2	29.3	0.0	1.2
FRYINGPAN	37.6	5.8	0.1	21.1	0.0	35.5
MOWICH-PUYALLUP	29.7	21.1	1.2	23.8	0.2	24.0
SOUTH PRAIRIE	11.3	32.8	3.9	44.2	0.1	7.7
WILKESON	1.7	47.3	4.0	44.7	0.0	2.4
CARBON	19.3	34.2	2.7	32.0	0.1	11.7
ELECTRON	0.2	46.9	6.4	38.4	0.9	7.2

* Later seral: conifer cover 70%;>10% 21 in. dbeh. Mid-seral: conifer cover 70%; <10% 21 in. dbh. Early seral: conifer cover 10 to <70%. Other: cleared forest; shrubs. Water: lakes and large rivers. Non-forested: urban, agricultural, glaciers. Seral data is from 1988 although some updates have occurred.

4.0 IDENTIFICATION OF HISTORIC HABITAT ALTERATIONS

Historically, in large undeveloped floodplain rivers such as the Puyallup River, habitat variability was the most defining and key attribute. Engineers and technicians exploring routes for the Northern Pacific Railroad conducted the first habitat surveys in the Puyallup River basin during the mid 1800's. They found a mosaic of old growth coniferous forests, prairies, meandering rivers, wetlands and complex estuaries (US Army Corps of Engineers, 1992). Flood events, while occasional, scoured the river channel and altered its course. This process caused banks to erode, river channels and side-channels to shift across the floodplain floor, and gravel beds to scour and aggrade. While initially viewed as destructive, this process continually resulted in the formation and loss of channels, off-channel sloughs and oxbows, input of woody debris (both large and small); and changes in the mosaic pattern of the riverine and riparian habitats. While the river habitats were ever changing, the proportion of those habitats was held in dynamic equilibrium to which salmonid populations were well adapted.

The commercial harvest of old growth forests began in the 1850's. By 1915 there were already indications that these forests were disappearing when M.R. Campbell wrote: "Although the great forests that have made this part of the northwest coast famous are fast disappearing, lumbering continues to be the chief industry…".

Specific flow requirements of salmonids varies by species, life history stage, rearing trajectory and by season. Local populations of salmonids evolved behavioral and physical characteristics that allow them to survive the constant background energy associated with changes in flow regimes encountered during each phase of their development. The abundance and diversity of salmonids is linked and dependent upon analogous natural characteristics of flow regimes. Phases of these flow regimes include seasonal patterns, random variations, and magnitudes of flood and low flows.

Today, the Puyallup River basin has a population of over 241,500 in fourteen incorporated communities and unincorporated Pierce and King counties. The most extensive development occurs along the Interstate 5 corridor and along state routes that lead east and west from the interstate. The headwaters of the Puyallup, Carbon and White Rivers originate inside Mt. Rainier National Park (Williams, 1975); habitat in this area is considered quite pristine. The Mt. Baker – Snoqualmie National Forest forms a ring around the national park. Outside this ring lies another ring of large private commercial timber landholdings (Champion and Plum Creek timber companies) and state owned timber lands that is managed for timber production, recreation and other uses. Table 7 shows characteristics of land ownership as of 1997.

Moving westward, towards Tacoma, there is a mix of agricultural, residential, urban and industrial areas. The closer one gets to the Interstate 5 corridor and Tacoma, the higher the degree of development and industrialization.

Currently the Pierce Conservation District is involved in a comprehensive project to survey fish passage barriers (culverts) and assess anadromous fish habitat upstream of those barriers within the Puyallup River basin. This project, started in January 1999 is scheduled for completion in mid-2000. The objective is to identify fish impasses and place them in a database for use by appropriate agencies and individuals. As of this writing, over 357 individual culverts have been identified and approximately 70% are partial barriers to anadromous salmon upstream and downstream migration. Approximately 40% were determined to be complete barriers to salmonid migration (M. Wicke 1999).

Table 7: Watershed Administrative Unit characteristics of land ownership in 1997. Land holdings do not reflect changes form the Huckleberry Land Exchange between the USFS and Weyerhaeuser. Data is from various sources, and is a generalization and is not a substitute for site specific information. It does not take into account small private holdings of forest land or non-forestry uses.

Watershed Administrative Unit	Size (acres)	Ownership	% of WAU[1]	Predominant Land Use	Length of anadromous streams (miles)[2,3,4]	Recent or pending federal actions supported by state watershed analysis process.	State of Watershed Analyses
Puyallup-White Basin							
Clearwater	23,975	Forest Service Wilderness Weyerhaeuser	14 32 54	Forestry Recreation	8	(1) USFS/Weyerhaeuser Huckleberry Land Exchange (2) Clean Water Act	In prescription phase.
Middle White	28,473	State DNR Forest Service State Parks Weyerhaeuser	1 8 2 89	Forestry Recreation	14[5]	(1) USFS/Weyerhaeuser Huckleberry Land Exchange (2) Plum Creek HCP (3) Clean Water Act	In prescription phase.
Carbon	91,800	Champion USFS Others	45 45 10	Forestry Agricultural	34		May be initiated in 1997
South Prairie	38,186	Champion USFS Plum Creek Weyerhaeuser Scott Other	31 17 10 9 3 30	Forestry Rural Agriculture	16.9		High priority for DNR
Wilkeson	18,100	Plum Creek Champion Scott Other	75 10 5 10	Forestry	6.8		High priority for DNR
Total	200,534				79.7		

1) Personal conversation R. Malcom 1999
2) Natural Resource Trustees, 1996. Commencement Bay Programmatic Environmental Impact Statement.
3) Mt. Baker-Snoqualmie National Forest, North Bend Ranger District. 1996. Green River Watershed Analysis
4) Washington Department of Fisheries. 1975. A Catalog of Washington Streams and Salmon Utilization, Olympia, WA
5) Side channel habitat is not include

4.1 Commencement Bay and Nearshore

Commencement Bay (Bay) is a natural deep water embayment of approximately 5,700 acres in size. Surrounded on three sides, the Bay has extensive areas of heavy, medium and light industry, commercial and residential influences (US Fish and Wildlife Service and NOAA.1997). Habitat types within this subbasin are divided into four categories. A comparison of historical and current levels of four habitat divisions is contained in Table 8.

Table 8: Shoreline Habitat Types in Commencement Bay

Habitat Type	Historical Acreage	Current Acreage	Percent Gain/<Loss>
Vegetated Shallows	Unknown	57	NA
Mudflat, sandflat Gravel-cobble	2,100	180	<91.4 %>
Open Water	0	510	510 %
Emergent Marsh	3,900	50	<98.7 %>

NA = Not Available

Development in the Bay first started in the late 19th Century and the ensuing actions have fragmented the remaining estuarine habitats (US Army Corps of Engineers, 1993). Altered shorelines and/or industrial development consisting of vertical or steeply sloping bulkheads and/or overwater piers of lowered habitat value separate the remaining estuarine habitats. The historical migration routes of anadromous salmonids into off-channel distributary channels and sloughs have largely been eliminated and historical saltwater transition zones are lacking. In addition, the chemical contamination of sediments, in specific areas of the Bay, has in those areas compromised the effectiveness of the remaining habitat (US Army Corps of Engineers, 1993; US Fish and Wildlife Service and NOAA, 1997; Collier, 1998). Despite these extensive modifications, the remaining habitats continue to support some of the biological resources associated with the historical functioning habitat in the Bay (US Fish and Wildlife Service and NOAA, 1997).

It has been estimated that of the original 2,100 acres of historical intertidal mudflat approximately 180 acres remain today (Commencement Bay Cumulative Impact Study, 1992). Extensive anthropogenic activity such as dredging and filling is responsible for the decline of these habitats. The majority of the remaining mudflat habitat lies within the Hylebos, Middle, Wheeler-Osgood and St. Paul Waterways and near the mouth of the Puyallup River (US Army Corps of Engineers, 1993; US Fish and Wildlife Service and NOAA, 1997).

In a report to the 72nd Congress, the War Department described the historical habitat of Commencement Bay (Bay) in 1875 as follows:

"[Near its mouth] the [Puyallup] river divided into two channels, sending about two-thirds of its water into the easterly one (now the Puyallup Waterway) and the rest through the one on the west (now Thea Foss Waterway), which was nearly straight and 150 to 200 feet wide. The easterly channel was crooked, 400 feet wide, and not over 6 inches deep at low tide and filled with shifting sandbars. It discharged part of its volume about one-half mile north of the west channel and the rest through several smaller sloughs into Commencement Bay" (US Congress, 1931)."

The configuration of the mouth of the river is notable in that it discharged to the bay with two short distributaries separated by approximately one-half mile apart. The distance between the mouths of the distributaries is of interest in the distribution of freshwater to the bay. This outlet configuration contrasts with the much wider separation between distributaries that occurs at the mouths of rivers with substantial deltas (e.g.; the Fraser, Skagit and Nooksack rivers). Because of the position of the Puyallup River mouth and distributaries, it is presumed that freshwater influence would have been focused in the southwest portion of the Bay in the Puyallup River estuary in 1877. In the northeast portion of the bay, salinity would have been much more variable and primarily dependent upon input from Hylebos and Wapato Creeks. There are remnant topographic features in the Puyallup Valley that strongly suggest Wapato Creek may have served as a natural overflow channel to the Stuck/White River during periods of high flows. The location of the mouth(s) of the Puyallup River almost certainly varied through time.

Historically, tidal marshes formed the dominant habitat type in the Bay. Comprised of salt (low), brackish (medium) and freshwater (high) marsh habitats they formed a complex mosaic of dendritic channels and plant communities. By 1988 only approximately 57 acres (Shapiro and Associates, 1992), or approximately one (1) percent, of the original tidal marshes remained. Much of these remaining lands are probably not original habitat but the result of intentional filling.

Filling of mudflats and emergent marshes, channelization of the Puyallup River, and dredging of the waterways have significantly changed the configuration and areal extent of estuarine habitats in the Bay (US Army Corps of Engineers, 1993). Nearly all of the emergent tidal marsh areas and the majority of mudflat habitat have been lost (US Army Corps of Engineers, 1993). Concurrent with the loss of mudflat and marsh has been a dramatic increase in open water habitat within the area formerly occupied by mudflat and marsh and now occupied by the waterways (US Army Corps of Engineers, 1993). This habitat type has increased from zero to approximately 510 acres over the last 125 years (US Army Corps of Engineers, 1993).

Prior to 1850 the Bay ecosystem was characterized by interconnected and independent habitats dependent on one another to support the functioning ecosystem (US Army Corps of Engineers, 1993). The interaction of these habitats and their associated processes allowed for the natural flow of nutrients, energy and animal and plant species. A loss in ecosystem size and complexity is associated with a loss function. The magnitude of the habitat loss, and lack of connectivity of the remaining habitat, has reduced the ability of the Bay to effectively for either juvenile or adult salmon.

One of the habitat types difficult to assess in the Bay was vegetated shallows. Eelgrass (*Zostera marina*) and macroalgae are the dominant vegetative types found in this habitat type. Often referred to as nursery areas, shallow intertidal habitats are critical in providing food sources and shelter for juvenile salmonids. It has been theorized that the large amounts of sediments transported by the Puyallup River, and their continual deposition, was not conducive to the establishment of eelgrass beds and other species found in this type of habitat. The presence of vegetated shallows are currently scarce (David Evans and Associates, 1991) With the diversion of the White River into the Puyallup, sediment loads, particularly fine sediments, were greatly increased and further impacted intertidal vegetative habitats.

The freshwater - saltwater transition zone of the Puyallup River is extremely important for juvenile salmonids. While there is no historical data on the extent of the saltwater wedge and zone of tidal influence, the current upper boundary for the saltwater wedge is reported to be up to River Mile (RM) 2.5 and tidewater influence up to RM 6.8. Both the distance the saltwater wedge moves upstream and the zone of tidal influence are functions of freshwater flows down the Puyallup River and saltwater tides. It can be theorized that both the saltwater wedge and zone of tidal influence historically pushed further inland than current conditions. Current river flows, downstream of the confluence of the White and Puyallup rivers have been increased by the addition of the White River to the Puyallup River.

Additionally, the currently channelized Puyallup River effects the saltwater wedge. Channelization has reduced the width of the river and since the freshwater lens is less dense and overlays the saltwaters it can be hypothesized that the actual volume of the saltwater wedge that contributes to the saltwater transition zone has decreased. Additionally, within the tidally influenced zone, shallower sloping banks have been replaced by steeper banks comprised of rip rap that affords less surface area for benthic production and shallow water habitat for avoidance and escape from predatory fish.

Salinity is critical in determining the physiological influence of specific habitats on the different rearing trajectories of all salmonids and in particular chinook. In the Puyallup River estuary of 1877, freshwater influence would have been focused in the southwest portion of the bay. In the northeast portion of the bay salinity would have been much more variable and primarily dependent upon inputs from Hylebos Creek and Wapato Creek.

At present, salmonid habitat within Commencement Bay is gradually increasing in acreage due to construction of habitat restoration projects and natural processes. Development projects since the middle of the 1980's have included mitigation actions focused on conversion of subtidal and upland habitat into intertidal and shallow subtidal habitat. These mitigation actions have resulted in the construction of approximately 50 acres of intertidal and shallow subtidal habitat. After considering project impacts that prompted the mitigation actions, mitigation and sediment remediation have yielded a net increase of intertidal and shallow subtidal habitats through conversion of subtidal habitats. In addition to mitigation actions, the Commencement Bay Natural Resource Trustees are investigating and implementing habitat restoration actions as part of the Commencement Bay Natural Resource Damage Assessment pursuant to CERCLA. At present these project locations lack the connectivity found in a natural estuarine ecosystem. The natural reestablishment of habitat is occurring at the mouth of the Puyallup River, where sediment deposition is believed to be building mudflat/sandflat habitat at the rate of several acres per year (D. Gilmur pers. comm., 1999). The lack or organic materials in these mudflats/sandflats is believed to be a limiting factor in the recolonization of estuarine plant communities. The importation of organic soils is being considered in an effort to address this issue in the hope that plant community recolonization will be successful. However, rapid delta progradation results in unstable habitat for benthic organisms to successfully colonate due to the speed at which this process is occurring.

As of the late 1990's, the estuarine shoreline of Commencement Bay consisted of approximately 440 acres of intertidal habitat (+11.8 ft to –4 ft MLLW) and shallow subtidal habitat (-4 ft to –10 ft MLLW), and approximately 510 acres of open water habitat in the waterways. This area contains approximately 25 miles of shoreline (including the shoreline from Brown's Point to Ruston). Essentially absent from this area is the presence of emergent marsh and riparian vegetation.

Changes to Estuarine Habitat: The following discussion describes the sequence of habitat alterations within the estuary starting in 1877. These changes are shown in Figures 11 through 18. In Figures 11 and 12, two acreage numbers are shown for marsh habitat. They are presented due to disagreements in interpretation of the historical record as presented in Corps et al. (1993). Essentially, acreage estimates are calculated by Bortleson et al (1980), and based on a conclusion that marsh habitat did not extend to Interstate-5 while others have indicated that marsh habitats did extend beyond Interstate-5. Figures 11 and 12 contrast these assumptions. In the following figures and text, acreage is shown as presented in Corps et al. (1993) with emergent marsh extending to Interstate-5.

The Northern Pacific Railroad was constructed across the salt marsh and mudflats of the southwest portion of the estuary about 1894 (Figure 13), but likely had very little effect on habitat. When South 11th Street was constructed in the early 1900s, it was believed to have been constructed on pilings, and had only minimal effect on water exchange (Corps et al. 1993).

Overall, very little alteration of aquatic habitat by dredging and filling is believed to have occurred before 1894 (Corps et al. 1993). However, during the period 1894 to 1907, an estimated 1,020 acres of mudflat and emergent marsh were altered as a result of attempts to dredge and relocate the Puyallup River (USFWS and NOAA 1996). These impacts were focused in the southwest portion of the estuary, primarily southwest of the newly relocated mouth of the Puyallup River (Figure 14). This area would have been the portion of the estuary that previously was most influenced by freshwater. By 1917, several waterways, including the Thea Foss (formerly City), Puyallup, Middle, and Hylebos had been created by dredging and filling in the mudflats (Figure 15) during this time also created the Milwaukee Waterway and a basin between Middle and Puyallup waterways. Approximately 600 acres of mudflat and emergent marsh were removed by construction of these waterways and their adjacent upland fills, while yielding over 200 acres of open water habitat.

The conversion of emergent marsh to agricultural use began around 1916 with the construction of dikes to reduce tidal influence on the delta (Corps 1993). A 1-1/2 mile long dike was constructed on Lincoln Avenue, and 11th Street was modified and diked (Figure 16). Tide gates and ditches were installed in order to convert previously unusable land to agriculture. Tide gates were probably located only on the larger of the tidal channels while the smaller channels were isolated by road fills.

From 1917 to 1927, most of the habitat alteration (162 acres of mudflat, 72 acres of marsh) resulted from dredging the various waterways and from filling to build uplands for piers, wharves, and warehouses (USFWS and NOAA 1996) (Figure 16). The outer portion of Blair Waterway was constructed during this period.

From 1927 to 1941, the existing waterways were dredged to extend, widen, or deepen their channels. Additionally, St. Paul and Sitcum Waterways were constructed. From the late 1920s to the 1940s, marsh habitat along Hylebos and Wapato Creeks was gradually converted to agricultural and residential uses through drainage and dike construction (Corps et al. 1993). Total habitat losses during this period amounted to 133 acres of mudflat and 1,676 acres of marsh (USFWS and NOAA 1996) (Figure 17). Much of the marsh habitat filled during this period had been previously isolated from the Bay and saltwater influence by dikes.

By the 1980s, the majority of marsh and mudflat habitat had been dredged or filled (USFWS and NOAA 1996) (Figure 18). Between 1941 and 1988, most habitat alterations (412 acres of mudflat, 1,587 acres of marsh) resulted from deepening of existing channels, maintenance dredging, and filling. Most of the marsh filling was conducted southeast of Lincoln Avenue in areas that had varying degrees of connection to the Bay due to the earlier construction of dikes. Most of the mudflats that were dredged or filled in this period would have still been connected to the Bay and utilized directly or indirectly by salmonids. The dredging of Sitcum Waterway, and lengthening of Blair and Hylebos waterways created several hundred acres (over 200 acres) of open water habitat. This contrasted with early periods when filling was the primary impact on mudflats.

Impacts to Estuarine Habitat: The impacts to anadromous salmonids of these activities was significant and adverse. The dredging, filling, and diking of the complex habitats, present in the historical estuary, reduced and in some cases eliminated the availability of rearing habitats for salmonids through changes in availability and distribution of space and prey, salinity regimes, and fish access. The size of these habitats vary for the different salmonid rearing trajectories with salinity fluctuations. Shallow areas with low salinity (including emergent marshes and tidal channels) would have provided rearing habitat for emergent chinook fry and fry/fingerling life history trajectories. The emergent marshes provided either direct salmonid rearing habitats (freshwater dominated marshes) or indirect support (salt marsh) through production of prey and detrital material that would sustain prey items. The presence of these tidal channels provided the opportunity for physiological change, feeding areas and refuge during low tides. Saltwater mudflats produced prey and feeding areas for larger chinook migrants (fry/fingerling and fingerling rearing trajectories). Utilization of mudflats without tidal channels was probably less than for mudflats with tidal channels due to lesser availability of low tide refugia.

The reduction in estuarine habitat has reduced the number and relative contribution of different salmonid rearing life history trajectories that can use this estuary. Specifically, when compared to historical presence, the capacity of the estuary to support chinook emergent fry and chum has been substantially reduced. This limitation is also present for, but to a lessor degree, for the chinook fry/fingerling rearing trajectory. The larger chinook fry/fingerlings that have higher salinity tolerance have a greater area of habitat available for feeding and transition to salt water. Although coho and steelhead smolts use estuarine habitats for a shorter duration, these habitats are still important to their overall fitness and survival.

Impacts to Freshwater/Saltwater Transition Zone: The channelization of the lower Puyallup River, described previously, has also greatly affected lateral freshwater movement into a large portion of the adjacent nearshore area of Puget Sound. At present, freshwater flow is largely confined to drainage courses, except during storms when some of the dendritic patterns of outflow still occur. The net result of these alterations has been a gradual, but dramatic shift in habitat type from emergent marsh to uplands.

Prior to 1906, the White River flowed northerly into the Green River. A flood event (believed to be a 10 year event) diverted the White River into the Puyallup River via the Stuck River. Following this flood event, the White River was permanently diverted to the Puyallup River by a diversion dam completed in 1915 (Salo and Jagielo 1983). The diversion of the White River approximately doubled the drainage area of the Puyallup River system. This in turn dramatically increased the delivery of freshwater and sediment to the Bay (Salo and Jagielo 1983).

The increase in delivery of freshwater and the relocation of the mouth of the river had a major affect on the salinity regime in the estuary, the Bay, and the adjacent nearshore environment. This affect would have been most pronounced in the Bay proper and along the Brown's Point and Ruston shorelines. These areas likely had salinity regimes (28-30 ppt) typical of the greater Puget Sound estuary prior to the diversion. The increased flow essentially extended low salinity water well into the Bay and adjacent shoreline areas. It is unknown what other water quality parameters were altered.

The change in the salinity regime in the estuary had a significant impact on juvenile salmonid habitat by increasing the area that had suitable salinity for salmonid salinity-dependent rearing trajectories as discussed previously. Relatively low salinity water (mid-teens to mid-twenties ppt) is present annually well out along the Ruston Way and the Brown's Point shorelines during the spring (Duker et al. 1989). The change in salinity increases the value of such habitats for fry/fingerling and fingerling rearing trajectories of chinook. It is expected that there would be no benefit for emergent chinook fry as they are typically present in lower salinity habitats. Sampling has confirmed the extensive use of these shorelines by fry/fingerling and fingerling rearing trajectories of juvenile chinook (Duker et al. 1989, Port of Tacoma and Puyallup Tribe of Indians 1998).

Sediment: The increased delivery of coarse and fine sediments, caused when the White River was diverted into the Puyallup River, likely had immediate effects on specific areas of emergent marsh through reduction in light penetration and increases in smothering of vegetative and benthic communities. Similarly, light attenuation due to turbidity likely reduced the potential range of the already limited vegetated shallows (eelgrass beds) in the estuary and adjacent portions of the Bay.

Shoreline Protection Changes: The areas of the bay within 500 to 1000 feet of the shoreline and in the waterways are heavily used by juvenile chinook salmon, particularly after the releases of hatchery fish in mid to late May (Duker et al. 1989). Based on these results it is clear that currently substantial numbers of fingerling chinook (hatchery and naturally produced) are undergoing their physiological transition to salt water in the nearshore and open water habitats of the waterways and Bay instead of their historical intertidal and shallow subtidal habitats. The extent to which salmonids utilize the middle open water portion of the Bay that is influenced by the river plume has been documented by sampling efforts constructed in the spring of 1999 (Pacific International Engineering, in prep).

Shoreline protection is discussed separately although it is directly associated with the development of the uplands adjacent to the water. For the purposes of this report, two general categories of shoreline protection are described: 1) shore protection by sloping structures comprised of rip rap or other rubble; and 2) bulkheads of vertical or near vertical hardened structures that allow steeper slopes than historically present.

The shorelines of Commencement Bay have been altered by shoreline protection through the construction of bulkheads and covering of natural substrates with riprap or other materials for erosion protection. These activities have occurred at least since the late 1800s, when a fir bough "seawall" was constructed along the west bank of City Waterway (Corps et al. 1993). Railroads, traveling along the Ruston Way shoreline were one of the early activities that utilized various methods and materials to control erosion. Over the years, refuse, automobile bodies, rubber tires, and a variety of other materials have been placed along the shoreline to control erosion. Rock riprap of various sizes has been the standard material for shore protection over the last 20 years.

Based on shoreline surveys and aerial photo interpretation, it has been estimated that approximately 7,400 linear feet (1.4 miles) of bulkheads are present from Brown's Point to Ruston. This represents approximately 6 % of the length of the shoreline. Bulkheads are most common along Ruston Way (13%), Middle Waterway (8%), and Blair Waterway (7%) shorelines. This total only includes substantial bulkheads that typically extend well below the water line (to approximately elevation 0.0 ft. MLLW) and not the other bank hardening activities associated with these shorelines within the range of tidal influence such as rip rap placement. The above numbers likely underestimate the total impacts on habitat quality and quantity due to the steepening of the slope above MLLW. This reduces the surface area available for primary and benthic productivity and the shallow water habitat available as a refuge from predatory fish. Conversely, it also reduces the habitat available for shallow water avian predators of juvenile salmonids.

A summary of shoreline types in the Bay is illustrated in Table 9 below. Shore protection, other than bulkheads, are present along approximately 94,000 linear feet (17.8 miles) of shoreline from Brown's Point to Ruston. This represents approximately 71 % of the length of the shoreline. The total includes shorelines where only the upper portion is in shore protection and lower slopes have other substrate. Riprap and other large or artificial substrate cover approximately 92 acres (21 percent) of the intertidal and shallow subtidal habitat within this area. Sand, mud, gravel, and select fill (material ranging from gravel to cobble in mitigation sites) cover approximately 348 acres (79 percent) of this area. It should be noted that shoreline length and habitat acreage are not directly correlated because those areas with shoreline protection are typically steeply sloped (2 Horizontal :1 Vertical or 1.5 Horizontial:1 Vertical), while those areas with finer substrate are typically much flatter. Therefore, flat habitats cover large expanses of acreage for a given length of shoreline compared to steeper habitats. Further, as noted above, many shorelines with shore protection transition to finer substrates at lower elevations.

Table 9: Summary of Shoreline Protection in Commencement Bay (1)

Shore Protection Type	Percent of total shoreline
Bulkheads	6
Riprap	15
Fill	56
Natural and/or undefined	23

(1) See text for detailed explanation

The construction of wharves, piers, and docks began in the late 1800s on the western side of the Bay along the Tacoma waterfront (Corps et al. 1993). The construction of over-water structures has continues today as the areas adjacent to the waterways have developed.

Impacts of Shoreline Protection: The impacts of bulkheads and shoreline protection to anadromous salmonids differ. Typically, bulkheads are considered to have greater negative impact on salmonid habitat than shore protection. This difference is captured in regulatory programs such as the Hydraulic Project Approval under the Hydraulic Code administered by the Washington Department of Fish and Wildlife, which favors shore protection with bio-engineering over riprap or bulkheads. Bulkheads placed below the line of MHHW yield a net loss of aquatic habitat and provide very limited opportunity for supporting an epibenthic prey assemblage. Further, bulkheads are considered to deflect shoreward migrating juvenile salmonids to deeper water where predation is speculated to be higher.

The protection of shorelines through bank hardening activities interrupts the natural process of wave and current erosion of bluffs and banklines in Commencement Bay. This in turn interferes with natural processes of sediment recruitment. The use of shoreline protection methods can also alters substrate composition, increases slope, and natural successional processes of riparian plant communities. These changes have a negative impact to the quality of salmonid rearing habitat and limit survival. The presence of larger substrate on steep slopes, typically supports reduced epibenthic assemblages compared to flatter habitats with finer substrate. Although vascular vegetation is precluded, hard substrate provides abundant attachment sites for macroalgae. In contrast to bulkheads, epibenthic prey are available in decreased abundance on steeply sloped protected shorelines and juvenile chinook salmon utilize the habitats in the waterways that have substrate ranging from brick rubble to riprap through necessity. Juvenile salmonids in these habitats also have access to pelagic prey (e.g., calanoid copepods) in immediately adjacent open water habitats.

Based on shoreline surveys and aerial photo interpretation of the area from Brown's Point to Ruston, approximately 26,000 linear feet (5 miles) of shoreline is covered by wide over-water structures. This represents approximately 20% of the shoreline length. The acreage of intertidal and shallow subtidal habitat covered by piers is approximately 26 acres (6 percent) of this area. Nearly all of the pier-covered shoreline has either bulkhead and/or riprap shore protection.

Over water structures potentially have a negative impact on salmonid fitness and survival. Wide and continuous structures oriented parallel to the shore yield darkly shaded areas underneath that are utilized by juvenile salmonids less than adjacent non-covered habitat. However, juvenile salmonids do use, and feed was observed in their stomachs, in the habitats under structures, and at the face of piers (Weitkamp 1982). Use of areas under structures and fish behavior at pier faces appears to be related to the response of the fish to the dark/light interface. Juvenile salmonids can prefer the lighted side or the dark side of a structure depending upon the light conditions to which their eyes are adapted. Studies conducted under structures in Commencement Bay indicate that predators are present but do not concentrate in these habitats.

Structures also reduce habitat quality by reducing the light available for primary productivity, vascular plants and/or macroalgae. In Commencement Bay, the abundance of epibenthic organisms has been shown to be lower under pier aprons than outside pier aprons however substrate size & slope are confounding factors that also affect abundance. Juvenile salmonids have been shown to migrate around pier structures.

Water Quality: With the initiation of water related industries over time, a wide variety of hazardous substances have contaminated the Bay's waters and sediments (US Fish and Wildlife Service and NOAA, 1997). Many of these contaminants are toxic to marine life, predispose migrating anadromous fish to fish health issues (Varanasi, 1993) and pose potential health concerns to individuals who consume contaminated shell and finfish (US Fish and Wildlife Service and NOAA, 1997). A complete list can be found in Tables 10 and 11.

On October 23, 1981, after more than a century of the release of hazardous substances into the Bay, the U.S. Environmental Protection Agency listed the Bay as a federal Superfund site. Additional refinement of the site designations resulted in the Bay nearshore/tideflats area being placed on the National Priority List promulgated on September 8, 1983.

Table 10: Commencement Bay and Waterways Clean Water Act, 1996 303(d) List (Source: Washington Department of Ecology)

Waterbody Name	Parameter
Commencement Bay (outer)	Arsenic, Cadmium, Copper, Lead, Mercury, Silver, Zinc, Naphthalene, Acenaphthene, Fluorene, Phenanthrene, Fluoranthene, Diethyl Phthalate, Butyl Benzyl Phthalate, Bis(2-Ethylhexyl) Phthalate, Dibenzofuran, N-Nitrosodiphenylamine, Total PCBs, Phenol, 2-Methylphenol, 2,4-Dimethylphenol, Benzyl Alcohol, Benzoic Acid
Commencement Bay (inner)	Fecal Coliform, Sediment Bioassay, Bis(2ethylhexyl) Phthalate, Hexachlorobenzene, PCBs, Dieldrin, Copper, Arsenic, Lead, Zinc, Mercury, Hexachlorobenzene, Butyl Benzyl, Phthalate, Phenanthrene, Anthracene, Dibenzo(a,h)anthracene, Chrysene, Acenaphthene, 1,2,4-Trichlorobenzene, Benzo(a)pyrene, Indenol(1,2,3-c,d)pyrene, 2-Methylnaphthalene, Dibenzofuran, Benzo(g,h,I)perylene, Naphthalene, 1,4-Dichlorobenzene, Dimethyl Phthalate, 2,4-Dimethylphenol, Cadmium, Chromium, Di-n-butyl Phthalate, Benzyl Alcohol, Phenol, 2-Methylphenol, Pentachlorophenol.
Thea Foss (formerly City) Waterway	Copper, Lead, Mercury, Zinc, Acenaphthene, Acenaphthylene, Anthracene, Fluorene, Phenanthrene, 2-Methylnapthalene, LPAH, Fluoranthene, Pyrene, Benz(a)anthracene, Chrysene, Total Benzofluoranthenes, Indenol(1,2,3-c,d)pyrene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, Benzo(g,h,I)perylene, Bis(2-ethylhexyl Phthalate, Total PCBs.

In 1983 contaminated sediments led to the listing in the Bay as a federal Superfund site. In 1989, after several years of investigations a negotiated agreement (Record of Decision) was reached that designated the U.S. Environmental Protection Agency (EPA) and the Washington Department of Ecology (DOE) to develop a comprehensive plan for sediment contamination source control and cleanup. This approach can be summarized as initially defining the sources of contaminants, then controlling those sources, and reducing its contact with the human and natural environment. In the ensuing years DOE has conducted over 400 inspections and confirmed ongoing sources of problem chemicals at 70 locations. To date, upland cleanups are complete at sixty-three (63) sites and work is progressing at the other seven (7) sites.

Superfund clean-up efforts for contaminated sediments in the Sitcum, Milwuakee and St. Paul waterways were completed by 1994. The Hylebos, Middle and Thea Foss (formerly called City Waterway) waterways remain Superfund sites and no remedial action plan is in place as of this time. Additionally, no timeline for instituting such a plan exists as of this time. Consent decree negotiations may begin in the year 2000. After their conclusion remedial action plans would need to be developed prior to the initiation of actual cleanup efforts beginning. At this time pre-remedial design investigations are being conducted under Administrative Orders on Consent.

Inorganic or metallic contaminants such as zinc, copper, arsenic, lead, cadmium, chromium, nickel have been identified in sediments (US Fish and Wildlife Service and NOAA, 1997). Organic compounds such as polychlorinated biphenyls (PCB's), dibenzofurans, chlorinated pesticides, phthalates and polynuclear aromatic hydrocarbons (PAH's) have been detected at sites throughout the Bay (US Fish and Wildlife Service and NOAA, 1997).

Sampling programs for the presence of heavy metals, including for zinc, copper, arsenic, lead, cadmium, chromium, nickel and mercury were conducted in 1997-98 in surface and deep water sites from three (3) waterways in Commencement Bay (Ecology, 1999). The data were analyzed for detectable differences between waterways and depth, then compared to water quality criteria, historical data and Puget Sound background data. When data from 1997-98 was compared to data from 1984, levels of arsenic were found to be reduced by 94%, zinc by 73%, copper by 92% and lead by 97%. Levels of mercury and chromium were not analyzed in the 1984 studies. Cadmium levels were also significantly reduced. A summary of these data is shown in Table 10 (Ecology 1999).

Results from the 1997-98 surveys indicate that metal concentrations in surface and deep water samples from three waterways in the Bay are within the current criteria affording protection to aquatic organisms.

Contaminants of concern in the Hylebos waterway include organic compounds, PCB's, and chlorinated organics. Within the sediments of the Middle Waterway mercury, PAH's and tributyltin are of concern. The Thea Foss Waterway poses probably one of the most unique challenge of all the cleanup efforts. Within this waterway the contaminants of special concern include mercury, zinc and BEP's. The Thea Foss Waterway is the only Class C waterway in the state of Washington and recontamination is predicted for zinc after completion of cleanup efforts. The recent discovery of additional petroleum based substances in the Thea Foss Waterway is indicator that potentially undiscovered hazardous sites and contaminants still exist with the waterways.

Table 11: A Summary of Elemental Metal Contaminants in Commencement Bay Water Column Data for Sample Years 1984 and 1998.

Elemental Metal	Location	Average Concentration (ppb) in Surface Waters		Percent Decrease
		1984	1997-98	
Arsenic	Hylebos	34.2	2.3	93%
	Blair	33.8	1.3	96%
	Thea Foss	ND	1.1	NC
	Commencement Bay	ND	1.2	NC
Copper	Hylebos	28.8	2.6	91%
	Blair	25.2	1.3	95%
	Thea Foss	ND	2.2	NC
	Commencement Bay	ND	2.6	NC
Zinc	Hylebos	37.4	11.8	68%
	Blair	27.9	5.8	79%
	Thea Foss	ND	2.2	NC
	Commencement Bay	ND	3.2	NC
Lead	Hylebos	11.9	0.33	97%
	Blair	9.4	0.22	98%
	Thea Foss	ND	0.63	NC
	Commencement Bay	ND	0.14	NC
Cadmium	Hylebos	0.26	0.066	75%
	Blair	0.46	0.068	85%
	Thea Foss	ND	0.074	NC
	Commencement Bay	ND	0.048	NC

ND = No Data
NC = Not Calculated

When compared to fish sampled from reference estuaries, juvenile chum and chinook salmon sampled from the Hylebos Waterway have shown evidence of increased exposure to a wide range of chemical contaminants in their liver and bile (Collier 1998). These contaminants include high and low molecular weight aromatics, PCB's, DDT's, hexachlor, lindane, dieldrin, aldrin and chlordane. The levels of PCBs and chlorinated pesticides are elevated in salmon captured in the Hylebos Waterway when compared to salmon captured from reference locations or other contaminated estuaries. The presence of high levels of specific chemical contaminants in salmon sampled from the Hylebos Waterway provides strong evidence that the exposure originates in the Hylebos Waterway. These chemicals are found in high levels in the Hylebos Waterway and dramatically lower levels are found in other waterways of Commencement Bay.

Table 12: Water Quality Criteria and Ocean Water background Concentrations for Arsenic, Copper, Zinc, Lead and Cadmium (Ecology, 1999)

Metal	Ocean Water Background Concentrations	Water Quality Criteria for Human Protection	Water Quality for Protection Of Aquatic Organisms
Arsenic	1.7 ppb	0.14 ppb	36 ppb
Copper	0.14 ppb	NA	3.1 ppb
Zinc	0.36 ppb	NA	81 ppb
Lead	0.02 ppb	NA	8.1 ppb
Cadmium	0.086 ppb	NA	9.3 ppb

NA = Not Available

Associated with these high levels of chemicals are indications of biological alterations and damage. The elevated concentrations of contaminant concentrations found in the liver, stomach contents and bile samples from juvenile chum and chinook sampled from the Hylebos Waterway are associated with impaired growth, suppression of immune system function and increased mortality following pathogen exposure in salmon (Collier et al. 1998, Varanasi et al. 1993, Arkoosh et al. 1991.).

As salmon transition from freshwater, through the estuarine environment and into the marine ecosystem they must adapt to a wide range of predators, prey organisms and fish pathogens and parasites. The impaired ability to withstand pathogen (including parasites) challenges and the modified growth patterns are deleterious to their survival.

As cleanup efforts are conducted, it is expected that short-term adverse water quality impacts will occur. The complete extent of such impacts is not yet known. However, the clean-up efforts will improve the long term health and productivity of the Bay (US Fish and Wildlife Service and NOAA, 1997).

Key Findings - Commencement Bay and Nearshore

- Habitats within Commencement Bay have been irrevocably altered through and dredging and filling activities.
- The remaining estuarine habitats within Commencement Bay no longer function as a natural ecosystem.
- No clear timeline currently exists to address marine sediment contamination issues. Pre-remedial design investigations are being conducted.

- Estuarine habitat restoration activities are based upon availability of project sites and no information was provided that suggests a comprehensive plan has been developed.
- Juvenile salmonids sampled from the Hylebos Waterway have depressed immunological systems tissues that contain compounds associated with sediment contamination.
- A comprehensive estuarine habitat restoration plan needs to be established and implemented.

Data Gaps - Commencement Bay and Nearshore

- Additional assessments of potential contaminated sites need to be completed on sediment contamination.
- Rate and type of habitats being naturally constructed at mouth of Puyallup River needs determination and monitoring.
- Utilization of open water and mid-Bay by migrating juvenile salmonids needs evaluation.
- Site specific predator – prey relationships and behavior of salmonids in Commencement Bay needs assessment.
- A comprehensive list of shoreline protection structures, facilities and opportunities to modify or remove and make them more fish friendly needs to developed.

4.2 Lower Puyallup River Subbasin

The Lower Puyallup River Subbasin is defined as that portion of the Puyallup River downstream of the Puget Sound Energy Electron Powerhouse on the Puyallup River to Commencement Bay (RM 0.0 to RM 31.2) and associated tributaries, except the White and upper Carbon rivers.

Currently this subbasin produces chinook, pink, chum and coho salmon in addition to winter steelhead and cutthroat trout. Dolly varden/bull trout utilize these portions of the river for rearing and transportation (Puyallup River Technical Advisory Group, 1999). Sockeye salmon adults are observed annually in this subbasin but there is some question as to their origin and ability to be naturally sustaining.

Channel and Floodplain Modifications: Channelization has straightened, confined and simplified the river channel and urbanization are the predominant influences this subbasin (Williams et al, 1975; Muckleshoot Indian Tribe 1996; US Army Corps of Engineers 1993; US Fish and Wildlife Service and NOAA 1997). The mainstem Puyallup River is dominated throughout this reach by a series of dikes, revetments and levees along both banks downstream of the Champion Bridge (RM 28.6) to the river mouth at Commencement Bay. The active channel width throughout this reach is 130 feet (R. Brake per comm. 1999). One setback levee project was initiated as a result of levee damage caused by the February 1996 flood event. This project was completed in 1998 between river miles 23.8 and 24.8 and, within this restricted reach, resulted in an increase in the active channel width to 800 feet with a maximum of approximately 1300 feet (R. Brake per comm. 1999).

Dredging of the Puyallup River for flood control began in the period 1905 to 1908 (Corps et al. 1993, Dames & Moore 1981). Excavation of the channel continued until 1909, when floods caused excessive sedimentation in the channel. Later flood control efforts resulted in the permanent channelization of the Puyallup River and construction of an extensive system of dikes, levees and revetments.

In 1914, the Puyallup River mouth was dredged and permanently channelized (Dames & Moore 1981). The Puyallup River Flood Control Project, authorized in 1936 and completed in 1950, included the construction of levees and revetments along a 2-mile segment of the river between the 11th Street Bridge and the Tacoma city limits.

The construction of revetments and levees in the lower river eliminated connections with side- and off-channel aquatic habitats. The construction of the revetments and levees and their maintenance has decreased the contribution of prey organisms to the river by precluding functioning riparian vegetation habitats. Additionally, they have precluded the recruitment of small and large wood from areas most likely to contribute this material. Channelization and levees have also reduced river processes that form pools, side channels and other habitat features used by salmonids.

A comparison analysis of the length of the Puyallup, White and Carbon River channels from 1894-95 to 1999 are depicted in Table 13 and Figure 19. Maps and descriptions of the Puyallup River from the pre-settlement era do not provide an adequate level of detail that would allow a comparison between the complex side channels and off-channel rearing opportunities available under historical conditions. However, similar neighboring river systems such as the Nisqually River have numerous complex off-channel rearing opportunities beneficial to juvenile salmonids and a comparison of the two would likely allow insight into what may have been present in the Puyallup River basin.

Extensive changes in the mainstem river channel and throughout the valley floor have reduced the rearing habitat available for the migrating and non-migrating salmonids. As previously discussed, emergent chinook fry would have been present in high numbers in the lower river and the distributaries. Water velocity refugia along the lower Puyallup River has been reduced by alteration of the shoreline, thereby decreasing the suitability of this area for all salmonids, including juvenile chinook. The reduction in flow reduces habitat quality and quantity by increasing water velocities, degrades habitat quality by increasing metabolic energy demands of juveniles attempting to maintain position and defend territories.

This increase in metabolic demand may cause stress on juveniles unless their food supply increases proportionately.

Salmonid spawning ground surveys conducted by staff from Puyallup Tribe of Indians indicate that there is only limited spawning activity throughout the diked and leveed mainstem reach (Nelson pres. Comm., 1999). Bedload transport tends to be high because of levee induced increases in water velocities and survival from any spawning that does occur is believed to be low due to scour of the egg pocket (redd).

Table 13: Puyallup river mainstem channel lengths 1894-95 and 1998

River Geographic Location	1894-95 Mainstem Channel Length (miles)	1998 Mainstem Channel Length (miles)	Percent Loss
Puyallup River mouth to confluence with White River	12.36	10.52	14.89 %
Puyallup River mouth to confluence with Carbon River	21.26	18.31	13.88 %
Carbon River confluence with Puyallup upstream to confluence with South Prairie Creek	6.00	5.70	5.00%
White River confluence with Puyallup upstream to Lake Tapps Diversion Dam	25.72	23.87	7.2 %

Barriers: Barriers to adult and juvenile salmonid migration exist on a number of tributaries and are detailed in Table 2. Most of these barriers are caused by poorly located, designed and/or constructed culverts and represent complete passage problems. Some are the result of low flows or represent partial barriers based upon water velocities.

Water Quality: There are seven (7) National Pollutant Discharge Elimination System (NPDES) permits currently active in this section of the river. All are currently active and are meeting the discharge standards contained in their permits. Water quality does not appear to be a significant factor affecting the production of salmonids in mainstem reach.

Water quality parameters necessary for salmonid production have been established and are widely accepted. When monitoring programs detect that those parameters have been exceeded they can be proposed for listing as impaired under current water quality law. Applicable laws include the Clean Water Act, Chapter 90.48 RCW and Chapter 173-201 WAC. Table 13 is a summary of the Washington Department of Ecology (WDOE) 1996 listed 303(d) water bodies and exceeding parameters in the Puyallup River basin.

Every two years, the WDOE is required by the Federal Clean Water Act to identify waters in Washington State that do not meet minimum water quality standards. This list is known as the Section 303(d) list. The lower Puyallup River is listed on the Environmental Protection Agency (EPA) 303(d) 1996 approved list for flow and fecal coliform violations. The 1998 list has not yet been approved by the EPA. It is expected that when finalized, the 1998 list will be different than the 1996 (Table 13) or WDOE 1998 proposed list. However, it can not be presumed that is a body of water is not listed on the 303(d) list that it meets all water quality standards. As described above the 1998 list is not currently approved by EPA. In general, numerous changes from the 1996 list are expected when it is approved and finalized. One major area of change is for Commencement Bay and Thea Foss Waterway. Here due to cleanup efforts in place (CERCLA), federal requirements for excluding waters from the Section 303(d) list are met for some parameters and locations. The other area with extensive expected change will be upper watershed forested locations in the Clearwater, White and Greenwater River systems. Here roughly 50 listings for low levels of large wood in the rivers are anticipated. In addition, new listings for temperature are proposed for the following waters: Fox Creek, Kings Creek, South Prairie Creek, White River and Wilkeson Creek. The lack of resources often precludes a complete assessment of water quality in many of the smaller tributary streams.

Water Quantity: The United States Geological Service (USGS) operates five stream/river gaging stations in the Puyallup River Basin. It is the responsibility of the Washington Department of Ecology (DOE) to set instream minimum flows in the state of Washington. Instream minimum flows for the Puyallup River were established in 1980. The instream minimum flows established at the lower Puyallup River gauge are 1,000 cubic feet per second (cfs) and 500 cfs at the upper Puyallup River gauge. For the 14 year time period from 1980 to 1993 inclusive, instream flows were not met at the lower Puyallup River gauge an average of 35 days annually (Ecology 1995).

Table 14: Section 303(d) 1996 List of Puyallup River Water Bodies

River/Creek Name	Parameter(s) Exceeding Standards
Hylebos Creek	Fecal Coliform
West Fork Hylebos Creek	Fecal Coliform
Wapato Creek	Fecal Coliform, Dissolved Oxygen, Instream Flow
Clarks Creek	Fecal Coliform
Unnamed Tributary to Clarks Creek	Fecal Coliform
White River (RM 0 to 29.6)	Fecal Coliform, pH, Instream Flow
Boise Creek	Temperature (a)
Scatter Creek	Temperature
Clearwater River	Temperature
Voights Creek	Temperature
Greenwater River	Temperature
Swan Creek	Fecal Coliform
Clear Creek	Fecal Coliform
Meeker Ditch	Fecal Coliform
Fife Ditch	Ammonia-N, Dissolved Oxygen, Fecal Coliform
South Prairie Creek	Fecal Coliform
Puyallup River (RM 0 to 19.1)	Fecal Coliform, Instream Flow (2 listings)

(a) Specific cause has not been investigated

Generally, these flow violations were late fall and are not believed to be a significant limiting factor to the production of salmonids.

One measure of minimum stream flow is the seven day low flow. This statistic represents the lowest recorded flows that occur each year over a period of seven consecutive days. When averaged for flows in the previous ten years since 1926, the Puyallup River flows have shown a continuous decline despite the establishment of instream flows in 1980 (Ecology 1995). The 1980 regulation prohibited all new surface water withdrawals from the White River, Hylebos, Wapato creeks and many tributaries to the Puyallup River. During the 1973-1993 time period data from three USGS maintained Puyallup River basin gages show that the low flows have dropped, even though this same time period has had above average precipitation. This decline can be attributed to increased demand for groundwater water withdrawal through unregulated wells (5000 gallons or less per day) and increases in impervious surfaces that lead to a decline in groundwater and base surface water flows.

Un-premitted water withdrawals occur throughout the Puyallup River basin. Such withdrawals typically impact salmonids in two manners. Typically they occur when streams are at their lowest flow. This further reduces available rearing habitat for species such as coho and steelhead that rear through the summer months as discussed below. Additionally, they are usually unscreened and result in direct mortality through mechanical pumps or stranding of juveniles in fields to which the water may flow by gravity. There was no available data indicating the magnitude of this issue.

Low flows are considered a factor that can limit juvenile coho production in tributary streams due to reduced wetted area and pool volume available for summer and fall rearing. Additionally, reduced stream flows can reduce the survival of outmgirating juvenile chinook by increasing the outmigration time for juvenile salmon, which is hypothesized to increase predation (Wetherall 1971).

Data on Puyallup River flood events prior to 1914 is almost totally lacking. Water flow measurements and elevations were initiated in May 1914 and the first report published for Water Year 1915 (October 1, 1914 to September 30, 1915) (Pierce County 1991). Major flood events recorded by the United States Geological Survey (USGS) in the Puyallup River at the Puyallup gage include events in December 1917, two events in December 1933, January 1965, December 1977, November 1986, January 1990, November 1990 and February 1996. The 1996 flood is the current peak flood of record. Flows from this rain on snow event were record flows throughout the Puyallup River system at gages upstream and downstream of regulation effects.

The levee and revetment system have created a false sense of security that flooding can be prevented. Of the flood events mentioned in the previous paragraph, it is particularly notable that only three approach a 35-year flood event. This has resulted in a chronic and recently acute conversion of former floodplain areas on the landward side of the levees into residential and industrial development. The loss of natural vegetation and wetlands in the Puyallup basin has reduced the watershed's ability to store and process water in a manner to minimize flood event duration and peaks.

As the river flows downstream into more urban areas the associated land uses change. Urbanization is accompanied by the conversion of uplands and wetlands into residential, commercial and industrial uses. Because of increases in impervious surface and reduced floodplain storage this process results in increased peak flows, quicker peak flows and reduced base flows (Booth 1991; Booth and Jackson 1997). Confounding the increase in flood potential in this reach is the aggradation of the river channel which increases the potential for flooding.

Riparian Habitat: The lower reaches of the mainstem Puyallup River currently are lacking in the coniferous riparian habitat that was present historically. The habitat, which remains, is comprised of disconnected areas that do not meet the properly functioning categories of the NMFS matrix of habitat pathways and indicators. The riparian area in its entirety can not be rated as functioning properly. From an examination of aerial photographs, less than 5 % of this section of the mainstem Puyallup has what can be considered high quality riparian habitat and that habitat is fragmented into small segments often separated by distances of over a mile. No late-seral stage forests exist within the mainstem riparian corridor. The only significant area of mid-seral stage forest is that portion of the Champion Tree Farm immediately downstream of RM 26.3.

The current Army Corps of Engineers levee vegetation management standards pertaining to levees from RM 0.0 to RM 3.0 call for the removal of all vegetation with a trunk diameter exceeding 4 inches diameter at breast height (dbh). Pierce County maintains the remainder of the levees and follows vegetative management standards set forth in the settlement order in Puyallup Tribe of Indians vs. Pierce County, Cause No. C79-269T. Various criteria are applied to the different river reaches affected by the Court Case but in general any vegetation in excess of the six (6) inches dbh may be removed. This eliminates the opportunity for large and small wood to be recruited to the channel and restricts the potential for overhanging vegetation with resultant loss of associated habitat benefits. The lack of functioning riparian habitat is believed to be a limiting factor to the production of salmonids.

Presently, this section of the Puyallup River serves primarily as a transportation corridor with only minimal values for spawning and short or extended rearing. Because of the loss of riparian habitat, extremely limited spawning and rearing habitat, the natural production of anadromous salmonids in this reach is limited.

Tributary streams have suffered the fate of most streams found in urban settings. They carry high levels of fecal coliform bacteria and stormwater that is contaminated with heavy metals, oil, grease and organic compounds. Large amounts of fine sediments are also typically found in most reaches. Several streams in this reach are listed on the Clean Water Act 1996 303(d) list (Table 13).

Key Findings - Lower Puyallup River Subbasin

- The Puyallup River has been extensively altered through channelization and the loss of riparian and off-channel habitats from RM 0.0 to RM 26.8.
- Opportunities to reestablish, at least portions of, off-channel habitats still exist.
- LWD is virtually absent in this subbasin.
- Most of the tributaries in this reach suffer from the effects of urbanization.
- Summer low flows have declined continuously since at least 1980, in spite of the closure for new surface water withdrawals and the establishment of minimum flow requirements.
- The levee and diking system has created a false sense of security that flooding can be prevented.

- The extensive channelization of the mainstem reach of the Puyallup River serves as a salmonid transportation corridor with only limited spawning and rearing habitats available to salmonids.
- There are numerous barriers to adult and juvenile salmonid migration throughout this subbasin.
- Water quality in specific tributary streams and reaches is not fully supporting natural salmonid reproduction.

Data Gaps - Lower Puyallup River Subbasin

- Adequate information about salmonid life history and site specific habitat utilization of salmonids is lacking.
- Quantitative impacts of groundwater withdrawal on base flows of the mainstem and tributaries is absent.
- Site specific escapement numbers need development.
- Riparian buffers need to be mapped.
- A comprehensive list of floodplain encroachment structures, facilities and opportunities to remove or set back these structures and facilities needs to developed and mapped.

4.3 Carbon River Subbasin

The Carbon River is a glacial fed tributary of the Puyallup River Basin that contributes approximately 30 % of the Puyallup River flow (Williams 1975). Flowing approximately 32 miles from the Carbon and Russell glaciers on Mt Rainier, the Carbon River has nineteen tributary streams and has been considered to represent the largest and most productive habitat available for natural salmonid production in the Puyallup River basin. South Prairie Creek provides the largest production refugia for salmonids in the Carbon River subbasin.

4.3.1 Upper Carbon River Subbasin

The Upper Carbon River reach, identified as that portion of the river upstream from the terminus of 177^{th} St E., (River Mile 8.5) to its headwaters can be generally described as a braided system flowing through a broad, relatively flat floodplain and moderate to low stream gradient (Williams 1975). The river has a glacial source that delivers large pulsed volumes of sediments to the system and relatively steep tributary streams as supporting features (Williams 1975). Although some localized, constricted canyon conditions exist where channel widths are narrow though bedrock areas and stream gradients are increased, the preponderance of the reach is generally flat and braided. The braided active channels are quite unstable with bedload consisting of large rubble, boulders and pockets of fine sorted materials.

The upper reaches of the Carbon River are high gradient, flattening out as the river enters lower river valleys prior to joining the Puyallup River in the vicinity of Orting (Williams 1975). Currently this subbasin produces chinook, pink, chum and coho salmon in addition to winter steelhead and cutthroat trout (Williams 1975). The only recent observations of adult spring chinook in the Puyallup River basin, outside of the White River subbasin, are from the Carbon River in the vicinity of the US Forest Service Bridge at RM 23.0 (T. Demming 1999). In the early 1980's Puyallup Tribal biologists reported that they electroshocked several adult chinook from pools in this reach of the river during sampling efforts in June and July (T. Demming. 1999). Sockeye salmon adults are occasionally observed in this subbasin, but there is some question as to their ability to be naturally sustaining. A distinct dolly vardon/bull trout population is identified in Salmonid Stock Inventory (SaSI) (WDFW 1998) in the upper Carbon River.

With the exception of Mt. Rainier Park at the uppermost end of the watershed, the vegetation condition is primarily second growth coniferous forests with heavy concentrations of hardwoods occupying the immediate riparian corridors. Most of the watershed area outside the park is privately managed commercial tree farms with the exception of some United States Forest Service (USFS) ownership in the upper portion.

Hydromodifications: There are no known artificial blockages, dams or diversions in the upper Carbon River system within the anadromous zone. Culverts exist on tributary streams but do not pose anadromous salmonid passage problems due to the inherent steep gradients of the streams in which they are placed. The only remaining levees and revetments in this portion of the subbasin are low profile, remnant structures within Mt Rainier National Park between the Carbon River Road and the active river channel. The Mt. Rainier Carbon River entrance road functions similarly to a levee. Channel migration is inhibited and stream energy is likely compounded due to the confinement created by the road. Although damaged beyond use by the 1996 floods, the Forest Service is still considering repairs to this section of road. Thus, this structure could promote adverse habitat conditions similar to those of a levee if reconstruction occurs. Furthermore, the dilapidated road likely delivers non-native fill material to the channel during flooding. This material may impact salmonid life histories

Barriers: Barriers to adult and juvenile salmonid migration exist on a few tributaries and are detailed in Table 2. Most of these barriers are caused by poorly designed and/or constructed culverts and are total passage problems. Some are the result of low flows or represent partial barriers based upon water velocities.

Land Use: Upland land use within this subbasin is best characterized as commercial forestry and recreation within Mt. Rainier National Park and USFS lands (Williams 1975). However, there are isolated areas of low density single family residential housing. Very few roads exist along mainstem due to canyon features and high risk associated with flooding within the flat valley bottom.

There is one active bridge over narrow canyon reach and another bridge is proposed for reconstruction by USFS within broad floodplain reach. The Fairfax Forest Reserve Road locally constricts the floodplain in some areas but is not a significant problem due to the functional width of the floodplain (> 0.5 mile). While road density is considered low in the upper watershed, due the Mt. Rainier National Park, there are some poor road conditions on the USFS/Plum Creek cost share 7810 road system, USFS 7840 (Chenuis Cr.) and USFS 7920 (Tolmie to Evans Cr.) road systems. Road density is somewhat greater through the Champion tree farm along Lily and Evans creeks but road densities are relatively low and road conditions are generally good. Historically, the culverts and bridges on the smaller streams were not constructed to pass the largest storm events. This has led to an increase in the frequency of debris flows and destruction of stream habitat. Additionally, the historical lack of protection afforded to headwall and unstable slopes during timber harvest has lead to an increased frequencies of mass wasting and adverse impacts to stream habitat (USDA Forest Service 1995).

Mass wasting impacts are believed to be of only minor significance and limited to shallow slumps or earthflows in a few areas. There is no comprehensive landslide inventory for this subbasin.

No river dredging activities have been conducted in recent history in this subbasin. With the exception of the natural box canyon between the Fairfax bridge and the town of Carbonado, most other constrictions to the movement of water, sediment and wood are minor and very localized anthropogenic features. They include the USFS 7810 road bridge crossing, short portions of the Carbon River Reserve Road and the abandoned railroad grade immediately upstream from the 177th Street E terminus. There are no known regulating structures within this subbasin.

The Carbon Reserve Road and USFS 7810 Road occupy areas of the floodplain in very localized areas and some limited and restricted development within floodplain areas along the mentioned roads. Only one road crossing is known to have limiting impacts to salmonid production in this subbasin. Currently, that road, USFS 7810, remains washed out after flood events in 1996. This crossing has historically required a high level of maintenance and is of high risk of continued washout through the occupation of functional floodplain. Because it is in the active Carbon River floodplain the bridge approach requires fills and armoring which decrease the wetted river area and increase local water velocities with adverse influences on salmonid spawning and rearing habitat. Fills are chronically subject to washout and maintenance replacement. The latest crossing design employed three (3) separate bridge structures, all of which served to constrict and entrain the active channel configurations. The two other bridges in this subbasin are placed in good, stable locations within canyon or quasi-canyon features. The road accessing the Carbon River entrance to Mt. Rainier National Park also likely contributes to sedimentation as the river avulses and erodes it into the channel. The road is comprised of fill and clays not normally part of the Carbon River sediment load, and thus likely has an adverse impact on salmonids when avulsed in high quantities (M. Fox pers. comm. 1999).

Within the USFS Mt Baker-Snoqualmie National Forest land in this subbasin there are approximately 215 miles of existing roads (U.S. Forest Service, 1998). Tables 15, 16 and 17 provide a detail of these roads:

Table 15: Roads within Voight/Mowich Subbasin

National Forest system roads	2.9 miles
National Forest non-system	2.3 miles
Mt. Rainier National Park roads	5.1 miles
State, county and private roads	44.9 miles

Table 16: Roads with Carbon/Evans Subbasin

National Forest system roads	54.3 miles
National Forest non-system	6.8 miles
Mt. Rainier National Park roads	36.0 miles
State, county and private roads	4.8 miles

Table 17: Roads within South Prairie Subbasin

National Forest system roads	18.0 miles
National Forest non-system	0.7 miles
Mt. Rainier National Park roads	0.0 miles
State, county and private roads	39.0 miles

Riparian and Large Woody Debris: The historical forest management practices have involved the removal and/or disturbance of riparian conifers, which has resulted in the successional dominance of hardwoods (i.e.: alder and cottonwood) in some reaches. However, due to the instability and dynamics of floodplain, historic riparian community, at least in terms of species composition, may be relatively unchanged. It can not be readily determined if the channel is more instable due to the above mentioned changes than it was historically.

Historical timber harvest activities have resulted in the loss of the channel adjacent, old growth conifer tree component that served as the source of short and long-term recruitment of functional sized wood pieces. Due to flooding and other natural geomorphic processes, many of the remaining functional pieces of woody debris have lodged on intermediate benches and terraces above the wetted channel. This creates an even greater need for increased volumes of large woody debris (LWD). Therefore, even with Mt Rainier National Park serving as major source of functional LWD, the reach is generally starved of necessary LWD. The virtual lack of LWD is believed to be a limiting factor in providing channel stability and habitat necessary for successful salmonid production.

Current regulations also reduce potential sources of LWD to the stream channel. Wood recruitment is a function of tree height, and trees can contribute wood to the channel from a horizontal distance equal to its height, or more if on a steep slope (Van Sickle and Gregory 1990; McDade et al. 1990). Since current regulations allow harvest within 25 feet of the channel, trees that could potentially recruit wood to the channel can be logged and removed from the recruitment process. Often, the largest trees are removed from the riparian areas, reducing the recruitable number of trees of sufficient size to remain stable in the channel, form pools, trap sediment, and reduce stream energy. Additionally, removing trees within a site potential tree height also reduces the number of pieces that can enter the stream channel. Several small pieces can combine to function as a larger piece. Salmon habitat is often a function of the interaction of wood, water, and sediment, reducing the quantity and size of wood recruited to the stream. Regulations that allow for the harvest of trees that can potentially recruit wood to the channel can effectively limit the quantity and quality of salmon habitat.

Logging on unstable slopes without buffers will likely increase the rate of landslides from pre-management conditions (Krogstad et al. 1997). Until remaining areas are effective at protecting unstable slopes and increasing the probability of landslides, current forest practice rules are also a limiting factor.

Within the lands owned by the USFS in the South Prairie subbasin almost no mature or old growth forest stands currently exist (U.S. Forest Service, 1998). It is estimated that the majority of closed immature forested areas within the western hemlock zone will begin to evolve into mature forest status in approximately 75 years and attain old growth status in approximately 150 years. This has the potential to increase thermal protection and LWD input and increase pool:riffle ratios. Within USFS owned lands, the Carbon/Evans and Voight/Mowich subbasins the majority of the riparian and instream habitat is considered to be of high quality (U.S. Forest Service, 1998).

The amount of LWD in streams have been observed to decline for up to 100 years following timber harvest (Murphy and Koski 1989; Harmon et al. 1986). Given the time frame during which much of the harvest occurred in this basin, it is probable that instream habitat quality will continue to decline for a further 50 to 100 years, before natural processes can begin to reverse the decline in large woody debris presence. The US Forest Service notes that in the adjacent Green River basin, which has been subject to similar timber harvest patterns, that in some areas if a second riparian harvest occurred, instream large woody debris levels would be expected to decline even further over time to a point where instream large woody debris would be minimal to non-existent (USDA 1997). Given such observations, it is anticipated that large woody debris loadings will continue to decline in many streams for decades unless structural restoration actions are undertaken.

Currently, bank stability is not a significant problem due to the minor influence of human, structural presence and associated disturbance. However, loss of old growth trees and replacement with second growth conifers and hardwood has reduced the natural, functional integrity of bank margins.

Of particular note is the decline of beaver populations throughout this and other basins. Once abundant throughout this region, populations have declined throughout their historic range. Beaver populations were remarkable in their ability to alter habitat on a large scale. Through the construction of dams they modified stream processes by creating ponds that interrupted sediment and organic matter transport. This in turn often led to the formation of riparian wetlands to further altering nutrient cycles. Historically, this type of process provides benefits to many aquatic and terrestrial species dependent upon wetland habitat and also provided a degree of flood protection. Juvenile coho salmon particularly favor this type of habitat (Peterson 1982; Brown and Hartman 1988).

With exception of roads, fine sediment and loss of riparian support, other factors are minor due to low level of human occupation and disturbance to river reach. Problematic road systems (as discussed previously) serve as tributary sources of fine sediment inputs to tributary streams and raise occurrence intervals for debris torrents and flows due to road failures. Numerous examples are documented since 1990 (D. Nauer, 1999).

The loss of riparian shade in tributaries was probably significant in the past, but the maturity of existing second growth riparian trees and recent Forest Practices Act (FPA) regulations have reduced this negative impact. These impacts are mitigated somewhat by the cold glacial source and proximity of the mainstem Carbon River.

Substrate: Streambed substrate conditions in this subbasin are driven by the glacial influence of flows and sediment supply. Due to the low level of human presence and associated influence of outside factors there is only minimal disturbance.

Water Quality: The only known water quality issue in this reach is the Carbonado wastewater sewage treatment plant. The facility is currently undergoing system upgrades that should correct the existing violations. There are no industrial sources, reservoirs or artificial ponds documented or known to influence water quality within this subbasin.

The proposed 1998 303(d) list has a new listing for Wilkeson Creek for exceeding copper and temperature water quality parameters. Copper has been demonstrated to be harmful to salmonids particularly during smoltification.

Exotic Species: There are limited areas of terrestrial non-native plant communities and noxious weeds as designated by the Washington State Noxious Weed Board (RCW 17.10.080). There are two known populations of tansy ragwort in the vicinity of US Forest Service Road 7920. There are two known locations of Japanese knotweed along the Carbon River in Mt. Rainier National Park. Scott's Broom is known to occur along roadways throughout the subbasin and there is one site of orange hawkweed in the town of Buckley (U.S. Forest Service, 1998. " Carbon River Watershed Analysis". Schrenk, D. (Team Leader)). All are thought to have only minor influence and do not currently pose a threat to the production of salmonids within the subbasin.

Eastern brook trout are known to be present in the east fork and south fork of South Prairie Creek, mainstem Carbon River, Cayada Creek, Tolmie Creek and Chenuis Creek. Possible adverse interactions with native char have not been documented as of the date of this report.

Nutrients: The amount and availability of salmon carcasses historically present in this subbasin is unknown. Data are so limited that there is even the lack of anecdotal information. However, it is assumed that populations were higher and carcasses more available. Due to the glacial origin of the Carbon River, the lack of an adequate nutrient level is probably a significant limiting factor impacting production. . Salmon carcasses are an important source of nutrients to riparian vegetation and are also consumed by juvenile salmon. Some studies have indicated that salmon carcasses can provide significant amounts of the nitrogen in the vegetation and juvenile salmon biomass. The increased numbers of salmon carcasses have led to increased juvenile salmon biomass. Additionally, the loss of a nutrient source from adjacent old growth, functional sized in-stream wood and LWD recruitment is an even more significant limiting factor.

Water Quantity: Water quantity is not believed to be a limiting factor in this reach of the Puyallup basin. Because of the relative lack of human development, structures and influence in this river reach, there is believed to be only minor impacts to water quality in this reach. The single most important water quantity controlling feature in this reach is that the water source is glacial. Acting as a steady, continuous water source, but also subjecting the channel to catastrophic natural water flow events, the glacial source serves to control the quantity function in a process that is assumed to be relatively uninfluenced by human intervention.

Key Findings - Upper Carbon River Subbasin

- LWD is either absent or virtually past its useful life expectancy in this subbasin and land use practices are preventing the recruitment of LWD.
- The input of nutrients in the form of woody debris and salmon carcasses appear to be limiting.

- This subbasin is recovering from the adverse impacts on salmonid habitat from historical timber harvest practices.
- There exist a number of adult and juvenile salmonid barriers in tributary streams.

Data Gaps - Upper Carbon River Subbasin

- An inventory of landslides and mass wasting locations and relative sizes and their causes needs to be prepared.
- Utilization of stream reaches by life history for anadromous salmonids and native char needs to be fully documented.
- Stream inventories, that include stream typing and habitat surveys need to be initiated and completed.
- A comprehensive list of floodplain encroachment structures, facilities and opportunities to remove or set back these structures and facilities needs to mapped.
- A comprehensive list of preservation and restoration opportunities needs to be developed.

4.3.2 Lower Carbon River Subbasin

The lower Carbon River reach, identified as that portion of the river downstream from the terminus of 177th St E., (RM 8.5) to the confluence with the Puyallup River and can be generally described as a confined and leveed system within what was a broad, relatively flat floodplain. The rivers glacial source delivers large volumes of pulsed sediment to the system. The relatively few tributary streams originate off the canyon walls before flowing across the valley floor and joining the Carbon River are generally not accessible to anadromous salmonids (Williams 1975).

Land Use: The vegetation along the lower Carbon River consists of primarily willows, alders, maple and cottonwood along with grasses and dense patches of blackberry vines that are often intermingled with woody vegetation. There are only limited patches of second growth conifer with heavy concentrations of hardwoods occupying the immediate riparian corridors. The dominant land uses are rural residential and small farms (Williams 1975).

South Prairie Creek is the backbone of natural salmonid production in the Lower Carbon River subbasin and Puyallup watershed. As the major tributary to the Carbon River, South Prairie Creek produces nearly half of all the wild steelhead in the Puyallup River system, has the only significant run of pink salmon in the Puyallup River and enjoys healthy returns of chinook, coho and chum salmon and sea-run cutthroat trout. As a result of this recognition, WDFW, in concert with the Puyallup and Muckleshoot Indian tribes have targeted this section for habitat protection measures within the regulatory arena. Opportunities to protect and restore habitat are available in this creek.

The majority of the mainstem portion of this subbasin has been closed to recreational fishing for over 20 years to provide sanctuary for these natural populations and the habitat protection strategy has been employed to provide refugia. The success can be measured by the consistent returns of salmonids across the board. Although not yet approaching historical numbers, the salmonid populations are holding their own while other stocks have been decreasing. This has been accomplished during a time in which significant forest practice activities have been conducted in the upper watershed and development pressures exerted in the lower system. Successful habitat protection could not be possible without cooperation of the commercial landowners. There is however, additional room for habitat improvement, especially in the tributary streams and the lower mainstem. The success in South Prairie is illustrative that salmon populations can sustain themselves when provided with functioning habitat and adequate escapements.

The East Fork of South Prairie Creek originates from commercial timber lands owned by Weyerhaeuser, Plum Creek and Champion Pacific as well as the Clearwater National Wilderness Area controlled by the USFS. Some public timberlands are also administered by the USFS. The West Fork flows through a mixed ownership of public and private tree farms managed by the same entities. Both forks are sourced by snowmelt and springs that are dependent upon snow pack. Upper South Prairie Creek (above the diversion dam) supports healthy populations of resident rainbow, some cutthroat and introduced eastern brook trout. The South Prairie mainstem below the canyon is deeply incised with only a few tributary streams above RM 11.0 (Williams 1975) of which Beaver and Page creeks are the only anadromous tributaries. The stream changes character and reduces in gradient as it leaves the commercial tree farms and enters the Spiketon area. Residential development and agricultural uses are the main land uses where the creek meanders through a broad valley until it reaches the Carbon River. Wilkeson Creek, which enters South Prairie Creek at RM 6.8, provides anadromous access for some 6 miles where it reaches a natural falls, which blocks all upstream migration. Above the falls, Wilkeson and Gale Creeks support primarily resident cutthroat populations. Downstream from the falls, Wilkeson Creek contains coho, chinook and steelhead and sea-run cutthroat trout.

Upstream of RM 11.0 the dominant land use in the South Prairie Creek subbasin is commercial forestry. Here the stream gradient is steep and the channel is incised in contrast to the flat and meandering channel with stream gradient less than 2% present in the lower reach.

Wilkeson Creek, below the impassable falls, can be best classified as residential with commercial forestry, a channel primarily incised. Both South Prairie Creek and lower Wilkeson Creek are supported by only minor tributaries, and most of these function as wall base type channels unavailable to anadromous fish but providing additional inputs of water.

Due to channel incision on upper South Prairie and Wilkeson Creeks, the culverts that exist on tributary streams generally do not pose passage problems because they are outside the anadromous fish zone. Near the town of South Prairie there several small unnamed (or locally named) tributaries that are culverted through older revetments where passage is precluded. Downstream of the Burnett Bridge (RM 8.3) there are also several small tributaries that are cut off because of culverts. These culverts prevent off-channel rearing opportunities. Off-channel rearing opportunities have been demonstrated to be important to coho (Brown and Harman 1988; Peterson 1982; Bustard and Narver 1975).

Barriers: There are no known artificial blockages, dam or diversions in this reach of the Carbon River or its tributaries. Numerous culverts are present on tributary streams but do not pose passage problems for anadromous fish due to the inherently steep gradients of these streams. These barriers do pose movement problems to resident salmonids in some areas.

Currently, the Pierce Conservation District is undertaking a comprehensive fish passage barrier assessment project in the Puyallup River watershed. Using the protocol developed by the Washington Department of Fish and Wildlife, culverts are assessed to determine passability to anadromous salmonids. Data taken include: Global Position System (GPS) points; location legal descriptions; road and stream names, stream WRIA numbers, documented fish utilization, a digitized photo and latitude/longitude. The GPS points are used to digitize the location of the culvert and that location is plotted and attached to a GIS layer. As of May 1999, over 357 individual culverts on county and private roads had been identified of which approximately 70% were determined to be partial barriers and approximately 40% were complete barriers to anadromous fish migration. This project is scheduled for completion in the calendar year 2000.

There is an anadromous blockage on South Prairie Creek at RM 15.7 where the City of Buckley has a water diversion dam (Williams 1975). However, the natural canyon reach immediately below this diversion dam may have historically impaired at least portions of the anadromous upstream migration (Williams 1975). Wilkeson Creek has a natural barrier (falls) at RM 6.0 (Williams 1975).

The partial diversion of South Prairie Creek for City of Buckley drinking water supply may adversely impact juvenile rearing habitats for coho, steelhead and cutthroat trout and upstream migration of chinook during low flow conditions. Low flows are considered a factor that can limit juvenile coho production in tributary streams due to reduced wetted area and pool volume available for summer and fall rearing. Additionally, reduced stream flows can reduce the survival of outmgirating juvenile chinook by increasing the outmigration time for juvenile salmon, which is hypothesized to increase predation

Hydrology: The lower Carbon River's flood carrying capacity is less than the 100-year flood at numerous locations. A flood event of the magnitude of 100-year flood would severely compromise the levees near the confluences of the Carbon River and South Prairie and the Carbon River and the Puyallup River (Pyrch, 1988, USGS). Maintenance of the Carbon River channel is the responsibility of the Pierce County River Improvement District (PCRID). This agency was formed in 1908 by the Washington State legislature in response to floods in the previous year. Currently, the Pierce County Public Works and Utilities Department administers the PCRID. The levee system is in direct conflict with a functioning river ecosystem and the natural production of salmonids and many of the maintenance activities associated with the activities of the PCRID are also a source of conflict as described elsewhere in this report. However, much of the land within this section of the valley is in agricultural use, which does not necessarily preclude restoration activities.

The lower 5 miles of South Prairie Creek and a 1 mile segment on Wilkeson Creek in the Town of Wilkeson have been either channelized and/or are contained within constricting levees or revetments. The channel containment system precludes stream occupation of significant portions of historical floodplain within these reaches. The lower South Prairie Creek levees have not been actively maintained for at least the last 20 years and the stream is slowly recapturing portions of its historical floodplain. While restoration in these areas is possible, in some areas such as those reaches within the Towns of South Prairie and Wilkeson continued structure maintenance is likely be expected to maintain the dikes as necessary to protect developed properties, which have encroached upon former floodplain. The constricted channels in these diked reaches experience increased water velocities and lack adequate pool-riffle composition which reduce salmonid rearing potential. However, some spawning and rearing conditions persist despite the adverse effects of the flood control structures.

The lower reaches of the Carbon River are constricted between revetments and levees along both banks from its confluence with the Puyallup upstream to RM 8.2. Where natural bank features remain, the loss of old growth trees and replacement with smaller woody and non-woody vegetation along with patches of second growth conifer and hardwood has reduced the natural, functional integrity of bank margins.

Channelization: The previously mentioned diked reaches have significantly degraded salmonid habitat causing increased water velocities on the lower South Prairie and Wilkeson Creek channels. The loss of ability for the streams to dissipate energy with overflow create a scouring effect which reduces the streams capacity to store and properly distribute spawning gravels, retain wood in the channel and maintain and create functional pool/riffle sequences.

Besides the previously mentioned constrictions from existing levees and revetments and road encroachments, an abandoned railroad grade is located along lower Wilkeson Creek and along a segment lower South Prairie Creek. While the abandonment of the old grade for rail purposes has allowed the streams to reclaim portions of the former floodplains and channel, the proposed public trail system will resurrect maintenance projects to provide a “safe” public trail system. These activities could pose both future challenges and opportunities for stream habitat restoration opportunities.

Additional channel constrictions on South Prairie and Wilkeson Creeks include the numerous bridge crossings on SR 162 and SR 165. The SR 162 bridges on South Prairie Creek pose localized constrictions that increase water velocities and further increase localized scour and channel degradation downstream. During periods of high flows caused by rain on snow events they also cause South Prairie Creek to back up and inundate adjacent lands.

Land Use: Upland land uses in this part of the subbasin are commercial agriculture, forestry, hobby farms, outdoor recreation and very dispersed single family residential housing. The road density increases as you enter the lower Carbon River valley. Commercial forestry is the dominant land use in the upper portions of South Prairie and Wilkeson subbasins. In these natural but incised reaches, the stream channels and floodplains are basically unaltered but logging has removed many of the bank defining large trees, that and LWD recruitment sources that reduces instream and riparian habitat complexity. In lower South Prairie Creek and Wilkeson Creeks the dispersed single family residential areas and agricultural areas have exerted much more control to constrict the floodplains. This is especially true for the lower 5+ miles of South Prairie Creek where the floodplain area is significantly reduced due to localized development, channel constrictions and agricultural encroachment.

Historically, the PCRID, Inter-County River Improvement Commission (ICRI) and private parties have removed gravel from the riverbed in an attempt to control floods. Historical volumes of this activity are shown in Table 18.

Changes in this practice were made in 1981 when increasing restrictions were placed on the issuance of hydraulic project approval permits. In an attempt to regulate channel capacity and protect existing dikes, gravel removal still occurs in the Puyallup River basin by private parties. The vast majority of the gravel removal is from the Puyallup River and varies from 40,000 to 100,000 cubic yards annually (D. Nauer 1999).

Table 18: Volumes (in cubic yards) of Sediment Removed from the Puyallup, White, and Carbon Rivers 1974 to 1985 inclusive (USGS 1988)

Calendar Year	Puyallup River	White River	Carbon River	Volume Total
1974	127,960	70,780	137,130	335,870
1975	87,740	50,890	56,670	195,300
1976	133,860	246,690	31,110	411,660
1977	81,040	56,050	18,150	155,240
1978	41,900	152,680	18,850	213,430
1979	123,080	40,000 (a)	28,240	191,320
1980	35,400	560 (a)	94,700	130,660
1981	0	1,350 (a)	0	1,350
1982	6,770	27,940	23,100	57,810
1983	23,220	55,240	41,910	120,370
1984	64,950	66,730 (a)	32,320	164,000
1985	107,710	11,890	0	119,600
TOTALS	833,630	780,800	482,180	2,096,610

(a) Some of this material was removed from the Greenwater River, a tributary of the White River.

The locations of sediment removal by private parties since 1981 are available in the records of hydraulic project approval permits issued by the Washington Department of Fish and Wildlife. Unfortunately, no historical data are available that documents the volume of material removed. Starting in 1996, WDFW began to require documentation of the amount of material removed. Data for those three years exists in the WDFW hydraulic project approval permit files.

There has not been any current dredging activities in the South Prairie Creek or tributaries in recent history. However, following the November 1995 and February 1996 flood events, some gravel removal projects were proposed within the Town of South Prairie. An education program is necessary to help dissuade such destructive projects in critical spawning and rearing areas. Land use changes, or property acquisition, may be necessary to better accommodate the creek and natural creek functions, especially within the constricted, developed stream reaches. Gravel extraction activities have adverse impacts upon stream morphology and sediment transport which can result in direct and indirect destruction of salmonid redds and eggs; expose side channels to increased flows; reduce the number and size of pools in the side channels and the mainstem. Through channel incision, gravel removal, can isolate existing side channel habitat; impede the creation of future side channel habitat; and increase the quantity of lower quality main stem rearing habitat and the expense of higher quality side channel habitat.

Road density is considered moderate in the upper South Prairie and Wilkeson Creek subbasins within the commercial tree farms. Upper South Prairie Creek has problematic road systems along its South Fork, those being the USFS 7722 road and a portion of the Plum Creek/USFS road system on the northeast side of Burnt Mountain and O'Farrel lookout. Most of the Plum Creek and Champion road systems are well maintained but some site specific problems persist. In the lower reaches of both South Prairie and Wilkeson creeks, stream adjacent highways such as SR 162, SR 165, Lower Burnett Road, South Prairie Road, etc., encroach into the floodplain and displace historical rearing habitats for salmonids. This encroachment also reduces functional floodplain area, thereby necessitating adjacent bank hardening projects which further exacerbates the loss of riparian support. Bridges along the state highways also reduce functional floodplain area due to the insufficient design length of the bridge spans.

Peters et al (1998) examined seasonal fish densities found along five types of bank stabilization projects. The results from the first year of this two year study, indicate LWD-stabilized sites consistently had higher salmonid densities than the other types examined. Riprap only sites consistently had lower salmonid densities. The typical bank stabilizing material used throughout this subbasin is rip rap.

Significant development exists along the lower 5 miles of South Prairie Creek and within the Town of Wilkeson along Wilkeson Creek. Residential development in the Town of South Prairie occupies portions of the historical floodplain and further constricts the channel. Downstream from the Wilkeson, revetments and dikes have allowed significant conversion of the former floodplain for agricultural uses. The loss of overflow ability for the stream to dissipate energies within diked reaches causes scouring and degradation in the mainstem channel reducing available spawning habitat and adversely impacting rearing potential.

Past forest management practices and associated removal and disturbance of riparian conifers prompted successional dominance of hardwood (i.e.: alder, cottonwood) in some stream reaches. However, over 70% of the upper South Prairie Creek and Wilkeson Creek riparian corridor are dominated by second growth conifers of varying ages. Within the agricultural areas and residential development along the lower reaches of South Prairie Creek, the riparian condition is compromised by lack of a riparian corridor and hardwood trees dominate landward of the levees.

Within the South Prairie Creek subbasin, past timber harvest activities have resulted in a loss of channel adjacent, old growth forest component, which formerly served as a source of LWD recruitment. While some reaches of upper South Prairie Creek do contain persistent, relic old growth structural components in the channel, these remnant pieces are fast approaching their life expectancy and will soon decay and lose their ability to function. With only mid-seral second growth forests to provide LWD recruitment, we can expect a further loss of LWD function until these forests mature. Fortunately, riparian management zones within the commercial timberlands along upper South Prairie Creek have been drastically expanded over the last 10 years, which will eventually provide some degree of LWD replacement.

The loss of historical volumes of LWD and future recruitment sources are most pronounced in the lower reaches of South Prairie Creek and Wilkeson Creek in the vicinity of the Town of Wilkeson. As previously discussed, the narrow strips of riparian trees along the agricultural and developed reaches do not provide adequate opportunity for short and long term recruitment of functionally sized LWD. The fact that so little future LWD is available due to lack of standing timber along this stream reach and the time frame necessary to grow functional sized trees to act as suitable LWD means that aggressive riparian and instream structural restoration is paramount.

Further compounding the lack of LWD recruitment and presence in reaches of lower South Prairie Creek is the lack of ability of the channel to retain any wood present. Channel constrictions and actions by local property owners to remove LWD for firewood and prevent flooding further restrict recruitment and as a result the formation of pools and stabilization of spawning gravel.

Within the lower reaches of the Carbon River the past land use management and associated timber harvest activities have resulted in the loss of channel adjacent, old growth wood component to serve as short and long term recruitment of functional sized pieces woody debris. Channel constriction in this section of the river tends to transport the remaining functional sized pieces out of this reach. This creates an even greater need for increased volumes of LWD. The reach is generally starved of necessary LWD.

Within the Carbon River, with the exception of the lower river levee system, all factors can be characterized as minor impacts on substrate conditions due to low level density of anthroprogenic structures. This system is driven by the glacial influence of flows and sediment supply. However, historic sediment removal activities have impacted substrate availability.

The South Prairie subbasin is more problematic. There have been no recent dredging activities. The constriction of diking and associated stream channels has increased substrate size and the ability for the channel to naturally distribute and sort substrate materials. This is caused by bank hardening projects, the lack of channel forming features and increased water velocities. While some favorable spawning conditions still persist, levees and revetments within the lower reaches of this system currently pose significant limiting factors.

No current site specific data exists regarding basin development and timber harvest in these reaches. However, there is empirical information that suggests that development has altered the delivery sequence of surface water to the system and individual creeks in response to storm events. While overall basin impervious surface area is still relatively limited, development pressure and construction of new roads will exacerbate existing peak flows and their associated adverse impacts. Results of increased peak flows will be especially evident within the stream reaches constricted by levees, revetments and bridges due localized scouring and bankhardening effects.

Exotic Species: There currently exist only a few instances of invasive terrestrial non-native species within this subbasin. As such they are only a insignificant and not believed to be a limiting factor to salmonid production. There are no known populations of aquatic non-indigenous species within this reach.

Water Quality: The Washington Department of Fish and Wildlife operates the Orting Salmon Hatchery on Voight Creek under a general NPDES permit. The hatchery predominantly produces chinook and coho salmon. The hatchery effluent is discharged into Voight Creek and currently meets all standards in its discharge permit. However, Voight Creek is listed on the 303(d) list for exceeding water temperature parameters in the vicinity of the hatchery.

With exception of roads, fine sediment and loss of riparian shade, other habitat limiting factors are minor due to the low density of human occupation and disturbance to the river reach.

The loss of riparian shade along tributaries to the Carbon River was probably significant in the past, but the maturity of existing second growth riparian trees and recent Forest Practices Act (FPA) regulations have reduced the negative impacts of past clearcut logging within the riparian corridor. Those tributaries flowing through agricultural lands continue to experience significant loss of riparian vegetation and suffer elevated water temperatures. The cold glacial source of the Carbon River and proximity of the tributaries to the Carbon River help reduce impacts to the loss of riparian shade in the mainstem. The major tributary to the Carbon is South Prairie Creek. The lower reaches of this tributary contain increasing amounts of open farmlands separated by intermittent strips of deciduous shrubs and trees.

Nutrients: Since historical fish populations are unknown, the amount of nutrient recycling historically is also unknown. It can be assumed that historical spawning populations were significantly higher than those of present times. Recent efforts at nutrient enhancement from the placement of salmon carcasses may be helping to restore adequate nutrient cycling in this portion of the basin. Ironically, these efforts are often in violation of the Clean Water Act and require a variance to current water quality standards of that act. Due to the Carbon River's glacial origin, nutrient levels are probably a significant limiting factor and the loss of nutrients from adjacent old growth, functional sized in-stream wood and LWD recruitment may even be a more significant factor limiting production. Growth of this type of vegetation may also have benefited from and been a function of nutrients contributed by salmon carcasses.

Due to the relative lack of human development, structures and influence in this river reach, water quantity is believed to be relatively good. Acting as a steady, continuous water source, but also subjecting the channel to sediment pulses and periodic catastrophic flows, the glacial origin tends to meter out flows in a manner that is relatively uninfluenced by human intervention.

Key Findings - Lower Carbon River Subbasin

- South Prairie Creek has acted as a refugia for salmonids and is the major source of natural salmonid fish production in the Puyallup River system.
- Stream habitat has been compromised by roads, lack of riparian habitat and fine sediment input.
- Excellent opportunities for preservation and restoration exist throughout the lower Carbon River subbasin.
- Anthroprogenic impacts are generally site-specific and localized to smaller areas than elsewhere in the Puyallup River system.
- The lack of LWD and functioning riparian habitats limits the natural production of salmonids.

Data Gaps - Lower Carbon River Subbasin

- Completion of the barrier assessment project is essential to restoration activities.
- An assessment of habitat upstream of barriers needs to be initiated.
- A more detailed assessment of salmonid presence and habitat utilization needs to be undertaken.
- An assessment of impacts of gravel removal to fish habitat needs to be prepared and alternatives developed.
- A comprehensive list of floodplain encroachment structures, facilities and opportunities to remove or set back these structures and facilities needs to mapped.
- A monitoring and assessment program of riparian buffers and impervious surface to allow tracking development patterns should be developed and implemented.
- A prioritized list of preservation and restoration opportunities needs to be developed.

4.4 White River Subbasin

The White River subbasin originates at the terminus of the Winthrop, Fryingpan and Emmons glaciers on the slopes of Mt. Rainier and drains an area of approximately 494 square miles (Williams, 1975). Flowing from its origin to the confluence with the Puyallup River it is approximately 68 miles in length. Early in this century the majority of the White River flow was naturally directed north into the Green and Duwamish Rivers. A small overflow channel called the Stuck River, flowed south from the vicinity of Auburn into the Puyallup River at Sumner. A rain on snow event triggered a flood on November 14, 1906 creating a debris dam in the White River and the entire flow was redirected into the Stuck River. The former White River channel into the Green River went dry as a part of this event (Chittenden, 1907). A permanent diversion wall was constructed at Auburn in 1915 and the White River remains a tributary of the Puyallup today.

The upper White River is inherently unstable as it cuts through a series of glacial and mudflow deposits. Given the relatively steep gradient and gravelly soils that the river cuts through there is a tremendous amount of sediment transported within this system annually. Sediment transport has been estimated to range from 440,000 to 1,400,000 tons annually with the majority of these sediments characterized as fine sediments that are transported out of the upper reaches and deposited into lower gradient reaches and Commencement Bay. Dunne (1986) estimated that the average annual sediment transport rate for the White River upstream of the U.S. Army Corps of Engineers project at Mud Mountain Dam to be 500,000 tons per year. In either case, this bedload is transported out of the high gradient reaches and deposited into the low gradient reaches resulting in aggradation and flooding problems in the river valley where development has encroached into the floodplain. Because of this flooding there have been numerous attempts to redirect and control the river.

The ICRI began efforts to control flooding in 1914. Early flood control tasks included: construction of a 1,600 foot long concrete diversion dam at RM 8.5 to prevent the return of the White River to its pre-1906 course; construction of a 2,000 foot barrier upstream of the dam at RM 11.5; and gravel removal. The later activity was an unsuccessful attempt to create a new channel in the Stuck River reach from Auburn to the Puyallup River. There have been unsuccessful attempts at several other channel modifications utilizing several methods over the years.

Currently this subbasin produces chinook, pink, chum, and coho salmon in addition to winter steelhead and cutthroat trout. Sockeye salmon adults are observed almost annually in this subbasin but there is some question to their ability to be naturally sustaining. There are no available data of genetic sampling comparing these sockeye within or outside of the Puyallup River basin. A distinct dolly vardon/bull trout population is identified in SaSI (WDFW 1998) in the upper White River.

While not biological in origin, one significant predicament that was identified within this drainage is the number of jurisdictions that have regulatory authority and responsibility. The White River has its origin on the slopes of Mt. Rainier, flows out of Mt. Rainier National Park through US Forest Service lands, and unincorporated King and Pierce Counties. The river then flows in proximity to Enumclaw and Buckley (both of which influence water quality through permitted sewage effluent discharges) through the Muckleshoot Indian Reservation, Auburn, Pacific, Sumner and finally joining the Puyallup River. For an effective management program, all jurisdictions must agree on a single course of action and provide effective regulatory policy.

Barriers: Barriers to adult and juvenile salmonid migration exist on the mainstem White River and numerous tributaries and are detailed in Table 2. Most of the tributary barriers are caused by poorly designed and/or constructed culverts and are total passage problems. Some are the result of low flows or represent partial barriers based upon water velocities.

Critical to the natural production of salmonids within this basin are two impassable dams that prevent salmon from reaching their natal spawning areas, prohibit the passage of LWD and disrupt the natural sediment transport process. Puget Sound Energy operates the Lake Tapps diversion dam at RM 24.3 and the U.S. Army Corps of Engineers operates a flood control dam (Mud Mountain Dam) at RM 29.6 (Williams 1975). Water from the Lake Tapps Diversion Dam is returned to the White River at RM 3.5. Returning adult salmon are trapped at the diversion dam (R.M. 24.3) and trucked upstream of Mud Mountain Dam impoundment where they are released back into the White River at RM 33.9. The operation of these two projects essentially eliminates 9.6 miles of mainstem spawning and rearing habitat. Tributaries accessible to anadromous fish are very limited in this reach of the White River. The diverted reach, between RM 3.5 and 24.3 has historically suffered from lack of even minimal low flow protection. Currently, a minimum low flow regime is present in that section of the river and is discussed in more detail below.

The Army Corps of Engineers Buckley Fish trap partially mitigates the adverse fish passage impacts of both dams to some degree. However, it is likely that this trap causes delays in upstream migration, along with additional stress of fish through handling, hauling and release. Numerous fish caught in this trap exhibit wounds characteristic of injuries sustained as the result of poor trap design and/or construction or false attraction problems associated with the tailrace outlet canal at the Dierenger powerhouse. These injuries can have an adversely affect the reproductive success of individual fish and thereby potentially reduce the fitness of the entire population should if fish sustain enough injuries. Adult fish are able to drop back through the Mud Mountain Dam project. Mud Mountain Dam also disrupts the natural delivery of sediments by impounding fine sediments during high flow and/or high load periods and discharging those same sediments for persistent and prolonged periods during lower river flows which increases localized deposition. The dam operators also actively remove large woody debris thus depriving downstream reaches of this material. The removal of this wood likely reduces the quantity and quality of salmonid habitat downstream of the dams in the White River.

The City of Tacoma's water Pipeline Number 1 crossing has long been identified as blocking or delaying anadromous fish. A fish ladder was installed but continues to injure adult migrating salmonids because of protruding rebar. The pipeline and fish ladder were scheduled to be replaced and removed during the summer of 1999 with a buried crossing that should be more fish friendly, including removal of all of the structures presently in the river. However, this project has been delayed for at least one year because of permitting difficulties.

Water Quality: Water quality within this subbasin is generally good to excellent with one notable exception. Currently, the discharges from the Buckley and Enumclaw sewage treatment plants indirectly cause the bypass reach of the White River to exceed water quality standards for pH The high pH values are caused by photosynthesis of attached preiphyton algae in this reach, which affects the carbonate cycle, which in turns causes increases in pH. The preiphyton algae is obtaining nutrients from, at a minimum of, three point sources, the Enumclaw, Buckley and Rainier School wastewater treatment plants and nonpoint sources. . To address the high pH listing a TMDL in the White River is under development.

The Section 303(d) 1996 list has the White River listed as exceeding water quality standards for coliform, pH and instream flow. The proposed 1998 list includes temperature. Additionally, the 1998 proposed list approximately 50 stream segments for lacking large woody debris in the Clearwater and Greenwater watersheds and in smaller tributaries to the White River in the same vicinity.

Cooperative studies conducted by the Muckleshoot Indian Tribe, US Forest Service, the Puyallup Tribe of Indians and the WDOE were initiated in 1995 and 1996 to address CWA 303(d) listings for temperature in the Greenwater and Clearwater Rivers (WDOE in progress). These studies showed Huckleberry Creek in compliance with the temperature criteria of 16.0 C. The Greenwater, Clearwater and White Rivers and some tributary streams were not in compliance. Additionally, based upon fine sediment ratings in the Washington Forest Practices Board (1997), spawning gravel fine sediment percentages in 1995 in Huckleberry Creek and the Clearwater River rated good. Samples taken in three reaches in 1993 in the Clearwater River had a fair rating. The difference in values between the 1993 and 1995 Clearwater samples indicates spatial and/or temporal variation in this parameter. In the Clearwater River, fine sediments have been observed in the channel margins and side channels. No samples have been taken from these locations. Fines had a fair rating for 1995 in the Greenwater River. Channel cross-section and scour monitor results in the Clearwater River during the 1995-96 incubation period indicated substantial channel instability and a high likelihood of redd loss and egg/alevin mortality for multiple sites.

The Weyerhaeuser Company and Muckleshoot Indian Tribe, as a part of watershed analysis for the Middle Fork White River and Clearwater WAU's have collected data on current characteristics of salmonid habitat within drainages of the mainstem White River, the lower Greenwater River and the Clearwater River (R. Malcom pers. comm. 1999). The analyses found that amounts of both LWD key pieces and holding pools were in the poor category according to the rating criteria adopted by the Washington Forest Practices Board (1997). Similar findings were reported in the US Forest Service focused watershed analysis for Road 70 in the Greenwater River (US Forest Service, 1996).

A temperature assessment completed in 1996 in support of the Middle White and Clearwater subwatershed analysis and water quality data needs examined more thoroughly the Clearwater, Greenwater and White River water temperatures (WDOE, in progress). This work found exceedences of the water temperature criterion on the following rivers and creeks: Clearwater, Greenwater, mainstem White River, Lyle, Milky, Brush and Camp Creeks. Camp Creek had only one day of exceedence. However, the extent of exceedences within the mainstem Clearwater (RM 2.7 to RM 4.3) was 65% of the days between July 15 to August 15. In the Greenwater River (RM 1.2), 71% of the days in the same recording period were in exceedence. In the mainstem White River at RM 43.4, exceedences of the water temperature criteria occurred 46% of the days.

In the Clearwater River during 1996 reach assessment found the temperature exceedences were the linked to the following factors: shade and riparian characteristics; channel width/depth ratio; warm water being delivered from upstream locations (tributary and mainstem); lack of topographic shade; and a south facing exposure (RM 4.3 only) (WDOE in progress).

WDOE also reports a number of discharge permit elements that had violations between the time frame of January 1998 and April 1999. It is unclear and beyond the scope of this report to determine what impacts these violations may have had to the short and long term fitness of salmonids rearing in the vicinity of the discharges.

Sediments: Private parties, as an attempt at flood control, conduct gravel removal operations in the mainstem White River. The removal of gravel limits recruitment to downstream reaches.

Nelson (1979) examined the amount of suspended sediments transported in the White River and bedload movement in order to determine the amount of sediment transported into the reservoir behind Mud Mountain Dam. During the two year study period from July 1974 through June 1976 he estimated that 40,000 and 50,000 tons of bedload were moved respectively. Additionally, he estimated that 430,000 tons of suspended sediment was transported into the reservoir during the first year and 1,400,000 tons during the second year. The 1975-76 water year was a much wetter year than the 1974-75 water year. So far, no research has been conducted of which we are aware to determine if the rate of gravel removal is equal, less, or greater than the rate of deposition in the channels downstream of Mud Mountain Dam.

Hydromodifications: The removal of gravel (dredging and entrainment behind Mud Mountain Dam) contributes to the creation of a simplified channel lined with unnaturally large substrate. The channel of larger gravels and cobbles, are generally unsuitable for salmonid life history stages. The historic removal of LWD through forest management land use practices, entrapment behind Mud Mountain Dam, and the active removal in the name of flood control further serves to starve the White River subbasin of necessary structural components to provide successful reproduction of salmonids. These activities serve to substantially limit the natural production of salmonids.

An important requirement for gravel removal is the Hydraulic Project Approval (HPA) permit process administered by WDFW. Since 1981, the locations of sediment removal by private parties have been recorded in the records of hydraulic project permits issued by the WDFW. Unfortunately, there are no historical data available to document the volumes of material removed. Starting in 1996, WDFW began to require permit holders maintain a log of the amount of material removed. Data for those three years exists in the WDFW hydraulic project permit files.

Historically, four independent lakes were present on a plateau above the White River. As a part of the Lake Tapps project, completed in 1911, they were merged and now form Lake Tapps, an artificially created water storage reservoir used for power generation. Flow from the White River is diverted at a diversion dam located near Buckley at RM 23.4 through Lake Tapps and discharged back into the White River at the Dieringer Powerhouse RM 3.5. Since the completion of the project, required minimum flows in the bypass reach have ranged 0 cfs to 130 cfs (1986 Muckleshoot Indian Tribe v. Puget Power) and are currently 130 cfs. Minimum flows within the bypass reach are still the subject of considerable disagreement between resource management agencies, Puget Sound Energy (the operator of the project), local government and local property owners on Lake Tapps.

Historically, the project has undergone several significant renovations over the course of its operational history. The operation of this project has had a number of adverse impacts to salmonids and their habitats within the bypass reach (Muckleshoot Indian Tribe 1996). Reduced maximum and minimum flows have altered the formation of key habitat features such as gravel bars, pools, etc. The 20 mile bypass reach has historically had insufficient minimum flows to adequately protect upstream migration, holding and spawning life stages and juvenile salmon rearing and transport.

The fish screens, at the point of diversion, for this project historically did not meet criteria to adequately protect juvenile and migrating adult salmonids. The screen design allowed juvenile salmonids and steelhead kelts (downstream migrating adults) to enter the diversion canal and Lake Tapps prior to being run through the turbines at the Dieringer powerhouse , which discharges into the White River. Construction of new fish screens that meet current criteria was completed in 1996. Currently these screens are undergoing fish passage testing in an effort to determine their effectiveness in excluding salmonids from the Lake Tapps project.

At the point where water from the Dierenger Powerhouse flows into the White River there are high velocity attraction flows that attract migrating adult salmonids into the discharge channel (Muckleshoot Indian Tribe 1996). This causes a delay in their natural upstream migration, a needless expenditure of energy and potential injury. The powerhouse also changes river elevations as turbines are turned on and off to meet power needs. These ramping rates strand juvenile and adult fish thereby exposing them to increases in predation. All of these operational issues pose significant limiting factors to the production of salmonids in the White River subbasin.

The construction and completion of Mud Mountain Dam by the U.S. Army Corps of Engineers in 1948 is also believed to have had significant negative impacts associated with juvenile passage (Muckleshoot Indian Tribe et al. 1996). Until 1995, juvenile salmonids were required to pass through tunnels in the dam that were up to 90 feet below the water surface elevation of the dam and difficult for outmigrating juvenile anadromous salmonids to locate (Muckleshoot Indian Tribe 1996). Additionally, the discharge pipe was designed in a manner that resulted in significant mortality of any juvenile fish that entered it through striking hard metal surfaces. Modifications were completed in 1995 to the reservoir operation and tunnels that should reduce juvenile mortality. The pool created behind the reservoir also delays outmigration of juvenile salmonids and eliminates nearly 3 miles of mainstem rearing habitat when high pool conditions exist. As outlined above, the operations also eliminate the recruitment of LWD to downstream reaches, which as a consequence are starved, of this material. Approximately 8,000 to 10,000 cords of wood are removed annually. While not all of this removed wood can be characterized as LWD, small wood also creates highly functional habitats and provides necessary nutrients to the river system.

Debris removal by private parties and municipalities in the White River is regulated by the Hydraulic Project Approval (HPA) permit process administered by WDFW. While these permits typically prohibit the removal of large woody debris from the wetted channel, it is still often removed from the stream channel outside the wetted area, thereby reducing the amount of LWD debris available for redistribution in the river during future flow events.

Anadromous fish passage barriers have been identified on the Weyerhaeuser (WEYCO) 6000 Road system and U.S. Forest Service (USFS) 7020 Road at Slide

Creek: on Pyramid Creek at the USFS 70 Road; Jensen Creek at the WEYCO 6000 Road; at Clay and Cyclone Creeks at the WEYCO 3700 Road and Highway 410 respectively.

Channelization: The White/Stuck River is channelized between levees along both banks from its' confluence with the Puyallup upstream to RM 8.5. These levees constrain lengthy channel reaches and impair the movement of both adult and juvenile fish to tributary off-channel refuge areas. These off-channel features are now evidenced by wetland areas located on the landward side of the levees. Levees and revetments within the Muckleshoot Indian Reservation have been allowed to breach naturally by the White River in an effort to restore natural river channel sinuosity in this reach.

There are several areas of the upper White River subbasin where localized flood control structures are present. In the Town of Greenwater, along both the White and Greenwater rivers King County and private revetments have disconnected the river from its floodplain tributaries and old side channels.

Portions of State Route (SR) 410 are located within the active floodplain of the White River. The main channel where SR 410 encroaches into the White River floodplain is very unstable with numerous overflow channels and cut off meanders. Similar stream reaches without highway encroachments are more stable. These encroachments by the road restrict channel migration, side channel development, and confine the channel, increasing stream energy down stream. This increased stream energy likely causes gravel scour, potentially impacting local anadromous salmonid spawning success.

Between 1956 and 1970, the width of the White River Channel in sections 31, 36 and 25 nearly doubled in size as the channel became more braided and gained additional gravel bars. It is believed that these changes were the direct result of timber harvest and riparian vegetation removal (USFS 1995). Currently, this river reach is restabilizing itself with small hardwood trees beginning to recolonize the river banks.

Riparian: Land use within the lower eight miles of the White River can be best characterized as predominantly mixed commercial/residential. The Muckleshoot Indian Reservation occupies most of the land along both banks of the river between RM 9 and 15.5, with some non-tribal residential parcels in this reach. Puget Sound Energy owns numerous parcels of land in the diverted reach of the river (RM 3.6 to 24.3). There is some residential development along Mud Mountain Dam Road. The upper White River subbasin, upstream of RM 27, is dominated by commercial and public forests. A large, mostly rock lined revetment was constructed in 1996 along much of the shoreline within Federation Forest, a state park, in order to prevent the river channel from migrating into previously cleared picnic areas. There are only a few remaining pristine stands of old growth timber located outside of Mt Rainier National Park but these contribute substantial volumes of LWD into reaches of the upper White River . This LWD does provide some benefit through flow regulation, sediment retention and structural habitat.

Historically, wildfires were the most important agent of disturbance to forested areas of the Puyallup Watershed and in particular the White River Basin. Nearly all of the White River Basin was consumed by wildfires in 1508 and 1701. A large portion of the basin was reburned in 1899. At areas along riparian zones, burning is less uniform and a mosaic of unburned and burned areas is typical

Land Use and Riparian Buffers: Land ownership in the 240,000 acre upper basin is divided among three major landowners (Upper White River Chinook TMDL Framework Team, 1998). Approximately 44% is owned by the U.S. Forest Service, 29% is National Park and 26% (68,000 acres) by Weyerhaeuser. A recent land exchange between Weyerhaeuser and the USFS is not included in these figures.

The lower White River subbasin contains nearly equal amounts of residential (23%), agricultural (24%) and vacant land (22%). Urbanized areas containing commercial and industrial land occupy about 10% of the subbasin. The population in 1989 was estimated at 15,900 and is expected to increase 28% to 20,300 by the year 2000 (Pierce County 1990).

The primary land use is commercial forest production. Intensive logging began in the 1940's and continues today.

Forest cover vegetation patterns within the upper White River Basin were characterized by the U.S. Forest Service (USFS), Mt. Baker Snoqualmie National Forest in 1995 (USFS 1995). In the study area, the USFS determined current (1993) successional forest stages without regard to series to be: less than 5% late seral; 62% mid seral; and 20% early seral. Historical ranges were 3 to 32 % for late seral, 8 to 97% for mid seral and 0 to 87% for early seral.

Current timber harvest regulations also reduce potential sources of LWD to the stream channel. Wood recruitment is a function of tree height, and can contribute wood to the channel from a horizontal distance equal to its height, or more if on a steep slope (Van Sickle and Gregory 1990; McDade et al. 1990). Since current regulations allow harvest within 25 feet of the channel, trees that could potentially recruit wood to the channel can be logged and removed from the recruitment process. Often, the largest trees are removed from the riparian areas, reducing sizes needed to remain stable in the channel and form pools, trap sediment, and reduce stream energy. Therefore, by limiting the quantity and size of wood recruited to the stream, regulations that allow harvest of trees that can potentially recruit wood to the channel can effectively limit the quantity and quality of salmon habitat.

Logging on unstable slopes without buffers will likely increase the rate of landslides from pre-management conditions (Krogstad et al. 1997). Until leave areas are effective at protecting unstable slopes and increasing the probability of landslides, current forest practice rules are also a limiting factor.

There are relatively few public roads in this portion of the basin and density can best be described as light. However, there are numerous private logging roads in the Clearwater (WEYCO 6000 Road), the Greenwater (USFS/WEYCO 70 Road system) and the West Fork White River (USFS/WEYCO road system) subbasins. The roads that adversely influence stream reaches include: SR 410 near the Town of Greenwater, portions of the Mather Highway (SR 410), the WEYCO 6000 road in the Clearwater subbasin; the WEYCO 3700 road in the upper White River subbasin; the WEYCO 6014 Road along Mineral Creek; the WEYCO 6015 Road system along Byron and Milky Creeks; portions of the USFS 70 Road in the Greenwater subbasin; the USFS 74 Road in the West Fork White River and its tributaries; and the USFS 73 Road system along both sides of Huckleberry Creek (Nauer, pers comm 1999).

Several bridges cause channel constrictions in this subbasin, the most notable being the SR 410 over the Greenwater River (RM 0.01) which constricts the river to approximately 1/3 of its normal channel width. The center pier of this bridge catches woody debris causing a debris jam and localized backwater flooding. Nearby landowners have constructed flood walls of large concrete (ecology) blocks in an attempt to prevent this backwater flooding.

Additional bridges that cause channel constriction include the USFS 74 Road over the White River, the WEYCO Bridge Camp bridge over the White River, the WEYCO 3700 Road bridge over the White River and the USFS 73 Road bridges over the White River and the West Fork White River. Several small bridges over Boise Creek result in channel constrictions. Lower in the subbasin the 284th Street bridge south of the King County fairgrounds that also causes significant channel constrictions.

Road densities in the upper White River watershed were calculated by the USFS (USFS 1995). The extent of impacts and sediment erosion rates are not known, but because soil types are highly erosive they are believed to be significant. Table 9 illustrates road densities in tributary subbasins to the upper White River watershed.

Several of these subbasins have experienced extensive raveling of cutbanks and fillslopes as well as removal of riparian vegetation. Sanding activities along SR 410 associated with winter snows are also believed to be a contribute excessive amounts of fine sediments to the White River

Mass wasting in the upper watershed does not appear to be a significant impact. While some localized impacts are significant, subbasin wide debris flows pose even greater impacts. Overall, approximately 4% of the subbasin within USFS ownership is categorized as being susceptible to deep seated landslides (USFS 1995).

Only limited sampling efforts and analysis have characterized spawning gravel composition in this subbasin. Spawning gravel in three streams was collected in 1993 and 1995 (Keown et al, 1998). The Watershed Analysis Resource Condition Index generally rated gravel quality samples collected in 1995 as good or fair. This was an improvement over samples collected in 1993 when 38 percent were rated poor.

Water Withdrawals: Surface water withdrawals in this subbasin are significant in that they reduce the amount of available salmonid rearing habitat and can cause upstream and downstream migration delays. One example of this type of problem is Surface Water Certificate 369-A. This surface water right was issued by the Department of Ecology to the City of Buckley for an instantaneous withdrawal rate of 2.0 cfs, but the City is limited as to how much water per year they may actually withdraw to no more than 706 acre-feet. This limitation is to all water rights they currently hold. To put this into perspective, if the diversion operates 24 hours a day, it would be possible for the Town of Buckley to take 1,451 acre-feet from the White River, which would clearly exceeds their current water rights.

Certificate 6109-A was originally issued to the Washington State Department of Institutions for the Rainier Custodial School. This certificate allocates diversion of up to 3.5 cfs for the purposes of irrigation of 200 acres and domestic supply to approximately 3,000 people. This right consists of 3.0 cfs for irrigation and 0.5 cfs for domestic supply. The water use is now split between the school, which uses the domestic part, and Washington State University that uses the irrigation portion for their experimental agriculture facility. Buckley and Rainier School share a common diversion point for the domestic water, and are limited to taking no more than 2.5 cfs at any one time. WSU has its own diversion point for the irrigation water and they can remove up to 3.0 cfs at any one time.

Nutrients: The amount and availability of salmon carcasses historically present in this subbasin is unknown. Data are so limited that there is even the lack of anecdotal information. However, it is assumed that populations were higher and carcasses more available. Due to the glacial origin of the White River, the lack of an adequate nutrient level is probably a significant limiting factor impacting production. . Salmon carcasses are an important source of nutrients to riparian vegetation and are also consumed by juvenile salmon. Some studies have indicated that salmon carcasses can provide significant amounts of the nitrogen in the vegetation and juvenile salmon biomass. The increased numbers of salmon carcasses have led to increased juvenile salmon biomass.

Key Findings - White River Subbasin

- Mud Mountain Dam and the Lake Tapps Hydroelectric Project adversely limit natural production of salmonids through several means.
- Mud Mountain Dam interrupts the recruitment of LWD and the natural sediment flow regime, and adversely impacts salmonid migration and production.
- Water quality may be impaired due to high sediment and turbidity loads in specific subbasins in the upper watershed.
- The Lake Tapps Hydroelectric Project significantly adversely impacts salmonid production through adverse attraction and lack of suitable low flow regimes in the bypass reach of the White River.
- Flood control practices have adversely impacted fish production throughout the basin. The removal of riparian vegetation, construction levees and revetments and removal of LWD posed significant adverse impacts on natural production of salmonids.
- Water quality parameters are exceeded in the vicinity of the White River because of sanitary sewage effluent from the cities of Buckley and Enumclaw.
- Data from the drainages studied in this subbasin on temperature, spawning gravels, large woody debris and holding pools indicates the chinook beneficial uses are currently poorly supported.
- There exist numerous barriers to adult and juvenile salmonids on tributary streams throughout this subbasin.

Data Gaps - White River Subbasin

- Additional data on presence and distribution anadromous salmonids and native char needs to be collected.
- Freshwater life history data needs to be collected, including spawning run timing of all species of naturally produced salmonids.
- Information about the marine life history of salmonids within the basin needs to be collected and analyzed.
- A sediment budget for the White River needs to be prepared.
- Existing flood control facilities and opportunities to restore floodplain and off-channel salmonid habitat restoration opportunities need to be identified and mapped.
- Development of baseline data on habitat utilization by salmonid species in the subbasin needs to be addressed for effective management of the watershed.

4.5 Upper Puyallup River Subbasin

The Upper Puyallup River Subbasin is a glacial fed system that originates from the Klapatche area on the southwest slopes of Mt. Rainier (Williams, 1975). For the purposes of this report the upper Puyallup River subbasin is that portion of the Puyallup River upstream of the Electron Powerhouse (RM 31.2) and outside of the majority of influence of anthropogenic effects including the extensive diking that impacts the lower Puyallup River subbasin.

The majority of this subbasin lies in a rain-on-snow zone between 1000 and 4000 feet in elevation. With a drainage basin of approximately 110,000 acres this subbasin is about five times larger than the lower Puyallup River subbasin. The 11 tributaries accessible for anadromous fish within this subbasin have the potential to produce chinook and coho salmon along with winter steelhead and cutthroat trout. This subbasin also provides habitat that may be best suited for spring chinook salmon. However, there currently are no identified runs of this race of chinook in the upper Puyallup River subbasin. There have been recent cooperative efforts by the Puyallup Tribe of Indians and Washington Department of Fish and Wildlife to reestablish a self-sustaining run of chinook and coho salmon in this subbasin. Adult coho are transported from the WDFW Orting Hatchery, released at a site upstream of the diversion dam, and allowed to spawn naturally. Winter steelhead production does occur in tributaries to the Puyallup River in the diversion reach. Adult steelhead migrate into this section because at the time of adult migration flows are sufficient. The production is almost entirely from three tributaries (Nieson, Kellogg and LeDout Creeks).

A distinct dolly varden/bull trout population is identified in SaSI (WDFW 1998) in the upper Puyallup River. Native char have been captured in both the mainstem Puyallup River and in Mowich Creek (D. Nauer 1999). The presence of native char in other tributaries is unknown at this time.

Barriers: Barriers to adult and juvenile salmonid migration exist on the mainstem Puyallup River and tributaries. These barriers are detailed in Table 2. Most of these barriers are caused by poorly designed and/or constructed culverts, debris jams caused by past land use practices and are total passage problems. Some are the result of low flows or represent partial barriers based upon water velocities.

One of the most defining features in this subbasin is the Electron Hydroelectric Project. Puget Sound Energy Corporation (formerly Puget Sound Power and Light) operates this project on the mainstem Puyallup River with a diversion dam at RM 41.8 and an associated powerhouse at RM 31.2. Initially constructed in 1904, the dam completely blocked anadromous salmonid access to 26 miles of mainstem river habitat and 10 miles of tributary streams above the dam. In addition, water diverted from the main channel bypasses and partially dewaters 10.5 miles of mainstem channel, impacting both upstream and downstream fish passage, rearing, and spawning habitats. A 1997 Resource Enhancement Agreement between Puget Sound Energy and the Puyallup Tribe of Indians will provide salmonid access above Electron dam, and for the first time established a minimum flow in the bypass reach. With the full implementation of the Resource Enhancement Agreement an additional 11.8 miles of mainstem and over 23 miles of tributary habitat will eventually reopen for colonization by anadromous salmonids.

Land Use: Land ownership in this subbasin is primarily private commercial timber companies and US Forest Service. The majority of the logging activity occurred in the 25-year period from the early 1950's through the late 1970's. Today, there is intensive logging activity on the private forestlands of 35 to 40 year old second growth forests.

Road construction has had a significant adverse impact in this subbasin. The 25 Road system is partially abandoned and was constructed inside the functional floodplain of the mainstem Puyallup River. Portions of the road washed out in the 1996 flood and are not scheduled to be replaced. Portions of the 25 Road have been responsible for debris flows, which effectively dammed the Puyallup River on two occasions in the last ten years (D. Nauer pers. comm., 1999). However, some impacts within the floodplain still exist. The 62 Road downstream and upstream from the Electron Diversion dam washed out in the flood events of 1995 and 1996. This road and associated bridge had served as a channel constriction and they are currently not scheduled to be rebuilt. Also in this area is the 7 Road system and associated bridge. This road was similarly damaged during the previously detailed flood events and the bridge was lost. This bridge (at Moose Junction) was replaced with an improved bridge sized more appropriately to span the river. The 24 Road system has been responsible for significant sediment inputs into Deer Creek and the Puyallup River.

Riparian and Large Woody Debris: The riparian habitat has been severely compromised through logging and associated road construction practices. Generally, the forest stage can be classified as plantation type consisting of Douglas fir and western hemlock. Hardwoods have opportunistically colonized the riparian zones throughout the subbasin.

The only source of LWD recruitment is from inside Mt. Rainier National Park. Because of high stream gradients and associated energy there is little opportunity for this LWD to key in to the mainstem Puyallup River or its tributaries. The vast majority is transported out of the reach and downstream through a canyon where high energy flows and large boulders tend to break this material into smaller less functional pieces.

Because of past forest practices there is little to no LWD recruitment from private commercial timberlands in this section. With compromised riparian habitat it is estimated that it will take approximately 100 years for timber to mature sufficiently to contribute substantial volumes of LWD. For LWD to again play a significant role in this subbasin there is the need for large amounts of this material to be contributed from numerous sources. With the high gradient streams and their associated energy, the limited amounts of LWD available will not provide the necessary habitat. The recruitment of large amounts of LWD from multiple sources is necessary to allow for the formation of LWD complexes and the resulting collection of suitable sized spawning gravels and pool/riffle sequences necessary for successful salmonid rearing.

Substrate: Substrate within the mainstem is typically cobble and boulders with limited areas of pocket gravels typically associated with mainstem river sidechannels, tributary streams on the river floodplain and wall base channels. With the lack of LWD available for recruiting spawning gravels in tributaries and mainstem reaches, these areas become disproportionally important to salmonids.

Most of the tributaries to the mainstem Puyallup River within this subbasin are high gradient streams that are inaccessible to anadromous salmonids. Accessible and potentially significant include Deer, Swift, and Mowich Creeks and Rushingwater River.

Most of the tributary streams have suffered much the same demise as the mainstem. On the south side of the Puyallup River there have been numerous debris flows and associated mass wasting. Deer Creek, a major anadromous bearing left bank tributary, has experienced two debris flows and damming events within recent times. It was reported that these debris jams contained old growth trees with root wads 80 feet in the air (D. Nauer pers. comm., 1999).

Water Quality: Because this area lies outside the influence of the urban and residential areas water quality is not impacted from those sources. A more critical influence on water quality is the sedimentation caused by road construction and maintenance activities associated with logging. The extent of these impacts is not known at this time but it can be surmised to pose localized, site specific adverse effects.

Key Findings - Upper Puyallup River Subbasin

- There has been only limited natural production of salmonids (primarily winter steelhead) from this subbasin for the last 85 years due to the blockage at the Electron Diversion Project.
- Numerous passage barriers exist on tributary streams.
- Due to dewatering effects, there has been only limited natural production in the 10 mile reach between the Electron Powerhouse and Dam. The vast majority of this production is winter steelhead which enter the reach during high flow conditions.
- Peak flows and bedload movement have been adversely compromised due to historical logging activities, road construction and maintenance.
- LWD is a limiting factor to the creation of suitable spawning and rearing habitats.
- Land use practices preclude the near term recruitment of LWD in sufficient amounts to provide high quality salmonid spawning and rearing habitats.

- Mass wasting and associated debris flows can be expected to continue posing a potential threat to downstream restoration efforts.

Data Gaps - Upper Puyallup River Subbasin

- A current inventory of riparian habitat conditions is necessary.
- Salmonid habitat utilization needs to be developed to guide future stock reintroduction efforts and/or to monitor natural recolonization of currently inaccessible or underutilized parts of the subbasin..
- An inventory of LWD and riparian habitats needs to be initiated and completed to guide future management actions. This inventory should occur as a part of a larger watershed analysis.
- Forest stage data needs to be developed.

4.6 Independent Tributaries to Puget Sound

One significant predicament associated with some portions of these drainages is the number of jurisdictions, which have regulatory authority and responsibility. As an example, Hylebos Creek originates in portions of King County and the City of Federal Way, enters Pierce County, flows through portions of Milton before entering the City of Fife and then flows into Hylebos Waterway located in Tacoma. Adding to this are two drainage districts (Districts 21 and 23) that also have jurisdiction in the lower Hylebos subbasin. In order for an effective management program to be successful, all jurisdictions must agree on a single course of action.

4.6.1 Lakota and Joes Creeks

These streams are discussed jointly because of their geographic proximity to each other and similar characteristics. Both streams originate from the upland plateau and plunge through steepwalled canyons prior to entering lower gradient reaches on the shores of Puget Sound. Their headwaters are in areas of high density development and experience typical problems associated with urbanization.

Impervious surfaces associated with single and multi-family residences are the primary contributors to high flows and large sediment loads in these creeks. Peak flows are believed to be exceed 150 percent over historical flows (Federal Way 1990). Because the land is largely built out, current peak flows in these creeks are likely to approximate future flows.

Salmonid utilization on the lower reaches of these creeks is poorly documented. The major limiting factors in these creeks include decreased pool volumes due to sediment aggradation and debris jams, the later also cause potential barriers to upstream migration. Both the decreased pool volumes and debris jams are a function of increased flows caused by the extensive development within these subbasins.

The riparian habitat along these creeks consists of a 200-500 foot wide corridor of second growth cedar, western hemlock and Douglas fir. Interspersed in this corridor are hardwoods typical of lowland western Washington stream systems. Trees up to 28 inches diameter are found throughout this corridor. This vegetation stabilizes the slopes that are up to 150 feet high with slopes in the range of 60 percent to 90 percent. The presence of relatively intact riparian corridors that have been severely and adversely impacted by stormwater is illustrative how riparian buffers are a necessary component of a healthy stream ecosystem.

The substrate within these creeks consists of pebble and cobble sized particles with localized sand depositions. Gravel deposits are very local and spawning opportunities are typically few. Again, these features are the result of flow alterations from undetained stormwater.

Both creeks flow directly into Dumas Bay and as such provide an important freshwater input into this area of Puget Sound. Dumas Bay has been characterized as a 253 acre intertidal sandflat habitat integral to the nearshore ecosystem in this part of Puget Sound. No data are available detailing juvenile or salmonid usage of this area. However, searun cutthroat trout have been observed being caught in Dumas Bay (J. Kerwin pers. observ.).

Dumas Bay has suffered the impact of residential development on its shores. Extensive shoreline protection measures and bank hardening along the northern shores has occurred over time. Confounding any impacts that this activity might have is the slope clearing activities to the immediate south and improper drainage techniques dumping rainwater over the bluffs edge. A wastewater treatment plant discharging up to 100 million gallons of secondary treated wastewater per day is located in the northeastern part of Dumas Bay.

Key Findings - Lakota and Joes Creeks

- Water quality, peak flows and instream habitat have been adversely compromised due to upland development
- Sediment deposition into Dumas bay is accelerating due to increases in peak flows of Lakota and Joes Creeks
- Nearshore habitat in Dumas Bay may also be adversely affected by shoreline armoring, slope vegetation clearing and the discharge from the wastewater treatment plant.

Data Gaps - Lakota and Joes Creeks

- Current site specific water quality data from sampling sites throughout the basin.
- Salmonid utilization information including current use by life history stage of both the freshwater and estuarine environments.
- Sediment data and associated budget needs development.
- A comprehensive survey of fish passage barriers and habitat inventory with associated preservation and restoration opportunities needs to be developed.

4.6.2 Hylebos Creek

The Hylebos Creek subbasin consists of approximately 18,361 acres and 25 miles of streams, 11 named lakes and numerous wetlands. Land use trends and growth can only be termed as extremely rapid. The population was estimated in 1980 to be 60,000 and 90,000 in 1990; the year 2020 it is expected to be 154,000 (Federal Way, 1990).

Historically, Hylebos Creek is believed to have been one of the most productive small stream systems in southern Puget Sound. Accounts of Puyallup Tribal elders and early European settlers indicate the system supported several thousand coho, and chum salmon plus perhaps hundreds of chinook salmon, steelhead and cutthroat trout. Spawning ground surveys and juvenile sampling efforts have found all of these fish present in the system in low numbers. Some spawning ground survey information from the late 1970's appears to have been lost. Surveys made by Puyallup Tribal biologists during that period do not appear in databases but adult chinook salmon were observed actively spawning on several occasions in the West Fork Hylebos Creek, and in reaches within Spring Valley (J. Kerwin pers. observation). SASSI (WDFW and WWITT, 1994) does not identify any unique stocks in Hylebos Creek. Today, the production of salmonids is vastly reduced and no quantitative escapement numbers are available.

Habitat within the Hylebos Creek subbasin can only be described as severely altered from its historical natural state. Residential development, erosion and frequent flooding threaten the creek. Portions of this subbasin have been channelized with an associated loss of riparian habitat. Specific problems identified include the permitted and unpermited destruction of wetlands, bogs and streams by land use practices and both observable (point) and unobservable (non-point) pollution. Efforts have been carried out by the City of Federal Way to address flooding issues in the upper reaches of the west fork of Hylebos Creek and its tributaries which through the construction of large stormwater detention facilities should also benefit fish habitat in the lower reaches.

Land use surveys from 1897 (USGS, 1897) described the Hylebos Creek basin as an area of merchantable forests interspersed with burned areas. It is unclear if the burned areas are natural in origin, or resulted from the practice by local tribes of controlled burning to maintain open prairies or part of early settlement areas being cleared for agricultural purposes. The likelihood is that the burned areas are a function of all three activities. However, the description is typical of the coniferous forests of lowland Puget Sound and natural processes associated with that type of forest cover.

Land Use and Surface Water Management: Recent growth in this area has been rapid and large tracts of historic habitat have been replaced with urban and industrial areas. The City of Federal Way is the largest municipality in this basin and is presently 96 percent built out (D.Wise 1999). This high density of development consists of single and multi family residential dwellings throughout the basin. Recent data that is available from this basin includes a 1987 land cover analysis (City of Federal Way 1990) indicating impervious surfaces of 19.1 percent and 11.0 percent in the west fork and east fork of Hylebos Creek respectively. 1991, Pierce County determined the range of impervious surface in Hylebos Creek to be from 2-53 percent (Pierce County 1991). Klein (1979) published the first study showing a decline in biological diversity attributed to impervious surfaces in excess of 10%. More recently, Booth et al (1997) analyzed impervious areas in this subbasin and found a range of 0.2 – 54 percent in impervious surface subcatchment areas. This former analysis was conducted prior to the recent large growth in the area while the later is indicative of the growth experienced within the basin. Readily observable degradation of aquatic systems and associated functions occurs when impervious surfaces approach a 10 percent threshold within a watershed (Booth, 1997). Additional investigations by May et al (1997) have further documented a threshold of 5% impervious surface for retaining high quality aquatic ecosystems for Puget Sound lowland streams.

Surface water management objectives generally incorporate only goals to convey surface water created by rain and snowfall out of the geographic area of concern. This is accomplished in a manner to prevent, or minimize, flood problems, eliminate existing problems and coordinate cross jurisdictional issues. The first objectives are to prevent or mitigate damages to existing and/or proposed structures. Relatively little consideration is afforded to aquatic species (e.g.: salmonids) when stormwater management systems are designed and constructed. The combination of the simplification of channel habitat and stormwater has decreased the spatial and temporal availability of low velocity habitat for overwintering juvenile salmon (Washington Department of Fish and Wildlife 1997a, 1997b) and emergent fry. Direct impacts to rearing juvenile salmon can occur at flows below those which cause flooding or form the channel (Washington Department of Fish and Wildlife 1997a, 1997b).

The flood flows experienced in this subbasin in January and November 1990 both approximated the flows expected in 100 year events under pre development conditions. With the development pattern in this subbasin, flows of this magnitude are expected to occur every eight to nine years (Pierce County 1990).

The City of Federal Way and King County have within the past ten years implemented an integrated program to control flood waters to 1986 levels on the west fork Hylebos Creek through the construction of four regional surface water retention ponds. King County, the City of Federal Way and WSDOT have developed plans to implement a regional watershed surface water control program on the East Fork Hylebos. Even with this effort, peak flows under 1987 land use had increased from 65 to 300 percent over the forested conditions known to exist prior to urbanization (City of Federal Way, 1990). While controlling peak flood flows and potentially assisting base flows excess levels of contaminants typical of urbanization still exist within both forks.

The construction of revetments and levees in this subbasin has eliminated connections with side- and off-channel aquatic habitats. Encroachment into the flood plain and stream channels of all three forks of the Hylebos has resulted in diminished water capacity and degradation of riparian habitats. The construction of the revetments and levees and their maintenance and their impacts has been discussed previously in this report.

There is an almost total absence of any functional LWD within this system. The few remaining functional pieces are quickly approaching their useful life span and function. The opportunities for natural replacement of these pieces is virtually absent as the basin has been completely urbanized.

Barriers: Barriers to anadromous fish migration are present in several areas within the basin. King County performed a reconnaissance level passage inventory assessment in the 1980's but a current inventory needs to be completed. A blockage on the East Fork Hylebos Creek at SR 161 prevents all upstream access to this creek and its tributaries for anadromous salmonids. An undersized culvert in the Spring Valley reach (the most productive salmon spawning and rearing area along the West Fork Hylebos Creek) is a partial barrier. A culvert under Highway 99 is a complete barrier to anadromous fish eliminating the utilization of upstream areas.

Water Quality: Past water quality monitoring efforts have provided incomplete water quality data. Nonpoint and point source pollution problems continue to affect water quality throughout the basin. A federal Superfund site, the B and L Landfill, was identified as a source of heavy metals in the lower reaches of Hylebos Creek. This site has since been capped and a monitoring program is in place. High levels of fecal coliform bacteria increase downstream in Hylebos Creek. This is indicative of failing septic systems and agricultural practices (grazing and stock management) in the Hylebos basin.

Hylebos Creek has been found to contain elevated levels of fecal coliform bacteria, suspended solids, heavy metals (copper, lead, zinc, and mercury) along with nitrogen and phosphorus (Pierce County 1991).

Historically, Hylebos Creek originated in wetlands in the vicinity of SeaTac Mall. Those wetlands have since been filled impacting both base flows and the ability of the creek to handle peak flows. The City of Federal Way completed a wetland and stream inventory in 1999 and King County a wetland inventory in 1986.

Key Findings - Hylebos Creek

- Hylebos Creek represents one the most heavily urbanized watersheds in the state.
- Extensive filling of wetlands, removal of historical forested areas and impervious surfaces have reduced base flows and increased peak flow volume and durations.
- Stormwater facilities utilize Hylebos Creek and its tributaries as conveyances for water removal out of the geographic area of concern.
- The elimination of native functional riparian habitat has occurred along most segments of Hylebos Creek.
- Water quality degradation from point and non-point sources continues to be a problem.
- Sediment problems will persist with increases in flows. The West Fork Hylebos Creek is intrinsically more stable than the East Fork Hylebos Creek to impacts from urbanization because of stream gradient, water diversions and hydraulic buffering.
- Over 90 percent of the estuarine habitat formerly associated with Hylebos Creek has been lost.
- Non-permitted filling of wetlands, lack of compliance and enforcement are all contributing to the remaining functional habitat degradation of this watershed.

Data Gaps – Hylebos Creek

- Current site specific water quality data from sampling sites throughout the basin.
- Salmonid escapement information including current habitat utilization by life history stage.
- LWD inventory needs completion and restoration sites identified.
- Sediment data and a sediment budget needs development.
- Baseline groundwater recharge data is lacking.
- Comprehensive survey of fish passage barriers needs completion and the barriers remedied.
- An industrial survey of businesses that generate wastewater, stormwater treatments and water treatment processes (including chemical management).
- Stormwater system maintenance and performance data.
- Saltwater influence on the lower reaches of the creek requires data collection.
- Mapping of existing floodplain and habitat restoration opportunities.
- A comprehensive basinwide stormwater management plan should be developed.

- Restoration opportunities need to be prioritized.

4.6.3 Dash Creek

Two streams (WRIA numbers 10.0392b and 10.0392c) enter Dash Point State Park and flow directly into Puget Sound.

Land use surveys from 1897 (USGS, 1900) described these creeks and their associated uplands as an area of merchantable forests interspersed with burned areas as previously described earlier in this report. It is presumed that these creeks historically originated in wetlands atop the bluffs which would have provided the base flows present in the creeks with overflow and surface water runoff down the ravines incised by these streams.

The lower reaches of these creeks flow through a broad, largely intact riparian corridor that consists of second growth conifers and hardwoods. Only limited access to salmonids is present with natural impassable barriers at RM 0.2 in tributary 10.0392a and RM 0.42 for tributary 10.0392b. Little data are available for functional woody debris for these creeks but a site survey on May 20, 1999 showed functional small and larger woody debris in tributary 10.00392b starting approximately at RM 0.25 and extending upstream to approximately RM 0.4. Tributary 10.0392a contains smaller amounts of LWD and both creeks could be described almost as exclusively glides in that they are almost devoid of pools.

Both creeks originate in a similar manner to that of Joes and Lakota Creeks with similar upland development patterns. Thus it is likely that both would be expected to experience similar water quantity and water quality problems to those detailed previously in Lakota and Joes Creeks.

Very few data are available regarding salmonid usage in these creeks. The Puyallup Tribe (R. Ladley pers comm. 1999) reports finding up to four different age classes of cutthroat trout in these creeks.

Key Findings - Dash Creek

- Water quality, peak flows and bedload movement have been adversely compromised due to upland development
- Cutthroat trout usage is unknown

Data Gaps - Dash Creek

- Current site specific water quality data from sampling sites
- Salmonid utilization information including current use by life history stage
- Sediment baseline data and a sediment budget needs to be developed.

4.6.4 Wapato Creek

Wapato Creek historically originated from a diffuse series of springs and seeps along the toe of the bluffs almost directly north of the town Puyallup. Wapato Creek meanders almost 14 miles through historical agricultural lands that are today being developed into a mixture of residential, commercial warehouse and light industrial areas. After crossing Interstate 5 the creek enters a heavy industrial area before emptying into the Blair Waterway.

Historically, Wapato Creek supported runs of chum and coho salmon, cutthroat and steelhead trout. A run of smelt was observed (B. Stereud pers comm. 1976) in a reach of Wapato Creek in the Fife area in 1976. Historic topographic features indicate it may also have served as an overflow channel to the Stuck River, particularly at times when the White River overflowed into the Stuck River prior to the White River's permanent diversion in 1906.

Riparian Habitat: Wapato Creek does not have a functioning riparian habitat for salmonids. The presence of a historical coniferous riparian buffer is almost non-existent having been replaced by reed-canary grass, manicured lawns and limited small woody vegetation throughout the creek channel. In its lowest reaches the creek is heavily channelized.

Water Withdrawal: Presently, there are allocated surface water rights of approximately 12 cubic feet per second (cfs) in Wapato Creek. Primarily used for irrigation, the greatest demand for this water is during the irrigation season that typically extends from May through September. Recently observed low stream flows of approximately two cfs occurring in August and September are substantially less than the water allocation. The creek is in danger of being dewatered in some sections should enough users attempt to exercise their water withdrawal rights simultaneously.

A water diversion at RM 11.7 diverts Wapato Creek into a collection pipe that actively removes all flow from the upper Wapato Creek channel into a stormwater bypass system that flows into the Puyallup River. The project was conceived to prevent flooding along Wapato Creek by diverting peak flows into the stormwater bypass system. The project operates in reverse of its intention. Under normal flows, the project diverts all the water of upper Wapato Creek into the bypass and only flood flows into lower Wapato Creek. This diversion has significantly contributed to the critical low flows within the subbasin in the last 20 years.

Water Quality: Water quality is a significant limiting factor throughout Wapato Creek downstream of Simmons Creek. Wapato Creek is on the approved 1996 EPA 303(d) list for fecal coliforms and dissolved oxygen. Because of the total lack of riparian vegetation and overallocated stream flows it is surprising that Wapato Creek has not been 303(d) listed for high temperatures.

Land Use: Land use within this watershed was historically typical of western Washington lowland valley floors. Seral forests of cedar, western hemlock and Douglas fir were predominant. Early settler reports describe a prairie near the mouth of Wapato Creek where it entered Commencement Bay. The lower Puyallup River valley was one of the first areas cleared for agricultural purposes and was in continuous agricultural use up until the late 1980's for truck crops, berry, flower and bulb production. Beginning in the late 1980's, agricultural lands began to be converted to warehouses, single and multiple family dwellings. Today, there is no remaining functional riparian habitat throughout Wapato Creek. The remaining salmonid production is located in Simmons Creek, a right bank tributary which still has marginal riparian habitat consisting of second growth conifers and hardwoods. However, land use activities in the headwater reaches of Simmons Creek continue to increase peak flows and destabilize sensitive spawning areas.

Key Findings - Wapato Creek

- Instream and riparian habitats along Wapato Creek have been crippled due to land use practices and water withdrawal. Salmonid production is extremely limited because of these impacts.
- Water allocations are in excess of base flows.
- The remaining agricultural lands are being converting to industrial warehouses, multiple and single family dwellings, thus precluding most restoration opportunities.

Data Gaps - Wapato Creek

- Current site specific water quality data needs to be collected and analyzed.
- Salmonid habitat utilization information including current use by life history stage needs to be collected.
- Flow data needs to be collected and analyzed for impacts to salmonids.
- Complete a comprehensive survey of fish passage barriers within Wapato Creek.
- A survey of businesses for wastewater generation, stormwater treatments and water treatment processes (including chemical management) needs to be conducted to more adequately characterize water quality problems.
- Stormwater system maintenance and performance data needs to be documented and corrected where determined to be inadequate.
- For salmon recovery to be effective over time it will be necessary to develop a comprehensive salmon recovery plan.

4.6.5 Puget and Day Island Creeks

These streams are discussed jointly because of their geographic proximity to each other and similar characteristics. Both streams originated from highly developed upland plateaus and plunge through steepwalled canyons prior to entering lower gradient reaches on the shores of Puget Sound. These origins in areas of high development cause them to experience many of the problems associated with that activity.

Impervious surfaces associated with businesses, single and multi-family residences are the primary contributors to high flows and large sediment loads in these creeks. No data on peak flows is available but large portions of their historical drainage basins are piped directly into Puget Sound. Because the land is largely built out, the peak flows these creeks currently experience are likely to approximate future flows.

There is no known current natural salmonid usage in either of these systems. Puget Creek has an impassable barrier immediately upstream of tidewater. Some work has been done in an attempt to re-establish chum salmon back into this system. The Puyallup Tribe has released juvenile chum and local schools have released coho fingerlings here.
There is no known water quality or quantity data available for either of these creeks.

Key Findings - Puget and Day Island Creeks

- Water quality, peak flows and bedload movement have been adversely compromised due to urban upland development.
- Barriers exist near the saltwater entrance of these creeks.

Data Gaps - Puget and Day Island Creeks

- Current site specific water quality data from sampling sites
- Current inventory of functioning riparian habitat
- Salmonid utilization information including current use by life history stage

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Glossary

Adaptive management: Monitoring or assessing the progress toward meeting objectives and incorporating what is learned into future management plans.

Adfluvial: Life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults. Compare fluvial.

Aggradation: The geologic process of filling and raising the level of the streambed or floodplain by deposition of material eroded and transported from other areas.

Anadromous fish: Species that are hatched in freshwater mature in saltwater, and return to freshwater to spawn.

Aquifer: Water-bearing rock formation or other subsurface layer.

Basin: The area of land that drains water, sediment and dissolved materials to a common point along a stream channel.

Basin flow: Portion of stream discharge derived from such natural storage sources as groundwater, large lakes, and swamps but does not include direct runoff or flow from stream regulation, water diversion, or other human activities.

Bioengineering: Combining structural, biological, and ecological concepts to construct living structures for erosion, sediment, or flood control.

Biological Diversity (biodiversity): Variety and variability among living organisms and the ecological complexes in which they occur; encompasses different ecosystems, species, and genes.

Biotic Integrity: Capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region; a system's ability to generate and maintain adaptive biotic elements through natural evolutionary processes.

Biological oxygen demand: Amount of dissolved oxygen required by decomposition of organic matter.

Braided stream: Stream that forms an interlacing network of branching and recombining channels separated by branch islands or channel bars.

Buffer: An area of intact vegetation maintained between human activities and a particular natural feature, such as a stream. The buffer reduces potential negative impacts by providing an area around the feature that is unaffected by this activity.

Carrying capacity: Maximum average number or biomass of organisms that can be sustained in a habitat over the long term. Usually refers to a particular species, but can be applied to more than one.

Channelization: Straightening the meanders of a river; often accompanied by placing riprap or concrete along banks to stabilize the system.

Channelized stream: A stream that has been straightened, runs through pipes or revetments, or is otherwise artificially altered from its natural, meandering course.

Check dams: Series of small dams placed in gullies or small streams in an effort to control erosion. Commonly built during the 1900s.

Confluence: Joining.

Connectivity: Unbroken linkages in a landscape, typified by streams and riparian areas.

Critical Stock: A stock of fish experiencing production levels that are so low that permanent damage to the stock is likely or has already occurred.

Depressed Stock: A stock of fish whose production is below expected levels based on available habitat and natural variations in survival levels, but above the level where permanent damage to the stock is likely.

Debris torrent: Rapid movements of material, including sediment and woody debris, within a stream channel. Debris torrents frequently begin as debris slides on adjacent hillslopes.

Degradation: The lowering of the streambed or widening of the stream channel by erosion. The breakdown and removal of soil, rock and organic debris.

Deposition: The settlement of material out of the water column and onto the streambed.

Diversity: Variation that occurs in plant and animal taxa (i.e., species composition), habitats, or ecosystems. See *species richness.*

Ecological restoration: Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.

Ecosystem: Biological community together with the chemical and physical environment with which it interacts.

Ecosystem management: Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.

Endangered Species Act: A 1973 Act of Congress that mandated that endangered and threatened species of fish, wildlife and plants be protected and restored.

Endangered Species: Means any species which is in endanger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta as determined by the Secretary to constitute a pest whose protection under would provide an overwhelming and overriding risk to man.

Escapement: Those fish that have survived all fisheries and will make up a spawning population.

Estuarine: A partly enclosed coastal body of water that has free connection to open sea, and within which seawater is measurably diluted by fresh river water.

Eutrophic: Water body rich in dissolved nutrients, photosynthetically productive, and often deficient in oxygen during warm periods. Compare *oligotrophic.*

Evolutionary Significant Unit (ESU): A definition of a species used by National Marine Fisheries Service (NMFS) in administering the Endangered Species Act. An ESU is a population (or group of populations) that is reproductively isolated from other conspecific population units, and (2) represents an important component in the evolutionary legacy of the species.

Extirpation: The elimination of a species from a particular local area.

Flood: An abrupt increase in water discharge.

Floodplain: Lowland areas that are periodically inundated by the lateral overflow of streams or rivers.

Flow regime: Characteristics of stream discharge over time. Natural flow regime is the regime that occurred historically.

Fluvial: Pertaining to streams or rivers; also, organisms that migrate between main rivers and tributaries. Compare *adfluvial*.

Gabion: Wire basket filled with stones, used to stabilize streambanks, control erosion, and divert stream flow.

Geomorphology: Study of the form and origins of surface features of the Earth.

Glides: Stream habitat having a slow, relatively shallow run of water with little or no surface turbulence.

Healthy Stock: A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

Hydrograph: Chart of water levels over time.

Hydrology: Study of the properties, distribution, and effects of water on the Earth's surface, subsurface, and atmosphere.

Intermittent stream: Stream that has interrupted flow or does not flow continuously. Compare *perennial stream*.

Intraspecific interactions: Interactions within a species.

Large Woody Debris (LWD): Large woody material that has fallen to the ground or into a stream. An important part of the structural diversity of streams. LWD is also referenced to as "coarse woody debris" (CWD). Either term usually refers to pieces at least 20 inches (51 cm) in diameter.

Limiting Factor: Single factor that limits a system or population from reaching its highest potential.

Macroinvertebrates: Invertebrates large enough to be seen with the naked eye (e.g., most aquatic insects, snails, and amphipods).

Mass failure: Movement of aggregates of soil, rock and vegetation down slope in response to gravity.

Native: Occurring naturally in a habitat or region; not introduced by humans.

Non-Point Source Pollution: Polluted runoff from sources that cannot be defined as discrete points, such as areas of timber harvesting, surface mining, agriculture, and livestock grazing.

Parr: Young trout or salmon actively feeding in freshwater; usually refers to young anadromous salmonids before they migrate to the sea. See *smolt*.

Plunge pool: Basin scoured out by vertically falling water.

Rain-on-snow events: The rapid melting of snow as a result of rainfall and warming ambient air temperatures. The combined effect of rainfall and snow melt can cause high overland stream flows resulting in severe hillslope and channel erosion.

Rearing habitat: Areas required for the successful survival to adulthood by young animals.

Recovery: The return of an ecosystem to a defined condition after a disturbance.

Redds Nests made in gravel (particularly by salmonids); consisting of a depression that is created and the covered.

Resident fish: Fish species that complete their entire life cycle in freshwater.

Riffle: Stream habitat having a broken or choppy surface (white water), moderate or swift current, and shallow depth.

Riparian: Type of wetland transition zone between aquatic habitats and upland areas. Typically, lush vegetation along a stream or river.

Riprap: Large rocks, broken concrete, or other structure used to stabilize streambanks and other slopes.

Rootwad: Exposed root system of an uprooted or washed-out tree.

SASSI: Salmon and Steelhead Stock Inventory.

SSHIAP: A salmon, steelhead, habitat inventory and assessment program directed by the Northwest Indian Fisheries Commission.

Salmonid: Fish of the family salmonidae, including salmon, trout chars, and bull trout.

Salmon: Includes all species of the family Salmonid

Sediment: Material carried in suspension by water, which will eventually settle to the bottom.

Sedimentation: The process of sediment being carried and deposited in water.

Side channel: A portion of an active channel that does not carry the bulk of stream flow. Side channels may carry water only during high flows, but are still considered part of the total active channel.

Sinuosity: Degree to which a stream channel curves or meanders laterally across the land surface.

Slope stability: The degree to which a slope resists the downward pull of gravity.

Smolt: Juvenile salmon migrating seaward; a young anadromous trout, salmon, or char undergoing physiological changes that will allow it to change from life in freshwater to life in the sea. The smolt state follows the parr state. See *parr*.

Stock: Group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish. More specifically, a local population – especially that of salmon, steelhead (rainbow trout), or other anadromous fish – that originates from specific watersheds as juveniles and generally returns to its birth streams to spawn as adults.

Stream order: A classification system for streams based on the number of tributaries it has. The smallest unbranched tributary in a watershed is designated order 1. A stream formed by the confluence of 2 order 1 streams is designated as order 2. A stream formed by the confluence of 2 order 2 streams is designated order 3, and so on.

Stream reach: Section of a stream between two points.

Stream types:

Type 1: All waters within their ordinary high-water mark as inventoried in "Shorelines of the State".

Type 2: All waters not classified as Type 1, with 20 feet or more between each bank's ordinary high water mark. Type 2 waters have high use and are important from a water quality standpoint for domestic water supplies, public recreation, or fish and wildlife uses.

Type 3: Waters that have 5 or more feet between each bank's ordinary high water mark, and which have a moderate to slight use and are more moderately important from a water quality standpoint for domestic use, public recreation and fish and wildlife habitat.

Type 4: Waters that have 2 or more feet between each bank's ordinary high water mark. Their significance lies in their influence on water quality of larger water types downstream. Type 4 streams may be perennial or intermittent.

Type 5: All other waters, in natural water courses, including streams with or without a well-defined channel, areas of perennial or intermittent seepage, and natural sinks. Drainage ways having a short period of spring runoff are also considered to be Type 5.

Sub Watershed: One of the smaller watersheds that combine to form a larger watershed.

Thalweg: Portion of a stream or river with deepest water and greatest flow.

Watershed: Entire area that contributes both surface and underground water to a particular lake or river.

Watershed rehabilitation: Used primarily to indicate improvement of watershed condition or certain habitats within the watershed. Compare *watershed restoration*.

Watershed restoration: Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.

Watershed-scale approach: Consideration of the entire watershed in a project or plan.

Weir: Device across a stream to divert fish into a trap or to raise the water level or divert its flow. Also a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.

Wild Stock: A stock that is sustained by natural spawning and rearing in the natural habitat regardless.