

**SALMON AND STEELHEAD HABITAT LIMITING FACTORS  
WATER RESOURCE INVENTORY AREAS 3 AND 4, THE SKAGIT  
AND SAMISH BASINS**

By Carol J. Smith, Ph.D.  
Washington State Conservation Commission  
Lacey, Washington

With a Contributing Chapter by Devin Smith (Skagit System Cooperative) and Tyson  
Waldo (Northwest Indian Fisheries Commission)



## Acknowledgements

This report was developed by the WRIAs 3 and 4 Technical Advisory Group for Habitat Limiting Factors. This project would not have been possible without their vast expertise and willingness to contribute. The following participants in this project are gratefully thanked and include:

Eric Beamer, Skagit System Cooperative  
Karen Chang, U.S. Forest Service  
Brady Green, U.S. Forest Service  
Steve Hinton, Skagit System Cooperative  
Julie Klacan, WDFW  
Jeff McGowan, Skagit County  
Roger Nichols, U.S. Forest Service  
Ben Perkowski, Skagit Watershed Council  
Tom Slocum, Skagit Conservation District  
Dr. Carol Smith, WA Conservation Commission  
Devin Smith, Skagit System Cooperative  
Tyson Waldo, NWIFC SSHIAP  
Bob Warinner, WDFW  
Stan Zyskowski, National Park Service

A special thanks to Ron McFarlane (NWIFC), Tyson Waldo (NWIFC, SSHIAP), Josh Greenberg (Skagit County) and Andrea Nouffke (SSC) for mapping, to Rod Sakrison (DOE) for providing reports, and to Devin Smith (SSC) and Tyson Waldo (NWIFC, SSHIAP) for writing the Fish Access Chapter. I also extend appreciation to Devin Smith (SSC) and Kurt Fresh (NMFS) for compiling and developing the habitat rating standards, to Ed Manary for writing the “Habitat Limiting Factors Background”, and to Tim Beechie and Blake Feist (NMFS) for their sediment supply analysis. Also appreciated are the Stock Chapter reviews from Bob Hayman (SSC), Pete Castle (WDFW), and Ann Blakley (WDFW).



# EXECUTIVE SUMMARY

## Introduction

In the last few decades, many salmonid populations in Washington State have declined, leading to the inclusion of bull trout and Puget Sound chinook salmon on the Endangered Species List. In response, the Washington State Legislature passed several bills to address the problem in a logical, concerted manner. Two key pieces of legislation (Engrossed Substitute House Bill 2496 and Second Engrossed Second Substitute Senate Bill 5596, now 77RCW) initiated the process towards the development of “Habitat Limiting Factors” reports.

This report is the habitat limiting factors report for WRIAs 3 and 4, the Skagit and Samish Basins. It provides a consolidation of existing habitat information in a statewide consistent format, and rates various categories of habitat conditions. The habitat categories include fish habitat access, floodplain, sediment, streambed, riparian, water quality, flow, estuarine and nearshore conditions. Each of those conditions are rated as either “poor”, “fair”, “good”, or “data gap”, based upon a set of standards that are described in the Assessment Chapter. This Executive Summary presents only an overview of the worst habitat problems, but all the habitat ratings are provided in Tables 4 and 5 in the Assessment Chapter. More importantly, detailed discussions for each of these habitat conditions can be found within the Habitat Limiting Factors Chapter of this report. Maps of updated salmonid distribution, floodplain, and nearshore conditions are located in a separate electronic file on this disc.

The streams addressed in this report include all anadromous salmonid-producing streams and sloughs from Colony Creek in the north to the boundary with WRIA 5 in the south. The non-anadromous reaches of the basins are not included. Nearshore conditions include the shorelines in WRIA 3, the northeastern shoreline of Whidbey Island, and the northern shore of Camano Island, to fully encompass Skagit Bay.

## Habitat Conditions in the Skagit Basin

### Introduction

Of all the drainages in Puget Sound, the Skagit is the largest and produces the greatest abundance of salmonids and the greatest number of salmonid stocks. It produces the most abundant chum and pink salmon populations in the contiguous United States, and the largest char population in Puget Sound and possibly the State (Beamer et al. 2000; City of Seattle 2001). The Skagit is also the origin of the most abundant wild chinook salmon populations in Puget Sound.

The salmonid habitat conditions in WRIAs 3 and 4 are related to land use. For example, the greater the percentage of state or private land contained within a WAU, the higher the road density (see Sediment Chapter). Road density is often a major indicator of sedimentation and fish blockage impacts, and contributes to hydrologic changes. Because of the link between land use and habitat degradations, it is not surprising that

many of the major habitat impacts are located in areas where agriculture, urbanization, and private/state forestry predominates. These include the estuaries, the lower Skagit sub-basin, and the Samish Basin.

### Habitat Conditions in the Nearshore Environment

The nearshore environment is the interface between marine and terrestrial habitats, and extends from the outer limit of the photic zone to coastal landforms such as bluffs, sand spits, and coastal wetlands, including the riparian zone on or adjacent to any of these areas. Compared to estuarine and freshwater habitat, less is known about how alterations to the nearshore environments impact salmonids, resulting in less certainty regarding the benefit and certainty of restoration efforts. In this report, nearshore habitat conditions are rated for a variety of parameters, but the most important locations for restoration and potential benefit of restoration efforts are not well known for many of these conditions. However, protection of currently good nearshore habitat should be a priority.

Shoreline modifications (dikes, riprap, etc.) are one of the greatest nearshore impacts in WRIA 3, and “poor” rated areas include the shorelines along east Skagit Bay, Swinomish Channel, Padilla Bay, and north Fidalgo Island. These impacts can disrupt sediment and nutrient transport processes, although no information exists to determine which areas are important for these processes in WRIA 3. Coincident with shoreline hardening is lack of riparian vegetation that could provide shade for forage fish spawning areas.

Most of the other parameters rated “good” or “fair” for nearshore conditions in WRIA 3 with a few exceptions. Contaminated sediments are a problem in Padilla Bay, Fidalgo Bay, and Guemes Channel, though overall, sediment quality is much better in the WRIA 3 nearshore environment compared to many other areas in Puget Sound (Long et al. 1999). A few areas rated “poor” for overwater structures (boat ramps, piers, slips, etc.), which are a concern for shading eelgrass habitat and altering fish behavior. The two major overwater sites in WRIA 3 are along the Swinomish Channel and north Fidalgo Island.

### Habitat Conditions in the WRIA 3 Estuaries

The estuarine deltas in this report are the bodies of water adjacent to freshwater systems where saltwater mixes with freshwater. The estuary deltas in WRIA 3 include the Samish, east Padilla, Swinomish Channel, North and South Fork Skagit, central Skagit and Douglas Slough deltas.

The loss (72%) of intertidal habitat in the Skagit delta (including the nearby sloughs) has been considerable and is of particular importance to chinook salmon (Beamer et al. 2002a). Dikes have isolated much of the historic delta habitat, and fish-blocking tidegates associated with the dikes are numerous. While many of the tidegates do not allow salmon access, they also prevent adequate tidal flushing. Further impacts to the isolated delta habitat, such as ditching, channelization, filling, riparian loss, and loss of habitat complexity have highly degraded the isolated habitat.

The loss and degradation of Skagit estuarine habitat is one of the most important habitat issues for salmonids in the Skagit Basin, and because the Skagit produces the most salmonids and salmonid stocks in Puget Sound, restoration of the Skagit delta habitat and preservation/restoration of nearby non-natal pocket estuarine habitat should be a high priority not just for the basin, but for Washington State.

#### Habitat Conditions in the Lower Skagit Sub-Basin

The lower Skagit sub-basin (all streams downstream of the Sauk River confluence except for the Baker River) contains the most highly degraded freshwater salmonid habitat in the Skagit Basin with considerable impacts in every habitat category. Floodplain habitat is an essential type of habitat for salmonid production in the Skagit Basin, and is of particular importance to coho salmon. While the lower Skagit River has the most extensive floodplain area in the two WRIAs at an estimated 108 square miles, degradations have been abundant, especially from dikes and riprap. An estimated 62% of the Skagit River channel length from Sedro Woolley to the mouth has been hydromodified, and only 10% of this length has split channels or island habitat (Duke Engineering 1999; Beamer et al. 2000). An extensive loss of wetland habitat is likely when comparing current known wetlands to hydric soils maps. Road density in the lower Skagit floodplain is excessive at 3.3 mi/mi<sup>2</sup> indicating a high level of development in a crucial type of salmonid habitat.

Water quality within the lower Skagit River has been degraded by various types of development. Elevated levels of nutrients and chronic levels of lead and copper have been documented in the lower mainstem Skagit River. These are presumably from urban and highway runoff, wastewater treatment, failing septic systems, and agriculture/livestock impacts.

Water quality in the tributaries to the lower Skagit River is worse than the mainstem Skagit River and all other Skagit sub-basins. Most of the lower Skagit tributaries have very warm water temperatures in the summer months. These include reaches in the Nookachamps, Hansen, Coal, Wiseman, Morgan, Sorensen, Mannser, Red Cabin, Day, Cumberland, lower Finney, Grandy, and Jackman Creeks and in Gages and Hart Sloughs. The Nookachamps watershed has numerous other types of water quality problems as well, including elevated nutrients, low dissolved oxygen levels, and increased turbidity. Nookachamps sediment sampling has indicated five potentially toxic organic compounds and levels of lead, copper, and zinc above criteria.

Many of the same watersheds that have warm water temperatures also have riparian and sediment impacts, and these are likely contributors to at least part of the water quality problems in the lower Skagit tributaries. Watersheds with predominantly “poor” riparian conditions include the Nookachamps, Hansen, Jackman, Grandy, Alder, Gilligan, Loretta, Finney, Day, Cumberland, Marietta, and lower Pressentin drainages. “Good” riparian conditions are found along upper Pressentin Creek.

Excess sedimentation has been estimated for the Miller, Alder, Day, Grandy, Nookachamps, Hansen, Finney, Loretta, and Gilligan WAUs (Beechie and Feist, NMFS,

unpublished data). Very few drainages within the Skagit have been thoroughly assessed for sedimentation causes, and of those that have, landslides are the major sources; many associated with clearcuts and roads. A lack of large woody debris (LWD) and pool habitat has been noted in those areas that have been assessed, but in general, data are lacking for sediment sources and instream conditions such as LWD, pool habitat, and sediment quality.

Most of the lower Skagit tributary watersheds are also impaired for flow conditions based upon land cover analysis. Impaired or moderately impaired drainages include the lower Skagit River, Gages Slough, and Nookachamps, Hansen, Gilligan, Day, Alder, Grandy, and Finney Creeks (Beamer et al. 2000). Likely impairments were noted in the Loretta and Jackman WAUs and functioning conditions in the Presentin WAU. No information regarding low flow impacts or conditions was found. This should be a high priority data need in the lower Skagit tributaries because of the warm water temperatures and significant level of urban, agriculture, and residential development.

Fish access conditions (culverts, small dams, etc.) have been inventoried and prioritized via remote methods to guide future field assessments. Many high and medium priority blockages exist in the Carpenter, Nookachamps, and Hansen Creek watersheds.

#### Habitat Conditions in the Upper Skagit Sub-Basin

Much of the upper Skagit sub-basin (streams upstream of the Sauk River confluence) is within National Forest boundaries or protected in the National Park, a national recreation area, or a designated wilderness area. Because of this, habitat conditions are generally good. Known impacts include a fairly high road density (2.9 mi/mi<sup>2</sup>) in the upper Skagit River floodplain and “poor” riparian conditions in the Corkindale WAU, along the mainstem Skagit River, and in lower Jordan, Shoemaker, and lower Boulder Creeks. Excess sedimentation has been documented in Jordan and Boulder Creeks with a loss of habitat complexity in Jordan, Shoemaker, Razorback, and Lookout Creeks. All other areas rated “good” for riparian and sediment conditions, and no known water quality problems have been documented in this area.

The single largest type of habitat transformation in the upper Skagit sub-basin is the dams and associated hydroelectric and flood storage activities, which are located upstream of historic anadromous salmonid use. The Seattle City Light operations have evolved to protect downstream fish resources to a great degree through agreements for appropriate ramping rates and flows. Flood storage may also have aided salmonid survival in the short-term. However, the magnitude of peak flows by return period has decreased by 50%, and this has likely impacted the development of side channels (Beamer et al. 2000). The dams have also possibly impaired sediment and LWD transport. These issues are being addressed as much as possible through restoration efforts such as off-channel habitat enhancement.

### Habitat Conditions in the Sauk Sub-Basin

The Sauk River is the largest tributary to the Skagit, and much of the drainage is within National Forest boundaries. Many of the known impacts to salmonid habitat are in the areas that are predominantly private or state owned. These include the Rinker, Sauk Prairie, and part of the Hilt WAUs, all which have high road densities. “Poor” riparian conditions comprise the majority of the Sauk Prairie WAU with less but still considerable impacts in the Rinker WAU. In addition, the Dan Creek WAU has a low component of conifer in its riparian reaches. Excess sedimentation has been estimated for the Rinker, Dan, and Sauk Prairie WAUs, while all other areas in the Sauk sub-basin rated “good” for sediment supply. Reduced pool habitat and LWD has been noted in the some of the areas that have been sampled, but instream data are lacking for many of the Sauk River tributaries.

There is also a lack of water quality data for the Sauk River and its tributaries, and because spot checks indicated a possible increase in water temperatures from the 1980s to the 1990s, water quality monitoring is recommended for this drainage. Water quantity (peak flows) is a concern in the land cover-impaired WAUs, and these include Hilt, Rinker, Sauk Prairie, and Dan. Human water consumption is low in the Sauk sub-basin, and is not a likely threat to fish habitat at this time.

### Habitat Conditions in the Baker Sub-Basin

The greatest impact to salmonid habitat in the Baker River sub-basin is the activity associated with the dams and hydroelectric operations. In the recent past, flow and downramp agreements have not been met. In the water year of 1996, 93 instances of inadequate flows and fast downramps have been noted. In 2000, a large impact to salmon nests occurred when areas of the Baker and Skagit River were dewatered as flow was shut off for routine maintenance (Brulle 2002). Continued efforts to amend these problems are occurring.

The dams have also directly altered anadromous salmonid habitat in the Baker sub-basin. An estimated loss of 117 acres of wetlands and ponds, 5 miles of side-channel habitat, and 52 miles of tributaries has resulted from the creation of the reservoirs (U.S. Forest Service 2002). The dams and operations have also impacted sedimentation and riparian vegetation.

The Baker tributary habitat is generally good with a few exceptions. Although the number of landslides is low, many are associated with roads, and those have increased sediment delivery to streams by 21 fold in the Baker Lake drainage and 150 fold in the Lake Shannon drainage (U.S. Forest Service 2002). High road densities exist in Morovitz, lower Sulphur, and Little Sandy Creeks. Overall, the Shannon West WAU is rated “poor” for excess sedimentation, while the other three WAUs are rated “good”. The Shannon West WAU is the only WAU in the sub-basin that is mostly under private land ownership.

Riparian vegetation is either generally “good” or “fair” in the Baker sub-basin, and water quality conditions are mostly “good” with the exception of warm water temperatures in Bear Creek.

### **Habitat Conditions in the Samish River Basin**

The Samish River is well known for coho production with low gradients throughout much of its mainstem and its largest tributary, Friday Creek. However, most of the land is under private ownership, and salmonid habitat impacts are abundant. Much of the lower Samish River is diked, resulting in a loss of estuarine and freshwater habitat. The floodplain loss is generally an important impact to coho salmon, but the loss in the Samish has not been quantified or assessed.

Both the Samish and the Friday Creek WAUs have generally “poor” riparian conditions due to conversion to non-forest land uses. Water quality is “poor” too, with warm water temperatures, increased nitrogen, phosphorus, and turbidity throughout the Samish River. Warm water temperatures have also been documented in several tributaries, including Friday, Thomas, Swede, and Skarrup Creeks. The likely causes of the water quality problems include loss of riparian, sedimentation, hydrologic alterations (wetland losses), and inputs from agriculture and failing septic systems. However, these need to be assessed to provide definitive causes for restoration actions.

The overall sediment supply rates are estimated as high for both the Samish and Friday Creek WAUs. Road densities are high in Friday Creek and moderately high in the Samish WAU. No data regarding instream conditions such as pool habitat, LWD, and sediment quality were found.

### **Conclusions**

This report consolidates and rates salmonid habitat conditions from the freshwater to nearshore environments, and presents a list of action recommendations and data needs. It is one step in a coordinated effort towards salmonid recovery, providing the technical background that can aid in the development of restoration/protection projects, recovery strategy development, and project ranking. As conditions change over time, it is hoped that new information will be used to modify future versions of this analysis.

The most degraded areas are found in the lower Skagit sub-basin, the sloughs draining into Skagit and Padilla Bay, and the Samish Basin. All of these areas have extensive impacts to estuarine, floodplain, riparian, sediment, water quality, and land cover conditions. The impacts to estuarine and floodplain conditions are similar and include diking, ditching, draining, and filling. The loss of forested riparian vegetation and increased sedimentation are common in the tributaries to the lower Skagit River and all of the Samish Basin. The sloughs draining into Skagit and Padilla Bays have also experienced a loss of riparian vegetation and loss of habitat complexity in addition to floodplain and estuarine impacts.

Salmonid habitat in the upper Skagit, Sauk, and in the Baker River tributaries is generally good with a few exceptions. However, hydroelectric operations associated with the

Baker River dams have resulted in significant impacts to salmonids and is one of the greatest problems in the Baker River and nearby segments of the Skagit River.

## TABLE OF CONTENTS

### SALMON AND STEELHEAD HABITAT LIMITING FACTORS WATER RESOURCE INVENTORY AREAS 3 AND 4, THE SKAGIT AND SAMISH BASINS 1

EXECUTIVE SUMMARY .....	3
Introduction.....	3
Habitat Conditions in the Skagit Basin.....	3
Introduction.....	3
Habitat Conditions in the Nearshore Environment.....	4
Habitat Conditions in the WRIA 3 Estuaries.....	4
Habitat Conditions in the Lower Skagit Sub-Basin.....	5
Habitat Conditions in the Upper Skagit Sub-Basin .....	6
Habitat Conditions in the Sauk Sub-Basin .....	7
Habitat Conditions in the Baker Sub-Basin.....	7
Habitat Conditions in the Samish River Basin .....	8
Conclusions.....	8
Table of Contents.....	10
List of Figures.....	15
List of Tables .....	19
LIST OF MAPS (In separate files).....	20
INTRODUCTION .....	21
Habitat Limiting Factors Background .....	21
The Relative Role Of Habitat In Healthy Populations Of Natural Spawning Salmon .	22
Introduction to Habitat Impacts .....	28
Salmonid Populations and Status in the Skagit and Samish Basins .....	29
Introduction.....	29

Salmonid Populations in the Skagit Basin .....	29
Salmonid Populations in the Samish Basin .....	37
WATERSHED Description and Condition for streams in WRIAs 3 AND 4.....	41
Introduction.....	41
Watershed Description and Land Use in the Skagit Basin .....	44
Upper Skagit Sub-Basin.....	44
Lower Skagit Sub-Basin .....	46
Sauk River Sub-Basin.....	48
Baker River Sub-Basin .....	51
Watershed Description and Land Use in the Samish Basin and Edison Slough .....	51
Watershed Description and Land Use along the Estuarine and Near Shore Environments of WRIA 3 .....	52
Fish Access Conditions in WRIAs 3 and 4: GIS-based Assessment of Salmonid Habitat Upstream of Fish Passage Barriers in the Skagit and Samish River Basins ....	55
Introduction.....	55
Habitat Type.....	55
Methods.....	56
Scale/Format .....	56
Floodplain Conditions in the Skagit Basin .....	63
Floodplain Function and Types of Impacts .....	63
Floodplain Habitat in the Lower Skagit Sub-Basin .....	64
Lower Skagit Floodplain Habitat Conclusions.....	69
Floodplain Habitat in the Upper Skagit Sub-Basin.....	75
Floodplain Habitat in the Baker Lake Sub-Basin .....	79
Floodplain Habitat in the Sauk Sub-Basin.....	79
Conclusions and Data Needs for the Skagit Basin Floodplain .....	82

Floodplain Conditions in the Samish Basin and Edison Slough.....	82
Conclusions for Floodplain Conditions in the Samish Basin .....	83
Streambed and Sediment Conditions in WRIAs 3 and 4.....	87
Introduction.....	87
Streambed and Sediment Conditions in the Lower Skagit Sub-Basin.....	89
Streambed and Sediment Conditions in the Upper Skagit Sub-Basin .....	92
Streambed and Sediment Conditions in the Sauk Sub-Basin .....	94
Streambed and Sediment Conditions in the Baker River Sub-Basin.....	97
Streambed and Sediment Conditions in the Samish Sub-Basin.....	99
Riparian Conditions in the Skagit Basin.....	101
Introduction.....	101
Riparian Conditions in the Lower Skagit Sub-Basin.....	101
Riparian Conditions in the Upper Skagit Sub-Basin .....	105
Riparian Conditions in the Baker River Sub-Basin .....	108
Riparian Conditions in the Sauk River Sub-Basin.....	110
Riparian Conditions in the Samish Basin .....	113
Conclusions.....	114
Introduction.....	116
Water Quality Conditions in the Lower Skagit Sub-Basin.....	116
Stream Segment .....	119
Water Quality Conditions in the Upper Skagit Sub-Basin .....	126
Water Quality Conditions in the Sauk River Sub-Basin.....	126
Sampling Date.....	127
Water Quality Conditions in the Baker River Sub-Basin.....	127
Water Quality Conditions in the Samish River Sub-Basin.....	128

Water Quantity Conditions in the Lower Skagit Sub-Basin.....	132
Water Quantity Conditions in the Upper Skagit Sub-Basin .....	134
Water Quantity Conditions in the Sauk Sub-Basin.....	135
Water Quantity Conditions in the Baker Sub-Basin.....	135
Water Quantity conditions in the Samish Sub-Basin.....	136
The Condition of Estuarine and Nearshore Habitat in WRIA 3 .....	137
Estuarine Delta Habitat and Function in WRIA 3 .....	137
Nearshore Habitat and Function in WRIA 3.....	138
Types of Estuarine Habitat Impacts and Existing Impact Data .....	139
Estuarine Habitat Conditions in the South Fork and North Fork Skagit Deltas and Skagit Bay.....	142
Estuarine Habitat Conditions in Douglas Slough and the Central Skagit Sloughs.	150
Estuarine Habitat Conditions along Northeast Whidbey Island .....	151
Estuarine Habitat Conditions in the Swinomish Channel.....	154
Estuarine Habitat Conditions in Padilla Bay .....	154
Habitat Conditions in the Padilla Bay Sloughs.....	157
Estuarine Habitat Conditions along North Fidalgo Island .....	159
Estuarine Habitat Conditions along South and West Fidalgo Island.....	161
Estuarine Habitat Conditions in Samish Bay, and Edison Slough.....	161
Habitat Conditions in Colony Creek.....	163
Estuarine Habitat Conditions along Sinclair, Vendovi, Cypress, Guemes, Burrows, and Allen Islands.....	164
WRIA Wide Habitat Concerns .....	164
Biological Processes Associated with the Estuarine and Nearshore Areas of WRIA 3 .....	165
WRIA 3 Estuarine and Nearshore Conclusions.....	167

ASSESSMENT OF HABITAT LIMITING FACTORS .....	169
Recommendations and data needs for WRIAs 3 and 4 habitat limiting factors.....	187
Introduction.....	187
Salmonid Access Conditions .....	187
Action Recommendations for Salmonid Access Conditions .....	187
Data Needs for Salmonid Access conditions.....	187
Floodplain Conditions.....	187
Action Recommendations for Floodplain Conditions .....	187
Data Needs for Floodplain Conditions .....	188
Streambed and Sediment Conditions.....	188
Action Recommendations for Streambed and Sediment Conditions.....	188
Data Needs for Streambed and Sediment Conditions.....	189
Riparian Conditions .....	189
Action Recommendations for Riparian Conditions.....	189
Data Needs for Riparian Conditions.....	189
Water Quality Conditions .....	190
Action Recommendations for Water Quality Conditions.....	190
Data Needs for Water Quality Conditions.....	190
Water Quantity Conditions in the Skagit Basin.....	190
Action Recommendations for Water Quantity Conditions.....	190
Data Needs for Water Quantity Conditions.....	191
Estuarine and Nearshore Conditions.....	191
Action Recommendations for Estuarine and Nearshore Conditions .....	191
Data Gap Recommendations for WRIA 3 Estuarine and Nearshore Conditions ...	192
LITERATURE CITED .....	193

## LIST OF FIGURES

Figure 1. Skagit chinook escapement estimates . . . . .	31
Figure 2. Annual escapement estimates of chum salmon in the mainstem Skagit River and Sauk River and tributaries . . . . .	32
Figure 3. Adult coho trends in the Skagit Basin. . . . .	33
Figure 4. Estimated adult pink salmon returns in the Skagit Basin . . . . .	34
Figure 5. The total number of sockeye adults returning to the Baker River trap . . . . .	35
Figure 6. Estimated escapement of Skagit and Sauk winter steelhead . . . . .	36
Figure 7. Chum salmon adult escapement estimates for the Samish River and independent streams in WRIA 1. . . . .	38
Figure 8. Estimated adult coho escapement into the Samish Basin. . . . .	39
Figure 9. Samish winter steelhead escapement estimates. . . . .	40
Figure 10. The Location of WRIAs 3 and 4 in Washington State. . . . .	42
Figure 11. Land use designations in Skagit County (Skagit County Planning and Permit Center 1997). . . . .	44
Figure 12. Land Use in Skagit Count . . . . .	54
Figure 13. Dikes and bank hardening along the middle and lower Skagit River (Map from Beamer et al. 2000). . . . .	67
Figure 14. Wetland habitat (dark green and orange) and hydric soils (light green) in the Mount Vernon area. . . . .	70
Figure 15. Wetland habitat (dark green and orange) and hydric soils (light green) in the Sedro Woolley area . . . . .	71
Figure 16. Wetland habitat (dark green) and hydric soils (light green) in the Hamilton area (Skagit County Geographic Information Services 2002). . . . .	72
Figure 17. Wetland habitat (dark green) and hydric soils (light green) in the Birdsvie area (Skagit County Geographic Information Services 2002). . . . .	73
Figure 18. Wetland habitat (dark green) and hydric soils (light green) in the area near Concrete (Skagit County Geographic Information Services 2002). . . . .	74
Figure 19. Dikes and bank hardening along the upper Skagit River and major tributaries (Map from Beamer et al. 2000). . . . .	76

Figure 20. Wetland habitat (dark green) and hydric soils (light green) in the Sauk/Rockport area.....	77
Figure 21. Wetland habitat (dark green) and hydric soils (light green) in the upper Skagit near Illabot Creek .....	78
Figure 22. Wetland habitat (bright green) and hydric soils (light green; rare) in the lower Sauk sub-basin.....	80
Figure 23. Wetland habitat (dark green) and hydric soils (light green) in the middle Sauk/Suiattle sub-basins.....	81
Figure 24. Wetland habitat (dark green) and hydric soils (light green) in the lower Samish sub-basin.....	84
Figure 25. Wetland habitat (dark green) and hydric soils (light green) in the middle Samish sub-basin .....	85
Figure 26. Wetland habitat (dark green) and hydric soils (light green) in the Friday Creek sub-basin.....	86
Figure 27. Estimated sediment supply rates in the Skagit and Samish Basins (Beechie and Feist, NMFS, unpublished data).....	88
Figure 28. The relationship between road density (mi/mi <sup>2</sup> ) and the percent of state and privately owned land on a WAU scale.....	89
Figure 29. Road density and the percentage of state and privately owned lands on a WAU scale in the lower Skagit sub-basin.....	91
Figure 30. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. ....	93
Figure 31. Road density and the percentage of state and privately owned lands on a WAU scale in the Cascade River drainage.....	94
Figure 32. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River.....	96
Figure 33. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. ....	99
Figure 34. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. ....	100
Figure 35. Riparian conditions in the Alder, Day, Gilligan, Hansen, and Nookachamps WAUs (data from Lunetta et al. 1997). ....	104

Figure 36. Riparian conditions in the Finney, Jackman, Grandy, Presentin, and Loretta WAUs (data from Lunetta et al. 1997). .....	105
Figure 37. Riparian Conditions in the upper Skagit tributary WAUs (data from Lunetta et al. 1997). .....	107
Figure 38. Riparian conditions in the Cascade River . .....	108
Figure 39. Riparian conditions in the Baker River sub-basin WAUs (data from Lunetta et al. 1997). .....	109
Figure 40. Riparian conditions in the Suiattle and lower Sauk River watersheds (data from Lunetta et al. 1997). .....	112
Figure 41. Riparian conditions in the upper Sauk sub-basin (data from Lunetta et al. 1997). .....	113
Figure 42. Riparian Conditions in the Samish and Friday Creek WAUs (data from Lunetta et al. 1997). .....	114
Figure 43. The location of “poor” rated water quality stream segments in WRIAs 3 and 4.....	118
Figure 44. Daily maximum water temperatures during 2001 in Finney Creek (Stan Zyskowski, National Park Service unpublished data). .....	124
Figure 45. Daily maximum water temperatures in Finney Creek during 2002 (Stan Zyskowski, National Park Service unpublished data). .....	125
Figure 46. Surface water withdrawal uses in the lower Skagit sub-basin (data from U.S. Geological Survey 1998b). .....	134
Figure 47. Aquatic Vegetation in WRIA 3 (data from Berry et al. 2001). .....	139
Figure 48. Changes in the Skagit Delta Channels and Wetlands .....	143
Figure 49. Ditches and Lost Tidal Wetlands in the Skagit River Delta.....	144
Figure 50. Loss of habitat in the Skagit Delta (data from Beamer et al. 2002a) .....	145
Figure 51. Changes in the Skagit Delta Channel Habitat .....	146
Figure 52. Riparian conditions along the streams and sloughs within the Skagit Delta and the Padilla Bay watershed (data from Lunetta et al. 1997).....	148
Figure 53. Classification of the Skagit Bay Shoreline (Nouffke and Beamer 2001).....	148
Figure 54. Sites of Sediment Quality Problems in and near WRIA 3 . .....	152

Figure 55. Generalized areas of current, known spawning habitat for herring (blue), surf smelt (red), and sandlance..... 153

Figure 56. Wetlands in the Padilla Bay Watershed (Padilla Bay National Estuarine Research Reserve 2002)..... 156

Figure 57. Channel and wetland changes in the Samish Delta (Bortleson et al. 1980). 162

## LIST OF TABLES

Table 1. Generalized habitat types used by the Skagit Watershed Council.....	55
Table 2. GIS data layers used in the culvert assessment.....	56
Table 3. Screening criteria for barriers that were excluded from the assessment.....	58
Table 4. Weighting system used for habitat area for different habitat and land use classifications.....	60
Table 5. Priority ranking.....	61
Table 6. Floodplain area and road density in WRIAs 3 and 4 (floodplain data from Beamer et al. 2000).....	66
Table 7. Quantity and percentage of modified stream bank by channel length in the Skagit Basin in the current, known anadromous areas (data from GIS layers contained in Beamer et al. 2000).....	68
Table 8. Large woody debris recruitment potential in Baker River sub-basin streams (U.S. Forest Service 2002).....	110
Table 9. Water Quality Exceedances in the Lower Skagit River (DOE 2003).....	119
Table 10. Water Temperatures in the Sauk River (U.S. Forest Service 1996).....	127
Table 11. Water Quality Exceedances in the Samish River near Burlington (DOE 2003). .....	129
Table 12. Number and spawning locations of baitfish stocks in WRIA 3 (data from Bargmann 1998; Penttila 2001a).....	167
Table 13. Source documents for the development of standards.....	170
Table 14. Salmonid habitat condition standards.....	171
Table 15. System for rating estuarine habitat conditions.....	176
Table 16. Summary of estuarine and nearshore conditions in WRIA 3.....	177
Table 17. Summary of WRIAs 3 and 4 Freshwater Limiting Factors Results.....	179

## **LIST OF MAPS (IN SEPARATE FILES)**

Map W1. Gradient and Channel Confinement Classifications in the Upper Skagit Sub-Basin (SSHIAP 1995 to present).

Map W2. Gradient and Channel Confinement Classifications in the Lower Skagit Sub-Basin (SSHIAP 1995 to present).

Map W3. Gradient and Channel Confinement Classifications in the Sauk River Sub-Basin (SSHIAP 1995 to present).

Map W4. Gradient and Channel Confinement Classifications in the Baker River Sub-Basin (SSHIAP 1995 to present).

Map W5. Gradient and Channel Confinement Classifications in the Samish Sub-Basin (SSHIAP 1995 to present).

Map A1. Barriers to Salmonids in the Lower Skagit Sub-Basin.

Map A2. Barriers to Salmonids in the Upper Skagit Sub-Basin.

Map A3. Barriers to Salmonids in the Sauk River Sub-Basin.

Map A4. Barriers to Salmonids in the Baker River Sub-Basin.

Map A5. Barriers to Salmonids in the Samish Sub-Basin.

Map F1. Estimated Floodplain in the Skagit and Samish Basins (data from Beamer et al. 2000).

Map F2. Dikes in the Lower Samish Sub-Basin (data from Skagit County 2003).

Map E1. Documented tidegates in WRIA3.

Map E2. Shoreline Modifications in WRIA 3 (data from Berry et al. 2001).

Map E3. Shoreline Modifications in Skagit Bay (data from SSC and Skagit County).

Map E4. Known Eelgrass Beds in WRIA 3 (data from Berry et al. 2001).

Map E5. Overhanging Riparian Vegetation Conditions in WRIA 3 (data from Berry et al. 2001).

Map E6. Overwater structures (Boat Ramps, Slips, Piers) (data from Berry et al. 2001).

## INTRODUCTION

### Habitat Limiting Factors Background

The successful recovery of naturally spawning salmon populations depends upon directing actions simultaneously at harvest, hatcheries, habitat and hydro, the 4H's. The 1998 state legislative session produced a number of bills aimed at salmon recovery. Engrossed Substitute House Bill 2496 (now 77RCW) was a key piece of the 1998 Legislature's salmon recovery effort, with the focus directed at salmon habitat issues.

Engrossed Substitute House Bill (ESHB) 77RCW in part:

directs the Conservation Commission in consultation with local government and the tribes to invite private, federal, state, tribal and local government personnel with appropriate expertise to act as a technical advisory group;

directs the technical advisory group to identify limiting factors for salmonids to respond to the limiting factors relating to habitat pursuant to section 8 sub 2 of this act;

defines limiting factors as "conditions that limit the ability of habitat to fully sustain populations of salmon."

defines salmon as all members of the family salmonidae, which are capable of self-sustaining, natural production.

The overall goal of the Conservation Commission's limiting factors project is to identify habitat factors limiting production of salmon in the state. In waters shared by salmon, steelhead trout and bull trout we will include all three. Later, we will add bull trout only waters as well as cutthroat trout.

It is important to note that the responsibilities given to the Conservation Commission in 77RCW do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

## **The Relative Role Of Habitat In Healthy Populations Of Natural Spawning Salmon**

During the last 10,000 years, Washington State anadromous salmonid populations have evolved in their specific habitats (Miller 1965). Water chemistry, flow, and the physical stream components unique to each stream have helped shaped the characteristics of every salmon population. These unique physical attributes have resulted in a wide variety of distinct salmon stocks for each salmon species throughout the State. Within a given species, stocks are population units that do not extensively interbreed because returning adults rely on a stream's unique chemical and physical characteristics to guide them to their natal grounds to spawn. This maintains the separation of stocks during reproduction, thus preserving the distinctiveness of each stock.

Throughout the salmon's life cycle, the dependence between the stream and a stock continues. Adults spawn in areas near their own origin because survival favors those that do. The timing of juveniles leaving the river and entering the estuary is tied to high natural river flows. It has been theorized that the faster speed during out-migration reduces predation on the young salmon and perhaps is coincident to favorable feeding conditions in the estuary (Wetherall 1971). These are a few examples that illustrate how a salmon stock and its environment are intertwined throughout the entire life cycle.

Salmon habitat includes the physical, chemical and biological components of the environment that support salmon. Within freshwater and estuarine environments, these components include water quality, water quantity or flows, stream and river physical features, riparian zones, upland terrestrial conditions, and ecosystem interactions as they pertain to habitat. However, these components closely intertwine. Low stream flows can alter water quality by increasing temperatures and decreasing the amount of available dissolved oxygen, while concentrating toxic materials. Water quality can impact stream conditions through heavy sediment loads, which result in a corresponding increase in channel instability and decrease in spawning success. The riparian zone interacts with the stream environment, providing nutrients and a food web base, woody debris for habitat and flow control (stream features), filtering runoff prior to surface water entry (water quality), and providing shade to aid in water temperature control.

Salmon habitat includes clean, cool, well-oxygenated water flowing at a normal (natural) rate for all stages of freshwater life. In addition, salmon survival depends upon specific habitat needs for egg incubation, juvenile rearing, migration of juveniles to saltwater, estuary rearing, ocean rearing, adult migration to spawning areas, and spawning. These specific needs can vary by species and even by stock.

When adults return to spawn, they not only need adequate flows and water quality, but also unimpeded passage to their natal grounds. They need deep pools with vegetative cover and instream structures such as root wads for resting and shelter from predators. Successful spawning and incubation depend on sufficient gravel of the right size for that particular population, in addition to the constant need of adequate flows and water quality, all in unison at the necessary location. Also, delayed upstream migration can be critical. After entering freshwater, most salmon have a limited time to migrate and

spawn, in some cases, as little as 2-3 weeks. Delays can result in pre-spawning mortality, or spawning in a sub-optimum location.

After spawning, the eggs need stable gravel that is not choked with sediment. River channel stability is vital at this life history stage. Floods have their greatest impact to salmon populations during incubation, and flood impacts are worsened by human activities. In a natural river system, the upland areas are forested, and the trees and their roots store precipitation, which slows the rate of storm water into the stream. The natural, healthy river is sinuous and contains large pieces of wood contributed by an intact, mature riparian zone. Both slow the speed of water downstream. Natural systems have floodplains that are connected directly to the river at many points, allowing wetlands to store flood water and later discharge this storage back to the river during lower flows. In a healthy river, erosion or sediment input is great enough to provide new gravel for spawning and incubation, but does not overwhelm the system, raising the riverbed and increasing channel instability. A stable incubation environment is essential for salmon, but is a complex function of nearly all habitat components contained within that river ecosystem.

Once the young fry emerge from the gravel nests, certain species such as chum, pink, and some chinook salmon quickly migrate downstream to the estuary. Other species, such as coho, steelhead, bull trout, and chinook, will search for suitable rearing habitat within the side sloughs and channels, tributaries, and spring-fed "seep" areas, as well as the outer edges of the stream. These quiet-water side margin and off channel slough areas are vital for early juvenile habitat. The presence of woody debris and overhead cover aid in food and nutrient inputs as well as provide protection from predators. For most of these species, juveniles use this type of habitat in the spring. Most sockeye populations migrate from their gravel nests quickly to larger lake environments where they have unique habitat requirements. These include water quality sufficient to produce the necessary complex food web to support one to three years of salmon growth in that lake habitat prior to outmigration to the estuary.

As growth continues, the juvenile salmon (parr) move away from the quiet shallow areas to deeper, faster areas of the stream. These include coho, steelhead, bull trout, and certain chinook. For some of these species, this movement is coincident with the summer low flows. Low flows constrain salmon production for stocks that rear within the stream. In non-glacial streams, summer flows are maintained by precipitation, connectivity to wetland discharges, and groundwater inputs. Reductions in these inputs will reduce that amount of habitat; hence the number of salmon dependent on adequate summer flows.

In the fall, juvenile salmon that remain in freshwater begin to move out of the mainstems, and again, off-channel habitat becomes important. During the winter, coho, steelhead, bull trout, and remaining chinook parr require habitat to sustain their growth and protect them from predators and winter flows. Wetlands, stream habitat protected from the effects of high flows, and pools with overhead cover are important habitat components during this time.

Except for bull trout and resident steelhead, juvenile parr convert to smolts as they migrate downstream towards the estuary. Again, flows are critical, and food and shelter are necessary. The natural flow regime in each river is unique, and has shaped the population's characteristics through adaptation over the last 10,000 years. Because of the close inter-relationship between a salmon stock and its stream, survival of the stock depends heavily on natural flow patterns.

The estuary provides an ideal area for rapid growth, and some salmon species are heavily dependent on estuaries, particularly chinook, chum, and to a lesser extent, pink salmon. Estuaries contain new food sources to support the rapid growth of salmon smolts, but adequate natural habitat must exist to support the detritus-based food web, such as eelgrass beds, mudflats, and salt marshes. Also, the processes that contribute nutrients and woody debris to these environments must be maintained to provide cover from predators and to sustain the food web. Common disruptions to these habitats include dikes, bulkheads, dredging and filling activities, pollution, and alteration of downstream components such as lack of woody debris and sediment transport.

All salmonid species need adequate flow and water quality, spawning riffles and pools, a functional riparian zone, and upland conditions that favor stability, but some of these specific needs vary by species, such as preferred spawning areas and gravel. Although some overlap occurs, different salmon species within a river are often staggered in their use of a particular type of habitat. Some are staggered in time, and others are separated by distance.

Chum and pink salmon use the streams the least amount of time. Washington adult pink salmon typically begin to enter the rivers in August and spawn in September and October, although Dungeness summer pink salmon enter and spawn a month earlier (WDFW and WWTIT 1994). During these times, low flows and associated high temperatures and low dissolved oxygen can be problems. Other disrupted habitat components, such as less frequent and shallow pools from sediment inputs and lack of canopy from an altered riparian zone or widened river channel, can worsen these flow and water quality problems because there are fewer refuges for the adults to hold prior to spawning.

Pink salmon fry emerge from their gravel nests around March and migrate downstream to the estuary within a month. After a limited rearing time in the estuary, pink salmon migrate to the ocean for a little over a year, until the next spawning cycle. Most pink salmon stocks in Washington return to the rivers only in odd years. The exceptions are the Snohomish and Nooksack Basins, which support both even- and odd-year pink salmon stocks.

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum adults enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum adults enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary,

juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

Chinook salmon have three major run types in Washington State. Spring chinook are generally in their natal rivers throughout the calendar year. Adults begin river entry as early as February in the Chehalis, but in Puget Sound, entry doesn't begin until April or May. Spring chinook spawn from July through September and typically spawn in the upper watershed areas where higher gradient habitat exists. Incubation continues throughout the autumn and winter, and generally requires more time for the eggs to develop into fry because of the colder temperatures in the headwater areas. Fry begin to leave the gravel nests in February through early March. After a short rearing period in the shallow side margins and sloughs, all Puget Sound and coastal spring chinook stocks have juveniles that begin to leave the rivers to the estuary throughout spring and into summer (August). Within a given Puget Sound stock, it is not uncommon for other chinook juveniles to remain in the river for another year before leaving as yearlings, so that a wide variety of outmigration strategies are used by these stocks. The juveniles of spring chinook salmon stocks in the Columbia Basin exhibit some distinct juvenile life history characteristics. Generally, these stocks remain in the basin for a full year. However, some stocks migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the Columbia River, where they are believed to over-winter prior to outmigration the next spring as yearling smolts.

Adult summer chinook begin river entry as early as June in the Columbia, but not until August in Puget Sound. They generally spawn in September and/or October. Fall chinook stocks range in spawn timing from late September through December. All Washington summer and fall chinook stocks have juveniles that incubate in the gravel until January through early March, and outmigration downstream to the estuaries occurs over a broad time period (January through August). A few of these stocks have a component of juveniles that remain in freshwater for a full year after emerging from the gravel nests.

While some emerging chinook salmon fry outmigrate quickly, most inhabit the shallow side margins and side sloughs for up to two months. Then, some gradually move into the faster water areas of the stream to rear, while others outmigrate to the estuary. Most summer and fall chinook outmigrate within their first year of life, but a few stocks (Snohomish summer chinook, Snohomish fall chinook, upper Columbia summer chinook) have juveniles that remain in the river for an additional year, similar to many spring chinook (Marshall et al. 1995). However, those in the upper Columbia, have scale patterns that suggest that they rear in a reservoir-like environment (mainstem Columbia upstream from a dam) rather than in their natal streams and it is unknown whether this is a result of dam influence or whether it is a natural pattern.

The onset of coho salmon spawning is tied to the first significant fall freshet. They typically enter freshwater from September to early December, but has been observed as early as late July and as late as mid-January (WDF et al. 1993). They often mill near the river mouths or in lower river pools until freshets occur. Spawning usually occurs between November and early February, but is sometimes as early as mid-October and can extend into March. Spawning typically occurs in tributaries and sedimentation in these tributaries can be a problem, suffocating eggs. As chinook salmon fry exit the shallow low-velocity rearing areas, coho fry enter the same areas for the same purpose. As they grow, juveniles move into faster water and disperse into tributaries and areas which adults cannot access (Neave 1949). Pool habitat is important not only for returning adults, but for all stages of juvenile development. Preferred pool habitat includes deep pools with riparian cover and woody debris.

All coho juveniles remain in the river for a full year after leaving the gravel nests, but during the summer after early rearing, low flows can lead to problems such as a physical reduction of available habitat, increased stranding, decreased dissolved oxygen, increased temperature, and increased predation. Juvenile coho are highly territorial and can occupy the same area for a long period of time (Hoar 1958). The abundance of coho can be limited by the number of suitable territories available (Larkin 1977). Streams with more structure (logs, undercut banks, etc.) support more coho (Scrivener and Andersen 1982), not only because they provide more territories (useable habitat), but they also provide more food and cover. There is a positive correlation between their primary diet of insect material in stomachs and the extent the stream was overgrown with vegetation (Chapman 1965). In addition, the leaf litter in the fall contributes to aquatic insect production (Meehan et al. 1977).

In the autumn as the temperatures decrease, juvenile coho move into deeper pools, hide under logs, tree roots, and undercut banks (Hartman 1965). The fall freshets redistribute them (Scarlett and Cederholm 1984), and over-wintering generally occurs in available side channels, spring-fed ponds, and other off-channel sites to avoid winter floods (Peterson 1980). The lack of side channels and small tributaries may limit coho survival (Cederholm and Scarlett 1981). As coho juveniles grow into yearlings, they become more predatory on other salmonids. Coho begin to leave the river a full year after emerging from their gravel nests with the peak outmigration occurring in early May. Coho use estuaries primarily for interim food while they adjust physiologically to saltwater.

Sockeye salmon have a wide variety of life history patterns, including landlocked populations of kokanee which never enter saltwater. Of the populations that migrate to sea, adult freshwater entry varies from spring for the Quinault stock, summer for Ozette, to summer for Columbia River stocks, and summer and fall for Puget Sound stocks. Spawning ranges from September through February, depending on the stock.

After fry emerge from the gravel, most migrate to a lake for rearing, although some types of fry migrate to the sea. Lake rearing ranges from 1-3 years. In the spring after lake rearing is completed, juveniles enter the ocean where more growth occurs prior to adult return for spawning.

Sockeye spawning habitat varies widely. Some populations spawn in rivers (Cedar River) while other populations spawn along the beaches of their natal lake (Ozette), typically in areas of upwelling groundwater. Sockeye also spawn in side channels and spring-fed ponds. The spawning beaches along lakes provide a unique habitat that is often altered by human activities, such as pier and dock construction, dredging, and weed control.

Steelhead have the most complex life history patterns of any Pacific salmonid species (Shapovalov and Taft 1954). In Washington, there are two major run types, winter and summer steelhead. Winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May. Summer steelhead adults enter the river from about May through October with spawning from about February through April. They enter the river in an immature state and require several months to mature (Burgner et al 1992). Summer steelhead usually spawn farther upstream than winter stocks (Withler 1966) and dominate inland areas such as the Columbia Basin. However, the coastal streams support more winter steelhead populations.

Juvenile steelhead can either migrate to sea or remain in freshwater as rainbow or redband trout. In Washington, those that are anadromous usually spend 1-3 years in freshwater, with the greatest proportion spending two years (Busby et al. 1996). Because of this, steelhead rely heavily on the freshwater habitat and are present in streams all year long.

Bull trout/Dolly Varden stocks are also very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Within a given stock, some adults remain in freshwater their entire lives, while others migrate to the estuary where they stay during the spring and summer. They then return upstream to spawn in late summer. Those that remain in freshwater either stay near their spawning areas as residents, or migrate upstream throughout the winter, spring, and early summer, residing in pools. They return to spawning areas in late summer. In some stocks juveniles migrate downstream in spring, overwinter in the lower river, then enter the estuary and Puget Sound the following late winter to early spring (WDFW 1998). Because these life history types have restrictive habitat requirements, especially as it relates to temperature, bull trout are generally recognized as a sensitive species by natural resource management agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation.

In addition to the above-described relationships between various salmonid species and their habitats, there are also interactions between the species that have evolved over the last 10,000 years such that the survival of one species might be enhanced or impacted by the presence of another. Pink and chum salmon fry are frequently food items for coho smolts, Dolly Varden char, and steelhead (Hunter 1959). Chum fry have decreased feeding and growth rates when pink salmon juveniles are abundant (Ivankov and Andreyev 1971), probably the result of occupying the same habitat at the same time (competition). These are just a few examples.

Most streams in Washington are home to several salmonid species, which together, rely upon freshwater and estuary habitat the entire calendar year. As the habitat and salmon review indicated, there are complex interactions among different habitat components, between salmon and their habitat, and between different species of salmon. For just as habitat dictates salmon types and production, salmon contribute to habitat and to other species.

### **Introduction to Habitat Impacts**

The quantity and quality of aquatic habitat present in any stream, river, lake or estuary is a reflection of the existing physical habitat characteristics (e.g. depth, structure, gradient) as well as the water quality (e.g. temperature and suspended sediment load). There are a number of processes that create and maintain these features of aquatic habitat. In general, the key processes regulating the condition of aquatic habitats are the delivery and routing of water (and its associated constituents such as nutrients), sediment, and wood. These processes operate over the terrestrial and aquatic landscape. For example, climatic conditions operating over very large scales can drive many habitat-forming processes while the position of a fish in the stream channel can depend upon delivery of wood from the forest adjacent to the stream. In addition, ecological processes operate at various spatial and temporal scales and have components that are lateral (e.g., floodplain and riparian), longitudinal (e.g., landslides in upstream areas) and vertical (hyporheic processes).

The effect of each process on habitat characteristics is a function of variations in local geomorphology, climatic gradients, spatial and temporal scales of natural disturbance, and terrestrial and aquatic vegetation. For example, wood is a more critical component of stream habitat than in lakes, where it is primarily an element of littoral habitats. In stream systems, the routing of water is primarily via the stream channel and subsurface routes whereas in lakes, water is routed by circulation patterns resulting from inflow, outflow and climatic conditions.

Human activities degrade and eliminate aquatic habitats by altering the key natural processes described above. This can occur by disrupting the lateral, longitudinal, and vertical connections of system components as well as altering spatial and temporal variability of the components. In addition, humans have further altered habitats by creating new processes such as the actions of exotic species. The following sections identify and describe the major alterations of aquatic habitat that have occurred and why they have occurred. These alterations are discussed as limiting factors. Provided first though, is a general description of the current and historic status of habitat and salmon populations.

## **Salmonid Populations and Status in the Skagit and Samish Basins**

### Introduction

The Skagit Basin is the most important salmonid-producing basin within Puget Sound in terms of abundance, population diversity, and types of habitat. It produces eight species of anadromous salmonids with the overall abundance comprising about 30 percent of all anadromous fish entering Puget Sound (North Cascades Institute 2002). The Skagit also supports the largest population of char in Puget Sound (Beamer et al. 2000) and probably in Washington State (City of Seattle 2001), and the largest populations of chum and pink salmon in the contiguous United States (City of Seattle 2001).

In addition to producing the greatest abundance of salmonids, the Skagit Basin is an important contributor to the diversity of salmonid populations with more salmon and steelhead populations than any other single drainage in Puget Sound except for the Snohomish Basin, which has the same number (19) of stocks (WDFW et al. 1993). Most of the salmonid populations within the Skagit Basin are considered to be native origin with relatively little influence from non-native introductions (WDFW et al. 1993). Many of the salmonid populations in the Skagit drainage are considered to be healthy, but a notable exception is that most of the chinook populations are classified as depressed (WDFW and WWTIT 2003 draft). One steelhead population is listed as depressed as well, with an unknown status for the remaining steelhead populations and the cutthroat trout population (WDFW 1998a, 2000a; WDFW and WWTIT 2003 draft).

In contrast, the Samish Basin has had extensive non-native population influences on its salmon populations. The Samish Basin supports three populations of salmon (coho, chum, chinook), one population of steelhead, and one population of cutthroat trout (WDFW 1998a, 2000a; WDFW and WWTIT 2003 draft). These populations are classified as either healthy or unknown. Details regarding all of the salmonid populations are described below, beginning with those in the Skagit Basin.

Descriptions of each salmonid population in WRIAs 3 and 4 are provided below along with information regarding population status. For population status, the stock inventory reports by WDFW and the tribes focus on individual populations specifically originating from these two WRIAs. In contrast, federal status designations are provided for much larger populations that include Skagit salmonids among many other basins within the region. Therefore, variations among status designations between agencies may be due to the different scales of populations that are assessed.

### Salmonid Populations in the Skagit Basin

#### *Chinook Salmon*

The Skagit River once supported the largest populations of chinook salmon in Puget Sound. Now they are all classified as threatened under the Endangered Species Act (Meyers et al. 1998). There are six different chinook salmon populations recognized in the stock inventory report for the Skagit Basin, and all are described as being native

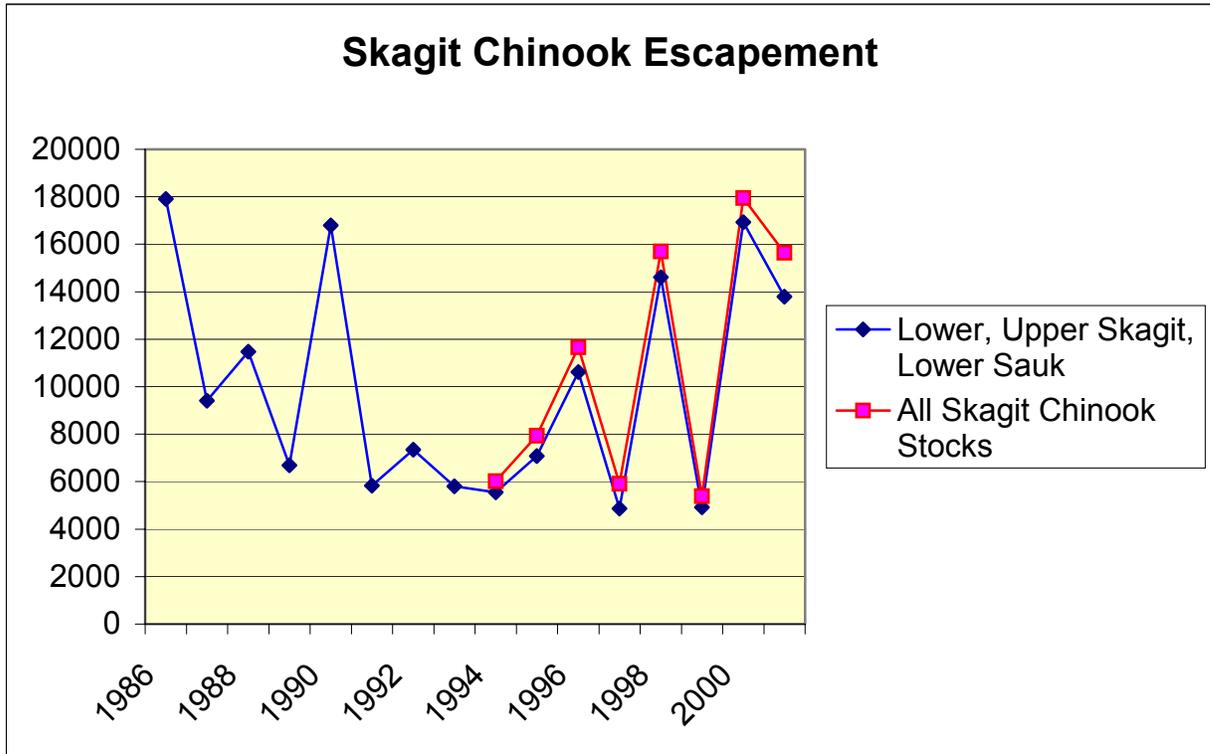
origin with wild production (WDFW and WWTIT 2003 draft). The six populations include the: lower Skagit, upper Skagit, lower Sauk, upper Sauk, Suiattle, and upper Cascade populations. All but the Suiattle chinook are currently considered depressed (WDFW and WWTIT 2003 draft).

The lower Skagit chinook population has been classified as depressed in both the 1992 and the 2003 versions of SASSI/SaSI (WDFW et al. 1993; WDFW and WWTIT 2003 draft). The lower Skagit chinook spawns in the mainstem Skagit River and tributaries downstream of the Sauk River confluence with most of the spawning in the mainstem Skagit River between Sedro Woolley and the Sauk River (WDFW and WWTIT 2003 draft). Upper Skagit chinook spawn in the mainstem Skagit River and tributaries upstream of the Sauk confluence. Illabot, Diobsud, Bacon, Falls, and Goodell Creeks are important tributaries for this population. Its status has changed from healthy in 1992 to depressed in 2003, but the changed status is primarily due to using a different methodology (Bob Hayman, SSC, personal communication). In 1992, abundance trends and absolute levels of abundance were used to assess status. In 2002, population status was rated relative to recovery goals for chinook salmon, which took into consideration habitat capacity and productivity, relative to properly functioning conditions (Bob Hayman, SSC, personal communication). The combined adult spawner counts for the lower Skagit, upper Skagit, and lower Sauk chinook are shown in Figure 1. These three populations contribute the greatest abundance of chinook from the Skagit Basin, even at currently depressed levels.

The lower Sauk chinook population spawns in the Sauk River from the mouth upstream to the Darrington Bridge (RM 21.2). Its status was classified as depressed in both the 1992 and 2003 population inventories (WDFW et al. 1993; WDFW and WWTIT 2003 draft). It is an earlier timed population compared to the mainstem Skagit populations with spawning beginning in late August and continuing to early October. Upper Sauk chinook spawn upstream of the Darrington Bridge and into the North and South Forks of the Sauk River. The status has changed from healthy in 1992 to depressed in 2003 (WDFW et al. 1993; WDFW and WWTIT 2003 draft). The spawn timing is early, from late July through early September. Suiattle chinook also have the same early spawn timing as upper Sauk chinook. They spawn in the mainstem Suiattle River and in Big, Tenas, Straight, Circle, Buck, Lime, Downey, Sulphur, and Milk Creeks. Its population status changed from depressed in 1992 to healthy in 2003.

Upper Cascade chinook spawn in the mainstem Cascade River above RM 7.8, in the lower reaches of the North and South Forks of the Cascade River, and in Marble, Found, Kindy, and Sonny Boy Creeks. Its population status has changed from unknown in 1992 to depressed in 2003. The population is an early timed population, spawning from late July through early September.

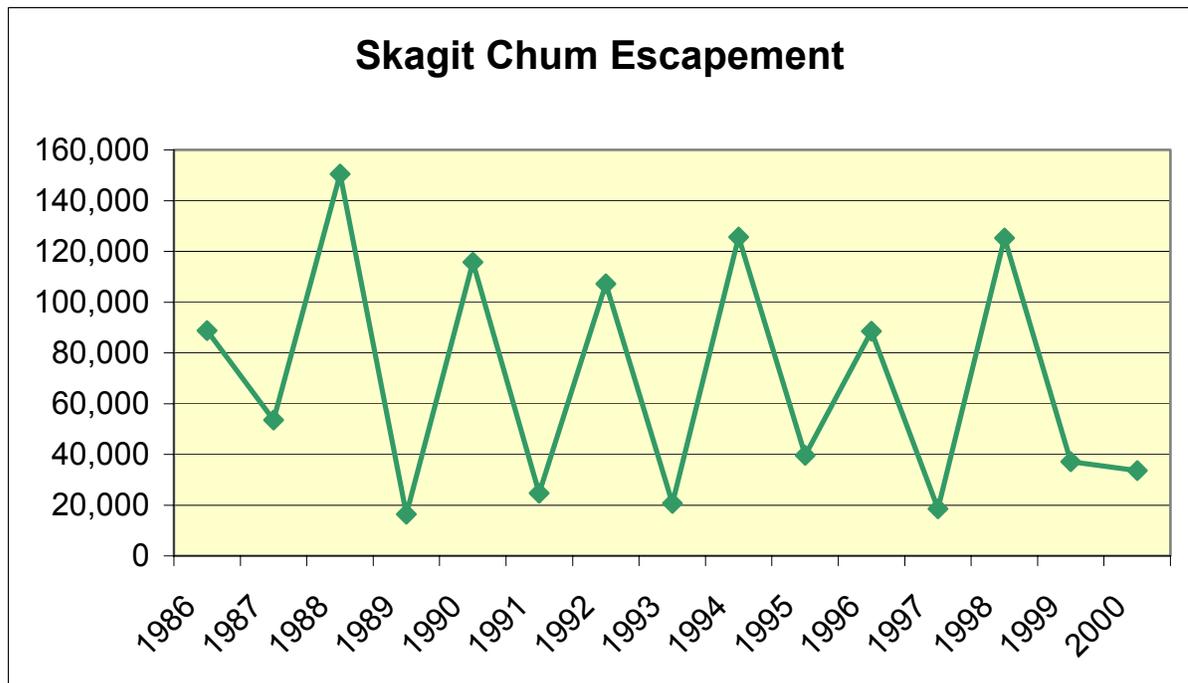
Figure 1. Skagit chinook escapement estimates (data from WDFW and WWTIT 2003 draft).



### *Chum Salmon*

The Skagit River produces the most abundant run of chum salmon in the contiguous United States (City of Seattle 2001). There are three chum salmon populations identified in the Skagit Basin: mainstem Skagit fall chum, lower Skagit tributary fall chum, and Sauk fall chum. The mainstem Skagit and Sauk chum populations have been classified as healthy in the 1992 and 2003 stock inventory reports, while the lower Skagit tributaries chum population remains as an unknown status. The Skagit Tributary chum population spawns earliest, from October through November with most spawning occurring in Finney, O’Toole, Pressentin, Mill, and Turner Creeks. The Sauk chum population spawns from mid-October through mid-November to RM 39 in the Sauk River. The mainstem Skagit chum spawns from mid-November through December in the mainstem Skagit River from RM 34 to 93 and in the Cascade River, Nookachamps, Gilligan, Illabot, and Bacon Creeks. All three chum populations are of native origin with wild production. The annual escapement estimates appear to have remained stable in the last 15 years (Figure 2).

**Figure 2. Annual escapement estimates of chum salmon in the mainstem Skagit River and Sauk River and tributaries (data from WDFW and WWTIT 2003 draft). The Sauk chum estimates are based upon fish days in index areas and are not absolute counts of adults.**

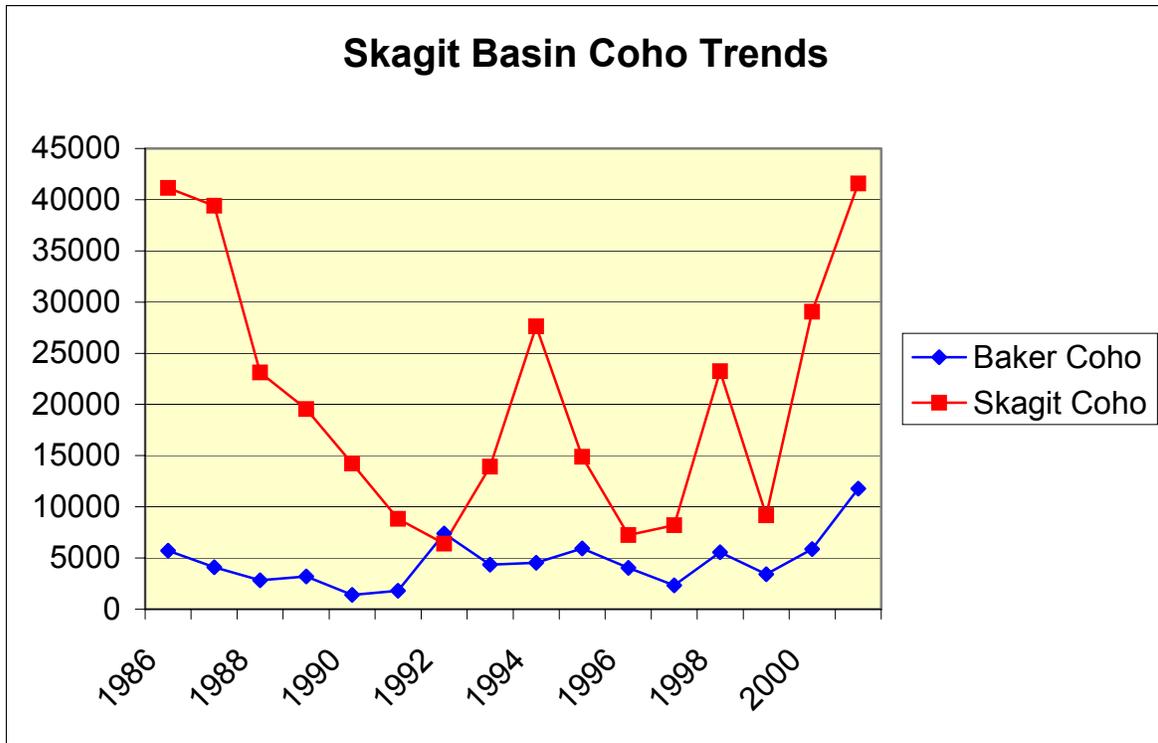


*Coho Salmon*

There are two coho salmon populations in the Skagit Basin. One spawns in the Baker River and tributaries and the other spawns in accessible areas elsewhere in the Skagit Basin (WDFW and WWTIT 2003 draft). The Baker River coho are different from the Skagit coho because they are smaller in size, return earlier (September through October), and generally spawn later (beginning of January until early February). Baker River coho are a mixed-origin run. Adults are collected at the trap in the lower Baker River then released into Baker Lake. They spawn in the Baker River and tributaries such as Sandy, Boulder, Park, Swift, Morovitz, Lake, Channel, Beaver, Little Park, and Little Sandy Creeks (Puget Sound Energy 2002).

Both the Baker River and the Skagit coho populations are classified as healthy in the 2003 stock inventory, although the Skagit coho was previously described as depressed in 1992 and the Baker River was previously listed as unknown. In recent years, the Skagit coho population has shown an increasing trend in adult returns (Figure 3) (WDFW and WWTIT 2003 draft). The Skagit coho population spawns from early October through mid-February, and is native origin with a mix of hatchery and wild production.

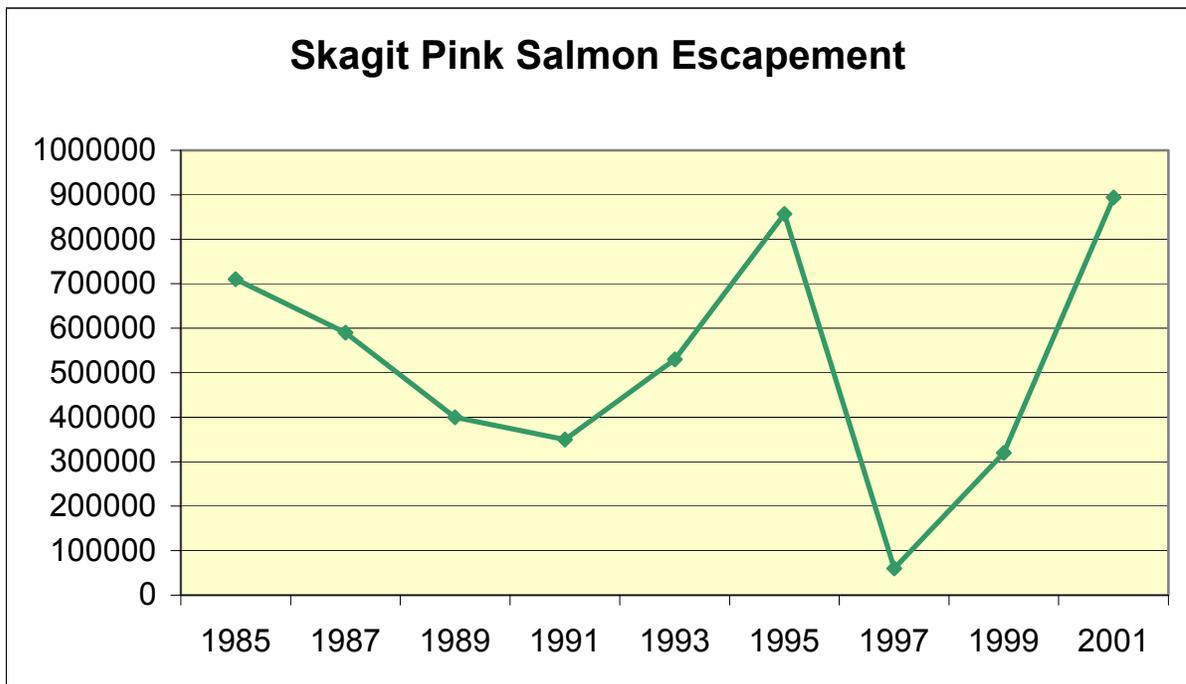
**Figure 3. Adult coho trends in the Skagit Basin (data from WDFW and WWTIT 2003 draft). Baker coho counts are based upon the number of adults trucked upstream, while the Skagit coho trend data are based upon fish days in various indices. The Skagit coho data are not absolute counts of adults.**



*Pink Salmon*

The largest population of pink salmon in the contiguous United States is produced by the Skagit River (City of Seattle 2001). A native, wild pink salmon population spawns in odd years in the mainstem Skagit River and tributaries such as Bacon, Diobsud, Goodell, Cascade, Illabot, Finney and Day Creeks and the Sauk and Suiattle Rivers. Escapement has been increasing and it is classified as healthy in both the 1992 and 2003 population inventories (Figure 4) (WDFW and WWTIT 2003 draft).

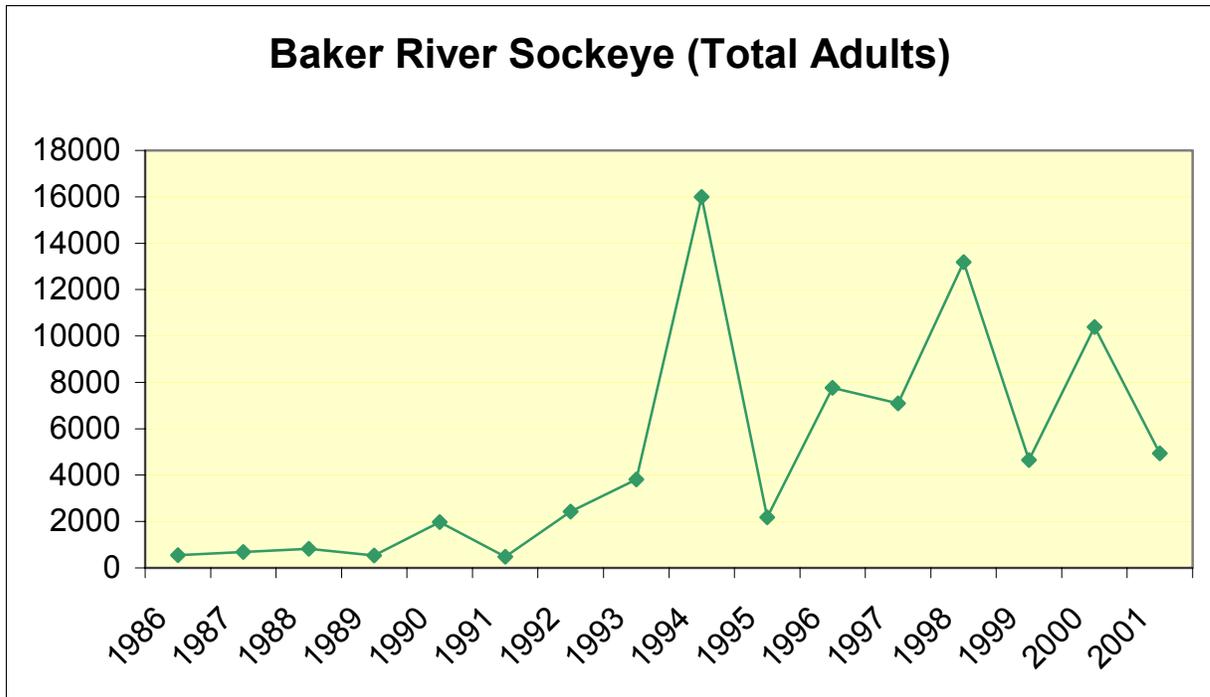
**Figure 4. Estimated adult pink salmon returns in the Skagit Basin (WDFW and WWTIT 2003 draft).**



*Sockeye Salmon*

A single population of sockeye salmon has been identified in the Skagit Basin. It spawns in the Baker River sub-basin, and its status has changed from critical in 1992 to healthy in 2003 (WDFW and WWTIT 2003 draft). Large increases in adult returns have occurred in recent years, partially due to increased ocean survival, increased harvest protection, and restoration activities (Figure 5) (U.S. Forest Service 2002). The population is native with cultured production. The cultured production includes the artificial spawning beaches, transportation as fry to Baker Lake, and transportation as smolts to below the lower Baker dam. Baker River sockeye formed the basis for the Lake Washington sockeye stock (U.S. Forest Service 2002). In addition to the Baker River sockeye, a consistent number of riverine sockeye are found during index surveys in the same locations within the Skagit Basin (Karen Chang, U.S. Forest Service, personal communication). These are not listed as a distinct stock in the stock inventories.

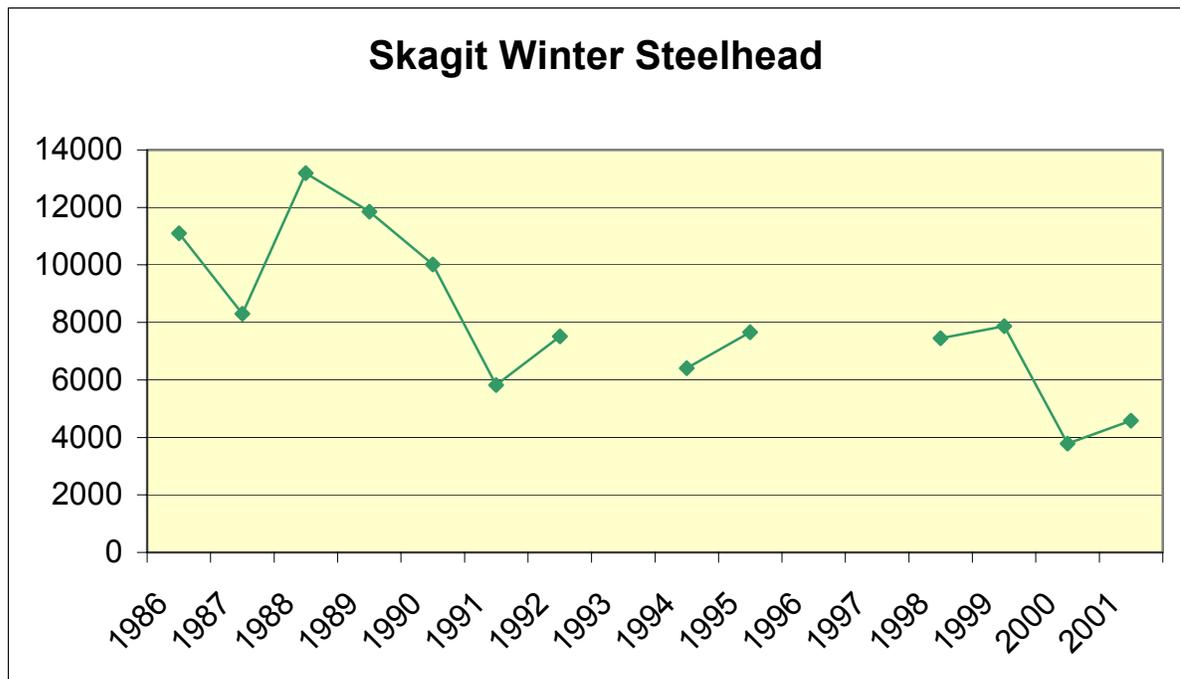
**Figure 5. The total number of sockeye adults returning to the Baker River trap (WDFW and WWTIT 2003 draft).**



### *Steelhead Trout*

In 1992, six populations of steelhead were described in the Skagit Basin: three populations of winter steelhead and three populations of summer steelhead. All of the winter steelhead populations are listed as being native origin with wild production, and the Skagit winter steelhead population has declined from a healthy status in 1992 to a depressed status in 2003 (WDFW et al. 1993; WDFW and WWTIT 2003 draft). In the 2003 report, statements are made that the spawning areas are generally continuous for the three winter steelhead populations and the data for the Sauk winter steelhead are now combined with the Skagit winter steelhead populations (Figure 6). No data were available for the Cascade winter steelhead population.

**Figure 6. Estimated escapement of Skagit and Sauk winter steelhead (data from WDFW and WWTIT 2003 draft). These numbers are based upon cumulative redd counts in the mainstem Skagit River from RM 22.5 to 94.1 and in Alder, Diobsud, Rocky, O’Toole, Cumberland, Day, Sorenson, Hansen and Jones creeks.**



There are three summer steelhead populations in the Skagit Basin. All are classified as having an unknown status (WDFW and WWTIT 2003 draft). The three populations are greatly separated spatially in spawning distribution. One population spawns in Finney Creek, another in the upper Cascade River, and the third in the upper Sauk River. The Finney and Sauk summer steelhead are native origin with wild production, while the Cascade population has an unknown origin and wild production (WDFW and WWTIT 2003 draft). No spawning abundance estimates are available for any of these populations.

### *Cutthroat Trout*

A single population of coastal cutthroat trout has been described for the Skagit River Basin, even though genetically separate populations have been identified in various Skagit River tributaries (WDFW 2000a). Anadromous and resident cutthroat are found throughout the basin. Their status is listed as a candidate species by NMFS, as sensitive by the U.S. Forest Service, and unknown by WDFW (WDFW 1998a; 2000a, U.S. Forest Service 1999).

### *Char*

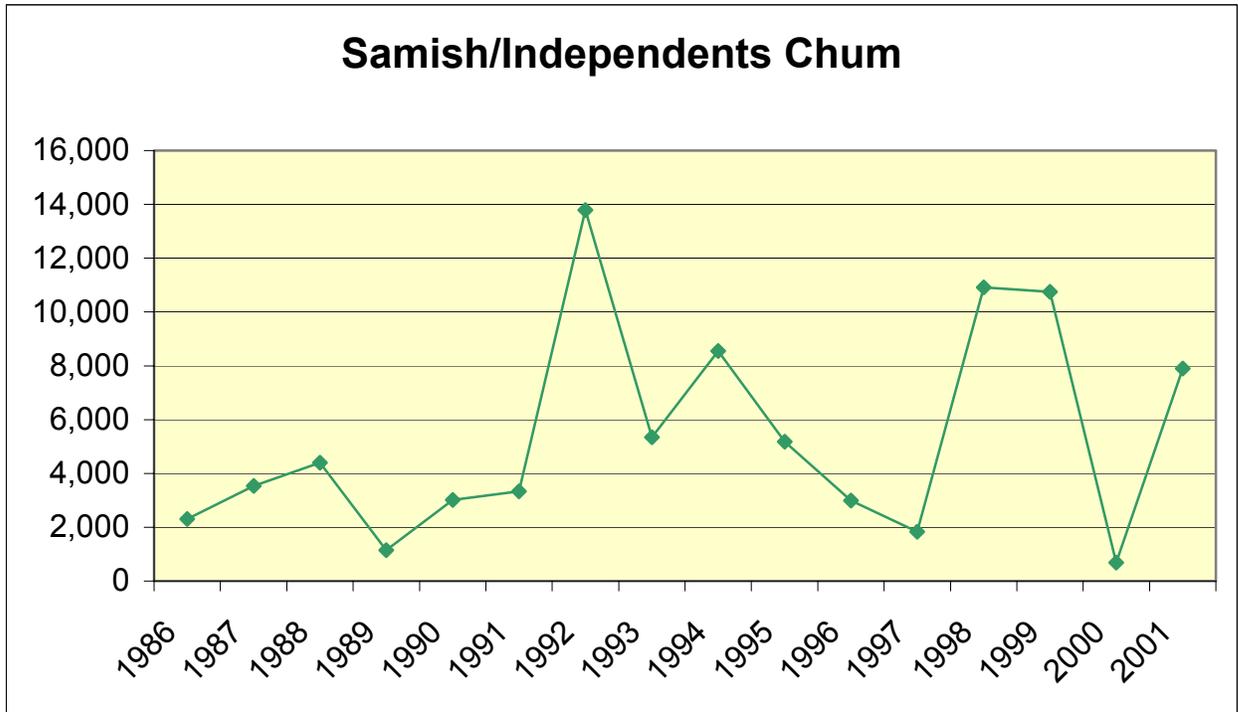
Native char are also found throughout the Skagit Basin, but specific spawning areas are generally not well known. They are listed as threatened by the U.S. Fish & Wildlife Service (1998), sensitive by the U.S. Forest Service, and healthy in SaSI (WDFW 1998a). The Fish and Wildlife service designation of “threatened” is for the Coastal/Puget Sound Distinct Population Segment, which includes char found throughout the coastal and Puget Sound streams, and is not specific to the Skagit Basin.

### Salmonid Populations in the Samish Basin

The Samish River has one population each of chinook, chum, coho, and steelhead (WDFW and WWTIT 2003 draft). The chinook population was derived from Green River chinook and is non-native in origin with significant hatchery production at the Samish Hatchery. The population includes natural spawners within the mainstem Nooksack River and tributaries because Green River origin chinook have been cultured and released there as well. Chinook in the mainstem Nooksack River are not monitored, resulting in an unknown status for the Samish/mainstem Nooksack chinook population (WDFW and WWTIT 2003 draft).

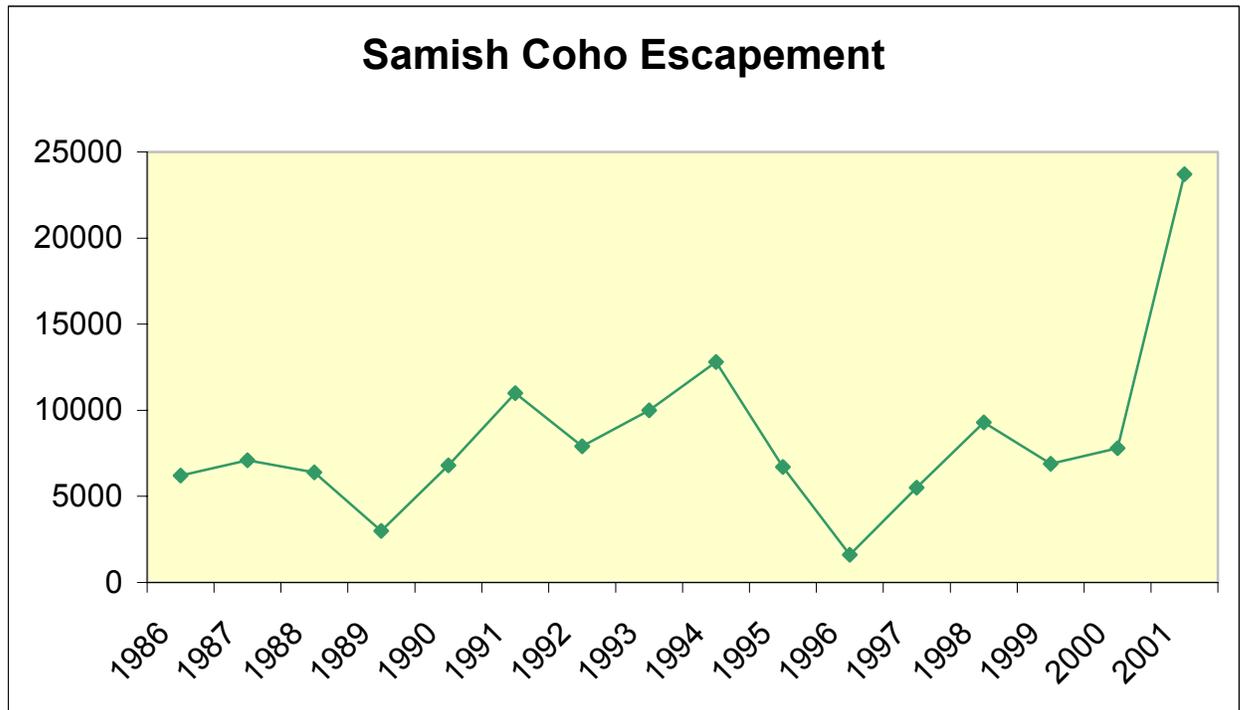
The Samish/Independents chum population spawns in the Samish River system and in Squalicum, Whatcom, Padden, Chuckanut, Oyster, Colony, and Whitehall Creeks. Chum spawning in Dakota and California Creeks are also included (WDFW and WWTIT 2003 draft). It is described as a mixed origin population with a mix of hatchery and wild production. Currently, the chum production in the Samish River is wild. The population has been classified as healthy in both the 1992 and 2003 stock inventory reports (WDFW et al. 1993; WDFW and WWTIT 2003 draft).

**Figure 7. Chum salmon adult escapement estimates for the Samish River and independent streams in WRIA 1 (WDFW and WWTIT 2003 draft).**



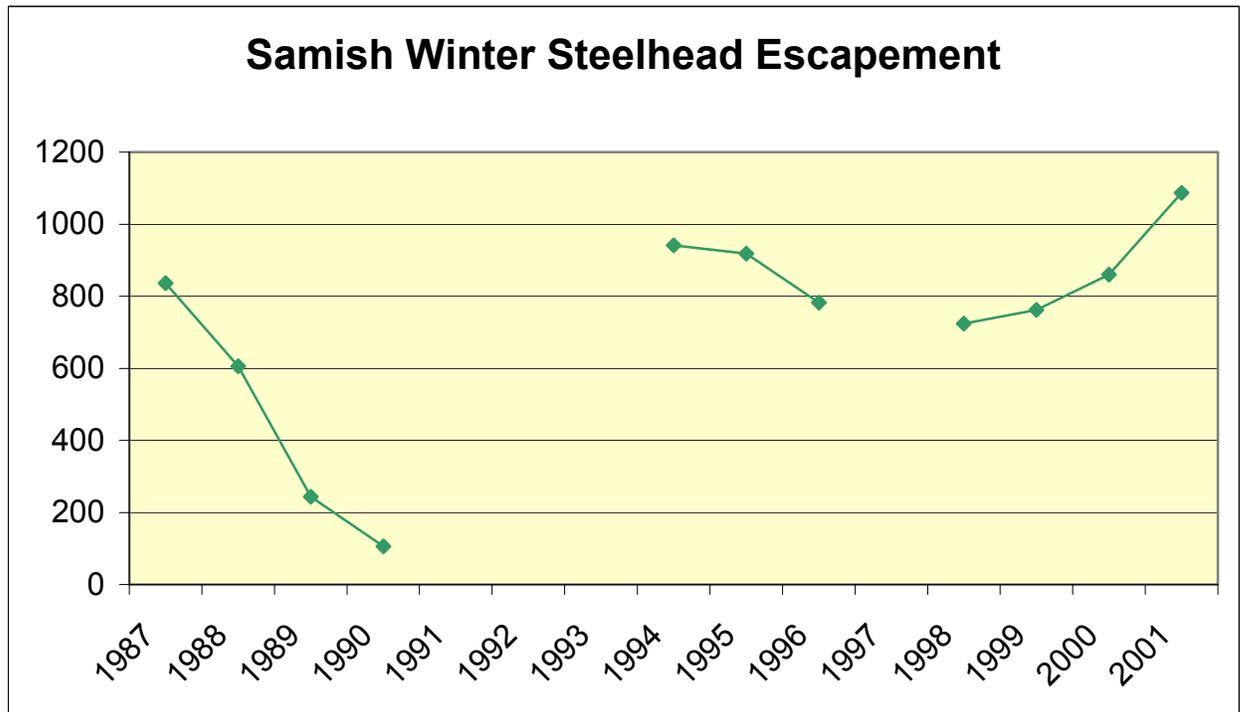
Coho salmon are the most abundant salmon in the Samish Basin. Samish coho are of mixed-origin with wild production (WDFW and WWTIT 2003 draft). Hatchery releases of non-native coho occurred until 1979, and the hatchery program was terminated in the late 1970s. The coho population has been classified as healthy in the 1992 and 2003 stock inventory reports (WDFW et al. 1993; WDFW and WWTIT 2003 draft).

**Figure 8. Estimated adult coho escapement into the Samish Basin (WDFW and WWTIT 2003 draft).**



A native, wild population of winter steelhead spawns throughout the Samish River and Friday Creek and tributaries. Its status has changed from depressed in 1992 to healthy in 2003 (WDFW et al. 1993; WDFW and WWTIT 2003 draft). The sporadic escapement estimates are shown in Figure 9 and illustrate an increase in recent years. One population of coastal cutthroat trout has been identified for the Samish Basin (WDFW 2000a). Its status is listed as unknown, and it is of native origin with wild production. No trend information is available for this population.

**Figure 9. Samish winter steelhead escapement estimates (WDFW and WWTIT 2003 draft).**



# **WATERSHED DESCRIPTION AND CONDITION FOR STREAMS IN WRIAS 3 AND 4**

## **Introduction**

This report describes habitat conditions and salmonid populations throughout WRIAs 3 and 4 (Figure 1). The two major freshwater drainages within these WRIAs are the Samish and Skagit Basins, which are discussed separately in this report. The Skagit Basin is further divided into four sub-basins, the lower Skagit (downstream from the Sauk River), the upper Skagit (between the Sauk River and the upper end of the anadromous zone), the Sauk, and the Baker River sub-basins. In addition, there are several smaller independent sloughs and watersheds within the two WRIAs. Edison Slough is discussed with the Samish Basin, while the habitat conditions for the Padilla Bay, Fir Island, and Colony Creek drainages are discussed in the Estuary/Nearshore Chapter.

Much of the Skagit Basin is within Skagit County. However, the northern boundary of the WRIAs extends into Whatcom County, and the northeastern region ends at the U.S./Canadian border, although the Skagit drainage originates in British Columbia. The southern border continues into Snohomish County with Douglas Slough to the west, and the headwaters to the Sauk River further eastward. The western boundary includes all the waters and shorelines within Skagit County, such as Cypress, Guemes, Sinclair, Burrows, Allen, and Fidalgo Islands. To avoid fragmenting the analysis of Skagit Bay, the eastern shoreline of Whidbey Island south to the outer edge of Crescent Harbor and all of Samish Bay are included in this report even though most of these areas are in other WRIAs.

The Skagit Basin is the largest drainage in Puget Sound, supplying over 30 percent of the freshwater to Puget Sound, an estimated 10 billion gallons of water a day (North Cascades Institute 2002). The Washington State Department of Fish and Wildlife Stream Catalog lists 2,989 streams and 4,540 linear miles of streams in these two WRIAs (Phinney and Williams 1975). The linear miles estimate does not include many of the small streams important to coho and cutthroat production that are not in the stream catalog. The Skagit Basin produces eight species of anadromous salmonids, comprising about 30 percent of all anadromous fish entering Puget Sound (North Cascades Institute 2002).

The Skagit Basin has a marine climate with mild winters and drier summers. In the mountains, precipitation can exceed 140" per year, while the lowlands average less than 80" annual rainfall (Drost and Lombard 1978). Most (75%) of the precipitation falls from October through March.

**Link to Figure 10. The Location of WRIAs 3 and 4 in Washington State.**

Skagit County was established in 1883, and compared to nearby areas, was slow to develop (Luxenberg 1986). The reasons for the delayed settlement were two large logjams near present day Mount Vernon that prevented upstream navigation and a lack of government-surveyed lands. The jams were hundreds of years old with mature trees growing on top, and were removed in the 1870s leading to quick upstream settlement. Instream large woody debris (LWD) removal continued. Between 1898-1908, about 30,000 snags (LWD) were removed from the lower Skagit River (Collins and Montgomery 2001).

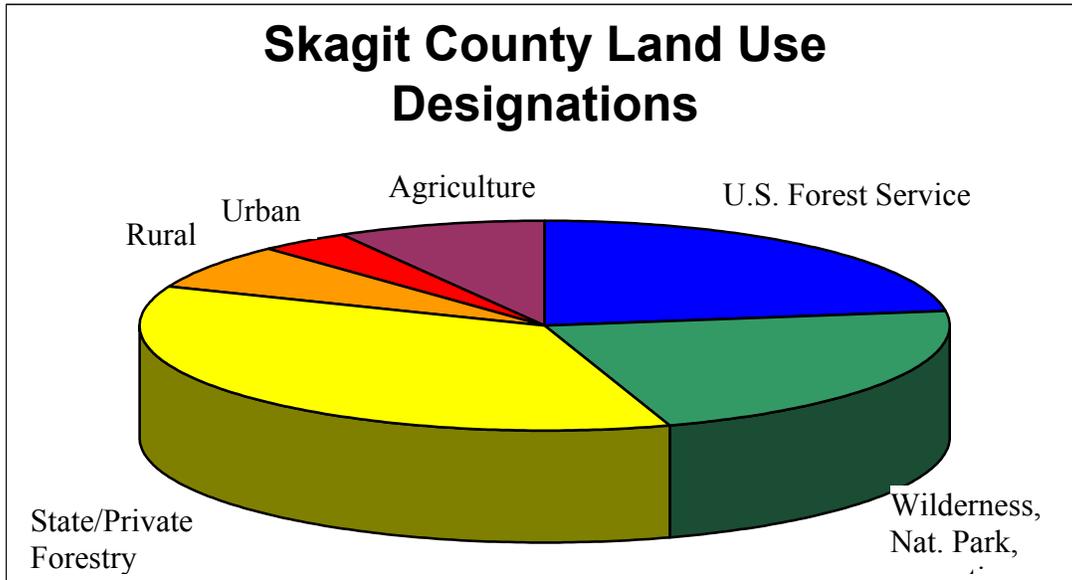
Commercial fishing and salmon canneries in Anacortes were among the first industries to develop in the county with the 1897 pack for the county at 9,840,000 cans (Bourasaw 2002). Around this time, the Skagit flats area was subjected to other types of development such as dikes, drainage, land clearing, and logging. Agriculture became an important development in the lowlands with oats, barley, hay and other crops grown on the rich floodplain soils (Bourasaw 2002).

In 1889, the first steam locomotive came into Skagit County, and by 1901, the main cities in Skagit County were on railroad lines from Seattle. Around this time, the upper valley line had reached Baker and Rockport (Dwelley 1953). Railroad and road construction expanded rapidly in the early 1900s, leading the way for increased mining, logging, and milling. The upstream areas had a later start in the logging industry. In the Sauk sub-basin, logging primarily started in the 1930s, and in the 1940s, cable logging and truck hauling began. In the 1970s, logging on steeper slopes occurred.

Other developments included the construction of three major dams in the upper mainstem Skagit River beginning in the 1920s. In the 1950s, the Shell and Texaco oil refineries were built near Anacortes, followed by numerous marinas and boat-related industries. Skagit County now has a population of 43,000, and its industries range from agriculture, dairy farms, quarrying, logging, oil refineries, and other manufacturing.

Currently, land ownership within the basin is comprised of 47% U.S. Forest Service, 24% National Park Service, 24% private, and 6% State (Lunetta et al. 1997). A considerable portion of the basin is in various protective categories. Within Skagit County, 45% of the basin is within National Forest boundaries or protected in the National Park, a national recreation area, or a designated wilderness area (Figure 2) (Skagit County Planning and Permit Center 1997). The Canadian portion of the Skagit Watershed is almost entirely protected within the boundaries of Manning Provincial Park, Skagit Valley Provincial Park, and the Cascade Recreation Area (British Columbia Heritage River System 2002). Industrial forestry occurs in 36% of the basin, which provides some protection through Forest Practice regulations (Figure 2) (Skagit County Planning and Permit Center 1997). Less protective land use occupies much less land area, but its location is significant as it covers much of the Skagit delta where critical salmonid habitat was once abundant. These include agriculture (8% of the county) and designated urban lands (4% of the county area) (Figure 2) (Skagit County Planning and Permit Center 1997). Three Native American tribes live within these two WRAs. They include the Upper Skagit, Sauk-Suiattle, and Swinomish Indian tribes.

**Figure 11. Land use designations in Skagit County (Skagit County Planning and Permit Center 1997).**



## **Watershed Description and Land Use in the Skagit Basin**

### Upper Skagit Sub-Basin

The Skagit River originates near Allison Pass in Canada, 35 miles north of the border (Phinney and Williams 1975). From the Canadian border to Newhalem, the Skagit River flows southward through the rugged landforms of the Cascade Mountain Range. Three dams have been constructed in this region: Ross (river mile (RM) 105.1), Diablo (RM 100.9), and Gorge (RM 96.5) Dams, but all are upstream of the natural anadromous salmonid distribution. The upper extent of anadromous salmonid distribution in the Skagit River is near Newhalem at RM 94.3 (Cutler 2001), which is also the upper extent for the discussion of habitat conditions in this report based upon a decision by the Technical Advisory Group (TAG). Chinook, chum, coho, pink, and sockeye salmon, and steelhead, anadromous char and cutthroat trout have been documented in the mainstem Skagit River to this point (Cutler 2001).

Between Newhalem and Marblemount, the Skagit River flows through a narrow valley. The Skagit River mainstem has been classified as an unconfined, low gradient channel in this area, but the tributaries entering the Skagit River are much steeper and more confined (Map W1) (SSHIAP 1995 to present). The upper Skagit mainstem River is the primary spawning site for the most abundant chinook stock in the Skagit Basin, the Upper Skagit Summer Chinook (WDFW et al. 1994). Forestry is the primary land use in this sub-basin with agriculture and residences in the valleys. A considerable area (from Bacon Creek upstream and in the upper Cascade River watershed) is protected within the North Cascades National Park and a national recreation area.

Major tributaries in this section include: Goodell, Bacon, Diobsud, and Illabot Creeks and the Cascade River. Goodell Creek enters the Skagit River near the upper extent of the anadromous distribution. The channel is primarily confined or moderately confined with a mix of gradients (Map W1) (SSHIAP 1995 to present). It provides habitat for coho, steelhead, and native char to about RM 5.1, and chinook have been recorded in its lower reaches (Cutler 2001; Stan Zyskowski, National Park Service, personal communication). Nearly all of this watershed is within National Park boundaries (Lunetta et al. 1997).

Bacon Creek has known coho, chinook, cutthroat, native char, pink, sockeye, and steelhead spawning up to about RM 7.5, in addition to chum in the lower reaches (Cutler 2001). It has a low to moderate gradient and is unconfined or moderately unconfined in the lower reaches and confined in the middle reaches (Map W1) (SSHIAP 1995 to present). Most (65%) of the Bacon Creek watershed is within National Park boundaries with 33% within National Forest boundaries (Lunetta et al. 1997).

Diobsud Creek provides important spawning habitat for chinook in its lower reaches, and habitat for coho, pinks, sockeye and steelhead to RM 2 to 2.5 (Cutler 2001). Much of the lower 1.8 miles has a low (1 to 2%) gradient and the channel ranges from unconfined near the mouth to confined near RM 1.8 (Map W1) (SSHIAP 1995 to present). Near RM 1.8, the gradient steepens to 2-4%, then increases again to 4-8% at the upper extent of anadromous distribution (SSHIAP 1995 to present). Roughly 15% of the Diobsud Creek watershed is within the North Cascades National Park and 75% is within National Forest boundaries. Upper Diobsud Creek is designated as Wilderness by the U.S. Forest Service. About 10% is under private ownership (Lunetta et al. 1997).

Illabot Creek has about 9.8 miles of mainstem anadromous habitat for coho, steelhead, cutthroat, and native char, and its lower reaches provide habitat for chinook and pink salmon (Cutler 2001). Most (64%) of the Illabot Creek watershed is within National Forest boundaries with 29% privately-owned and 6% State-owned (Lunetta et al. 1997).

The largest tributary in the upper Skagit sub-basin is the Cascade River. Its upper reaches are comprised of three major forks originating from various glaciers. The North and South Forks support anadromous salmonid production to RMs 0.4 and 22.7, respectively, and the South Fork is a continuation of the mainstem Cascade River. While the upper reaches are steep, there are considerable stretches of low gradient (<1%) unconfined channels in the mainstem Cascade River, especially near the mouth and between Marble Creek and the South and North Fork confluence (Map W1) (SSHIAP 1995 to present). Spring chinook, coho, cutthroat, native char, pink, sockeye, and steelhead are found throughout much of the Cascade River drainage (Cutler 2001). Several tributaries contribute to anadromous salmonid production, including Jordan, Marble, Found, and Kindy Creeks. Lower Jordan Creek has been especially important for abundant levels of coho spawners (Phinney and Williams 1975). The middle and upper Cascade River lies either within National Park boundaries (23 to 32%) or National Forest boundaries (68 to 77%). The lower Cascade River is a mix of ownerships including the U.S. Forest Service (36%), private (36%), State (24%), and National Park Service (3%) (Lunetta et al. 1997).

Several smaller tributaries, as well as the lower reaches of larger tributaries also contribute to anadromous salmonid production in the upper Skagit sub-basin. Some of these include: Newhalem, Olson, and Corkindale Creeks, which provide limited habitat for coho, steelhead, and cutthroat (Cutler 2001).

**Link to Map W1. Gradient and Channel Confinement Designations in the Upper Skagit River Sub-Basin (SSHIAP 1995 to present). Gradient definitions are as follows: Class 1 = <1%, Class 2 = 1-2%, Class 3 = 2-4%, Class 4 = 4-8%, Class 5 = 8-20%, and Class 6 = >20%.**

This map is in a separate file

### Lower Skagit Sub-Basin

The lower Skagit sub-basin consists of the mainstem Skagit River and tributaries downstream of the Sauk River to the confluence of the North and South Fork Skagit Rivers. The Forks are discussed in the estuarine chapter. The largest tributary in this section is the Baker River, which because of its size, is discussed as a separate sub-basin. The lower Skagit sub-basin provides habitat for a unique stock of fall chinook, in addition to various stocks of chum, coho, pink, sockeye, steelhead, char, and cutthroat. The entire length of the lower Skagit mainstem is classified as having a low gradient (<1%) with an unconfined channel (Map W2) (SSHIAP 1995 to present).

Larger tributaries in this sub-basin include Finney, Grandy, Alder, Day, Hansen, and Nookachamps Creeks, all which provide habitat for at least four species of salmon. Finney Creek joins the Skagit River at RM 47.5 and is over 23 miles long (Phinney and Williams 1975). About 49% of the Finney Creek watershed is within National Forest boundaries with 47% in private ownership and 4% in State lands (Lunetta et al. 1997). The Finney Creek headwaters originate near Gee Point, and much of the upper 12 miles are steep with a gradient predominantly ranging from 2 to 8% (Map W2) (SSHIAP 1995 to present). A falls near RM 11.6 is a total block for anadromous salmonids (Phinney and Williams 1975). Downstream of RM 12, the gradient is mostly low (<1%) and the channels are generally moderately confined from RM 5 to 12 and unconfined downstream of RM 5 (Map W2) (SSHIAP 1995 to present). Chinook, chum, coho, and pink salmon, and steelhead and char are presumed to use the area from the falls downstream, and sockeye salmon have been observed as far up as RM 8 (Cutler 2001). Cutthroat trout are found throughout the watershed, including the upper river tributaries such as Gee and Clendenen Creeks. Most tributaries to Finney Creek are very steep (8 to >20% gradients), limiting salmon access and production (Map W2) (SSHIAP 1995 to present).

Grandy Creek joins the Skagit River at RM 45.6. It originates from springs located about one mile upstream of Grandy Lake. Much of Grandy Creek has a low to moderate

gradient (1 to 4%) with moderately confined channels providing habitat for chum and pinks in the lowest reaches, chinook and char to RM 2.9, and steelhead, coho, and cutthroat throughout much of the mainstem (Map W2) (SSHIAP 1995 to present; Cutler 2001). The tributaries to Grandy Creek are generally steep (>20% gradients). Most (83%) of the Grandy WAU is under private ownership and the remainder is State-owned (Lunetta et al 1997). Other tributaries to the Skagit River in this area include Jackman, Pressentin, Mill, and Boyd Creeks, all of which provide salmon habitat, but to a lesser number of species.

The boundary between WRIAs 3 and 4 is at RM 44.5, just downstream of Boyd Creek. Alder Creek is one of the larger tributaries in this area and provides known habitat for coho, cutthroat, and char to RM 4.8, steelhead to RM 2.7, and chum, chinook, and pinks in the lower reaches (Cutler 2001). Much of the salmon habitat is in the lower four miles where there is a low 1 to 2% gradient with moderately confined channels (Map W2) (SSHIAP 1995 to present). Upstream, the gradient increases to 4 to 8%. Nearby Muddy Creek joins the Skagit River at RM 39, and has char and cutthroat up to RM 3, coho to RM 2.2, steelhead to RM 1.8, and chum and chinook in the downstream low gradient reaches (Cutler 2001). The Alder WAU is a mix of private (46%) and State (54) ownership (Lunetta et al. 1997).

Other Skagit River tributaries that provide salmon habitat in this area include O'Toole (coho, steelhead, and cutthroat), Cumberland (chum, coho, steelhead, and cutthroat), and Loretta (coho, steelhead, and presumed cutthroat) Creeks on the right bank (Cutler 2001). These streams have very steep gradients (8 to >20%) except in the lowest reaches (Map W2) (SSHIAP 1995 to present). The Loretta WAU is mostly (55%) privately-owned with 37% in National Forest boundaries and 8% State-owned (Lunetta et al. 1997).

The left bank tributaries in this area are Red Cabin (chum, pink, coho, presumed steelhead, and cutthroat), Mannser (chinook, coho, and cutthroat), and Jones (chum, coho, steelhead, and cutthroat) Creeks (Cutler 2001). These are characterized by having low gradients in the lowest reaches, moderate (2 to 8%) gradients in the middle reaches, and 8 to >20% gradients in the upper reaches (Map W2) (SSHIAP 1995 to present). Jones Creek serves as Lyman's water supply.

Day Creek is the next major tributary to the lower Skagit River. It enters the Skagit at RM 34.7 via Day Creek Slough, a split from the Skagit River. Day Creek originates on Cole Mountain and with the exception of the reaches near Day Lake, the gradients upstream of RM 4.7 are steep, ranging from 4 to greater than 20% (Map W2) (SSHIAP 1995 to present). The lower three miles provide important salmon habitat for chinook, pink, chum, coho, sockeye, and char with unconfined channels having low gradients from less than 1 to 2%. Steelhead trout are presumed to use the creek from the mouth to Day Lake, and cutthroat are presumed to Rocky Creek around RM 3.5 (Cutler 2001). However, most of the tributaries to Day Creek are steep with gradients from 8 to greater than 20%, although Rocky Creek has some segments that are moderately steep (4 to 8%). Most (83%) of the Day Creek WAU is privately owned with 9% in National Forest boundaries and 8% State-owned (Lunetta et al. 1997).

Downstream of Day Creek, smaller tributaries provide habitat for limited salmon species, including Morgan, Gilligan, Childs, Wiseman, and Cool Creeks. Most of these provide habitat for only chum, coho, steelhead, and char, although chinook can be found in Morgan Creek (Cutler 2001). Much of the observed salmonid use is in the downstream reaches that are unconfined channels with low (<1%) gradients (Map W2) (SSHIAP 1995 to present). Gages Slough provides abundant low gradient habitat for coho salmon.

Hansen Creek enters the Skagit River at RM 24.1. The lower 3.8 miles has a low gradient (<1 to 2%) (SSHIAP 1995 to present), and this is where much of the Hansen Creek pink, chinook, and chum salmon are found (Cutler 2001). Steelhead, coho, and cutthroat are thought to use most of the watershed. Much (84%) of the Hansen Creek WAU is privately owned with the remainder State-owned (Lunetta et al. 1997).

The Nookachamps watershed empties into the Skagit River at RM 18.8. The West Fork Nookachamps Creek extends for about 12 miles, originating from Lake McMurray and passing through Big and Barney Lakes (Phinney and Williams 1975). Nearly all of the West Fork is classified as an unconfined channel with very low gradient (<1%) (SSHIAP 1995 to present), which combined with the abundant wetlands, makes it prime coho habitat. Coho, steelhead, char, and cutthroat use much of the West Fork Nookachamps Creek, and chum are in the lower reaches of the West Fork (Cutler 2001).

The East Fork Nookachamps Creek also has a predominantly low gradient downstream of RM 5 and in Walker Creek (Map W2) (SSHIAP 1995 to present). However, elsewhere including the tributaries, the gradients are moderately to very steep. Chinook and chum salmon have been observed to RM 3.2, while coho and steelhead extend to RM 6.5 and pink salmon to RM 5.1 (Cutler 2001). Cutthroat use much of the watershed.

Land use in the Nookachamps watershed includes forestry along its slopes with residential and small farm development in the lowlands. Along with this development has been diking and bank stabilization (Phinney and Williams 1975). About 71% of the WAU is under private ownership with the remainder owned by the State (Lunetta et al. 1997).

**Link to Map W2. Gradient and Channel Confinement Designations in the Lower Skagit River Sub-Basin (SSHIAP 1995 to present). Gradient definitions are as follows: Class 1 = <1%, Class 2 = 1-2%, Class 3 = 2-4%, Class 4 = 4-8%, Class 5 = 8-20%, and Class 6 = >20%.**

This map is in a separate file

### Sauk River Sub-Basin

The Sauk River is the largest tributary to the Skagit River with about 59 mainstem miles and numerous large to small tributaries, including the Suiattle and White Chuck Rivers (Phinney and Williams 1975). All three of these rivers have headwaters in high mountain

areas. The upper Sauk (Sloan and Monte Cristo WAUs) is completely within National Forest boundaries (Lunetta et al. 1997), and the North and South Forks converge at RM 39.7.

The North Fork Sauk is a continuation of the Sauk River, and has limited anadromous salmonid use. The lower mile is moderately confined with a 1 to 2% gradient (Map W3) (SSHIAP 1995 to present), and is known habitat for steelhead, chinook, coho, pink, sockeye, and char. Cutthroat are known to RM 53.5, which is about 13.5 miles from the Forks confluence (Cutler 2001). The South Fork Sauk River provides an additional three miles of habitat for chinook, coho, and sockeye, seven miles for pink salmon, over ten miles for steelhead, and twelve miles for char. The lower three miles have a moderately low gradient of 1 to 4%, which then steepens just downstream of Elliott Creek (SSHIAP 1995 to present). The South Fork channels are moderately confined to confined.

The White Chuck River joins the Sauk River at RM 31.9. It is turbid with glacial inputs, and lies within National Forest boundaries. Steelhead, sockeye, chinook, and coho spawning have been recorded in the lower 10 to 11 miles of the White Chuck River (Cutler 2001). Char have been sighted as far as 17.8 miles and cutthroat to 5.6 miles. The mainstem White Chuck River is confined to moderately confined with gradients from 1 to 4% in the lower and middle reaches (Map W3) (SSHIAP 1995 to present). Two smaller tributaries, Pugh and Camp Creeks, also provide limited habitat for chinook, coho, and char (Cutler 2001).

Clear Creek enters the Sauk River at RM 25.1. It has confined channels in its lower reaches with gradients ranging from 1 to 8%, and provides habitat for steelhead trout (SSHIAP 1995 to present; Cutler 2001). The WAU containing Clear Creek and the nearby segment of the Sauk River is primarily (88%) within National Forest boundaries (Lunetta et al. 1997).

The middle reaches of the Sauk River have several right bank tributaries that provide habitat for anadromous salmonids. The largest of these is Dan Creek, whose lower 0.8 miles are used by steelhead, chinook, coho, chum, and pink salmon (Cutler 2001). Other tributaries, such as Gravel, Everett, and Prairie Creeks, and a few unnamed streams, are used by chum, coho, cutthroat, and/or char. These streams have low gradients (<1%) in the lower reaches that quickly increase in gradient due to the steep-sloped terrain (Map W3) (SSHIAP 1995 to present). This area of the mainstem Sauk River has an unconfined channel and low gradient (<1%). Its ownership is mixed with 50% private ownership, 32% State-ownership, and 18% within National Forest boundaries (Lunetta et al. 1997).

The next major tributary to enter the Sauk River is the Suiattle River at RM 13.2. The Suiattle River is a large, steep river originating from Glacier Peak. It is turbid much of the time. Downstream of Buck Creek (RM 18.1), the Suiattle River is mostly unconfined with a low gradient (<1%) (Map W3) (SSHIAP 1995 to present). From Buck Creek upstream, the river gradually increases in gradient and most channels are moderately confined to confined. Native char extend up to around RM 40 in the Suiattle River, while coho, pinks, steelhead, cutthroat, and chinook are known up to RMs 24 to 32 (Cutler

2001). The Suiattle spring chinook stock is a native stock that spawns primarily in the Suiattle and White Chuck Rivers and tributaries.

Several large tributaries to the Suiattle River provide limited habitat for anadromous salmonids due to their steep gradients. Spring chinook, coho, and pink salmon, as well as steelhead trout are known in the lower 0.5 miles of Big and Lime Creeks, the lower 1.2 miles of Tenas Creek, the lower 1.1 miles of Straight Creek, the lower 1.5 to 2 miles of Downey Creek, and the lower mile of Sulphur Creek (Cutler 2001). Several other tributaries provide habitat for fewer species, with native char extending into the upper river tributaries such as Milk, Vista, and Dusty Creeks. Much of the Suiattle River watershed is within National Forest boundaries. However, the Tenas WAU has 13% private ownership and 10% State ownership with the remainder in National Forest lands (Lunetta et al. 1997).

From the Suiattle River to its confluence with the Skagit River, the Sauk River has a low (<1%) gradient with a mix of unconfined to moderately confined channels (Map W3) (SSHIAP 1995 to present), and near RM 4, the valley around the Sauk River broadens to allow for greater channel meander. Rinker, White, and Hilt Creeks are the larger tributaries in this reach, providing habitat for coho, chum, and pink salmon and cutthroat and steelhead trout (Cutler 2001). The land ownership in this region has a significant portion of private ownership. The Rinker WAU is 44% privately owned, 44% State owned, and 11% within National Forest boundaries (Lunetta et al. 1997). The Hilt WAU consists of 49% National Forest lands, 41% private lands, and 9% State lands. Agriculture and residences are common in the valleys, while forestry occurs on the hillsides.

**Link to Map W3. Gradient and Channel Confinement Designations in the Sauk River Sub-Basin (SSHIAP 1995 to present). Gradient definitions are as follows: Class 1 = <1%, Class 2 = 1-2%, Class 3 = 2-4%, Class 4 = 4-8%, Class 5 = 8-20%, and Class 6 = >20%.**

This map is in a separate file.

#### Baker River Sub-Basin

The Baker River is the second largest tributary to the Skagit River, draining about 10% of the entire Skagit Basin (U.S. Forest Service 2002). The anadromous salmonid habitat within the Baker River sub-basin has been substantially altered by two dams. The Lower Baker Dam was built in 1927 and is located at RM 1.1, although the fish collection facility is at RM 0.25 (Phinney and Williams 1975). Behind the Lower Baker Dam is 8.1-mile long Lake Shannon, the reservoir created by the dam. The Upper Baker Dam is located at RM 9.1 with Baker Lake behind the dam, extending for 10.1 miles. The construction of Upper Baker Dam resulted in a 60-foot surface elevation of Baker Lake (Puget Sound Energy 2002). Baker River originates from snowfields on Mounts Baker and Shuksan. Chinook, coho, char, sockeye, cutthroat, and steelhead have been documented in the upper Baker River from RMs 26 to 30 and pink salmon are known to RM 19 (Cutler 2001). However, the primary salmon species in this sub-basin are coho and sockeye (Puget Sound Energy 2002).

Numerous tributaries enter into Lake Shannon and Baker Lake, but most have moderately steep gradients and confined to moderately confined channels (Map W4) (SSHIAP 1995 to present), limiting their productivity for anadromous salmonids. The lower reaches of most tributaries are used by char and coho, while known cutthroat distribution usually extends further upstream in the same tributaries (Cutler 2001). Sockeye salmon spawn throughout the system, especially along the beaches of the lakes and in the lower reaches of the tributaries to Baker Lake. Steelhead have been documented in Bald Eagle, lower Pass, Swift, Noisy, lower Thunder, and lower Bear Creeks. Chinook and pink salmon have been recorded in only a few of the tributaries such as Swift and Morovitz Creeks.

**Link to Map W4. Gradient and Channel Confinement Designations in the Baker River Sub-Basin (SSHIAP 1995 to present). Gradient definitions are as follows: Class 1 = <1%, Class 2 = 1-2%, Class 3 = 2-4%, Class 4 = 4-8%, Class 5 = 8-20%, and Class 6 = >20%.**

This map is in a separate file.

#### **Watershed Description and Land Use in the Samish Basin and Edison Slough**

The Samish River originates near Saxon in Whatcom County in an area with numerous wetlands. It flows predominantly southward, then west to where its largest tributary,

Friday Creek, enters. The Samish River continues to flow west then north to empty into Samish Bay. Friday Creek flows from Samish Lake for about nine miles before its confluence with the Samish River. Overall, 85 streams and 215 linear miles have been recorded in the Samish Basin (Phinney and Williams 1975). This estimate likely does not include smaller salmonid streams.

The Samish River is well known for its coho production, and coho are found throughout the lower 27.5 miles of mainstem, the entire length of Friday Creek, and in most tributaries (Cutler 2001). In addition, chinook, steelhead, and chum have been recorded up to RM 25.2 in the mainstem Samish River, as well as in lower Ennis Creek, most of Friday Creek, and lower Silver Creek. Pink and sockeye salmon have been recorded to about RM 10 in the Samish River (Cutler 2001).

Nearby Edison Slough has chum up to RM 2 and cutthroat in its lowest reaches (Cutler 2001). Edison Slough was once the North Fork Samish River, but dikes have disconnected it from the Samish River (Phinney and Williams 1975). It is now used for irrigation water with a tidegate controlling saltwater intrusion.

Both the Samish River and Friday Creek WAUs are a mix of private (84 and 80%, respectively) ownership with the remainder owned by the State (Lunetta et al. 1997). The mainstems of Samish River and Friday Creek are nearly all very low gradient reaches (<1%) and unconfined channels (Map W5) (SSHIAP 1995 to present). However, gradients and channel confinement within the tributaries vary, with those in the upper Samish being very steep.

**Link to Map W5. Gradient and Channel Confinement Designations in the Samish River Sub-Basin (SSHIAP 1995 to present). Gradient definitions are as follows: Class 1 = <1%, Class 2 = 1-2%, Class 3 = 2-4%, Class 4 = 4-8%, Class 5 = 8-20%, and Class 6 = >20%.**

This map is in a separate file.

### **Watershed Description and Land Use along the Estuarine and Near Shore Environments of WRIA 3**

Estuaries serve many important salmonid habitat functions such as providing habitat for smoltification, migration, rearing, and refuge, as well as contributing to habitat complexity and ecological processes, such as detritus cycling (Williams and Thom 2000; Aitkin 1998). For anadromous fish species, estuaries provide a critical mixing zone of fresh and salt water where juvenile and adult life stages can physiologically transition between freshwater and saltwater habitats. Intertidal and shallow subtidal habitats provide juvenile salmonids protection and refuge from avian and fish predators, while blind channel and side-channel estuary habitats serve as refuge from high water river

discharge events. Distributary channels provide critical migration and movement routes between habitats.

Not only are the estuarine and nearshore habitats in this WRIA important for salmonids, but they also serve as vital spawning and rearing areas for herring, surf smelt, and anchovy, which are important food components of salmonids. All three species of forage fish have been noted in this area (Bargmann 1998; Pentilla 2001a).

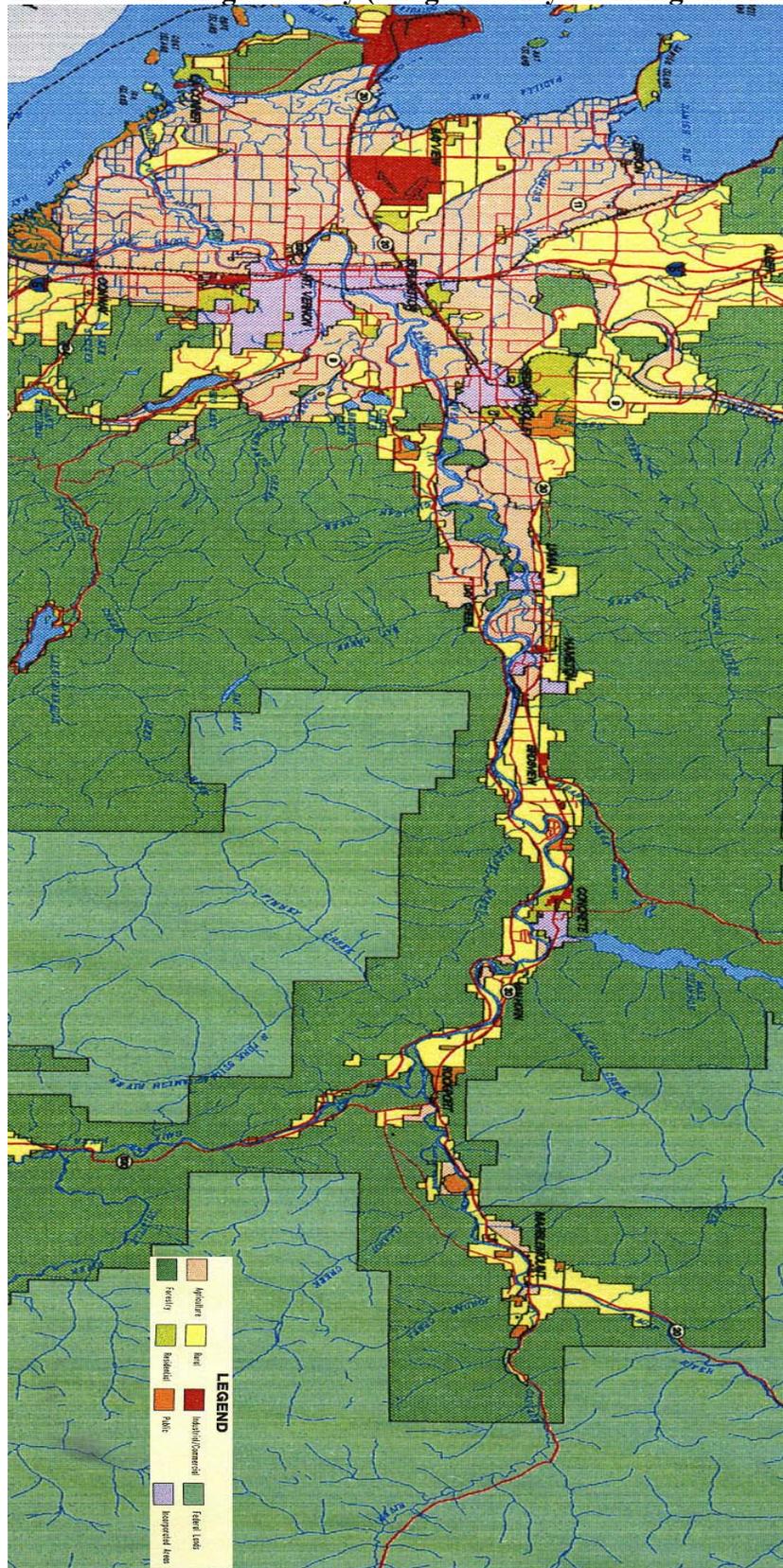
The estuarine deltas within WRIA 3 include the Samish River, Padilla Bay Slough estuaries, Swinomish Channel, North Fork Skagit River, Central Skagit Slough estuaries, South Fork Skagit River, and the Douglas Slough deltas. The nearshore estuarine areas are categorized by area in this report, and include: Samish Bay, Padilla Bay, the northern shore of Fidalgo Island and March Point, the western and southern shorelines of Fidalgo Island, northeast Whidbey Island, and all other WRIA 3 islands not previously mentioned. Although Whidbey Island is part of another WRIA, the northeast shoreline is included in this report because it borders Skagit Bay and is an integral part of the immediate nearshore and estuary to the Skagit River.

Many of the estuarine lands in WRIA 3 are in or near lands used for agriculture. Agriculture land use is concentrated in the Samish delta, northeast and south Padilla Bay deltas, the Skagit delta, and along parts of the Swinomish Channel (Figure 3) (Skagit County Planning and Permits 1997). Industrial land use is primarily located along the northern Fidalgo Bay shoreline, March Point, and near Bayview. Central Padilla Bay is primarily rural, whereas public lands surround the lower South Fork Skagit River (Figure 3).

Typically, different types of land use result in divergent habitat impacts. Common agricultural impacts include water quality problems in the sloughs that drain into Padilla and Skagit Bays, and diking, ditching, and filling of salmonid habitat. The loss of estuarine habitat has been extensive throughout the Skagit, Samish, and Padilla deltas, mostly due to diking, which has isolated former estuarine habitat. Further losses have occurred as the isolated habitat is ditched, drained, or filled to convert estuarine habitat into agricultural land. Diking and bank protection is also used in residential and urban lands, and these land uses can also contribute to water quality problems.

The industrial areas within WRIA 3 have documented sediment contamination problems, and contribute to the loss of estuarine habitat by dredging, filling, and overwater structures. All of these impacts are described in detail in the Estuarine/Nearshore Habitat Limiting Factors Chapter.

Figure 12. Land Use in Skagit County (Skagit County Planning and Permits 1997).



# Fish Access Conditions in WRIs 3 and 4: GIS-based Assessment of Salmonid Habitat Upstream of Fish Passage Barriers in the Skagit and Samish River Basins

By Devin Smith and Tyson Waldo June 2, 2003

## Introduction

Poorly designed road culverts and other stream crossing structures can prevent fish from passing upstream to access habitat. Restoration projects that upgrade or remove these structures can increase the amount of habitat available to migratory fish. In order to identify where these types of restoration projects could benefit anadromous salmonids, the Skagit System Cooperative (SSC), the Washington Department of Fish and Wildlife (WDFW), and the Skagit Fisheries Enhancement Group (SFEG) recently completed an inventory of all stream crossings in the anadromous portion of the Skagit and Samish River basins. This inventory used WDFW methods (1998) to determine if crossing structures were barriers to adult or juvenile salmonids.

Restoration projects should target barriers that prevent access to the greatest amount of high quality habitat. However, the stream crossing inventory did not assess habitat conditions upstream of barriers that would be made available to salmonids if the passage problem were corrected. To address this need, the assessment described here used existing data and Geographic Information System (GIS) layers to estimate the amount and type of habitat upstream of each passage barrier in the original inventory. While there are some limitations in the accuracy of existing data, the results identify barriers that should be a high priority for more detailed field inventory and restoration planning.

The amount of habitat available upstream of each barrier was determined by estimating the low flow wetted surface area for the generalized habitat types used by The Skagit Watershed Council (Table 1). This classification system was based on channel types and habitat needs for multiple life stages of five different salmonid species (Beamer et al. 1999). The habitat types are designated as either “key” or “secondary” depending on their importance to these species and “degraded” or “important” depending on their level of impairment.

**Table 1. Generalized habitat types used by the Skagit Watershed Council.**

Habitat Type	Gradient	Disturbed	Pristine
pool:riffle	<1%	degraded-important	key
forced pool:riffle	1-4%	degraded-important	key
plane bed	1-4%	degraded	secondary
step-pool/cascade	4-8%	secondary	secondary

Habitat was classified into these types based on gradient information taken from topographic maps and land use information taken from satellite imagery. Stream length was measured using GIS from each barrier to the next upstream barrier or to the upper extent of usable habitat if there were no upstream barriers. Upstream extent of usable habitat was determined using known natural barriers to fish migration and existing fish distribution maps. Surface area was calculated by multiplying the measured length for each habitat type by wetted width, which was estimated using two regression models. More detailed methods, limitations and the results of the assessment are described below.

## Methods

### *Data Sources*

Table 2 describes the various GIS layers and data sources that were used in this assessment.

**Table 2. GIS data layers used in the culvert assessment.**

<b>Data</b>	<b>Scale/Format</b>	<b>Description</b>	<b>Source</b>
Streams	1:24,000 Arcs	Hydrography layer identifying the location of streams and waterbodies.	Washington Department of Natural Resources (uncertain date)  Skagit County (2003)  Updates included from a variety of sources
Anadromous Zone	1:24,000 Polygon	Identifies approximate extent of habitat usable by anadromous salmonids. Based on topography and locations of known natural fish passage barriers.	Skagit System Cooperative (1999)
Fish Distribution	1:24,000 Arcs	Known presence of fish by species, compiled from a variety of sources.	Washington Conservation Commission (2002)
Barriers	1:24,000 Points	Field inventory of all stream crossing structures in anadromous zone. Collected	Skagit System Cooperative

Habitat Information	1:24,000 Arcs	by Skagit System Cooperative, Washington Department of Fish and Wildlife, and Skagit Fisheries Enhancement Group using WDFW Methods (1998)  Gradient, habitat type and length of discrete stream segments taken from USGS topographic maps and DNR hydro layer.	(2002)  Salmon and Steelhead Habitat Inventory and Assessment Program/NWIFC (2003)
Precipitation	1:250,000 Polygons	Average precipitation zones based on modeled precipitation information.	Oregon State University PRISM model (1996)
Topography	20-m DEM (re-sampled from 10-m DEM to improve processing speed)	“Hydrography-modified” Digital Elevation Model (DEM). This DEM was used to generate streams that match WA DNR hydrography to improve processing capability for stream applications.	Northwest Fisheries Science Center/NOAA-Fisheries (2003)
Land Use	1:24,000 Polygons	Information on land use compiled from county land use maps Forest Service maps.	Skagit System Cooperative (2000)

### *Screening the Barrier Data*

The SSC barrier inventory layer has information on 1758 stream crossings. The first step in the analysis involved screening the inventory to determine which barriers would be included in the assessment (Table 3). All stream crossings that were not identified as barriers or that have been repaired since the original inventory were excluded. Stream crossings with multiple structures were treated as a single barrier for the purpose of this analysis. Barriers located in the estuary were excluded because they are not suited to habitat analysis using these methods. Fish passage barriers in the estuary provide very important restoration opportunities, but will need to be addressed in a separate assessment.

**Table 3. Screening criteria for barriers that were excluded from the assessment.**

Screening reason	Number	Future action needed
Not a passage barrier	805	No assessment needed
Multiple structures	130	No assessment needed
Located in estuary	207	Need a different type of assessment for these crossings
Not snapped to hydro (no stream identified in GIS) or questionable hydro information	62	Need better information on stream location
Barriers included in analysis:	554	These were included in the analysis. Structures identified as barriers, unknown passage status, or requiring level B hydraulic analysis were included. Some of these will require more detailed analysis to determine passage status.

The remaining barrier points were snapped onto the DNR hydro layer in GIS. For culverts that did not snap, which means the hydro layer did not have a stream at the location of the culvert, additional sources were used to update the hydro information. These included the WCC fish distribution layer, Skagit County hydro layer, and information provided by field crew who performed the original inventory. After these updates, there were 40 culverts that still did not snap to a hydro arc, so were excluded from the analysis. In addition, 22 of the culverts that did snap were excluded because the hydro arcs were suspected to be inaccurate but no suitable updates could be identified. This left 554 barriers included in the assessment.

Degree of blockage could provide an additional screen, but was not incorporated into the analysis. The WDFW methodology (1998) used for the inventory requires that stream crossings provide passage for all life history phases under all flow conditions up to a 2-year flow event. This is conservative, meaning that some crossings identified as barriers may block juveniles but not adults or only block fish at some flows. The degree of blockage and the life history phases affected by a barrier has an important influence on restoration potential, so it is expected that a more detailed evaluation of these factors will be used to improve the assessment in the future.

Some crossings were identified as “unknown” or “Level B” barrier status. This means that the hydraulic conditions at the site require more detailed analysis to determine if they were a barrier. These were considered barriers for the purpose of this assessment, but

will need further evaluation to determine their barrier status before restoration is conducted.

### *Habitat Assessment*

Out of the 554 barriers assessed, there were 80 that were identified in the field as having “No Gain” for repair. These were automatically assigned a low priority because they have minimal habitat upstream. The next step was to assess habitat conditions upstream of the remaining 474 barriers. Information for stream length and gradient came from the Salmon and Steelhead Habitat Inventory and Assessment (SSHIAP) GIS database, which contains habitat information for discrete stream segments throughout the Skagit and Samish river basins. For each of these segments, gradient was measured from 1:24000 USGS topographic maps and length was measured from the DNR hydro layer in GIS. This database was used to generate a GIS layer with arcs for each stream segment upstream of each identified barrier.

Where there were multiple barriers on a single stream system, habitat was measured from each barrier to the next upstream barrier. For the uppermost barrier on a stream, the extent of potential habitat was identified using the anadromous zone layer. This layer was developed using field inventories of natural barriers and topography to determine the likely upstream extent of accessibility to anadromous fish. Where the WCC fish distribution layer documented anadromous fish presence upstream of the anadromous zone, this further upstream extent was used. In the few cases where barriers were located upstream of the anadromous zone and fish distribution layer, only the very first SSHIAP segment was used to estimate habitat conditions.

Bankfull width and summer low flow wetted width information were estimated using two regression models. The bankfull width model was developed using field data from throughout northern Puget Sound (Hyatt et al. 2002). The model uses gradient, watershed area, and precipitation information that can be determined using existing GIS layers. To run this model, watershed area was determined using a 20-m DEM from NOAA fisheries. This DEM layer was modified using the DNR hydro to simplify calculations for streams. Precipitation information was taken from the PRISM precipitation model and gradient information was taken from the SSHIAP database. Bankfull width was estimated for the upstream and downstream ends of each SSHIAP segment and the results averaged to estimate average bankfull width for the segment. Wetted width was estimated from the bankfull width information using a regression model based on habitat information collected in the Skagit basin.

The results of using these two models were tested using field data from 111 streams. The results showed that 76% of the modeled estimates were within 50% of the actual wetted stream width and a regression analysis showed that the estimates were significantly correlated with actual wetted stream widths with an  $r^2$  of 0.6308. Habitat area was calculated by multiplying stream length by the estimated wetted width and adding the areas of lakes, ponds, and wetlands measured directly from maps.

Habitat type was classified using the Skagit Watershed Council System based on the gradient information from the SSHIAP database. Habitat types with gradients between 1-4% require further classification into forced pool:riffle and plane bed channel types based on the amount of large woody debris in the channel. This distinction is best determined with field surveys. However, lacking detailed field surveys, land use information taken from satellite imagery was used as a surrogate for habitat quality. An assessment of riparian conditions in the Skagit basin showed < 25% were functioning to provide large woody debris recruitment to streams draining agricultural and urban/industrial land, 37% were functioning in rural areas, greater than 50% were functioning in commercial forest land, and > 75% were functioning in parks/wilderness/national forest (Beechie et al. 2003).

The general trend in habitat quality by land use was used to support a weighting system for the habitat area estimates for streams with gradients between 1-4%. In addition, step pool habitat types were weighted to reflect their relative less importance to salmonid production than the other habitat types and channels steeper than 8% gradient were not included in the weighted area estimates at all. The multipliers in Table 4 were used to weight the area estimates for each habitat type and then the weighted habitat areas were summed to estimate a single weighted habitat area for each barrier. These numbers are not intended to reflect actual habitat area available to fish, but can be used to compare the relative differences in habitat quantity and quality upstream of barriers.

**Table 4. Weighting system used for habitat area for different habitat and land use classifications.**

Habitat Type	Gradient	Weighted Multiplier	
Pool:riffle, lakes, ponds, wetlands	< 1%	1.00	
Forced pool:riffle, plane bed	1-4%	Agricultural/Urban	0.50
		Rural	0.70
		Forestry	0.85
		National Forest/Parks/ Wilderness	1.00
		Unknown	1.00
Step pool, Cascade	4-8%	0.50	
Steep	> 8%	0.00	

Barriers were assigned a priority ranking based on the weighted habitat area according to the values in Table 5. It is expected that barriers with a “High” ranking would be most suitable for further field-based habitat assessment to determine potential for restoration.

**Table 5. Priority ranking.**

Weighted Habitat Area (square meters)	Priority Ranking
> 1000	High
100 – 1000	Medium
0 – 100	Low

*Limitations*

Degree of blockage is difficult to estimate with existing information, but is important for evaluating fish response to a barrier or restoration project

Habitat conditions are more complex than can be represented simply by gradient and width information. In addition, limitations in the accuracy of width model, map-based gradient information, hydro coverage, and anadromous zone layer mean that habitat conditions are a “best-guess” for individual barriers. This information should be useful for general prioritization, but field-based information will be needed to refine the results for the highest priority barriers.

*Results*

A complete table of barrier data with upstream gradient and wetted habitat area is included as a spreadsheet in Appendix 1 (in separate file). With this analysis, approximately 122 culverts have been identified as high priority barriers, 179 as medium priority barriers, and 253 as low priority barriers for further field assessment. The field assessment may result in changes in prioritization, and field verification is necessary before restoration activities are planned.

Most of the high priority barriers for further field assessment are located within the lower Skagit sub-basin. The Carpenter, Nookachamps, and Hansen Creek watersheds have many high and medium priority barriers (Map A1), and these watersheds are rated as “poor” for fish access conditions. High or medium priority barriers also exist to a lesser degree in the Jones, Mannser, Red Cabin, Gilligan, Morgan, Careys, Alder, and Grandy Creek watersheds as well as in several unnamed tributaries to the lower Skagit River (Map A1). Ratings were not assigned to these watersheds in the lower Skagit, pending further analysis to determine impact.

Several watersheds in the lower Skagit sub-basin are rated “good” for salmonid access conditions. These include Sorenson, Loretta, Cumberland, Presentin, and Jackman Creeks because no barriers to salmonids were documented in these watersheds. Finney and Miller Creeks are also rated “good” because they contained only a few low priority blockages.

Overall, the upper Skagit sub-basin had few high and medium priority barriers (Map A2). Some were located in the Barnaby Slough area and one in Babcock Creek. The lower Cascade River also had several high and medium priority barriers with high priority barriers in Jordan, and Shoemaker Creeks. Large upper Skagit watersheds that had no barriers to salmonids are the middle Cascade, upper Cascade, Goodell, and Newhalem watersheds. These are rated “good” for fish access conditions. Others were not rated due to a need for additional information.

Several high and medium priority fish blockages were found in the Sauk sub-basin, particularly in the Prairie and Everett Creek watersheds (Map A3). Others were documented in several unnamed streams within the Suiattle River, in the South Fork Sauk River, and in the left bank tributaries to the lower Sauk River (Map A3). Because of the extent of high and medium priority blockages in Prairie and Everett Creeks, these streams are rated “likely poor” for fish access conditions, pending field analysis. “Good” rated areas (no fish blocking barriers) include the Hilt WAU, Dan Creek (except nearby streams 04.1087 and 04.1088), upper Suiattle, the White Chuck, and the North Fork Sauk Rivers. The Tenas/Big WAU has mostly “good” fish access conditions.

The Baker sub-basin has very few high and medium priority blockages, such as those located in Little Sandy and Channel Creeks (Map A4) (Appendix 1). The impact of these will not be fully known until further field analysis is completed. “Good” rated areas within the Baker sub-basin include the Shannon West and Shannon East WAUs, which have no barriers to salmonids (Map A4).

Many high and medium priority fish blocking culverts were documented in the Samish sub-basin. Friday Creek had numerous blockages, and Thomson, Swede, and Skarrup Creeks also had high priority blockages (Map A5). These areas are rated as “likely poor” pending additional analysis.

## **Floodplain Conditions in the Skagit Basin**

### Floodplain Function and Types of Impacts

Floodplains are relatively flat areas adjacent to larger streams and rivers that are periodically inundated during high flows. In a natural state, they allow for the lateral movement of the main channel and provide storage for floodwaters, sediment, and large woody debris. Floodplains generally contain numerous sloughs, side-channels, and other features that provide important spawning habitat, rearing habitat, and refugia during high flows. Connected wetland habitat is part of the floodplain and provides rearing and refuge habitat, as well as contributes to water storage and recharge, macroinvertebrate production (food), and sediment storage. The importance of floodplain habitat to salmonids cannot be overstated. In the Skagit and Stillaguamish Basins, more than half of the total salmonid habitat is contained within the floodplain and estuarine deltas, while this habitat encompasses only 10% of the total basin area (Beechie et al. 2001).

Floodplain impacts include the direct loss of aquatic habitat from human activities (filling), disconnection of main channels from floodplains with dikes, levees, revetments, and roads, and impeding the lateral movement of flood flows with dikes, roads, levees, and revetments. Floodplain disconnection can also result from channel incision caused by changes in hydrology or sediment inputs. The loss of large woody debris (LWD) can lead to channel incision and a loss of side channel habitat, while bank hardening impedes lateral migration that recruits LWD. The loss of large wood has contributed to the disruption of natural processes that create and sustain floodplain habitat, and is discussed more fully in the Streambed/Sediment Chapter. Floodplain impacts can also increase water and sediment transport, as well as disrupt hydrologic connectivity that can recharge stream flows during the low flow season.

Hydromodifications have been shown to directly impact salmonids in the Skagit Basin. Juvenile coho and chinook salmon were generally more abundant in areas with natural banks compared to hydromodified banks (Hayman et al. 1996). Natural banks had a higher percentage of area with wood, cobble, boulders, and aquatic plants, which is important because juvenile abundance was correlated with wood. Natural banks had more complex types of wood cover such as rootwads that are preferred by chinook and coho (Hayman et al. 1996).

The stream banks along the mainstem Skagit River are heavily modified, which could impact rearing habitat through loss of complex cover, loss of side-channels, and modified and reduced edge habitat. The modifications can also impact spawning/incubation habitat through the alteration of water and sediment transport. Increased peak flows have been correlated with decreased freshwater survival for chinook salmon in the Skagit Basin (Dave Seiler, WDFW, personal communication), but it is not known whether the increased flows result in scour of redds or juvenile flushing. Peak flow impacts to salmonids can be worsened by floodplain impacts, and are discussed in the Water Quantity Chapter. The location of the hydromodified banks is especially important for two stocks of native chinook salmon. The mainstem Skagit River provides most of the

spawning habitat for two stocks of chinook salmon (Upper Skagit Summer Chinook and Lower Skagit Fall Chinook) that spawn in these areas (WDFW et al. 1994).

Specific floodplain conditions are discussed below for four different Skagit sub-basins followed by the Samish Basin. In WRIAs 3 and 4, the floodplain has been delineated and is shown on Map F1. A floodplain was defined where it was greater than two channel widths using FEMA maps or USGS 7.5-minute quads and 1996 aerial photographs (Beamer et al. 2000). Floodplain impacts are not well defined, although sufficient information exists regarding hydromodifications along the mainstem Skagit and Sauk Rivers. A preliminary estimate of road impacts has also been done to indicate where further assessments should be prioritized. In addition, current known wetlands are shown in maps throughout this chapter (maps from Skagit County using NWI data coupled with aerial photographs). Extensive loss of freshwater wetlands has occurred throughout the lower Skagit basin due to diking, draining, and filling. However, quantification of the losses is not available.

**Link to Map F1. Estimated Floodplain in the Skagit and Samish Basins (data from Beamer et al. 2000).**

This map is in a separate file

Floodplain Habitat in the Lower Skagit Sub-Basin

The lower Skagit sub-basin (from the Sauk River downstream) has the most extensive floodplain area within the entire Skagit Basin with an estimated 108 square miles of floodplain (Map F1 and Table 6). The mainstem Skagit River from the confluence of Alder Creek (river mile (RM) 41.7) downstream to Skagit Bay (RM 0) is particularly broad. Scattered reaches along the mainstem Skagit River between Alder Creek and the Sauk River also have considerable floodplain habitat (Map F1). The lower reaches of many tributaries to the lower mainstem Skagit River contribute to floodplain habitat, especially the lower Nookachamps, Hansen, Coal, Wiseman, Childs, Day, Mannser, Red Cabin, and Alder Creeks (Map F1).

Impacts to the lower Skagit floodplain have been considerable. An estimated 45% of the side channel habitat has been lost in the Skagit Basin (Beechie et al. 2001) with much of the loss in the lower Skagit sub-basin. More than 90% of the loss of floodplain and delta habitat is due to diking, draining of sloughs and wetlands, and loss of beaver ponds with 46% of the loss due to diking, draining, and ditching and 44% a result of lost beaver dams (Beechie et al. 2001). Historically beaver ponds occupied at least 8 percent of the tributary channel length, and anastomosing channels (stable, forested islands between channels) accounted for about 44% of channel length (Beechie et al. 2001). Presently many former channels have been converted into ditches to drain farmlands and are no longer accessible at their upper ends, reducing flood refuge habitat. Also, much of the lower Skagit River is a single, hydromodified channel, particularly from RM 8.1 to 18.6 and from RM 22.3 to 24.3 (Duke Engineering 1999). Only 10% of the river from Sedro Woolley (RM 24.3) to the Forks (8.1) has split channels or island habitat. This reach

consists mostly of deep glides with rip-rap on one or both sides of the river (Duke Engineering 1999).

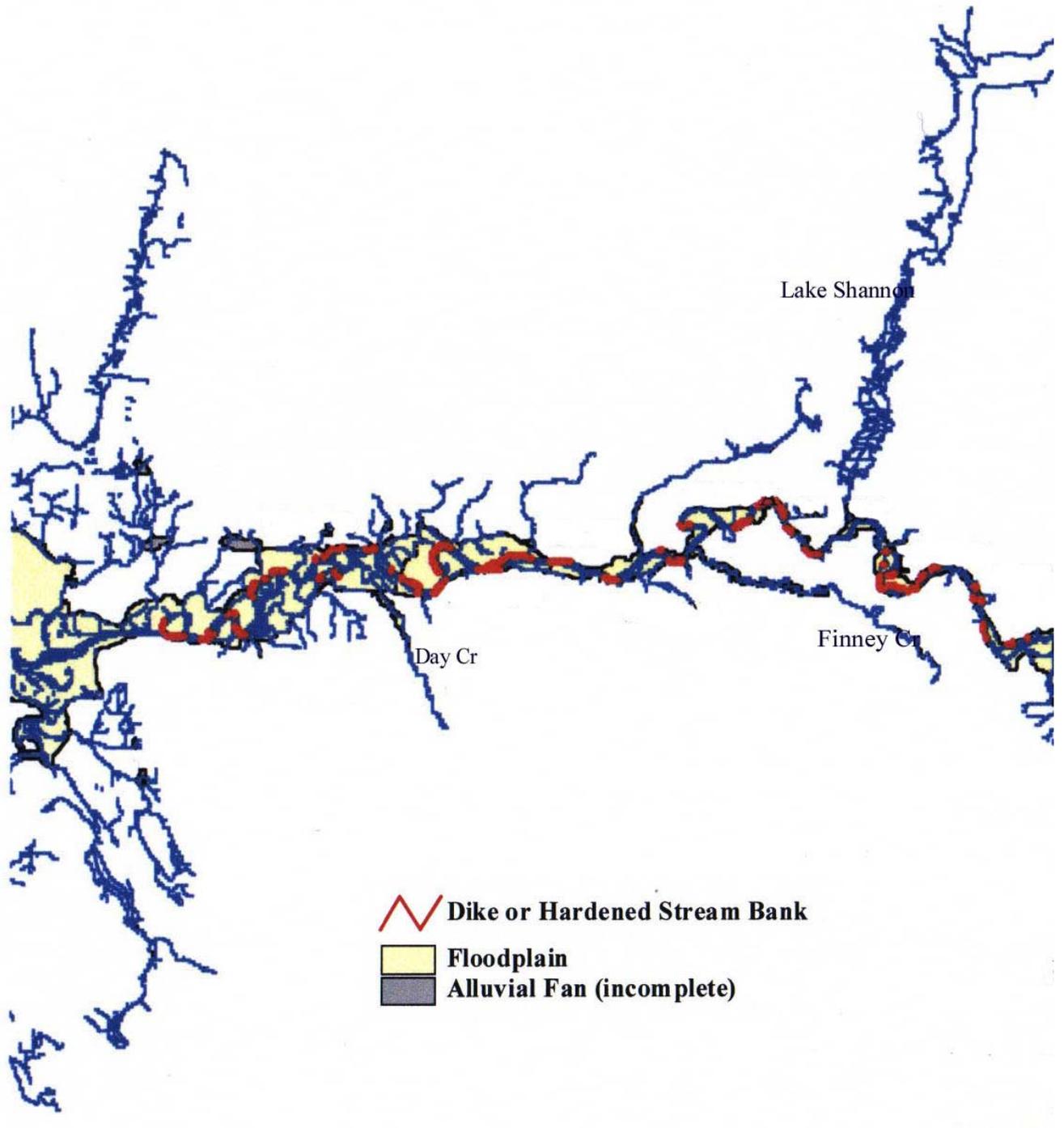
Hydromodifications disconnect floodplain habitat, increase water and sediment transport, and disrupt other natural habitat processes, such as LWD recruitment, riparian vegetation growth, hydrologic connectivity, and off-channel/side-channel development. Along the lowest reaches of the mainstem Skagit River, the losses are sizeable as 50.9 km of channel length (62%) are modified downstream of Sedro Woolley (Beamer et al. 2000). Upstream of Sedro Woolley, 45.6 km of stream channel length are modified (Figure 4) (Beamer et al. 2000). However, the overall percent of modified mainstem Skagit River channel length ranges from only 1 to 2 percent from Sedro Woolley to the Sauk River (Table 7). While these percentages may seem low, they do not reflect the quantity of lost floodplain area and the importance of the isolated habitat to salmonid production.

Another coarse measurement of floodplain impact is the level of road density contained within the floodplain habitat. In the lower Skagit River, 3.3 miles of roads/square mile of floodplain habitat have been estimated (Table 6). This is the greatest level of floodplain road density in WRIAs 3 and 4, and indicates a high degree of development within a crucial salmonid environment.

**Table 6. Floodplain area and road density in WRIAs 3 and 4 (floodplain data from Beamer et al. 2000).**

<b>Sub-Basin</b>	<b>Floodplain Area (mi2)</b>	<b>Floodplain Roads (miles)</b>	<b>Floodplain Road Density</b>
Lower Skagit	108.4	355.2	3.3
Upper Skagit	15.2	43.5	2.9
Baker	2.4	2.7	1.1
Sauk	19.9	33.1	1.7
Samish	55.7	171.9	3.1

**Figure 13. Dikes and bank hardening along the middle and lower Skagit River  
(Map from Beamer et al. 2000).**



**Table 7. Quantity and percentage of modified stream bank by channel length in the Skagit Basin in the current, known anadromous areas (data from GIS layers contained in Beamer et al. 2000).**

Reach	Reach Feet	Modified Feet	Percent Modified	Miles Modified
1) Suiattle	201513	1087	0.54	0.21
2) Upper Sauk (from the confluence of Suiattle, upstream)	198481	2499	1.26	0.47
3) Lower Sauk (from the mouth of the Sauk to the Suiattle confluence)	70766	3118	4.41	0.59
4) Cascade River	N/A	1446	N/A	
5) Skagit mainstem upper most reach, from upper extent (Newhalem RM 94) down to Cascade	85923	6801	7.92	1.29
6) Skagit mainstem from the Cascade River to Sauk River	55878	5205	9.31	0.99
7) Skagit mainstem from Sauk R to Finney Creek	102584	8837	8.61	1.67
8) Skagit mainstem from Finney Cr to Day Creek	73055	11325	15.50	2.14
9) Skagit mainstem from Day Creek to Sedro Woolley (RM 24.8)	49542	5357	10.81	1.01

Current, known wetland habitat has been delineated, although it is a conservative estimate likely underestimating the actual wetland habitat. Even though, when compared to a map of hydric soils, it is apparent that the loss of wetlands is substantial. Hydric soils are formed during saturation or flooding with anaerobic upper layers, one of three conditions for wetland identification. Drained hydric soils can be an indication of historic wetlands, as well as areas suitable for restoration (U.S. Geological Society 1998a). Hydric soils can also indicate where present wetlands might be located but not yet inventoried.

Current known wetlands are more numerous and extensive from the town of Lyman (Day Creek area) downstream (Figures 5-9). Also, the extent of hydric soils increases in a downstream direction with large differences in area between hydric soils and currently known wetlands from Lyman downstream to the South and North Forks of the Skagit River. It is apparent from Figures 5 and 6 that considerable development has occurred

throughout areas with hydric soils in this sub-basin, indicating likely extensive wetland loss. Upstream of Hamilton, important wetland complexes are limited to areas immediately adjacent to the mainstem Skagit River and tributaries.

Within the lower Skagit sub-basin, the Nookachamps watershed provides important floodplain habitat. An estimated 19% of the drainage is within the 100-year floodplain (NWMC and SCDPCD 1995). Barney Lake and Debays Slough are two of the larger wetlands, but numerous others exist in this watershed as well. Diking has occurred in the lower Nookachamps drainage, where the most extensive floodplain habitat exists, but these impacts have not been quantified.

Diking has occurred in the floodplain areas of the Hansen WAU streams (DNR 1994), but these impacts have not been quantified. Also in this WAU, excellent side-channel habitat has been noted in Skiyou Slough and lower Wiseman Creek (DNR 1994), and these areas should be preserved.

#### Lower Skagit Floodplain Habitat Conclusions

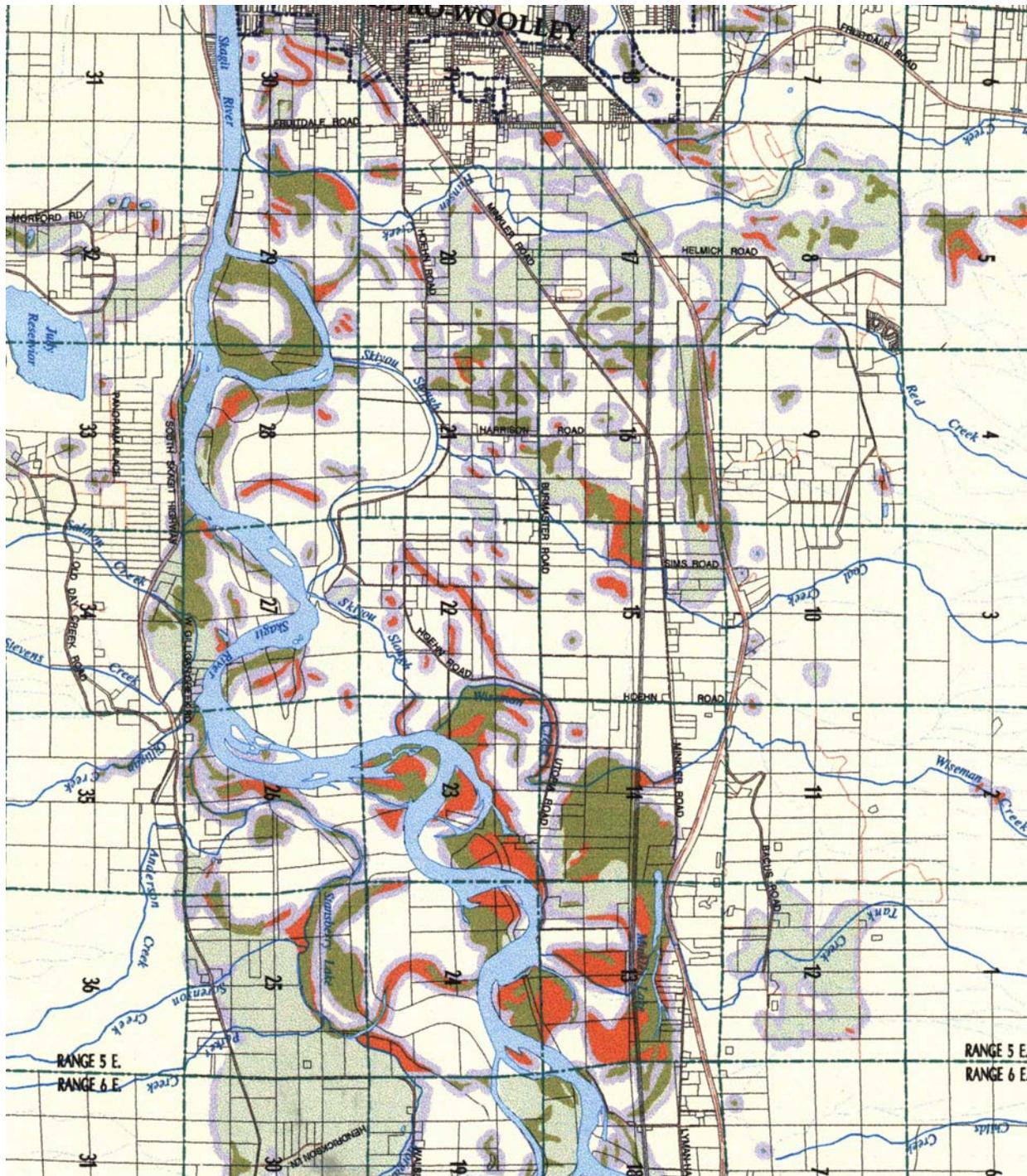
The lower mainstem Skagit River is rated “poor” for floodplain conditions due to the extensive diking coupled with the probable loss of considerable wetland habitat. Without additional quantification, floodplain conditions in the tributaries to the lower Skagit River cannot be rated.

Because of the importance of side channel and off-channel habitat to salmonids, the Skagit River from Day Creek to the mouth deserves high priority investigation for floodplain habitat restoration. Projects that preserve functioning floodplain habitat, reduce hydromodifications, and reconnect or restore riverine wetland habitat should be a high priority within the two WRIAs.

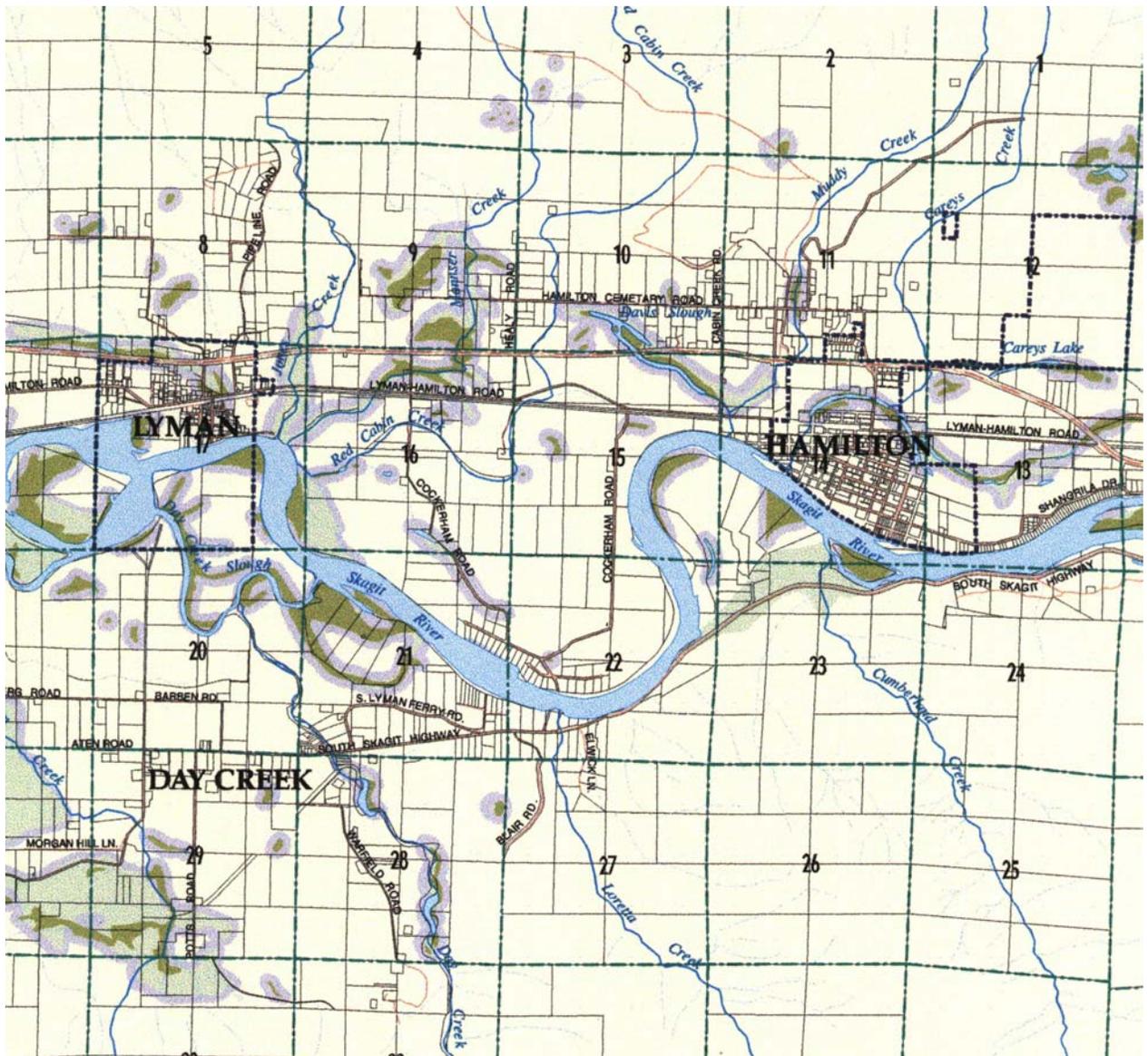
**Figure 14. Wetland habitat (dark green and orange) and hydric soils (light green) in the Mount Vernon area (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory, while the orange areas have been interpreted from aerial photographs.**



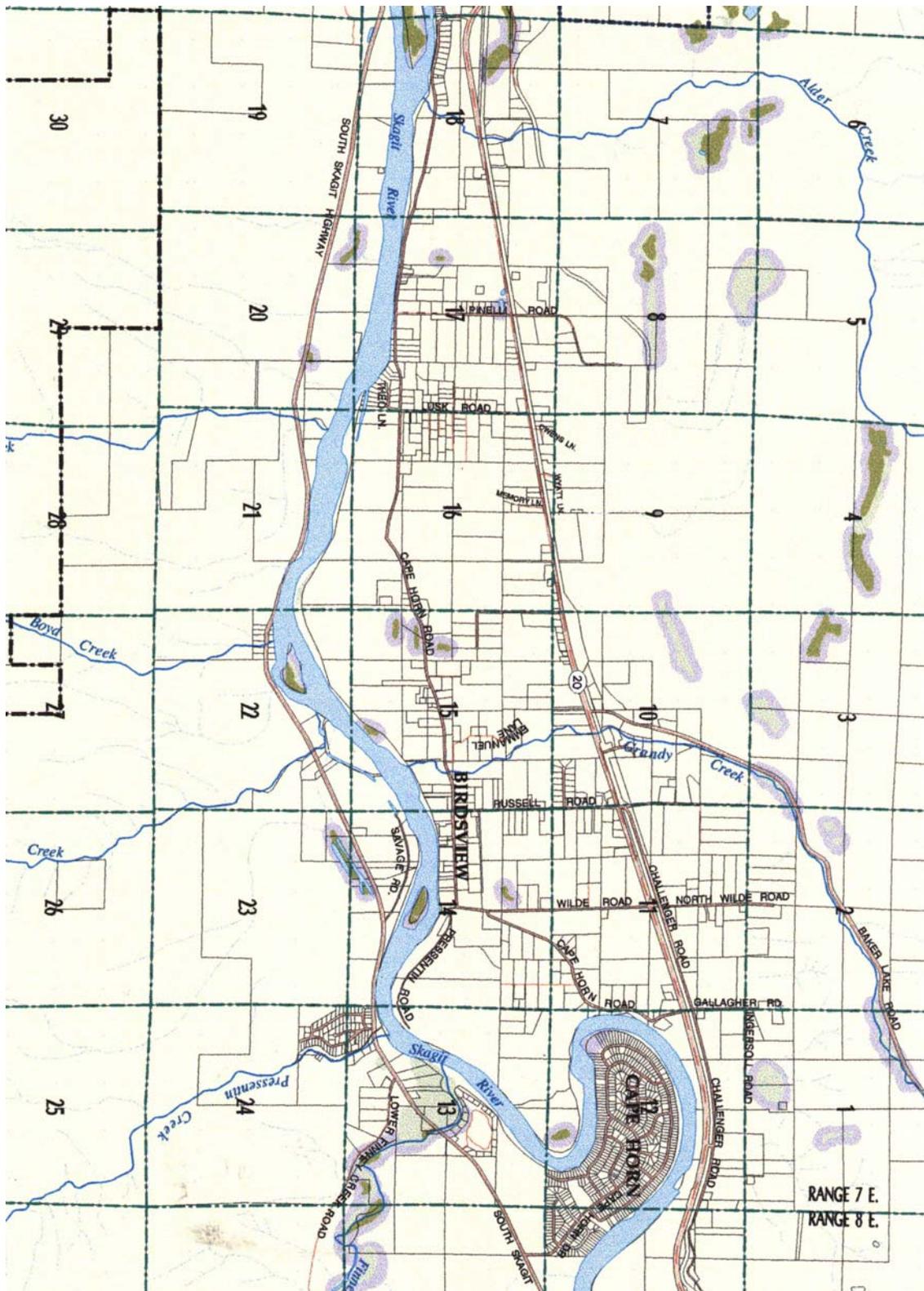
**Figure 15. Wetland habitat (dark green and orange) and hydric soils (light green) in the Sedro Woolley area (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory, while the orange areas have been interpreted from aerial photographs.**



**Figure 16. Wetland habitat (dark green) and hydric soils (light green) in the Hamilton area (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.**



**Figure 17. Wetland habitat (dark green) and hydric soils (light green) in the Birdsvew area (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.**





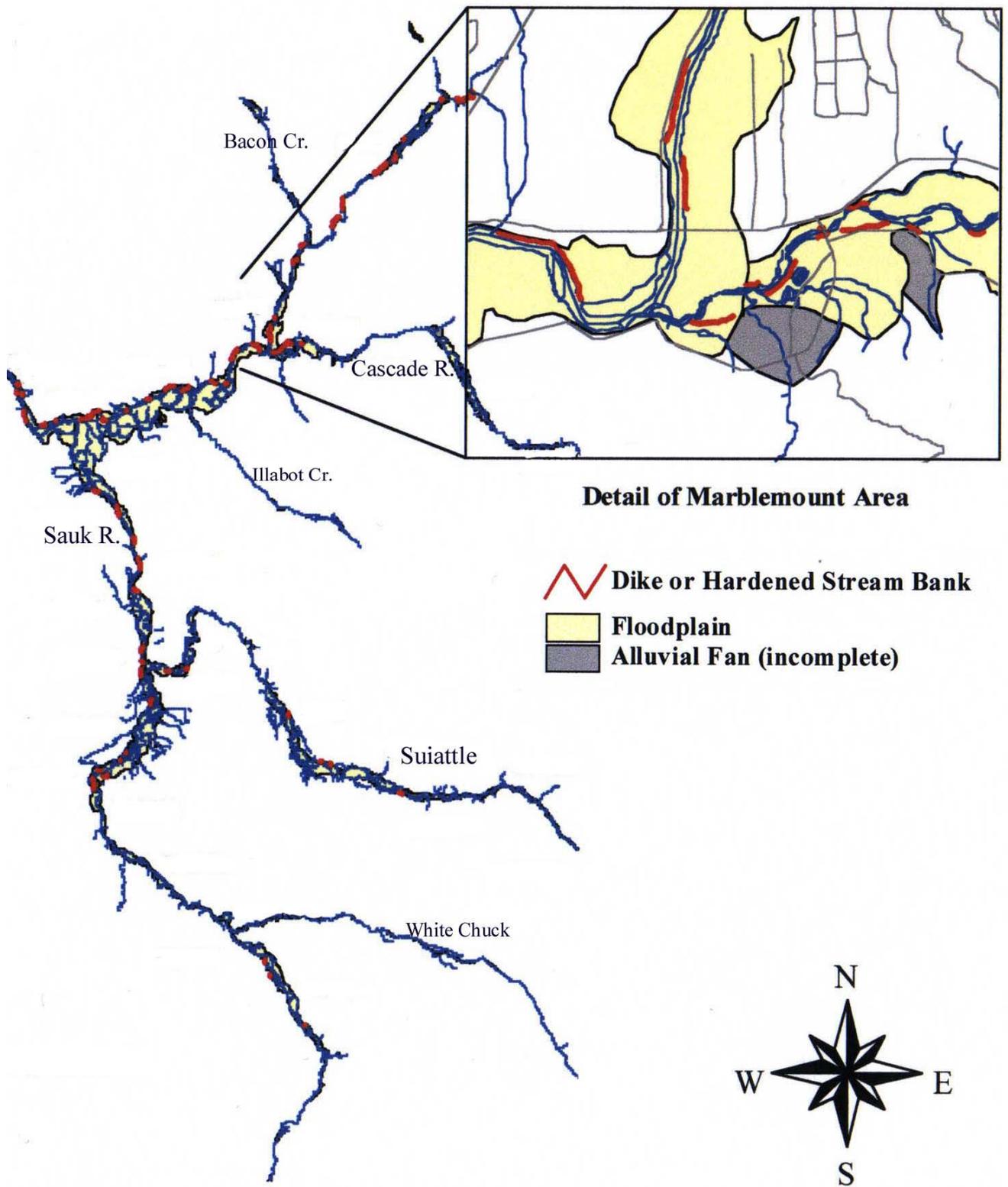
### Floodplain Habitat in the Upper Skagit Sub-Basin

The upper Skagit sub-basin has 15.2 mi<sup>2</sup> of floodplain habitat, much less than in the lower Skagit sub-basin (Table 6). The locations of areas with considerable floodplain habitat are more limited, and include the lower three miles of the Cascade River and from the confluence of the Sauk River (RM 67.2) upstream to Diobsud Creek (RM 80.7) (Map F1) (data from GIS layers used in Beamer et al. 2000).

Hydromodifications are common along the upper mainstem Skagit River (Figure 10), but based upon channel length, comprise an estimated 1 to 2 percent of total channel length (Table 7). Again, channel length estimates do not reflect the impact to lost area and importance to salmonid production. Floodplain road densities are high (2.9 miles/square mile floodplain) in the upper Skagit sub-basin (Table 6), but just below the 3.0 standard that separates a “fair” from a “poor” condition (see the Assessment Chapter). The floodplain road density and extent of hydromodification are lower than in the lower Skagit and Samish sub-basins, but are still problematic impacts, resulting in a “fair” rating for floodplain conditions in the upper Skagit sub-basin.

Along the upper Skagit River, important wetland complexes are primarily limited to areas immediately adjacent to the mainstem Skagit River and lower reaches of tributaries (Figures 11 and 12). Except in the limited wetland areas immediately adjacent to streams, soils are predominantly not hydric in many areas of the upper Skagit sub-basin, suggesting that historically, wetland habitat was not as abundant as in the lower Skagit sub-basin. The differences between hydric soils and current, known wetland habitat are not nearly as great as in the lower Skagit and Samish sub-basins, inferring that wetland loss has not been a major problem in this sub-basin. However the wetland complexes adjacent to streams are likely important habitat areas for salmonids and should be conserved.

**Figure 19. Dikes and bank hardening along the upper Skagit River and major tributaries (Map from Beamer et al. 2000).**



**Figure 20. Wetland habitat (dark green) and hydric soils (light green) in the Sauk/Rockport area (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.**

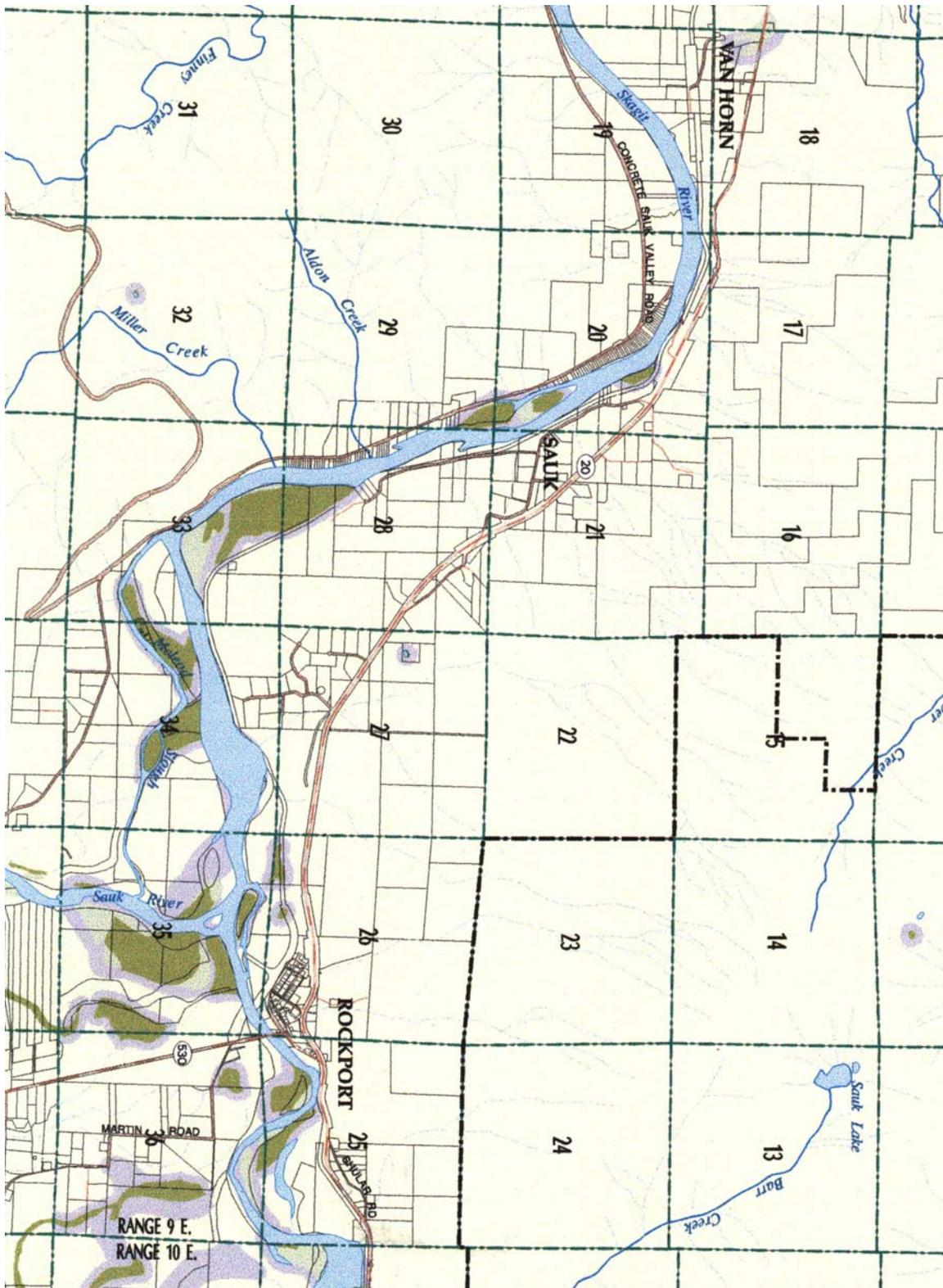
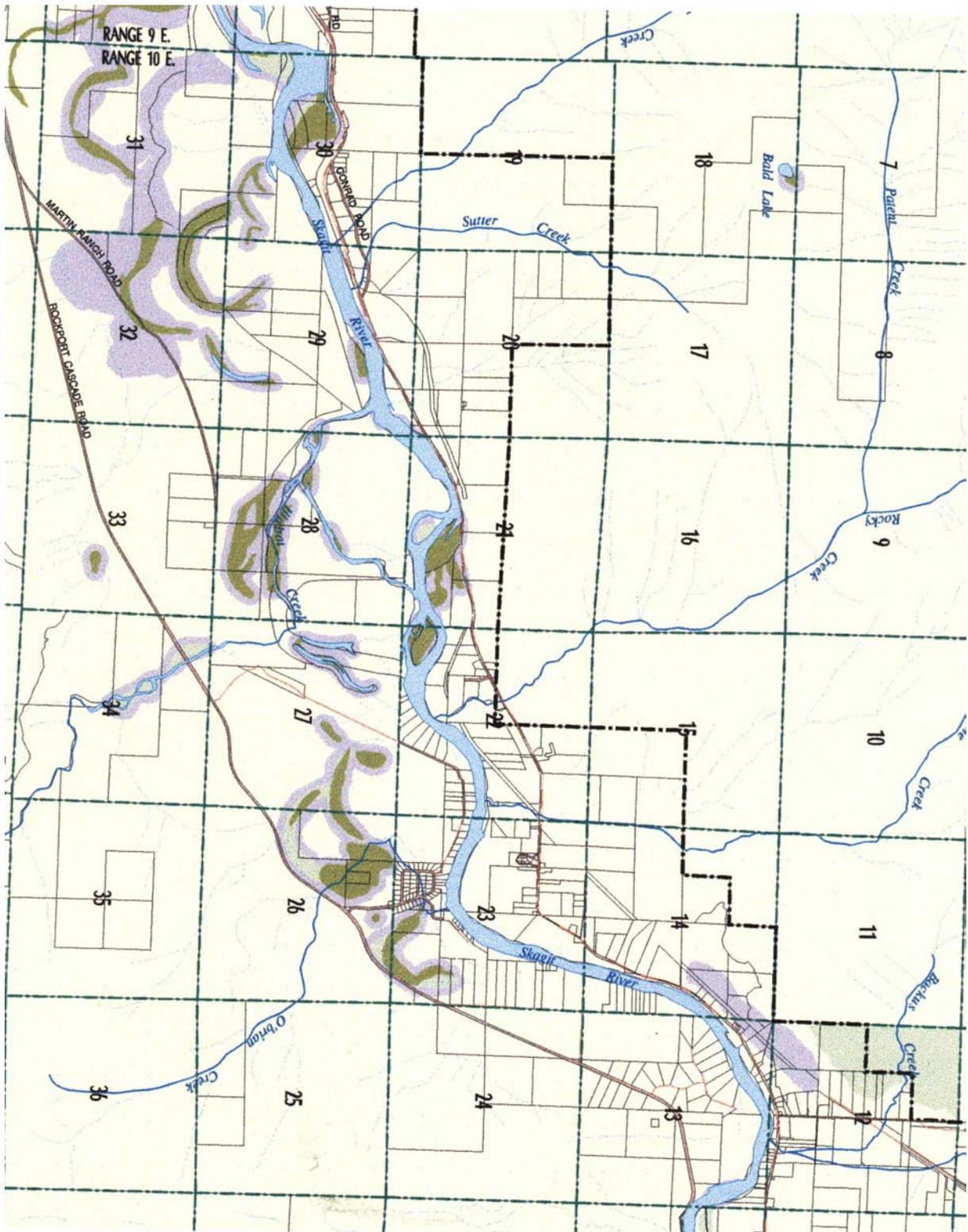


Figure 21. Wetland habitat (dark green) and hydric soils (light green) in the upper Skagit near Illabot Creek (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.



### Floodplain Habitat in the Baker Lake Sub-Basin

Historically the lower Baker River shifted across a broad floodplain that was associated with a hardwood swamp and a network of side-channels and wall-based tributaries (U.S. Forest Service 2002). The construction of two major dams in the Baker River sub-basin has completely altered historic floodplain conditions along the Baker River and the lower reaches of tributaries. Historic floodplain habitat has been converted into lake habitat, especially in the Lake Shannon area. And, although Baker Lake was a natural lake, its surface elevation was raised by 60' with the construction of the dam (Puget Sound Energy 2002). This inundated not only the lakeshores, but the lower reaches of tributaries to the lake. The estimated loss of habitat includes 52 miles of tributaries to the Baker River, 5 miles of side-channel habitat along the Baker River, and 117 acres of ponds and wetlands (U.S. Forest Service 2002).

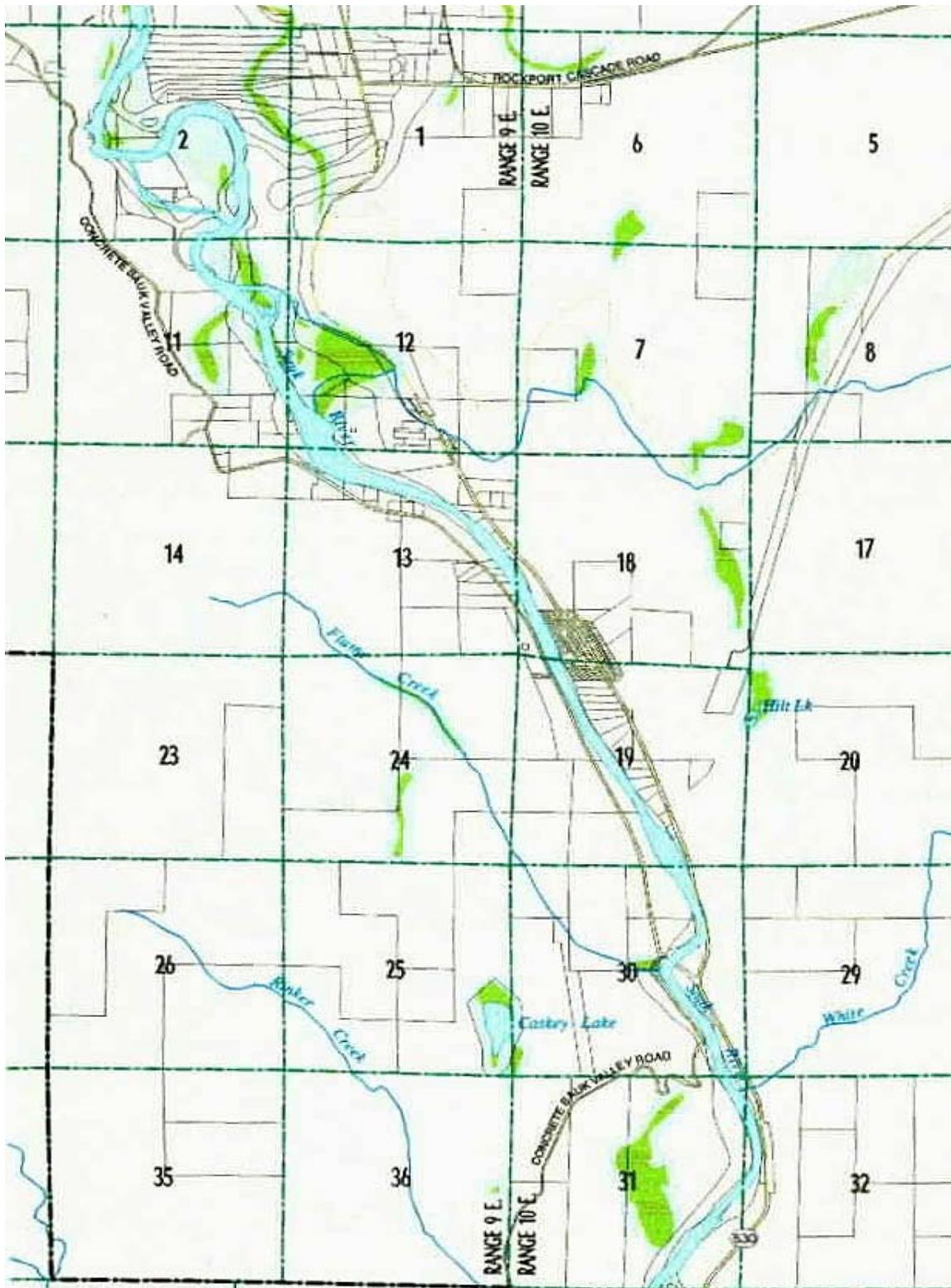
These alterations result in a “poor” rating for floodplain habitat of the mainstem Baker River. Specific floodplain conditions for the middle and upper reaches of the tributaries to Lake Shannon and Baker Lake are not well documented, but many of these tributaries are steep and have naturally limited floodplain habitat. The area is largely uninhabited, further decreasing the likelihood of typical floodplain impacts such as bank hardening. The floodplain conditions for the upper and middle reaches of the Baker River tributaries are “unknown”, but are likely not significantly impacted.

### Floodplain Habitat in the Sauk Sub-Basin

The Sauk River has 19.9 mi<sup>2</sup> of floodplain habitat, a relatively low quantity (Table 6). However, fairly extensive floodplain habitat exists along much of the lower twenty-two miles of the Sauk River (Map F1). In addition, floodplain habitat is moderately abundant along the Suiattle River from RM 0 to 4.7 and from RM 9.6 (Tenas Creek) to 22.3 (just upstream of Captain Creek). Unfortunately, the same areas with significant floodplain habitat have hydromodifications (Figure 10). The extent of hydromodification ranges from 0.2 to 0.6 percent (Table 7). Floodplain road density is 1.7 miles per square mile of floodplain habitat, which falls into the “fair” category (Table 6).

Similar to the upper Skagit River, important wetland complexes are primarily limited to areas immediately adjacent to the mainstem Sauk and Suiattle Rivers (Figures 13 and 14). Except in the limited wetland areas immediately adjacent to streams, soils are predominantly not hydric in the Sauk sub-basin, suggesting that historically, wetland habitat was not as abundant as in the lower Skagit sub-basin. Also, the differences between hydric soil areas and current, known wetlands are relatively low. This implies that wetland loss has not been a major impact in the Sauk River sub-basin. However the wetland complexes adjacent to streams are likely important habitat areas for salmonids and should be conserved.

Figure 22. Wetland habitat (bright green) and hydric soils (light green; rare) in the lower Sauk sub-basin (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.





## **Conclusions and Data Needs for the Skagit Basin Floodplain**

Historically, extensive floodplain habitat existed in the lower Skagit sub-basin. This type of habitat is vital for salmonid production and its loss is a major impact not only for the Skagit drainage, but also for Puget Sound because the Skagit River has been historically the largest producer of salmonids in the region. Projects that preserve functioning floodplain habitat throughout the mainstem Skagit, Sauk, and Samish Rivers should be a high priority action. Projects that restore or reconnect isolated floodplain habitat in these areas should also be a high priority.

While the extent of hydromodifications by channel length along the mainstem Skagit River is known, the impacts to salmonid habitat cannot yet be estimated. A better understanding of the importance of floodplain habitat to salmonid production is needed along with an estimate and prioritization of lost floodplain area.

Other types of potential impacts needing further understanding are various types of development within the floodplain such as roads that impede channel movement and how development impacts hydrologic connections. The road density estimates suggest that considerable impact is likely along the entire anadromous reaches of the mainstem Skagit River and while development within the Sauk floodplain is lower, it is still a concern.

## **Floodplain Conditions in the Samish Basin and Edison Slough**

Abundant floodplain habitat once existed in the Samish Basin with an estimated 56 square miles of area (Table 6). The majority of floodplain habitat is in the lower Samish sub-basin, downstream of Friday Creek and along the south side of Thomas Creek (Map F1). Edison Slough is also part of the extensive floodplain area of the lower Samish. It is apparent from Maps F1 and F2 that much of this habitat has been developed into farms and residences.

Extensive diking exists along the lower five miles of the Samish River as well as along unnamed stream 03.0006 and the lower 1.3 miles of Edison Slough (Map F2). However, quantification of hydromodifications upstream of this area has not been done. This is a high priority data need. It is known that continuous dikes exist along both sides of the Samish River from RM 0 to 5 with intermittent dikes from RM 5 to 12 (Phinney and Williams 1975). The lower mile of Friday Creek is also diked.

Hydric soils predominate in the middle and lower Samish River basin, yet current, known wetlands are very small in comparison (Figures 15 and 16) (data from Skagit County, using NWI data coupled with aerial photos). The major land use in this area is agriculture, and draining and filling of wetlands has been known to occur. The wetland loss has not been quantified, but is likely extensive. Hydric soils are also common in the lower and middle reaches of Thomas Creek, with few wetlands mapped. Dry, Parson, and Friday Creeks have much less area covered by hydric soils, but a large wetland exists along upper Friday Creek, and is bisected by Interstate 5 (Figure 17).

## **Conclusions for Floodplain Conditions in the Samish Basin**

Floodplain conditions for the Samish sub-basin are tentatively rated “poor” due to extensive diking along the lower reaches, a high road density within the floodplain area, and large differences between hydric soil areas and current, known wetlands. While it is visually apparent that considerable floodplain impacts have occurred within the Samish Basin, quantification of those impacts and their effect on salmonids have not been analyzed. This includes the potential impact of dikes, filling, draining, and development within the Samish floodplain. Because the Samish River is an important coho salmon producer, floodplain habitat is especially important. Understanding the floodplain impacts and prioritization of areas for protection and restoration should be a high priority data need.

**Link to Map F2. Documented dikes along salmonid bearing streams in WRIA 3 (data from Joshua Greenberg, Skagit County GIS, 2003).**

This map is in a separate file

Figure 24. Wetland habitat (dark green) and hydric soils (light green) in the lower Samish sub-basin (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.

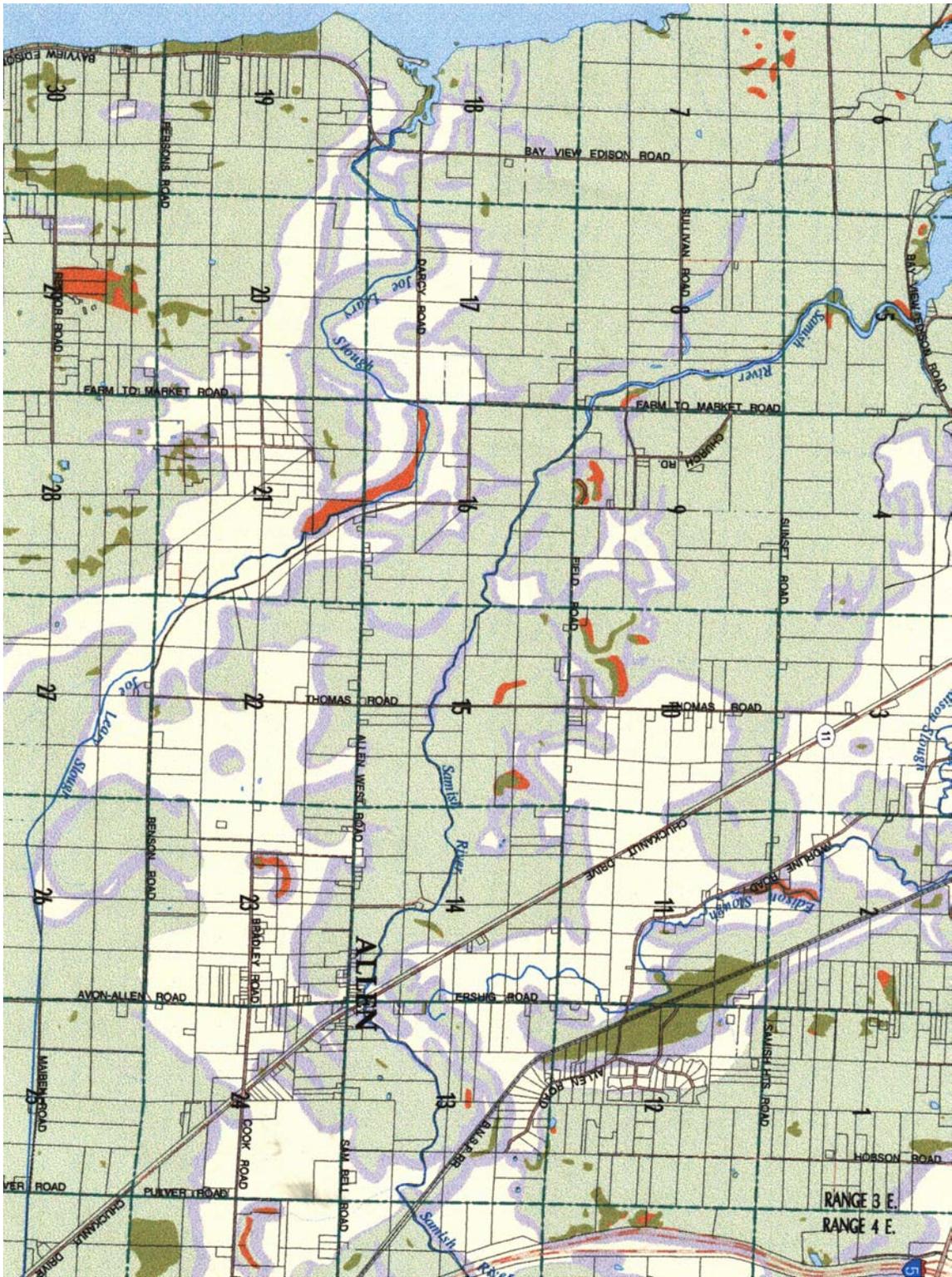


Figure 25. Wetland habitat (dark green) and hydric soils (light green) in the middle Samish sub-basin (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.

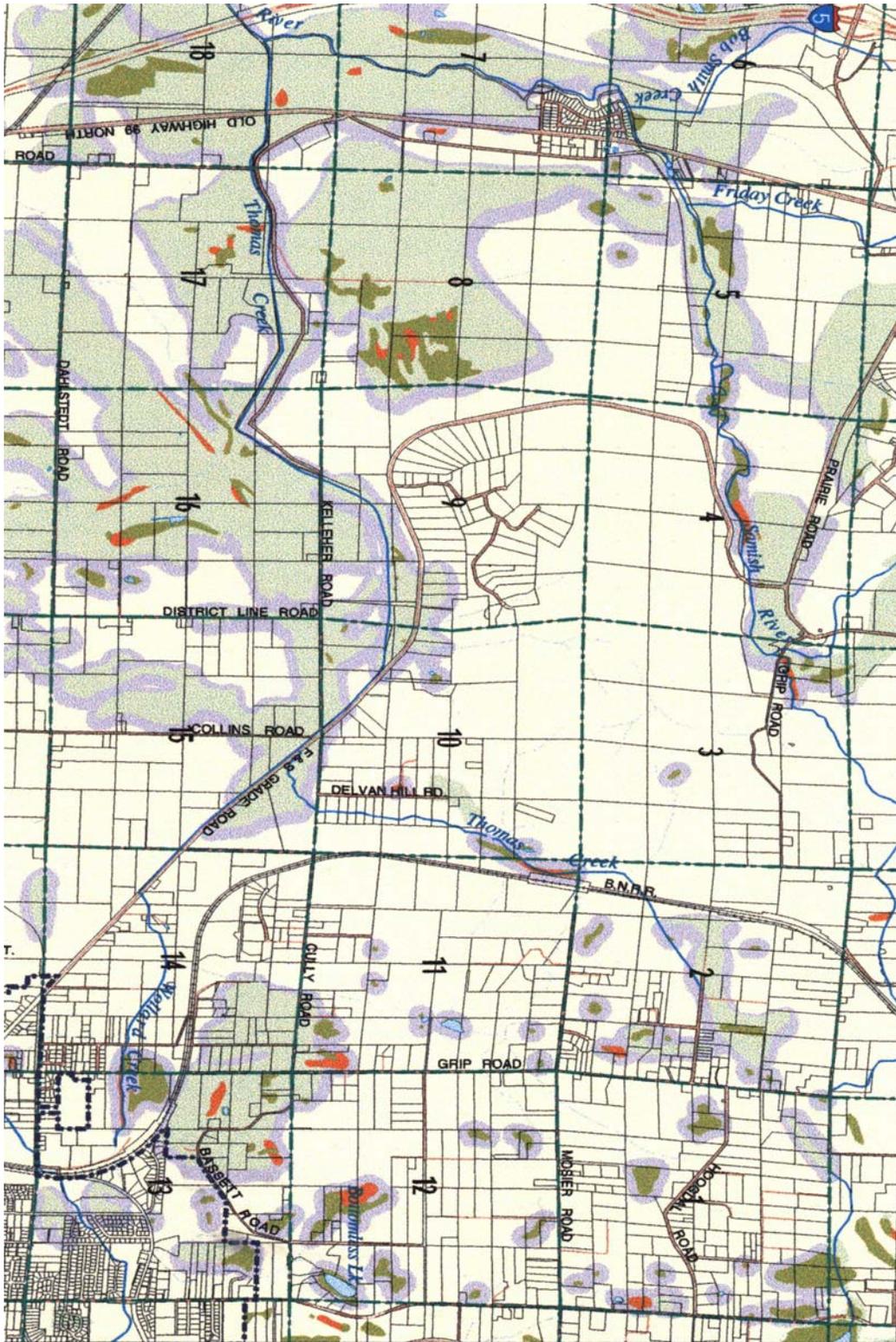
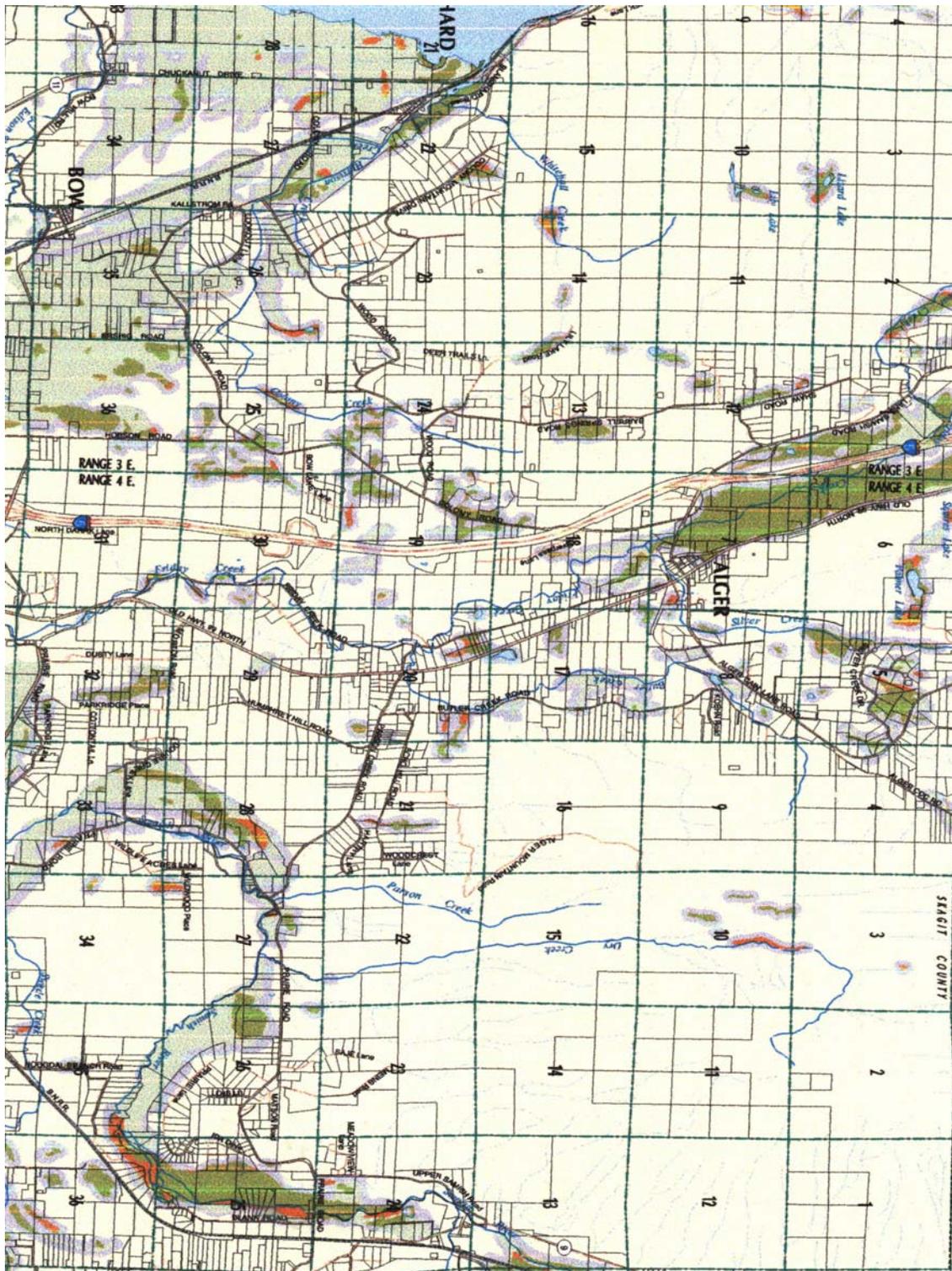


Figure 26. Wetland habitat (dark green) and hydric soils (light green) in the Friday Creek sub-basin (Skagit County Geographic Information Services 2002). The dark green areas represent data from the National Wetlands Inventory.



## Streambed and Sediment Conditions in WRIs 3 and 4

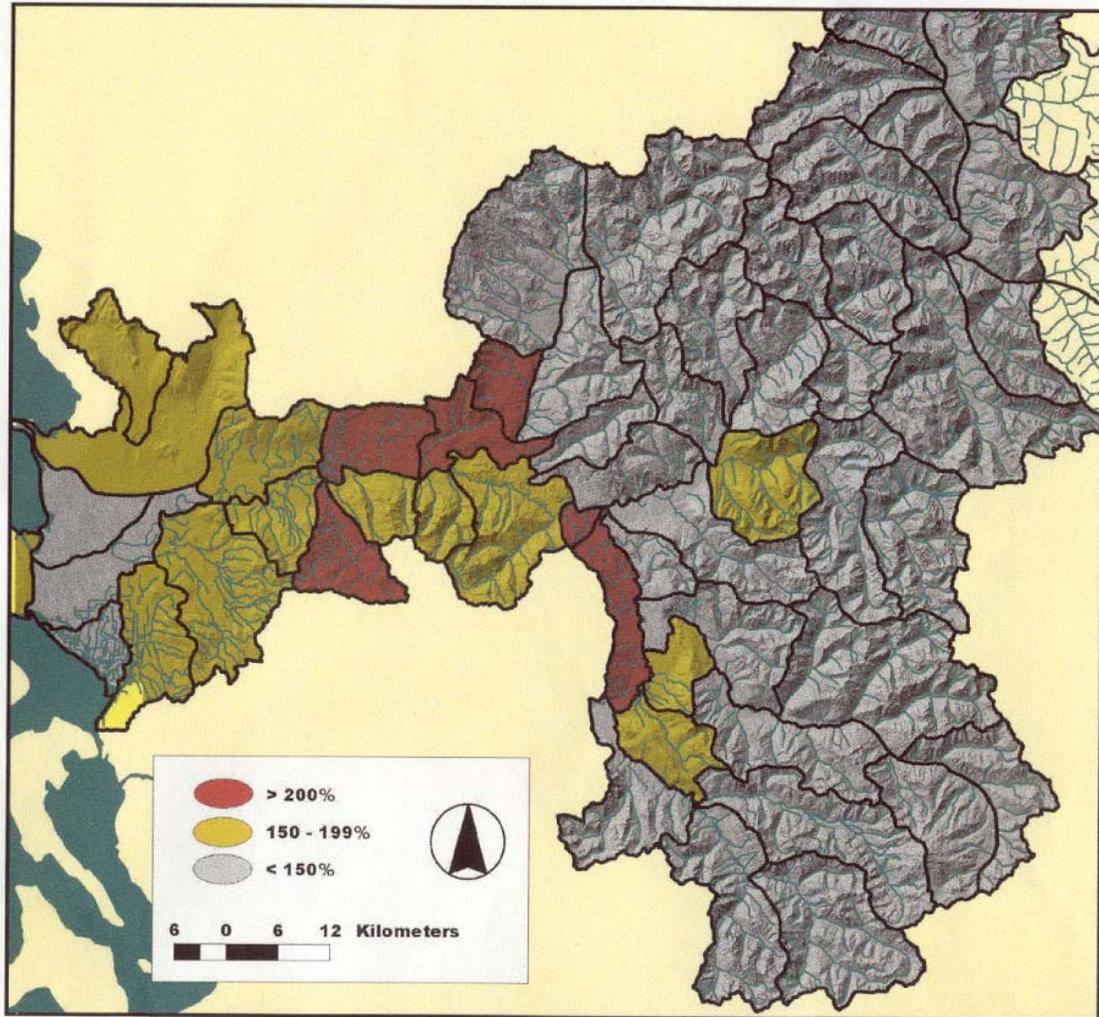
### Introduction

Changes in the inputs of fine and coarse sediment to stream channels can have a broad range of effects on salmonid habitat. Increases in coarse sediment can create channel instability and reduce the frequency and volume of pools, while decreases can limit the availability of spawning gravel. Increases in fine sediment fill pools, lower the survival rate of eggs deposited in the gravel (through suffocation), and lower the production of benthic invertebrates. As part of this analysis, increased sediment input from landslides, roads, and agricultural practices is examined, as well as decreased gravel availability caused by dams and floodplain constrictions. This chapter also assesses instream habitat characteristics that are related to sedimentation and sediment transport, such as bank stability and erosion, large woody debris (LWD), and pool habitat.

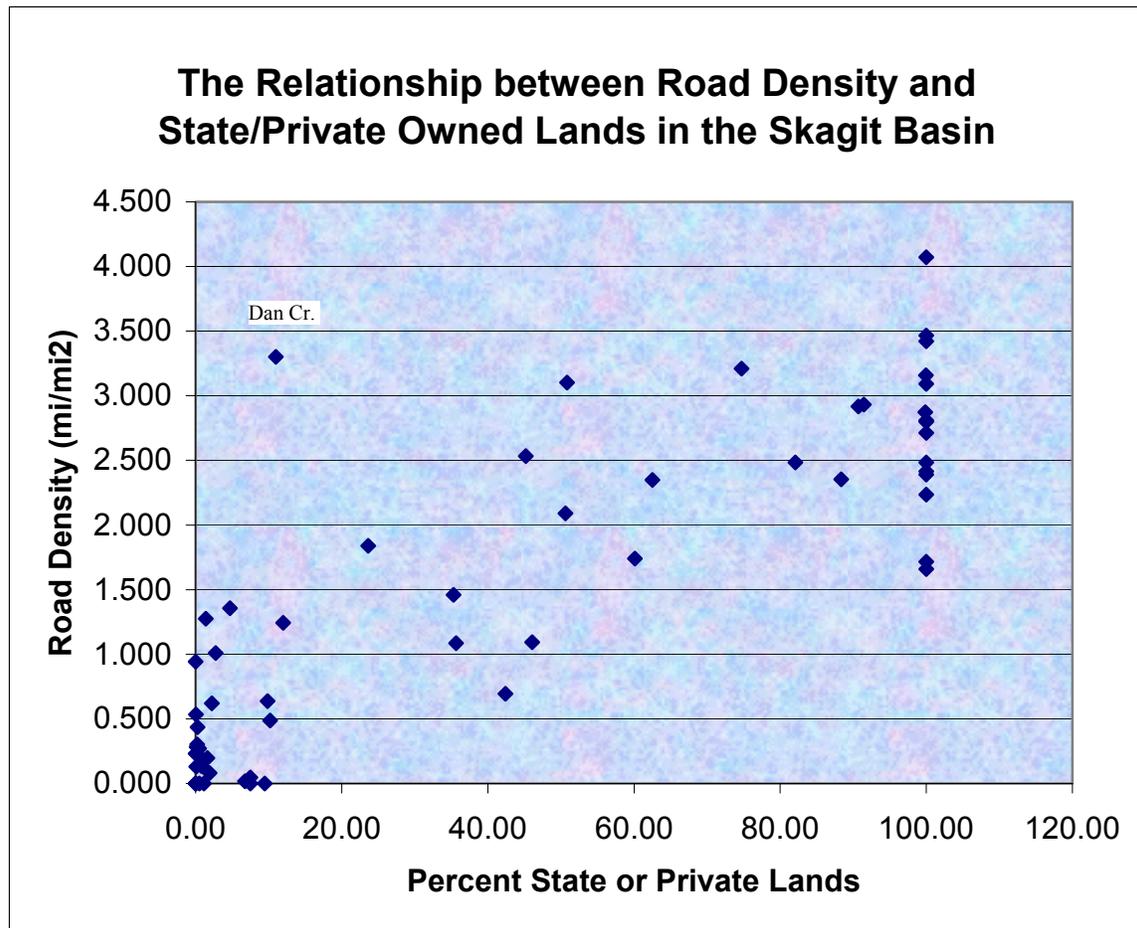
Unfortunately, few analyses were found describing streambed and sediment conditions in the Skagit and Samish Basins, especially for sediment quality conditions, pool habitat, and instream levels of LWD. Although sedimentation rates have been modeled, the specific sources of excess sediment have not been identified in most areas, and more field-based assessments are needed. The two primary types of data available for this chapter include road densities and estimated sediment supply rates, usually on a WAU scale. The sediment supply rates were updated in 2003 (Beechie and Feist, NMFS, unpublished data), and are based upon natural sediment supply rates as derived from geology (Paulson 1997) multiplied by a land use factor based upon land cover vegetation, such as seral stage and clearcuts (Beamer et al. 2000). This methodology was chosen because clearcuts and roads can increase sediment supply rates from an average of 4 to 45 times over natural rates (Paulson 1997). In the limiting factors analysis, clearcut conditions are included in the sediment supply rates, and road density values are summarized separately.

In general, the estimated sediment supply rates suggest that excess sedimentation is a major problem in many of the watersheds within the lower Skagit sub-basin and in limited areas of the Sauk River sub-basin (Figure 18). Better conditions have been modeled in the upper Skagit sub-basin, most of the Baker sub-basin, and much of the Sauk sub-basin where significant federal land ownership exists. When road density is correlated to the percentage of private and state-owned lands on a WAU scale, the Pearson product moment correlation coefficient is 0.85, indicating a strong relationship between a common cause of sedimentation (roads) and the percentage of state and private owned lands (Figure 19). Graphs of this relationship, as well as other detailed sedimentation, LWD, and pool data are described in detail below.

**Figure 27. Estimated sediment supply rates in the Skagit and Samish Basins (Beechie and Feist, NMFS, unpublished data).**



**Figure 28. The relationship between road density (mi/mi<sup>2</sup>) and the percent of state and privately owned land on a WAU scale (raw data from Lunetta et al. 1997). The Person product moment correlation coefficient is 0.85 with a p<0.0001. Dan Creek is labeled because it is an outlier (but was still included in the analysis).**



Streambed and Sediment Conditions in the Lower Skagit Sub-Basin

Sediment supply rates have been recently modeled with rates at 200% or more above natural conditions in the Miller, Day, Alder, and Grandy WAUs (Figure 18) (Beechie and Feist, NMFS, unpublished data). These WAUs are rated “poor” for sedimentation. In addition, the following WAUs are also rated “poor” for sediment supply rates even though they have lower (150 to 199% over natural) but still excessive modeled rates. These include the Nookachamps, Hansen, Finney, Loretta, and Gilligan WAUs (Figure 18). Two lower Skagit WAUs had modeled rates that did not seem to match observed conditions. These include the Presentin and Jackman WAUs. The Presentin WAU had an estimated sediment supply rate of 150 to 199% above natural, which would result in a “poor” rating, while the Jackman WAU had a modeled rate of less than 150% (“good”).

Because observed conditions suggest that Presentin should be rated “good” and Jackman should be rated “poor”, they are flagged as unknown until data are collected specific to these areas. The remaining lower Skagit WAUs are in the delta area, where other sedimentation issues (surface erosion, loss of habitat complexity, and dredging/ditching) are problems, and where data are greatly needed to clarify sediment and streambed conditions (see Estuary Chapter).

Road density estimates are available on a WAU scale and are shown in Figure 20 (data from Lunetta et al. 1997). Using NMFS standards (see Assessment Chapter), only one WAU (Presentin) in the lower Skagit sub-basin rates “good” for road density. Several WAUs have a “fair” rating, including the Nookachamps, Hansen, Loretta, Gilligan, Miller, Jackman, and Day Creek WAUs. The Alder, Grandy, and Finney Creek WAUs have overall road densities that rate “poor”. However, a watershed analysis for Finney Creek has further refined road densities to result in a “poor” rating for non-federal lands and a “fair” rating for federal lands (U.S. Forest Service 1999).

In the Hansen WAU, landslides have contributed most (90%) of the sediment to streams with surface erosion from logging roads contributing only 10% (DNR 1994). Most (95%) of the landslides are shallow rapid and debris torrents, and all are located upstream of the Highway 20 crossing (DNR 1994). Recent timber harvest (clearcuts) accounts for 40% of the landslides with 27% associated with roads. In addition to landslides, local inputs of fine sediment from cattle access to streams occur in this WAU. The percent of fine sediments has been high (>17%) throughout Hansen Creek with lower “fair” levels in Jones Creek (DNR 1994). The high sediment loads are thought to result in decreased pools, and increased water temperatures, channel instability, and aggradation/scour (DNR 1994). Streambed aggradation and dredging activity are known in lower Red, upper Hansen, middle Coal, middle Wiseman, lower Childs, and lower Jones Creeks (DNR 1994).

Instream LWD is lacking throughout much of Hansen Creek and its tributaries with “poor” ratings assigned to 8 out of 10 sampled areas (DNR 1994). The decreased levels of LWD have resulted in reduced pool habitat. The percent of area occupied by pools has been rated “poor” in 9 out of 10 sampled reaches of Hansen Creek. Lower and upper Jones Creek were also assessed for LWD and were rated “good” in the watershed analysis. Jones Creek had one “poor” reach and one “fair” reach for percent pool habitat (DNR 1994).

Although natural sedimentation levels are high in the Finney Creek watershed, human-caused landslides have greatly increased sediment delivery to lower Finney Creek. Most of the landslides originate from the tributaries to lower Finney Creek or from upper Finney Creek (U.S. Forest Service 1999). The majority (64%) of the landslides are inner gorge failures, and 52% of these are associated with clearcuts with 14% related to roads. Many of the shallow, rapid slides become debris torrents or dam breaks during rain-on-snow events, damaging streambed and channel conditions.

Sediment delivery rates to Finney Creek have been the greatest from 1988 through 1991 (U.S. Forest Service 1999). These levels are six times higher than pre-1940 and two

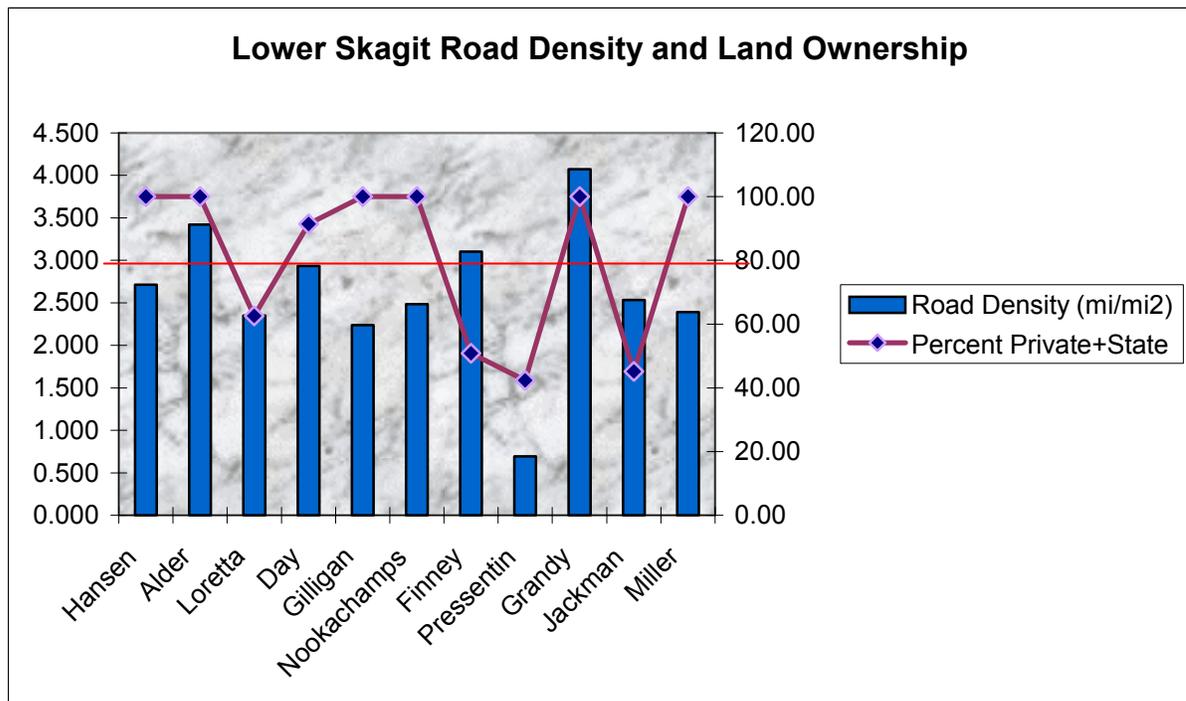
times greater than rates from 1956 through 1979. The high rates correspond to timber harvest in the Quartz, Hatchery, and Ruxell Creek watersheds (U.S. Forest Service 1999).

Roads have been associated with 14% of the landslides in Finney Creek, and road densities are high in the drainage with an average of 2.5 mi/mi<sup>2</sup> (“fair rating”) on National Forest lands and greater than 4.5 mi/mi<sup>2</sup> (“poor”) on private lands. Although more than 33 miles of roads have been decommissioned within the National Forest boundaries since 1986, further road projects that reduce sediment delivery to Finney Creek are needed on non-federal lands once a risk assessment has been completed for existing roads.

Other habitat impacts noted in Finney Creek include a lack of LWD, potential scour, a reduced number of pools, and shallower pools (U.S. Forest Service 1999). No estimates were provided for LWD, scour, and pool conditions, and because of this, they are rated as “unknown, but likely poor”.

In the nearby watersheds, Day Creek was noted as having fewer and shallower pools, and Mill Creek as having mass wasting and road failures. These statements appeared to be based upon observations, and data are needed to clarify the sources and extent of the problems.

**Figure 29. Road density and the percentage of state and privately owned lands on a WAU scale in the lower Skagit sub-basin. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>. Presentin is the only WAU in the lower Skagit sub-basin with a “good” road density rating.**



### Streambed and Sediment Conditions in the Upper Skagit Sub-Basin

Using estimated sediment supply rates, all but one WAU in the upper Skagit sub-basin rated “good” with rates of less than 150% over natural rates (Figure 18). The “poor” rated WAU is Jordan/Boulder in the lower Cascade drainage, which had an estimated sediment supply rate ranging from 150 to 199% over natural rates (Beechie and Feist, NMFS, unpublished data). Road density values are all rated “good” in the upper Skagit sub-basin when examined on a WAU basis, although higher road densities were strongly associated with state and private land ownership (Figures 21 and 22). Higher (“poor”) road densities were recorded in Shoemaker Creek and parts of the lower Cascade system, when watersheds were examined individually under a watershed analysis (DNR 1995).

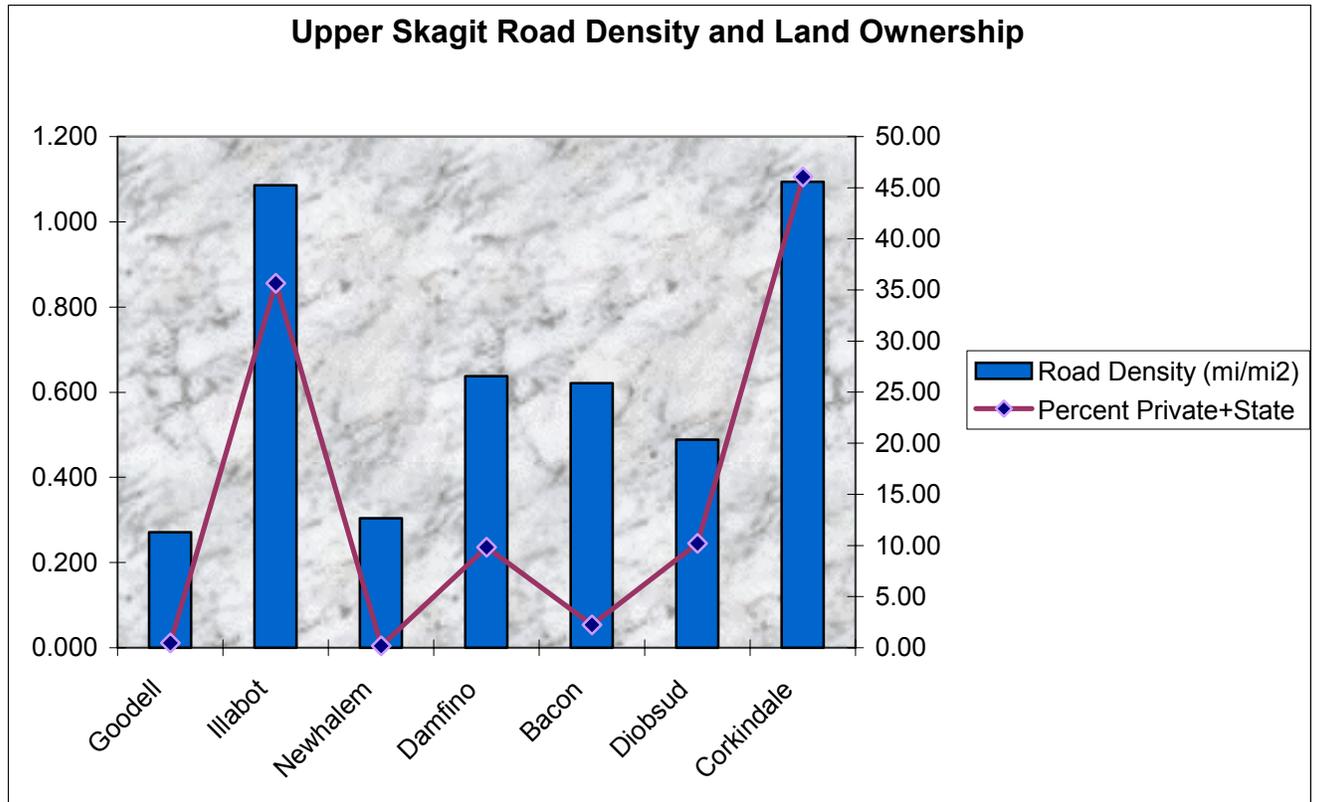
The only “poor” rated WAU for sediment conditions in this sub-basin is the Jordan/Boulder WAU in the lower Cascade drainage. In this WAU, landslides are common and most (53%) of the inventoried landslides have been associated with roads (DNR 1995). Clearcuts accounted for an estimated 13% of the documented landslides. Only a small portion of the WAU was examined for mass wasting (landslides), and a total of 181 slides were found in this small sampled area. Most (72%) were shallow rapid slides, of which 41% developed into debris flows (DNR 1995). Many (49%) delivered sediment directly to streams of order 3 or greater.

The excess sedimentation in the lower Cascade drainage has resulted in channel widening and aggradation in the alluvial fans of Jordan, Shoemaker, and Nugget Creeks (DNR 1995). The channel widening has impacted riparian vegetation, which has further decreased stability. These areas are also degraded by dredging and diking (DNR 1995). Landslides have also degraded riparian conditions in the upper portions of Shoemaker, Nugget, and the Muddy Fork of Jordan Creek.

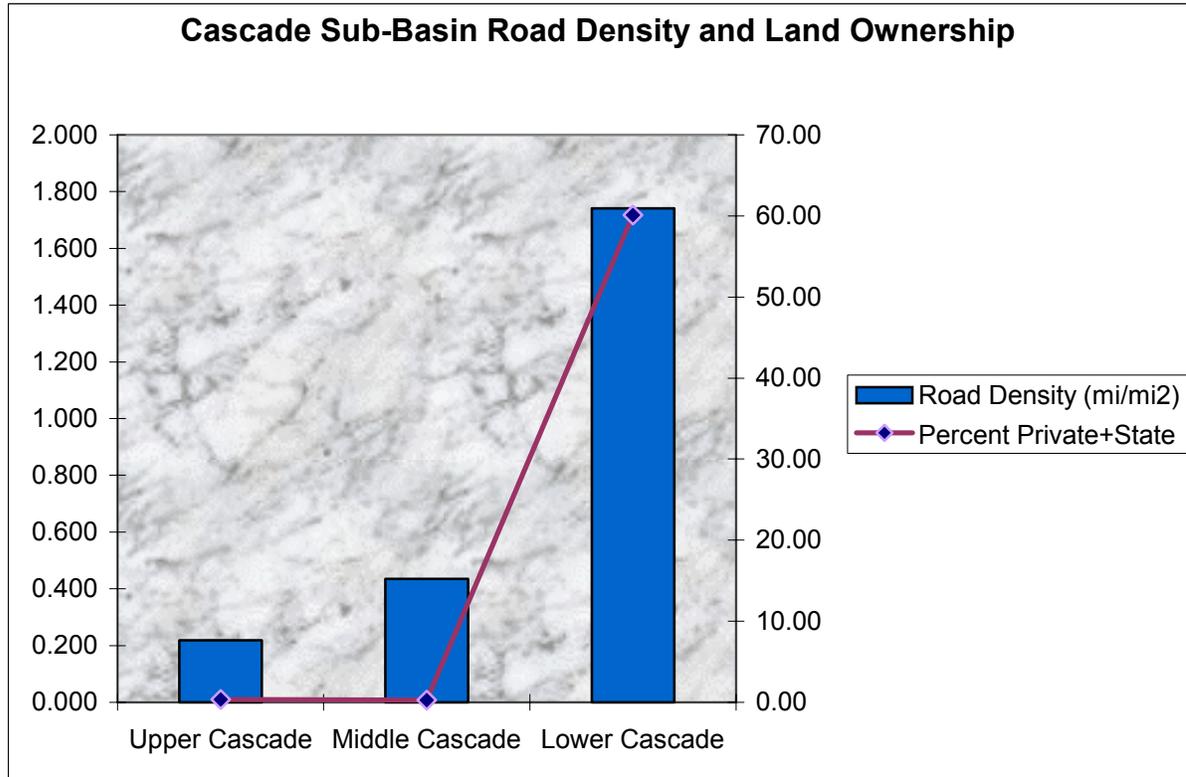
Fine sediments were sampled in parts of the Jordan/Boulder WAU with “poor” levels in Day, Nugget, and Razorback Creeks (DNR 1995). “Good” levels were found in Boulder, Irene, and Lookout Creeks. Mostly coarse sediment was noted in Jordan Creek (DNR 1995).

Limited sampling of pool habitat and instream LWD has been done in the Jordan/Boulder WAU, and most areas that were sampled are low in both. The percent pool habitat was “poor” in Jordan (0%), Shoemaker (0%), lower Irene (23%), Lookout (0%), Day (0%), and lower Razorback Creeks (DNR 1995). Pool habitat was rated “good” in lower Boulder Creek. Instream LWD was “poor” in Jordan, Lookout, Monogram, Shoemaker, Day, and Razorback Creeks with only one segment in Irene Creek rating “fair” (DNR 1995). No samples had “good” levels of LWD. Although the lower mainstem Cascade River was not sampled for pool habitat and LWD levels, it was noted that both were generally low (DNR 1995).

**Figure 30. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>. All WAUs in this area had “good” road densities.**



**Figure 31. Road density and the percentage of state and privately owned lands on a WAU scale in the Cascade River drainage. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>. All WAUs in this area had “good” road densities, although higher road densities were found in the lower Cascade (Jordan/Boulder) WAU that had considerably more private and state owned lands.**



Streambed and Sediment Conditions in the Sauk Sub-Basin

The Sauk River sub-basin has naturally high levels of sedimentation from landslides and glacial inputs. Although 1293 landslides have been identified in the Sauk River sub-basin (not including the White Chuck and Suiattle Rivers), less than 10% of them are human-caused (U.S. Forest Service 1996). Most (71%) of the landslides are located in the Sauk River watershed downstream of the Forks, and about 20% of these are human-related (U.S. Forest Service 1996). The remainder (29%) are in the Forks drainages where only 1% are human-caused. Of the human-caused landslides, 82% were associated with clearcuts and 17% with roads.

Only one WAU (Rinker) in the Sauk sub-basin had a greater than 200% above background sediment supply (Figure 18) (Beechie and Feist, NMFS, unpublished data). Two other WAUs (Dan and Sauk Prairie) had estimated rates ranging from 150-199% over natural sediment supply rates. These three WAUs are rated “poor” for sediment supply rates. All other WAUs are tentatively rated “good” with the exception of the

Tenas and Lime Creek WAUs, which are rated as unknown. There is concern that sediment conditions in the non-federal portions of these WAUs are likely impaired. Additional analysis is needed to determine sediment supply rates and sources within WAUs with divergent land ownership.

Roads are a particular concern in the Everett, Rinker, and Dan Creek watersheds and in the Sauk River reach downstream of the White Chuck River (U.S. Forest Service 1996). This is due to a road density of greater than 2.5 mi/mi<sup>2</sup> on unstable geology. These drainages are rated “poor” for road density. A “poor” rating for road density is also assigned to the lower Sauk and its tributaries such as Hilt and White Creeks because of a density greater than 3 mi/mi<sup>2</sup>. These road density estimates were done on a watershed scale (U.S. Forest Service 1996), while those shown in Figure 23 are a coarser WAU scale (Lunetta et al. 1997). The WAU scale data are only used in the road density ratings where finer scale data are not available. It is noteworthy that Dan Creek is the only WAU in the entire Skagit Basin that has a high road density and low percentage of private or state-owned lands (Figure 19).

The Sauk River watershed in the area of Murphy, Goodman, Swift, and Falls Creeks is rated “fair” for road density due to an overall density of 2 mi/mi<sup>2</sup> (U.S. Forest Service 1996). Other “fair” rated watersheds include Prairie, lower Clear, Helena, Murphy, and Goodman Creeks and the Sauk River reach just downstream of the Suiattle River confluence. These areas have less than 2.5 mi/mi<sup>2</sup> roads on unstable geology.

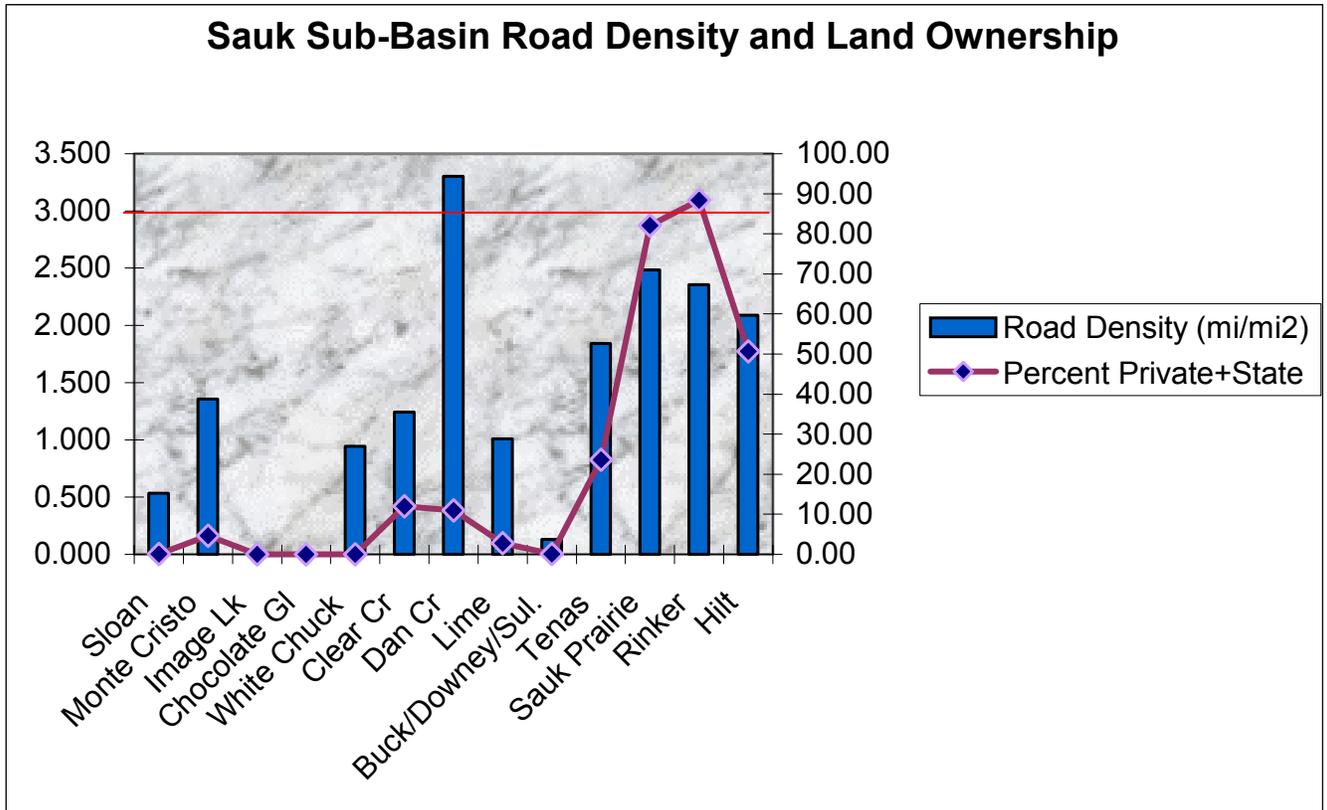
Watersheds with a “good” rating for road density include the South Fork Sauk (0.4 mi/mi<sup>2</sup>), North Fork Sauk (0.1 mi/mi<sup>2</sup>), Sloan Creek (0.4 mi/mi<sup>2</sup>), and Clear Creek (0.8 mi/mi<sup>2</sup>) (data from U.S. Forest Service 1996). In addition, all of the WAUs that comprise the White Chuck and Suiattle drainages are rated “good” for road density with estimates below 2 mi/mi<sup>2</sup> (Figure 23) (data from Lunetta et al. 1997). However, the road density estimate for the Tenas WAU is approaching the “fair” range and because it is under divergent land ownership, it would be more appropriate to examine sediment conditions on a finer scale.

High flows combined with sedimentation, dikes, and a lack of LWD have resulted in filled pools, scour, and channel changes in the Sauk Prairie and lower Dan Creek area (U.S. Forest Service 1996). Streambed aggradation has been observed but not measured in the lower four miles of the Sauk River (U.S. Forest Service 1996). Studies are needed to determine the extent and causes of these possible impacts.

Low levels of instream LWD are found throughout much of South Fork Sauk River and in the Sauk River from 36.2 to the Forks (U.S. Forest Service 1996). Reaches with “good” levels of LWD include RM 31.9 to 36.2 in the Sauk River and RM 6.2 to 8.4 in the South Fork Sauk River. “Good” levels of LWD were also measured in Dan, Murphy, Goodman, and Peek-a-Boo Creeks (U.S. Forest Service 1996). No estimates of LWD levels were found for the Sauk River downstream of RM 31.9 and in the tributaries other than those listed above.

Pool habitat characteristics were assessed in the Sauk River watershed analysis. This included measurements of pools per mile, pool spacing, and percent pool habitat, and each of these were assigned a “poor”, “fair”, “good” rating within the Forest Service (1996) analysis. Using that analysis, pool habitat is generally “poor” in the mainstem Sauk from RM 31.9 to 39.7, “poor” to “fair” in the South Fork Sauk with one “good” segment (RM 6.2 to 7), and generally “poor” in Dan, Murphy, Dutch, Lyle, and Peek-a-Boo Creeks (U.S. Forest Service 1996). Pool habitat was “fair” in lower Goodman Creek and from RM 0.5 to 0.8 in Murphy Creek. Of even more concern is the possible decrease in pool area over time. In comparing the percent pool area measured in 1984 to the early 1990s, there is an 82% decrease in Dan Creek, 80% decrease in Murphy Creek, 22% decrease in Goodman Creek, 90% decrease in Lyle Creek, and a 74% decrease in Peek-a-Boo Creek (U.S. Forest Service 1996). Some of this decrease might be to a difference in methodology, but overall, the decline is considerable and warrants further investigation.

**Figure 32. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>.**



### Streambed and Sediment Conditions in the Baker River Sub-Basin

Only 149 landslides were documented in the Baker River sub-basin (Paulson 1999), and in general, road density is relatively low at less than 2% of the area (U.S. Forest Service 2002). However, 26% of the landslides were associated with roads, and road-related landslides increased sediment delivery to streams or lakes by 21 fold in the Baker Lake drainage and 150 fold in the Shannon Lake drainage compared to delivery from landslides in mature forest. This compares to sediment delivery from landslides associated with clearcuts being 10 times higher than mature forest in the Baker River drainage and 19 fold higher than mature forest in the Shannon Lake area (U.S. Forest Service 2002).

Road-related sediment is a major concern in the Baker sub-basin based upon the sediment delivery information. While the Shannon West WAU has an overall road density that is in the “fair” range (Figure 24) (Lunetta et al. 1997), road densities on a finer scale show some watersheds with high (“poor”) road densities, including Morovitz (4.1 mi/mi<sup>2</sup>), lower Sulphur (3.6 mi/mi<sup>2</sup>), and Little Sandy (3.3 mi/mi<sup>2</sup>) Creeks (U.S. Forest Service 2002). “Fair” road density levels (2 to 3 mi/mi<sup>2</sup>) are found in the Lake Shannon, South Fork Thunder, lower Rocky, Baker Lake, lower Sandy, and lower Swift watersheds (data from U.S. Forest Service 2002). “Good” rated watersheds for road density include Thunder, Watson, Bear, upper Rocky, upper Sulphur, Welker, Anders, Silver, Noisy, Dillard, upper Sandy, Boulder, Park, upper Swift, Shuksan, Hidden, Baker, and Sulphide Creeks. Some road decommissioning has occurred on National Forest lands.

In the Baker River sub-basin, all but one WAU (Shannon West) is rated “good” for estimated sediment supply rates (Figure 18). Shannon West is rated “poor” due to a modeled rate of greater than 200% above natural rates (Beechie and Feist, NMFS, unpublished data), and this region has experienced heavy timber harvest on naturally unstable soils (U.S. Forest Service 2002). Outside of the Shannon Lake area, the Baker sub-basin has had moderate timber harvest levels that peaked in the 1960s. Extensive, intact mature forests exist in unroaded and wilderness areas (U.S. Forest Service 2002).

Natural sedimentation is influenced by glacial runoff for six months of the year, especially in Swift, Boulder, and Park Creeks, and the upper Baker River (U.S. Forest Service 2002), and the upper Baker River carries 18,500 cubic yards per year of bedload material (Geo Engineers 1984). Naturally high sediment loads are found in Swift, Park, Boulder, Rocky, and Sandy Creeks. In addition, the high precipitation levels (averages 150”/year on the Mt. Baker slopes) have triggered debris and snow avalanches and debris torrents and slides. The naturally high sediment load has resulted in numerous channel shifts in the low gradient reaches of the Baker River from RM 23 downstream (U.S. Forest Service 2002).

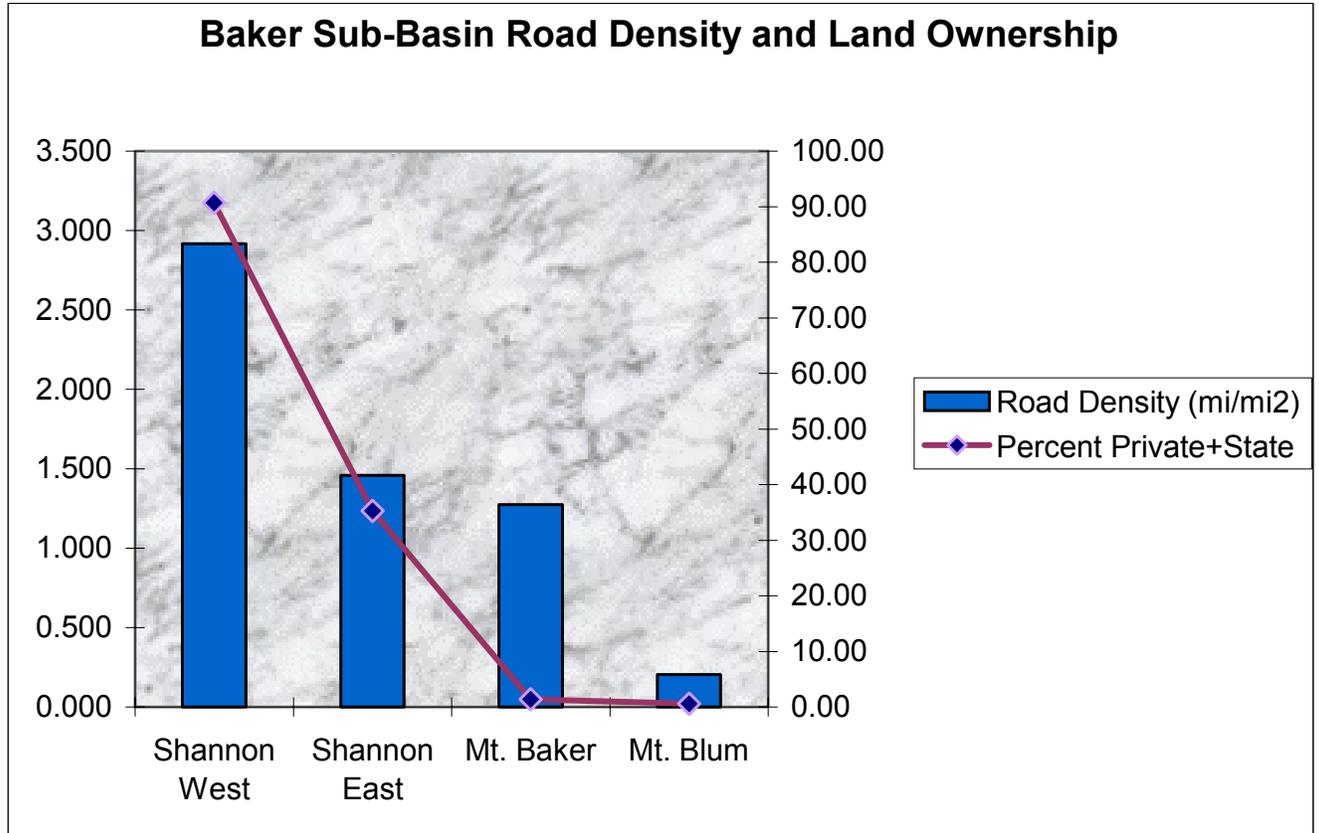
The delta where the Baker River enters the reservoir is also unstable, due at least partially to hydroelectric operations (U.S. Forest Service 2002). The shifting of the Baker River has impacted the two artificial spawning beaches at the upper end of Baker Lake (Puget Sound Energy 2002). In addition, the dam has increased the elevation of Baker Lake causing the Baker River to deposit sediment further upstream, creating a new delta (U.S. Forest Service 2002). The shoreline soils around both reservoirs are exposed to increased

erosive forces from the water fluxes that occur during flood storage and hydroelectric operations. The changing depth of the reservoirs results in a 50' elevation of shoreline soils that are exposed to erosion. For these reasons, sediment conditions around Baker Lake, Lake Shannon, and near the deltas to the lakes are rated "poor".

There is a mix of LWD and pool conditions in the Baker River tributaries. Using NMFS pool criteria of 26 pools per mile as "good", and applying that standard to the U.S. Forest Service data collected in the early 1990s, Beaver, Little Sandy, lower Shuksan, and most of Rocky Creek are rated "good" (data from the U.S. Forest Service 2002). Except in one reach of Swift Creek, much of the pool per miles values were well below the NMFS standard in Morovitz, Park, and Swift Creeks. These streams are rated "poor" for pool conditions.

Using the Forest Service standard of 80 pieces of LWD per mile as "good", most of Shuksan, Rocky, and Park Creeks had "good" levels of LWD (U.S. Forest Service 2002). Numbers of LWD were lower in Little Sandy, Morovitz, and lower Swift Creeks, ranging from 52 to 75 pieces per miles. This results in a "fair" rating for LWD in these streams. In addition to LWD levels within the tributaries, LWD transport through the Baker River and into the Skagit River has been greatly altered by the two dams and resulting reservoirs (U.S. Forest Service 2002).

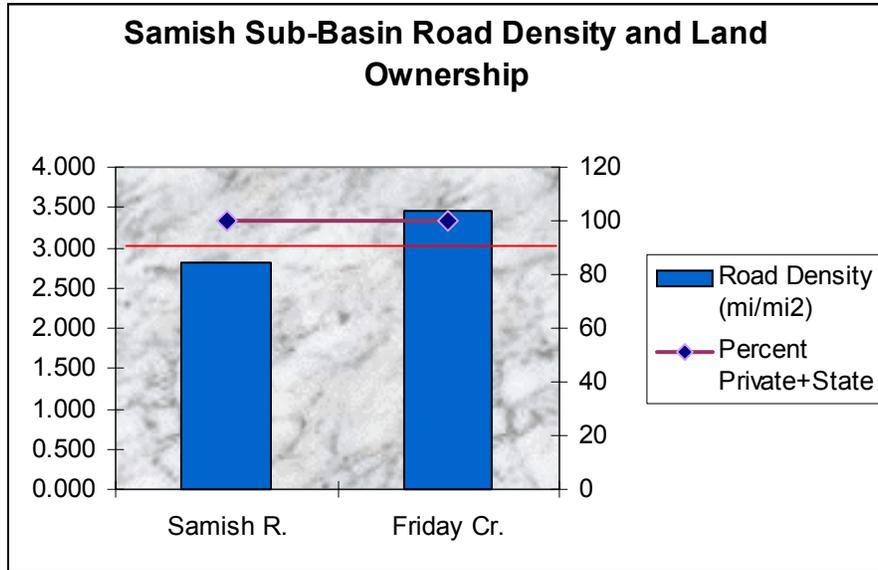
**Figure 33. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>.**



Streambed and Sediment Conditions in the Samish Sub-Basin

Data regarding sediment and streambed conditions in the Samish Basin are sparse. No data regarding pools, LWD, sediment quality, and sediment sources were found. A tentative rating of “poor” is assigned to the Samish and Friday Creek WAUs based upon estimated sediment supply rates. The modeled sediment supply rates in these WAUs range from 150 to 199% over natural rates (Figure 18) (Beechie and Feist, NMFS, unpublished data). The overall road density is “poor” in the Friday Creek WAU and “fair” in the Samish WAU (Figure 25) (Lunetta et al. 1997).

**Figure 34. Road density and the percentage of state and privately owned lands on a WAU scale in the upper Skagit sub-basin excluding the Cascade River. “Poor” road density values include those greater than 3 mi/mi<sup>2</sup>. “Good” road density values are those less than 2 mi/mi<sup>2</sup>.**



## **Riparian Conditions in the Skagit Basin**

### Introduction

Riparian areas include the land adjacent to streams, rivers, and nearshore environments that interact with the aquatic environment. This category addresses factors that limit the ability of native riparian vegetation to provide shade, nutrients, bank stability, and large woody debris. Riparian impacts include timber harvest, clearing for agriculture or development, and direct access of livestock to stream channels. This section also examines future LWD recruitment where data are available. The data used to determine riparian conditions are temporal and subject to sometimes-rapid changes. Also, connectivity of good riparian conditions is important. Even if a watershed has generally good riparian conditions, restoration activities might be important for specific reaches to improve overall watershed processes.

The data sources used in this chapter include watershed analyses for the Baker River, Sauk River, Finney Creek and nearby watersheds, and the Hansen WAU. In addition, the riparian analysis by Beamer et al. (2000) was used, especially in areas lacking a watershed analysis. This approach used a combination of Landsat data (Lunetta et al. 1997) and field inventories, but the field inventories were limited to the Nookachamps, Hansen, Illabot, Bacon, and the Mt. Baker WAUs. Lastly, Landsat data from Lunetta et al. (1997) was used to determine the conifer and non-forest components on a WAU scale. None of these data sources provide recent digitized reach-scale riparian conditions, and all ratings are provisional, due to the lack of specificity or the age of the data. A basin-wide riparian analysis that includes both shade hazard and LWD recruitment potential is greatly needed for the Skagit and Samish Basins, particularly because of the known water temperature and sediment problems and likely impacts to shade and LWD recruitment.

### Riparian Conditions in the Lower Skagit Sub-Basin

The Skagit Watershed Council's Strategy Application contains an analysis of riparian conditions along the mainstem Skagit River and its tributaries, and in general, riparian conditions along the lower Skagit River are "poor" (Beamer et al. 2000). Approximately 58 to 68% of the lengths from Sedro Woolley to Grandy Creek are described as impaired, while 72 to 76% are either impaired or moderately impaired, resulting in a "poor" rating for this long stretch. Riparian conditions are generally better ("fair") from Grandy Creek to Grassmere with about 35% impaired channel lengths, and 45 to 50% impaired or moderately impaired lengths (Beamer et al. 2000). From Grassmere to the Sauk River, impaired riparian lengths comprise an estimated 38 to 57% of the reaches, and the combined impaired to moderately impaired riparian consists of 51 to 63% (Beamer et al. 2000). These reaches are rated "poor" for riparian conditions.

The tributaries to the lower Skagit River have considerable amounts of degraded riparian habitat (Beamer et al. 2000). The Nookachamps, Hansen, Jackman, and Grandy WAUs have impaired riparian in more than 50% of the riparian lengths (Beamer et al. 2000). The Gilligan and Alder WAUs have impaired or moderately impaired riparian buffers in more than 50% of the channel lengths.

A greater than 20% conversion of riparian forest to non-forest lands has occurred in the Gilligan and Alder WAUs, while a nearly 40% conversion exists in the Nookachamps and over 50% in the Hansen Creek WAU (Figures 26 and 27) (Lunetta et al. 1997). A non-forest classification is unlikely to supply any type of riparian function, such as shade or LWD recruitment. In addition, even greater percentages of the riparian buffers in these tributaries consist of cleared land, brush, or hardwoods, which would be unable to supply adequate large woody debris (LWD) and in some cases, unable to provide adequate shade (Figures 26 and 27). Unfortunately, the hardwood/cleared category does not separate riparian areas that would naturally support only hardwoods or have mature hardwoods versus riparian buffers that are more severely impacted by human activities.

In all of the lower Skagit tributaries, it is very probable that the historic levels of riparian conifers along all of these tributaries have been reduced. In all of the watersheds except for Presentin, the conifer component comprises less than 50% of the riparian buffers (Figures 26 and 27) (Lunetta et al. 1997). In the Nookachamps, Hansen, and Grandy watersheds, the conifer component is especially low at 10% or less, and in the Alder and Gilligan drainages, it is less than 20%. The Nookachamps, Hansen, Grandy, Alder, Gilligan, and Jackman WAUs are tentatively rated “poor” for riparian conditions. This is due to the high percentage of impaired riparian lengths reported in Beamer et al. (2000) for all of these streams, coupled with the low levels of conifer and large-scale conversion to non-forest land use in all of these except for Jackman Creek.

The buffers along Loretta Creek are classified as 52% functioning with most of the remainder described as impaired (Beamer et al. 2000). However, a greater than 20% conversion to non-forest lands has occurred in the Loretta watershed (Lunetta et al. 1997). In addition, the U.S. Forest Service (1996) describes this watershed as having poor LWD recruitment with only 9% of the riparian area stream miles along Loretta Creek comprised of mature conifer, and only slightly more than 20% of the buffers consist of any age of conifer (Figure 27) (Lunetta et al. 1997). Because of this, riparian conditions in Loretta Creek are tentatively rated as “poor”, but field surveys are recommended to provide better information.

Overall, the Finney Creek riparian area consists of 56% saplings (very young trees with a canopy cover ranging from 11 to 60%), 26% mature trees, 11% immature trees, and 7% small or non-forest by stream miles (U.S. Forest Service 1999). The saplings and the non-forest component would be unable to supply adequate riparian functions, such as shade and LWD recruitment. The conifer component throughout the Finney Creek watershed is only slightly more than 30% (Figure 27), which results in generally low LWD recruitment potential. The watershed analysis also noted that there is a lack of shade along Finney Creek (U.S. Forest Service 1999), which coupled with the high level of sedimentation, has likely contributed appreciably to the warm water temperatures.

Riparian conditions vary within Finney Creek with the worst conditions in the anadromous zone. All of the mature riparian trees are located within the National Forest boundary (U.S. Forest Service 1999). The buffers along the middle and upper Finney Creek are a mix of young trees with fragments of old growth in some areas, but the lower reaches off National Forest have riparian areas of nearly entirely young stands (U.S.

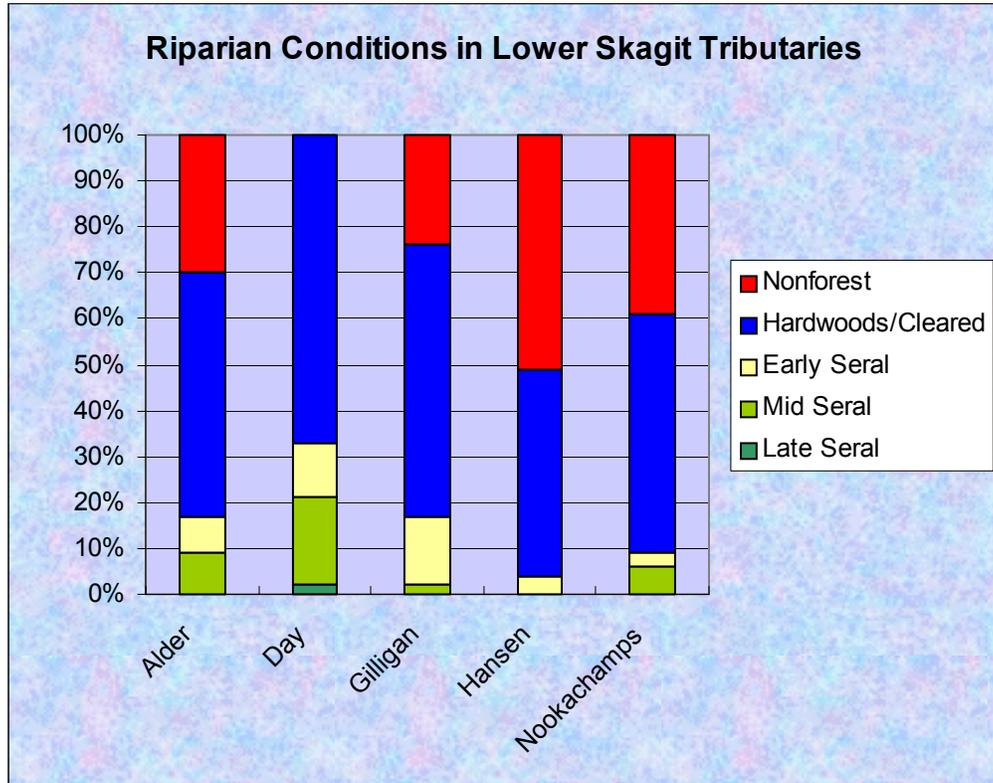
Forest Service 1999). In a detailed analysis of the lower 12 miles (the anadromous zone in Finney Creek), 72% of the riparian acreage (150' from bankfull edge) was dominated by hardwoods (70% or more hardwood) with most being alder (Haight 2002). Out of a total of 690 subplots, only 13 subplots had trees that would supply key sized pieces of LWD in the near future, and only 14% of the subplots were dominated by conifer. Most (87%) of the conifer present in the riparian zone along lower Finney Creek was small, less than or equal to 10" in diameter (Haight 2002).

This results in a "poor" riparian rating for Finney Creek in general. Some areas in the upper watershed have "good" riparian conditions, but these are scattered and upstream of anadromous salmonid production. Efforts to improve the conifer component in the Finney Creek watershed are recommended.

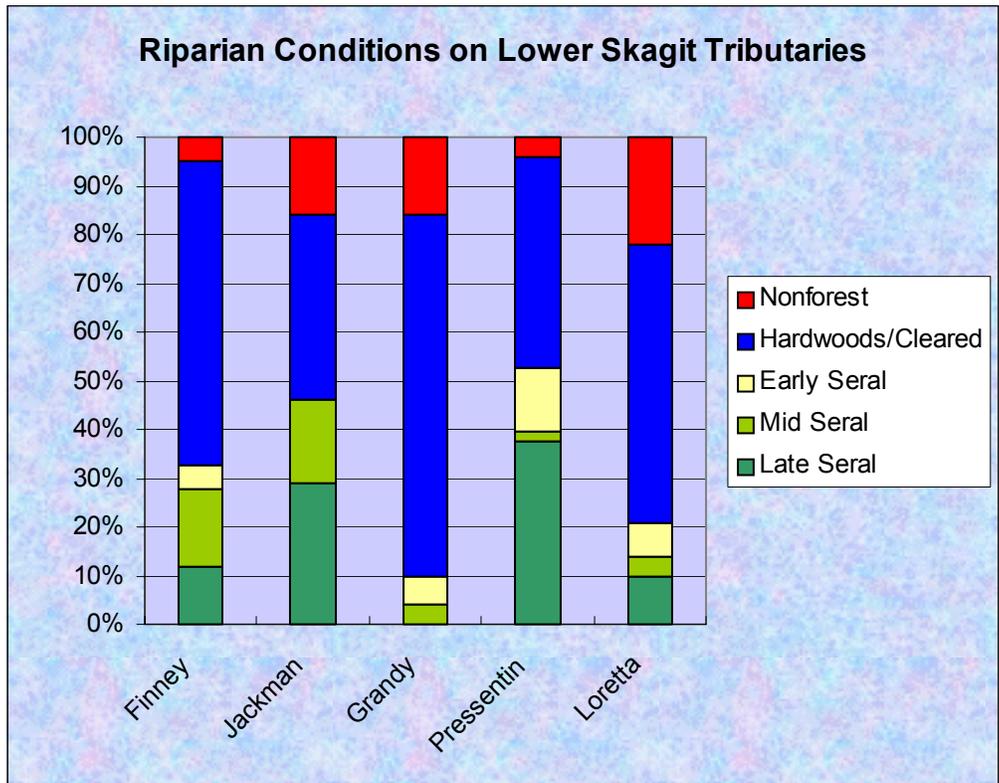
The riparian zones along Day, Cumberland, and Marietta Creeks consist of greater than 50% saplings, which would be unable to provide adequate shade or LWD recruitment (U.S. Forest Service 1999). These watersheds are provisionally rated "poor" for riparian conditions. A "poor" rating is also assigned to Miller Creek. About 24% of the riparian buffers along Miller Creek have been converted to a non-forest use and an additional 39% are non-conifer (Lunetta et al. 1997).

Better riparian conditions exist in the Pressentin WAU, which has 61% functional buffers (Beamer et al. 2000). Old growth can be found along the upper reaches of Pressentin Creek, and overall the riparian area along upper Pressentin consists of 77% mature conifer, and is rated "good" (U.S. Forest Service 1999). However lower Pressentin has less than 23% of riparian conifer in a mature category (U.S. Forest Service 1999), which would lower future LWD recruitment, and this reach of Pressentin is rated "poor" for riparian conditions.

**Figure 35. Riparian conditions in the Alder, Day, Gilligan, Hansen, and Nookachamps WAUs (data from Lunetta et al. 1997).**



**Figure 36. Riparian conditions in the Finney, Jackman, Grandy, Presentin, and Loretta WAUs (data from Lunetta et al. 1997).**



Riparian Conditions in the Upper Skagit Sub-Basin

In general, the riparian conditions appear to be much better along the tributaries to the upper Skagit River compared to the lower Skagit tributaries, but the conditions along much of the mainstem are impaired. From the Sauk confluence to Bacon Creek, 41 to 51% of the riparian lengths are impaired (“poor”), and 50 to 61% of the reaches are either impaired or moderately impaired (Beamer et al. 2000). Riparian conditions are much better along the Skagit River from Bacon Creek to Newhalem with only 22% impaired reaches and 29% impaired or moderately impaired lengths. This reach is rated “good” for riparian conditions.

In the tributary watersheds, riparian conditions are mostly “good”. The conifer component is considerably higher along most of the upper Skagit tributaries compared to the lower Skagit streams. It is greater than 60% in the Bacon, Newhalem, and the middle and upper Cascade River WAUs, and near or above 50% in the Damfino, Illabot, Diobsud, and lower Cascade (Jordan/Boulder) WAUs (Figures 28 and 29) (Lunetta et al. 1997). Only the Goodell and Corkindale WAUs had conifer components of considerably less than 50% (Figure 28). The non-forest category in the Goodell WAU is likely natural alpine or meadow conditions found at higher elevations and not due to human impact.

In the Beamer et al. (2000) analysis, the percentage of functional riparian is high for the Illabot, Newhalem, Bacon, Goodell, Diobsud, and Damfino WAUs with approximately greater than 90%, 80%, 70%, 60%, 55% and 55% of functional riparian lengths, respectively. These WAUs are all tentatively rated “good” for riparian conditions.

In contrast, the Corkindale WAU has less than 40% functional riparian conditions and about 55% impaired riparian conditions (Beamer et al. 2000), and it has a slightly greater than 30% conifer component (Figure 28) (Lunetta et al. 1997). In general, this WAU is rated “poor” for riparian conditions with a note that more data are needed to better delineate the extensive hardwood/cleared category reported in Lunetta et al. (1997).

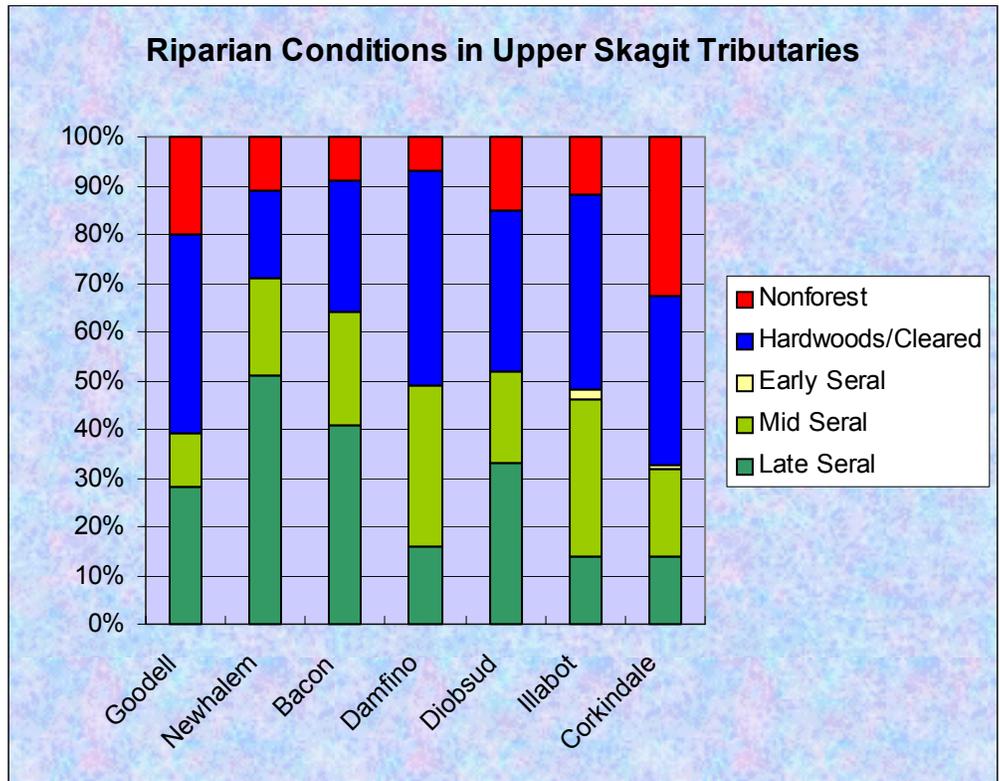
All three of the Cascade River WAUs have greater than 70% functional riparian buffers with the upper Cascade WAU and the Jordan/Boulder WAU having greater than 80% functional riparian areas (Beamer et al. 2000). The conifer component of these WAUs ranges from 47 to 73% (Lunetta et al. 1997), and the non-forest component is likely mostly natural alpine, glacial, or meadow areas (Figure 29).

Specific reaches within the lower WAU (Jordan/Boulder) have been impacted. Shade is well below target levels in lower Jordan, Muddy Fork, and parts of Shoemaker Creek (DNR 1995). Lower Jordan, lower Boulder, and Shoemaker Creeks also have been identified as having low near-term LWD recruitment. Although the remainder of the Cascade River is rated “good” for riparian conditions, these specific areas are rated “poor”.

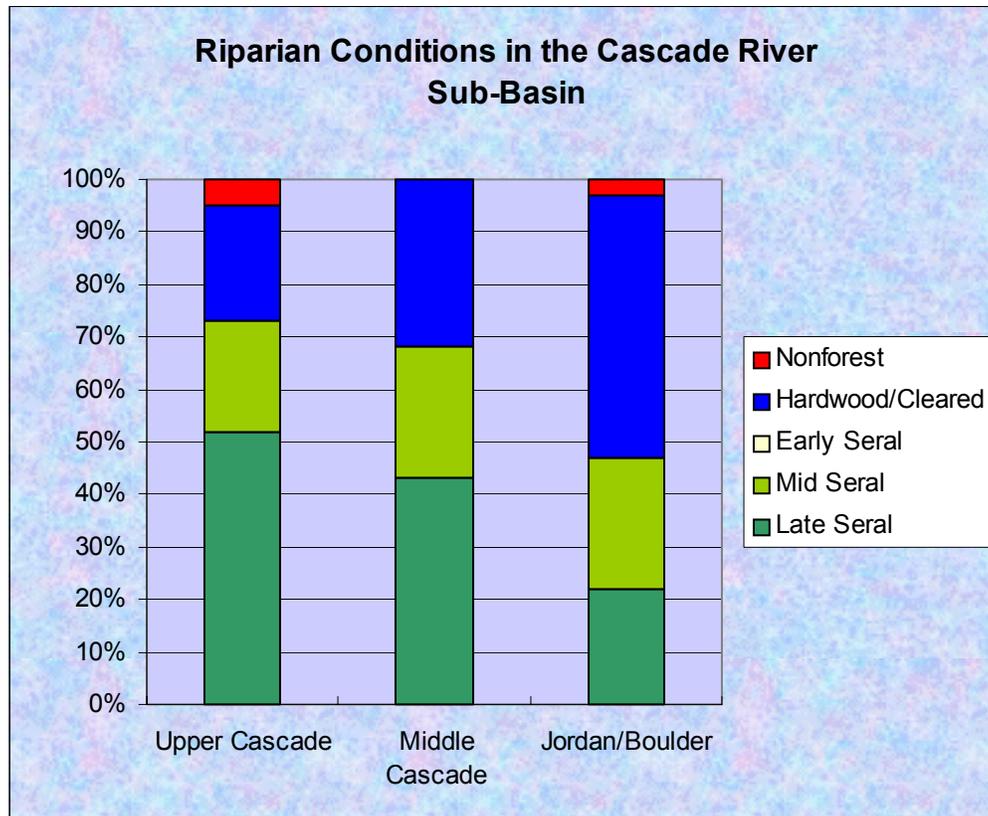
The mainstem Cascade River has significant impairments along some of its lower reaches. About 42% of the lowest reach (downstream of the Boulder Creek confluence) is described as impaired, and 52% is either impaired or moderately impaired (Beamer et al. 2000). However, because the remaining reaches are functioning (“good”), the lower Cascade is rated as a mix of “good” and “poor” conditions. The reach from Boulder Creek to Sibley Creek has mostly (74%) “good” riparian conditions (Beamer et al. 2000).

With some exceptions, the overall riparian conditions in the upper Skagit sub-basin are “good”. These ratings are generalized over a broad area though, and specific reaches within “good” rated areas are likely to still need riparian restoration. Site-specific information is greatly needed, and opportunities to restore functional habitat connectivity should be encouraged.

**Figure 37. Riparian Conditions in the upper Skagit tributary WAUs (data from Lunetta et al. 1997).**



**Figure 38. Riparian conditions in the Cascade River (data from Lunetta et al. 1997). The Jordan/Boulder WAU encompasses the lower Cascade River and tributaries.**



#### Riparian Conditions in the Baker River Sub-Basin

The riparian areas within the Baker River sub-basin are in generally good condition. The Mt. Baker WAU riparian was rated as near 90% functional, while just fewer than 60% of the riparian areas in the Mt. Blum and Lake Shannon East WAUs were described as functional (Beamer et al. 2000). A little over 50% of the riparian areas in the Lake Shannon West WAU had functional riparian reaches. Conifer comprised over 60% of the Mt. Baker WAU and nearly 50% of the Lake Shannon East WAU (Figure 30) (Lunetta et al. 1997).

While only about 10% of the riparian areas within the National Forest boundaries have been disturbed in the Baker River sub-basin, an estimated 78% of the riparian areas in non-federal lands have been impacted by timber harvest through 1990 (U.S. Forest Service 2002). Some of these areas are listed below as having current moderate LWD recruitment and good future LWD recruitment potential, suggesting that riparian conditions are “fair” and are expected to improve over time.

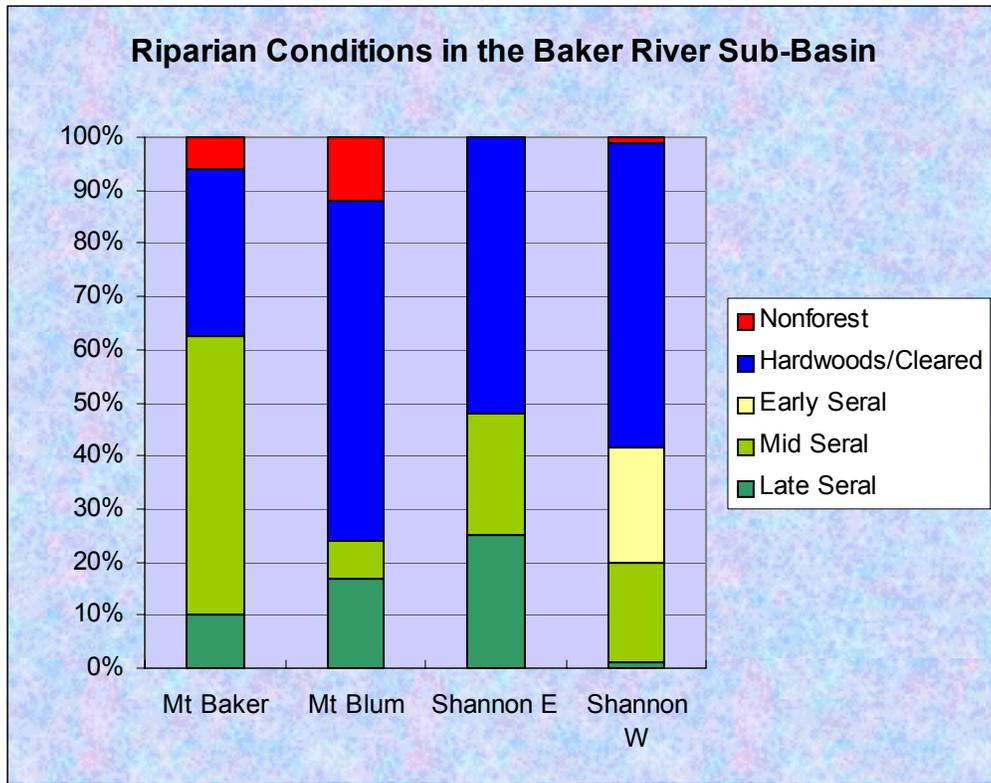
Most of the riparian functions within the Baker River sub-basin appear to be adequate. In general, the Baker River streams have sufficient shade except for the alpine areas, which

have naturally low shade levels, and the lower air temperatures in these regions keep water temperatures cool (U.S. Forest Service 2002).

Large woody debris recruitment conditions vary with area, and ratings are listed in Table 8 (data from U.S. Forest Service 2002). The areas with low LWD recruitment are either naturally low due to alpine areas or listed as low because of a different classification of land cover by the Park Service. Streams that have been impacted by human activities are found in the moderate LWD recruitment category, and are rated “fair” for riparian conditions. These include Lower Thunder, South Fork Thunder, lower Sandy, Little Sandy, Dillard, lower Boulder, Shannon, Morovitz, and lower Swift Creeks. All other streams in the Baker River sub-basin are rated “good” for riparian conditions based upon the assessment by Beamer et al. (2000) and the LWD recruitment classifications by the U.S. Forest Service (2002).

Several areas have been listed as a concern for unstable soils within the riparian reserve areas. Upper Thunder, Watson, Lower Sulphur, Welker, and Anderson Creeks have greater than 30% unstable soils within the riparian zone (U.S. Forest Service 2002). Rocky, upper Sulphur, Baker Lake, lower Sandy, Dillard, lower Boulder, Shannon, and lower Swift Creeks have between 15-30% unstable soils. Future riparian vegetation disturbance in these areas could have impacts on sedimentation.

**Figure 39. Riparian conditions in the Baker River sub-basin WAUs (data from Lunetta et al. 1997).**



**Table 8. Large woody debris recruitment potential in Baker River sub-basin streams (U.S. Forest Service 2002).**

LWD Recruitment Classification	Stream Reach
High LWD recruitment (>75% mature)	Upper Thunder, Watson, Welker, Anderson, Silver, lower Park, and upper Swift Creeks.
Moderate LWD recruitment (>50%<75 mature)	Lower Thunder, South Fork Thunder, upper Rocky (alpine), Baker Lake, lower Sandy, upper Sandy (alpine), Little Sandy, Dillard, lower Boulder, Shannon, Morovitz, and lower Swift Creeks.
Low LWD recruitment, current and future	Upper Sulphur (alpine), upper Boulder (alpine), upper Park (alpine), upper Rainbow, Swift headwaters, and Sulphide Creeks and the Baker River.
Good future LWD recruitment	Lake Shannon, lower Thunder, South Fork Thunder, Bear, lower Rocky, lower Sulphur, Shannon, and Hidden Creeks.

Riparian Conditions in the Sauk River Sub-Basin

The overall riparian composition in the Sauk River sub-basin is fairly good with 57% mid-seral, 39% late seral, and 4% early seral forest cover (U.S. Forest Service 1996). These estimates do not include the White Chuck or Suiattle River watersheds. Historically, there was a greater percentage range for the late seral category and less mid-seral component compared to current conditions. A greater percentage of late seral exists in the Sauk Forks drainages (62%) versus downstream of the Forks (47%) (U.S. Forest Service 1996). More specific conditions are discussed below.

A mix of riparian conditions is found along the mainstem Sauk River. The lowest reach of the Sauk mainstem (downstream of the Hilt Creek confluence) has 44% impaired riparian lengths and about 52% impaired or moderately impaired riparian (Beamer et al. 2000). This reach is rated as a mix of “good” and “poor”. Riparian conditions are “good” from Hilt Creek to the Suiattle River, where impaired riparian reaches comprise only 9 to 26% of the floodplain lengths, while impaired and moderately impaired reaches consist of 12 to 36% (Beamer et al. 2000). From the Suiattle River to Helena Creek, the Sauk River riparian conditions worsen with 43 to 90% impaired lengths and 52 to 93% either impaired or moderately impaired. The worst reach is in the Darrington area. From Helena Creek to the Forks, most of the riparian lengths are rated “good” with impaired

conditions ranging from 27 to 37% and moderately impaired conditions ranging from 36 to 48% of floodplain lengths.

Within the Sauk sub-basin, impaired riparian conditions prevail in two WAUs, Rinker (located along the lower left bank side of the Sauk River) and Sauk Prairie (Figure 31). Both of these WAUs have less than 40% conifer within their riparian areas (Lunetta et al. 1997). In addition, Beamer et al. (2000) have classified nearly 40% of the Rinker and more than 70% of the Sauk Prairie stream length as having either an impaired or moderately impaired riparian. This results in a “poor” riparian rating for the Sauk Prairie WAU and a “fair” rating for the Rinker WAU. The other lower Sauk WAU (Hilt) has more than 90% functional riparian (Beamer et al. 2000) and is rated “good”.

The Dan Creek WAU has 56% functional riparian stream lengths (Beamer et al. 2000), but conifer comprises only about 46% of the riparian buffer (Lunetta et al. 1997). Overall, the WAU is tentatively rated as “fair”, and further assessment is recommended especially with regard to the low conifer component and the future LWD recruitment potential in this area. The Clear Creek WAU is rated “good” with more than 80% of the stream lengths classified as functional (Beamer et al. 2000) and slightly more than 50% of the buffers containing conifer (Figure 32) (Lunetta et al. 1997). However, the large percentage of the hardwoods/cleared riparian category warrants concern regarding LWD recruitment (Figure 32) (Lunetta et al. 1997).

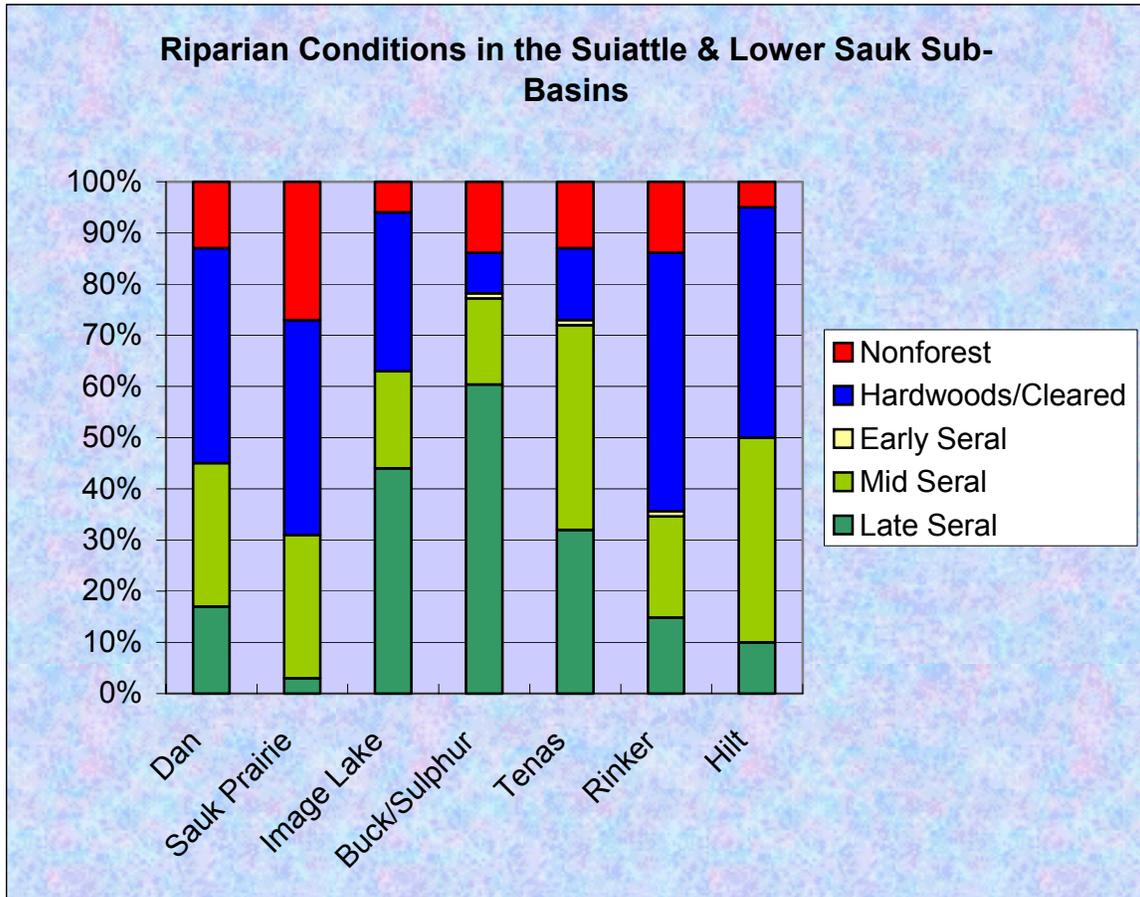
The Suiattle River has predominantly good riparian conditions. Most of the anadromous salmonid production is in the Tenas, Lime, and Buck/Downey/Sulphur WAUs, and all have near or above 90% functional riparian stream lengths (Beamer et al. 2000). The Tenas and Buck/Downey/Sulphur WAUs also have greater than 70% conifer in their riparian buffers (Figure 31) (Lunetta et al. 1997). The upper Suiattle WAUs are Image Lake and Chocolate Glacier, both are classified with nearly 100% functional riparian (Beamer et al. 2000). Impaired areas within the Suiattle are uncommon, but some are scattered along the middle reaches of the mainstem Suiattle River (Beamer et al. 2000). The percentage of impaired riparian reaches along the Suiattle River ranges from only 18 to 0% (Beamer et al. 2000), resulting in a “good” rating for riparian conditions.

The White Chuck River has more than 90% functional riparian stream lengths (Beamer et al. 2000) with nearly 90% of the area covered with conifer (Figure 32). This results in a “good” rating for riparian conditions. The uppermost reaches of the Sauk River are also rated “good” for riparian conditions. The Sloan Creek WAU has more than 90% functional riparian stream lengths, while the Monte Cristo WAU has a greater than 70% function riparian (Beamer et al. 2000).

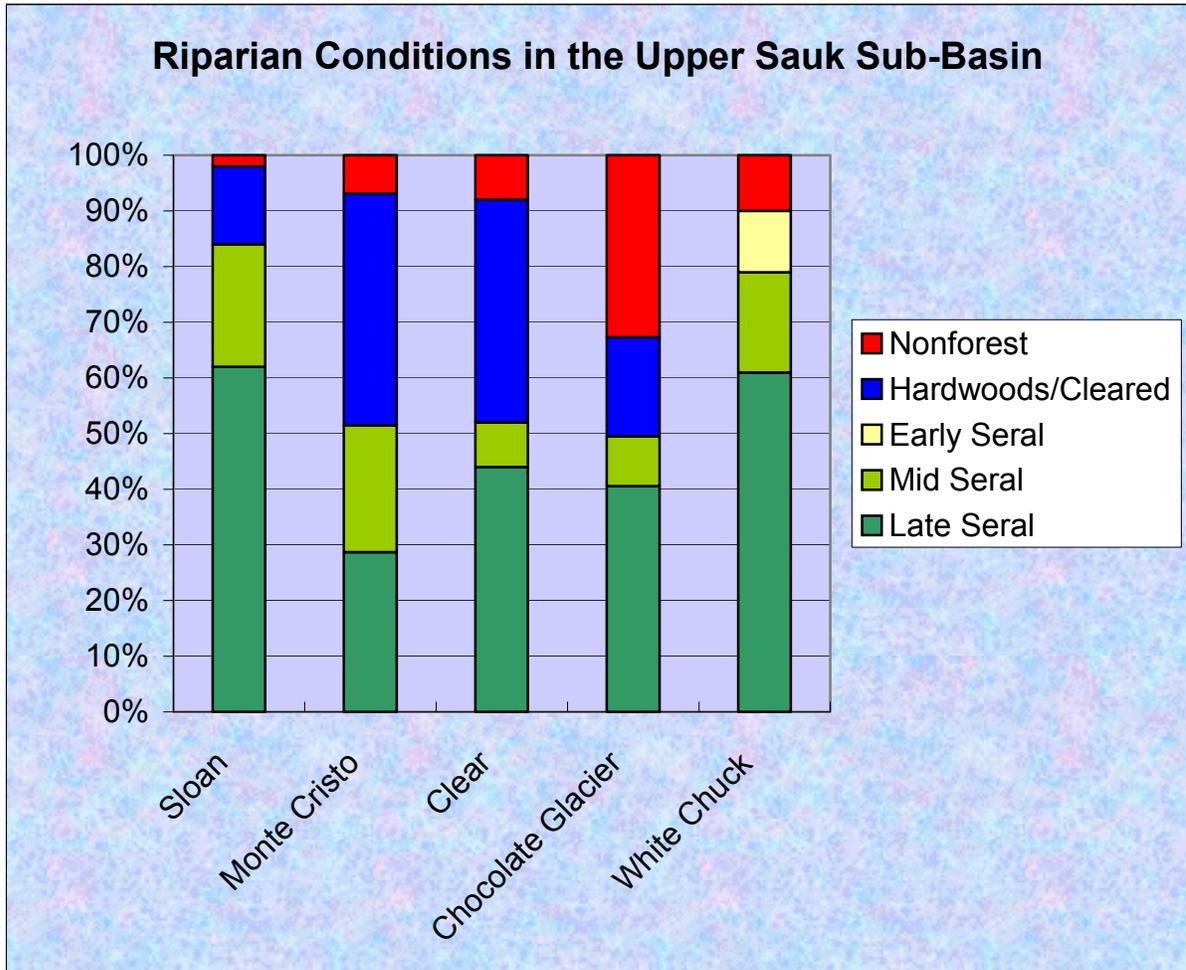
Large woody debris recruitment is somewhat impaired in the Sauk River sub-basin downstream of the Forks, not including the White Chuck and Suiattle Rivers (U.S. Forest Service 1996). Even though more reaches (42%) have high LWD recruitment potential, 36% have moderate, and 22% have low. In contrast, the Forks drainages have 51% high LWD recruitment potential, 9% moderate, and 40% low, but most of the low category includes areas with naturally low LWD recruitment potential (U.S. Forest Service 1996). The low and moderate LWD recruitment potential in the lower Sauk is related to the

lower levels of conifer discussed above for the Sauk Prairie, Rinker, and Dan Creek WAUs.

**Figure 40. Riparian conditions in the Suiattle and lower Sauk River watersheds (data from Lunetta et al. 1997).**



**Figure 41. Riparian conditions in the upper Sauk sub-basin (data from Lunetta et al. 1997).**



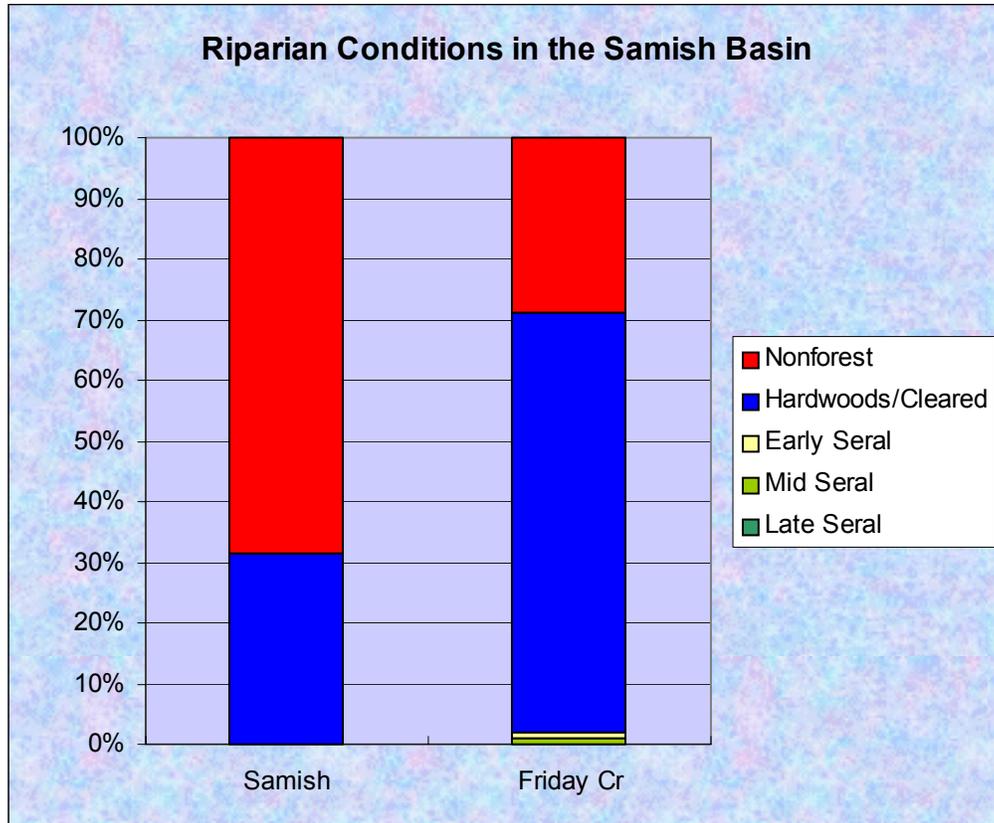
### Riparian Conditions in the Samish Basin

Riparian conditions in the Samish Basin appear to be greatly impaired. Conversion of riparian buffers to non-forest use has occurred throughout 68% of the riparian area within the Samish Basin excluding Friday Creek (Figure 33) (Lunetta et al. 1997). The remaining riparian buffers are comprised of predominantly hardwoods, brush, or cleared forestlands. The lack of conifer results in very poor LWD recruitment potential. In addition, nearly 70% of the Samish riparian buffers were described as impaired or moderately impaired in Beamer et al. (2000). The only functional riparian buffers were mapped in tributaries to the upper Samish, such as sections of Thunder, Jackson, and Ennis Creeks (Beamer et al. 2000). Overall, the riparian conditions in the Samish WAU are rated “poor”.

Within the Friday Creek watershed, 29% of the riparian areas have been converted to a non-forest use with 69% consisting of hardwoods, brush, or cleared forestlands (Figure

33) (Lunetta et al. 1997). These types of riparian conditions would be unable to supply future LWD debris in adequate quantities. Beamer et al. (2000) classified nearly 65% of the Friday Creek WAU riparian buffers as either impaired or moderately impaired. These impacts result in a “poor” rating for riparian conditions in the Friday Creek WAU.

**Figure 42. Riparian Conditions in the Samish and Friday Creek WAUs (data from Lunetta et al. 1997).**



### Conclusions

Not surprisingly, extensive riparian impacts have occurred in the areas where non-forest land use predominates. This includes the Samish Basin, many reaches of the Skagit River mainstem, much of the riparian along the tributaries to the lower Skagit River, and limited areas within the Sauk sub-basin. Specific lower Skagit watersheds with extensive riparian impacts include the Nookachamps, Hansen, Grandy, Alder, Gilligan, Jackman, Loretta, Finney, Day, Cumberland, and Marietta drainages. Better conditions are found in upper Pressentin Creek. Widespread riparian impacts have also occurred in the Skagit Delta and Padilla Bay streams, but those are described in the Estuarine/Nearshore Chapter.

In the upper Skagit sub-basin, riparian conditions are better with fewer “poor” rated riparian areas. Impacted riparian conditions exist along the mainstem Skagit River downstream of Bacon Creek, in the Corkindale WAU, and along a few reaches within the lower Cascade WAU. All other upper Skagit watersheds are rated “good”.

Within the Sauk sub-basin, all areas are rated “good” for riparian conditions except for scattered reaches of the mainstem Sauk River, and the Sauk Prairie, Rinker, and Dan WAUs. The Baker sub-basin tributaries are mostly rated “good” except for Lower Thunder, South Fork Thunder, lower Sandy, Little Sandy, Dillard, lower Boulder, Shannon, Morovitz, and lower Swift Creeks, and these are rated “fair” due to moderately impaired LWD recruitment potential.

All of these riparian ratings are provisional until a comprehensive analysis that includes shade hazards and LWD recruitment potential is completed. This type of project is recommended for the entire Skagit and Samish Basins. While field-based inventories have been completed in the Bacon, Mt. Baker, Nookachamps, and Hansen WAUs and in all of the Sauk River WAUs, some of these are more than five years old, and all need to be standardized and digitized. It is important to note that these ratings are generalized for a broad area, and specific reaches within a “good” rated area might be impaired and in need of restoration activities.

## **Water Quality Conditions in the Freshwater Habitat of WRIAs 3 and 4**

### Introduction

This chapter summarizes and rates the water quality data in the Skagit Basin that pertains directly to salmonids. This includes water temperature, dissolved oxygen, turbidity, phosphorus, nitrogen compounds, and toxins in both the water column and sediments. Fecal coliform exceedances are not discussed because they don't directly relate to salmonid impacts. When data are available, the causes of impacts are also provided. The water quality standards used for this report are described in detail in the Assessment chapter. Generally, summer water temperatures are "good" when below 14°C, "fair" in the range of 14 to 15.6°C, and "poor" when warmer than 15.6°C. Dissolved oxygen levels are considered "good" when above 8 mg/L, "fair" when in the range of 6 to 8 mg/L, and "poor" when less than 6 mg/L.

It is important to note that these standards may not be sufficient to describe impacts to bull trout and Dolly Varden. Char are very dependent on the freshwater environment, where they reproduce only in clean, cold, relatively pristine streams. Because these life history types have restrictive habitat requirements, especially as it relates to temperature, bull trout are generally recognized as a sensitive species by natural resource management agencies. Reductions in their abundance or distribution are inferred to represent strong evidence of habitat degradation. The Environmental Protection Agency (EPA) is in the process of drafting new temperature guidelines for Region 10 (the Pacific Northwest) that take into account the cooler temperatures needed by bull trout. Their current draft recommendations are for Summer Maximum Conditions (7-day average of daily maximum) to be no warmer than 12°C in areas known to be used for bull trout rearing (Environmental Protection Agency 2002 draft). EPA temperature recommendations for other salmonid species and for bull trout during other life history stages are warmer than the standards used in this report.

### Water Quality Conditions in the Lower Skagit Sub-Basin

Several water quality problems have been documented in the mainstem Skagit River downstream of the Sauk confluence, most being elevated nutrients and turbidity. Water quality impairments are also common within many of the tributaries to the lower Skagit River, but the majority of these impacts are warm water temperatures. The specific exceedances and their locations are discussed below, and the "poor" rated sites are shown in Figure 34.

#### *Lower Mainstem Skagit River*

Three segments in the lower mainstem Skagit River have been monitored in recent years. The Skagit River near Mount Vernon (RM 15.9) has been monitored from 1982-2002 and water quality exceedances are summarized in Table 9. These include frequently elevated levels of nitrogen, nitrate, ammonia, or phosphorus, and infrequent warm water temperatures and turbidity. The Washington State Department of Ecology has rated this segment "poor" for suspended solids in 2 of the last 10 years and "moderate" in the

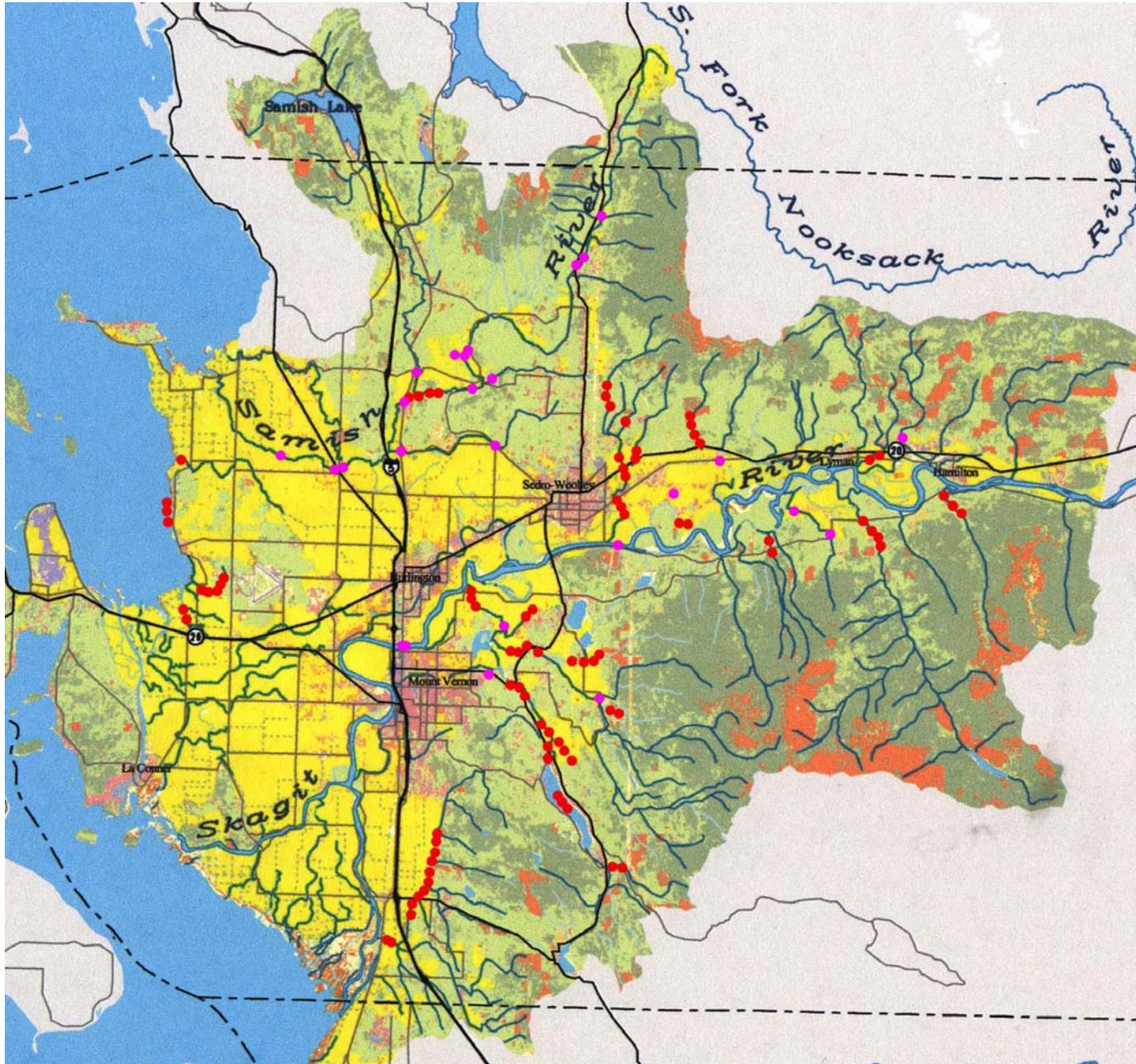
remaining 8 years (DOE 2003). Phosphorus levels were rated “moderate” in 6 out of 10 years and “poor” in 1 out of 10 years. Turbidity was rated “moderate” in 6 out of 10 years and “poor” in 2 out of 10 years. Because of the frequent elevated nitrogen, nitrate, or ammonia levels, this segment is rated “poor” for water quality conditions in this analysis. The causes of these problems were not stated, but are likely related to the surrounding urban and agricultural land use (Figure 34) and possibly from discharges from the four wastewater treatment plants (City of Sedro Woolley, City of Burlington, City of Mount Vernon, and Big Lake/Skagit County Sewer District #2) in the area. In 1992, the discharge from these plants had very high nutrient levels and warm water temperatures (Entranco 1993).

The Skagit River near Sedro Woolley was sampled in the 1970s, which indicated warm water temperatures and high levels of phosphorus (DOE 2003). However, these data are too old to use in this analysis. A segment upstream of Sedro Woolley (RM 24.4) was sampled in 2000, and the Department of Ecology rated the segment as “moderate” for suspended solids, phosphorus, and turbidity with September as the worst month. Water temperatures and dissolved oxygen levels were within acceptable ranges. This segment is rated “fair” for water quality conditions because of the moderate levels of suspended solids, phosphorus, and turbidity.

Chronic levels of lead and copper and acute levels of copper were found in the mainstem Skagit River in 1992 (Entranco 1993). These metals were detected above metals criteria near RMs 15, 20, and 26. The significance of these findings is unknown. Typical sources of metals include industry, urban and highway runoff, and landfills, and heavy industry is not located in this area. Further investigation is needed to determine if metals are at levels that can impact salmonids and if so, identify the sources of pollution.

The Skagit River near Concrete (RM 54.1) was sampled from 1977 through 1993 with the exception of 1992. The Department of Ecology rated this segment as “poor” for suspended solids and turbidity, and “moderate” for phosphorus (DOE 2003), resulting in a “poor” rating for this report. Water temperatures and dissolved oxygen levels were good.

Figure 43. The location of “poor” rated water quality stream segments in WRIAs 3 and 4. Red dots denote 303(d) Listings except for fecal coliform, and pink dots are “poor” rated areas derived from other data sources. Data are superimposed on a land use/cover map from DOE. Yellow represents agricultural areas. Dark green is conifer forest, and light green is mixed forest.



**Table 9. Water Quality Exceedances in the Lower Skagit River (DOE 2003).**

Stream Segment	Water Quality Parameter	Dates Exceeding Standard
Skagit River near Mt. Vernon	Nitrate, Nitrogen, Ammonia, or Phosphorus	January 2002, September 2001, September 1999, May 1999, December 1998, November 1998, March 1997, April 1997
	Water Temperature	August 1998
	Turbidity or Suspended Solids	June 1997
Skagit River near Marblemount	Nitrate, Nitrogen, Ammonia, or Phosphorus	October 2002, September 2002, August 2002, May 2001, September 1999, August 1999, July 1999, May 1999, January 1999, December 1998, November 1998, September 1997, August 1997, June 1997, April 1997, March 1997

*Lower Skagit Tributaries*

Most of the larger tributaries to the lower Skagit River are on the 1998 303(d) List for impaired water quality, including Nookachamps, Hansen, Coal, Wiseman, Sorenson, Mannser, Day, Cumberland, Finney, Grandy, and Jackman Creeks (DOE 2000). Gages Slough and Hart Slough have also experienced warm water temperatures (18 °C), low dissolved oxygen levels (1.3 and 5.1 mg/L), and elevated phosphorus levels (Entranco 1993). Lead, copper, and zinc have also been detected above criteria in Gages Slough (Entranco 1993). Many of these streams are very important for salmonid production, and all are rated “poor” for water quality conditions. The specific impacts and causes, when known, are discussed below.

One of the more extensively impacted tributary systems for water quality in the Skagit Basin is the Nookachamps drainage. Several segments within Nookachamps Creek are on the 303(d) List for warm water temperatures in addition to a segment in the East Fork Nookachamps, and segments in Mud Lake, Turner, and Cold Spring Creeks, tributaries to the Nookachamps (Figure 34) (DOE 2000). One of the warmest of these is near the outlet to Big Lake, which has experienced summer water temperatures above 21 °C (Skagit County 2003). In addition to those on the 303(d) List, other reaches of the Nookachamps drainage have documented water temperatures in the “poor” range during

the summer months (Skagit County Department of Public Works 2003). These include the East Fork Nookachamps at Beaver Lake Road, Nookachamps Creek at Swan Road, and College Way Creek at College Way.

There are several potential causes for the warm temperatures, such as a highly degraded riparian (Beamer et al. 2000), agriculture waste, failing septic systems, and impaired hydrology (wetland loss, floodplain impacts, impervious surfaces, stormwater runoff) from development (NWMC and SCDPCD 1995). Of the 12 dairy farms surveyed in the Nookachamps drainage in the early 1990s, it was estimated that about 20 million gallons of waste was produced annually, that 58% of the dairy farms stored waste for six or more months a year, and that 58% of the farms had animal confinement that was less than 50 feet from a waterway (NWMC and SCDPCD 1995).

Other water quality problems that impact salmonids in the Nookachamps drainage are low dissolved oxygen levels and increased turbidity. Very low dissolved oxygen levels (below 6 mg/L) have been recorded from July through early October in Nookachamps Creek at Knapp Road (RM 5) (Skagit County Department of Public Works 2003) and during 1992 spot checks at Big Rock, the mouth of Nookachamps Creek, the East Fork Nookachamps at SR 9, and the outlet from Lake McMurray (Entranco 1993). College Way Creek, a Nookachamps tributary, has also experienced “poor” dissolved oxygen levels along with occasionally high turbidity. A few high turbidity readings have been recorded in the Nookachamps at Swan Road (RM 2) and the East Fork Nookachamps at Highway 9 (RM 1.6) (Skagit County Department of Public Works 2003).

Water quality in Big Lake, which is located in the upper West Fork Nookachamps drainage, is also on the 303(d) List for elevated phosphorus levels. In the past, Big Lake has experienced low dissolved oxygen levels, and high nutrient inputs from tributaries were thought to be the cause (DOE 2000). The nutrients are from forestry, agriculture, and residential activities in addition to maintenance of a golf course (SCPCD 1995). Recent sampling by Skagit County Department of Public Works (2003) at the outlet to Big Lake indicates a mix of “fair” to “good” levels of dissolved oxygen and turbidity. Generally “good” water quality conditions were found upstream in Lake Creek, which drains into Big Lake, although this reach is near a segment that is on the 303(d) List for warm water temperatures.

All of the segments in the Nookachamps drainage that are either on the 303(d) List or have “poor” levels of water temperature, dissolved oxygen, elevated nitrogen, phosphorus, or turbidity are rated “poor” for this report. These are highlighted in Figure 34.

There are other water quality concerns in the Nookachamps drainage. 1992 water sampling has shown levels of lead, copper, and zinc above metals criteria in Nookachamps Creek and some of its tributaries (Entranco 1993). Sediments were also sampled at two sites (the mouth of Nookachamps Creek and College Way Creek) and showed levels of antimony (at both sites), chromium (at Nookachamps mouth), copper (in College Way Creek), and nickel (at both sites but higher at Nookachamps mouth) above at least one set of criteria for pollution (Entranco 1993). The significance of metal

detection to salmonids is not known, and further investigation is warranted to determine the extent of pollution, and if levels are still above criteria, identify the sources. The metals are likely related to stormwater inputs and automobile use and maintenance. It is noteworthy that many of the levels of metals measured at these two sites are higher than those found in King County streams (Entranco 1993).

Five potentially toxic organic compounds were found above detection limits in sediments at College Way Creek and two compounds above limits were found in sediments near the mouth of Nookachamps Creek (Entranco 1993). Because no freshwater criteria exist to relate these concentrations to salmonid impacts, they are listed as a concern, but are not part of the rating process for water quality. The detected compounds and their most common sources include 4-methylphenol (wood preservatives and herbicides), three types of flouranthenes or PAHs (automobile use, stormwater inputs), phthalate (pesticides), and dichloroprop (herbicide) (Entranco 1993).

Hansen Creek is another Skagit River tributary watershed with many segments on the 303(d) List for warm water temperatures and impaired fish habitat (Figure 34). Impaired fish habitat denotes a lack of LWD and pool habitat caused by logging and agriculture (DOE 2000). Red Creek, a tributary to Hansen Creek, is also on the 303(d) List for warm water temperatures. Skagit County Department of Public Works (2003) monitored water temperatures at two different sites in Hansen Creek; both are already on the 303(d) List. At Hoehn Road RM 1.4 (listed for warm water temperatures), 20 out of 47 days had peak water temperatures in the “poor” range and 8 days in the “fair” category during June and July 2002. The warmest temperature was 18.1°C. Monitoring also occurred in August 2001 with nearly all the days having peak water temperatures above 15.6°C. The warmest temperature was 19.7°C (Skagit County Department of Public Works 2003).

The other sampled site in Hansen Creek was near Northern State (RM 3.7), which is on the 303(d) List for impaired fish habitat. Of 29 days sampled in August 2001, 21 had peak water temperatures in the “poor” range and the remainder in the “fair” category (Skagit County Department of Public Works 2003). The first 24 days of September were monitored with 10 days in the “poor” and 7 in the “fair” range. Both sites in Hansen Creek had generally good levels of dissolved oxygen, although both sites experienced occasional high turbidity levels. Because of the warm water temperatures and 303(d) listings, Hansen Creek and Red Creek are rated “poor” for water quality conditions. The Hansen WAU is also noted as having extensive impaired riparian areas with over 50% of its riparian converted to non-forest use (Lunetta et al. 1997). In addition, 1992 sampling has shown levels of lead and zinc above metals criteria in Hansen Creek (Entranco 1993). The significance of metal detection is not known.

Warm water temperatures have also resulted in 303(d) listings in the lower reaches of Wiseman, Sorenson, Mannser, Finney, Grandy, Jackman, and Cumberland Creeks, as well as in a long segment in the middle reaches of Day Creek and a segment in upper Coal Creek (Figure 34) (DOE 2000). These are rated “poor” for water quality conditions. Grandy, Jackman, and Cumberland Creeks also have “poor” for riparian conditions, which might be related to water quality problems (see the Riparian Chapter).

The results of recent water temperature sampling in Finney Creek by the National Park Service are shown in Figures 35 and 36. In the lower two sampled sites (RMs 2.3 and 4.0), nearly all of the water temperatures from mid July through mid September were in the “poor” range (Stan Zyskowski, National Park Service unpublished data). Upstream at RMs 12.8 and 18.7, most of the summer water temperatures were in the “fair” range until September, when maximum daily temperatures cooled to the “good” category. However in 2001, over one week in August and several days in late July had daily maximum temperatures that were in the “poor” category for these sites. Only the most upstream site near RM 20.4 had daily maximum water temperatures that were predominantly “good” (Stan Zyskowski, National Park Service unpublished data). Finney Creek also has a “poor” rated riparian coupled with excessive sedimentation impacts. Both of these likely contribute to the warm water temperatures.

In addition to the data leading to the 303(d) listing, Coal Creek was monitored at two different sites in 2002, resulting in the warmest recorded water temperatures found for the entire WRIA (Skagit County Department of Public Works 2003). At Hoehn Road in the lower mile of the stream, 18 out of 48 days in June and July had peak water temperatures in the “poor” and 6 days in the “fair” category. In August 2001, 24 out of 30 sampled days were in the “poor” and 6 were in the “fair” range. Some of these temperatures were extremely high with the warmest at nearly 37°C and many of the peak temperatures were above 20°C. September was also sampled with 13 days of peak temperatures in the “poor” and 8 days in the “fair” category (Skagit County Department of Public Works 2003). The warmest temperature during September 2001 was 21 °C. This reach of Coal Creek is rated “poor” for water quality, and frequently, recent summer peak temperatures have been at lethal levels for some salmonids.

The second sampled site in Coal Creek (at Highway 20) had cooler temperatures, but still has sufficiently degraded conditions to warrant its placement on the 303(d) List for warm water temperature. During the 45 sampled days of June and July 2002, no peak temperatures were in the “poor” and 9 were in the “fair” range (Skagit County 2003). During 29 sampled days in August 2001, 6 were in the “poor” range and 15 in the “fair” range. The warmest recorded temperature at this site was 16.7°C. Both Coal Creek sites have generally good levels of dissolved oxygen with sporadic high turbidity levels. The Hoehn Road site dries up at times (Skagit County Department of Public Works 2003).

Wiseman Creek was sampled at Minkler Road (RM 2.8) during 43 days of June and July 2002. During this time, 15 days had peak water temperatures in the “poor” range and 4 in the “fair” range. Dissolved oxygen levels were generally “good” at this site with occasional high turbidity levels (Skagit County Department of Public Works 2003). The warm water temperatures result in a “poor” rating for water quality in lower Wiseman Creek.

Morgan Creek has been monitored at two different sites (Figure 34). At the South Skagit Highway (RM 5.4) from June to July 2002, 11 out of 48 days had peak water temperatures in the “poor” and 16 in the “fair” range (Skagit County Department of Public Works 2003). Temperatures were warmer during August of 2001 with 19 out of 29 days in the “poor” and 9 days in the “fair” category. During September of 2001, 11

days had peak water temperatures in the “fair” range and all other temperatures were “good”. Dissolved oxygen levels were “fair” in the summer and “good” at other times in the year at this site.

In Morgan Creek at Walberg Road (RM 4.2), 24 out of 45 days had peak water temperatures in the “poor” and 12 days in the “fair” category (Skagit County Department of Public Works 2003). The warmest water temperature during this time was 19.6 °C. During August 2001, 22 out of 29 days had peak temperatures in the “poor” and 6 in the “fair” range. During September 2001, 5 days had peak water temperatures in the “poor” and 14 days in the “fair” category. Dissolved oxygen levels were mostly “poor” in the summer months and “good” other times of the year at this site (Skagit County Department of Public Works 2003). The warm water temperatures result in a “poor” rating for water quality conditions in Morgan Creek.

Recent monthly sampling has occurred in Mannser Creek from October 2000 through March 2001 near RM 0.52 (Summers 2001). Moderately low dissolved oxygen levels were noted in October (6.5 mg/L) and January (7.3 mg/L), which are in the “fair” range for this analysis. One single low pH was noted in February, and all other water quality values were “good”, including water temperature, copper, zinc, nitrate, ammonia, phosphorous, and turbidity (Summers 2001). However, these measurements did not occur during the summer months when water temperatures are warmer. B-IBI was scored at 40 near RM 2, which the author classified as “good” and compared within this study to values assigned to Issaquah Creek (30), Big Beef Creek (28) and Bingham Creek (38) in the Satsop River drainage.

Skagit County Department of Public Works (2003) has also measured water temperatures in Mannser Creek at the Lyman-Hamilton Road (RM 0.8); a reach that is already on the 303(d) List for warm temperatures. During the 45 sampled days in June and July 2002, only 3 days had peak temperatures in the “fair” range and no days in the “poor” category. Most days had peak temperatures that were “good” (Skagit County Department of Public Works 2003). Sampling during August and September of 2001 indicated that all peak temperatures were “good”. Dissolved oxygen levels were a mix of “poor”, “fair”, and “good” levels at this site with an extremely high relative turbidity reading in October 2001. This reach is rated “poor” due to low dissolved oxygen levels and the 303(d) Listing for warm water temperatures. More water quality monitoring is recommended for this site because of the discrepancy between the older data for the 303(d) List and the more recent monitoring.

Red Cabin Creek was sampled at the Hamilton Cemetery Road (RM 1.9) during June and July 2002, and all samples were in the “good” range (Skagit County Department of Public Works 2003). However, in August 2001, 5 out of 29 days were “poor” and 13 were “fair”. In September of 2001, 3 days had peak water temperatures in the “poor” category and 4 in the “fair” range. Dissolved oxygen levels were generally “good” at this site with one very high turbidity reading in October 2001 (Skagit County Department of Public Works 2003). This site is tentatively rated “poor” due to the warm water temperatures, but continued monitoring is needed.

Figure 44. Daily maximum water temperatures during 2001 in Finney Creek (Stan Zyskowski, National Park Service unpublished data).

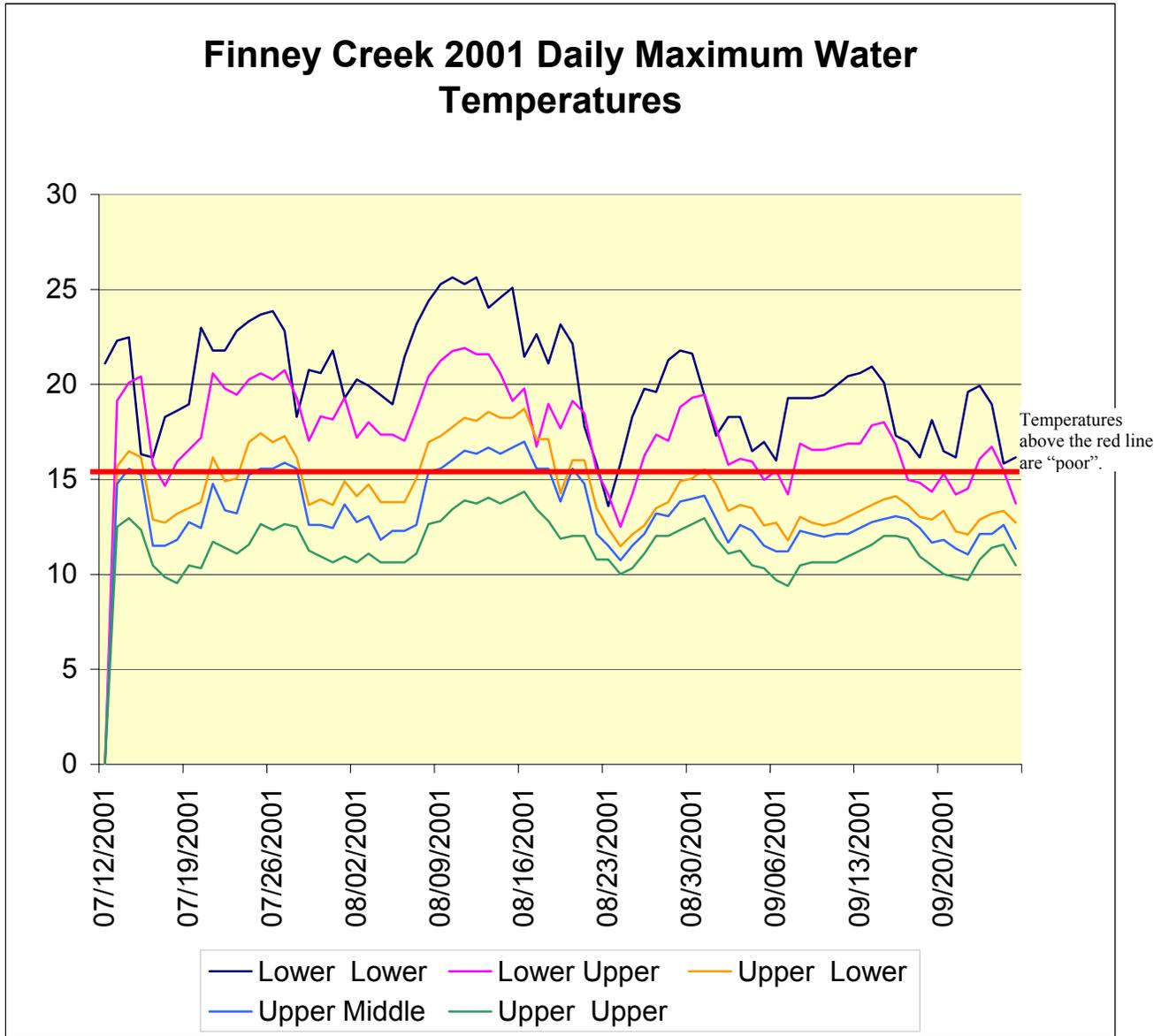
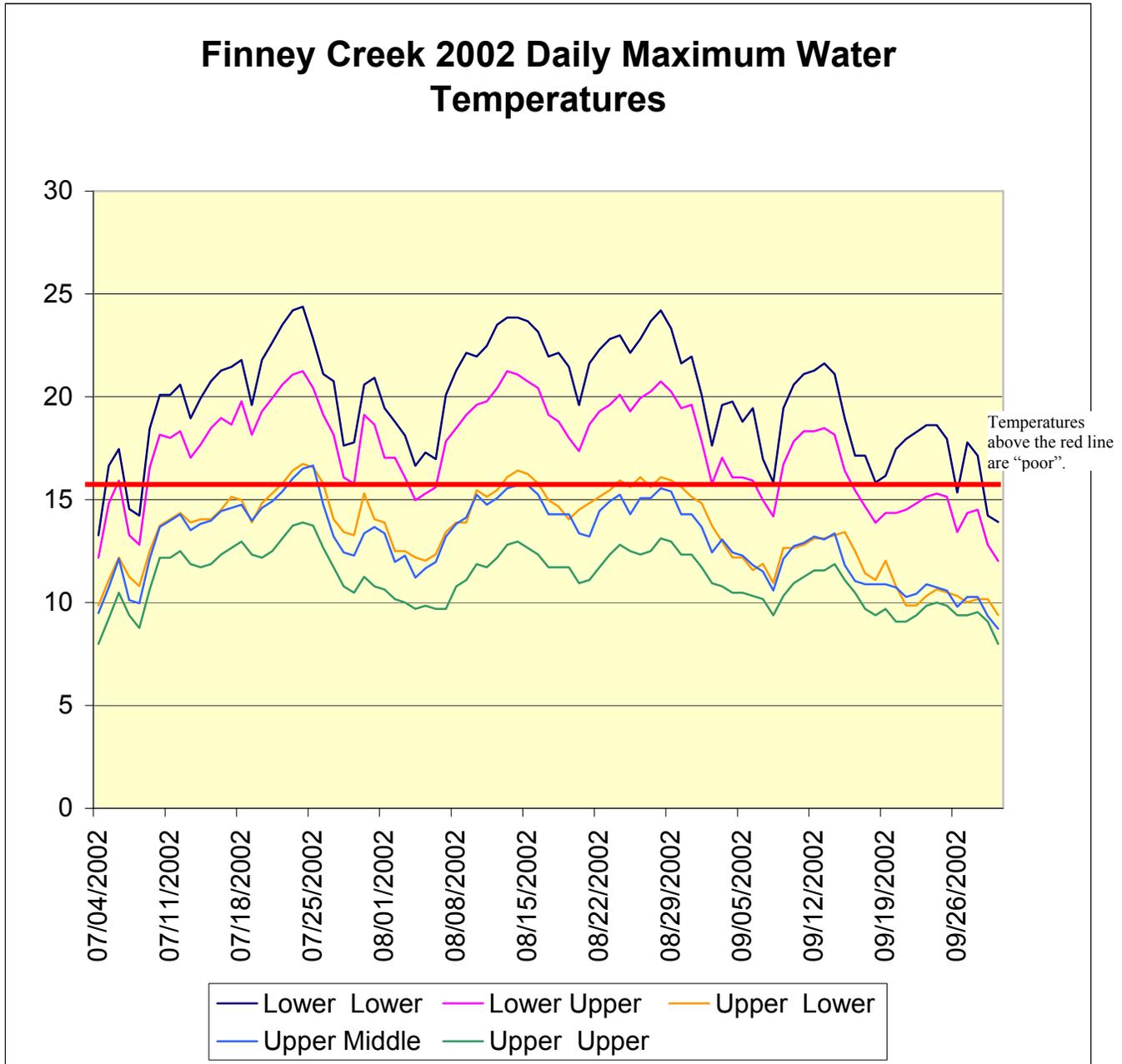


Figure 45. Daily maximum water temperatures in Finney Creek during 2002 (Stan Zyskowski, National Park Service unpublished data).



### Water Quality Conditions in the Upper Skagit Sub-Basin

No 303(d) listings are located in the upper Skagit sub-basin (DOE 2000), and less water quality data were available for this sub-basin. The Skagit River near Marblemount (RM 78.2) has been sampled as early as 1959 with regular sampling from 1978 to 2002 (DOE 2003). This segment was rated “moderate” for suspended solids and turbidity by the Washington Department of Ecology, while water temperatures and dissolved oxygen levels were within standards. Overall, water quality is tentatively rated “good” in the mainstem upper Skagit River. In addition, the Skagit River near Park Slough was sampled for water temperatures from September 1996 through June 1997. Several measurements per day were recorded with all values in the “good” range (National Park Service unpublished data).

Very limited water quality data were found for the tributaries to the upper Skagit River within the anadromous zone. Water temperatures were measured in Zander Creek, a tributary in the Bacon Creek drainage with all temperatures in the “good” range. These measurements were recorded from June 2001 through May 2002 (Stan Zyskowski, National Park Service unpublished data). Water temperatures were also measured several times per day in Taylor Channel from July 2001 to May 2002, located upstream of Taylor Creek near RM 80 along the Skagit River. All of the temperatures were in the “good” category (Stan Zyskowski, National Park Service unpublished data). All water temperatures within Park Slough (just upstream of RM 90) were in the “good” range as well, although recordings occurred from September 1996 through June 1997 and did not include July and August (Stan Zyskowski, National Park Service unpublished data). All of these tributaries are rated “good” for water quality conditions.

Riparian buffers are generally functioning along Bacon, lower Diobsud, Illobot Creeks and along the Cascade River (Beamer et al. 2000), suggesting that shade levels are likely adequate and water temperatures may be less problematic than in the lower Skagit Basin. However, the tributaries to the upper Skagit River that are lacking specific water quality data are not rated.

Water temperatures (several/day) have been measured in Thunder Creek and associated tributaries from August 1995 to August/September 1996. This watershed is located upstream of anadromous salmonid access and lies within the North Cascades National Park and a national recreation area, and has pristine habitat conditions. As expected, all of the recorded water temperatures in McAllister, Thunder, West Fork Thunder, Fisher, upper Fisher, and Logan Creeks were “good” (Stan Zyskowski, National Park Service unpublished data). A few excursions into the “fair” and “poor” categories were documented in the unnamed tributary 04.2045 to Thunder Creek and an unnamed tributary to Fisher Creek, although most of the temperatures in these streams were “good”.

### Water Quality Conditions in the Sauk River Sub-Basin

No segments within the Sauk River sub-basin are on the 303(d) List for water quality problems. However, specific water quality data were not easily found. In 1974 and 1993, the EPA sampled water quality parameters in Elliott, Clear, and Burns Creek, as

well as at four different sites in the Sauk River in various years. The four Sauk River sites include the Sauk River at Rockport (1976–1993), at Darrington (1959-1961), at the Government Bridge (1971–1974), and the Rockport Bridge (1971-1974). All sites had water temperatures, dissolved oxygen levels, and pH readings within standards. Width/depth problems were noted in the Monte Cristo Lake area, the South Fork at RM 4.4 to 5.1, and the lower Sauk River from RM 0 to 21.1 (U.S. Forest Service 1996).

In addition to these data, spot checks of water temperature occurred, and these results are listed in Table 10. These data suggest an increasing trend in water temperatures between the White Chuck confluence and the Forks and in the lower South Fork Sauk River. The Sauk River between the White Chuck confluence and the Forks is tentatively rated “poor” due to the temperature exceedance, but more data are greatly needed. The lower South Fork Sauk River is assigned a tentative rating of “fair”. Again, additional water quality monitoring is highly recommended in the Sauk River sub-basin. Known riparian impacts have occurred in the Sauk Prairie, Rinker, and Dan Creek WAUs.

**Table 10. Water Temperatures in the Sauk River (U.S. Forest Service 1996).**

River Segment	Sampling Date	Temperature Range	Rating
Between White Chuck and the Forks	August 1992	12.2-16.1 °C	Peak temperatures are “poor”
Between White Chuck and the Forks	July 1981	10-11.1 °C	“Good”
Lower South Fork Sauk	August 1992	11.1-15.0 °C	“Fair”
Upper South Fork Sauk	August 1992	10-12.2 °C	“Good”
South Fork Sauk	July 1981	8.9-13.3 °C	“Good”

Water Quality Conditions in the Baker River Sub-Basin

Except for the dams, very little human use occurs in the Baker River sub-basin. About 56% of the land is within National Forest boundaries and 30% within National Park lands (Puget Sound Energy 2002). Some private and state-owned lands are in the lower sub-basin.

Most of the streams within the Baker River sub-basin have good water quality conditions. These include Rocky, Sulphur, Boulder, Park, Swift, Little Sandy, Beaver, Shuksan, and Noisy Creeks as well as the Baker River. All of these streams had water temperatures below 14 °C (Puget Sound Energy 2002; U.S. Forest Service 2002). North Bear, Thunder, and Sandy Creeks had upper ranges into the “fair” category, and Bear Creek had temperatures reaching 16 °C, resulting in a “poor” rating. Dissolved oxygen levels

were in the “good” range for North Bear, Rocky, Sulphur, Park, Swift, Noisy, Thunder, and Sandy Creeks, but fell into the “fair” category for Bear Creek (Puget Sound Energy 2002).

Naturally occurring low pH levels have been recorded in Boulder Creek due to sulfuric acid from volcanic activity. Because this is a natural condition, it does not alter the “good” water quality rating for Boulder Creek.

Within Baker Lake, all of the dissolved oxygen measurements have been in the “good” range with a summer and fall mean of 10.7 mg/L. Summer water temperatures can be warm, ranging from 10.7 to 18 °C and averaging 15.2 °C. The Washington State Department of Ecology temperature standard for lakes is “no measurable change from natural conditions” (DOE 1992). Because natural, pre-dam temperatures for Baker Lake are unknown, water quality is unknown and not rated in this report.

#### Water Quality Conditions in the Samish River Sub-Basin

Water quality problems are abundant in the Samish River (Figure 34). One segment of the Samish River near the Friday Creek confluence is mapped as a 303(d) listing for impaired fish habitat, but is not on the tabular 303(d) list (DOE 2000). Although all other 303(d) List segments are listed because of elevated fecal coliform levels, many other water quality parameters that more directly impact salmonids are frequently impaired in the Samish Basin. These are highlighted in Figure 34 and discussed in detail below.

Sampling in 1995 and 2000 has occurred near RM 4.7 in the Samish River, and nitrogen levels were recorded as “poor” along with “moderate” levels of suspended solids and phosphorus (DOE 2003). Water temperatures were warm with a sample of 15.9 °C (“poor”) in August and 14.7 °C (“fair”) in September. Oxygen levels were all “good”. Skagit County (2003) measured water temperatures near Chuckanut Drive (RM 6.5) from June 3 through July 18, 2002. During that time, there were 20 days with peak water temperatures in the “poor”, 13 days in the “fair”, and only 13 days in the “good” category (Skagit County Department of Public Works 2003).

Near Burlington at RM 10.4 in the Samish River, monitoring has occurred from 1982 through 2002 with the exception of 1992 and 1994. Numerous water quality problems have been documented in the last 5 years, and are summarized in Table 11. Exceedances include elevated turbidity, suspended solids, water temperatures, nitrate, nitrogen, ammonia, and phosphorus, and of these, elevated nitrogen levels are the greatest problem (DOE 2003). At the F & S Grade Road, 10 out of 46 days were in the “poor” and 16 in the “fair” category. This site was also monitored in 2001 from August 14 through October 30. During the later half of August, 1 day was in the “poor” and 12 days in the “fair” range. It is noteworthy that so many days are either in the “poor” or “fair” categories because these temperatures were measured early in the season, before the peak temperature months.

Upstream near Prairie (RM 14.3), “poor” levels of nitrogen were noted with “moderate” levels of phosphorus in a single year of sampling in 1995 (DOE 2003). Water

temperatures and dissolved oxygen levels were all within standards in this reach. Skagit County Department of Public Works (2003) sampled water quality in the Samish River at Prairie Road in 2002. Out of 46 days in June and July 9 days had peak water temperatures in the “poor” and 15 days in the “fair” range.

Skagit County Department of Public Works (2003) measured upper Samish River water temperatures near Highway 9 (RM 20.9) from June 3 through July 18, 2000 with 20 days of peak water temperatures in the “poor” and 9 days in the “fair” category (Skagit County Department of Public Works 2003). In general, the numerous and frequent water quality exceedances result in a “poor” rating for water quality conditions in the Samish River. In addition to potential inputs from failing septic systems and agriculture, riparian conditions are generally poor along much of the stream lengths of the Samish River and Friday Creek.

**Table 11. Water Quality Exceedances in the Samish River near Burlington (DOE 2003).**

River Segment	Elevated Parameter	Date
Samish near Burlington (1997 through October 2002)	Turbidity or suspended solids	June 2002, April 2001, April 2000, March 1997
	Water temperature	July 2002 (17.6 °C), May 2001 (14.6 °C), June 2001 (14.9 °C)
	Nitrate, Nitrogen, Ammonia, or Phosphorus	September 2002, October 2002, January 2001, March 2001, April 2001, January 2000, April 2000, December 1999, September 1999, April 1999, March 1999, December 1998, November 1998, October 1998, April 1998, September 1997, April 1997, March 1997

Water temperatures were worse in the Samish River tributaries. Thomas Creek was sampled at two sites, at Highway 99 (RM 0.3) and the F & S Grade Road (RM 3.6) from June 3 to July 18, 2002. At the Highway 99 site, 33 days out of 47 had peak water temperatures in the “poor” and 14 days in the “fair” category (Skagit County Department of Public Works 2003). None of the days at this site had peak water temperatures in the “good” range, and the warmest water temperature was 19.7°C. In Thomas Creek at the F

& S Grade Road, 5 days out of 46 were in the “poor” and 19 days in the “fair” range. From August 9 through 31, 11 out of 23 days had peak water temperatures in the “poor” and 10 in the “fair” category. These water temperatures result in a “poor” rating for water quality conditions in Thomas Creek.

Water temperatures were also warm in Friday Creek at Prairie Road near the hatchery. Out of 47 days in June and July 2002, 32 days had peak water temperatures in the “poor” and 15 days in the “fair” category (Skagit County Department of Public Works 2003). Again, no days had peak water temperatures in the “good” range, and the highest water temperature was 19.5°C. In August 15 out of 17 days were in the “poor” and 1 day in the “fair” range. In September 7 days were “poor”, 17 days were “fair”, and 6 days were “good”. In addition to these data, several water quality parameters were measured in Friday Creek just downstream of the hatchery rack at RM 0.8 in 1995 and 1998 (DOE 2003). Nitrogen levels were listed as “poor” with “moderate” levels of phosphorus, turbidity, and suspended solids. While all dissolved oxygen levels were in the “good” range, water temperatures reached 16.4°C (poor) in July of 1995. Further upstream near Alger (RM 7.2), water temperatures were very warm in the single year sampled of 1974 (DOE 2003). Temperatures were all above 20 °C from June through September, a level that approaches lethal levels for some salmonids. These data result in a “poor” water quality rating for lower Friday Creek. The reach near Algiers was not rated because the only available data are old. Because past data indicates a severe impairment to salmonids, future monitoring is highly recommended.

Water temperatures in Swede Creek at Grip Road were monitored for 45 days in June and July of 2002 (Skagit County Department of Public Works 2003). Swede Creek is a Samish River tributary located shortly upstream of the Friday Creek confluence. In this period, 23 days had peak water temperatures in the “poor” and 17 days in the “fair” category, and the warmest temperature was 18.9°C. The latter half of August 2001 was also monitored with 9 out of 17 days in the “poor” and 9 days in the “fair” category. These data result in a “poor” rating for water quality conditions in Swede Creek.

Skarrup Creek, a Samish tributary, was sampled at Double Creek Lane during June and July 2002, and 15 out of 45 days had peak water temperatures in the “poor” and 10 days in the “fair” range (Skagit County Department of Public Works 2003). The warmest water temperature was 17.3 °C. In late August of 2001, 9 out of 18 days had peak temperatures that are considered “poor” in this analysis with 9 days in the “fair” category. During September 2001, 10 days had peak temperatures in the “fair” and 1 day in the “poor” range (Skagit County Department of Public Works 2003).

Dissolved oxygen levels were generally good at all sampled sites within the Samish drainage except for Thomas Creek at Highway 99, which was mostly “poor” at several times in the year, and at the Samish Highway 9 site, which had mostly “fair” levels (Skagit County Department of Public Works 2003).

Occasional high turbidity readings were recorded in the Samish River at four different sites. These include: Chuckanut Drive, Highway 99, F & S Grade Road, and Prairie Road, which had very high relative turbidity levels at times (Skagit County Department

of Public Works 2003). Similar conditions were recorded at both sampled sites in Thomas Creek (F & S Grade Road and Highway 99).

## Water Quantity Conditions in WRIs 3 and 4

### Water Quantity Conditions in the Lower Skagit Sub-Basin

The flows in the Skagit River are partially regulated by dams in the upper Skagit River and the Baker River. The Skagit River Hydroelectric Project is operated by Seattle City Light and includes the Ross, Diablo, and Gorge Dams. Of these, Ross Dam has the greatest flood capacity storage and is located the farthest upstream (Puget Sound Energy 2002). The three Skagit dams are upstream of the natural anadromous salmonid distribution. Details regarding the Baker Project are in the Baker River section of this chapter.

About 29% of the flow in the Skagit River goes through the Seattle City Light project and 17% through the Baker project (Puget Sound Energy 2002). Water storage occurs behind each of the dams in the mainstem Skagit River and in Baker Lake, and because of dam storage and operations, it is estimated that the magnitude of peak flows by return period has been reduced by about 50% (Beamer et al. 2000). However in spite of reduced peak flows, development within and near the historic Skagit floodplain has resulted in flooding of Mount Vernon or Sedro Woolley about every 2.2 years since 1900 (Puget Sound Energy 2002). This has led to increased large-scale impacts to the floodplain (dikes, bank hardening, etc.), which can accelerate water velocity and result in scour.

In the past, dam operations have resulted in another type of impact to salmonids, especially from rapidly changing flows, which can lead to stranding and redd (nest) dewatering. However, improved management has greatly decreased this impact from the Seattle City Light operations. Continued concerns exist for this problem from the Puget Sound Energy operations in the Baker sub-basin.

Most of the tributaries to the Skagit River are unregulated, and changes in land cover, road density, and floodplain habitat are the primary types of impacts to flow conditions. Peak flow conditions for the tributaries within the lower Skagit sub-basin have been analyzed using effective impervious area (Beamer et al. 2000). This parameter is based upon land use categories for future use and may not accurately reflect current conditions, but is the best available analysis. The analysis resulted in several streams classified as predominantly impaired, including the South Fork Skagit River, Gages Slough, and parts of Nookachamps Creek and the lower Skagit River (Beamer et al. 2000). These are rated “poor” for water quantity conditions. Moderately impaired conditions dominate the North Fork Skagit River, Hansen Creek, sections of the lower Skagit River, and parts of Nookachamps Creek. These are rated “fair” for water quantity conditions.

In the mountainous tributaries to the lower Skagit River, peak flow impairment has been based upon land cover vegetation and road density. The criteria for impairment are either more than 50% of immature vegetative land cover area or more than 2 km/km<sup>2</sup> road density (Beamer et al. 2000). Using these criteria, WAUs that have been designated as impaired include the Nookachamps, Hansen, Gilligan, Day, Alder, Grandy, and Finney with likely impairments for the Loretta, and Jackman WAUs (Beamer et al. 2000). These are tentatively rated “poor” for water quantity conditions. Functioning WAUs with

sensitivity to land use are the Pressentin and Corkindale WAUs. These are tentatively rated “good”, but changes in land cover vegetation or road density could change the conditions.

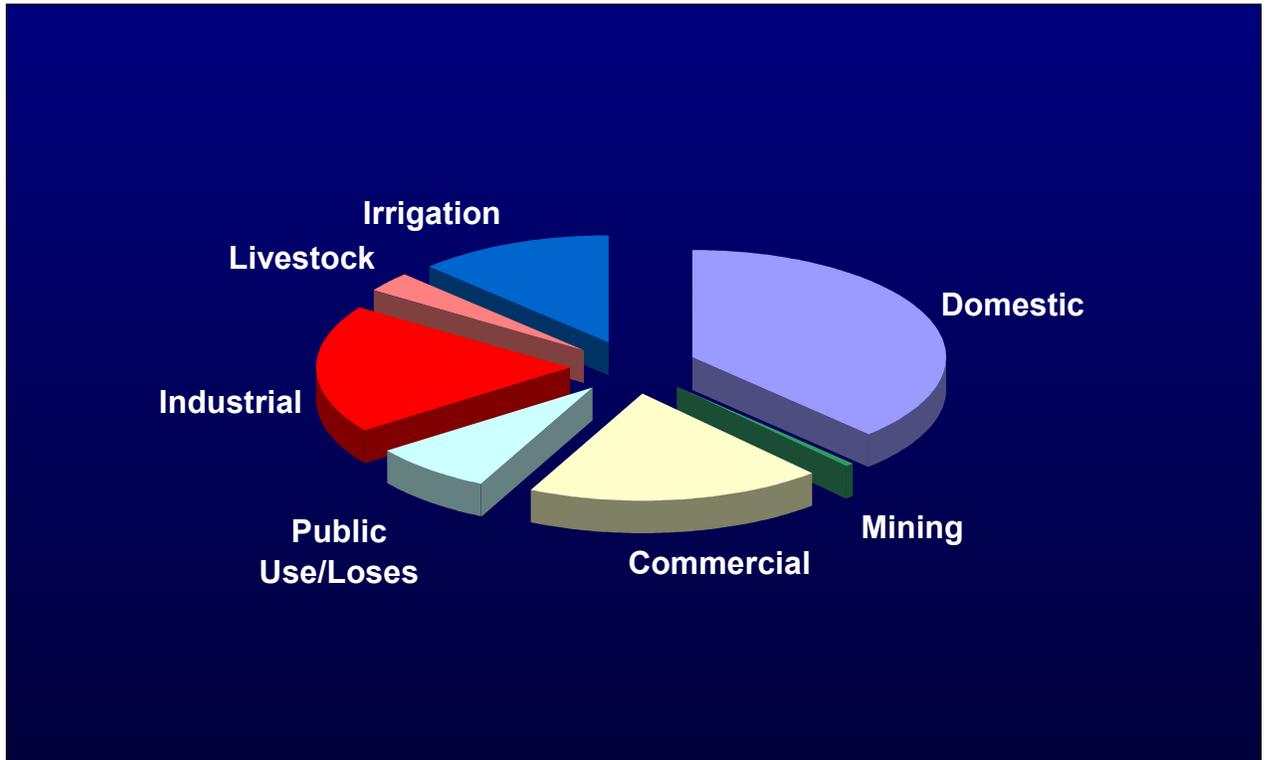
The Nookachamps watershed serves as a natural flood storage area. High flows in the Skagit River can back up into the Nookachamps to RM 1.5, and over 19% of the Nookachamps watershed is in the Skagit 100 year floodplain (NWMC and SCDPCD 1995). However, the lower reaches of the Nookachamps have been altered by diking and other floodplain impacts that reduce its natural flood control function.

In the early 1990s, the land cover vegetation was examined for a watershed analysis within the Hansen WAU. These data are consistent with the later results using Lunetta et al. (1997) in Beamer et al. (2000). The Hansen WAU had predominantly (73%) immature vegetative cover with 18% classified as intermediate and 9% as mature (DNR 1994). Most of the land cover consisted of hardwoods (alder and cottonwood) or mixed hardwoods and Douglas fir, and these were typically immature. When impacts to peak flows were examined, the percent increase in a two year event under either average current or immature land cover conditions was less than three percent, but the percent increase for unusual storms ranged from 5.2 to 8.2% (DNR 1994). The percent increase in 50-year events was less than 2% for average current or immature conditions and a 6% or less increase for unusual storms.

Water use for human purposes is higher in the lower Skagit sub-basin than elsewhere in the two WRIAs. An estimated 14.28 million gallons of surface water and 6.93 million gallons of ground water are used per day in the lower Skagit sub-basin (U.S. Geological Survey 1998b). The greatest (5.42 million gallons per day) single use of surface water is for domestic use with 2.75 million per day used for industrial and 2.7 per day for commercial use (Figure 37) (U.S. Geological Survey 1998b).

No information was found for low flow conditions in the lower Skagit sub-basin other than a note that extreme low flows exist in Day Creek in the summer (U.S. Forest Service 1999). It is likely that there are low flow problems given the land use, water withdrawals, loss of wetlands, and isolation of habitat with dikes. Low flows also contribute to warm water temperatures, which are known to occur in many of the tributaries to the lower Skagit River. However, analyses are needed to determine the cause(s) of the warm water temperatures. Information regarding the actual human water use for salmonid streams is also needed.

**Figure 46. Surface water withdrawal uses in the lower Skagit sub-basin (data from U.S. Geological Survey 1998b).**



#### Water Quantity Conditions in the Upper Skagit Sub-Basin

Much of the flow in the upper mainstem Skagit River is regulated by the Ross Dam, and it is estimated that the magnitude of peak flows by return period have been reduced by about 50% (Beamer et al. 2000) due to flood water storage and hydroelectric needs. The upper Skagit mainstem is more directly influenced by flow regulation than the lower Skagit River, which has more flow buffer from tributary inputs.

In the past, dam operations have resulted in impacts to salmonids, especially from rapidly changing flows, which can lead to stranding and redd dewatering. However, improved management by Seattle City Light has greatly decreased this impact. There is a consensus program requiring flows to be adjusted for salmon habitat needs on a seasonal and daily basis with gradual ramping rates. In addition, Seattle City Light provides funds for salmon production, research, and habitat restoration (American Rivers 2002).

Water withdrawals for human uses are relatively low in the upper Skagit sub-basin. An estimated 0.15 million gallons of surface water and 0.61 gallons of ground water are used for human purposes per day (U.S. Geological Survey 1998b). This compares to over 14 million gallons per day of surface water used in the lower Skagit sub-basin.

In the mountainous tributaries to the upper Skagit River, peak flow impairment has been assessed based upon land cover and road density. The criteria for impairment are either more than 50% of immature land cover area or more than 2 km/km<sup>2</sup> road density (Beamer et al. 2000). Using these criteria, most of the WAUs in the upper Skagit sub-basin are designated as functioning. These include Newhalem, Bacon, Diobsud, upper and middle Cascade, and Illabot. Jordan-Boulder is the only other WAU within the anadromous salmonid zone and it is also classified as functioning, although sensitive to land use (Beamer et al. 2000). All of these streams are rated “good” for water quantity conditions.

#### Water Quantity Conditions in the Sauk Sub-Basin

Peak flow impairment has been analyzed in the Sauk sub-basin and is based upon land cover and road density as described in the earlier sections (Beamer et al. 2000). Using these criteria, four WAUs within the Sauk sub-basin have been classified as likely impaired. These include the Hilt, Rinker, Sauk Prairie, and Dan Creek WAUs, and they encompass the lower and middle Sauk River sub-basin (Beamer et al. 2000). These are provisionally rated “poor” for water quantity conditions with a need for more information and analysis. In addition, the Clear Creek and Tenas WAUs were designated as functioning with a sensitivity to land use. All other WAUs were rated as functioning, including the WAUs in the upper Sauk and much of the Suiattle and White Chuck River drainages. These are rated “good” for water quantity conditions. However, the watershed analysis noted that increased peak flows and sedimentation appears to have led to aggradation and channel shifting in the Sauk River, impacting the mouths of many tributaries (U.S. Forest Service 1996). This indicates that more information is needed to better understand the hydrologic processes in the Sauk River sub-basin.

Water use appears to be relatively low within the Sauk sub-basin. An estimated 0.17 million gallons of surface water per day are withdrawn (U.S. Geological Survey 1998b). Ground water use is even lower at 0.07 million gallons per day.

#### Water Quantity Conditions in the Baker Sub-Basin

In 1924, construction began on the Lower Baker Dam, forming Lake Shannon, which now covers 160,000 acre-feet at normal full pool. Construction of the Upper Baker Dam began in 1956, resulting in a 60-foot elevation of Baker Lake, inundating sockeye spawning beaches and the lower reaches of tributaries to Baker Lake (Puget Sound Energy 2002). The normal full pool capacity of Baker Lake is now 285,000 acre-feet.

Puget Sound Energy manages the flow from Shannon Lake for hydroelectric needs, but these dam operations have resulted in impacts to salmonids, especially from rapidly changing flows that lead to stranding and redd dewatering. The problems have been persistent. In 1997, the Skagit System Cooperative analyzed the downramp flows from the Baker Project for the 1996 water year. They found 93 downramps where the flow of the Skagit River at Concrete was lower than the agreed upon 18,000 cfs and 92 downramps that were faster than the agreed upon 2,000 cfs per hour protocol (Stan Walsh, SSC, letter to Brady Green 2003). In a 1997 meeting, Puget Sound Energy

agreed to resolve the problem. However, in November 2000, the flow was shut off from the Lower Baker River Project for routine maintenance and the Baker River flow rapidly changed from 2,600 cfs to 130 cfs. The effect translated to the mainstem Skagit River where the flow dropped from 9,000 to 5,700 cfs resulting in a large loss of salmonid production due to dewatered nests (Brulle 2002). Because of these continued problems, water quantity conditions in the Baker River are rated “poor”.

In addition, the hydroelectric operations have likely impacted other habitat conditions by changing the Baker River flow from a free flowing river to still water. This can alter channel processes, river/floodplain interactions, and the diversity and productivity of the ecosystem (U.S. Forest Service 2002).

Peak flow impairment has been analyzed for the Baker River and tributaries, and is based upon land cover and road density as described in the earlier sections (Beamer et al. 2000). Using these criteria, the Shannon West WAU has been classified as likely impaired, and is provisionally rated “poor” for water quantity conditions with a need for more information and analysis. In addition, the Shannon East WAU was designated as functioning with a sensitivity to land use, and is rated “good” for this analysis. The Mount Baker and Mount Blum WAUs were described as functioning, and are rated “good” for water quantity conditions.

#### Water Quantity conditions in the Samish Sub-Basin

An analysis of instream flows is underway in the Samish drainage under the 2514 Watershed Planning process. Results from their draft report indicate that consumptive uses slightly lower flows that are already inadequate to support maximum levels of chinook and steelhead spawning in the Samish River (Duke 2001). The estimated flow within the Samish River that is needed for maximum habitat use is 190 cfs, but the flows measured for the analysis indicate existing flows of 30 cfs in September and 80 cfs in October (Duke 2001).

Most of the small and medium sized Samish tributaries also have insufficient flows for the maximum production of salmonids (Duke 2001). For example, Silver Creek flows are not adequate for coho and chum. Overall, the Samish basin habitat is limited in the summer and early fall. However, the Samish River has adequate flows during the coho and chum spawning seasons.

The lower Samish River appears to have little impervious surfaces. Several segments in the middle reaches of the mainstem Samish River and most of Friday Creek are classified as moderately impaired (Beamer et al. 2000). This results in a tentative “fair” rating for water quantity in Friday Creek, pending additional analysis. Water quantity conditions are unknown in the Samish River. No segments were labeled as functioning and only a few were described as impaired with much of the lower Samish River unknown (Beamer et al. 2000).

## **The Condition of Estuarine and Nearshore Habitat in WRIA 3**

### Estuarine Delta Habitat and Function in WRIA 3

The estuarine delta in this report refers to a body of water adjacent to freshwater systems where saltwater mixes with freshwater. The estuary deltas in WRIA 3 include the Samish, east Padilla, Swinomish Channel, North and South Fork Skagit, central Skagit and Douglas Slough deltas. Each of which are discussed below. The upstream-most extent of estuaries moves with the tides, and tidal influence for the Skagit River extends to Mount Vernon (Pickett 1997).

Estuaries serve many important functions such as providing habitat for smoltification, migration, rearing, and refuge, as well as contributing to habitat complexity and ecological processes, such as detritus cycling (Williams and Thom 2000; Aitkin 1998). For anadromous fish species, estuaries provide a critical mixing zone of fresh and salt water where juvenile and adult life stages can physiologically transition between freshwater and saltwater habitats. If the habitats necessary for successful rearing and predator refuge are not available within this mixing zone, the survival of these fish is jeopardized.

Estuary habitats produce a host of prey species important to juvenile salmonids and forage fish species that are in turn, prey of adult salmonids. Certain prey items appear to be selectively chosen over others depending on the salmonid life history stage. For example, juvenile chum salmon feed on a certain type of copepod that lives on the bacteria near decaying eelgrass (Simenstad and Salo 1982). In order to support the diverse prey needs of the different salmon species and life history stages in the estuary, a mosaic of habitat types in an estuary need to be available and hydrologically accessible. The intertidal, shallow sub-tidal, blind channel, and distributary channel habitats in the estuary provide juvenile salmonids with access corridors to estuary habitats producing preferred prey species (Shreffler and Thom 1993). In addition, the interaction of tides and channel habitats provides a delivery system that transports preferred prey species from estuary habitats that are not accessible by juvenile salmonids to obtainable areas.

Estuaries provide a complex variety of shallow water habitats and distributary channels that serve as migration corridors for juvenile salmonids, while deeper water distributary channels serve as migration corridors for adults (Shreffler and Thom 1993). Intertidal and shallow subtidal habitats provide juvenile salmonids protection and refuge from avian and fish predators, while blind channel and side-channel estuary habitats serve as refuge from high water river discharge events. Distributary channels provide critical migration and movement routes between habitats.

Vegetative biomass produced in the estuaries is exported as detritus, and is the primary fuel source for the estuary and nearshore marine detritus-based food webs upon which juvenile salmonids depend. The complex estuarine habitats support salmonid survival by providing a wide variety of rearing and refuge opportunities to accommodate different juvenile out-migration strategies.

### Nearshore Habitat and Function in WRIA 3

The nearshore environment is the interface between marine and terrestrial habitats, and extends from the outer limit of the photic zone to coastal landforms such as bluffs, sand spits, and coastal wetlands, including the riparian zone on or adjacent to any of these areas. There is an estimated 229 miles of estuarine shoreline in Skagit County (Berry et al. 2001). The nearshore reaches in this report include all estuarine shorelines that are not immediately adjacent to a freshwater drainage including Samish Bay, Padilla Bay, north Fidalgo Island, south and west Fidalgo Island, northeast Whidbey Island, and all other islands within WRIA 3 (Sinclair, Vendovi, Cypress, Guemes, Burrows, and Allen Islands). The northeast shoreline of Whidbey Island is not in WRIA 3, but is discussed here because of its proximity to the Skagit River delta.

Nearshore habitat functions as important migration corridors, rearing and refuge habitat, habitat for prey species, and detritus input (Williams and Thom, 2000). Specifically, the nearshore intertidal and shallow sub-tidal habitats provide a critical migration corridor for juvenile salmonids, which use these areas for feeding, shelter from predators, and rearing. The nearshore riparian, intertidal, and shallow sub-tidal habitats produce a host of prey species important to juvenile salmonids and forage fish species. The nearshore terrestrial, salt marsh, eelgrass, and macro-algae habitats are a valuable source of detritus that fuels the nearshore detritus-based food chain (Thom and Williams 2001). In addition, juvenile salmonids are dependent upon the intertidal, shallow sub-tidal, and marine vegetation communities for refuge from avian and fish predators until they transition to deep-water habitats.

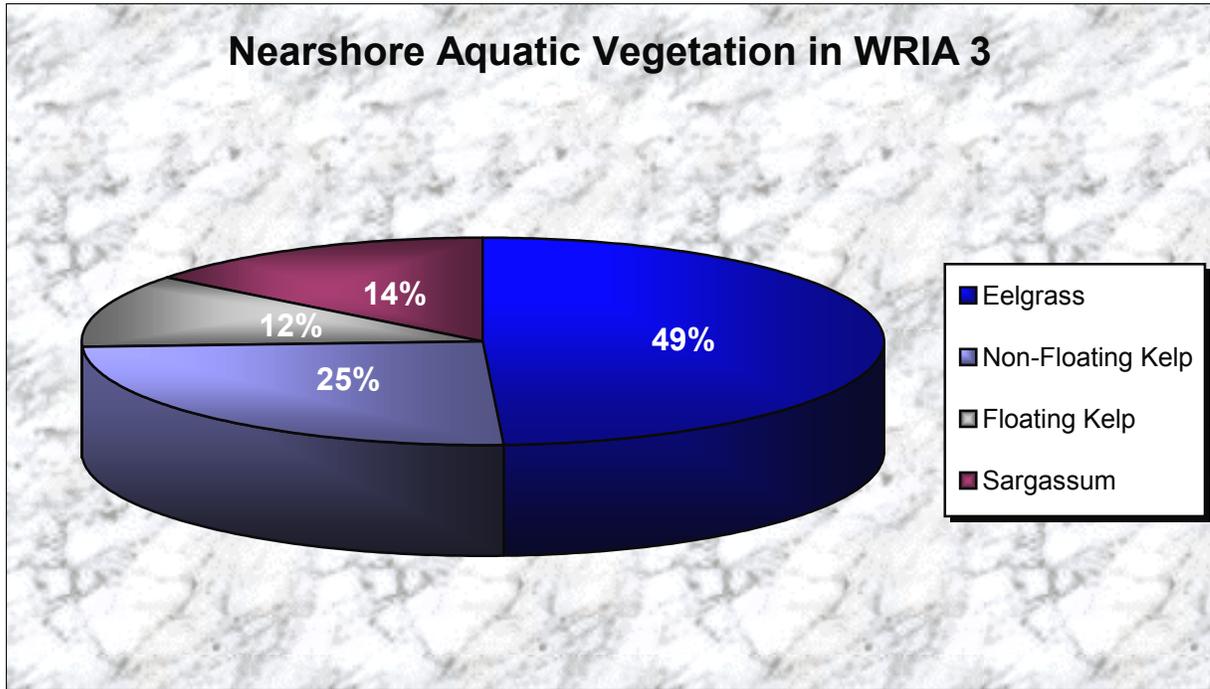
The nearshore intertidal, eelgrass, and macro-algae habitats provide valuable spawning habitats for forage fish species that are important prey for juvenile and adult salmonids, while the complex variety of intertidal, shallow sub-tidal, and sub-tidal habitats provides a wide range of diverse rearing and refuge opportunities to accommodate different juvenile chinook out-migration and survival strategies (reviewed in Cederholm et al. 2000).

The aquatic vegetation along the WRIA 3 shoreline consists of 49% eelgrass, 26% non-floating kelp, 12% floating kelp, and 15% sargassum, a non-native brown algae (Figure 38) (Berry et al. 2001). Kelp beds provide food and shelter for a variety of species, including salmonids, and floating vegetation mats provide transport in addition to food and shelter (Simenstad et al. 1991; Shaffer et al. 1995). Adult chinook and coho salmon use kelp beds for feeding and staging prior to freshwater re-entry (Shaffer 1998). Kelp also provides a spawning substrate for herring (Harrold et al. 1988).

Eelgrass is abundant in WRIA 3, and provides several benefits for salmonids, including nursery habitat, food, protection from predators, and shoreline stabilization (Levings and Thom 1994). In eelgrass beds, about half of the primary productivity comes directly from eelgrass, while the other half comes from algae and diatoms that live on the eelgrass blades (Thom 1987). It is also an important component of nutrient cycling. Eelgrass beds have the greatest variety of epibenthic animals compared to salt marsh and mudflat habitat, with two of three species of copepods that are a major food source for fish, found only on eelgrass (Simenstad et al. 1988). Chum salmon feed on copepods that live on the

bacteria near decaying eelgrass (Simenstad and Salo 1982), and eelgrass provides spawning substrate for herring, another prey item of salmonids (Humphreys and Hourston 1978).

**Figure 47. Aquatic Vegetation in WRIA 3 (data from Berry et al. 2001).**



#### Types of Estuarine Habitat Impacts and Existing Impact Data

Shoreline modifications, such as dikes, dredging, and fills, have had a considerable influence on estuarine habitat in WRIA 3. These types of impacts interrupt the riverine and tidal hydrologic processes that create and support estuarine delta and nearshore habitats. Shoreline modifications can be detrimental to nearshore and estuarine processes by fragmenting the nearshore intertidal and shallow sub-tidal habitats, reducing nearshore habitat complexity, reducing sediment recruitment (erosion), and disrupting longshore sediment transport processes that support and sustain the physical character and biological productivity of the upper intertidal habitats (Clark 1996). The loss of habitat and habitat complexity reduces refuge opportunities and survival options available to juvenile salmonids. Shoreline modifications can also result in a loss of intertidal habitats including eelgrass and macro-algae habitats and the loss of associated prey and detritus production (reviewed in Nightingale and Simenstad 2001a). Nearshore fills and dredging have been shown to be an obstacle to juvenile salmonid nearshore migration (reviewed in Nightingale and Simenstad 2001a). When the migration behavior of juvenile salmonids is altered, the risk of predation by avian and fish species is potentially increased.

Shoreline modifications, such as bulkheads, riprap, or fills, impact an estimated 35 % of the shoreline length in Skagit County (Berry et al. 2001), and this is likely an underestimate when the data are compared to a more detailed survey in Skagit Bay (Nouffke and Beamer 2001). Out of the 14 counties included in the inventory, Skagit County ranks 7<sup>th</sup> in the percentage of modified shoreline miles (Berry et al. 2001), and is the 5<sup>th</sup> highest out of 18 regions for the number of bank protection permits per shoreline mile (Broadhurst and Wlakinshaw 1998).

Tidegates are another type of impact to salmonids associated with diking. They isolate significant estuary habitat and disconnect the riverine and tidal hydrologic processes that create and support estuary habitats (Brian Williams, WDFW, personal communication). This contributes to the loss and fragmentation of migration corridors, rearing habitats, and refuge habitats for juvenile salmonids. While an inventory of tidegates has been conducted for WRIA 3, the impacts from each tidegate have not been assessed, resulting in an inability to prioritize each tidegate for salmon recovery purposes. Tidegate locations are shown in Map E1.

The shoreline modifications conclusions in this report rely on two separate inventories. The Department of Natural Resources inventory (Berry et al. 2001) is used throughout WRIA 3 and nearby shorelines in Island County. In addition, a more detailed inventory of shoreline classifications and modifications has been done by the Skagit System Cooperative (Nouffke and Beamer 2001). These data include the shorelines surrounding Skagit Bay, and conclusions for Skagit Bay shoreline modifications are based upon this survey, although the results from both inventories are shown in Maps E2 and E3.

**Link to Map E1. Documented tidegates in WRIA3. These have not been assessed to determine potential impact to salmonids. This map is in a separate file.**

**Link to Map E2. Shoreline Modifications in WRIA 3 as identified through the DNR Shoreline Inventory (data from Berry et al. 2001). This map is in a separate file.**

**Link to Map E3. Shoreline Modifications in Skagit Bay (data from SSC and Skagit County). This map is in a separate file.**

Gravel/sand beaches provide spawning substrate for surf smelt and sand lance and are dependent on the longshore transport of sediment from feeder bluffs (Clark 1996). Large increases and decreases in the level of sedimentation can have impacts on the food web that supports salmonids. Excess sediment from land alterations is likely detrimental for certain plants, surf smelt, and herring (Levings and Moody 1976; Morgan and Levings 1989). For example, the densities of algae were significantly different following a landslide along Puget Sound that resulted in a sediment plume that lasted weeks (Shaffer and Parks 1994). Sediment transport processes are disrupted by shoreline modifications, filling, and dredging, as discussed above. However, specific sediment transport analyses are needed in WRIA 3, and no conclusions regarding sediment transport can be provided in this report.

Additional impacts to nearshore habitat can occur from overwater structures. The shadow cast by overwater structures fragments the nearshore intertidal and shallow subtidal habitats (reviewed in Nightingale and Simenstad 2001b). The shadow cast by overwater structures has also been shown to change juvenile salmonid nearshore migration, and this altered behavior can potentially increase the risk of predation by avian and fish species, as well as reduce feeding success (reviewed in Nightingale and Simenstad 2001b). The shadow reduces the light available for photosynthesis thus impacting the health, survival and productive functions of the epiphyte, eelgrass, and macro-algae habitats and reducing the production of prey and detritus (Fresh et al. 1995; reviewed in Nightingale and Simenstad 2001b). Overwater structures have been inventoried in WRIA 3 (Berry et al. 2001), and this report rates areas for their quantity of structures (see the Assessment Chapter for details on rating criteria).

One of the major concerns with overwater structure is their effect on eelgrass beds, although dredging, filling, and increased sediment (turbidity) are other common types of impacts to eelgrass beds. Ratings for eelgrass beds are not generally provided in this report unless there are quantified or known impacts. Instead, ratings are given for the causes of the impacts where known, and these causes (dredging, structures, filling, sedimentation) can impact other types of habitat besides eelgrass beds. Existing eelgrass bed data are limited. A coarse inventory is provided in Berry et al. (2001), but there is a lack of historical data to support trend information regarding the status of eelgrass habitat.

The riparian vegetation along estuarine and nearshore environments constitutes a transition zone between tidally influenced aquatic habitat and terrestrial habitat, and provides several important functions. These can include shade, detritus input, marsh plant colonization, bank stability, wave energy deflection and absorption, large woody debris (LWD), and terrestrial insects which serve as salmonid prey, depending on the type of vegetation (Volk et al. 1984; Simenstad and Wissmar 1985; Everett and Ruiz 1993; Whitehouse et al. 1993; Maser and Sedell 1994). For example, Pentilla (2001b) compared the effect of shade on surf smelt egg survival, noting 36% dead eggs in shaded areas compared to 60% in non-shaded areas, underscoring the importance of riparian vegetation. Numerous species of marine riparian vegetation can be found, determined by environmental conditions such as salinity and soils.

Residential bulkheads, residential view corridors, commercial shoreline armoring, dikes, culverts, and commercial fills are among the more common types of impacts that reduce riparian vegetation. Riparian vegetation has been inventoried (Berry et al. 2001), but it is not clear whether some areas might be naturally low in overhanging riparian vegetation. For this reason, the areas with 10% or less riparian vegetation are highlighted and additional clarification is needed to determine if these are areas with naturally low riparian vegetation or had historically important vegetation for salmonids and forage fish habitat and habitat processes.

Another type of impact to estuarine habitat is water quality. Toxins and degradations that alter dissolved oxygen and water temperatures can be detrimental to salmonids or to the food web that supports salmonids. These problems are often related to industrial, urban,

and agricultural activities. Elevated fecal coliform levels indicate degraded water quality conditions, and are most likely the result of failing septic systems, failures from sewage treatment plants, or farm animals. However, because they are not known to directly impact salmonids, fecal coliform levels are not specifically discussed in this report.

Contaminated sediments are an important impact to estuarine habitat. Phthalates are a waste product of plastics and can accumulate in fish. Increased levels of organochlorines such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls PCBs can be toxic, and accumulate in tissue, causing tumors and suppressing the immune systems in salmonids (Varanasi et al. 1993). These chemicals can also be lethal to benthic organisms, which serve as food for salmonids, resulting in a potential reduction of prey, and the toxins accumulate in benthic organisms, contaminating the food web. And, at least two studies have indicated that these toxins can impact herring (see EVS Environment Consultants 1999). Many industrial sites in WRIA 3 have been monitored by Washington State Department of Ecology for elevated toxins, and ratings are provided for these areas.

Much of the remainder of this chapter discusses the extent, cause, and location of each of these estuarine habitat impacts, as they are known for each estuarine delta and nearshore region. The regions are discussed in a south to north manner. The relative importance of these impacts to salmonid habitat is discussed at the end of the chapter.

### Estuarine Habitat Conditions in the South Fork and North Fork Skagit Deltas and Skagit Bay

This section of the report covers two distinct estuarine areas. The Skagit estuarine delta extends from the mouths of the North and South Fork Skagit Rivers upstream to their confluence, although tidal influence reaches as far upstream as Sedro Woolley. The second section includes waters and eastern shoreline of Skagit Bay.

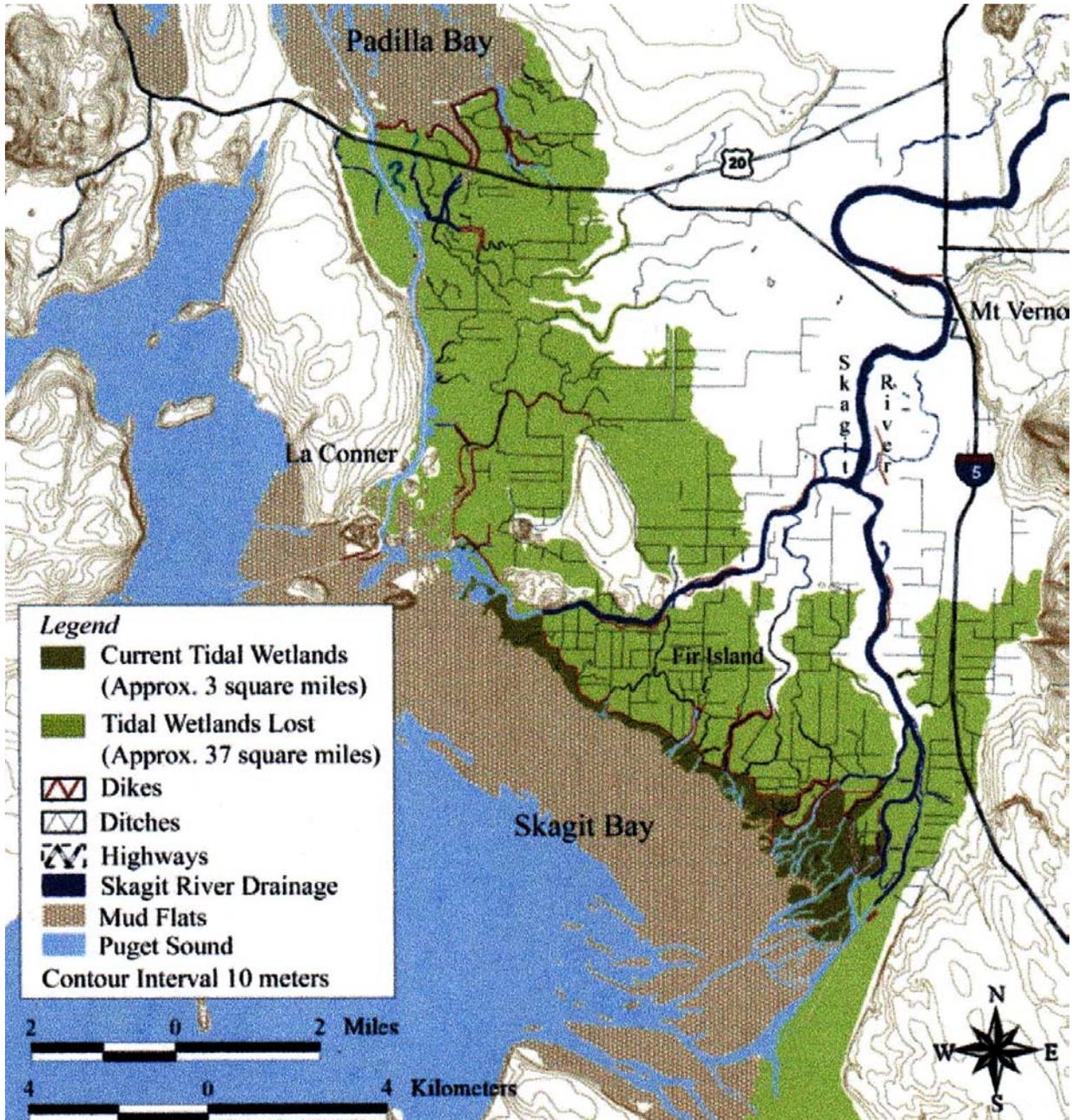
#### *Skagit River Delta*

In the Skagit River delta, distributary channels (channels that branch from the mainstem and drain into the estuary) were historically numerous, and wetland complexes covered more than half of the Skagit River delta resulting in a large amount of land in contact with saltwater (Figure 39) (Bortleson et al. 1980; Collins and Montgomery 2001). Prior to human impacts, blind tidal habitat comprised an estimated 8250 hectares (ha), while riverine tidal wetlands covered about 4200 ha in the Skagit and Samish deltas for a total of 12,450 ha (Collins and Montgomery 2001). By the end of the 19<sup>th</sup> century, dikes had isolated most of the Skagit wetlands and by the mid 20<sup>th</sup> century, numerous distributary channels had been closed off (Collins and Montgomery 2001). Many channels were converted to ditches that drain farmlands and are no longer accessible to salmonids at their upper ends (Figure 40), and more than 100 miles of drainage ditches exist in the Skagit delta (Phinney and Williams 1975). In addition, much of the land isolated by dikes has been ditched, dredged, or filled, resulting in a considerable loss and conversion of wetland habitat.

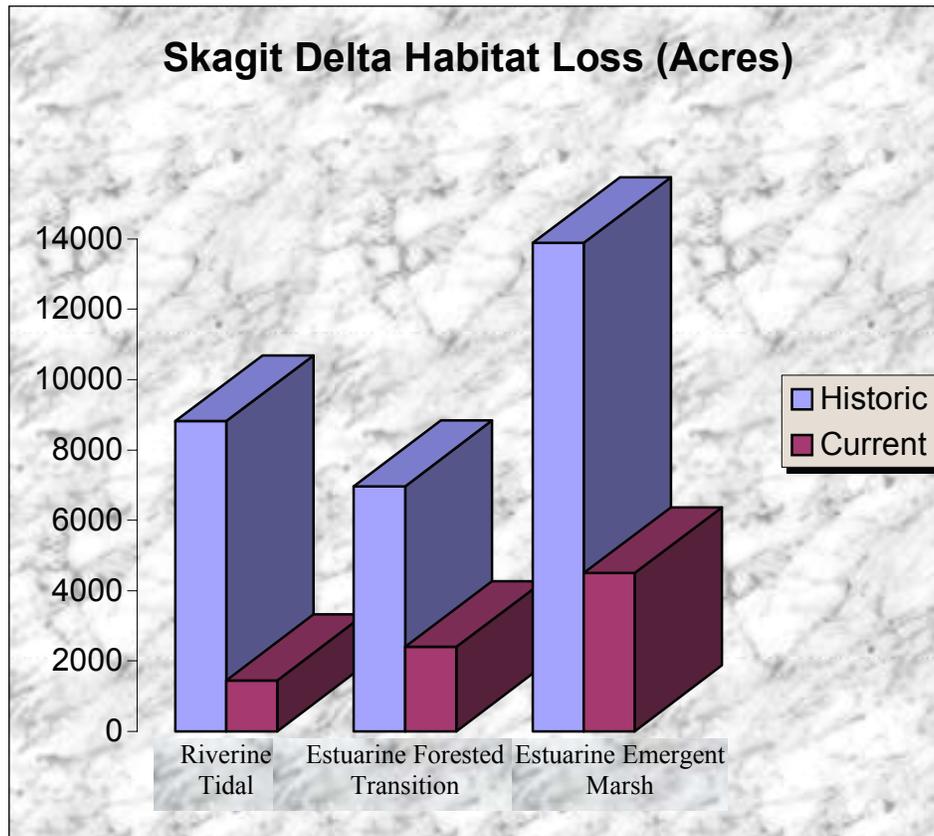


al. 2001). Currently, there is a fringe of marsh habitat seaward of the dikes in the north Skagit delta and an area of marsh along the South Fork Skagit River mouth (Figure 39 and Map E3) (Bortleson et al. 1980).

**Figure 49. Ditches and Lost Tidal Wetlands in the Skagit River Delta (map from Dean et al. 2000).**



**Figure 50. Loss of habitat in the Skagit Delta (data from Beamer et al. 2002a)**

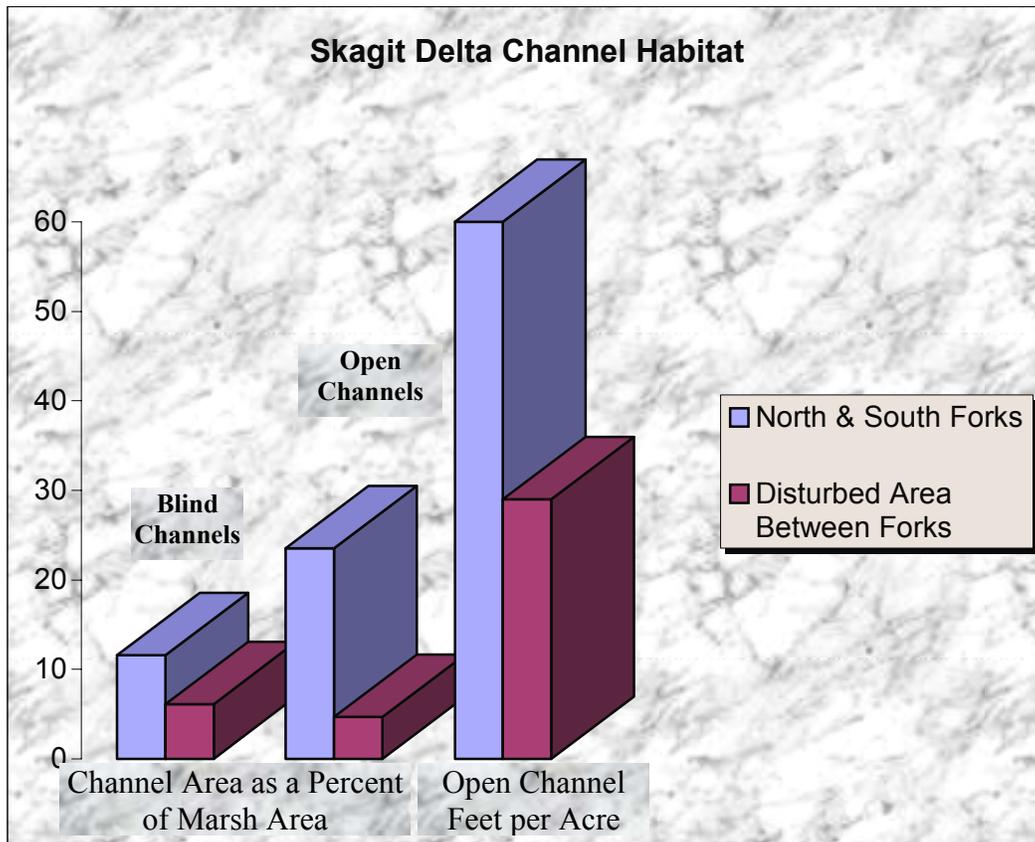


The reduction in emergent marsh habitat has great impact to chinook salmon. Historically, this habitat included an extensive network of blind and open channels. These types of channels are essential to juvenile chinook salmon with up to 7,800 fish per acre of blind channel recorded within them (Beamer et al. 2002a). Currently, the North and South Fork Skagit Rivers still have numerous blind channels, while the area between the Forks has been greatly altered and has an average of 6% blind channel habitat per marsh area compared to nearly 12% in the North and South Fork areas (Figure 42). The disturbed area also has much less open channel area; about 1/5 the area and 1/2 the length compared to the North and South Fork Skagit (Figure 42) (Beamer et al. 2002a).

Beamer et al. (2002a) have demonstrated that estuarine habitat is constraining for chinook juveniles that rear in the delta, even with current depressed populations. They have also found that when the smolt population increases, the number of chinook juveniles that migrate quickly from the estuary increases and the fish that remain to rear in the estuary delta are smaller (shorter fork length). Survival to adult is much lower for non-estuary rearing chinook (Reimers 1973; Levings et al. 1989), indicating that the loss of Skagit estuarine habitat is likely a serious impact to the overall abundance of Skagit chinook. Seining has indicated that juveniles that do not rear in Skagit delta appear to be primarily using nearby non-natal estuaries (such as Similk Bay along Fidalgo Island and

Dugualla Bay off of Whidbey Island) and nearshore areas secondarily (Beamer et al. 2002b). Skagit Bay areas with known substantial juvenile chinook use include Pull and Be Damned Flats, Snee-Oosh Beach, Hoypus Point, North Fork Flats, Strawberry Point, and Lone Tree Point.

**Figure 51. Changes in the Skagit Delta Channel Habitat (data from Beamer et al. 2002a)**



The loss of estuarine habitat in the Skagit Basin impacts other salmonid species as well. Beechie et al. (2001) has estimated that the loss of distributary channels in combination with the loss of freshwater side-channel habitat reduces coho salmon winter rearing habitat by 50% in the Skagit and Stillaguamish Basins combined. Because the overwintering habitat loss is greater than the loss of other types of coho salmon habitat, they surmised that winter habitat, such as distributary and side channels, are constraining coho salmon production in the Skagit Basin. They also demonstrated that in combination, the floodplain and deltas contain more than half of the salmonid habitat, while comprising less than 10% of the salmonid area, illustrating how productive this habitat can be. Because the Skagit River is the largest river draining into Puget Sound and has produced the greatest number of salmonids, its delta is one of the most important salmonid habitats in the region. And, even though studies have illustrated the delta's importance to chinook and coho salmon, other species of salmonids that utilize these habitats are also impacted by the loss.

Dikes are one of the major causes of estuarine habitat loss in the Skagit Delta. An estimated 62% of the mainstem channel edge has been diked within 60 meters of the channel edge, bank hardened, or both (Beamer et al. 2000). This estimate includes the mainstem channels from the mouth to Sedro Woolley. When the Skagit delta (from the confluence of the Forks to Skagit Bay) is examined, nearly all of the channel length is diked (Map E3). The few areas that are not diked have a naturally elevated topography that acts as a natural dike (Map E3). Extensive diking is also located along the lower 5.5 miles of Carpenter Creek (Map E3). As discussed above, the dikes have resulted in the isolation of large quantities of productive salmonid habitat. This is illustrated in Figure 40 (Dean et al. 2000). The loss and isolation of delta habitat due to dikes result in a “poor” rating. However, other habitat alterations behind the dikes, such as draining, ditching, and filling, have further degraded historic salmonid habitat. Excess sedimentation has been reported for the Carpenter Creek WAU with sedimentation rates estimated at 150 to 199% above natural rates (Beechie and Feist, NMFS, personal communication). As isolated habitat is reconnected, restoration actions will be necessary in many of these once productive areas.

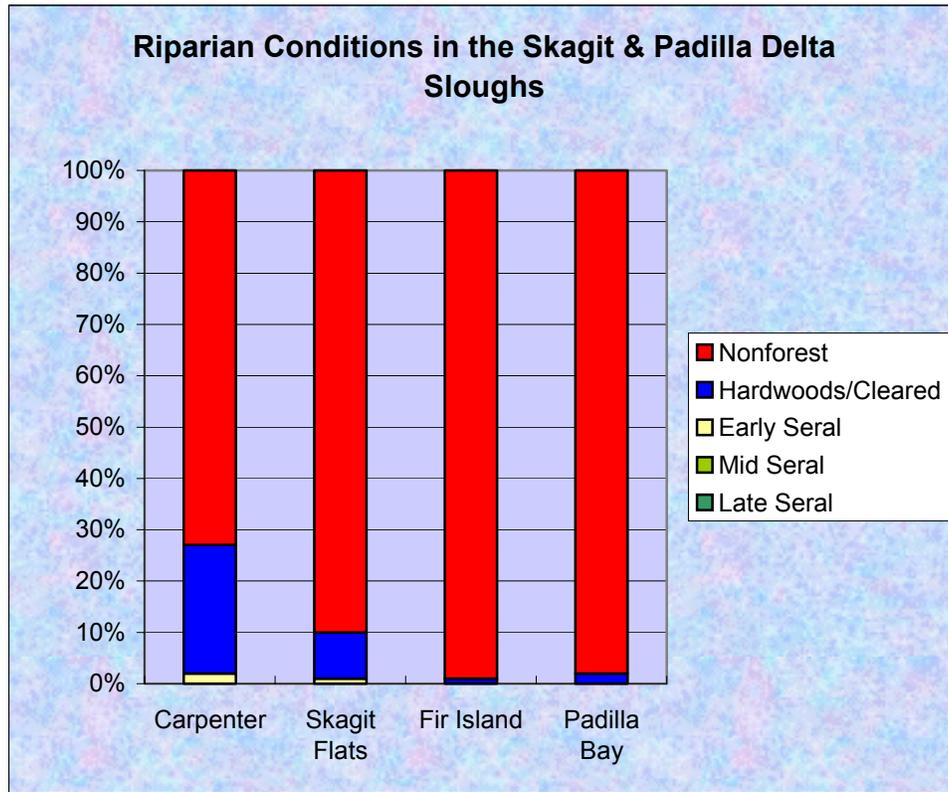
Riparian conditions along the sloughs and streams within the Skagit delta are rated “poor”. Nearly all of the riparian areas along the Fir Island sloughs and 90% along the Skagit Flats streams and sloughs have been converted to a non-forest use (Figure 43) (Lunetta et al. 1997). Also, over 70% of the riparian along the streams in the Carpenter Creek WAU have been converted to non-forest. A non-forest land use results in a complete loss of riparian function, and likely contributes considerably to the warm water temperatures that are found in many of these streams.

#### *East Skagit Bay Shoreline and Waters*

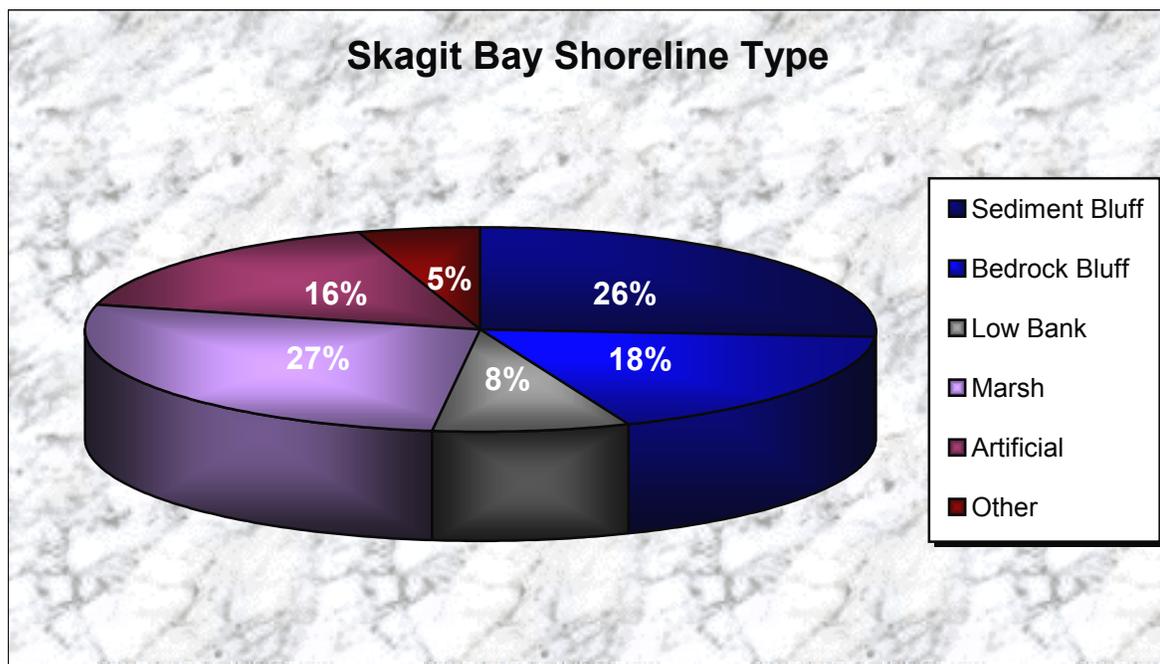
Skagit Bay is one of the most important areas for salmonids because of its proximity to the Skagit River. Yet, dikes have extensively modified its shoreline. Nearly all of the eastern Skagit Bay shoreline from the southern end of the Swinomish Channel to West Pass is diked (Map E3). In addition, north Camano Island near West Pass is diked. These sections are highlighted in red on Map E3 and are rated “poor” for shoreline modifications. Historically, the Stillaguamish River used to flow through West Pass into Skagit Bay until diking occurred around 1906 (Collins and Montgomery 2001). And while this primarily impacts the Stillaguamish River, the change is potentially significant for freshwater, nutrient, and sediment inputs to Skagit Bay. The impacted Fir Island area was also historically very productive delta habitat, and is now isolated from contact with saltwater by dikes (Collins and Montgomery 2001).

The nearshore habitat (combinations of vegetation and substrate in a geomorphic context) along Skagit Bay has been classified, and the percentages described below include all shorelines to Skagit Bay such as northeast Whidbey and north Camano Islands. For backshore type, there are considerable quantities (percent of shoreline) of marsh, sediment bluff, bedrock cliff, and modified reaches (Figure 44) (Noffke and Beamer 2001). The backshore type provides information as to what might be happening to the adjacent geomorphic nearshore habitat unit.

**Figure 52. Riparian conditions along the streams and sloughs within the Skagit Delta and the Padilla Bay watershed (data from Lunetta et al. 1997).**



**Figure 53. Classification of the Skagit Bay Shoreline (Nouffke and Beamer 2001).**



By geomorphic classifications, the greatest area is comprised of flats, while the greatest percent of shoreline consists of flats and open beaches. The flats consist of 66% unvegetated fines and 34% eelgrass and fines. Open beaches have 39% unvegetated fines, 31% eelgrass and fines, 20% unvegetative coarse substrate, and two classifications that include green algae. Headlands are the most diverse of the habitat types with a variety of substrates and vegetation (kelp, algae, eelgrass). Coves consist of 53% unvegetated fines, 27% eelgrass and fines, and the remainder either green algae/fines, salt marsh, or unvegetated coarse substrate (Nouffke and Beamer 2001).

Limited information was found regarding aquatic vegetation for estuarine habitat in WRIA 3. No trend data were available, but significant levels of eelgrass beds are located in Skagit Bay (Map E4) (Berry et al. 2001), and these are recommended for protection because of the importance of eelgrass beds to salmonid production. Also, many of the east Skagit Bay shoreline segments have less than 10% overhanging riparian vegetation (Map E5) (data from Berry et al. 2001). Much of this is likely the result of dikes, but no information was found to delineate the historic riparian vegetation in this area, and it is possible that some areas are naturally low in vegetation.

**Link to Map E4. Known Eelgrass Beds in WRIA 3 (data from Berry et al. 2001).**

**Link to Map E5. Overhanging Riparian Vegetation Conditions in WRIA 3 (data from Berry et al. 2001). This map is in a separate file.**

*Spartina* has also been documented in Skagit Bay (Berry et al. 2001; Noffke and Beamer 2001), but trend data are not available. *Spartina* grows on mudflats and traps sediment from the water column, causing increased elevation of the mudflat. The change in elevation and vegetation can alter the animal assemblages that live in the mud and the loss of open mudflats can reduce foraging habitat for fish. Skagit County has applied for a permit to treat 30 acres in 2002 (DOE 2002a). Continued eradication of *Spartina* in WRIA 3 is recommended.

Water quality in Skagit Bay appears to be good. One site in the WRIA 3 portion of Skagit Bay was sampled for a variety of industrial toxins such as phenols, phthalates, and PAHs in addition to a bioassay (Long et al. 1999). This site passed all tests (Long et al. 1999).

Low dissolved oxygen levels have been documented in the South Fork Skagit River near Conway, and will be addressed through a Total Maximum Daily Load (TMDL) process (Pickett 1997). Low dissolved oxygen levels (4.4 mg/L) have also been documented in Carpenter Creek (RM 3). In addition, warm water temperatures (18°C) have been noted at RMs 2.2 and 4.0 in the Skagit River with very warm temperatures (23 °C) near RM 3 in Carpenter Creek (Entranco 1993). Carpenter Creek has also shown elevated phosphorus (157 ug/L) during low flow spot checks in 1992. The impaired dissolved oxygen levels and water temperatures in the lower Skagit River and in Carpenter Creek results in a “poor” rating for water quality in these areas.

Chronic levels of lead and copper were found in the lower Skagit River in 1992 (Entranco 1993). Lead and copper were found in the Skagit River near Blakes Resort and Conway and in Carpenter Creek, while copper was found to be above metals criteria near RM 10. The significance of these findings is unknown. Typical sources of metals include industry, urban and highway runoff, and landfills, and heavy industry is not located in this area. Further investigation is needed to determine if metals are at levels that can impact salmonids and if so, the source of pollution.

Potential sources of pollution that contribute to water quality problems include four wastewater treatment plants (City of Sedro Woolley, City of Burlington, City of Mount Vernon, and Big Lake/Skagit County Sewer District #2), stormwater discharge, agricultural inputs, and failing septic systems (Pickett 1997). Spot checks of water temperatures discharged from the wastewater treatment plants showed temperatures ranging from 20 to 26 °C in 1992 (Entranco 1993).

#### Estuarine Habitat Conditions in Douglas Slough and the Central Skagit Sloughs

Several sloughs drain into east Skagit Bay including Sullivan, Hall, Browns, Dry, Freshwater, Deepwater, Steamboat, Tom Moore, and Douglas Sloughs. Anadromous salmonid usage is known in Sullivan, Hall, and Browns Sloughs (Cutler 2001). As discussed in the Skagit delta section, dikes have isolated and transformed much of the historic salmonid distribution with a considerable loss of blind and open channels (Figure 42). In addition to dikes, there are 76 tidegates in the Skagit Basin (Map E1). These need to be assessed to determine the quality and quantity of habitat for restoration prioritization. Even without quantification, the high number of blocking tidegates and the associated extensive diking results in a “poor” rating for estuarine habitat loss for the central Skagit sloughs. The shoreline modifications in this area are also significant and discussed in the Skagit Bay section.

Not only has the quantity of lost habitat been extensive in this area, but the type of lost habitat is particularly important for the estuarine ecosystem. In the Browns and Hall Slough watersheds, the estuarine scrub-shrub has been extremely impacted with an estimated 93% lost (Beamer et al. 2001). Within this region is sweetgale (*Myrica gale*), a nitrogen-fixing plant. This is significant because nitrogen is a limiting nutrient in estuarine wetlands (Beamer et al. 2001).

Water quality conditions are also rated “poor” for many of these sloughs. Warm water temperatures and low dissolved oxygen levels have been recorded in Hall, Browns, Dry, and Wylie Sloughs, particularly in the summer months (Entranco 1993). High pH readings (9.2 to 9.4) have been documented in Browns Slough with higher pH samples towards the bay (Beamer and LaRock 1998). Low and high pH readings have also been measured in all of these sloughs (Entranco 1993). In 1992, the pH ranged from 5.9 to 8.7, and extreme fluctuations suggest high nutrient loading. Phosphorus and nitrogen levels were also high in each of these sloughs (Entranco 1993).

The causes are thought to be low flows, non-point pollution, loss of riparian vegetation, loss of wetland habitat, and absence of flushing and circulation due to

hydromodifications. Sullivan Slough and the Fir Island Sloughs have been described as having an impaired riparian zone based upon Landsat land cover data, and the Skagit Flats WAU has about a 70% impaired riparian (Beamer et al. 2001 using data from Lunetta et al. 1997).

*Spartina* infestations are known in this area. Snohomish County has applied for a permit to treat 65 acres in south Skagit Bay, north Port Susan, and other unnamed Snohomish County shorelines (DOE 2002a). Sites in or near Skagit Bay that have had past infestations are near Hall and Browns Sloughs and Kiket Island. The northern Camano Island shoreline has documented *Spartina* invasion, especially near Davis Slough, West Pass, Livingston Bay, and Triangle Cove (Wilkosz 2000).

#### Estuarine Habitat Conditions along Northeast Whidbey Island

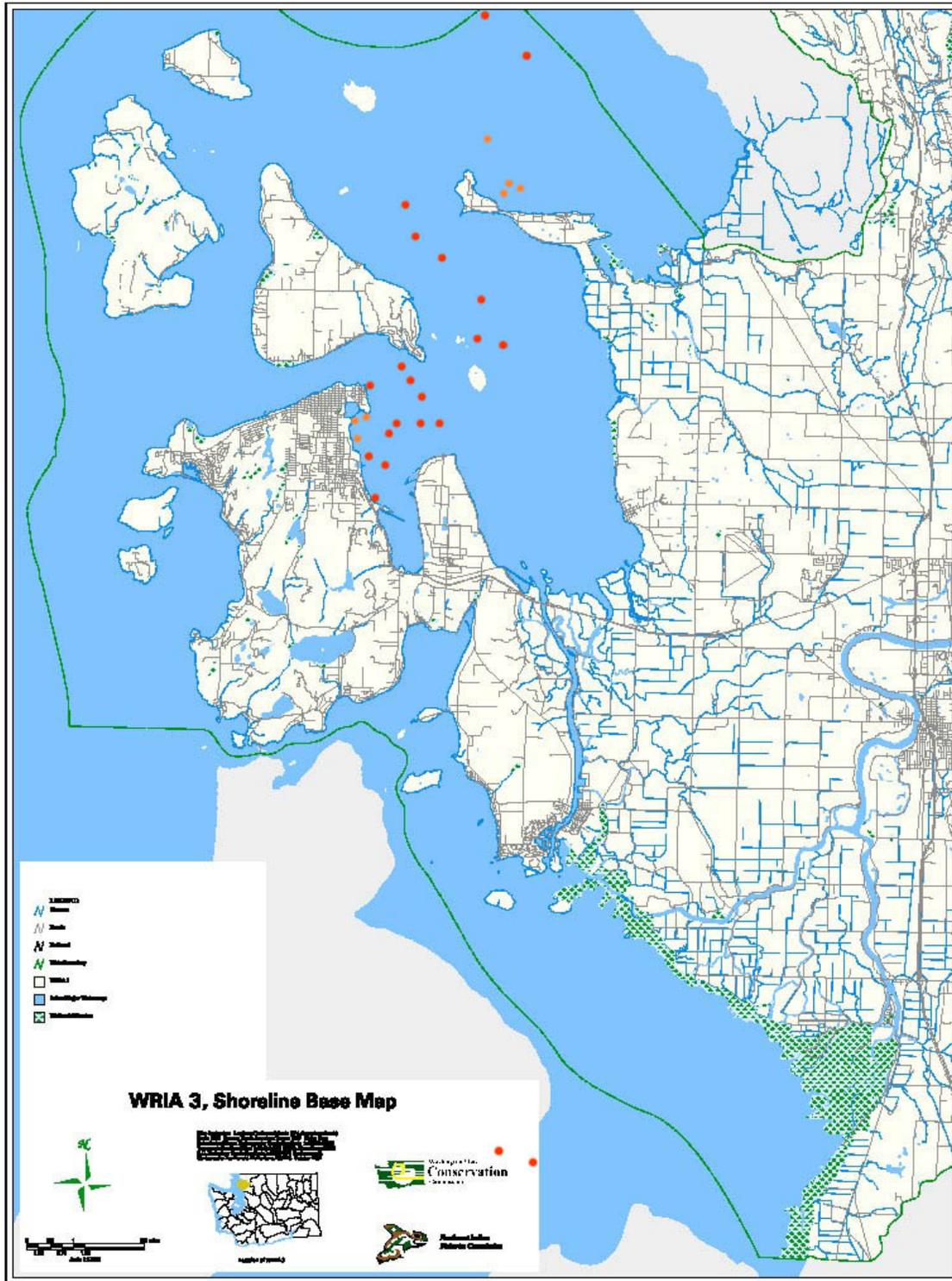
The western Skagit Bay shoreline (northeast Whidbey Island) is in a relatively natural condition, and most of the land is classified as rural with park zoning along the northern tip of Whidbey Island (see Map 6 in Wilkosz 2000). No dikes have been documented (Map E2), although two small jettys, a few boat-related sites, and a large fill (dike) at the head of Dugualla Bay have been noted (Map E3) (data from the Skagit System Coop. 2002). Another problem is a blocking tidegate to Dugualla Creek (Wilkosz 2000). The Dugualla estuary is an important pocket estuary potentially serving as a non-natal estuarine site for Skagit juvenile chinook (Beamer et al. 2002b). For these reasons, most of the northeast Whidbey Island shoreline is rated “good” for shoreline modifications. The exception is Dugualla Bay, which is rated “poor” for shoreline modifications due to the dike and tidegate.

Shoreline riparian vegetation is rated “poor” near the Dugualla estuary as this area is farmed and has no riparian vegetation (Wilkosz 2000). Also, long stretches of the north shore of Whidbey Island, the reaches near Polnell Point, and the north shore of Camano Island have less than 10% overhanging riparian vegetation (Map E5) (data from Berry et al. 2001). These areas are not rated because specific impacts have not been documented, but have likely occurred.

Water or sediment quality problems have been found in this region. Two sites within the Island County portion of Skagit Bay tested positive for toxicity and had elevated phenols and phthalates (Figure 45) (Long et al. 1999). One of these sites (off of Strawberry Point) is on the 1998 303(d) List for low dissolved oxygen levels (DOE 2000).

Northeast Whidbey Island is an important area for forage fish production. All three forage fish species spawn along the northeast shoreline of Whidbey Island, near Sneeoosh Beach, and along parts of Hope Island (Figure 46). Additional areas of herring spawning are known in Skagit and Similk Bays (Figure 46).

**Figure 54. Sites of Sediment Quality Problems in and near WRIA 3 (data from Long et al. 1999). Red dots are sites with significant toxicity or contamination from Long et al. 1999. Orange dots are sites with elevated contaminants from Washington Department of Ecology Sediment Quality database.**





### Estuarine Habitat Conditions in the Swinomish Channel

The Swinomish Channel is greatly impacted by shoreline modifications, resulting in a “poor” rating (Maps E2 and E3). Most of the segments along the channel have an extensive level (greater than 30% by miles) with most of it comprised of riprap followed by landfill (dikes), and bulkhead impacts. Coincident with the modified shoreline is a lack of riparian vegetation. Much of the Swinomish channel has less than 10% overhanging riparian vegetation (Map E5) (data from Berry et al. 2001). Riparian vegetation is not rated in this report due to a lack of information regarding historic vegetation levels and types.

The Swinomish Channel also has large numbers of overwater structures, which include boat ramps, piers, and slips (data from Berry et al. 2001). These areas are shown on Map E6 and most of the structures are piers and slips. Overwater structures are rated “poor” in the Swinomish Channel.

**Link to Map E6. Overwater structures (Boat Ramps, Slips, Piers) (data from Berry et al. 2001). This map is in a separate file.**

Patchy eelgrass beds have been documented in the channel, particularly on the west bank (Map E4) (data from Berry et al. 2001). Eelgrass habitat is not rated for this area due to a lack of historic or trend information, but the dredging and numerous overwater structures have likely impacted historic eelgrass beds in this area.

Few water or sediment quality data were found for this area. Shellfish in the Swinomish Channel were sampled for metals and organic compounds, and elevated levels of tributyltin and PAH were found (Johnson, A. 2000). The suspected sources are marinas and boat traffic. This results in a “poor” rating for water/sediment quality.

### Estuarine Habitat Conditions in Padilla Bay

Padilla Bay was established as a National Estuarine Research Reserve in 1980 (DePhelps 1993) with the purpose of “developing and providing information that promotes informed resource management partnerships between NOAA and State agencies and to help communities develop strategies to successfully address coastal resource issues” (NOAA 2000). Padilla Bay is the only estuarine reserve in Washington State. The 11,000 acres in the reserve are managed by the Washington State Department of Ecology (Jennings and Jennings 2001).

Padilla Bay was originally formed by sediments from the Skagit River (NOAA 2000). In the last 5,000 years, only floodwaters from Skagit River have flowed to Padilla Bay, and since the late 1800s, the construction of dikes has artificially reduced input from the Skagit River (Bulthuis 1993; NOAA 2000). Currently, Padilla Bay is a shallow bay with exposed mudflats on out-going tides. Sloughs deliver freshwater to the bay, and these sloughs have numerous water quality problems that are discussed in the section below. The land use in the Padilla Bay watershed is mostly agriculture (65%) (DePhelps 1993).

Warm water temperatures have been documented in Padilla Bay with some reaching as high as 23<sup>0</sup>C (Bulthuis 1993). However, the shallow nature of the bay results in naturally warm temperatures in the summer. To a limited extent, low dissolved oxygen levels have also been recorded with 4% of the samples below 6 mg/L in August and 6% below standard in September of 1985 to 1986 (Bulthuis 1993). Because the warm water temperatures appear to be natural and the low dissolved oxygen levels are few, water quality in Padilla Bay is tentatively rated “good”.

Two other concerns are sediment toxicity and the potential of eutrophication. The potential for eutrophication is likely worsened by increased nutrient flow to Padilla Bay from the sloughs (Bulthuis 1993). More data exist regarding contaminated sediments, which are rated “poor” for Padilla Bay. Recently, Long et al. (1999) documented sediment quality problems in Padilla Bay. Inner Padilla Bay had elevated phenols and failed three different toxicity tests (Figure 45). Outer Padilla Bay had elevated phenols and phthalates, but did not fail any toxicity tests (Figure 45) (Long et al. 1999). However, these sediment exceedances were not as bad as those found in Commencement Bay, the Duwamish Waterway, Everett Harbor, and Bellingham Bay, which have contaminants that are at least twice as high as those in WRIA 3, and in some cases an order of magnitude higher (Johnson, A. 2000). The sediment contamination near March Point is discussed in the north Fidalgo Bay section.

A significant loss of both estuarine and freshwater wetland habitat has occurred in the Padilla Bay watershed. Diking, draining, and filling have obliterated nearly all of the salt marsh that was once associated with Padilla Bay (Jennings and Jennings 2001). Only a fringe of saltmarsh remains (Figure 47). An estimated 454 wetlands have been identified in the Padilla Bay watershed, but most of these no longer have contact with streams that either provide or directly connect to salmonid habitat, and of those on Port of Skagit County property (181 wetlands) most (133) are small at less than 1 acre (MacWhinney and Thomas 1996). While the land use in the Padilla Bay watershed is primarily agriculture (65%), an estimated 67% of the industrial land in Skagit County has wetlands (DePhelps 1993; MacWinney and Thomas 1996). Although a quantitative comparison of historic versus current wetlands was not found for the Padilla Bay watershed, a map illustrating hydric soils (where historic wetlands were likely) versus current wetlands in shown in Figure 47, showing a considerable difference between the two.

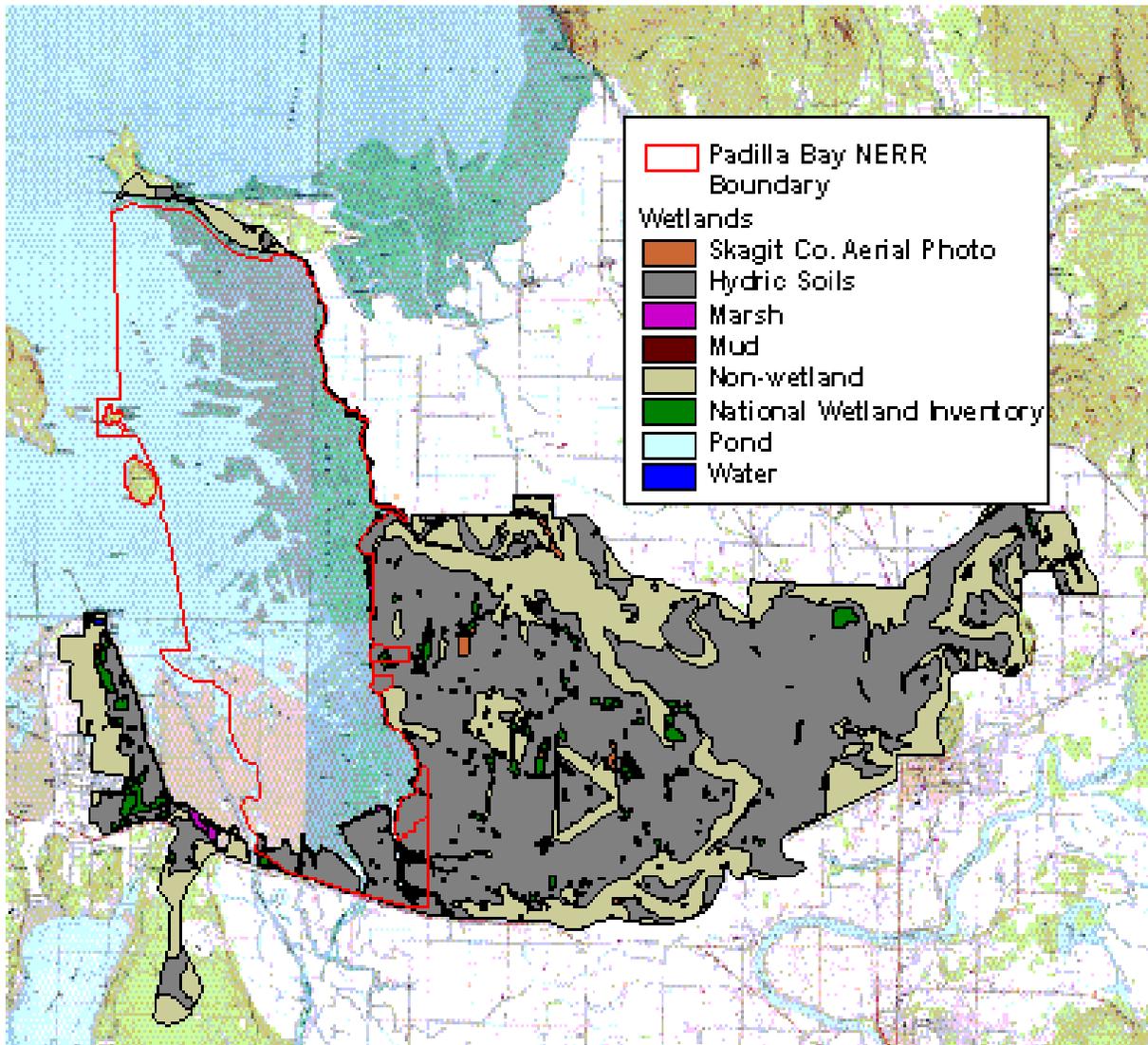
A coarse estimation of shoreline modifications indicated that most of the east and south sides of Padilla Bay have extensive (greater than 30% by miles) modifications (Map E2) (data from Berry et al. 2001). Landfill (dikes) comprises the greatest number of feet of shoreline modifications along Padilla Bay with riprap as the second greatest (Berry et al. 2001). Several sections of the Padilla Bay shoreline also have less than 10% overhanging riparian vegetation, but information regarding historic riparian conditions has not been documented for these areas (Map E5) (data from Berry et al. 2001).

Padilla Bay has one of the largest intertidal eelgrass beds in the western United States (Riggs and Kolbe 1998), and it is believed that Padilla Bay eelgrass beds may have increased in area due to the diversion of freshwater (Skagit River) away from the bay, as eelgrass prefers saltier water (Mayer and Elkins 1990). Because the bay is a National

Reserve, continued protection of this habitat is likely. Overwater structures were very few in number, resulting in a “good” rating (Map E6) (Berry et al. 2001).

*Spartina* was introduced to north Puget Sound in the 1940s and again in the 1960s to control eroding shorelines and to serve as cattle forage (Riggs and Kolbe 1998; Dept. Agriculture 2000). Its presence in Padilla Bay was known as early as the 1970s, but surveys were not conducted until 1987. In 1987, six acres were found to have *Spartina*, and that increased to 17 acres by 1997 (Riggs and Koble 1998). In 1998, eradication efforts removed much of it, but 3-5 acres were noted in 1999 (Dept. Agriculture 2000). In 2002, a permit application was received to treat 15 sparse acres in Padilla Bay (DOE 2002a). Additional *Spartina* treatments have occurred near the Sand Islands north of the Swinomish Channel (Dept. Agriculture 2000). Continued monitoring and effort is needed to maintain control.

**Figure 56. Wetlands in the Padilla Bay Watershed (Padilla Bay National Estuarine Research Reserve 2002).**



### Habitat Conditions in the Padilla Bay Sloughs

Several sloughs input freshwater to Padilla Bay: Joe Leary, No Name, Big Indian, Little Indian, and Telegraph Sloughs. The habitat conditions for these sloughs are discussed here, even though some of the habitat is freshwater. This is because the Padilla freshwater habitat is limited compared to the larger streams in WRIA 3, and because the water quality problems in the sloughs strongly relate to Padilla Bay water quality. These sloughs have been severely impacted both in terms of access conditions (loss of habitat) and quality of habitat. Most lack riparian cover and substrate, and most have been ditched. Water quality conditions are rated “poor” in all of the sloughs draining into Padilla Bay, and the specific problems are discussed below. These water quality problems contribute to increased turbidity, nutrients, and fecal coliform levels in Padilla Bay (NOAA 2000).

Joe Leary Slough is the largest stream in the Padilla Bay watershed with historically extensive marsh habitat (PBWMC and SCPCD 1995). However currently, its lower reaches are diked (Map E3). It is on the 303(d) List for warm water temperatures and low dissolved oxygen levels (DOE 2000). The dissolved oxygen levels have been consistently below the State standard in both high and low flow conditions (PBWMC and SCPCD 1995). In addition, nutrient (nitrogen and phosphorus) levels are high during low flow conditions, while ammonia levels are elevated in high flows. Bulthuis (1996) reported elevated suspended sediments from Joe Leary Slough in winter and early spring with the worst areas coming from farmland without crop cover and where V ditches drain fields. The turbidity standard of 5 NTU was greatly exceeded with a range of 23-99 NTU, and the mean turbidity in Joe Leary Slough is higher than other Puget Sound streams (Bulthuis 1993). In the 1993 monitoring, exceedances of metals occurred at high flows (PBWMC and SCPCD 1995). In the late 1980s, elevated PAH levels were measured in sediments at the mouth of Joe Leary Slough (USFWS 1994). Joe Leary Slough flows through tilled cropland, and many of its tributaries are ditches that drain farmland.

Big Indian Slough is the second largest stream draining into Padilla Bay and is also on the 303(d) list for warm water temperatures and low dissolved oxygen levels (DOE 2000). The low dissolved oxygen levels have been recorded during storm events as well as during some low flows coinciding with fertilizer inputs (PBWMC and SCPCD 1995). Levels of metals were generally good in 1993, but turbidity was very high, ranging from 15 to 65 NTU (Bulthuis 1993; PBWMC and SCPCD 1995). Little Indian Slough had exceedances of total suspended solids and metals (chromium, copper, nickel, and zinc), and low levels of dissolved oxygen during low flow conditions.

No Name Slough is on the 303(d) list for dissolved oxygen (DOE 2000) with recorded violations during high flow conditions (PBWMC and SCPCD 1995). Nutrient levels high enough to sustain an algae bloom were also noted during 1993, but the levels of metals were within standards (PBWMC and SCPCD 1995). In the late 1980s, elevated levels of zinc were documented (USFWS 1994). Few data were found for water quality conditions in Telegraph Slough, but increased levels of aliphatic hydrocarbons were found in sediments at its mouth in the early 1990s (USFWS 1994).

Herbicides and pesticides are not believed to be a major water quality problem in the Padilla Bay sloughs. Herbicides (14 different) were monitored for two years in Padilla Bay, and only two were detectable, and those were at levels that were 10 to 10,000 times lower than would be toxic for eelgrass (Mayer and Elkins 1990). The source of the herbicides is believed to be from road crews. In the late 1980s, measurements for pesticides occurred in Padilla Bay, but none were above limits (Entranco 1993).

The sources of the water quality problems in the Padilla Bay sloughs appear to be from a combination of agricultural, urban, and industrial sources (PBWMC and SCPCD 1995). The most common land use in the area is agriculture, and examples of potential pollution sources have been found, including improper pasture management, livestock access to streams, cropland tilling, V ditching, and loss of vegetation cover. Urban and residential sources include stormwater inputs and failing septic systems. About half of the residents have septic systems (PBWMC and SCPCD 1995). In addition to failing septic systems, the Skagit River has flooded over the west delta to Padilla Bay during large flood events, saturating systems. Three landfills exist in the watershed, and the Whitmarsh fill is discussed in the north Fidalgo Island section. Industry is another potential source of pollutants, particularly near March Point, which is also discussed below in the north Fidalgo Island section.

Approximately 77% of the Padilla WAU is classified as having an impaired riparian zone (Beamer et al. 2000). Joe Leary and Big Indian Sloughs have the most degraded riparian conditions and are the largest drainages in the WAU. Nearly all of the riparian areas within the Padilla Bay WAU have been converted to a non-forest land use, which would be unable to provide shade and other riparian functions (Figure 43) (Lunetta et al. 1997). The riparian classifications are based upon the 1993 Landsat land cover theme (Lunetta et al. 1997), and further work is needed to determine specific current riparian conditions as well as the type of riparian vegetation that would be appropriate for degraded sites.

With the exception of two short tributary segments (one flowing into No Name Slough), the Padilla Bay Sloughs lack diverse habitat to support salmonid production. Ditching and other agriculture-related land use activities have resulted in a lack of appropriate substrate, LWD, channel meanders, and riparian vegetation. Dikes are located along the lower reaches of Joe Leary, Indian, Telegraph, and Higgins Sloughs (Map E3). In addition, 29% of the Padilla Bay WAU is peak flow impaired and 40% moderately peak flow impaired based upon an estimation of impermeable surfaces from planned land use categories (Beamer et al. 2000). Past splash dam activity in Joe Leary Slough has likely had adverse effects on salmonid habitat, such as channel incision and a loss of substrate and LWD (PBWMC and SCPCD 1995).

The disruption of natural hydrology has been extensive in the Padilla Bay sloughs. The loss of wetlands has not been quantified, but data suggest it is considerable. Currently, wetlands comprise 5% of the Padilla Bay/Bay View watershed, but hydric soils account for 64% of the watershed (Figure 10) (PBWMC and SCPCD 1995). Hydric soils can indicate where historic wetlands occurred and can also be used as a guide for wetland restoration. Industry on Port lands has increased impermeable surfaces, creating a further hydrologic disruption. Big Indian Slough was been tentatively classified as “impaired”

and much of the east Padilla Bay shoreline is described as “moderately impaired” based on planned land use classifications (Beamer et al. 2000). Joe Leary, Big Indian, Little Indian, and No Name Sloughs have tidegates with storage channels behind the gates (Bulthuis 1993). These discharge water on low tides and store water on high tides, creating a more distinct boundary between freshwater and saltwater. However, the historic diking, draining, ditching, blocking tidegates, and wetland filling is by far, the greatest disruption to natural hydrology, and has likely had a considerable impact on the water quality in these sloughs.

#### Estuarine Habitat Conditions along North Fidalgo Island Including March Point

This region includes the northern shore of Fidalgo Island and the shoreline of March Point, whose eastern shore borders on Padilla Bay. This region is dominated by urban and industrial land use. Industries include oil refineries, fish processing plants, and marine-related industries. The types of habitat problems in this area reflect these land uses.

One major problem in this area is contaminated sediments, and sediment quality is rated “poor” for this area. Fidalgo Bay, March Point, and Guemes Channel are on the 1998 303(d) List for polychlorinated biphenyls (PCB)-1254 (DOE 2000). They were on the 1996 list for phthalate due to exceedances found at the Texaco outfall, and were removed from the 1998 list for that chemical until the confirmatory designation process for sediment standards is completed (DOE 2000). The primary causes for the contaminated sediments include industrial and landfill pollution. March Point is believed to be impacted by road runoff, stormwater inputs, wastewater treatment plant effluent, refinery effluents, and boat vessel traffic (Johnson, A. 2000).

In recent tests, March Point had elevated phenols and phthalates, and failed one toxicity test, while another site north of March Point had elevated phenols and passed all toxicity tests (Figure 45) (Long et al. 1999). Polynuclear aromatic hydrocarbons (PAHs) have been found near March Point (Johnson 1999). These are typically a byproduct of petroleum products and elevated levels were located in eelgrass close to piers and pipelines used for crude oil transfer from tankers to refineries along March Point (USFWS 1994). Arsenic residues were also found in eelgrass near March Point, and are thought to be a result of the landfill (USFWS 1994). In 1993 sampling near March Point, levels of metals exceeded standards during storm events, especially in South Ditch (PBWMC and SCPCD 1995).

Additional work has continued documentation of continued sediment quality problems in Fidalgo Bay and March Point, and compares the severity of the problem to other areas in Puget Sound (Long et al. 1999). Inner Fidalgo Bay had elevated phenols, phthalates, and PAHs, in addition to failing two different types of toxicity tests (Figure 45) (Long et al. 1995, 1999). The same monitoring demonstrated elevated phenols and phthalates in outer Fidalgo Bay and toxicity for one type of bioassay. However, these sediment exceedances were not as bad as those found in Commencement Bay, the Duwamish Waterway, Everett Harbor, and Bellingham Bay, which have contaminants that are at

least twice as high as those in WRIA 3, and in some cases an order of magnitude higher (Johnson, A. 2000).

The Department of Ecology (2001) has listed five sites near Fidalgo Bay that remain as sediment cleanup sites. These are associated with maritime and industrial activities, not with refineries. One of the more studied of these sites is the Whitmarsh Landfill. The Whitmarsh Landfill is located in the upper west end of Padilla Bay. It was an unregulated public dump from the 1950s to 1973 and historically, Texaco and Northwest Petrochemical have dumped at this fill (Johnson 1999). In 1973, the landfill was covered with 2 to 3 feet of soil and abandoned. It is now under jurisdiction of the Department of Natural Resources. It has been recommended for inclusion on Ecology's Contaminated Sediments Site List due to several chemicals that have exceeded DOE's Sediment Management Standards. These include 2-methylphenol, 4-methylphenol, and 2,4-dimethylphenol, in addition to failing bioassays. Other concerns with the Whitmarsh site are increased levels of dioxin, PAH, and phthalates. Although seepage could impact water quality, it is considered to be a low risk. The greater concern is the contaminated sediments (Johnson 1999).

Water quality data for this area was rare and not rated in this report. Collections at the Anacortes water treatment plant indicate increased turbidity in the five years of measurements in the late 1980s (Entranco 1993). However, no other water quality data were found, and these measurements need to be updated.

The northern shoreline of Fidalgo Island has extensive (greater than 30% by miles) shoreline modifications (Map E2) (data from Berry et al. 2001). In the Anacortes area, riprap is the most extensive type of shoreline modification, followed by bulkheads, landfills, and sheet piles. The Fidalgo Bay shoreline is primarily impacted by riprap, and secondarily by landfill. In addition, the Anacortes area has the greatest number of overwater structures in WRIA 3. More than 1500 boat ramps, piers, and slips have been recorded with slips being the most numerous (data from Berry et al. 2001). The locations are shown on Map E6. These areas are rated "poor".

Potential problems with vegetation are a concern in this area, but these are not rated due to a lack of specific data. These include a possibly degraded shoreline riparian zone (Berry et al. 2001) and the presence of *Spartina* in Fidalgo Bay (Dept. Agriculture 2000). Many sections along Fidalgo Island have less than 10% overhanging riparian vegetation (Map E5) (data from Berry et al. 2001).

All three forage fish species spawn in Fidalgo Bay (Figure 46). Other areas of either sand lance and/or surf smelt spawning are located along March Point and north Fidalgo Island (Figure 46) (data from Penttila 1995, 2000). The Fidalgo herring stock is 4<sup>th</sup> or 5<sup>th</sup> among Puget Sound stocks for annual escapement biomass, and it is unusual in having a summer spawning component in addition to a fall/winter population (Penttila 1995). The fall/winter population is described as having a depressed abundance (Penttila 1995). There has been a loss of herring spawning habitat in Fidalgo Bay due to dredging, filling, and overwater structures. This includes the dredging for the construction of Cap Sante Marina, Anacortes Marina, and the navigational channel (Penttila 1995). Tideland filling

has occurred in the northwest Fidalgo Bay by lumber mills and petroleum and marine related activities. Significant overwater structures include the March Point piers associated with oil companies and the Burlington Northern railroad trestle. Another potential impact is thought to be sedimentation due to decreased flushing from the rock causeway, but this needs further investigation.

#### Estuarine Habitat Conditions along South and West Fidalgo Island

The southern and western shorelines of Fidalgo Island are generally less developed than the northern and eastern shores, and subsequently are in better condition. Most of the western and southern shoreline segments rate “good” (less than 10% modified miles) for modifications (Map E2) (data from Berry et al. 2001). Overwater structures are less numerous than along other shorelines of Fidalgo Island with the exception of the large number of boat ramps, piers, and slips in the Skyline Marina in Burrows Bay (Map E6) (data from Berry et al. 2001), resulting in a “poor” rating.

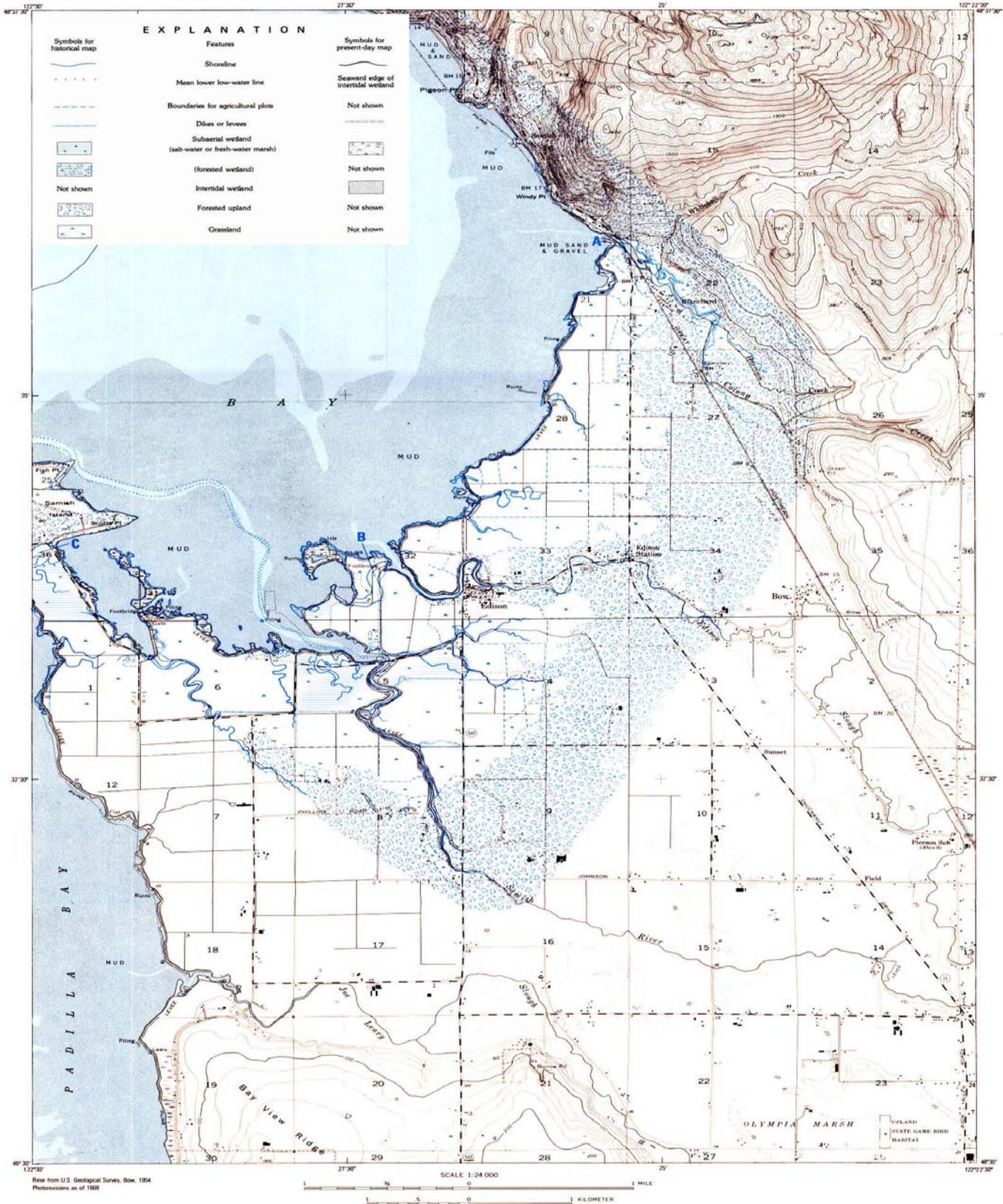
The only other potential salmonid habitat problem in this area is the presence of *Spartina*. Treatments have occurred in Similk Bay and Lottie Bay near Deception Pass (Dept. Agriculture 2000).

#### Estuarine Habitat Conditions in Samish Bay, and Edison Slough

The Samish Bay delta has been diked to support pastureland with agricultural discharge passed to Samish Bay via tidegates and pumps (Determan 1995; Whatcom County Council of Governments 2000). Dikes exist along the lower 5.5 miles of the Samish River including the estuary (tidal influence extends to about RM 4) (Map E3) (data from Skagit County 2003; Phinney and Williams 1975). The diking has isolated former salmonid habitat. Subaerial wetlands in Samish Bay (Fish Point to Pigeon Point) have been reduced from approximately 1.9 to 0.4 km<sup>2</sup> (data from Pacific International Engineering and Anchor Environmental 1999), but the historic estimate of 1.9 km<sup>2</sup> is based upon conditions that were already impacted. Bortleson et al. (1980) estimated that the quantity of subaerial wetlands in Samish Bay prior to any diking or land conversion could be as high as 11 km<sup>2</sup> (Figure 48). Edison Slough was once the former North Fork Samish River, but was disconnected by diking (Phinney and Williams 1975). Diking and loss of wetlands and channel habitat result in a “poor” habitat rating for the quantity of estuarine habitat in Samish Bay. Historic estimates of intertidal wetlands were not found for Samish Bay, but in 1980, current levels were estimated at 15 km<sup>2</sup> (Bortleson et al. 1980).

South Samish Bay and the shoreline near Edison Slough have extensive (greater than 30% by miles) shoreline modifications (Map E2) (data from Berry et al. 2001). The primary shoreline modifications near the Samish River delta are riprap followed by landfill (dikes), whereas the most common modification (in feet) along Samish Island is bulkheads (Berry et al. 2001). Riprap and landfill is also located in considerable quantities along Samish Island. Samish Island has several segments with less than 10% overhanging riparian vegetation (Map E5) (data from Berry et al. 2001).

Figure 57. Channel and wetland changes in the Samish Delta (Bortleson et al. 1980).



Not much data were found regarding aquatic vegetation for the Samish Bay region. Eelgrass beds are known in Samish Bay (Berry et al. 2001), but some of those beds are routinely plowed for Pacific oyster cultivation (West 1997). For that reason, the Samish Bay eelgrass beds are downgraded to a “poor” rating. In addition, a recent patch of *Spartina* has been noted near Samish Island (Dept. Agriculture 2000).

Most of the water quality data for Samish Bay focuses on fecal coliform, which is not discussed in this report. However, contaminated sediments might also be a problem and would more directly impact salmonid habitat and food supply. Two out of three sites in Samish Bay had either elevated phenols or failed bioassay tests, while one other site passed all tests (Figure 45) (Long et al. 1999).

This area supplies important habitat for forage fish. All three forage fish species spawn near north Samish Island (Figure 46). Additional areas of herring spawning are known in Samish Bay (Figure 46).

#### Habitat Conditions in Colony Creek

This small stream drains into Samish Bay. Although it is technically part of WRIA 1, the Skagit Watershed Council includes Colony Creek in their restoration activities. Not much habitat information is available for Colony Creek. No information on access, floodplain, and water quality conditions has been found. The only information on sediment, LWD, channel condition, and pool habitat for Oyster and Colony Creeks is the broad-scale road density estimate that encompasses the entire WAU. Road density is rated “fair” for the WAU, with a value of 2.4 miles of road/sq. mi. watershed (data from Lunetta et al. 1997). No other ratings can be assigned due to a lack of data.

The only riparian data is also on a WAU scale and not reach-specific. About 48% of the riparian response reaches in the Oyster/Colony Creek WAU have been converted to non-forestland (data from Lunetta et al. 1997). Most of the land conversion has occurred in the lower Colony Creek drainage where agricultural lands predominate (Whatcom Conservation District maps, unpublished data, 1991). Forty three percent of the WAU riparian reaches are documented as hardwood or cleared/open forestland. A very small (2%) percentage of mid-seral conifer riparian was noted and no late seral was documented (data from Lunetta et al. 1997). Because of the large conversion to non-forest and the low level of mature conifer, the WAU is rated “poor” for riparian conditions with the note that more data are needed. Reach-specific riparian data are needed for these streams with identification of wetland areas expected to support a naturally hardwood riparian.

Historically, the land cover consisted of old growth forests of Douglas fir and climax communities of western hemlock, cedar, and broad-leafed maple (DOE 1995), while currently much of the land cover vegetation in the Oyster and Colony Creek WAU is hydrologically immature. In this WAU, 45% of the land cover consists of hardwoods or cleared forestland, 19% has been converted to non-forest uses, and 15% is covered with young conifer (data from Lunetta et al. 1997). Only 14% consists of mature conifer. This results in a “poor” rating for hydrologic maturity. Impervious surface percentages

have been estimated using land use information, resulting in 12.6% of impervious surfaces in the Colony Creek drainage (Whatcom Conservation District maps, unpublished data, 2000). In comparing these percentages to the Washington Conservation Commission standards (see Assessment section), Colony Creek rates “poor” for percent impervious surfaces. No other data regarding flow conditions were found for Oyster and Colony Creeks.

#### Estuarine Habitat Conditions along Sinclair, Vendovi, Cypress, Guemes, Burrows, and Allen Islands

The shorelines along these islands are in generally good condition for salmonid habitat. Shoreline modification conditions are rated “good” (less than 10% modified miles) along most of the shores of Guemes, Cypress, Sinclair, Vendovi, Burrows, Allan, Skagit, Hope, Goat, and Ika Islands (Map E2) (data from Berry et al. 2001).

Overwater structures are few in number (Map E6), and this parameter is rated “good” (data from Berry et al. 2001). Aquatic vegetation also appears to be in good condition. Significant eelgrass beds are also located in sporadic locations around the islands in WRIA 3 (Map E4). Because of the importance of eelgrass beds to salmonid production, all eelgrass habitat should be protected throughout WRIA 3. In 1999, many of the islands in Skagit County were surveyed for *Spartina* for the first time, and none was found. These include Allan, Burrows, Cone, Cypress, Deception, Jack, Sinclair, Strawberry, Townhead, and Vendovi Islands (Dept. Agriculture 2000).

#### WRIA Wide Habitat Concerns

##### *Additional Water Quality Concerns*

Other potential impacts to water quality conditions in WRIA 3 are from preservative-treated wood structures. Creosote-treated products contain 65 to 85% polycyclic aromatic hydrocarbons (PAHs) with smaller percentages of phenolic compounds and nitrogen- sulfur- or oxygenated heterocyclics (EPRI 1995, Brooks 1994). These chemicals can impact fish through toxicity, carcinogenesis, and disturbance of immune or hormone regulation (Krahn et al. 1986; Meyer et al. 1990; van Brummelen et al. 1998; Karrow et al. 1999; Johnson, L. 2000). In addition, 100% of the Pacific herring embryos that survived to hatch after exposure to creosote-treated wood were abnormal (Vines et al. 2000). The effects of creosote on aquatic life are also long lasting. After 40 years, pilings can still release creosote into the environment (Vines et al. 2000).

Wood treated with ammoniacal copper zinc arsenate and chromated copper arsenate release trace metals (copper, zinc, chromium, and arsenic) into the environment, but do so initially and for a much shorter duration than the release of PAHs by creosote-treated wood (Poston 2001). However, each of these metals has toxic effects on salmonids, and protective water quality standards have been developed for each. Contamination to salmonids can be direct or indirect (through the food chain).

Another water quality issue is the potential risk of a major oil spill near or in WRIA 3 waters. North Puget Sound is one of the country's primary petroleum refinery centers with 550,000 barrels of unrefined oil imported daily and 300,000 gallons of refined oil exported every day (Jennings and Jennings 2001). This results in 3,515 entering transits of tank ships or barges that transport petroleum products in Puget Sound in the year 2001 (DOE 2002b). The number of tank ships bound for Washington ports via the Strait of Georgia or Haro Strait was 27 in 2001, but the number of tank barges was not reported. Other types of boat traffic have the ability to create large spills. The number of cargo or passenger ships bound for Puget Sound or Canadian ports via Puget Sound waters (including the Strait of Juan de Fuca and Strait of Georgia) was estimated at 4,808 in the year 2001 with 565 bound for Washington ports via the Strait of Georgia or Haro Strait (DOE 2002b). Commercial fishing vessels or processors made 145 transits for Washington ports via the Strait of Georgia or Haro Strait, with 374 transits within Puget Sound. Ferries accounted for 168,960 transits within Puget Sound waters in 2001 (DOE 2002b). In 1991, a 20,000-gallon crude oil spill occurred in Fidalgo Bay, and the effects are still apparent as 1997 and 1999 sampling of an intertidal area inside Crandall Spit still indicates contamination by oil and PAHs (Johnson, A. 2000).

### Biological Processes Associated with the Estuarine and Nearshore Areas of WRIA 3

Estuaries are extremely dynamic ecosystems, both spatially and temporally, resulting in a broad diversity of habitats and food resources. Maintaining habitat connectivity and diversity is vital to provide the maximum opportunities for a variety of salmonid life history strategies. Corridors between the estuarine and open water environments aid in salmonid migration, encounter with prey items, reduction of predation on salmonid juveniles, and allows for the exchange of energy and materials (Shreffler and Thom 1993). Within WRIA 3, the loss of delta habitat in the Skagit Basin is the largest impact to habitat connectivity, but other significant losses exist in Padilla and Samish Bays.

Estuarine and nearshore ecosystems have detritus-based food webs that begin with primary productivity, the rate which plants convert sunlight to food (Simenstad 2001). It is known that the timing of juvenile chum salmon to seawater correlates with plankton blooms (Salo 1991). In the summer, winds, river discharges, and tidal cycles alter the level of productivity by vertically mixing nutrients, and winds are the most variable of these factors (Yin et al. 1997). However, not much information is available regarding local levels of productivity, changes in productivity with time, and potential impacts to productivity. There is also a lack of understanding of how primary productivity relates to salmonid production, as well as what effects primary productivity might have on estuarine entry timing and salmonid growth and mortality. This information would be useful to more fully understand salmonid habitat issues in the marine environment.

As plant material grows and decays, it supplies food for microorganisms. The coating of microorganisms on dead plant material is called detritus, and this is a major source of food supply for small invertebrates. Many juvenile salmonids and forage fish feed on these invertebrates. Declines in available prey have been shown to result in small juvenile salmonids migrating more quickly to other areas in search of prey (Simenstad et al. 1980). The expenditure of extra energy for this migration is thought to slow the growth, leading to an increased risk of predation.

The health of forage fish populations, such as herring, surf smelt, and sand lance are important because they are the primary food components of salmonids. All of these forage fish species have been noted in this area (Figure 46) (Penttila 1995, 2000) with herring spawning in eelgrass beds, surf smelt in the upper intertidal gravel beaches, and sand lance in the intertidal zone. All three forage fish species spawn in Fidalgo Bay, near north Samish Island, along the northeast shoreline of Whidbey Island, near Snee-oosh Beach, and along parts of Hope Island (Figure 46). Other areas of either sand lance and/or surf smelt spawning include March Point, north Fidalgo Island, Bayview, and small sections along Goat and Guemes Islands (Figure 46) (data from Penttila 1995, 2000). Additional areas of herring spawning are known in Skagit, Similk, northwest Padilla and Samish Bays (Figure 46). Known data gaps exist for Samish, Sinclair, Cypress, and Guemes Islands, and Burrows Bay, Padilla Bay, and the Swinomish Channel.

The local herring stocks have been listed as “healthy” (Table 12) (Bargmann 1998; Penttila 2001a), and the Fidalgo herring stock is 4<sup>th</sup> or 5<sup>th</sup> among Puget Sound stocks for annual escapement biomass (Penttila 1995). There has been a loss of herring spawning habitat in Fidalgo Bay due to dredging, filling, and overwater structures. This includes the dredging for the construction of Cap Sante Marina, Anacortes Marina, and the navigational channel (Penttila 1995). Tideland filling has occurred in the northwest Fidalgo Bay by lumber mills and petroleum and marine related activities. Significant overwater structures include the March Point piers associated with oil companies and the Burlington Northern railroad trestle. Another potential impact is thought to be sedimentation due to decreased flushing from the rock causeway, but this needs further investigation.

Status trends for sand lance and surf smelt are not available for most stocks. The Fidalgo Bay surf smelt spawns year round rather than just in the fall and winter (Penttila 1995). The summer spawning population is more abundant than the fall/winter population, and it spawns over a broader area. The fall/winter stock has a depressed status (Penttila 1995). The spawning area of surf smelt in Fidalgo Bay is limited with only 4.3 total known lineal miles. One half mile on the north shore of Waverling Spit is the longest stretch of high quality habitat that is used year round (Penttila 1995). The protection of surf smelt spawning areas would also protect not only a food source for salmonids, but also protect juvenile salmonid refuge and feeding habitat. Other important actions include maintaining the processes that create and maintain beaches and flush fine sediments, as well as maintaining the natural riparian vegetation along the shorelines.

Because anadromous salmonids migrate long distances, the overall status of forage fish stocks throughout the migration range should be a concern. In Puget Sound, four herring stocks are either critical or depressed, including the nearby Cherry Point herring population, which is listed as a Washington State Candidate Species of Concern (WDFW 2000b). The Cherry Point herring stock historically comprised about half of the Pacific herring population in Washington State, but numbers have declined by 91% since the early 1970s (Bargmann et al. 1999; EVS Environment Consultants 1999). A review of potential causes for the herring stock decline led to three likely sources: warmer sea surface temperatures, declining food supply, and organic contaminants (EVS

Environment Consultants 1999), such as those described above in the Water Quality section.

**Table 12. Number and spawning locations of baitfish stocks in WRIA 3 (data from Bargmann 1998; Penttila 2001a).**

<i>Baitfish Stocks</i>	<i>Stock Status/Known Spawning Areas</i>
<b>Samish/Portage Bay Herring Stock</b>	<b>Healthy. Average 77-96 run size = 283 tons</b>
<b>Fidalgo Herring</b>	<b>Healthy. Average 77-96 run size = 775 tons</b>
<b>Skagit Bay Herring</b>	<b>Healthy. Average 77-96 run size = 867 tons</b>
<b>Surf Smelt</b>	<b>Sporadic sites along Samish, Padilla, Fidalgo, and Skagit Bays. Status unavailable.</b>
<b>Sand Lance</b>	<b>Sporadic sites along Samish, Padilla, and Skagit Bays, also sporadic sites on Guemes, Cypress, and Fidalgo Islands. Status unavailable.</b>

**WRIA 3 Estuarine and Nearshore Conclusions**

The greatest impact in the estuarine and nearshore areas of WRIA 3 appears to be the loss of habitat in the Skagit delta. This area was historically very productive, and because the Skagit River is one of our State’s largest basins, producing abundant numbers of numerous stocks of salmonids, the delta is one of the most important areas for restoration within Puget Sound. Secondly, maintaining and improving conditions in nearby non-natal estuaries should also be a restoration and conservation consideration because of the presence of juvenile salmonids in those areas that are likely driven from the limited habitat of the Skagit delta. The estuaries within Samish and Padilla Bays are also important and have experienced large losses of marsh habitat and connectivity.

In addition, habitat protection is vital towards maintaining areas needed by forage fish and juvenile salmonids. These include beaches, eelgrass, and kelp. Common impacts to these habitats include shoreline modifications that disrupt sediment transport processes, overhead structures, and impacts to water and sediment quality. In WRIA 3, overhead structures are generally limited to a few isolated sites, but shoreline modifications are more numerous, resulting in a mid-range of impact compared to other counties in Puget Sound. However, no data are available to show which areas in WRIA 3 are most important to support the processes (sediment supply and transport) that form habitat for salmonids and their prey. This data need should be addressed prior to large-scale restoration activities regarding shoreline modifications. Protection of currently natural

shorelines should be done to prevent the additional disruption of habitat forming processes.

Estuarine water quality conditions are generally good for salmonids, except in the Padilla Bay sloughs and the South Fork Skagit River, and a TMDL has been developed to improve conditions in the South Fork Skagit. Isolated sediment contamination exists in a few areas of Fidalgo and Padilla Bays, with a lesser impact in Samish Bay. Cleanup for these areas should continue, but overall, the level of current contamination is moderate, and on a much lower scale than for many other areas in Puget Sound. In general, the sediments in the estuaries of WRIA 3 are of good quality. However, some isolated problems exist, and even those have a low toxicity compared to other U.S. estuaries (Long et al. 1999). Estuarine water and sediment quality impacts to salmonids in WRIA 3 are limited and consist primarily of contaminated sediments in Fidalgo Bay and water quality problems (high water temperatures/low dissolved oxygen levels, metals, suspended sediments, nutrients) in many of the sloughs that enter Padilla and Skagit Bays.

## ASSESSMENT OF HABITAT LIMITING FACTORS

Under the Salmon Recovery Act (passed by the legislature as House Bill 2496 and later revised by Senate Bill 5595), the Washington Conservation Commission (WCC) is charged with identifying the habitat factors limiting the production of salmonids throughout most of the state. This information should guide lead entity groups and the Salmon Recovery Funding board in prioritizing salmonid habitat restoration and protection projects seeking state and federal funds. To provide the best guidance possible, current, known habitat conditions were identified and rated. Rating habitat limiting factors requires a set of standards that can be used to compare the significance of different factors and consistently evaluate habitat conditions in each WRIA throughout the state.

To develop a set of standards to rate salmonid habitat conditions, several tribal, state, and federal documents that use some type of habitat rating system (Table 13) were reviewed. The goal was to identify appropriate rating standards for as many types of habitat limiting factors as possible, with an emphasis on those that could be applied to readily available data. Based on the review, it was decided to rate habitat conditions into three categories: “good”, “fair”, and “poor”. For habitat factors that had wide agreement on how to rate habitat condition, the accepted standard was adopted by the WCC. For factors that had a range of standards, one or more of them were adopted. Where no standard could be found, a default rating standard was developed, with the expectation that it will be modified or replaced as better data become available.

The ratings adopted by the WCC are presented in Tables 14 and 15. These ratings are not intended to be used as thresholds for regulatory purposes, but as a coarse screen to identify the most significant habitat limiting factors in a WRIA. They also will hopefully provide a level of consistency between WRIs that allows habitat conditions to be compared across the state. However, for many habitat factors, there may not be sufficient data available to use a rating standard or there may be data on habitat parameters where no rating standard is provided. For these factors, the professional judgment of the TAG should be used to assign the appropriate ratings. In some cases there may be local conditions that warrant deviation from the rating standards presented here. This is acceptable as long as the justification and a description of the procedures used are clearly documented in the limiting factors report.

A summary of the habitat conditions for WRIs 3 and 4 are presented in Tables 16 and 17. These represent generalized conditions within that stream. There are likely some reaches of the stream that will be better or worse condition than the rating suggests. In many cases, insufficient data and knowledge about the conditions was found. For those instances, the rating is left blank. The conditions are based upon the standards in Tables 14 and 15, and are described in more detail in the Habitat Limiting Factors chapters. Recommendations and data needs are described in more detail in the following chapter.

**Table 13.** Source documents for the development of standards.

<b>Code</b>	<b>Document</b>	<b>Organization</b>
WSP	Wild Salmonid Policy (1997)	Washington Department of Fish and Wildlife
PHS	Priority Habitat Management Recommendations: Riparian (1995)	Washington Department of Fish and Wildlife
WSA	Watershed Analysis Manual, v4.0 (1997)	Washington Forest Practices Board
NMFS	Coastal Salmon Conservation: Working Guidance (1996)	National Marine Fisheries Service
Skagit	Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)	Skagit Watershed Council
Hood Canal	Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Habitat Recovery Plan (1999)	Point No Point Treaty Council and Washington Department of Fish and Wildlife

Table 14. Salmonid habitat condition standards.

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Access and Passage						
Artificial Barriers	% known/potential habitat blocked by artificial barriers	All	>20%	10-20%	<10%	WCC
Floodplains						
Floodplain Connectivity	Stream and off-channel habitat length with lost floodplain connectivity due to incision, roads, dikes, flood protection, or other	<1% gradient	>50%	10-50%	<10%	WCC
Loss of Floodplain Habitat	Lost wetted area	<1% gradient	>66%	33-66%	<33%	WCC
Channel Conditions						
Fine Sediment	Fines < 0.85 mm in spawning gravel	All – Westside	>17%	11-17%	≤11%	WSP/WSA/ NMFS/Hood Canal
	Fines < 0.85 mm in spawning gravel	All – Eastside	>20%	11-20%	≤11%	NMFS

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Large Woody Debris	pieces/m channel length	≤4% gradient, <15 m wide (Westside only)	<0.2	0.2-0.4	>0.4	Hood Canal/Skagit
	or use Watershed Analysis piece and key piece standards listed below when data are available					
	pieces/channel width	<20 m wide	<1	1-2	2-4	WSP/WSA
	key pieces/channel width*	<10 m wide (Westside only)	<0.15	0.15-0.30	>0.30	WSP/WSA
	key pieces/channel width*	10-20 m wide (Westside only)	<0.20	0.20-0.50	>0.50	WSP/WSA
	* Minimum size to qualify as a key piece:		<u>BFW (m)</u>	<u>Diameter (m)</u>	<u>Length (m)</u>	
		0-5	0.4	8		
		6-10	0.55	10		
		11-15	0.65	18		
		16-20	0.7	24		
Percent Pool	% pool, by surface area	<2% gradient, <15 m wide	<40%	40-55%	>55%	WSP/WSA
	% pool, by surface area	2-5% gradient, <15 m wide	<30%	30-40%	>40%	WSP/WSA
	% pool, by surface area	>5% gradient, <15 m wide	<20%	20-30%	>30%	WSP/WSA
	% pool, by surface area	>15 m	<35%	35-50%	>50%	Hood Canal
Pool Frequency	channel widths per pool	<15 m	>4	2-4	<2	WSP/WSA

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
	channel widths per pool	>15 m	-	-	chann pools/ cw/ width mile pool 50' 26 4.1 75' 23 3.1 100' 18 2.9	NMFS
Pool Quality	pools >1 m deep with good cover and cool water	All	No deep pools and inadequate cover or temperature, major reduction of pool volume by sediment	Few deep pools or inadequate cover or temperature, moderate reduction of pool volume by sediment	Sufficient deep pools	NMFS/WSP/WSA
Streambank Stability	% of banks not actively eroding	All	<80% stable	80-90% stable	>90% stable	NMFS/WSP
Sediment Input						
Sediment Supply	m <sup>3</sup> /km <sup>2</sup> /yr	All	> 100 or exceeds natural rate*	-	< 100 or does not exceed natural rate*	Skagit
* Note: this rate is highly variable in natural conditions						
Mass Wasting/Landslide Density		All	Significant increase over natural levels for mass wasting events that deliver to stream. >3 events/square mile, human-induced.	1-3 landslide events/square mile, human-induced.	No increase over natural levels for mass wasting events that deliver to stream. Less than 1 landslide/square mile.	WSA (increase over natural levels)
Road Density	mi/mi <sup>2</sup>	All	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads	NMFS

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
or use results from Watershed Analysis where available						
Riparian Zones						
Riparian Condition	<ul style="list-style-type: none"> <li>riparian buffer width (measured out horizontally from the channel migration zone on each side of the stream)</li> <li>riparian composition</li> </ul>	Type 1-3 and untyped salmonid streams >5' wide	<ul style="list-style-type: none"> <li>&lt;75' or &lt;50% of site potential tree height (whichever is greater)</li> </ul> <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> <li>Dominated by hardwoods, shrubs, or non-native species (&lt;30% conifer) unless these species were dominant historically.</li> </ul>	<ul style="list-style-type: none"> <li>75'-150' or 50-100% of site potential tree height (whichever is greater)</li> </ul> <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> <li>Dominated by conifers or a mix of conifers and hardwoods (≥30% conifer) of any age unless hardwoods were dominant historically.</li> </ul>	<ul style="list-style-type: none"> <li>&gt;150' or site potential tree height (whichever is greater)</li> </ul> <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> <li>Dominated by mature conifers (≥70% conifer) unless hardwoods were dominant historically</li> </ul>	WCC/WSP
	<ul style="list-style-type: none"> <li>buffer width</li> <li>riparian composition</li> </ul>	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50'-100' with same composition as above	>100' with same composition as above	WCC/WSP
	<ul style="list-style-type: none"> <li>buffer width</li> <li>riparian composition</li> </ul>	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above	WCC/WSP

Habitat Factor	Parameter/Unit	Channel Type	Poor	Fair	Good	Source
Water Quality						
Temperature	degrees Celsius	All	>15.6° C (spawning) >17.8° C (migration and rearing)	14-15.6° C (spawning) 14-17.8° C (migration and rearing)	10-14° C	NMFS
Dissolved Oxygen	mg/L	All	<6	6-8	>8	ManTech
Hydrology						
Flow	hydrologic maturity	All	<60% of watershed with forest stands aged 25 years or more	-	>60% of watershed with forest stands aged 25 years or more	WSP/Hood Canal
		or use results from Watershed Analysis where available				
	% impervious surface	Lowland basins	>10%	3-10%	≤3%	Skagit
Biological Processes						
Nutrients (Carcasses)	Number of stocks meeting escapement goals	All Anadromous	Most stocks do not reach escapement goals each year	Approximately half the stocks reach escapement goals each year	Most stocks reach escapement goals each year	WCC
Lakes (further work needed)						
Estuaries – See Table 3 Below						

Table 15. System for rating estuarine habitat conditions

<b>Impact</b>	<b>Poor</b>	<b>Fair</b>	<b>Good</b>
Wetland Loss	30% or greater loss of habitat	10-30% loss	Less than 10% loss
Water Quality	Any exceedance above standard of a parameter known to directly impact salmonids.	An exceedance above standard of a parameter that impairs water quality, but not known to directly impact salmonids.	No exceedances of known standards.
Shoreline Modification	30% or greater modified shoreline length.	10-30% modified shoreline length.	Less than 10% modified shoreline length.
Eelgrass Habitat and Man-Made Shade Structures	50 or more shade structures, or 30% or more loss of historic eelgrass.	25-50 shade structures, or 10-30% loss of historic eelgrass.	Continuous eelgrass beds with less than 10% historic loss.

**Table 16. Summary of estuarine and nearshore conditions in WRIA 3.**

<b>Region</b>	<b>Hydromodifications</b>	<b>Water Quality/Sediment Contamination</b>	<b>Wetland/Habitat Loss</b>	<b>Boat Ramps, Slips, Piers</b>	<b>Riparian and Instream Habitat</b>
<b>ESTUARIES</b>					
Skagit Delta/Estuary	Poor	Poor in SF Skagit	Poor	Mostly Good (some in NF)	Poor
Carpenter Creek	Poor	Poor	DG	NA	Poor
Skagit Bay Sloughs	Poor	Poor	Poor	NA	Poor
Padilla Bay Sloughs	Poor	Poor	Likely Poor	NA	Poor
Samish Estuary	Poor	DG	Poor	NA	DG
Edison Slough	Poor	DG	Poor	NA	DG
Colony Creek	DG	DG	DG	NA	Poor to Fair
<b>NEARSHORE AREAS</b>					
Skagit Bay East	Poor	Good	Poor	Good	NA
Skagit Bay West	Good	Poor	Good	Good	NA
Swinomish Channel	Poor	Poor (DG)	Poor	Poor	NA

<b>Region</b>	<b>Hydromodifications</b>	<b>Water Quality/Sediment Contamination</b>	<b>Wetland/Habitat Loss</b>	<b>Boat Ramps, Slips, Piers</b>	<b>Riparian and Instream Habitat</b>
Fidalgo Island North	Poor	Poor	DG	Poor	NA
Fidalgo Island West & South	Good	DG	DG	Mostly Good	NA
Padilla Bay East	Poor	Poor (DG)	Poor	Good	NA
Samish Bay	Poor	Poor (DG)	Poor	Good	NA
Guemes, Cypress and other islands	Good	DG	DG	Good	NA

Table 17. Summary of WRIAs 3 and 4 Freshwater Limiting Factors Results

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Stream-bed Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Lower Skagit River		Poor	See tribs	DG	See tribs	DG	DG (likely poor)		Poor	
Nook-achamps	Likely Poor	DG	Poor	DG	Fair	DG	DG	Poor	Poor	Poor (DG)
Hansen	Likely Poor	DG	Poor	DG	Fair	DG	Poor	Poor	Poor	Poor (DG)
Gilligan	DG	DG	Poor	DG	Fair	DG	DG	Poor	DG	Poor (DG)
Sorenson	Good	DG	Poor	DG	DG	DG	DG	Poor (DG)	Poor	DG
Childs	DG	DG	Poor	DG	DG	DG	DG	Poor (DG)	DG	DG
Jones	DG	DG	Poor	DG	DG	DG	Good	Poor (DG)	DG	DG
Mannser	DG	DG	Poor	DG	DG	DG	DG	Poor (DG)	Poor	DG
Red Cabin	DG	DG	Poor	DG	DG	DG	DG	Poor (DG)	Poor	DG
Day	DG	DG	Poor	DG	Fair	DG	DG	Poor (DG)	Poor	Poor (DG)

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Stream-bed Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Loretta	Good	DG	Poor	DG	Fair	DG	DG	Poor (DG)	DG	Poor (DG)
Cumberland	Good	DG	Poor	DG	DG	DG	DG	Poor (DG)	Poor	DG
Alder	DG	DG	Poor	DG	Poor	DG	DG	Poor	DG	Poor (DG)
Grandy	DG	DG	Poor	DG	Poor	DG	DG	Poor	Poor	Poor (DG)
Pressentin	Good	DG	DG	DG	Good	DG	DG	Poor in lower; Good in upper	DG	Good (DG)
Finney	Good	DG	Poor	DG	Poor low; Fair up	DG	DG (likely Poor)	Poor	Poor	Poor (DG)
Jackman	Good	DG	DG	DG	Fair	DG	DG	Poor	Poor	Poor
Miller	Good	DG	Poor	DG	Fair	DG	DG	Poor	DG	DG

	<b>Fish Passage</b>	<b>Floodplain Conditions</b>	<b>Sediment: gravel quantity</b>	<b>Sediment: gravel quality</b>	<b>Road Density</b>	<b>Stream-bed Stability</b>	<b>Current Instream LWD (quantity)</b>	<b>Riparian</b>	<b>Water Quality</b>	<b>Water Quantity</b>
Upper Skagit River		Fair	Good	DG	Good	DG	DG		Good	Good
Illabot	DG	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Corkindale WAU	DG	DG	Good	DG	Good	DG	DG	Poor (DG)	DG	Good
Diobsud	DG	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Bacon	DG	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Goodell	Good	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Newhalem	Good	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good

	<b>Fish Passage</b>	<b>Floodplain Conditions</b>	<b>Sediment: gravel quantity</b>	<b>Sediment: gravel quality</b>	<b>Road Density</b>	<b>Stream-bed Stability</b>	<b>Current Instream LWD (quantity)</b>	<b>Riparian</b>	<b>Water Quality</b>	<b>Water Quantity</b>
Lower Cascade	DG (poor areas)	DG	Poor	Mixed; poor and good	Poor in areas	Poor	Poor	Poor in areas	DG	Good
Middle Cascade	Good	Likely Good	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Upper Cascade	Good	Likely Good	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Sauk River (mid to lower)		Fair	See tribs	DG	Poor in areas	Likely Poor in lower (DG)	DG (likely Poor)	Poor along lower	DG	DG
Hilt WAU	Good	DG	Good (DG)	DG	Poor	DG	DG	Good	DG	Poor (DG)
Rinker WAU	Poor areas	DG	Poor	DG	Poor	DG	DG	Fair	DG	Poor (DG)
Sauk Prairie	Poor	DG	Poor	DG	Fair	Likely Poor (DG)	DG	Poor	DG	Poor (DG)

	<b>Fish Passage</b>	<b>Floodplain Conditions</b>	<b>Sediment: gravel quantity</b>	<b>Sediment: gravel quality</b>	<b>Road Density</b>	<b>Stream-bed Stability</b>	<b>Current Instream LWD (quantity)</b>	<b>Riparian</b>	<b>Water Quality</b>	<b>Water Quantity</b>
Suiattle	Good	DG	Good	DG	Good	DG	DG	Good	DG (likely good)	Good (DG)
Tenas/Big	Mostly Good	DG	DG	DG	Good (DG)	DG	DG	Good (DG)	DG	Good (DG)
Lime/Buck/Downey	DG	Likely Good	DG	DG	Good	DG	DG	Good	DG (likely good)	Good
Upper Suiattle	Good	Likely Good	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Dan	Good (except 1087, 1088)	DG	Poor	DG	Poor	DG	Good	Fair (DG)	DG	Poor (DG)
Clear	DG	DG	Good	DG	Fair low; Good up	DG	DG	Good (DG)	DG	Good (DG)
White Chuck	Good	Likely Good	Good	DG	Good	DG	DG	Good	DG (likely good)	Good

	Fish Passage	Floodplain Conditions	Sediment: gravel quantity	Sediment: gravel quality	Road Density	Stream-bed Stability	Current Instream LWD (quantity)	Riparian	Water Quality	Water Quantity
Upper Sauk	DG	Likely Good	Good	DG	Fair	DG	Poor to Good	Good	DG (Poor in one reach)	Good (DG)
South Fork Sauk	DG	Likely Good	Good	DG	Good	DG	Good	Good	Fair lower; Good upper (DG)	Good
North Fork Sauk	Good	Likely Good	Good	DG	Good	DG	DG	Good	DG	Good
Baker River		Poor (from Baker Lake downstream)	Poor around lakes			Poor near reservoirs				Poor
Lake Shannon West	Good	DG	Poor	DG	Fair	DG	DG	Good	Poor	Poor (DG)

	<b>Fish Passage</b>	<b>Floodplain Conditions</b>	<b>Sediment: gravel quantity</b>	<b>Sediment: gravel quality</b>	<b>Road Density</b>	<b>Stream-bed Stability</b>	<b>Current Instream LWD</b>	<b>Riparian</b>	<b>Water Quality</b>	<b>Water Quantity</b>
Lake Shannon East	Good	DG	Good	DG	Good (some fair areas)	DG	DG	Good to Fair	Fair to Good	Good (DG)
Mt Baker WAU	DG	Likely Good (DG)	Good	DG	Good (some poor areas)	DG	Fair to Good	Good to Fair	Fair to Good	Good
Mt Blum WAU	DG	Likely Good (DG)	Good	DG	Good	DG	DG	Good	DG (likely good)	Good
Samish River	DG	Poor in lower	Poor	DG	Fair	DG	DG	Poor	Poor	DG
Friday Cr.	Poor	Poor in lower	Poor	DG	Poor	DG	DG	Poor	Poor	Fair (DG)
Thomas Cr.	Poor	Poor	DG	DG	DG	DG	DG	DG	Poor	DG
Swede Cr.	Poor	DG	DG	DG	DG	DG	DG	DG	Poor	DG

DG= Data Gap; When a DG accompanies a rating of good, fair, or poor, it means that the rating is provisional and additional assessments are needed.

NA=Not Applicable



# RECOMMENDATIONS AND DATA NEEDS FOR WRIAS 3 AND 4 HABITAT LIMITING FACTORS

## Introduction

The known, current salmon and steelhead habitat conditions for the Skagit Basin have been identified and assessed as “good”, “fair”, or “poor”. In addition, the impacts, sources of impact, and species impacted have been described whenever possible in the Habitat Limiting Factors Chapter. Some of the major factors have also been mapped to show the extent of the conditions. Based upon this assessment, the following recommendations for habitat improvements and protection are listed by type of factor. Some recommendations are marked with a red diamond. This indicates that more information exists to highlight these as important action items or studies. As assessments occur, priorities may change and new issues may be prioritized.

## Salmonid Access Conditions

### Action Recommendations for Salmonid Access Conditions

- Using the prioritization analysis and other factors such as cost effectiveness, geographic location, landowner willingness, and habitat quality, address passage problems that pose considerable impacts to salmonids in WRIAs 3 and 4.

### Data Needs for Salmonid Access conditions.

- Collect field data to verify habitat quantity and quality as well as type of blockage for passage problems in WRIAs 3 and 4. Begin with blockages in the top prioritization tier.

## Floodplain Conditions

### Action Recommendations for Floodplain Conditions

- ◆ Preserve functioning floodplain habitat, such as edge habitat associated with the mainstem Skagit River, wetted off-channel habitat, and connected functional riparian.
- ◆ Remove hydromodifications that would lead to a significant increase in the quality and quantity of off-channel habitat.
- ◆ Remove or set-back mainstem dikes and hydromodifications to improve edge habitat, restore and connect off-channel habitat, and improve hydrologic conditions.
- ◆ Restrict development and hydromodifications in the geomorphic floodplain.

- ◆ Reconnect and restore riverine wetland habitat along the mainstem Skagit, Sauk, and Samish Rivers and larger tributaries.
- Prevent further losses of wetlands throughout the Skagit Basin, including the Samish River.
- Because of the changed hydrograph and loss of off-channel habitat development resulting from high flows that have been reduced by dam operations, create appropriate off-channel habitat in the upper Skagit Basin.
- Reduce channelization impacts in tributaries and sloughs connected to the lower Skagit River.

#### Data Needs for Floodplain Conditions

- ◆ Identify and prioritize floodplain habitat for restoration and protection.
- Study fish habitat in the alluvial fans to determine the importance of this habitat to salmonid production in the Skagit Basin.
- Monitor the effectiveness of human created off-channel habitat. How much more of this type of habitat is needed in the upper Skagit?
- Investigate the impacts of floodplain alterations (such as dikes) on hydrologic connections, such as the hyporheic zone.

#### **Streambed and Sediment Conditions**

##### Action Recommendations for Streambed and Sediment Conditions

- ◆ Decommission or treat road segments that are at a high risk of delivering sediment to streams after a risk assessment is conducted. Focus on road segments that pose a greater threat to salmonid habitat. For example, orphaned roads frequently create sediment problems and are not addressed under Timber Fish and Wildlife agreements.
- Improve LWD transport from dams and around bridges (ex. Highway 9 bridge).
- Pursue funding opportunities for road restoration activities above and beyond regulatory requirements.
- Decrease sedimentation impacts to salmonids from diking, such as reduced gravel recruitment and potentially increased scour.

### Data Needs for Streambed and Sediment Conditions

- ◆ Identify and prioritize sediment sources in “poor” rated watersheds for possible future restoration projects, focusing primarily on roads. The WAUs with excess sedimentation include: Miller, Alder, Day, Grandy, Nookachamps, Hansen Finney, Loretta, Gilligan, Rinker, Dan, Sauk Prairie, Shannon West, Jordon/Boulder, Samish, and Friday Creek. A process to prioritize these WAUs or streams based upon benefit to salmonids is recommended to apply a focused approach to improving sedimentation.
- ◆ Conduct assessments on stream stability, gravel quality, and instream LWD quantities in a prioritized manner (see above). Identify potential project areas.
- ◆ Sediment conditions in non-forested land use WAUs need to be assessed for impacts to salmonids. Examples of potential problems that should be examined are lack of crop cover, V ditching, loss of riparian, and ORV use.
- Monitor and evaluate the effectiveness of sediment reduction efforts on state and private lands.
- Examine the possibility of re-establishing sediment supply and transport downstream of dams.

### **Riparian Conditions**

#### Action Recommendations for Riparian Conditions

- ◆ Restore degraded riparian conditions throughout the Skagit Basin, including tributaries, based upon impact to salmonids and watershed processes.
- Reduce the impact of hydromodifications (dikes) on riparian processes.
- Eliminate non-native plants from riparian zones, such as Japanese knotweed, blackberry, and Reed canarygrass.
- Encourage volunteer riparian restoration and fencing along salmonid streams.
- Encourage local groups to implement TMDLs for water temperature and dissolved oxygen.

#### Data Needs for Riparian Conditions

- Conduct a basin-wide analysis of riparian conditions that include shade hazards and LWD recruitment potential, incorporating previous assessments where possible.

## **Water Quality Conditions**

### Action Recommendations for Water Quality Conditions

- ◆ Improve water quality throughout the Skagit Basin by addressing riparian, sedimentation, flow, and wetland loss conditions as well as inputs from agriculture, urban, and forestry land uses. These are further described in the Water Quality Chapter.
- ◆ Improve riparian conditions in the Nookachamps, Hansen, Cumberland, Finney, Grandy, and Jackman watersheds to help improve water quality.
- Reduce livestock waste, livestock access, and failing septic systems in the Nookachamps sub-basin.
- Reduce industrial and urban pollution inputs, including stormwater run-off into the lower Skagit River and tributaries.
- Improve water quality conditions in the Samish River by restoring riparian vegetation, reducing nutrients (phosphorus and forms of nitrogen), and reducing turbidity.
- Apply stormwater quality and quantity controls to existing impervious infrastructure.
- Encourage low impact development techniques for new construction.

### Data Needs for Water Quality Conditions

- ◆ Analyze potential causes of water quality problems in the lower Skagit tributaries to determine the best course of action to restore functional water quality. This would include riparian conditions, sedimentation, flow, and inputs from agriculture, urban, and forestry land use.
- ◆ Monitor water temperatures in the Sauk River and tributaries. Spot checks have detected warm water temperatures in the mainstem Sauk River, making this action a high priority.
- Monitor water temperatures in the tributaries to the upper Skagit sub-basin.

## **Water Quantity Conditions in the Skagit Basin**

### Action Recommendations for Water Quantity Conditions

- ◆ Continue to work towards improved water flow conditions from the Baker River hydroelectric projects.

- Apply stormwater quality and quantity controls to existing impervious infrastructure.
- Maintain functional land cover vegetation conditions in those WAUs identified as having good conditions. In impaired or moderately impaired WAUs, improve land cover vegetation conditions through limitations on clearcut acreage. Impaired or moderately impaired WAUs in forestry areas include the Hilt, Rinker, Sauk Prairie, and Dan WAUs in the Sauk sub-basin.

#### Data Needs for Water Quantity Conditions

- Monitor low flow conditions in the tributaries to the lower Skagit River.
- Assess surface water withdrawals associated with the lower Skagit River and tributaries.
- Analyze the impacts of high flow to salmonid production in the mainstem Skagit River and larger tributaries.
- Effects to and from hyporheic zones should be investigated.

#### **Estuarine and Nearshore Conditions**

##### Action Recommendations for Estuarine and Nearshore Conditions

- ◆ Reconnect and restore potentially functional estuarine habitat associated with the Skagit Basin. This includes habitat on public and private lands, and should be a high priority action item that will primarily benefit chinook, chum, and pink salmon. This recommendation includes:
  - Setting back dikes along the mainstem within tidal influence to encourage development of back channels.
  - Restoring tidal influence to relic channels.
  - Setting back sea dikes to reconnect saltmarsh area and sloughs.
  - Restoring freshwater inputs to relic sloughs.

Refer to the Fir Island Feasibility study for specific recommendations for Fir Island streams.

- ◆ Reconnect and restore potentially functional slough habitat including restoration of tidal influence, reconnection of stream to floodplain, riparian restoration, and addressing freshwater access problems.

- ◆ Protect and if applicable, restore, non-natal estuaries (pocket estuaries or small estuarine areas along Skagit Bay that are not associated with the Skagit River). An example of an important pocket estuary is Dugualla Bay.
- ◆ Address salmonid access issues to Padilla Bay (jetty and filling of Sullivan Slough).
- Complete the South Fork Skagit TMDL (Total Maximum Daily Load) actions to address low dissolved oxygen levels in the South Fork Skagit River.
- Control *Spartina* within WRIA 3.
- Protect existing forage fish habitat.
- Minimize additional shoreline modifications.
- Encourage improved shoreline riparian vegetation.

#### Data Gap Recommendations for WRIA 3 Estuarine and Nearshore Conditions

- ◆ Develop a process that will prioritize nearshore areas for protection or restoration of salmonid and forage fish habitat.
- Analyze potential causes of water quality problems in slough habitat to determine the best course of action to restore functional water quality. This would include tidal flux, riparian conditions, sedimentation, flow, and inputs from agriculture and urban land use.
- Monitor potential sediment contamination in the sloughs that drain into Skagit and Padilla Bays.
- Regularly monitor water quality conditions that pertain to salmonids in the South Fork and North Fork Skagit Rivers.
- Analyze and identify impacts to salmonids from boat and marina pollution and the sediment contamination in the March Point area.
- Develop a prioritization process for addressing fish blockages (tidegates) within the estuarine areas.
- Assess the effects of tidegates including historic and current habitat quality and quantity.
- Determine the linkage of forage fish production to Skagit Basin salmonid productivity.
- Identify areas for LWD restoration in the estuarine environment.

## LITERATURE CITED

- Aitkin, J.K. 1998. The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: a literature review. U.S. Fish and Wildlife Service, Aquatic Resources Division, in cooperation with the U.S. Fish and Wildlife Service, Puget Sound Program.
- American Rivers. 2002. River renewal: mitigation packages. American Rivers, Washington DC.  
<http://www.amrivers.org/hydropowertoolkit/rmitpackages3.htm#skagit>
- B.C. Ministry of Environment, Lands and Parks and Environment Canada. 1993. State of the environment report for British Columbia. Vancouver, British Columbia. 127 pp.
- Bargmann, G. 1998. Forage fish management plan. Washington Department of Fish and Wildlife. Olympia, Washington.
- Bargmann, G. and eleven other authors. 1999. Washington contribution to the 1999 meeting of the technical sub-committee (TSC) of the Canada-U.S. Groundfish Committee. Washington Department of Fish & Wildlife. Olympia, Washington.
- Beamer, E. M. and R.G. LaRock. 1998. Fish use and water quality associated with a levee crossing the tidally influenced portion of Browns Slough, Skagit River Estuary, Washington. Skagit System Cooperative, La Conner, Washington. Prepared for: Skagit County Diking District No. 22. 47 pp.
- Beamer, E., T. Beechie, B. Perkowski, and J. Klochak. 1999. Application of the Skagit Watershed Council Strategy. Mount Vernon, Washington.
- Beamer, E.R., T. Beechie, B. Perkowski, and J. Klochak. 2000. Application of the Skagit Watershed Council's Strategy. River basin analysis of the Skagit and Samish Basins: Tools for salmon habitat restoration and protection. Skagit Watershed Council. Mount Vernon, Washington. 86 pp.
- Beamer, E., R. Henderson, and K. Larsen. 2002a. Evidence of an estuarine habitat constraint on the production of wild Skagit chinook. Presentation at Western Division AFS Meeting in Spokane April 29-May1, 2002. Skagit System Cooperative. LaConner, Washington.
- Beamer, E. R. Henderson, and K. Larsen. 2002b. Moving towards a more complete understanding of Skagit chinook production. Presentation made May 15, 2002 for the Salmon Habitat Modeling in the Puget Sound Basin workshop (Ray Hilborn, Mary Ruckleshaus, and Jeff Richey, instructors). University of Washington. Seattle, Washington.
- Beechie, T.J., B.D. Collins, and G.R. Pess. 2001. Holocene and recent geomorphic processes, land use, and salmonid habitat in two North Puget Sound River Basins.

- In: Geomorphic Processes and Riverine Habitat* (Dorava, J.M., D.R. Montgomery, B.B. Palcsak, F.A. Fitzpatrick, eds.). Water Science and Application Volume 4, pp.37-54.
- Beechie, T., G. Pess, E. Beamer, G. Lucchetti, R. Bilby. 2003. Role of watershed assessments in recovery planning for salmon. *In: Restoration of Puget Sound Rivers*. University of Washington Press. Seattle, Washington.
- Berry, H.D., J.R. Harper, T.F. Mumford, Jr., B.E. Bookheim, A.T. Sewell, and L.J. Tamayo. 2001. The Washington State Shore Zone Inventory User's Manual. Nearshore Habitat Program, Washington State Department of Natural Resources. Olympia, Washington.
- Blocking, R. C. 1997. A portrait of a mighty river. University of Washington Press. Seattle, Washington. 294 pp.
- Bortleson, G.C., M.J. Chrzastowski, and A.K. Helgerson. 1980. Historical changes of shoreline and wetland at eleven major deltas in the Puget Sound Region, Washington. U.S. Dept. of the Interior, Geological Survey.
- Bourasaw, Noel. 2002. Skagit River Journal of History & Folklore. <http://www.geocities.com/skagitjournal/Towns-West/MVHistory1940.html>.
- British Columbia Heritage River System. 2002. <http://www.bcheritagerivers.ca/rivers/skagit.shtml>
- Broadhurst, G. and R. Wlakinshaw. 1998. Puget Sound nearshore habitat regulatory perspective: A review of issues and obstacles. Puget Sound Water Quality Action Team. Olympia, Washington. Puget Sound/Georgia Basin Environmental Report Series: Number 7.
- Brooks, K. M. 1994. Literature review, computer model and assessment of the environmental risks associated with creosote treated wood products used in aquatic environments. Aquatic Environmental Sciences. Port Townsend, Washington. 136 pp. (Reissued in 1997).
- Brulle, R.V. 2002. Washington Trout files notice to sue Puget Sound Energy and the FERC. Washington Trout, Duvall, Washington. <http://www.washingtontrout.org/pse.shtml>
- Bulthuis, D. A. 1993. A review of water quality data in the Padilla Bay/Bay View watershed. Department of Ecology. Mount Vernon, Washington. 24 pp.
- Bulthuis, D.A. 1996. Suspended sediments in Joe Leary Slough, a North Puget Sound coastal stream draining an agricultural watershed. <http://www.padillabay.gov/researchprojects>

- Cederholm, C.J., D.H. Johnson, R.E. Bilby, L.G. Dominguez, A.M. Garrett, W.H. Graeber, E.L. Greda, M.D. Kunze, B.G. Margot, J.F. Palmisano, R.W. Plotnikoff, W.G. Percy, C.A. Simenstad, and P.C. Trotter. 2000. Pacific salmon and wildlife-ecological contexts, relationships, and implications for management. Special edition technical report, prepared for D.H. Johnson and T.A. O'Neil (Manag. Dirs.) Wildlife-Habitat Relationships in Oregon and Washington. Washington Department of Fish and Wildlife. Olympia, Washington.
- City of Seattle. 2001. Seattle's watersheds outside the municipal boundaries. In: Seattle's Urban Blueprint for Habitat Protection and Restoration. City of Seattle, Seattle Public Utilities, Seattle, Washington.
- Clark, J.R. 1996. Coastal Zone Management Handbook. Lewis Publishers. Boca Raton, Florida.
- Collins, B.D. and D.R. Montgomery. 2001. Importance of archival and process studies to characterizing pre-settlement riverine geomorphic processes and habitat in the Puget lowland. *In: Geomorphic Processes and Riverine Habitat* (Dorava, J.M., D.R. Montgomery, B.B. Palcsak, and F.A. Fitzpatrick, eds.). Water Science and Application Volume 4, pp. 227-243.
- Cutler, J. 2001. Salmon habitat limiting factors anadromous and resident salmonid distribution water resource inventory areas 3 and 4 Skagit and Samish Watersheds. Washington State Conservation Commission. Lacey, Washington.
- Dean T., Z. Ferdana, J. White, and C. Tanner. 2000. Skagit Estuary Restoration Assessment Puget Sound Washington. People for Puget Sound. Seattle, Washington. 22 pp.
- Department of Agriculture. 2000. 2000 *Spartina* management plan for north Puget Sound. In cooperation with the North Puget Sound *Spartina* Task Force. Department of Agriculture. Olympia, Washington.
- Department of Natural Resources. 1994. Hansen watershed analysis. Washington State Department of Natural Resources, Olympia, Washington.
- Department of Natural Resources. 1995. Jordan-Boulder watershed analysis. Washington State Department of Natural Resources, Olympia, Washington.
- Department of Ecology (DOE). 1992. WAC 173-201A. Department of Ecology, Olympia, Washington.
- Department of Ecology (DOE). 1995. State of the Nooksack River watershed. Department of Ecology Nooksack Initiative Office, Bellingham, Washington.
- Dept. of Ecology (DOE). 2000. Ecology's final 1998 list of impaired and threatened waterbodies- the 303(d) List. <http://www.wa.gov/ecology/wq/303d/index.html>

- Department of Ecology (DOE). 2001. Sediment cleanup status report. Washington State Department of Ecology Toxics Cleanup Program. Publication number 01-09-046. Olympia, Washington. 21 pp.
- Department of Ecology (DOE). 2002a. Aquatic noxious weed control NPDES general permit. Washington Department of Ecology. Olympia, Washington.  
[http://www.ecy.gov/programs/final.pesticides/noxious/spartina\\_coverages.html](http://www.ecy.gov/programs/final.pesticides/noxious/spartina_coverages.html).
- Department of Ecology (DOE). 2002b. Vessel entries and transits for Washington waters VEAT 2001. Washington Dept. of Ecology Spills Program. Olympia, Washington. Publication 02-08-003. 6 pp.
- Department of Ecology (DOE). 2003. River and stream water quality monitoring. Department of Ecology, Olympia, Washington.  
<http://www.ecy.wa.gov/apps/watersheds/riv/station.asp?wria=03>
- DePhelps, C. 1993. Agriculture/estuary natural resource and water quality issues: models for research and education. Padilla Bay National Estuarine Research Reserve. Washington State University. Pullman, Washington. 176 pp.
- Determan, T. 1995. Watershed briefing paper: shellfish issues. Washington Department of Ecology Watershed Management Section, Olympia, Washington.
- Drost, B.W. and R.E. Lombard. 1978. Water in the Skagit River Basin Washington. Water Supply Bulletin.
- Duke Engineering. 1999. Final technical report lower Skagit River instream flow studies. Prepared for Public Utility District No. 1 of Skagit County and the City of Anacortes. Duke Engineering and Services, Inc., Bellingham, Washington. 140 pp.
- Duke Engineering. 2001. Instream flow assessment- Samish sub-basin. Lower and upper Skagit watershed plan. Prepared for: Skagit Council of Governments by Duke Engineering and Services, Inc. Portland, Maine.
- Dwellely, C. 1953. History of Skagit County. On:  
<http://www.geocities.com/skagitriverjournal/DwellelyCounty.html>
- Entranco. 1993. Lower Skagit River Basin water quality study. Final report November 1993. For: Skagit County Dept. of Planning and Community Development and Washington Dept. of Ecology. Bellevue, Washington. 75 pp.
- Environmental Protection Agency. 2002 draft. Draft EPA Region 10 guidance for Pacific Northwest state and tribal temperature water quality standards. U.S. EPA Region 10 Seattle, Washington.
- EPRI. 1995. Management practices for used treated wood, final report. EPRI TR-104966. Electric Power Research Institute. Pleasant Hill, California.

- EVS Environment Consultants. 1999. Cherry Point screening level ecological risk assessment. For the Washington Dept. of Natural Resources. Olympia, Washington.
- Everett, R.A. and G.M. Ruiz. 1993. Coarse woody debris as a refuge from predation in aquatic communities: an experimental test. *Oecologia* 93:475-486.
- Fresh, K.L., B.Williams, and D. Pentilla. 1995. Overwater structures and impacts on eelgrass in Puget Sound. Washington Puget Sound Research 1995 Proceedings. Puget Sound Water Quality Authority. Seattle, Washington.
- GeoEngineers Inc. 1984. Report of consultation, river channel migration, Upper Baker River, Whatcom County, Washington. File No. 186-35. For Puget Sound Power & Light Company. 11 pp.
- Haight, R. 2002. An inventory and assessment of the Finney Creek riparian forest methodology and results. Skagit System Cooperative, LaConner, Washington. 58 pp.
- Hall, K., G. Larkin, D. McCallum, and P. Zandbergen. 2002. Brunette River watershed: the impacts of urbanization. <http://www.ire.ubc.ca/ecoresearch/brunette.html>
- Harrold, C., J. Watanabe, and S. Lisin. 1988. Spatial variation in the structure of kelp forest communities along a wave exposure gradient. *Marine Ecology* 9(2): 131-156.
- Hayman, R., E. Beamer, R. McClure. 1996. FY 1995 Skagit River chinook research. Skagit System Cooperative chinook restoration research progress report #1, NWIFC Contract #3311 for FY 1995. Skagit System Cooperative, La Conner, Washington.
- Humphreys, R.D. and A.S. Hourston. 1978. British Columbia herring spawn deposition survey manual Fisheries and Marine Service Miscellaneous Special Publication No. 38. Canadian Fisheries and Marine Service 38. 40 pp.
- Hyatt, T., T.Z. Waldo, and T.J. Beechie. 2002. Watershed assessment of riparian forests. Presentation at the Salmon Summit 2002, Restoring our Watershed. October 17, 2002, Bellingham, Washington.
- Jennings, A. and T. Jennings. 2001. Estuary management in the PNCERS study area. An overview of programs and activities in Washington, Oregon, and N. California. For Pacific Northwest Coast Ecosystems Regional Study. North Coast Consultants. Cannon Beach, Oregon. 151 pp.
- Johnson, A. 1999. Investigation of chemical contamination at Whitmarsh Landfill and Padilla Bay Lagoon. Washington Dept. of Ecology. Lacey, Washington. Publication 99-306.

- Johnson, A. 2000. Results of a screening analysis for metals and organic compounds in shellfish from Padilla Bay and vicinity. Washington Dept. of Ecology. Lacey, Washington. Publication 00-03-008.
- Johnson, L. L. 2000. An analysis in support of sediment quality thresholds for polycyclic aromatic hydrocarbons (PAH) to protect estuarine fish. National Marine Fisheries Service. Seattle, Washington (Draft white paper).
- Karrow, N. A., H. J. Boermans, D. G. Dixon, A. Hontella, K. R. Solomon, J. J. Whyte, and N. C. Bols. 1999. Characterizing the immunotoxicity of creosote to rainbow trout (*Oncorhynchus mykiss*): a microcosm study. *Aquat. Toxicol.* 45:223-239.
- Krahn, M. M., L. D. Rhodes, M. S. Meyers, L. K. Moore, W. D. MacLeod, and D.C. Malins. 1986. Associations between metabolites of aromatic hydrocarbons in bile and the occurrence of hepatic lesions in English sole (*Parophrys vetulus*) from Puget Sound, Washington. *Arch. Environ. Contam. Toxicol.* 15:61-67.
- Levings, C.D. and A.I. Moody. 1976. Studies of intertidal vascular plants, especially sedge (*Carex lyngbyei*), on the disrupted Squamish River delta, British Columbia. *Fish. Mar. Serv. Tech. Rept.* 606. 56 pp.
- Levings, C.D., C.D. McAllister, J.S. Macdonald, T.J. Brown, M.S. Kotyk, and B.A. Kask. 1989. Chinook salmon (*Oncorhynchus tshawytscha*) and estuarine habitat: a transfer experiment can help evaluate estuary dependency. Pp. 116-122 *In: Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks* (C.D.Levings, L.B.Holtby, and M.A.Henderson, eds.). *Can. Spec. Publ. Fish. Aquat. Sci.* 105.
- Levings, C.D. and R. M. Thom. 1994. Habitat changes in the Georgia Basin: implications for resource management and restoration. *British Columbia/Washington Symposium on the marine environment Puget Sound and Juan de Fuca Strait.* Pp. 330-349.
- Long, E.R., D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effect within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management* 19 (1): 88-97.
- Long, E.R., and 13 other authors. 1999. Sediment Quality in Puget Sound Year 1 - Northern Puget Sound December 1999. NOAA NOS NCCOS CCMA No. Technical Memo No. 139 and Washington State Department of Ecology Publication No. 99-347.
- Lunetta, R.S., B.L. Cosentino, D.R. Montgomery, E.M. Beamer, and T.J. Beechie. 1997. GIS-Based evaluation of salmon habitat in the Pacific Northwest. *Photogrammetric Engineering & Remote Sensing.* Vol. 63, No. 10, pp.1219-1229.

- Luxenberg, G. 1986. Historic Resource Study North Cascades National Park Service Complex, Washington. North Cascades National Park, Marblemount, Washington.
- MacWhinney, E.J. and J.G. Thomas. 1996. Phase II: Skagit wetland & industry negotiations. Indicator value assessment (IVA) of wetland functions at the Port of Skagit County, located in the Padilla Bay/Bayview watershed, Washington. Port of Skagit County. Mount Vernon, Washington. 163 pp.
- Marshall, A.R., C. Smith, R. Brix, W. Dammers, J. Hymer, and L. Lavoy. 1995. Genetic diversity units and major ancestral lineages for chinook salmon in Washington. *In: Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington*. Washington Department of Fish and Wildlife. Technical Report Number RAD 95-02.
- Maser, C. and J.R. Sedell. 1994. From the Forest to the Sea. The Ecology of Wood in Streams, Rivers, Estuaries, and Oceans. St. Lucie Press. Delray Beach, Florida.
- Mayer, J.R. and N.R. Elkins. 1990. Potential for agricultural pesticide runoff to a Puget Sound estuary- Padilla Bay, Washington. *Bull. Environ. Contam. Tox.* Vol. 45: 215-222.
- Meyer, M. S., J. T. Landahl, M. M. Krahn, L. L. Johnson, and B. B. McCain. 1990. Overview of studies on liver carcinogenesis in English sole from Puget Sound; Evidence for a xenobiotic chemical etiology I: pathology and epizootiology. *Sci. Total Environ.* 94:35-50.
- Meyers, J.M., R.G. Kope, G.J. Bryant, D. Teel, L.J. Lierheimer, T.C. Wainwright, W.S. Grant, F.W. Waknitz, K. Neely, S.T. Lindley, and R.S. Waples. 1998. Status review of chinook salmon from Washington, Oregon, Idaho, and California. U.S. Dept. Commerce, NOAA Technical Memo. NMFS-NWFSC-35. 443 pp.
- Miller, R. R. 1965. Quaternary freshwater fishes of North America. Pages 569-581 *In: The Quaternary of the United States*. Princeton University Press, Princeton, New Jersey.
- Ministry of Water, Land, and Air Protection. 2002. Government of British Columbia. <http://wlapwww.gov.bc.ca/soerpt/07-2-surface-water.html>
- Morgan, J.D. and C.D. Levings. 1989. Effect of suspended sediment on eggs and larvae of lingcod (*Ophiodon elongates*), Pacific herring (*Clupea harengus pallasi*), and soft smelt (*Hypomesus pretiosus*). *Can. Tech. Rept. Fish. Aquat. Sci.* 1729. 31 pp.
- National Oceanic and Atmospheric Administration (NOAA). 2000. Polluted run-off: lessons learned from the National Estuarine Research Reserve System. U.S. Dept. of Commerce, NOAA, Estuarine Reserves Division. Silver Springs, Maryland.

- Nightingale, B. and C. Simenstad. 2001a. Dredging activities: marine issues. Prepared for: the Washington Department of Fish and Wildlife, Washington Department of Ecology, and the Washington Department of Transportation. 182 pp.
- Nightingale, B. and C. Simenstad. 2001b. Overwater structures: marine issues. Prepared for the Aquatic Habitat Guidelines Steering Committee and jointly published by the Washington Dept. of Fish and Wildlife, Washington Dept. of Ecology, and Washington Dept. of Transportation. Olympia, Washington. 133 pp.
- Nookachamps Watershed Management Committee and the Skagit County Department of Planning and Community Development (NWMC and SCDPCD). 1995. Nookachamps watershed nonpoint action plan. Skagit County Department of Planning and Community Development, Mount Vernon, Washington.
- North Cascades Institute. 2002. Skagit Watershed Education Project. North Cascades Institute. 2105 State Route 20, Sedro-Woolley, Washington.
- Nouffke, A. and E.R. Beamer. 2001. Skagit Bay nearshore habitat characterization. Skagit System Cooperative, Report to Seattle City Light, Seattle, Washington.
- Pacific International Engineering and Anchor Environmental. 1999. Bellingham Bay demonstration pilot. Final habitat restoration documentation report. For the Bellingham Bay Demonstration Pilot Work Group. Bellingham, Washington.
- Padilla Bay/Bay View Watershed Management Committee and Skagit County Dept. of Planning and Community Development (PBWMC and SCPCD). 1995. Padilla Bay/Bay View watershed nonpoint action plan. Skagit County Department of Planning and Community Development. Mount Vernon, Washington.
- Padilla Bay National Estuarine Research Reserve. 2002. National Oceanic Atmospheric and Administration. <http://www.padillabay.gov/>
- Paulson, K. 1997. Estimating changes in sediment supply due to forest practices: a sediment budget approach applied to the Skagit River Basin in Northwestern Washington. M.S. Thesis, University of Washington, Seattle, Washington. 156 pp.
- Paulson, K.M. 1999. Baker River Basin Landslide Mapping. FERC #121750. Estimates of Land-Use Effects on Sediment Delivery within the Baker River Basin. Fulfillment of Order No. 43-035M6-8-0231. Mt. Baker-Snoqualmie National Forest. Mt. Baker Ranger District. Sedro Woolley, Washington. 39 pp.
- Pentilla, D.E. 1995. Baitfish resources and habitats of Fidalgo Bay, Skagit County, WA. Washington Department of Fish and Wildlife Marine Resources Division. Mt. Vernon, Washington. 40 pp.

- Penttila, D.E. 2000. Documented spawning areas of the Pacific herring (*Clupea*), surf smelt (*Hypomesus*), and Pacific sand lance (*Ammodytes*) in Skagit County, Washington. Washington Department of Fish and Wildlife Marine Resources Division. Mt. Vernon, Washington. 26 pp.
- Penttila, D. 2001a. Documented spawning areas of the Pacific herring, *clupea*, the surf smelt, *hypomesus*, and the Pacific sand lance, *ammodytes*, in Whatcom County, Washington. Washington Dept. Fish and Wildlife, Marine Resources Division. LaConner, Washington. 17 pp.
- Penttila, D. 2001b. Effects of shading upland vegetation on egg survival for summer spawning surf smelt on upper intertidal beaches in Puget Sound. *In: Proceedings on Puget Sound Research 2001.* 9 pp.
- Phinney, D. and Williams. 1975. A catalog of Washington streams and salmon utilization. Vol. 1 Puget Sound. Washington Department of Fisheries. Olympia, Washington.
- Pickett, P. 1997. Lower Skagit River Total Maximum Daily Load Water Quality Study. Washington Department of Ecology. Olympia, Washington. Publication 97-326A.
- Poston, T. 2001. Treated wood issues associated with overwater structures in marine and freshwater environments. White Paper submitted to: Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation. Olympia, Washington. 85 pp.
- Puget Sound Energy. 2002. Baker River Project Relicense: Initial Consultation Document. Puget Sound Energy, Bellevue, Washington.
- Reimers, P.E. 1973. The length of residence of juvenile chinook salmon in the Sixes River, Oregon. Fish Commission of Oregon Research Reports 4(2) 1-43.
- Riggs, S. and D. Kolbe. 1998. Control of *Spartina* in Padilla Bay, Washington, in 1998. Department of Ecology Padilla Bay National Estuarine Research Reserve. Mount Vernon, Washington. 18 pp.
- Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP). 1995 to present. MS Access Database; ESRI ArcInfo Coverages. Northwest Indian Fisheries Commission, Olympia, Washington.  
<http://www.nwifc.org/sshiap2/index.asp>
- Salo, E. O. 1991. Life history of chum salmon. *In: Pacific Salmon Life Histories* (Groot, C. and L. Margolis, eds). UPC Press. Vancouver, British Columbia. Pp. 233-309.

- Shaffer, J.A. 1998. Kelp bed habitats of the inland waters of western Washington. Pp. 353–362 in Puget Sound Research '98 Proceedings. Puget Sound Water Quality Action Team, Olympia, Washington. 947 pp.
- Shaffer, J.A. and D.S. Parks. 1994. Seasonal variation in and observations of landslide impacts on the algal composition of a Puget Sound nearshore kelp forest. *Botanica Marina*. 37: 315-323.
- Shaffer, J.A., D.C. Doty, R.M. Buckley, and J.E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish *Sebastes diploproa*. *Marine Ecology Progress Series* 123:13-21.
- Shreffler, D.K. and R. Thom. 1993. Restoration of urban estuaries: new approaches for site location and design. Prepared for Washington Dept. of Natural Resources. Olympia, Washington. 107 pp.
- Simenstad, C.A. and E.O. Salo. 1982. Foraging success as a determinant of estuarine and near-shore carrying capacity of juvenile chum salmon (*Oncorhynchus keta*) in Hood Canal, Washington. Pages 21-37 *In*: Proceedings of the North Pacific Aquaculture Symposium (B.R. Meltreiff and .A. Neve, eds). Alaska Sea Grant Rep. 82-2.
- Simenstad, C.A. and R.C. Wissmar. 1985. Delta<sup>13</sup>C evidence of the origins and fates of organic carbon in estuarine and nearshore food webs. *Mar. Ecol. (Progress Series)* 22:141-152.
- Simenstad, C.A., W.J. Kinney, S.S. Parker, E.O. Salo, J.R. Cordell, and H. Buechner. 1980. Prey community structure and trophic ecology of outmigrating juvenile chum and pink salmon in Hood Canal, Washington: a synthesis of three years' studies, 1977-1979. Fisheries Research Institute, University of Washington. Seattle, Washington.
- Simenstad, C. A., J. R. Cordell, R. C. Wissmar, K. L. Fresh, S. Schroder, M. Carr, and M. Berg. 1988. Assemblages structure, microhabitat distribution, and food web linkages of epibenthic crustaceans in Padilla Bay National Estuarine Research Reserve, Washington. NOAA Tech. Rep. Ser. OCRM/MEMD, FRI-UW-8813, Fish. Res. Inst., University of Washington. Seattle, Washington. 60 pp.
- Simenstad, C. A., J. R. Cordell, and L. A. Weitkamp. 1991. Effects of substrate modification on littoral flat meiofauna: Assemblage structure changes associated with adding gravel. FRI-UW-9124. University of Washington. Seattle, Washington.
- Simenstad, C.A. 2001. The relationship of estuarine primary and secondary productivity to salmonid production: bottleneck or window of opportunity? NOAA-NMFS-NWFSC Publication TM-29: Estuarine and Ocean Survival of Northeastern Pacific Salmon.

- Skagit County Geographic Information Services. 2002.  
<http://www.skagitcounty.net/Common/Asp/Default.asp?d=GIS&c=General&p=Gallery/main.htm#hydricsoils>
- Skagit County Department of Public Works. 2003. Water temperature baseline map. Skagit County. Mount Vernon, Washington.  
<http://www.skagitcounty.net/Common/Asp/Default.asp?d=PublicWorksSurfaceWaterManagement&c=General&p=baselinemapWater.htm>
- Skagit County Planning and Permit Center. 1997. Skagit County comprehensive plan. Skagit County, Mt. Vernon, Washington.
- Summers, John H. VII. 2001. Salmon recovery index watershed monitoring program water quality index report October 2000-September 2001. Department of Ecology Publication # 01-03-046. Lacey, Washington.
- Thom, R.M. 1987. Benthic primary production in the eelgrass meadow at the Padilla Bay National Estuarine Research Reserve, Washington. (U.S.) National Oceanic and Atmospheric Association Technical Report Series OCRM/MEMD. 33 pp.
- Thom, R.M. and G.D. Williams. 2001. Executive summary: marine and estuarine shoreline modification issues. <http://www.wa.gov/wdfw/hab/ahg/execsl.pdf>.
- U.S. Geological Survey. 1998a. Classification of wetlands and deepwater habitats of the United States. <http://www.npwrc.usgs.gov/resource/1998/classwet/wetlands.htm>
- U.S. Geological Survey. 1998b. Estimated use of water in the U.S. in 1995. Circular 1200.
- U.S. Fish and Wildlife Service. 1994. Trace elements and oil-related contaminants in sediment, bivalves, and eelgrass from Padilla and Fidalgo Bays, Skagit County Washington 1988. U.S. Fish Wildlife Service. Olympia, Washington.
- U.S. Fish and Wildlife Service. 1998. Bull trout interim conservation guidance. U.S. Fish and Wildlife Service. Lacey, Washington. 50 pp.
- U.S. Forest Service. 1996. Sauk River watershed analysis. U.S. Forest Service, Mt. Baker Ranger District. Sedro Woolley, Washington.
- U.S. Forest Service. 1999. Watershed analysis Finney Creek/ Lower Skagit River. U.S. Forest Service, Mt. Baker Ranger District. Sedro Woolley, Washington.
- U.S. Forest Service. 2002. Baker River watershed analysis. U.S. Forest Service, Mt. Baker Ranger District. Sedro Woolley, Washington.
- van Brummelen, T. C., B. van Hattum, T. Crommentuijn, and D. F. Kalf. 1998. Bioavailability and Ecotoxicity of PAH. *In*: PAH and Related Compounds –

- Biology (Neilson, A. H., ed.). Vol. 3-J, The Handbook of Environmental Chemistry. Springer-Verlag. Berlin Heidenberg. Pp. 203-263.
- Varanasi, U., McClain, B.B., Stein, J.E. and Chan, S.L. 1993. Effects of coastal pollution on living marine resources. *In*: Transactions of the Fifty-Eighth North American Wildlife and Natural Resources Conference. Washington DC, 19-24 Mar. 1993, pp. 271-286.
- Vines, C. A., T. Robbins, F. J. Griffin, and G. N. Cherr. 2000. The effects of diffusible creosote derived compounds on development in Pacific Herring (*Clupea pallasii*). *Aquatic Toxicology* 51:225-239.
- Volk, E.C., R.C. Wissman, C.A. Simenstad, and D.M. Eggers. 1984. Relationship between otolith microstructure and the growth of juvenile chum salmon (*Oncorhynchus keta*) under different prey rations. *Canadian Journal of Fisheries and Aquatic Sciences* 41:126-133.
- Waldichuck, M. 1957. Physical oceanography of the Strait of Georgia, British Columbia. *Journal of Fisheries Research Board Canada* 14:321-486.
- Washington Department of Fish and Wildlife. 1998a. Salmonid Stock Inventory. Appendix Bull Trout and Dolly Varden. Olympia, Washington. 437 pp.
- Washington Department of Fish and Wildlife. 1998b. Fish Passage Barrier and Prioritization Manual of Washington Department of Fish and Wildlife. Olympia, WA.
- Washington Dept. of Fish & Wildlife. 2000a. Salmonid stock inventory (SaSI): coastal cutthroat trout. Olympia Washington.
- Washington Dept. of Fish & Wildlife. 2000b. Species of concern in Washington State. <http://www.wa.gov/wdfw/wlm/diversity/soc/soc.htm>
- Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, Washington. 212 pp.
- Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory. Appendices. Olympia, Washington.
- WDFW (Washington Department of Fish and Wildlife) and WWTIT (Western Washington Treaty Indian Tribes). 2003 draft. SaSI 2002. Washington state salmon and steelhead stock inventory. WDFW. Olympia, Washington.
- West, J.E. 1997. Protection and restoration of marine life in the inland waters of Washington State. Puget Sound/Georgia Basin Environmental Report Series: Number 6. Puget Sound Water Quality Action Team. Olympia, Washington.

- Whatcom Council of Governments. 2000. State Route 11 Chuckanut Drive corridor management plan. Whatcom County, Bellingham, Washington.
- Whitehouse, T.R., C.D. Levings, and J.S. Macdonald. 1993. Chironomid (*Diptera*) insects from natural and transplanted estuarine marshes in British Columbia. *In*: Proceedings of the 1993 Canadian Coastal Conference, Vancouver, May 4-7, 1993 (Leighton, D, ed.). Pp.500-524. Coastal Zone Engineering Program. National Research Council Canada. Ottawa, Ontario.
- Wilkosz, M. 2000. Salmon and steelhead habitat limiting factors in Island County. Washington Conservation Commission, Lacey, Washington.
- Williams, G.D., and R. Thom. 2000. White paper: development of guidelines for aquatic habitat protection and restoration – marine and estuarine shoreline modification issues (review draft). Prepared for the Washington State Department of Transportation, the Washington Department of Fish and Wildlife, and the Washington Department of Ecology. Olympia, Washington.
- Yin, K., R.H. Goldblatt, P. J. Harrison, M.A. St. John, P.J. Clifford, and R.J. Beamish. 1997. Importance of wind and river discharge in influencing nutrient dynamics and phytoplankton production in summer in the central Strait of Georgia. *Marine Ecology Progress Series* 161:173-183.