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Skagit Watershed Council

Plan for Habitat Protection and Restoration in the Middle Reach of the Skagit River

Strategies, Treatments, and Priorities

July 13, 2011

Key Points

- Rearing habitat has been identified as the key factor limiting the Skagit's six independent Chinook salmon populations. The middle reach of the Skagit River is one of the most important freshwater rearing areas for juvenile Chinook salmon.
- The low velocity habitats required by juvenile Chinook salmon are scarce in some reaches of the middle Skagit due to manmade structures or natural confinement.
- The reaches with widest unrestricted floodplains and those with the most complex natural channel forms are those that provide the greatest habitat benefits of juvenile Chinook salmon, specifically the Ross Island, Cochreham Island, and Skiyou reaches.
- Sixteen percent (13.6 miles) of river bank along the 43-mile middle Skagit River is modified by riprap, levees, roads or other structures that isolate floodplain habitat, constrain floodplain building processes, and substantially reduce the availability of and access to the low-velocity habitat areas needed by rearing salmonids.
- Ten miles (73 percent) of all modified banks are located in the lower 3 reaches of the middle Skagit River, from Sedro Woolley to just above the town of Hamilton.
- Hydraulic modelling shows that bank armouring and river training structures in the lower reaches back water upstream and further out into the floodplain. This effect is most noticeable at flows associated with relatively frequent 2 and 5-year flooding.
- These structures limit the expansion of river water into portions of the floodplain which constrains natural biological productivity. Also constrained is the lateral migration of the river channel which is important for creating and sustaining rearing and refuge habitats for juvenile fish.
- A total of 21 project sites were identified in the middle Skagit as part of this planning process. Nineteen of these sites would restore significant areas of floodplain habitat and are located in the three most downstream reaches of the middle Skagit, which are also the highest priority reaches.
- The majority of restoration projects identified in the Plan are located on lands held in private ownership.
- Spatial data collected and analyzed for this project can be used to further develop restoration concepts and identify additional smaller-scale restoration and remediation sites.

Acknowledgements

We are grateful for the efforts of our many colleagues who contributed their time and expertise throughout the process of the project (Table 1) and for grant match funding from Skagit County and Seattle City Light. We offer special thanks to the following organizations and individuals for their work and assistance in producing this document: Ed Connor, fisheries scientist with Seattle City Light, for his habitat simulation analysis from the PSE cross section data, his work writing several sections of this report, and time editing drafts of the report; Bob Warinner, WDFW watershed steward, for producing many of the maps; Sue Madsen, restoration ecologist with Skagit Fisheries Enhancement Group, contracted to assist with final report writing and editing; and members of the Criteria Work Group for their service during the extended length of this project. Thanks are also due our contractors, the Upper Skagit Indian Tribe, Pacific Northwest National Laboratory, Skagit River System Cooperative, and Skagit County GIS Services, who collectively provided the spatial data used in the reach assessment and here for project identification. A special thanks to Kate Ramsden, GIS and data specialist with the Skagit River System Cooperative, who competently created, edited, and/or formatted all the spatial data sets.

Recommended Citation

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1 Introduction

The Skagit Watershed Council (Watershed Council) developed this Plan for Habitat Protection and Restoration in the Middle Reach of the Skagit River ("Plan") as a framework for implementing ecologically meaningful restoration and protection actions in the floodplain of the Skagit River between Sedro Woolley and the confluence with the Sauk River (Figure 1). The Plan is intended to communicate the need, goals, technical foundation, and biological priorities for restoration to benefit ESA-listed Chinook salmon in this area of the river to those who will be participating in the design and implementation phases of the work that will follow.

This effort helps to fill a gap in our knowledge between understanding the problem and knowing where to invest in actions that will best meet the restoration goals for Chinook populations in the Skagit. The strategies presented here integrate limiting habitat factors and restoration potential of the landscape to provide a framework for broad-scale, ecosystem-based restoration in the middle Skagit River. Although the actions prescribed here are directed at addressing limiting factors for Chinook, benefits also will be realized for other floodplain dependent species.

While the priorities identified will be updated as work is accomplished and new information becomes available, the strategies and actions prescribed here will continue to inform and guide that future work.

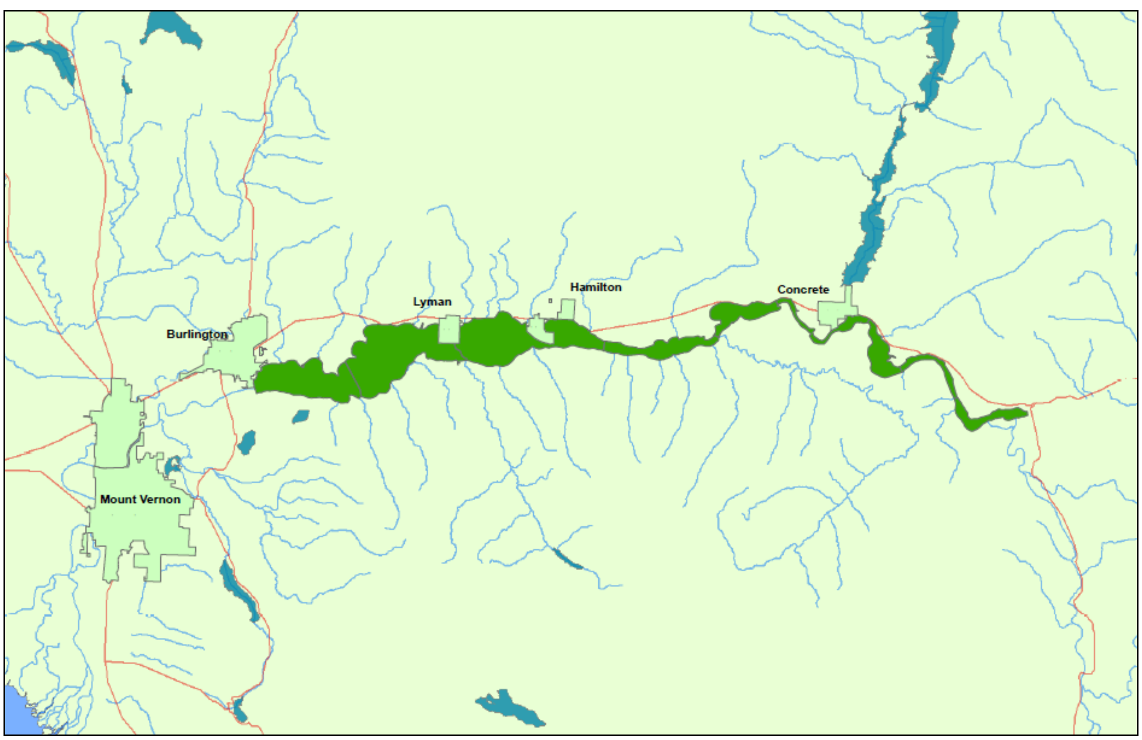

Figure 1. Floodplain of the middle Skagit River included in the project area.

Development of the Middle Skagit Plan

In 2008 the Watershed Council received funding to develop a restoration plan and list of projects in the middle Skagit River, the area with the greatest potential for meeting the freshwater restoration goals for Chinook salmon. Funding came from a Puget Sound Acquisition and Restoration (PSAR) grant with additional financial support from Skagit County and Seattle City Light.

The project was designed to engage the local salmon restoration community in proactively and collectively deciding what large-scale projects in the middle Skagit are vital to watershed and regional Chinook recovery. The Watershed Council established an advisory group of project participants referred to as the Steering Committee, and smaller technical groups directing and working on specific tasks (Table 1). The products of the work groups were presented to the steering committee. The work groups included:

- Criteria Work Group – formed to develop the criteria for identifying areas of greatest benefit for restoration and protection and for evaluating and prioritizing projects. The group considered primarily biologic factors with criteria to be applicable first at the broader reach scale then at a project, or site-specific scale.
- Conservation Database Work Group - formed to update an existing database of conservation lands for use in the project. This group met only once for this project to decide which data fields to include in the database to better facilitate partner data entry.
- Data Work Group - formed to identify the methods and direct the work of the contractors for gathering additional reach-level data.

From March of 2009 through October of 2010, the Council engaged restoration partners and consultants in collecting and updating data and conducting additional analyses and modelling associated with comparing different reaches in the middle Skagit River (Section 6). While the Criteria Work Group was able to identify the data important to the project goals early in the process, the group deferred developing an approach, or criteria for prioritizing actions until more information was available from the data collection and spatial analyses.

Following the results the reach-level assessment, the Criteria Work Group used available information to develop reach-level habitat strategies and to identify protection actions (including fee-simple land acquisition and conservation easements) and restoration treatments consistent with the strategies (Section 6). The Criteria Work Group then adopted a framework to prioritize actions and identified and prioritized a project list (Section 7). The next steps following completion of this Plan will involve resolving implementation issues for priority restoration actions, identifying sponsorship and forming partnerships, and identifying and securing funding to complete these projects.

Table 1. Organizations and representatives participating in the development of the Plan for Habitat Protection and Restoration in the Middle Reach of the Skagit River.

Steering Committee

North Cascades National Park (NPS)	Stan Zyskowski
Puget Sound Energy (PSE)	Jacob Venard
Seattle City Light (SCL)	Ed Connor
Skagit Conservation District (SCD)	Carolyn Kelly, Tom Slocum
Skagit County	Gary Sorenson, Josh Greenberg, Jeff McGowan, Chris Kowitz
Skagit Land Trust (SLT)	Molly Doran, Martha Bray
Skagit Fisheries Enhancement Group (SFEG)	Alison Studley
Skagit River System Cooperative (SRSC)	Steve Hinton, Devin Smith
Skagit Watershed Council (SWC)	Shirley Solomon, Mary Raines
Upper Skagit Indian Tribe (USIT)	Jon-Paul Shanahan
U.S. Forest Service (USFS)	Jon VanderHayden
Washington Dept. of Fish & Wildlife (WDFW)	Bob Warinner

Criteria Work Group

Bob Warinner, Brett Barkdull, WDFW
Ed Connor, SCL
Steve Hinton/Devin Smith, SRSC
Alison Studley, Sue Madsen, SFEG
Jeff McGowan, Skagit County
Jon-Paul Shannahan, USIT
Joshua Greenberg, Skagit County
Martha Bray, SLT
Mary Raines, Skagit Watershed Council
Phil Kincare, USFS
Tom Slocum, SCD
Jacob Venard, PSE

Conservation Database Work Group

Bob Warinner, WDFW
Joshua Greenberg, Skagit County
Kate Ramsden, SRSC
Martha Bray, SLT
Mary Raines, SWC
Phil Kincare, USFS

Data Work Group

Chris Kowitz, Skagit County
Ed Connor, SCL
Devin Smith, SRSC
Jeff McGowan, Skagit County
Jon-Paul Shannahan, USIT
Joshua Greenberg, Skagit County
Mary Raines, Skagit Watershed Council

Contractors

Upper Skagit Indian Tribe
Battelle PNNL
Skagit County GIS Services
Skagit River System Cooperative
Skagit Fisheries Enhancement Group

Plan Goal

The goal of this Plan, as adopted by the Steering Committee, is to apply a science-based approach to "Identify and prioritize the best opportunities to protect and restore floodplain function for salmonids on a large scale in the middle Skagit River."

The first part of this goal seeks to identify the most important places, or "hotspots," for habitat protection in the middle Skagit River under current conditions, while the second seeks to identify those areas that could provide abundant and high quality habitat if natural channel and floodplain processes were restored.

Plan Organization and Content

This section summarizes the organization and content of the Plan. Sections 1 through 4 provide the background and context for the assessment and results that follow.

Through the process of collecting and summarizing data for the project area, discrete project phases emerged: 1) data collection and reach assessment, 2) development of reach-level habitat strategies, 3) identification of protection and restoration actions consistent with the strategies, and finally 4) prioritizing actions.

The assessment phase of the project summarized in Section 5 was designed to collect and summarize relevant physical and habitat data available for the study area as the basis for identifying protection and restoration opportunities in the middle Skagit River. A decision was made early in the project to report the assessment data at the reach level – the scale at which river processes form and maintain fish habitat. The data reported from the reach assessment form the basis of identifying priority reaches and were used as the basis for the reach strategies described in Section 6. The spatial data developed in the reach assessment were then used to identify priority protection and restoration actions within the reaches consistent with an adopted prioritization scheme, as described in Section 7. References are found in Section 8.

The first two Appendices, A and B, contain results from the commissioned hydraulic analyses, and Appendix C contains maps supporting the identification of protection and restoration actions.

2 Relationship to Other River Planning Activities

River restoration for the purpose of addressing ESA goals for threatened species also occurs within the context of other local and state planning processes that influence the future protection and restoration of the river. A cohesive river restoration strategy such as presented here can serve to inform these efforts, which locally include the Skagit River Comprehensive Flood Hazard Management Plan, the Hamilton Public Development Authority, the EPA funded Envision Skagit project (all at www.skagitcounty.net), and possible in-lieu fee mitigation programs among others. Summaries of other processes and activities that inform, intersect, or complement the strategies described in this Plan are provided below.

Puget Sound Action Agenda

In 2007, Washington Governor Christine Gregoire proposed and the Legislature created the Puget Sound Partnership to restore Puget Sound to health by 2020 http://www.psp.wa.gov/. An Action Agenda for accomplishing this work was adopted in December of 2008 and established a unified set of actions needed to protect and restore Puget Sound. This document supports two of the highest priority near-term actions identified in the Action Agenda: 1) the protection of high-value habitat and land at immediate risk of conversion as identified through existing processes such as the salmon recovery plans; and 2) prioritize and implement restoration projects identified within existing species recovery plans, flood hazard management plans, road decommissioning plans, Shoreline Master Programs, and other documented processes that have scientific review and community support.

Skagit Flood Hazard Management Planning

Efforts have been ongoing for many years to address flood hazard reduction in the Skagit valley; the latest effort starting in February of 2008 to update the Skagit River Comprehensive Flood Hazard Management Plan under a new structure of the Skagit County Flood Control Zone District (FCZD) first established in 1970. The update is being developed in coordination with a protracted Skagit River General Investigation by the U.S. Army Corps of Engineers first begun in 1993. In the process, updated mapping procedures and differences between the methodologies used to calculate flood frequency that determine flood insurance requirements have fuelled much local debate and slowed progress. The revived FCZD has an Environmental Technical Committee tasked with providing technical assistance on environmental issues related to flood hazard reduction measures as requested. Protection and restoration planning assessments such as this document can provide valuable and necessary information on these river management decisions.

NMFS Biological Opinion on FEMA's National Flood Insurance Program

In September of 2008 the National Marine Fisheries Service (NMFS) issued a Biological Opinion (BiOp) on the effects of FEMA's National Flood Insurance Program (NFIP) on listed species in Puget Sound. In the biological opinion, the NMFS concludes that the effects of certain on-going elements of the NFIP are likely to jeopardize the continued existence of Puget Sound Chinook salmon, Puget Sound steelhead, Hood Canal summer-run chum salmon, and Southern Resident killer whales, and are likely to adversely modify critical habitat for these species. In response to the NMFS's Jeopardy Opinion, FEMA has developed three options for local jurisdictions to meet the floodplain development criteria in the BiOp for the protection of existing natural floodplain functions. Communities that do not address the new FEMA requirements by the extended deadline of September 22, 2011 risk losing the certification needed to participate in the NFIP. This program is important to local communities because it provides funds to public and private entities for repair of flood damages and because flood insurance is required to buy a home in a mapped floodplain with a federally insured loan. Efforts are still in play to assist local governments in this task, and it is unclear how or if our local governments will demonstrate the adequacy of local land use codes and floodplain programs to achieve FEMA's requirements for the protection of existing floodplain functions. One of the goals of this Plan is to identify areas of functioning floodplain for the protection of ESA species identified in the BiOp. The assessment techniques and results produced by this Plan may assist Skagit County communities in responding to the BiOp.

Skagit County Shoreline Master Program Update

Skagit County will undertake a process to update the County's Shoreline Master Program (SMP). The update is scheduled to start in late 2011 and take two years to complete. State regulations require local governments to collect information on the general location of channel migration zones and floodplains (WAC 173-26-201(3) (c)) and include provisions to "limit development and shoreline modifications that would result in interference with the process of channel migration that may cause significant adverse impacts to property or public improvements and/or result in a net loss of ecological functions associated with the rivers and streams" (WAC 173-26-221(3)(b-c)). Many of the products of this Plan for habitat protection and restoration can assist the County in the SMP update.

Skagit Countywide UGA Open Space Concept Plan

The Skagit County Board of Commissioners adopted an Urban Growth Area (UGA) Open Space Concept Plan that addresses a non-compliance issue in Western Washington Growth Management Hearings Board Case No. No.00-2-0046c and subsequent settlement agreement negotiated in Case No. 02-2-0005.

The UGA plan identifies and prioritizes open space corridors and greenbelts within and between urban growth areas that include lands useful for recreation, wildlife habitat, trails, and connection of critical areas. The Skagit County UGA Open Space Plan is a voluntary open space preservation program that does not mandate identified areas be regulated or protected, create a regulatory land use designation, or allow public access by default. Many of the same areas identified as priorities for habitat protection and restoration in this Plan are also identified as open space in the County's Open Space Plan.

Skagit River Hydroelectric Project

Flows in the Skagit River are regulated by a series of dams built in the upper watershed operated by Seattle City Light. Seattle City Light (SCL) operates the Skagit Project upstream of Newhalem which consists of three dams and associated reservoirs: Gorge Dam, Diablo Dam, and Ross Dam. Seattle City Light has been managing flows for fish since 1985 under an interim flow management agreement, and since 1995 under the Skagit Hydroelectric Project Fisheries Settlement Agreement as part of the city's Federal Energy Regulatory Commission (FERC) operating license. The settlement agreement requires fish management flow measures that minimize stranding impacts to juvenile salmon and steelhead, and protect salmon and steelhead eggs and embryos from dewatering during low flow periods, and scouring during peak flow events. The implementation of these flow measures has resulted in significant increases in the abundance of chum and pink salmon spawners in the upper Skagit, and has contributing to sustaining the healthiest population of wild Chinook salmon in the Puget Sound (Connor and Pflug 2004). In addition to flow management, a non-flow habitat program was implemented by SCL under the settlement agreement to protect and restore side channels in the upper Skagit, and to fund research on the salmonid species impacted by project operations. The side channel program was developed to mitigate for losses in natural side channel develop that occur as result reduced flood flows downstream of the hydroelectric project.

Seattle City Light also manages and funds the voluntary ESA Early Action program, which was implemented by the City of Seattle in 2000 to promote the recovery of ESA-listed fish species. The ESA Early Action Program acquires properties throughout the Skagit watershed for protecting the three ESA-listed fish species: Chinook salmon, steelhead, and bull trout. The program also provides funding for habitat restoration projects on SCL conservation lands, and for conducting life history and ecological research on these species in the watershed. Funds from this program have been used to protect and restore watersheds and streams in the Skagit, and to leverage federal and state grants for protecting and restoring the habitats required by these fish. The priorities identified in this Plan will inform where funds are applied in the middle Skagit River.

Baker River Hydroelectric Project

Puget Sound Energy (PSE) operates two hydroelectric power plants on the Baker River near Concrete. The Baker River drains into the middle Skagit Reach at Concrete and is the largest tributary to the middle Skagit River, draining an area of 297 square miles. The Baker River project consists of two dams: Upper Baker Dam and Lower Baker Dam, each with its own powerhouse. Both dams were built without fish passage. PSE received a new, 50-year operating license for the Baker River Hydroelectric Project in October 2008 from the Federal Energy Regulatory Commission (FERC). Four years earlier, PSE and 23 other parties (federal, state and local government organizations, Native American tribes, environmental groups, and others) submitted a comprehensive, 162-page settlement agreement to FERC that contained the parties' recommended provisions for what later became the updated project license. This Plan for habitat protection and restoration incorporated and built on instream flow data collected from 2001 through 2006 in support of pre-license studies.

Among other fisheries and habitat provisions in the relicensing agreement, Puget Sound Energy developed and funded an Aquatic Riparian Habitat Protection, Restoration, and Enhancement Plan (Puget Sound Energy 2010). The plan establishes standards and guidelines for PSE's negotiated investment over the term in the license in protection and enhancement of low elevation bottomland ecosystems in the Skagit River basin, with a focus on aquatic and riparian habitats.

Goals for protection of aquatic habitats and ESA listed salmon species under the Baker Project License are similar to those of this Plan. Many of the projects or studies undertaken in support of the license will yield complementary data and results, and our results can help to inform where they invest in habitats within the middle Skagit.

3 Overview of the Middle Skagit Area

The Plan area includes the mainstem Skagit River and its floodplain from Sedro Woolley upstream to the confluence with the Sauk River (Figure 1). This 43-mile stretch of the river represents a major transition in the physical, biological, and human landscapes. We live, farm, and fish along this stretch of the river, and use this valley as a major transportation corridor connecting upriver communities and recreation areas to the downstream urban centers. This is also the river corridor by which all six populations of Skagit Chinook salmon connect to their spawning grounds.

Physical Landscape

The Skagit basin is the largest river in Washington draining into Puget Sound and second only to the Fraser River for rivers draining into the Salish Sea[1]. The Skagit River originates in Canada, and flows south for over 100 miles before emptying into Puget Sound. The upstream drainage area at the confluence with the Sauk River is approximately 2,330 square miles. By Sedro Woolley, tributary streams including the Baker River, Finney Creek and Day Creek have added an additional 685 square miles of drainage area.

The Skagit watershed is made up of high peaks and low valleys. The highest points in the basin are two volcanoes: Mount Baker (10,781 ft) and Glacier Peak (10,541 ft). The landforms of the Skagit basin have been sculpted by repeated glaciations and erosion by the river. Alpine glaciations produced sharp peaks and ridges in the basin headwaters,

[1] In 2009 the governments of both British Columbia and Washington officially adopted the name "Salish Sea" for their shared inland marine waters.

and cut deep valleys. Overriding continental glaciers rounded many of the ridges at lower elevations, and scoured pre-existing drainages. A large lobe of the cordilleran ice sheet pushed up the Skagit River valley. Ice and gravel moraines repeatedly blocked the Skagit, causing it to pool into lakes and forcing it to drain south into what is now the North Fork Stillaguamish River. Sea levels were also higher at the end of the last ice age, and the Skagit River Valley up to approximately the location of the present-day town of Hamilton was likely below sea levels.

After the ice retreated approximately 20,000 years ago the Skagit breached the moraine dam near Concrete, Washington and the river cut down through the glacial outwash and lacustrine sediments that had accumulated in the lakes (Tabor et al. 1999). The upper Skagit drainage above the town of Diablo formerly flowed into the Fraser River, British Columbia (Reidel 2007). The divide between the Fraser and Skagit rivers was breeched by glacial meltwater approximately 12,000 years ago, forming the Skagit River gorge above the town of Newhalem and increasing the drainage area of the Skagit by approximately 800 square miles. The Sauk and Suiattle rivers continued to drain into the North Fork Stillaguamish River until eruptions of Glacier Peak approximately 13,000 years ago deposited large amounts of sediment in an alluvial fan near present-day Darrington, Washington (Mastin and Waitt 2000). The deposited sediment forced the two rivers to the north to join the Skagit (Tabor et al. 1999).

The overall flow regime of the Skagit River is bimodal with the largest, short duration floods tending to occur during the late fall and winter (November through January) in response to rain-on-snow events. A secondary, and generally lower but more prolonged peak occurs during the late spring and early summer in response to seasonal snowmelt. There are currently 394 glaciers in the Skagit basin, and glacial meltwaters maintain relatively cold temperatures and high flows throughout the summer. However, after several decades of stability most North Cascade glaciers are in rapid retreat; from 1984 to 2006 ten glaciers lost between 20-40% of their total volume and summer streamflows correspondingly showed a 27% decline (Pelto 2008).

In the middle Skagit Reach, the river transitions from a relatively mountainous, semi-constrained river to a channel that occupies a broad floodplain. Downstream of the Sauk River to below the town of Concrete the Skagit is largely confined between high ice-age terraces 50 feet or more above the river. This portion of the Skagit valley was blocked by a large alpine glacier originating from the Baker Valley approximately 20-30 thousand years ago, creating a large lake upstream that may have persisted for as long as 4,000 years, resulting in the deposition of almost 40 meters of lake sediments in the Skagit Valley (Reidel et al. 2010).

Below Concrete the river transitions into a slightly less incised section where the river cuts through the Birdsview terrace prior to opening into the broad alluvial valley at Hamilton. It is the lower alluvial channels that have the greatest capacity to build floodplains and migrate laterally back and forth across the floodplain, leaving a mosaic of active channels, side channels, oxbow lakes and wetlands. Floodplain water bodies such as these are collectively referred to as "off-channel habitats," and provide prime rearing and feeding areas for juvenile salmonids. The channels develop this island-bar pattern because of the large sediment load carried by the river, the large-scale transport and storage of woody debris, and the effective resistance provided by dense stream-bank vegetation (Reidel 2008).

In contrast, channels constrained by steep mountain sideslopes or bedrock tend to be steeper and straighter, with limited floodplain development and relatively fewer off channel habitats. Transitional channels between the alluvial and constrained generally have coarser gravel beds, less sinuosity, and relatively little large wood accumulations. These relatively straight channels function as large wood and sediment transport zones. They tend to exhibit relatively stable floodplain features (over decades or centuries); where off channel habitats are present they often consist primarily of large side channels that transmit fast, deep flood waters when they become connected to the mainstem, and represent preferred sites for the main channel to shift to if it becomes obstructed (e.g. Reidel 2008).

4 Context for Floodplain Protection and Restoration

In this section we provide a brief summary of the important principles and technical information guiding this Plan. This work builds on previous analyses and restoration strategies developed for the Skagit River, including the Application of the Skagit Watershed Council's Strategy (report by Beamer et al. 2000) and the Skagit Chinook Recovery Plan (SRSC and WDFW 2005).

Process-based Restoration[2]

The Skagit Watershed Council's Habitat Protection and Restoration Strategy (1998) and 2010 Strategic Approach are founded upon an overarching restoration goal of encouraging the voluntary restoration and protection of natural landscape processes that formed and sustained the habitats to which salmon populations are adapted. This *process-based* approach, also referred to as ecosystem restoration, aims to re-establish natural rates and magnitudes of physical, chemical, and biological processes that create and sustain river and floodplain ecosystems, thereby supporting recovery of Chinook salmon while avoiding placing single species habitat needs over those of other aquatic species.

Important process-based restoration actions in the freshwater portion of the Skagit River include restoring river-floodplain interactions and the formation of off-channel

[2] Excerpted from the Skagit Watershed Council's Year 2010 Strategic Approach

habitats, and plant growth and successional processes in riparian areas (SRSC and WDFW 2005). Additional goals include re-establishing more natural rates of erosion and sediment transport, storage and routing of water, input of nutrients and thermal energy, and nutrient cycling in the aquatic food web. Process-based restoration focuses on correcting human disruptions to these processes, so that the river-floodplain ecosystem recovers with minimal future maintenance and has the capacity to respond to future climate change through natural physical and biological adjustments (Sear 1994, Beechie et al. 2010).

Efforts that re-establish habitat forming processes promote recovery of habitat and biological diversity, and include river dynamics as criteria for success. Because process restoration focuses on restoring critical drivers and functions, such actions will help avoid common pitfalls of engineered solutions such as creating habitats that are unsuited to the natural potential of a site or building habitats that are ultimately destroyed by untreated watershed or river processes (Beechie and Bolton 1999).

Restoration actions should (1) address the underlying cause of degradation, (2) be tailored to local physical and biological potential, and (3) match the scale of restoration with the scale of underlying problem (Beechie et al. 2010). Each reach in a river network has a relatively narrow range of channel and riparian conditions that match its physiographic and climatic setting and restoration actions should be designed to correct disruptions to driving processes and redirect channel and habitat conditions into that range. Moreover, in order for restoration actions to succeed, the scale of the action must be at a scale that matches the scale of the underlying cause of degradation. That is, reach-scale problems such as riparian degradation or channel constraint by levees can be addressed at the reach scale, whereas sediment supply or hydrology issues must be addressed at larger watershed scales.

Summary of Factors Limiting Skagit Chinook

The Skagit Chinook Recovery Plan (SRSC and WDFW 2005) identifies three major habitat types that currently limit population sizes of Chinook salmon in the Skagit River basin: (1) tidal freshwater and estuary habitats in the delta, (2) shallow nearshore habitats including pocket estuaries, and (3) freshwater rearing areas in floodplains. A fourth aspect of habitat loss is the alteration of watershed processes that control tributary habitat conditions, including changes in sediment supply, flow regime, and riparian functions. There has been a net loss of 73% of tidal delta and 98% of non-tidal delta areas, 86% of pocket estuaries, and 37% of the large river floodplain (upstream of the non-tidal delta) (SRSC and WDFW 2005). Each of these areas has the potential to provide significant rearing area for juvenile Chinook of all life history types, and all life-history types are present to colonize restored habitats. Therefore, the Chinook Recovery Plan recommends restoration and protection actions that address each of the factors that limit recovery of Skagit Chinook. The purpose of the majority of identified habitat restoration projects in the

Skagit Chinook Recovery Plan is to increase carrying capacity for juvenile Chinook to improve growth and therefore ocean survival rates.

The middle Skagit River is used by all five species of Pacific salmon (Chinook, pink, coho sockeye, and chum), including outmigrating juveniles from the six independent populations of Chinook (including spring, summer, and fall runs), summer and winter run steelhead, sea run cutthroat trout, and bull trout (SRSC and WDFW 2005). The mainstem and side channels support all life history stages for many of these populations.

The middle Skagit is an important spawning area for Chinook salmon, and supports the majority of fall-run Chinook spawners in the watershed (SRSC and WDFW 2005). The middle Skagit provides natal rearing habitat for the majority of these fall-run fish. It also provides non-natal rearing habitat for juveniles originating from upper areas of the watershed, including the upper Skagit, Cascade, Suiattle, and Sauk rivers. However, the middle Skagit can no longer support the number of juvenile Chinook that migrate through this section of the river. The maximum production of the riverine rearing juvenile Chinook is presently about two million fish (Zimmerman et al. in prep), with the number of smolts produced from riverine habitats declining when spawner abundance exceeds approximately 10,000 adults. While the middle Skagit may provide abundant habitat for adult spawners, it lacks the amount of habitat required for the juveniles produced by these spawners. This results in a "juvenile bottleneck" to population productivity, which is common in freshwater fish (Werner 1986). This bottleneck is evident in the middle Skagit from juvenile Chinook outmigration data that has been collected at the WDFW smolt trap for almost two decades (SRSC and WDFW 2005; Kinsel et al. 2008; Zimmerman In Prep). The decline in smolts that originate from river rearing juveniles indicates that the habitat capacity of the mainstem river is being exceeded, and that the survival rate of juvenile Chinook that rear in these areas is declining (Zimmerman et al. in prep). Reduced survival rates of juvenile Chinook rearing in the middle Skagit would likely result from competition due to the lack of suitable rearing habitat, and reduced growth rates in these areas due to limited food resources.

Levees and bank armoring have resulted in the channelization of several areas in the middle Skagit, resulting in a confined mainstem channel that lacks natural edge and bank morphology and vegetation. These hydromodifications have reduced the availability of the low-velocity habitats required by juvenile Chinook salmon and steelhead that rear along the mainstem Skagit. Changes in hydrology by dams and land-use practices also inhibit or affect the processes which form and maintain these low-velocity habitats. Habitat has been further degraded by land development throughout floodplain of the middle Skagit, resulting in the loss of riparian habitats and wetlands. These areas greatly improve invertebrate production in floodplain channels and along the margins of the mainstem river, thus improving the growth and survival of juvenile Chinook.

Impacts of Hydropower

Skagit River flows are controlled altered by two sets of the two hydropower projects described in Section 4 above. Both the Skagit and Baker projects are operated primarily for hydropower production and short-term flood control, and thus do not represent a consumptive use of water. However, project operations have affected Skagit River flows. Both projects are operated for flood control following requirements and procedures set by the U.S Army Corps of Engineers (Corps). Flood frequency analyses conducted by the Corps suggest that the current estimated 100-year flow is approximately 24% less that it would be under unregulated conditions (USACE 2003). The largest amount of flood control is provided by SCL's Ross Reservoir, with over one million acre-ft of usable storage. In addition, an analysis conducted in support of the Baker Project relicensing indicated that mean monthly flows are higher in the fall and winter and lower in the late spring and early summer. The frequency of late winter/early spring freshets, which provide cues for the downstream migration of juvenile salmonids, has also been reduced (R2 2004).

The Skagit and Baker hydroelectric projects primarily affect flows in the middle Skagit by capturing water in the reservoirs during the spring snowmelt period, and then releasing this stored water when natural inflows are low during the later summer, fall, and mid-winter. Consequently, flows during the spring snowmelt period are lower than natural, and flows during the late summer, fall, and mid-winter are higher then normal. The projects also reduce the magnitude and duration of natural peak flow events in the middle Skagit. Flow variability in the middle Skagit results from natural flows from major tributaries to the upper Skagit downstream of Skagit Hydroelectric Project (including the Cascade River), and from the Sauk and Suiattle river basins.

The Skagit and Baker project reservoirs also trap all bedload from upstream reaches as well as a significant proportion of the suspended load (R2 2004) that would naturally be transported into the middle Skagit. Currently, the Sauk River is the largest source of sediment to the Skagit River system. Interruption of sediment loads has the potential to initiate bed armouring and reduce spawning gravel. However, the interaction between reduced sediment inputs and reduced sediment transport capacity (due to smaller and less frequent floods) is poorly understood in the Skagit River. As a result of altered hydrology and bedload transport, channel migration and side-channel formation rates are reduced compared to natural conditions. The need to protect and restore flood-plain channels in the middle Skagit is increased as a consequence of these alterations.

Climate Change

We most often look to the change in rivers from historic conditions to inform our restoration efforts. However, the trend of future changes in climate could fundamentally alter basic assumptions we use in planning, prioritizing, and designing for river restoration.

Mantua et al. (2010) evaluated the sensitivity of freshwater habitat of salmon in Washington State to climate change by looking at warm season stream temperature and the volume and time distribution of streamflow under two scenarios for future greenhouse gas emissions. Temperature modeling under both climate scenarios predicts significant increases in water temperatures and thermal stress for salmon statewide, particularly in the interior Columbia Basin. Glacial fed rivers like the Skagit show some of the lowest increases in stream temperatures and warm season temperatures remaining less than 21°C.

The impacts of climate change on streamflow depend upon hydrologic characteristics of the watershed. By the 2080s, the hydrologic simulations predict a complete loss of snowmelt dominant basins in Washington. The snowmelt dominant watersheds of the upper Skagit, Sauk, and Suiattle Rivers are expected to become among the 10 remaining transient snow (mixed rain and snow) basins in the state. Rain-dominant watersheds, like the lower Skagit River, are predicted to experience small changes in flood frequency, while flood magnitudes and frequencies are predicted to increase most dramatically in winter months for those watersheds outside the Skagit that have historically been transient runoff. Increased flows peak flows will reduce the survival rates of eggs and embryos in redds and juveniles rearing in stream and river habitats. Hydrological models indicate that warming trends will reduce snowpacks decreasing the risk of springtime snowmelt-driven floods in the coldest snowmelt-dominated basins, including the upper Skagit, Sauk, and Suiattle rivers. Reduced flows during the spring snowmelt period may negatively impact adult and smolt migrations matched to peak snowmelt flows. The duration of the summer low flow period is projected to increase substantially for both transient and snowmelt dominant basins, including the Skagit, which will increase temperatures and reduce habitat availability for stream type salmon. Should the frequency or magnitude of winter peak flows increase, redd scour could reduce egg incubation, reduce the availability of slow-water habitats and cause displacement of rearing juveniles downstream of preferred habitats. The combination of increased air temperatures and reduced flows during the summer and fall will result in warmer water temperatures during these periods. Warmer water temperatures in turn will result in a reduction of the habitat capacity and survival rates for bull trout, juvenile steelhead, and yearling Chinook salmon.

Researchers in the Skagit are currently working to integrate various models and data sets to better understand and quantify the diverse impacts of climate change in the Skagit including changes in hydrology, sedimentation, and water and air temperatures; species (birds, fish and plants) and ecosystem responses; and sea level rise.

5 Middle Skagit Assessment

The assessment phase of the project was designed to collect and summarize relevant physical and habitat data available for the study area as the basis for identifying protection and restoration opportunities in the middle Skagit River. The Criteria Work Group supported an approach to evaluating reaches that was based on the strategies for freshwater rearing habitats identified in the Chinook Plan:

- Acquire floodplain parcels for conservation and/or restoration in priority areas.
- Reconnect historic floodplain channels
- Remove or relocate floodplain modifications to restore natural floodplain processes that form backwaters and floodplain habitat
- Remove or remediate hydromodifications (rip-rap) on the main channel to restore degraded edge habitat complexity.

A number of data sets were compiled and analyzed for this purpose. These are briefly summarized below with more detailed information included as appendices or as companion documents to this Plan. Much of the assessment data was incorporated into a reach-level assessment where the range of conditions present within the study area are summarized and contrasted to identify priority reaches to target for habitat protection and restoration. The spatial data developed in the reach assessment was next used to develop reach-level strategies and finally to identify priority protection and restoration locations within the reaches consistent with the reach strategies and the adopted prioritization scheme (Section 7). Many of the data sets and analyses will also be used to further develop the project concepts.

Assumptions

The restoration literature is clear that for stream restoration to be successful we need to understand and address the landscape processes that form and sustain habitats (Roni et al. 2002); or to treat the problem at the source rather than the symptom. In the middle Skagit River major channel and floodplain adjustments have occurred as a result of flow regulation and sediment storage behind the dams. Both the Baker River and Upper Skagit hydroelectric projects are operating under long-term licensing agreements that, while they do not restore pre-dam flows and sediment, provide flows necessary at critical times for fish. Because these disruptions to landscape processes have been negotiated through regulatory means, for the purpose of this assessment we assumed the current flow and sediment regimes as the processes operating and functioning within the reach at least for the foreseeable future. Other assumptions made for this analysis are described in the applicable sections below.

Reaches of the Middle Skagit River

The Plan study area was divided into nine reaches (Figure 2) based on floodplain reaches originally developed by Hayman et al. (1996) that were also used in the Application of the Skagit Watershed Council's Strategy (Beamer et al. 2000) and the Skagit Chinook Recovery Plan (SRSC and WDFW 2005). This floodplain area was selected for use not because it is considered more accurate than other or more recent floodplain delineations, but to ensure comparability between this Plan and the 2005 Recovery Plan.

The outer boundaries of the original floodplain reaches were based on the regulatory 100-year floodplain (FEMA 1989) as a starting point. In some areas the floodplain boundary was extended outward to terrace breaks for our analysis to account for potential future channel migration and to include recently eroded areas. The original breaks between the reaches were also modified for this analysis to better distinguish differences in channel pattern and degree of stream bank modification and to facilitate some analyses, such as the habitat modeling described below. A more detailed description and a map showing changes to the original 1996 floodplain reaches are found in the reach assessment report (SRSC 2011).

This floodplain delineation was intended for use in restoration planning and generally represents the area where channel migration and habitat formation might be expected to occur over the next few decades in the absence of roads, development, and erosion protection structures. It does not represent the area likely to be flooded at a specific flow and does not define the floodplain or channel migration zone for any regulatory purpose.

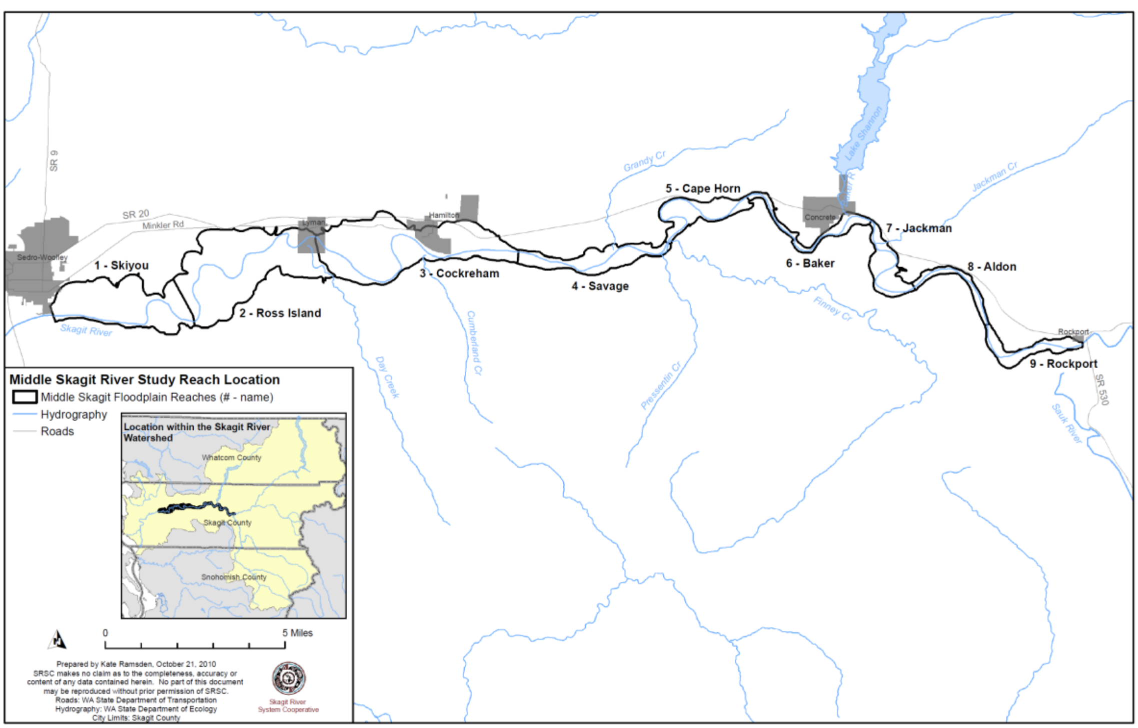

Figure 2. Floodplain reaches defined for the middle Skagit River assessment (SRSC 2011).

Streambank Modification Inventory

One of the first data sets to be contracted was an inventory of streambank structures, or hydromodifications, along the mainstem Skagit River in the project area (Upper Skagit Indian Tribe 2010). Bank structures such as riprap and levees degrade the low velocity edge habitat suitable for juvenile salmon, constrain the river, and impede the natural floodplain erosion and sediment deposition processes that create and maintain habitat for fish. Because of changes in the river and more precise field mapping techniques, this survey using similar methods provided a much needed update on these structures to data collected in 1994-95 (Beamer and Henderson 1996). For the inventory geographically registered data gathered by boat and wading were imported into GIS format and linked to field photographs providing a data set useable for a variety of analyses. Detail on the data collected and methods are in the report (Upper Skagit Indian Tribe 2010).

Data were collected based on the original floodplain reaches (Hayman et al. 1996) and summarized by the revised reaches in the reach assessment (Table 2; SRSC 2011). Data were used in the reach assessment to identify the potential impacts to floodplain processes from hydromodifications and for estimating the current habitat capacity for juvenile Chinook. The extent of modified banks also informed the reach strategies in Section 7, and was used to identify restoration opportunities. The data set will also be useful for prioritizing bank restoration or remediation sites in addition to those identified in this document, as recommended by the authors.

Table 2. Length of bank modifications by reach.

Reach	Mainstem Length (ft)	Hydromod Length (ft)	% Modified Banks
1 - Skiyou	24,994	20,438	41
2 - Ross Island	32,539	13,805	21
3 - Cockreham	40,481	18,231	23
4 - Savage	24,633	3,474	7
5 - Cape Horn	25,410	1,479	3
6 - Baker	25,577	4,151	8
7 - Jackman	19,351	6,357	16
8 - Aldon	16,713	1,947	6
9 - Rockport	18,166	1,952	5
Total	**227,864**	**71,834**	16

Hydrodynamic Modeling

The Skagit Watershed Council contracted with Pacific Northwest National Laboratory (PNNL) to extend a three-dimensional hydrodynamic model to cover all but the Rockport reach of the middle Skagit study area. The model grid was developed previously for a floodplain restoration analysis near Gilligan Creek (Anchor QEA 2009) and extended from Mount Vernon to the USGS stream gauge at Concrete. PNNL used the Finite Volume-Coastal Ocean Model (FV-COM) software which can be used to estimate water depth, velocity, and shear stress across the channel and floodplain for a range of flow conditions.

Hydraulic modeling is a useful tool for examining a number of conditions or alternatives, as individual model runs are relatively inexpensive once the model is developed. In general, the best use of model results is often in the comparison of alternative conditions or projects, where the differences between model runs is given more credibility than the actual values of the numerical output itself (Skidmore et al. 2009). For this project we used the model for the purpose of identifying areas inundated at different flows and affected by major floodplain modifications.

Three flood hydrographs were simulated to evaluate the extent of floodplain inundation and depth/velocity of water over the floodplain at each flow level. Flow levels were selected to represent a range of relatively frequent flood events (i.e. approximately 2-yr, 5-yr, and 25-yr return interval events). Peak flow conditions were selected so results from the model could be used to evaluate geomorphic potential for floodplain reaches, with the assumption that floodplain reaches with larger inundation areas during peak flows would have the greatest potential for channel movement and habitat formation. Specific flows were selected based on an initial model simulation completed by PNNL for the Data Work Group to evaluate which flows would show the greatest differences in area of inundation between model runs. Key model assumptions include:

- Constant inflow of 85 cfs from Baker River;
- No inflow from any other tributaries (or from groundwater contributions throughout the project reach);
- 10 hour duration of peak to ensure that discharge was consistent throughout the project reach; and
- 2 days of low flow between each simulated flood event in order to allow the area to completely "drain" before the next simulated flood.

Details on the model set up and validation are in Appendix A. More detailed information about how the model outputs were used for this analysis is provided in Reach Assessment (SRSC 2011).

The areas inundated by each of the three modeled flows under the existing condition are shown in Appendix A, Map 4 in SRSC (2011) and are summarized in Table 3 below. The reaches with larger and lower-lying floodplain areas stand out and suggest that large portions of these floodplains interact with the river relatively frequently and may have a higher likelihood of habitat formation.

Table 3. Inundation areas from hydrodynamic model for existing condition (SRSC 2011).

Reach	Mainstem Length (mi)	Floodplain Area (ac)	2-Yr Flow (ac)	5-Yr Flow (ac)	25-Yr Flow (ac)
1 - Skiyou	4.7	2,733	2,093	2,541	2,684
2 - Ross Island	6.2	4,388	2,692	3,922	4,322
3 - Cockreham	7.7	4,220	2,176	3,891	4,198
4 - Savage	4.7	1,183	584	802	1,228
5 - Cape Horn	4.8	989	790	963	1,083
6 - Baker	4.8	557	478	568	737
7 - Jackman	3.7	825	502	666	770
8 - Aldon	3.2	374	313	340	393
9 - Rockport	--	--	--	--	--
Total	**39.7**	**15,269**	**9,628**	**13,692**	**15,415**

PNNL also provided model outputs for the same three flow scenarios under an alternative condition with a number of hydromodifications removed from the model grid by setting the elevations of the levee structures to match the surrounding floodplain elevation. The hydromodifications removed were selected from the recent field inventory (USIT 2010) because they had elevations higher than the floodplain, were potentially isolating floodplain channel habitat, or were likely to result in significant changes to the model results if removed. No hydromodifications were removed from the Cape Horn reach or above. The areas inundated by each of the three modeled flows under the alternative condition are shown in Appendix A, Map 7 in Reach Assessment, and the change in area between the two conditions for the 5-year flow is shown in Figure 3 below.

While the area of inundation did not change significantly between the two conditions (-71, -314, and -10 acres respectively for the 2, 5, and 25-year flows), there is a larger net reduction in area inundated at the 5-yr flow, and velocity conditions in some areas of the floodplain changed substantially as shown in Figure 4. Removing the floodplain structures has the effect of reducing velocities on the margin of the floodplain and concentrating velocities toward the center. The areas of higher velocity change in Figure 4 also illustrates where channel erosion and avulsion are likely should those floodplain structures be removed.

The most significant change in area between the current and alternative conditions occurs in association with the removal of the large river training levee at the upstream end of Cockreham Island. In the alternative modeling condition for the 2-year flow without the levee more area of the island is flooded and the area inundated in the town of Hamilton is significantly reduced (Figure 5). In the current condition, while the levee prevents overtopping onto the floodplain at Cockreham Island it backs water upstream into Hamilton. The levee doesn't protect the island from flooding as water floods the area from downstream, but it does protect it from erosion.

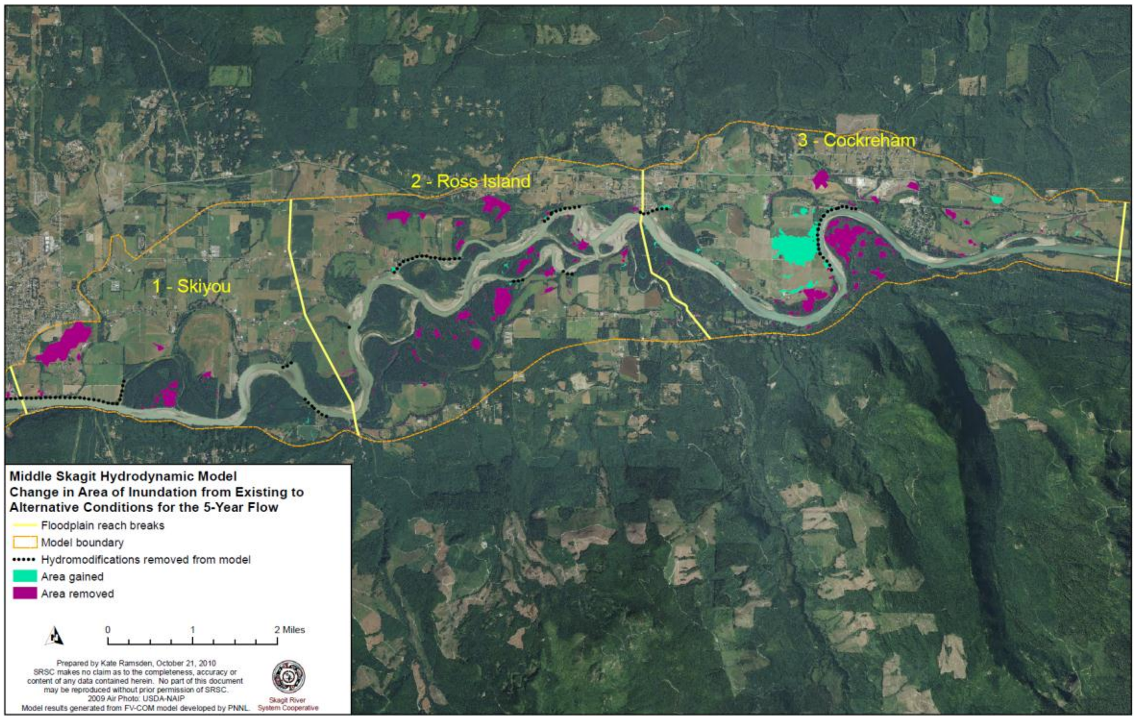

Figure 3. Change in floodplain area inundated from existing to alternative conditions for the 5-year flow (Map 8, SRSC (2011).

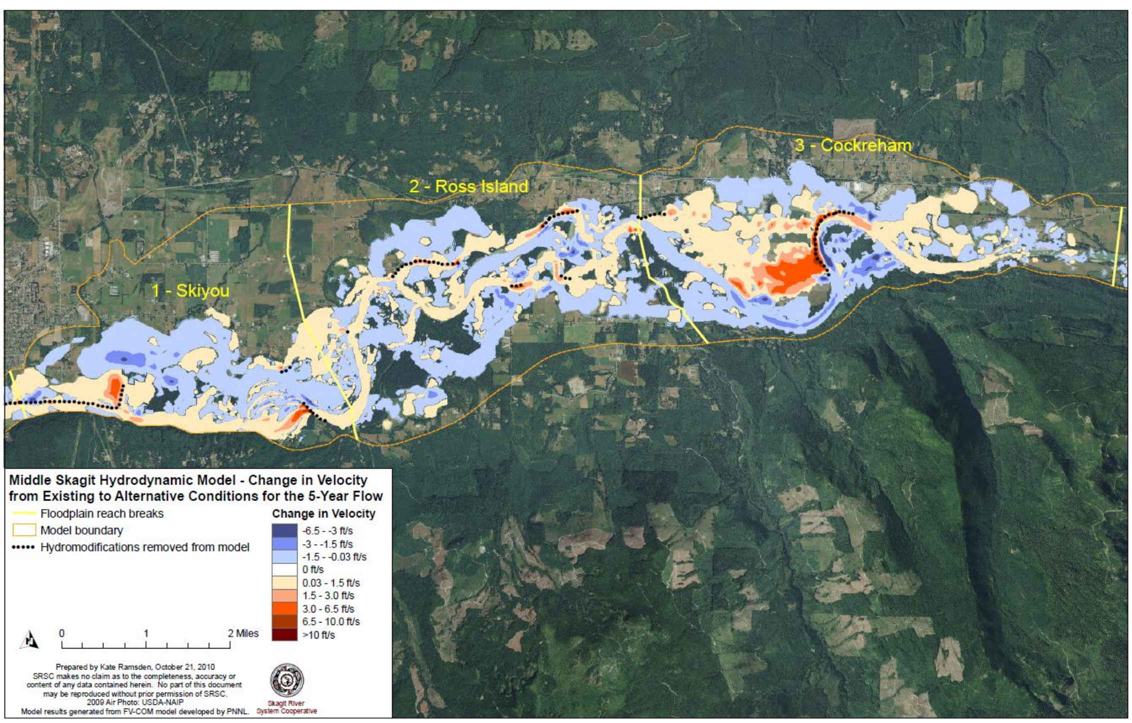

Figure 4. Change in velocity from existing to alternative conditions for the 5-year flow (Map 9, SRSC 2011).

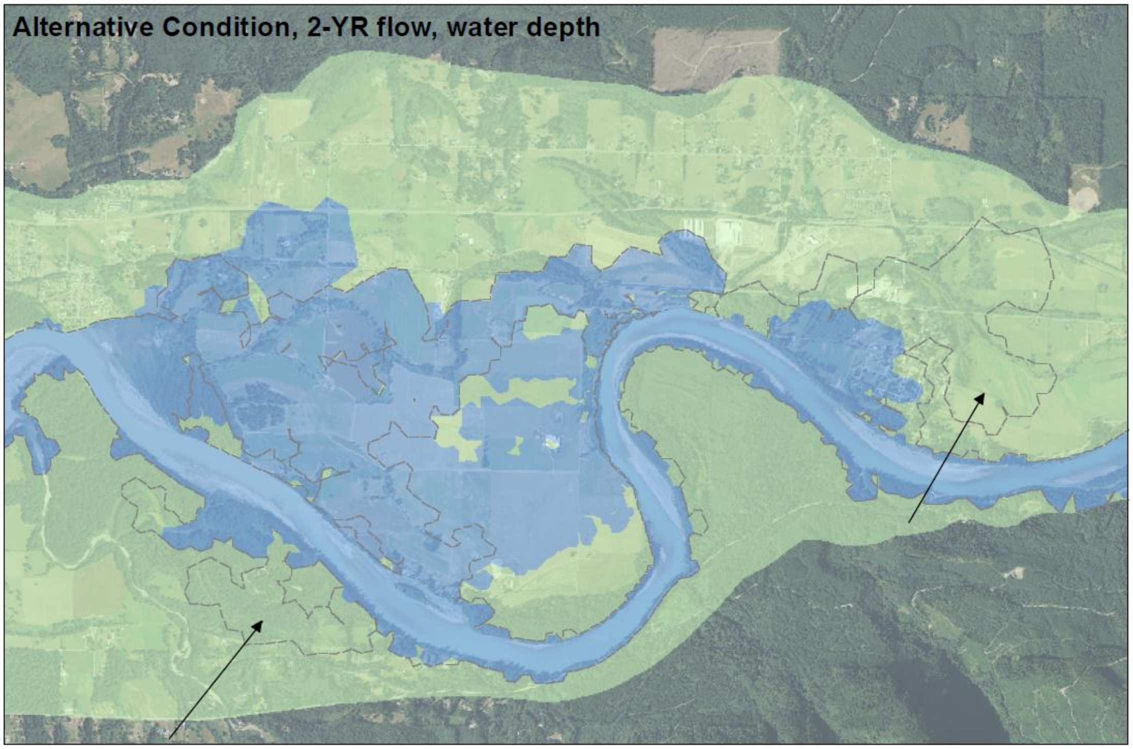

Figure 5. Change in area inundated between the existing (blue) and alternative conditions (outlined areas indicated by arrows) for the 2-year flow in the Hamilton area (SRSC map).

Velocity conditions predicted for each flow were provided but not used explicitly in the reach comparison. As with other data sets, the modeling data could be useful for future site level planning to characterize habitat distribution under different flow conditions or, if combined with information about floodplain substrate size, to identify areas that may be prone to erosion and channel formation.

Conservation Lands

To identify the best locations to protect river habitat we first identified those properties already owned or managed for conservation purposes. These were defined as properties that were acquired for conservation purposes or that have permanent easements specifically to protect habitat and most publicly owned lands. Several data sources were used that included a database of conservation properties (Skagit Conservation Database Consortium or SCDC – hyperlink below) periodically maintained and updated for this assessment by Skagit County GIS, public and protected lands data compiled previously by SRSC, and 2010 parcel data from Skagit County GIS/Mapping Services and the Assessor's Office. The following criteria were applied to construct the protected lands data set:

1. All properties in the SCDC database, except for agricultural easements and limited term legal easements of any kind

2. All exempt publicly owned properties, except for:
   - PSE modified properties at mouth of Baker River
   - Portions of Cascade Trail public lands that are above grade in the floodplain
   - Parcels owned by the town of Hamilton within the city boundaries.
   - Tribal owned parcel(s).

Ownership is uncertain in areas where the river historically migrates as parcel boundaries are often defined by the location of the river. Resolving ownership of previously platted river channel now part of the floodplain was outside the scope of this project, and those areas were labelled as "unknown" in the summary table below (Table 4). The area in "water" in the County parcel data was subtracted from the total floodplain area to get the percent of area protected. More detail on the creation of the protected lands data set is in the assessment report and appendix (SRSC 2011).

Table 4. Summary of protected land within the middle Skagit floodplain.

Reach	Total Floodplain Area (ac)	"Water" Parcels (ac)	Protected Parcels (ac)	% Protected	% Unprotected/ Unknown
1 - Skiyou	2,733.4	452.4	758.1	33.2%	66.8%
2 - Ross Island	4,388.1	573.1	1,651.4	43.3%	56.7%
3 - Cockreham	4,219.8	555.0	613.9	16.8%	83.2%
4 - Savage	1,182.5	316.5	469.7	54.2%	45.8%
5 - Cape Horn	988.5	235.7	300.1	39.9%	60.1%
6 - Baker	557.1	262.9	6.8	2.3%	97.7%
7 - Jackman	825.1	297.2	283.7	53.7%	46.3%
8 - Aldon	374.1	183.1	39.3	20.6%	79.4%
9 - Rockport	662.1	239.0	320.6	75.8%	24.2%
Total	**15,931**	**3,115**	**4,443**	**34.7%**	**65.3%**

The protected lands data were used to define those areas not protected for habitat and were used in combination with the habitat mapping to identify biologically significant areas for protection (Section 7). Information on the Skagit County Database Consortium can be found at:
http://www.skagitcounty.net/Common/Asp/Default.asp?d=SCDC&c=General&p=main.htm

Current Habitat Conditions

Current habitats types were delineated from 2009 aerial photographs and used with sampled fish densities to estimate the current capacity of juvenile Chinook habitat for each reach in the middle Skagit River (Table 5). Habitat types and estimates of fish density were based on methods used in the Skagit Chinook Recovery Plan (Hayman et al. 1996;

SRSC and WDFW 2005) explained in more detail in the Reach Assessment (SRSC 2011). An analysis of the total amount of habitat produced over the spring rearing period of juvenile Chinook salmon using hydraulic and habitat simulation models is described in the next section.

Table 5. Estimates of juvenile Chinook capacity under current conditions by habitat type for middle Skagit River reaches (SRSC 2011).

Reach	Natural Backwater	Hydro-modified Backwater	Natural Bar	Hydro-modified Bar	Natural Bank	Hydro-modified Bank	Mid-Channel Areas	Off-Channel Habitat	Total Fish
1 - Skiyou	52,644	3,525	37,002	167	15,140	5,015	1,086	8,749	123,328
2 - Ross Island	170,969	2,947	190,159	418	43,278	2,665	1,393	28,431	440,259
3 - Cockreham	63,478	4,555	96,197	321	28,248	4,308	1,653	19,739	218,498
4 - Savage	58,726	0	71,166	0	19,912	935	868	5,741	157,347
5 - Cape Horn	11,895	0	69,022	263	16,053	304	777	1,033	99,347
6 - Baker	0	0	37,318	0	27,648	1,136	908	139	67,149
7 - Jackman	1,668	0	66,563	468	20,374	1,535	755	794	92,158
8 - Aldon	23,185	0	28,408	0	19,679	423	607	297	72,599
9 - Rockport	7,538	0	60,188	101	18,426	485	629	3,287	90,653
Total	**390,102**	**11,026**	**656,022**	**1,737**	**208,758**	**16,806**	**8,676**	**68,211**	**1,361,340**

To estimate the collective impact to edge habitat from bank modification, the fish density estimates were recalculated assuming all banks were unmodified. The difference in habitat capacity for juvenile Chinook was 4%, or 53,282 more fish than the total currently produced. This relatively small number suggests that the larger impact to habitat from structures on or in the river comes from isolating off-channel habitats and modifying or eliminating more productive habitats. Interpretation of the available habitat is explored in more detail in the reach strategies (Section 7). These methods could also be used to quantify and compare the habitat benefits from different restoration projects provided detailed information was developed on habitat changes that would result from specific restoration projects.

Habitat Simulation Modeling

We employed a set of hydraulic and habitat simulation models to determine the availability of juvenile Chinook rearing habitat in the mainstem among six of the nine reaches of the middle Skagit River. This modeling approach was used to identify those mainstem reaches and major habitat types, which currently provide the most suitable rearing conditions for juvenile Chinook over the range of flows common during juvenile freshwater rearing. This work complements the habitat mapping described above and was used following the Reach Assessment to inform the reach strategies and prioritization criteria. The work is described in detail in Appendix B and summarized here.

The hydraulic and habitat simulation modeling was based upon transect data collected in the middle Skagit by Puget Sound Energy (PSE) as part of an instream flow study of the middle Skagit completed for the Baker Hydroelectric Project relicensing (R2 Resource Consultants 2008). PSE provided the transect data to the Skagit Watershed Council for the purpose of identifying conservation land acquisition and restoration projects for salmon in the middle Skagit. Recent transect data was not available for the three reaches of the middle Skagit upstream of the Baker River, so these reaches were not included in this hydraulic and habitat simulation modeling.

For this study, daily habitat values were calculated for the rearing period of juvenile Chinook salmon in the middle Skagit River, which was established to be March 1 through June 30 based upon smolt outmigration numbers and growth rates observed at the WDFW smolt trap in the lower Skagit River (Kinsel et. al 2008). Daily flow data from 2007, 2008, and 2009 was used to produce a time-series record of daily habitat conditions occurring within each reach of the middle Skagit. The resulting plots were used to estimate the total amount of habitat produced over the spring rearing period of juvenile Chinook salmon. These plots allowed identification of those reaches producing the greatest and least amount of juvenile Chinook rearing habitat over time.

The results of this study indicate that low-velocity habitats are more abundant where there is greater channel complexity and unaltered floodplains. Ross Island, an island braided reach, was found to be the most important reach for juvenile Chinook rearing habitat in the middle Skagit, and was the only reach to provide increasing habitat area when flows increased above 15,000 cfs (Appendix B, Figures 9-11). The habitat area available for rearing Chinook salmon increased in the Ross Island reach with increasing flow up to 35,000 cfs, and sustained high habitat area values as flow increased to 50,000 cfs (Appendix B, Figure 7). Cockreham was found to be the second most important reach for juvenile Chinook, as the reach provided fairly high and relatively consistent habitat area values throughout the spring rearing period. In contrast to the Ross Island and Cochreham reaches, rearing habitat area value in the Skiyou, Savage, and Baker reaches substantially declined as flows increased above 15,000 cfs during spring runoff period when Chinook salmon rear in the middle Skagit. The Cape Horn reach provided the lowest habitat benefits to rearing juveniles, maintaining consistently low habitat area values throughout the spring rearing period.

The Ross Island reach provides an additional benefit that is not provided by the other reaches that makes it the “keystone” reach of the middle Skagit in terms of Chinook rearing habitat. In addition to possessing the most extensive habitat area for rearing Chinook, the Ross Island reach has the unique characteristic of providing more habitat area with increasing flow (Appendix B, Figure 7). This may be of great importance to juvenile Chinook in the middle Skagit. Flows typically become higher in the middle Skagit during the latter part of the rearing period as a result of snowmelt runoff (Appendix B, Figure 8). Habitat area subsequently declines in the reaches above Ross

Island during May and June (Appendix B, Figures 9-11). As a result of the declines in habitat area, juvenile Chinook in the upper reaches are likely displaced by competitive pressures, and would then be expected to move downstream in search of suitable habitat areas for rearing. The Ross Island reach, by providing more habitat as flows become progressively higher, may provide the habitat area that is required by fish that are displaced from shrinking habitats in the upper reaches. The Ross Island reach therefore compensates for habitat loss in the upper reaches, and may be important for sustaining juvenile Chinook production in the middle Skagit.

This analysis suggests that protecting the best existing habitat areas for juvenile Chinook, especially the Ross Island reach, and restoring reaches that formerly provided low velocity rearing habitat, including the Cochreham and Skiyou, would provide the greatest benefit for sustaining and improving the productivity of Chinook in the middle Skagit River.

Floodplain Vegetation

The age and structure of vegetation on floodplain surfaces for each reach was estimated from 2009 aerial photographs and related to channel pattern using similar methods as described in Beechie et al. (2006). The aerial photography was used to classify the channel pattern for each reach and to delineate the floodplain into channels and four size classes of forest stands used in Beechie et al. (2006). Additional vegetation categories were added to characterize those floodplain areas modified by human activities (SRSC 2011). The more complete floodplain vegetation mapping was useful for determining how much floodplain disturbance from human activities is present in each reach (Table 6) and for identifying priority areas for riparian restoration.

In the 2006 study (Beechie et al. 2006), the authors use vegetation to quantify an average age and diversity of floodplain surfaces as a measure of disturbance from lateral movement of the channel across the floodplain. Generally, older floodplain surfaces associated with a straight channel pattern are least dynamic with relatively slow rates of floodplain erosion, and younger surfaces typical of braided channels more dynamic. Ecological theory suggests that habitat diversity is highest in intermediate disturbance regimes associated with meandering and island-braided channel patterns where channel movements create a shifting mosaic of habitat of different ages.

Comparing our results summarized in Table 7 below from the Reach Assessment with those reported by Beechie et al. (2006) for river systems in western Washington suggests the amount of modified floodplain vegetation and channel modification in our study area has an effect on both the area available for channel migration and the rate of disturbance reflected in the age of floodplain surfaces. Of interest is that the current channel pattern, either natural or forced, is a predictor of floodplain age and therefore dynamics regardless of channel confinement. There is no difference in floodplain age between meandering and island-braided types. The Skiyou Reach in particular stands out as the floodplain is functioning in response to the straight channel pattern imposed by the artificial confinement of the river. For this reason floodplain age was not used as an indicator for geomorphic potential in the Reach Assessment.

Table 6. Summary of channel patterns, reach totals for unmodified vegetation, and reach totals for human modified cover classes (SRSC 2011).

Reach	Observed Channel Pattern	Floodplain Area (ac)	Channel Area (ac)	Total Unmodified Veg (ac)	Total Unmodified Veg (%)	Total Human Modified Cover (ac)	Total Human Modified Cover (%)
1 - Skiyou	Straight	2,733	402	855	37%	1,476	63%
2 - Ross Island	Island-Braided	4,388	941	2,228	65%	1,218	35%
3 - Cockreham	Meandering	4,220	742	1,077	31%	2,401	69%
4 - Savage	Straight	1,183	411	408	53%	363	47%
5 - Cape Horn	Meandering	989	313	434	64%	242	36%
6 - Baker	Straight	557	283	164	60%	110	40%
7 - Jackman	Island-Braided	825	331	325	66%	169	34%
8 - Aldon	Straight	374	213	123	76%	38	24%
9 - Rockport	Straight	662	293	307	83%	62	17%

Table 7. Measures of floodplain vegetation age calculated for middle Skagit reaches.

Reach	Observed Channel Patern	Topographic Confinement Ratio	% Channel	% of Floodplain < 5 yrs old	% of Floodplain > 75 yrs old	Area weighted age of unmodified Floodplain (yrs)
1 - Skiyou*	Straight	9.9	14.7%	4.0%	23.0%	64.9
4 - Savage	Straight	3.4	34.8%	2.2%	27.3%	71.8
6 - Baker	Straight	2.1	50.7%	7.1%	22.7%	62.1
8 - Aldon	Straight	1.8	57.0%	7.1%	42.4%	89.1
Average			39.3%	5.1%	28.9%	71.9
3 - Cockreham*	Meandering	8.6	17.6%	5.2%	9.2%	52.0
5 - Cape Horn	Meandering	3.7	31.6%	2.8%	10.3%	49.4
Average			24.6%	4.0%	9.7%	50.7
2 - Ross Island*	Island-Braided	9.2	21.5%	6.7%	11.2%	46.8
7 - Jackman	Island-Braided	5.6	40.1%	11.0%	13.8%	52.3
Average			30.8%	8.8%	12.5%	49.6
9 - Rockport**	Straight	2.5	44.3%	5.7%	7.7%	45.6

* Unconfined channels; ** Anomalous reach at confluence with Sauk R.

Reach Assessment

SRSC (2011) used the data sets described in the previous sections to rate floodplain reaches based on the conceptual model described in Figure 6. The conceptual model includes geomorphic potential, existing habitat function, and floodplain impairment as the primary factors. Geomorphic potential was considered the most important factor for identifying high priority reaches because dynamic channels and large floodplain areas are essential for creating and maintaining the floodplain and mainstem rearing habitats that are the focus of this work. Existing habitat function and level of floodplain impairment were primarily used to distinguish between protection and restoration actions.

In order to rate reaches based on the conceptual model, one or more metrics were used for each factor and reaches were ranked in order based on the results. Reaches were compared on a relative scale, with the top reaches rated as "High" for each factor and the bottom reaches rated as "Low." Each factor in the model is described below followed by a table with all metrics used to rate the reaches (Table 8) and the summary reach evaluation matrix (Table 9) that compiles the rankings for each factor to make a recommendation for restoration and protection priorities.

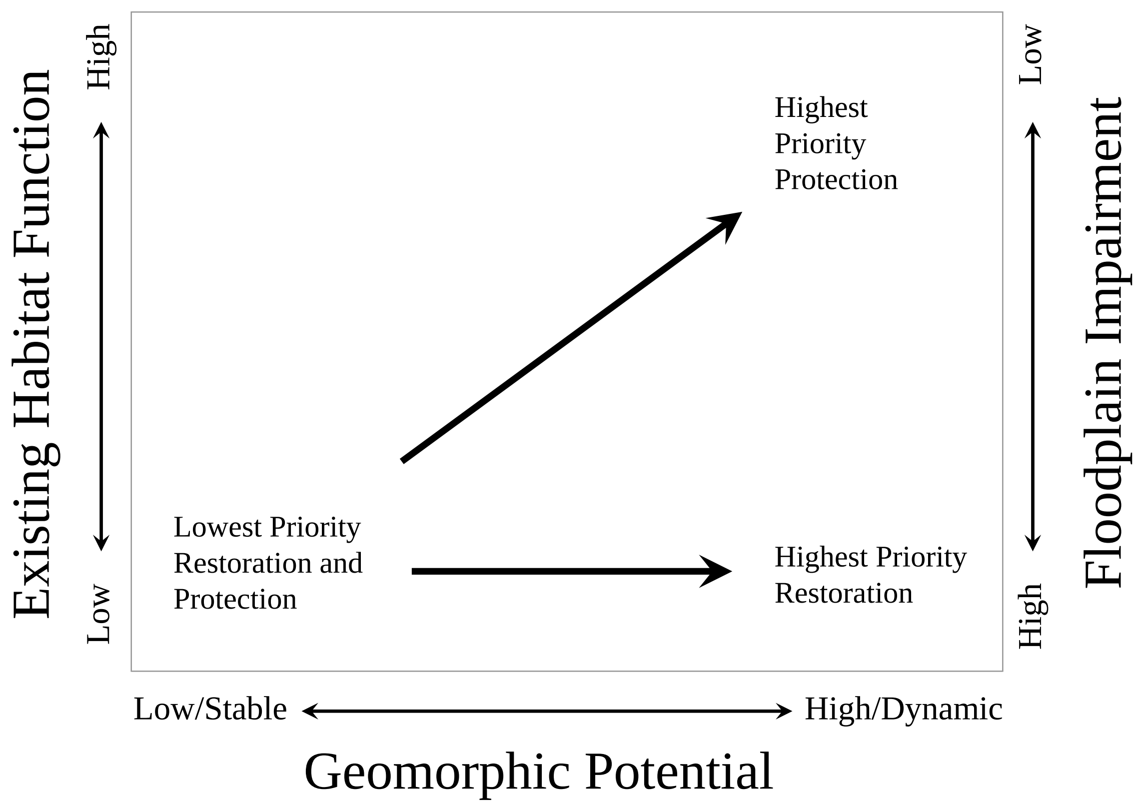

Figure 6. Conceptual model for rating reaches (SRSC 2011).

Geomorphic Potential Indicators

A number of channel and floodplain metrics were generated from the spatial data. While not used to rate the reaches, Table 8 provides a summary of some important geomorphic characteristics of the reaches reported in the Reach Assessment.

Table 8. Summary of geomorphic characteristics of the floodplain reaches.

Reach Number	Reach Name	Channel Plan Form	Sinuosity	Avg. Floodplain Width (ft)	Topographic Confinement Ratio	Valley Confinement
1	Skiyou	Straightened	1.3	5,975	9.9	Unconfined
2	Ross Island	Island braided	1.5	8,840	8.6	Unconfined
3	Cockreham	Meandering	1.4	6,179	9.2	Unconfined
4	Savage	Straight	1.1	2,247	3.4	Moderately confined
5	Cape Horn	Meandering	1.7	2,939	5.6	Entrenched
6	Baker	Straight	1.0	992	2.1	Confined
7	Jackman	Meandering	1.5	2,724	3.7	Moderately confined
8	Alden	Straight	1.0	988	1.8	Confined
9	Rockport	Straight	1.0	1,658	2.5	Variable confinement

Channel pattern describes the way the river looks on a map or plan view and is often defined by the sinuosity of the channel (channel length/valley length). Generally, straight channels are least dynamic with relatively slow rates of floodplain erosion, and braided channels more dynamic. Ecological theory suggests that habitat diversity is highest in intermediate disturbance regimes associated with meandering and island-braided channel patterns. The degree to which a channel is constrained by the valley walls or by resistant terraces is known as confinement. Many applied scientists use some description of valley confinement to define hillslope constraint on channel processes. Although confinement is often reported as the ratio of average valley width to average channel width, little empirical data exists to support a numerical interpretation of this relationship. However, it remains a useful relative measure. Rivers and streams unconfined by hillslopes can also be artificially constrained by dikes or road grades constructed on the floodplain or in the channel.

Two metrics were used to evaluate geomorphic potential to rank the reaches (Table 9): the area of floodplain inundated during the 25-year flow reported in acres per mile of channel, and the amount of off-channel area per channel length. The first metric assumes that wide floodplains provide a good indicator of where channel changes or habitat formation may occur in the future and then persist during lower flow conditions. The 25-

yr flow was selected for this metric because this highest modeled flow captures the largest potential differences in floodplain inundation, and therefore river-floodplain interaction between reaches, and it more uniformly compares this potential than the floodplain boundary. Ross Island, Skiyou, and Cockreham are the top reaches based on this metric, with inundation area per channel length for each of these reaches more than double the next rated reach. Baker and Aldon were the two lowest rated reaches. Rockport was not included in the flow modeling.

The second metric assumes that dynamic reaches are most likely to form off-channel habitat, and reaches with high geomorphic potential will have more floodplain channels currently than reaches with lower geomorphic potential even if impaired. The results are very similar to those from the flow inundation area metric, with Ross Island, Cockreham, and Skiyou rated the highest, and Aldon and Baker rated lower.

Existing Habitat Function

The metric used for evaluating current habitat function was juvenile Chinook capacity of existing habitat reported as numbers of fish per mile of mainstem channel length (Table 9). This metric is used as a factor in the conceptual model to distinguish between restoration and protection actions. Reaches that have high current habitat function should be targeted for protection, although restoration may still be important if geomorphic potential is high and there are specific impairments that can be addressed.

Table 9. Summary of indicator metrics used in the reach ranking.

Reach	25-yr Inundation Area/Channel Length (ac/mi)	Off-channel Area/Channel Length (sq ft/ft)	Fish per Channel Length (#/mi)	% Floodplain Impairment	% Non-forest
1 - Skiyou	566.9	77.8	26,053	33.8%	44.6%
2 - Ross Island	701.3	194.2	71,440	28.9%	25.7%
3 - Cockreham	547.5	108.4	28,499	66.1%	53.2%
4 - Savage	263.3	51.8	33,726	17.8%	30.7%
5 - Cape Horn	225.1	9.0	20,643	33.3%	23.8%
6 - Baker	152.0	1.2	13,862	12.0%	18.0%
7 - Jackman	210.0	9.1	25,146	14.0%	17.1%
8 - Aldon	124.3	4.0	22,936	5.8%	9.0%
9 - Rockport	--	40.2	26,348	10.0%	6.6%
Total	388.1	66.5	31,545	36.4%	34.6%

Floodplain Impairment Indicators

The primary metric used to determine floodplain impairment was the percentage of floodplain area impaired by all hydromodifications (Table 9). An additional metric used for evaluating floodplain impairment was percent of floodplain cleared of native forests due to human modification (Table 9) with the assumption that areas cleared for development, agriculture, or other purposes are likely to continue to have poor floodplain function unless they are restored.

Summary of Reach Assessment Results

A simple relative ranking system was used to apply the conceptual model described in Figure 6. Reaches were ordered based on each of the evaluation metrics for each factor, and the top three reaches were rated "High," the lowest three were rated "Low," and the remaining three were rated as "Medium." These factors were then combined into a final rating for protection and restoration (Table 10). The percentage of protected lands in each reach is included in the matrix for reference although it was not used to rate the reaches for protection or restoration. SRSC (2011) provide additional elaboration on the rankings. These relative rankings were provided to the Criteria Work Group for a final determination of priority reaches.

Table 10. Reach evaluation matrix.

Reach	Geomorphic Potential	Existing Habitat Function	Floodplain Impairment	Protected lands	Protect	Restore
1 - Skiyou	High	Med	High	Med	Med/ High	High
2 - Ross Island	High	High	Med	High	High	Med/ High
3 - Cockreham	High	High	High	Low	High	High
4 - Savage	Med	High	Med	Med	Med/ High	Med
5 - Cape Horn	Low	Low	High	Med	Low	Low
6 - Baker	Low	Low	Low	Low	Low	Low
7 - Jackman	Med	Med	Med	High	Med	Med
8 - Aldon	Low	Low	Low	Low	Low	Low
9 - Rockport	Med	Med	Low	High	Med	Med

Reach Priorities

Based on the reach analysis and habitat modelling results, the Criteria Work Group organized the nine reaches in the project area into three priority groupings following the recommendation in the Reach Assessment:

1. Ross Island, Cockreham Island, Skiyou
2. Savage, Jackman, Rockport
3. Baker, Cape Horn, Aldon

The first group includes the three reaches within the broadest part of the valley and thus most able to migrate and create and maintain complex channel habitats. The Ross Island reach is the least modified and has the best existing habitat areas for juvenile Chinook. The Cochreham and Skiyou reaches contain the greatest potential to restore former low velocity rearing habitat to provide the greatest benefit for sustaining and improving the productivity of Chinook in the middle Skagit River.

The second group includes those with intermediate or variable valley widths that allow for some channel-floodplain interactions and hence some opportunities for developing bar and off-channel habitat. The best habitat areas in these reaches for juvenile Chinook are islands, backwater pools, connected side channels, and shallow lateral pools associated with broad gravel bars.

The third group includes those reaches with narrow floodplains and channels confined by hillslopes, bedrock, or glacial terraces and therefore limited in those low-velocity habitats suitable for juvenile Chinook and other salmonids. Although the Cape Horn reach has a valley width comparable to those in the second group, we include it in the third group as it is entrenched, or locked in place, by a glacial terrace which limits migration and therefore habitat potential.

While grouped similarly, the habitat protection and restoration needs vary considerably and by degrees among the reaches, as elaborated upon in the individual reach strategies below.

6 Protection and Restoration Strategies

Following the Reach Assessment, restoration and protection strategies were developed for each reach and treatment types appropriate to the strategies were identified by the Criteria Work Group. Strategies were based on the conceptual model for ranking the reaches (Figure 7) using the reach assessment results and the data sets described above. The relative size of the arrows in Figure 7 indicates that more habitat is gained from restoration in geomorphically dynamic reaches.

We intended to concentrate our efforts first on developing strategies and identifying projects for only the priority reaches identified above. However, the restoration opportunities in the second and third groups were limited enough, and perhaps because of that, potentially important enough to include in a project ranking. Identification of priority actions within and among the reaches followed the development of the reach strategies (Section 7).

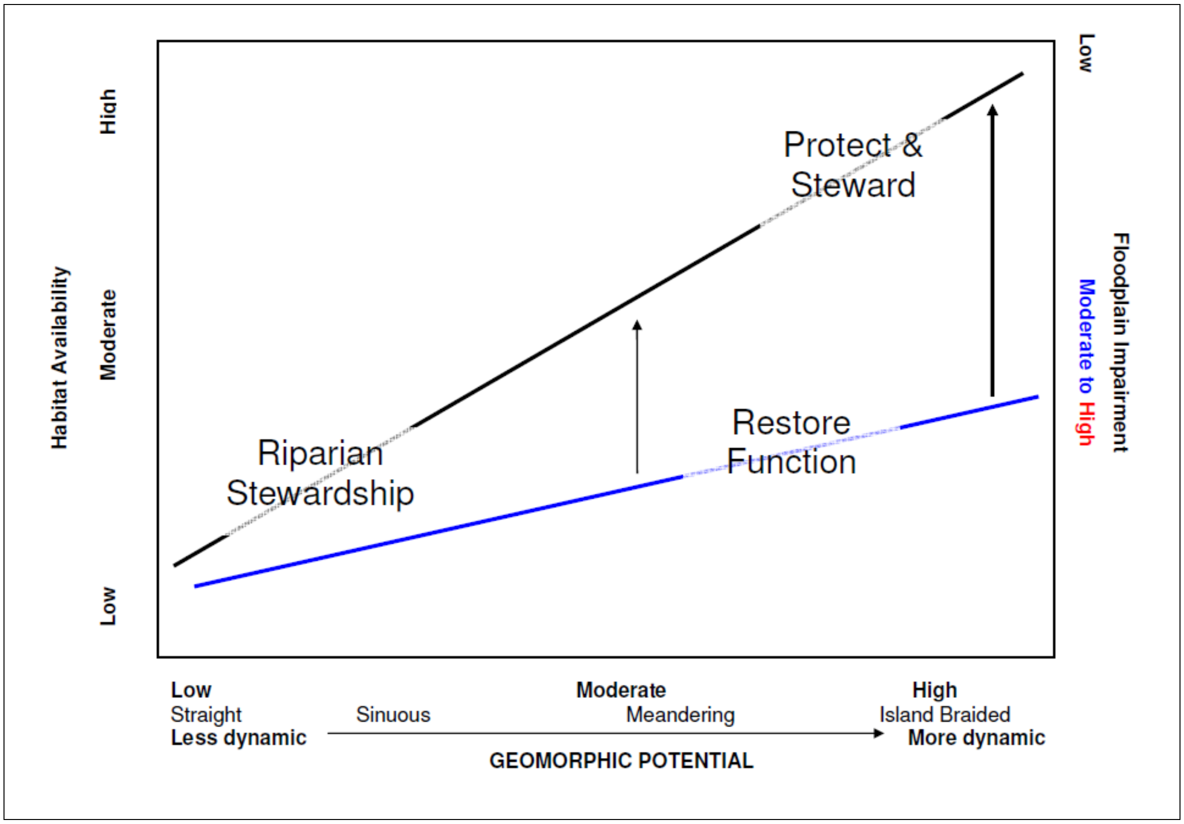

Figure 7. Conceptual model for generalized reach strategies.

Below are the habitat strategies for protection and restoration actions developed for each reach. The habitat strategies are preceded by a supporting summary of reach characteristics based on the reach assessment (SRSC 2011) and other available information, including the habitat simulation modeling, Chinook tributaries within a reach, valley- and reach-scale physical features, channel conditions, channel forming processes and migration characteristics.

The strategies fall into four main categories: protection, restoring floodplain processes, improving existing habitat, and landowner stewardship. More specific actions or treatments fall within each of those categories. The general strategies and treatments are also summarized in table format (Table 11) at the end of this section. We begin with the one strategy common to all reaches – landowner stewardship.

Strategies That Apply to All Reaches

Landowner Stewardship – Actions under landowner stewardship are common to all the reaches. These include maintaining or restoring riparian vegetation along the river channels, floodplain channels, and floodplain areas accessible to juvenile Chinook; and livestock exclusion within the riparian area.

Native floodplain vegetation provides an important food source to juvenile salmon, provides cover, and creates habitat complexity when recruited to the river. While native riparian vegetation is important to the riverine ecosystem, degraded riparian zones in the middle reach of the Skagit River are not the primary factor limiting juvenile Chinook rearing habitat identified in the Chinook Recovery Plan. Landowner stewardship is called out here as an activity in addition to these same actions under floodplain restoration as a matter of scale and for directing resources. Floodplain vegetation modified by human activities varies from 17% in the Rockport reach to 69% in the Cockreham reach, and averaged 50% for the entire middle Skagit River floodplain (SRSC 2011). The relative importance of riparian stewardship to each reach is indicated by the size of the "dot" in Table 11 and expanded upon in the reach strategies below.

Reach 1 – Skiyou

Characteristics of the Reach – The Skiyou Reach (Figure 8) is an alluvial channel that occupies a section of valley that was likely below sea level at the end of the last glaciations (Riedel 2007). The historic and geomorphic potential of the Skiyou Reach is in contrast to its current condition. Historically an island-braided reach (Kroll Map Co. 1913) with an average floodplain width of over a mile, former side and floodplain channels have been isolated from the mainstem by levees and rip-rap, reducing the mainstem channel length by more than half. Prior to white settlement and floodplain development the channel form was sinuous; old channel traces can be distinguished across the approximately 1-mile wide valley. Currently the channel has been straightened and prevented from meandering, and the connectivity of many of these off-channel habitats has been compromised or cut off. Skiyou has double the amount of modified channel bank of any other reach in the project area at 41 percent (Table 2). A greater amount of floodplain is inundated at the 2 year flow (76%) in this reach than the reaches immediately upstream (61 and 52%) indicating a high potential for channel-floodplain interaction. However, despite the high potential current mainstem habitat capacity is lower than other reaches (Table 5) and suitable juvenile Chinook mainstem habitat in the reach modelled over a range in spring flows decreases with increasing flow (Appendix B, Figure 7) due to the effect of extensive riprap on edge habitat. Although the amount of off-channel (floodplain) area in Skiyou ranks among the top three out of the nine reaches, only the lowest slough channel is known to be used by Chinook. With the levees removed modeling shows that the floodplain area inundated at the 2 and 5-year flows actually drops by 4-5 percent in this reach; whether this is a result of removing the Cockreham or Skiyou levees would need more evaluation.

While an estimated one third of the floodplain is in some form of public or protected ownership (Table 4), those numbers do not yet translate to functional floodplain conditions for juvenile salmonids in this reach. Within the project area Skiyou is second only to Cockreham in degree of floodplain and riparian vegetation conversion (Table 6), a consequence of a wide floodplain in close proximity to the county population center and infrastructure.

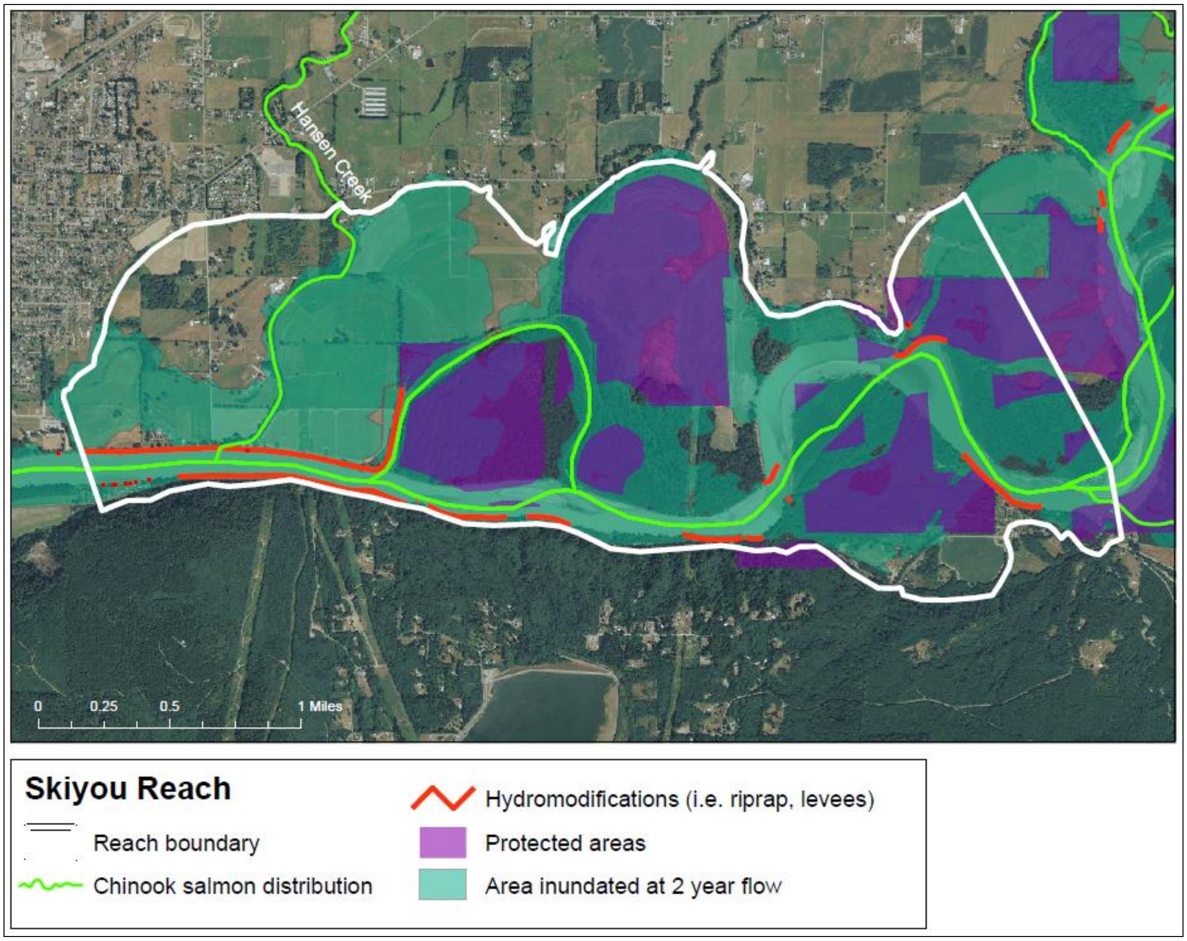

Figure 8. Skiyou Reach.

Habitat Strategy – Reconnecting floodplain channels, removing the impediments to channel migration that formed these habitats, and improving edge habitat where restoration isn't feasible are priority restoration strategies for this reach. As native floodplain vegetation provides an important food source to juvenile salmon restoring riparian conditions, particularly in frequently flooded areas, is a restoration and stewardship strategy.

Reach 2 - Ross Island

Characteristics of the Reach – The Ross Island Reach (Figure 9) is also alluvial, and has the widest valley bottom of any of the reaches in the Plan area. The channel is generally unconstrained, with an island braided plan form and abundant active side channel/off channel habitats relative to the other reaches. Ross Island reach provides the greatest amount of habitat in middle Skagit. Current juvenile Chinook habitat capacity in the reach is estimated to be two to six times greater than other reaches (Table 5). As the only island-braided reach in the project area, the multiple channels of the main stem and relict side channels provide the low-velocity habitat preferred by juvenile salmonids along channel edges, bars, and backwaters. For this reason, Ross Island is the only reach where habitat increases with flows during spring outmigration periods (Appendix B, Figures 6 and 7), and may compensate by providing habitat to fish displaced from upstream reaches (Appendix B, Connor 2011). Additionally, four tributaries used by Chinook for spawning and/or rearing enter the Skagit within this reach (Wiseman, Sorenson, Morgan, and Day creeks).

The floodplain is widest in the Ross Island reach due in part to the cross-valley orientation of the river at this location. The geomorphic processes that create and sustain habitat in the Ross Island reach are less impeded here than elsewhere in the middle Skagit project area. Of the three lower unconfined reaches, Ross Island is the least impaired by structural modifications in the floodplain and channels, and floodplain vegetation is least disturbed or modified by human activity. In addition, approximately 45% of the floodplain is in public or protected ownership (Table 4). While providing good existing habitat benefit, however, close to 30% of the floodplain in the Ross Island reach is in some way impaired or isolated from the river, so there are opportunities for restoring or improving habitat and floodplain function in this important reach.

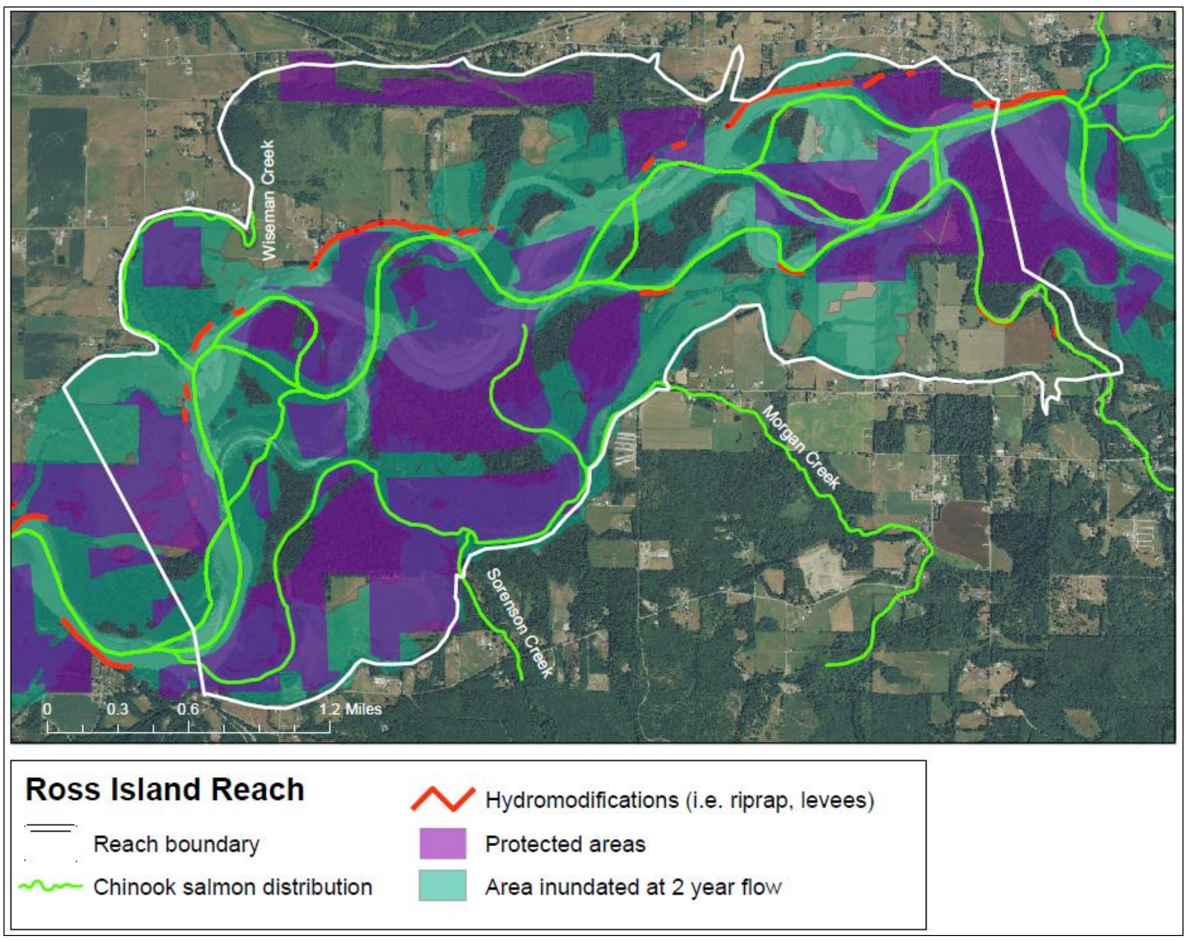

Figure 9. Ross Island Reach.

Habitat Strategy – An important if not the most important habitat strategy for the Ross Island reach is to target additional acquisitions for protection of existing high quality habitats or the processes that create them, specifically high quality backwater and bar habitat and areas where floodplain function and vegetation are unmodified. The restoration strategy in the Ross Island reach is focused first on reconnecting floodplain channels to the river and restoring the natural floodplain processes that form backwaters and floodplain habitat, then on improving degraded habitat and restoring riparian areas. This strategy would be accomplished by the following actions in order of importance: removing or modifying floodplain structures and barriers to reconnect floodplain channels and restore floodplain function; removing rip-rap and other bank protection structures to restore or improve low-velocity edge habitat; planting native vegetation adjacent to mainstem and side channels and within frequently flooded areas; improving in-channel habitat in Skagit floodplain channels and tributaries; and reducing the impacts from recreational activities.

Reach 3 – Cockreham

Characteristics of the Reach – The Cockreham Reach (Figure 10) is alluvial, and likely coincides with the approximate furthest upstream extent of post-glacial sea inundation (Riedel 2007). The channel is generally unconstrained, with a meandering plan form. Side channel/off channel habitats are present, but many appear to be disconnected from the active channel. The Cockreham Reach has the highest percent of modified vegetation cover (69%) in the project area (Table 6) attributed to agricultural fields, residential and recreational lots, and roads. Regardless the degree of floodplain modification and land use in the reach, Cockreham is the second most important reach in existing quantity of habitat and for sustaining habitat over a range of flows (Appendix B, Figure 7) due primarily to quality backwater and off-channel habitat present at the downstream end of the reach. Additionally, five tributaries used by Chinook enter the Skagit within this reach (Jim's Slough, Jones, Manser, Muddy, and Alder creeks).

The geomorphic potential for creating and maintaining target habitat is high within the Cockreham reach due to floodplain width and area in floodplain channels. However, significant amount of available off-channel habitat is degraded or inaccessible due to a river training levee in the middle of the reach that locks a meander bend in place. The 1.2 mile long Cockreham levee, located just downstream from the frequently-flooded town of Hamilton, is the most significant floodplain modification in the project area. While protecting the area known as Cockreham Island from erosion by migration of the channel bend, hydraulic modelling completed for this project shows that the levee also backs more water upstream into the town of Hamilton during the most frequent flood flows than would occur if the levee were removed. Bank hardening located above Hamilton also protects the town from high velocity flood flows. Efforts have been on-going over the past decade to buy out frequently flooded properties in this area and relocate the Hamilton town site, and Skagit County commissioned a flood damage reduction feasibility study (GeoEngineers 2007) that concludes a buy-out of the Cockreham Island properties is potentially cost effective. The Skagit Countywide UGA Open Space Concept Plan of 2009 adopted by the county's Board of Commissioners also envisions the Cockreham area as open space. Because many landowners and much infrastructure are involved, continued efforts to relocate area residents out of harms way will take time, political will, and funding.

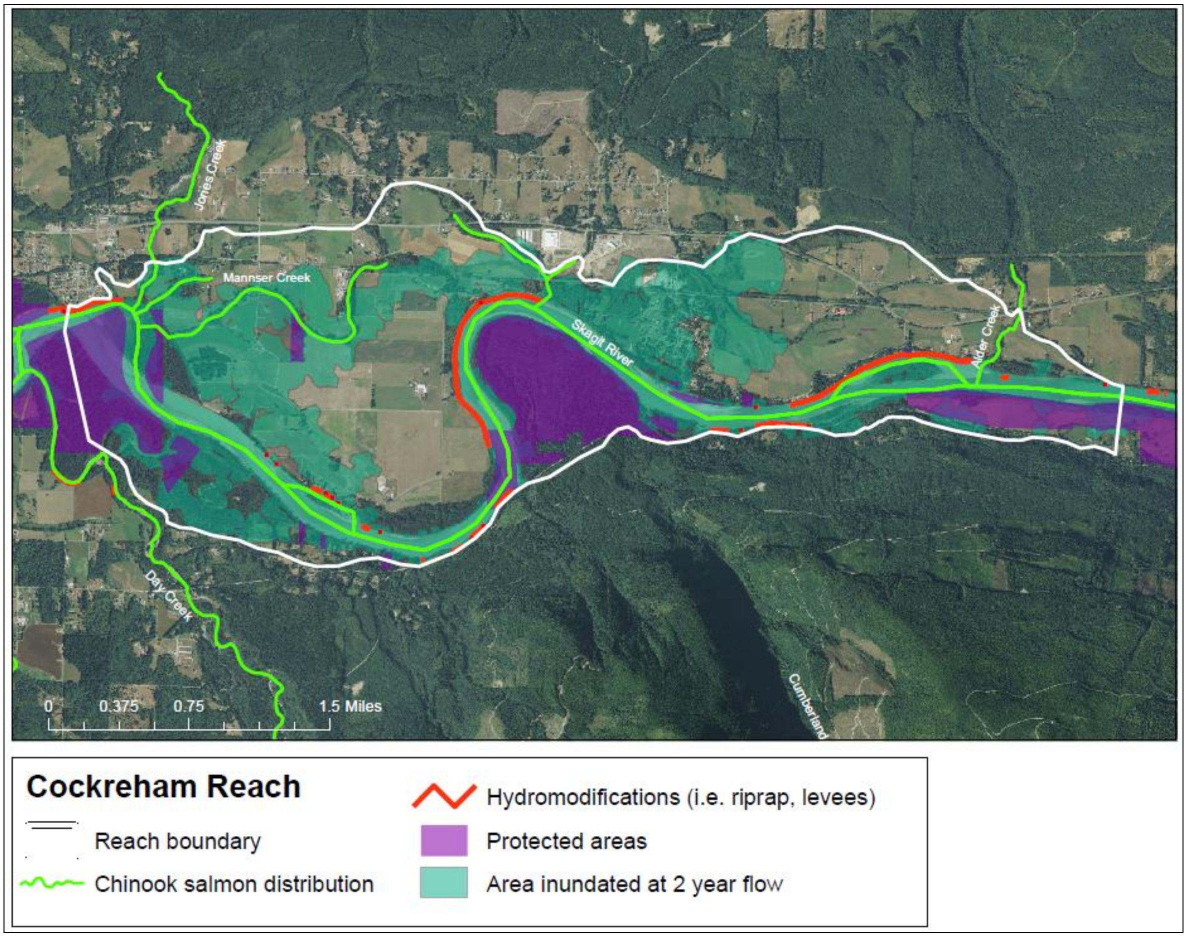

Figure 10. Cockreham Reach.

Habitat Strategy – Significant potential exists to both reconnect floodplain channels and restore floodplain processes in the floodway associated with the Cockreham and Hamilton areas. This will require major land acquisitions to achieve. Therefore, an important step in the strategy for this reach is to develop a plan for acquisition and restoration options for the Cockreham Island area. While this constitutes an implementation rather than a restoration strategy, the need for coordinated planning is important to emphasize here. In the interim, implementing early actions and targeting acquisitions to protect the existing habitat are priorities in this reach. Identifying and pursuing additional opportunities to reconnect off-channel habitat, remove barriers, and restore floodplain function where possible outside the Cockreham-Hamilton area is also part of the near-term reach strategy.

Reach 4 – Savage

Characteristics of the Reach – The Savage Reach (Figure 11) is transitional between the unconstrained alluvial lower valley and the narrower alluvial reaches upstream. The river in this area has downcut through glacial terrace deposits, and is thus moderately confined. Compared with the lower reaches, Savage falls within the group of reaches that have intermediate or variable valley widths which allow for some channel-floodplain interactions and hence some opportunities for developing bar and off-channel habitat, but not to the same extent as the unconfined reaches downstream. Juvenile Chinook habitat capacity estimated for the reach (SRSC) indicates abundant habitat at the lower flow conditions in the 2009 aerial photography used to map habitat (Table 5); however, habitat modelling shows Savage undergoes the greatest decline in that habitat with increasing flows (Appendix B, Figure 7). Although mapped backwater and off-channel habitats are comparable to the Skiyou reach, hydraulic modelling results show that this reach has the lowest area of floodplain inundated at the 2 and 5-year flows (Table 3), indicating a higher floodplain elevation and less frequent channel-floodplain interaction than other reaches. As 1937 photographs show active side channels in these areas the current condition is likely a consequence of the changes to flow and sediment from the hydroelectric project upstream. Two tributaries used by Chinook, Grandy and Pressentin Creeks, join the Skagit River in this reach. About half the floodplain area is cleared of vegetation (Table 6), and about 3,470 feet (12%) of river bank are modified in the reach (Table 2). The area in public and protected lands is high, totalling 54% (Table 4), given a boost by a recent large conservation acquisition.

Habitat Strategy – Based on the geomorphic potential and assessment data, the habitat strategy for the Savage reach is to protect through acquisition and stewardship the existing high quality (higher juvenile density) habitats and focus restoration efforts on reconnecting off-channel habitats. Secondary restoration strategies are to improve edge habitat along hydromodified river banks and restore riparian vegetation along stream banks and frequently flooded areas.

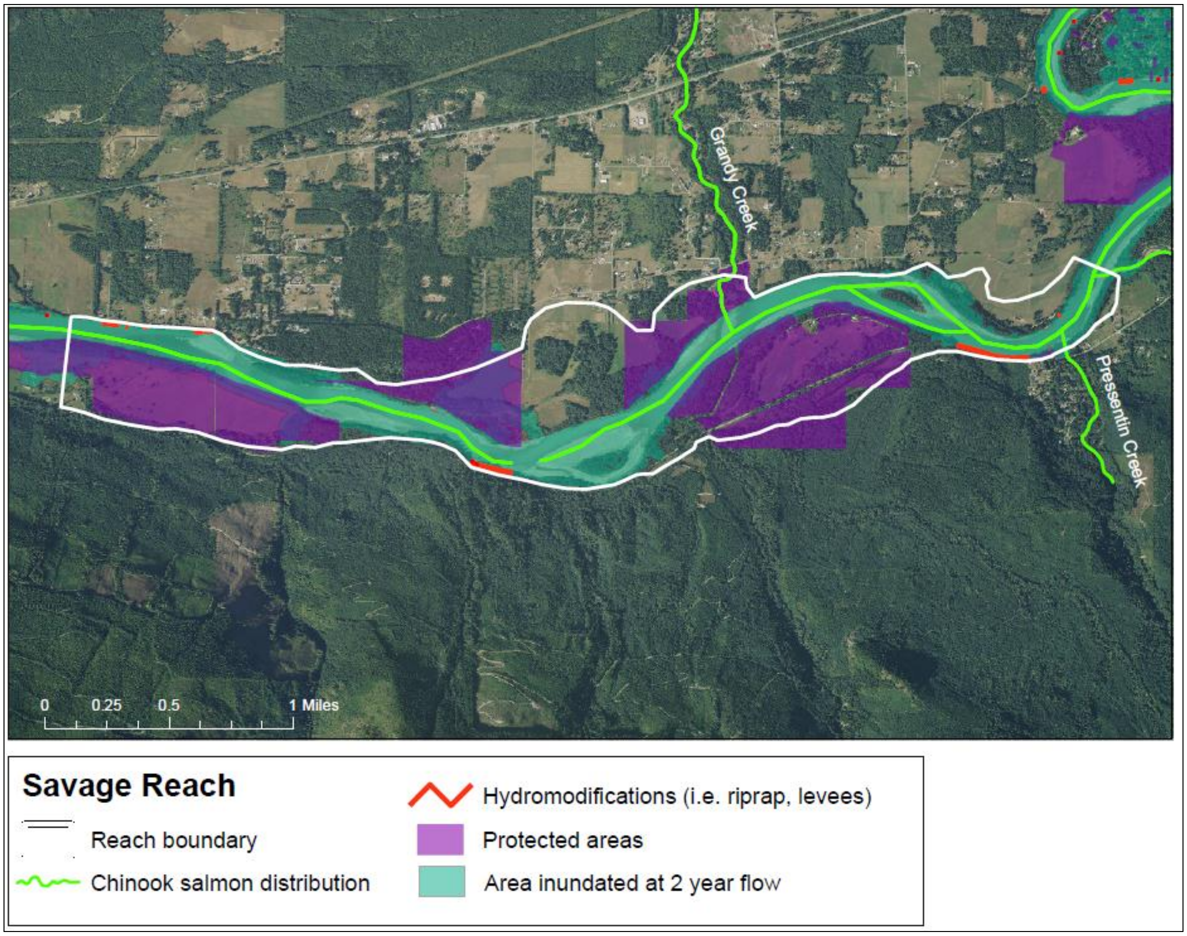

Figure 11. Savage Reach.

Reach 5 – Cape Horn

Characteristics of the Reach – Like the Savage Reach, the Cape Horn Reach (Figure 12) is transitional between the unconstrained alluvial lower valley and the narrower alluvial reaches upstream. While some indicators, such as confinement and sinuosity, suggest Cape Horn would be a geomorphically dynamic reach and therefore possess much habitat potential, other assessment metrics show the opposite. On the plus side, at 3% Cape Horn has the least amount of modified bank (Table 2), 80% of the floodplain in the reach is inundated at the 2 year flow (Table 3), 40% of the floodplain is in public or conservation status (Table 4), and only 25% of the floodplain vegetation was inventoried as modified (Table 6). The estimated current available mainstem habitat for juvenile Chinook falls in the middle of the reach values (Table 5), although the reach is among the lowest in off-channel area and, of the 6 reaches where habitat modelling was conducted, Cape Horn provides the least amount of habitat over a range of flows during the outmigration period (Appendix B, Figure 7). Off-channel habitat area is found in a single open wetland on conservation property managed as an elk refuge (Hurn Field). Connectivity to the river during out-migration is uncertain, although the area is shown as flooded at the 2 year flow (SRSC 2011). Finney Creek, an important Chinook tributary, enters the reach at the very downstream end.

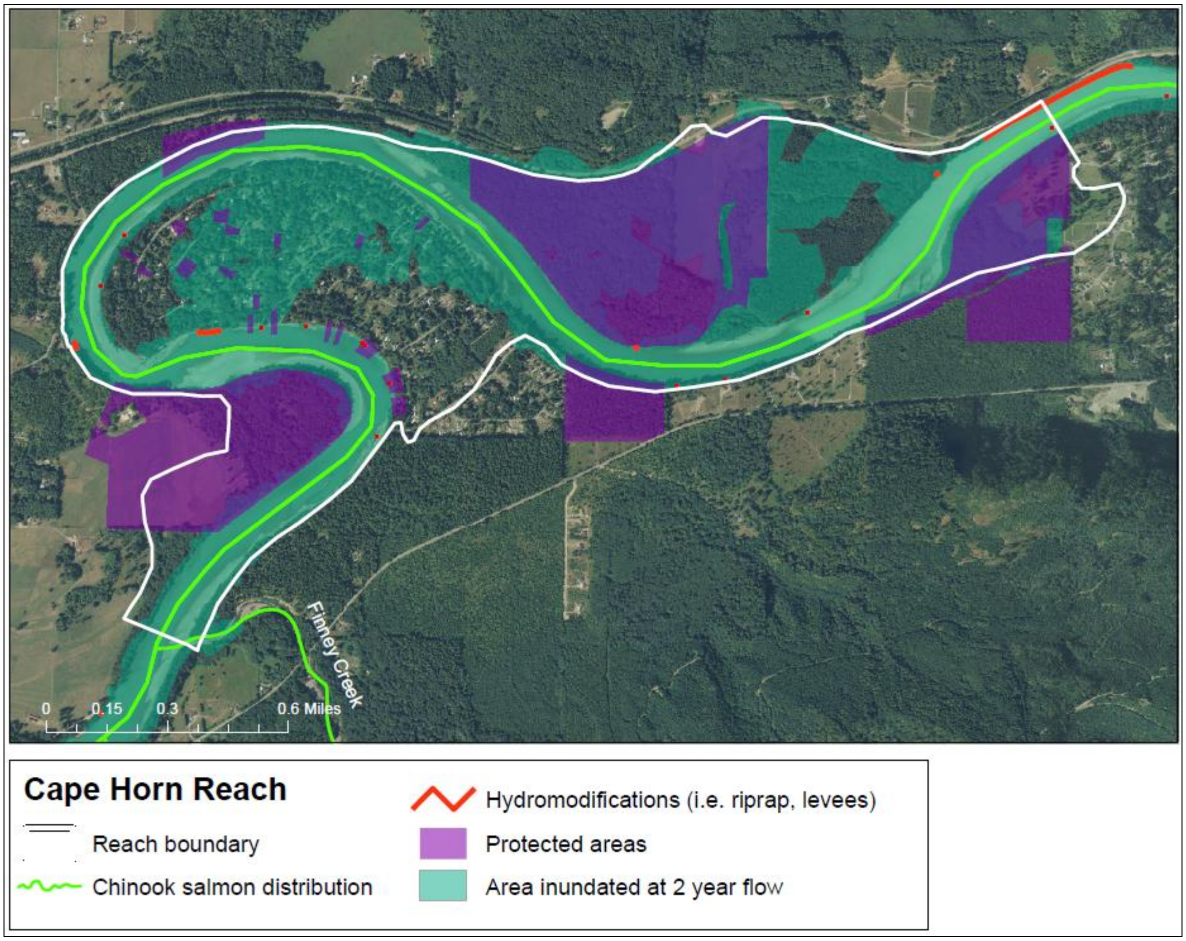

Figure 12. Cape Horn Reach.

Although heavily developed with recreational lots, the namesake Cape Horn peninsula has few inventoried streambank modifications that would impede channel migration. Regardless of the generous valley width the Cape Horn meander bend is entrenched, or locked in place, by a glacial terrace which limits migration potential in the reach. The floodplain impairment assessment does show a large portion of low elevation floodplain in conservation ownership shadowed by a road on privately owned land containing floodplain channels. Subsequent field verification found that the road is at grade or lower, so the road grade is not impeding floodplain processes. However, several culverts within floodplain channels could be repaired to better accommodate the on-site groundwater and flood flows.

Habitat Strategy – Continue to build on the conservation and public ownership within the Hurn Field area where floodplain function is good; investigate the potential to reactivate floodplain channels in this area.

Reach 6 - Baker

Characteristics of the Reach – The Baker Reach (Figure 13) is tightly confined, with a valley bottom width of less than 1,000 feet and less than 120 acres of floodplain per mile of river. This portion of the Skagit valley was blocked by a large alpine glacier originating from the Baker Valley approximately 20-30 thousand years ago, creating a large lake upstream that may have persisted for as long as 4,000 years, resulting in the deposition of almost 40 meters of lake sediments in the Skagit Valley (Reidel et al. 2010). The current Skagit River is confined between terraces formed of this material and overlying glacial outwash and locally by bedrock where the river flows against the southern valley wall below the Baker River confluence at the "Dalles." As a result both extensive floodplain deposits and off channel habitats are rare, and the reach tends to transport large wood and gravel introduced from upstream. What floodplain that has developed is found where the Baker River enters the Skagit River just upstream of the channel constriction at the Dalles. Habitat modelling over a range of flows shows an increase in juvenile habitat peaking at 15,000 cfs that declines rapidly to the lowest level among the six modelled reaches (Appendix B, Figure 7). Bank protection affects only 8 percent of the bank length (Table 2) and is located at the margins of the floodplain for protection of state and local highways. The mouth of the Baker River has undergone significant modification or straightening visible in a comparison between 1937 and 2009 aerial photography. Apparently, the channel was cut into channel substrate to allow for capture of returning sockeye salmon for transport above the Baker River dams (citation). A long-standing proposal to create a side channel at the mouth of the Baker River was determined to have minimal benefit to juvenile Chinook and to potentially be an "attractive nuisance" to the capture and transport of migrating Baker River sockeye. Some restoration potential for the benefit of other species may be possible at the site but would not be a priority for Chinook.

Habitat Strategy – The primary restoration strategy for the Baker Reach is riparian planting and/or rehabilitation on the limited floodplain and adjacent river banks through stewardship by existing landowners. The protection strategy is to sustain what limited available floodplain there is from development through acquisitions where possible.

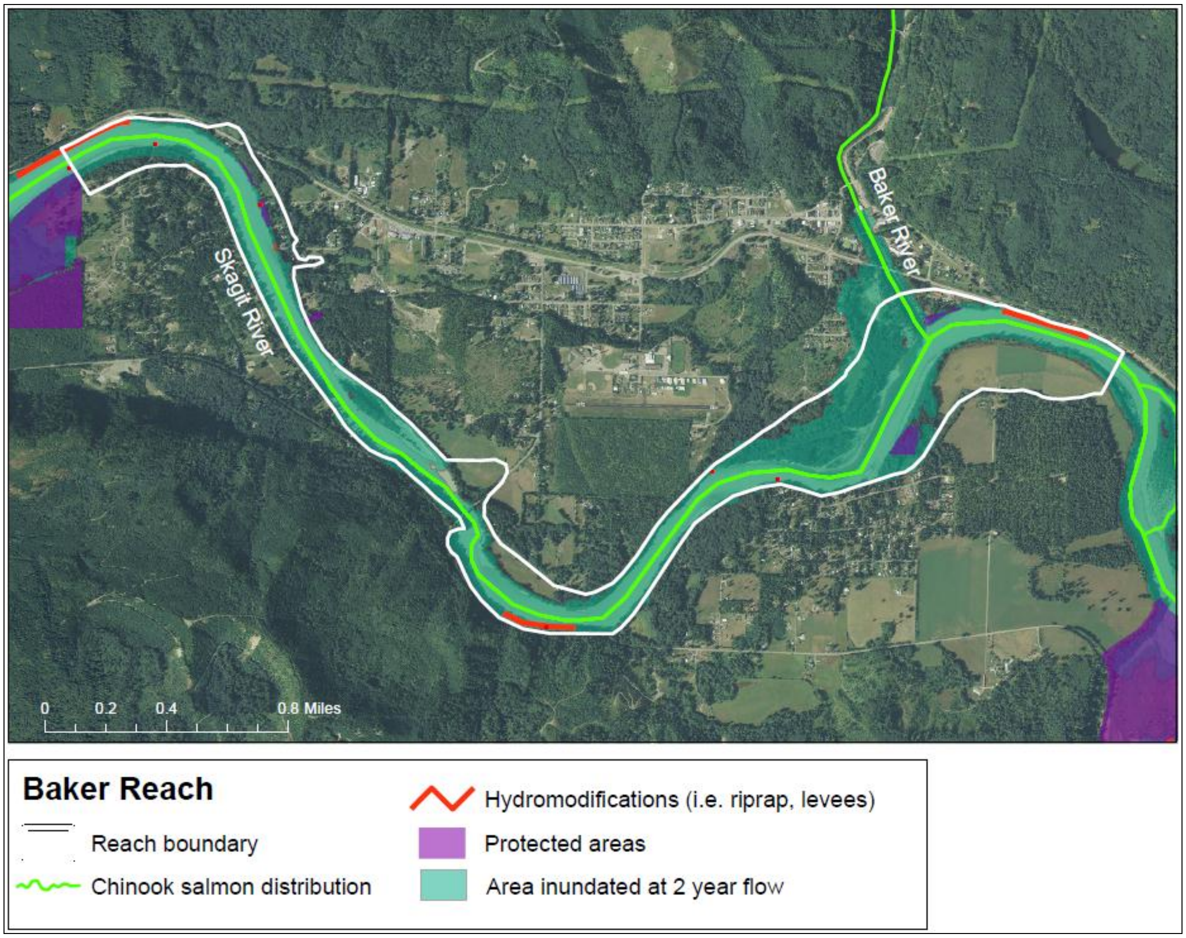

Figure 13. Baker Reach.

Reach 7 - Jackman

<u>Characteristics of the Reach</u> –Located in the upper end of our study area the moderately confined Jackman Reach (Figure 14) is sandwiched between the two valley-confined reaches of Aldon upstream and Baker downstream. The valley is somewhat wider in the Jackman Reach, but still contained between high glacial terraces with glacial lacustrine sediments at the base. Jackman Creek, a Chinook tributary, enters the Skagit here and in combination with the downstream valley constriction allows for sediment deposition and some channel braiding and off channel habitats in the reach. Many of the index values and assessment results for this reach fall squarely in the mid range, including estimates of juvenile Chinook capacity (Table 5). However, the lower portion of Jackman Creek and the area of island-braided channel in this reach provide an important local expansion of low velocity habitat not available for several miles in either direction.

The degree of floodplain modification associated with hydromodifications and roads is on the low end at 14% (Table 2), and non-forested floodplain is 17% in the reach (Table 6). Hydromodifications are located at the margins of the floodplain protecting the South

Skagit Highway and along Thunderbird Lane in the Van Horn area protecting properties from erosion. Residential and recreational properties in this area are vulnerable to erosion and several areas of failed rock in the river were inventoried in this island braided area. Currently, over half of the floodplain area is in public or conservation ownership (Table 4) that includes a number of the recreational lots.

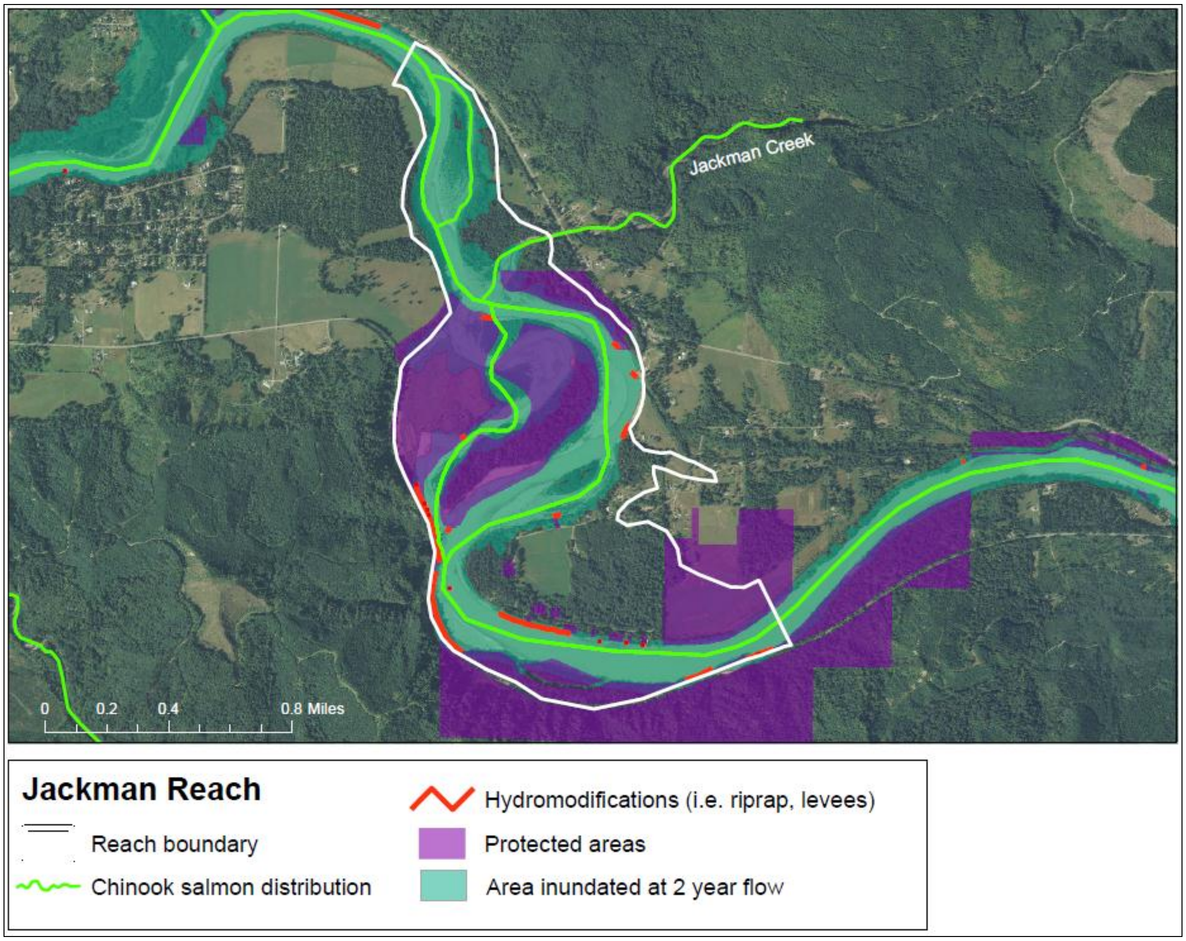

Figure 14. Jackman Reach.

Habitat Strategy – The opportunities for protection and restoration in the Jackman Reach are straightforward: protect the habitat and natural processes at the junction with Jackman Creek and its alluvial fan; restore edge habitat associated with bank armouring; and continue acquisition of floodplain properties to restore/protect floodplain processes in the Van Horn area.

Reach 8 - Aldon

Characteristics of the Reach – Like the Baker Reach, the river is tightly confined by glacial terraces in the Aldon Reach (Figure 15) with few floodplain surfaces or associated off-channel habitats and offering less than 120 acres of floodplain per mile of river. Although only 20% of the floodplain is in public or conservation ownership (Table 4), vegetation in the narrow floodplain in the Aldon Reach is dominated by intermediate and mature forests – only 9% is unforested and 24% modified by land use activities (Table 6). Total habitat (wetted channel) area is the lowest in the project area; however, less than 6% of channel banks are modified or rip-rapped (Table 2), providing more quality edge habitat than some of the more highly modified reaches. The reach also provides some good bar habitat and one pocket of quality backwater. Juvenile Chinook habitat over a range of flows was not modelled above the Baker reach.

Habitat Strategy – In consideration of the current good, but geomorphically-limited habitat conditions, the primary habitat strategy for the Aldon Reach is protection of the existing habitat through both regulatory means and riparian stewardship opportunities.

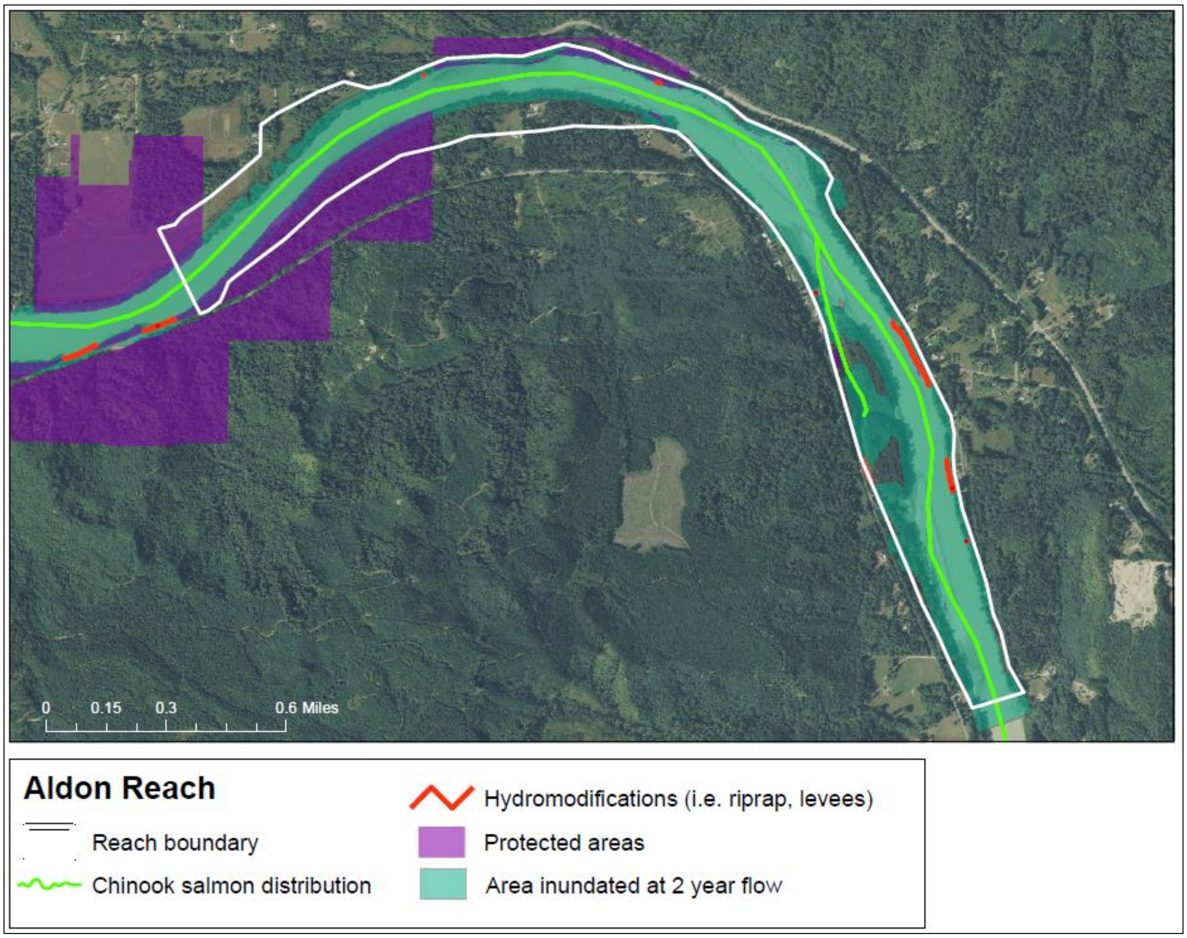

Figure 15. Aldon Reach.

Reach 9 - Rockport

Characteristics of the Reach – The Rockport Reach (Figure 16) is anomalous in the project area because it includes only a portion of the floodplain it shares at the confluence with the Sauk River (Figure 2) – an artefact of adopting reach breaks used in both the river basin analysis (Skagit Watershed Council 2000) and the Skagit Chinook Recovery Plan (SRSC and WDFW 2005). Instream gravel bars are more common than in the other transitional reaches (Table 5), reflecting the large amounts of sediment that deposits on the alluvial fan/delta at the mouth of the Sauk River. Active floodplain surfaces and associated off-channel habitats are uncommon, except at the upstream end of the reach on the Sauk delta. Hydrodynamic modelling conducted for this project did not include this reach because of the additional work to quantify the split flow. This dynamic intersection at the confluence of the two rivers is largely unimpeded by land use impacts. Over 75% of the floodplain delineated for this project is in public or conservation ownership (Table 4). With only a portion of this area included in our assessment, it ranks fourth in mainstem juvenile Chinook habitat (Table 5) and fifth in off-channel area. Aging bank protection structures are limited and associated with floodplain impairment at only one location in Howard Miller Steelhead Park.

Habitat Strategy – Because over 75 percent of the floodplain is in public or conservation status and land use impacts are low, protecting the remaining area of floodplain is a priority strategy for this reach followed by stewardship actions that include restoring floodplain vegetation adjacent to existing channels and reducing impacts from recreational activities, specifically in the much-used Howard Miller Steelhead Park.

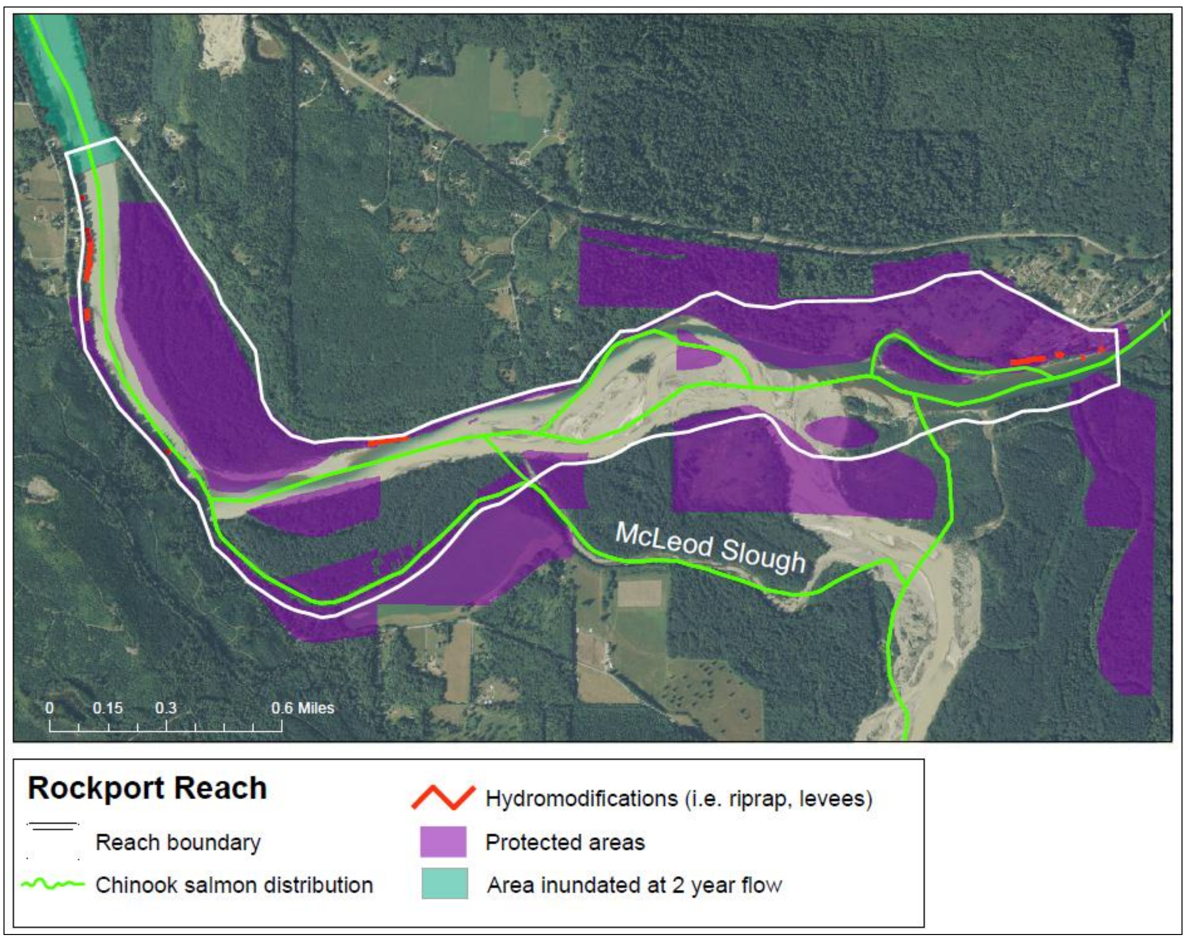

Figure 16. Rockport Reach.

Table 11. Summary of restoration strategies and treatments by relative importance to each reach.

Strategies	Protection			Restore Floodplain Processes						Improve Habitat			Landowner Stewardship		More Info
Treatments	**Acquisitions to protect high quality habitats**	**Acquisitions to protect functioning floodplains**	**Regulatory protection enforcement of existing habitats**	**Acquisition to enable priority restoration sites**	**Remove modifications to reconnect floodplain channels & low velocity habitat**	**Remove or relocate floodplain modifications to restore habitat-forming processes**	**Restore native vegetation adjacent to mainstem & active side channels**	**Restore native vegetation adjacent to floodplain channels**	**Restore native vegetation within frequently flooded areas**	**Remove or remediate bank protection structures to improve edge habitat**	**Improve in-channel habitat in floodplain & tributary channels**	**Reduce impacts from recreational activities**	**Restore or maintain riparian vegetation along channels**	**Livestock exclusion**	**Additional analysis or planning needed**
Ross Island	●	●		●	●	●	•		•	•	·	·	·	·	
Cockreham	●			●	●	●					•		·	·	●
Skiyou				●	●		·	·		•			·	•	
Savage	•		•		●		·		·	•			•	·	
Jackman	•	•		•		•				•			·	·	
Rockport	•						•	•				•	•	·	
Baker		·										·	•	·	
Cape Horn		•											·	·	•
Aldon			•										•	·	

Importance:

● High • Moderate · Lower *Blank* – doesn't apply

7 Protection and Restoration Priorities

This section contains the criteria, or rationale, used for prioritizing the protection and restoration actions identified. Below are the prioritization criteria adopted by the Criteria work group. Ideally, developing the criteria by which to prioritize a project list should have been done at the beginning of the project (Beechie et al. 2008). While delaying this step did not preclude the gathering of relevant data because our target habitat was specific to juvenile Chinook, it did delay the identification and ranking of projects and subsequently our ability to further develop information and strategies for the top ranked projects within the timeframe of this grant.

Prioritization Criteria

The Criteria Work Group adopted a hierarchial strategy for prioritizing protection and restoration actions (Figure 17) based on a scheme from Roni et al. (2002) and revised in Roni et al. (2008). These priorities reflect key findings for floodplain restoration summarized in Roni et al. (2005) from the international restoration literature:

- Reconnection of isolated floodplain habitats is particularly effective at improving habitat diversity, providing access to existing habitats for various fishes, and increasing species diversity.
- Levee removal, channel re-meandering, and construction of floodplain habitats have all shown promising results both physically and for biota, but long term data on their success are not yet available.

Roni et al. (2010) found that estimates of fish response to other types of restoration, such as riparian restoration and road removal or repair, were not available and therefore calculating whole-watershed restoration benefits for these types of actions was not possible. It appears doubtful that fish response from these types of activities can be quantified as it may take decades to produce changes in habitat that would result in a measurable change in fish production (Roni et al. 2002). Recent modeling efforts by Fullerton et al. (2010) also suggest that concentrating restoration efforts in specific subwatersheds or contiguous reaches will produce larger increases in salmon than spreading restoration actions equally across the landscape, supporting the strategy of reach priorities as identified here.

The protection and restoration priority sequence diagrammed in Figure 8 is followed by the criteria that define the numbered priority actions. Additional criteria were adopted to provide a ranking of identified sites based on reach priority, the type of restoration action or treatment (Figure 8), and habitat area (Table 12) with an emphasis placed on those actions likely to yield the largest habitat benefit.

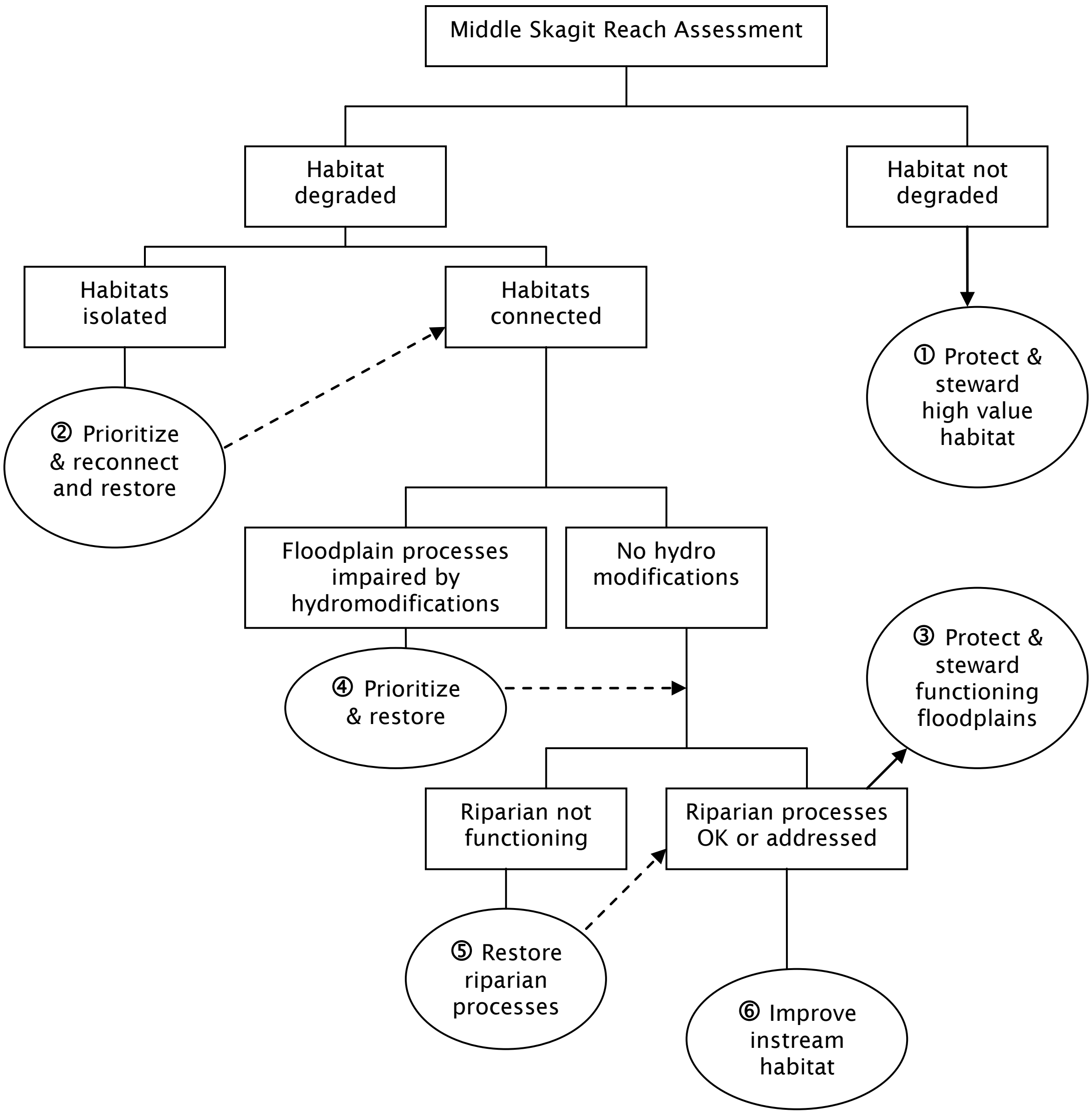

Figure 17. Hierarchical strategy for prioritizing and sequencing restoration activities in the middle Skagit River (adapted from Roni et al. 2002 & 2008). The numbered actions in ovals indicate priority sequence with associated criteria defined in text.

1. Protecting high value habitats is our highest priority. High value habitat is defined as those habitats supporting higher densities of juvenile Chinook (citations). Criteria for protecting high value habitats:
   a. Property meets SWC protection formula minimum score
   b. High value habitat defined as mainstem backwater, mainstem secondary channel, off-channel and at tributary junctions with the mainstem
   c. Habitat is not degraded
2. The next highest priority is reconnecting habitats that benefit juvenile Chinook. Because reconnecting existing isolated habitat provides an immediate known benefit with little uncertainty, these actions are the first restoration priority.
3. Our next priority is protecting functioning floodplain areas, defined as: floodplains not impeded by roads, bank protection or other structures; and with natural or native vegetation intact. Priority areas for protection of functioning floodplains in order of importance are:
   a. Floodplains with overflow channels or inundated in the 2-year flow
   b. Floodplains inundated at flows greater than the 2 year flow
4. Where floodplain and channel habitats are impaired by hydromodifications, habitat-forming processes are also impaired. However, more uncertainty is associated with removing hydromodifications to restore floodplain processes than reconnecting isolated habitats, hence a lower priority for restoration. Criteria for prioritizing removing or remediating hydromodifications to restore floodplain processes are:
   a. Amount of area of floodplain behind structure
   b. Height of the structure above the floodplain
   c. Extent or length of structure
   d. Frequently maintained – no LWD or trees
   e. Large rock (less erodible) vs. smaller rock (more erodible)
5. The success of projects to improve instream habitat structure is dependent on first addressing the processes or factors limiting the existing habitat where possible, which is why riparian restoration should occur prior to or simultaneously with any projects to install instream structures. Priority areas for riparian restoration in order of importance are:
   a. Unforested areas within 150 feet of existing mainstem, tributary, and floodplain habitat
   b. Unforested floodplain within area inundated at 2-year flow (frequently flooded areas)
6. After first addressing the processes and factors limiting habitat, projects to improve instream habitat can be successful.

Table 12. Criteria for prioritizing protection and restoration actions in the middle Skagit River.

Criteria	Scoring		
	Low	Medium	High
Reach Priority	Lower third = 1	Middle third = 3	Upper third = 5
Treatment type or strategy	Riparian restoration = 2 Bank remediation = 1 LWD or instream treatment = 1	Reconnects isolated other habitat = 4 Restores floodplain processes with avulsion potential = 4 Protects functioning floodplains = 3 Restores floodplain processes = 3	Protects high quality habitat=5 Reconnects isolated high quality habitat=5 Multiple treatments & strategies addressed=5
Habitat Gain: Increase in target habitat or floodplain area	Small scale acquisition; localized or limited action or impact = 1-2	Potential for moderate increase in protection or restoration of habitat or floodplain area = 3-4	Potential for large increase in protection or restoration of habitat or floodplain area = 5

Identification of Treatment Locations

Following development of the reach strategies, work group members gathered to review the available GIS data and reach assessment maps (SRSC 2011) to determine the locations of potential protection and restoration actions within the reaches. Data used to identify the priority treatment areas are shown in a series of maps (Appendix C) prepared to support identification of the actions numbered 1 through 5 in Figure 17. Early in this project participants were given an opportunity to provide information on current, past, proposed, or stalled restoration or protection efforts in the study area. The information provided was captured on data sheets and maps then archived in a database which was used as an additional reference during the project identification. Restoration sites on Maps 2 and 4 are numbered by ranked priority. The prioritized list of sites follows in the next section.

Field checking of some roads mapped from aerial photographs as impairing, shadowing, or isolating sizeable areas of floodplain (Map 14, Appendix A, SRSC 2011) was conducted to confirm or eliminate those areas as potential priority treatment locations. Those roads determined to be at grade or of insufficient elevation above the floodplain to not impede floodplain processes were removed from consideration if they were not also associated with streambank modifications. A revised floodplain impairment map layer was used to identify priority sites for restoring floodplain habitat-forming processes and protection of functioning floodplains.

A map was prepared to aid in the identification of priority areas for protecting high value existing habitat (Map 1 in Appendix C) as defined in our priority criteria on the previous page. For this purpose we used the following data: current habitat mapping, Chinook fish distribution to identify known Chinook spawning and rearing habitat and tributaries, protected lands, and floodplain impairment. High priority areas for protection are those backwater, off-channel, and tributary junction habitats mapped within the "unprotected" areas. Habitats within those areas also shown as isolated or shadowed by bank protection structures or roads may be degraded and identified as a restoration priority identified in Map 2. Specific properties have not been prioritized for acquisition.

To identify priority areas for reconnecting isolated habitat (Map 2) we used the following data: current habitat mapping, Chinook fish distribution to identify known Chinook spawning and rearing habitat and tributaries, hydromodification features, and LiDAR hillshade to identify potential unmapped floodplain channels. Restoration sites were identified where mapped hydromodifications or roads intersect with mapped off-channel habitats or channel-like features visible in the LiDAR image. Projects identified on Map 2 are listed in Table 15 in order of priority. One known stream crossing of a floodplain channel (site 13) was verified as obstructing flow during field verification of the road as a floodplain impairment. Other floodplain channels not visible under the tree canopy may exist in the island-braided Ross Island reach. A systematic field survey of this area for channels and obstructions, such as old farm tract crossings, could net additional habitat reconnection sites.

Data used to identify priority areas for protecting functioning floodplains in Map 3 include: current habitat mapping, protected lands, revised floodplain impairment, vegetation mapping, and the area within the 2-year flow inundation. High priority areas for protection of functioning floodplains are those forested areas not shown overlain by either protected lands or as isolated or shadowed hydromodifications. As with priority habitat protection (Map 1), specific properties have not been prioritized.

The following data were used to identify priority areas for restoration of impaired floodplains (Map 4): current habitat mapping, Chinook fish distribution to identify known Chinook spawning and rearing habitat and tributaries, hydromodification features, floodplain impairment, areas within the 2-year flow inundation. The velocity distributions for the 25-year flow (not shown) were also useful for identifying "hot spots" of potential erosion and channel shifting. High priority areas for restoring floodplain habitat-forming processes are those mapped as isolated or "shadowed" (disconnected) from the river. Sites are associated with both isolated habitat and impaired floodplain processes are shown on both Maps 2 and 4. Several of the large, impaired areas were identified as non-priority sites at this time (yellow dots). In the Ross Island reach between sites 11 and 16 on Map 4, an extensive length of riprap is protecting a portion of Utopia Road along a major side channel to the river. The area behind the road is not mapped as inundated during the 2-year flow, and field scoping by WDFW and Skagit County staff found that while the road fill is fully armored the banks are well vegetated. As there is no alternative access route and there are other upland drainage and routing issues associated with Wiseman Creek and Minkler wetland in the area, removing the riprap is not a priority here. Although heavily developed with recreational lots, the Cape Horn peninsula has few inventoried streambank modifications that would impede channel migration as most of the peninsula is on the inside of a meander curve. There are certainly issues associated with the development here, but the gain in habitat area given the density of development is unclear and therefore not a priority floodplain restoration site. Additional, lesser priority floodplain and edge habitat restoration sites can be identified from a sort of the streambank modification inventory using the criteria listed in the previous section.

The floodplain vegetation data described in Section 5 above were used to identify the priority areas for riparian restoration in Map 5. High priorities for riparian restoration are unforested areas within 150 feet of existing mainstem or off-channel habitat and unforested floodplain shown within the 2-year flow. Table 13 provides a summary by reach of those high priority areas. The lower three floodplain reaches with the widest floodplain and most floodplain habitats are also those with the largest unforested riparian and low floodplain areas. This spatial analysis can be used to direct appropriate conservation programs and grant sources available to landowners to these priority areas, and to include in the identified habitat and floodplain restoration sites.

Table 13. Total by reach of priority riparian restoration areas.

Reach	Unforested areas 150 ft from habitat (ac)	Unforested within 2 yr flow area (ac)
1 - Skiyou	114	865
2 - Ross Island	194	633
3 - Cockreham	230	1,100
4 - Savage	15	124
5 - Cape Horn	12	140
6 - Baker	2	21
7 - Jackman	17	62
8 - Aldon	11	11
9 - Rockport	11	41
Total	605	2,997

The majority of identified restoration locations listed in Table 14 are located in the priority floodplain reaches: Skiyou, Ross Island, and Cockreham. Only two of the 21 sites are found upstream where restoration opportunities are limited in the landscape (refer to reach characteristics in Section 6). Three of the 21 sites (those ranked 1, 3, and 4) were previously identified in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), and four sites had been added to the Three Year Work Program since adoption of the plan in

2006 (those ranked 2, 7, 10 and 15). The remaining fourteen projects on the list will be added to Skagit Watershed Council's web-based Habitat Work Schedule database of projects supporting Chinook recovery: http://hws.ekosystem.us.

The list of proposed treatment areas in this report is not inclusive of all potential or known restoration locations or activities for two reasons: resolution and scale. There are limits to the data collected and photography used, in particular identifying floodplain channels under forest canopy and bank hardening covered in silt and vegetation and, for the purpose of this effort, we were targeting projects with larger benefit vital to watershed and regional Chinook recovery. The data exist, however, for us to identify more projects as the priority projects are completed or stalled.

Implementation Priorities and Sequencing

Priority habitat and floodplain protection areas can be identified from Maps 1 and 4 and implemented as opportunities arise. The restoration projects listed here (Table 14) were identified based on the hierarchy of priorities in Figure 17 and ranked using the criteria in Table 12. Projects with the same score were ordered based on the potential area in habitat and/or floodplain benefit as extracted from the assessment data. To sequence restoration actions into short, near-term, and long-term we considered the number of landowners potentially involved and other major factors that could affect or limit implementation. Our prioritized and sequenced list of restoration actions follows (Table 14). Five projects were identified as potentially implemented within the next five years.

Implementation of the priority actions in this plan will be iterative as the actions identified are at different stages of development and feasibility. A compilation of information available to date along with a brief overview of the restoration potential at each site is being developed separately. The highest priority actions able to be implemented and appropriately sequenced (Figure 17) will be identified for further design work and funding. Project areas in need of more in-depth analysis, planning, or design work can be sequenced based on relative priority.

This Plan does not include the project level detail and data or the stakeholders necessary to refine the biologic priorities or implementation schedules listed here based on cost and balancing other interests. By necessity we expect considerations of what is possible and realistic in the human landscape to be further developed during implementation of the priority projects presented here.

Table 14. Ranked list of priority restoration projects identified for the middle Skagit River with additional implementation sequencing considered.

Project Number and Rank	Habitat Priority Score[3] Columns 1+2+3	Project	(1) Reach Priority 1, 2, 3	(2) Treatment Type or Strategy	(3) Scale/ Benefits	Est. area of habitat re-connected	Est. area of floodplain shadowed or isolated	Acquisitions or # willing landowners needed for restoration (few, many)	Other factors limiting implementation	Short term < 5 yrs	Near term 5-10 yrs	Long term 10-20+ yrs
1	15	Cockreham Island restoration complex	5	5	5	9 ac	1200 ac	many	Large scale design & risk assessment			✓
2	14	Hamilton floodplain restoration	5	4	5	12+ ac	400-900 ac	many	Hamilton PDA process			✓
3	14	Gilligan Creek floodplain restoration	5	4	5		170-230 ac	6			✓	
4	14	Skiyou Slough upstream connectivity	5	5	4	13 ac[4]	-	3	should follow Gilligan project			✓
5	14	Etach Slough interim reconnection	5	5	4	9 ac	-	few	feasibility		✓	
6	13	Youngs Slough reconnection and restoration (former Wiseman Creek channel)	5	5	3	4 ac	63 ac	5	assess risk to landowners			✓
7	13	Davis Slough reconnection	5	5	3	4.5 ac	-	2		✓		
8	13	Ross Island off-channel reconnection at SK060A-13	5	5	3	2 ac	49 ac	1	Field check to verify	✓		
9	13	Careys Slough interim off-channel reconnection & restoration	5	5	3	12 ac	-	town, Co.	Needs additional scoping, water quality; Chinook benefit		✓	
10	12	Savage-Mill Creeks off-channel reconnection complex	3	5	4	22 ac	57 ac	2	cost to move county road		✓	
11	12	Black Slough floodplain restoration	5	3	4	-	112 ac	4	Field check		✓	
12	12	Robinson Rd floodplain restoration	5	3	4	-	117 ac	3	risk analysis associated with levee removal		✓	
13	12	Day Creek Meadows off-channel reconnection	5	5	2	2 ac	-	5	connected at higher flows	✓		
14	11	Day Creek Slough floodplain restoration	5	3	3	-	69 ac	2			✓	
15	11	Cascade Trail floodplain restoration	5	3	3	-	26 ac	6	trail right of way relocation			✓
16	10	Utopia Rd at Minker Rd floodplain restoration	5	3	2	-	10 ac	2	assess risk to other landowners		✓	
17	10	Ross Island Slough inlet improvement at SK060A-14	5	3	2	-	29 ac	few		✓		
18	10	Coal Creek trib junction floodplain restoration at SK060A-1	5	3	2	-	260 ac total 30 ac poss.	2	Levee setback limited as protects infrastructure downstream			✓
19	9	Thunderbird Lane floodplain restoration	3	3	3	-	20-85 ac	many	many small recreational lots			✓
20	8	Cumberland off-channel habitat improvement	5	1	2	2 ac		1	County road		✓	
21	8	Lyman side channel habitat improvement	5	1	2	3.6 ac		3		✓		

[3] Ordering among projects with the same score based on area and current function where appropriate
[4] Area of slough not shown as used by Chinook

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APPENDIX A Hydrodynamic Modeling Report

Hydrodynamic Modeling for Assessment of Floodplain Restoration Potential on the Middle Skagit River, WA

Project Report
June, 2010

Prepared for

Skagit Watershed Council

by

Integrated Coastal Ocean Modeling Group (ICOM)
Marine Science Laboratory, PNNL
Seattle, WA

Pacific Northwest
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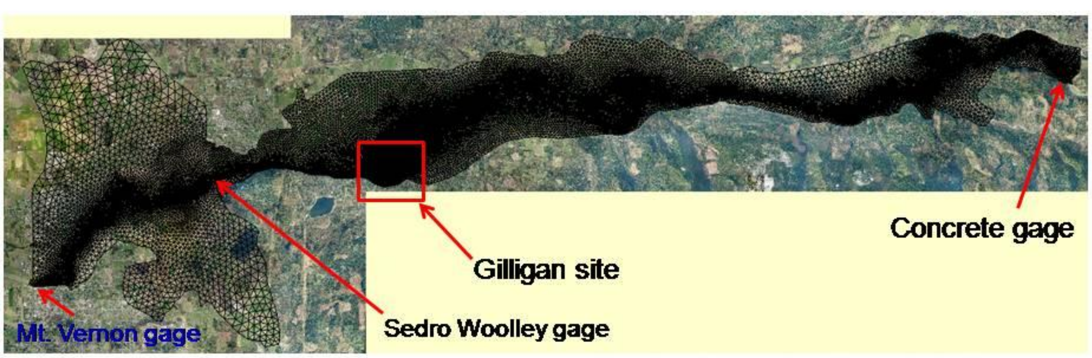
Previous Floodplain Modeling Analysis

- Hydraulic Analysis for Floodplain Restoration near Gilligan Creek conducted for SRSC (PNNL, 2009)
- Objectives
  - Develop 3D hydrodynamic model for Middle Skagit Floodplain from Mt Vernon to Concrete gage
  - Evaluate existing hydrodynamic conditions at Gilligan Creek site
  - Evaluate three alternatives for their effect on flood potential



Extension of Modeling Analysis - Objectives

- Extend model grid upstream to the conference of Sauk River and Skagit River using geo-referenced USACE cross-sections
- Incorporate key hydro-modifications into the model
- Validate the model for existing condition using water level data and PSE velocity data
- Simulate three flood hydrographs for existing conditions
- Evaluate flood potential with removal of key hydro-modifications
- Provide model results for habitat potential mapping

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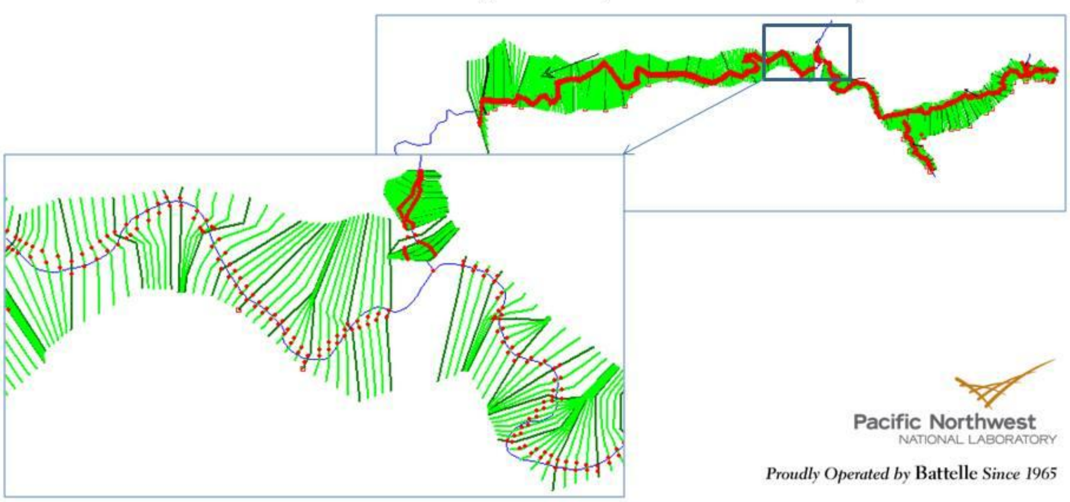
USACE New Cross Sections (HEC-RAS)

- HEC-RAS model
  - 1-D hydraulic model for simulating water flow through natural rivers and other channels (http://www.hec.usace.army.mil/software/hec-ras/)
- HEC-RAS model bathymetry (total 669 cross sections)
  - Data used to check existing model grid for consistency



4

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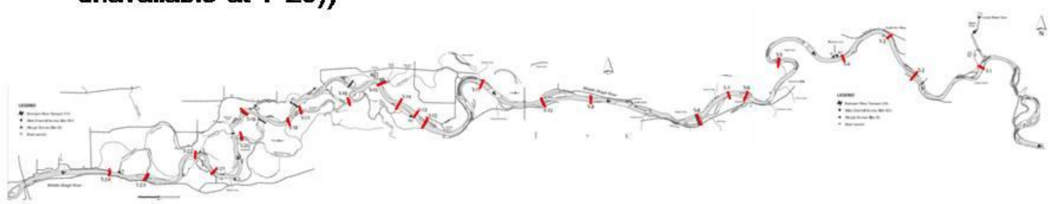
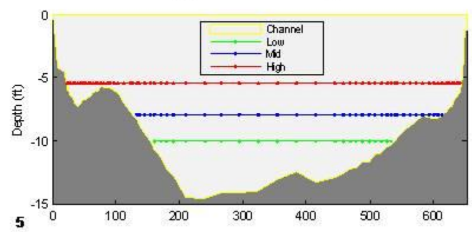
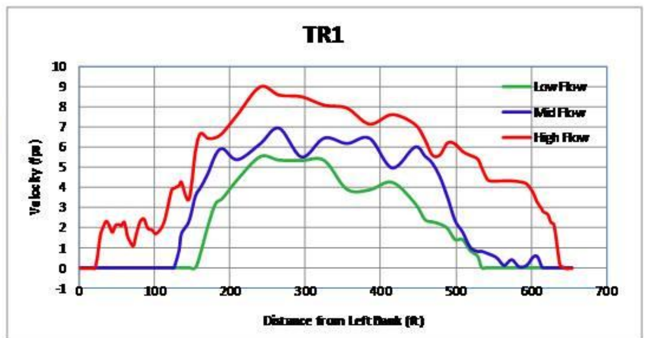
PSE Velocity Data (8/2002 – 3/2003)

- Cross-section distribution (24 cross sections **(field data unavailable at T-20)**)



- Velocity data for three flow conditions
  - Low flow: 4,500 cfs
  - Mid flow: 11,000 cfs
  - High flow: 23,000 cfs





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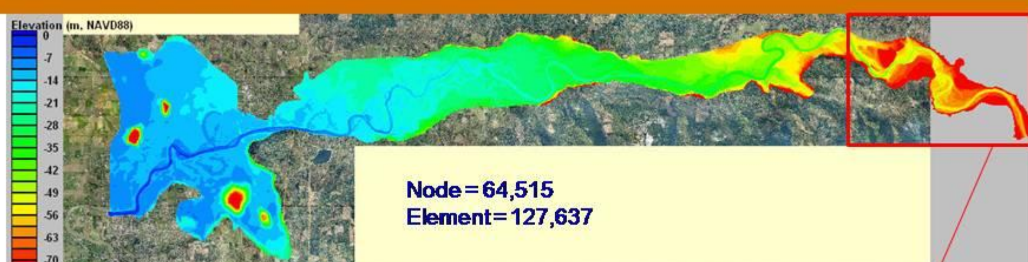
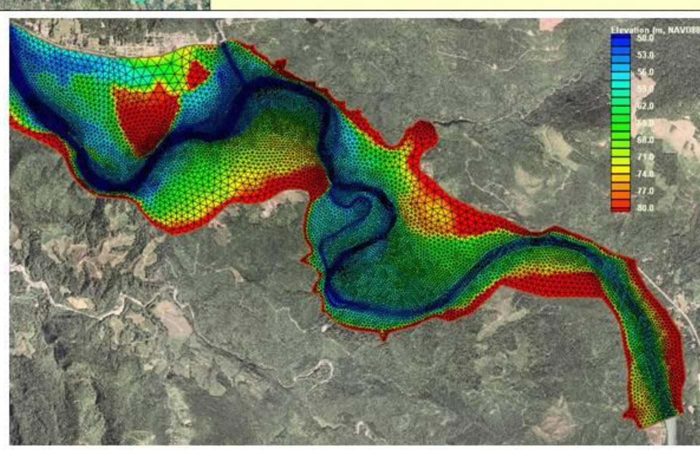
Extension of Model Domain





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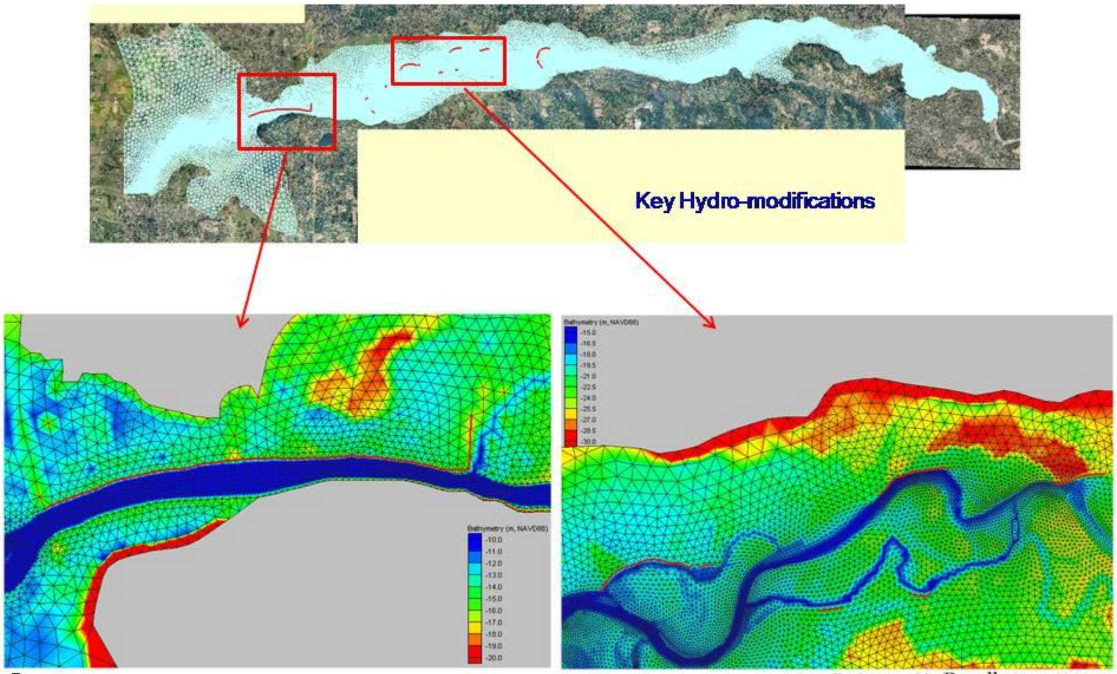
Incorporation of Key Hydro-modifications



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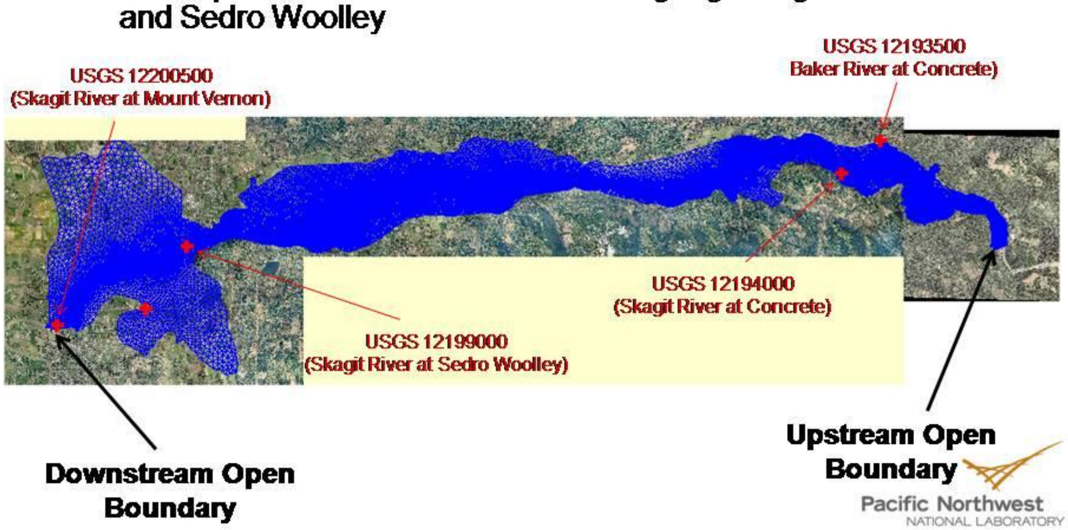
Model Setup for Validation

- Water level validation
  - Validation period: 2003 October flood
  - Model prediction vs. USGS measured gauge height at Concrete and Sedro Woolley



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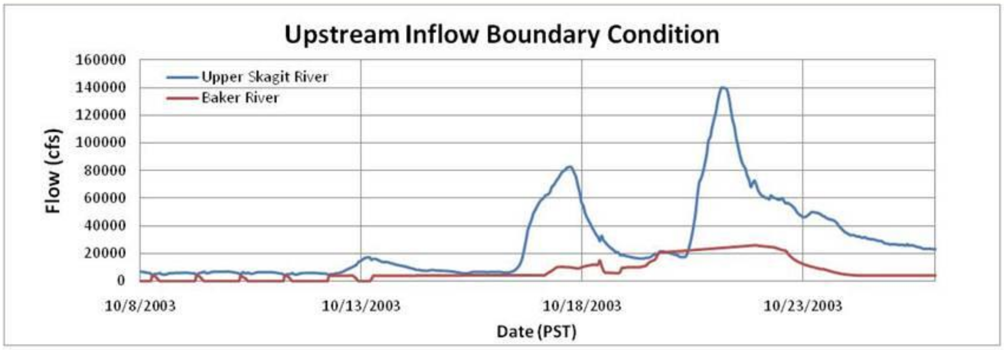
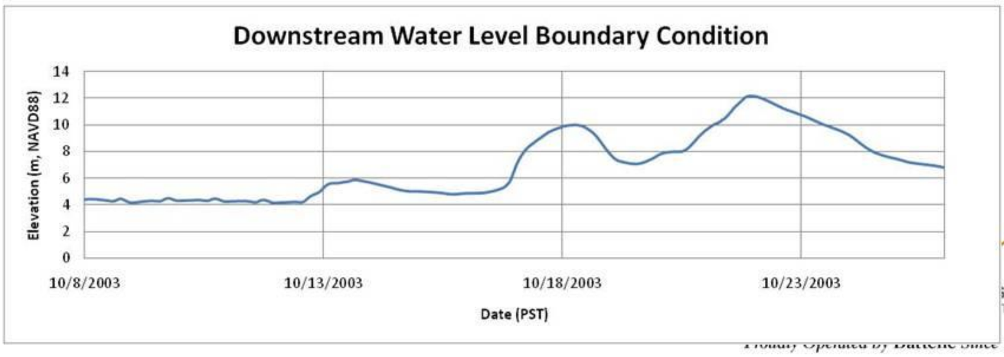
Model Boundary Conditions





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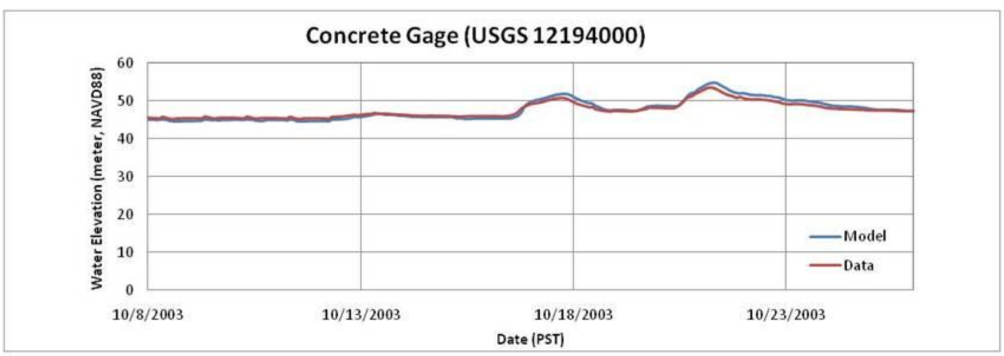
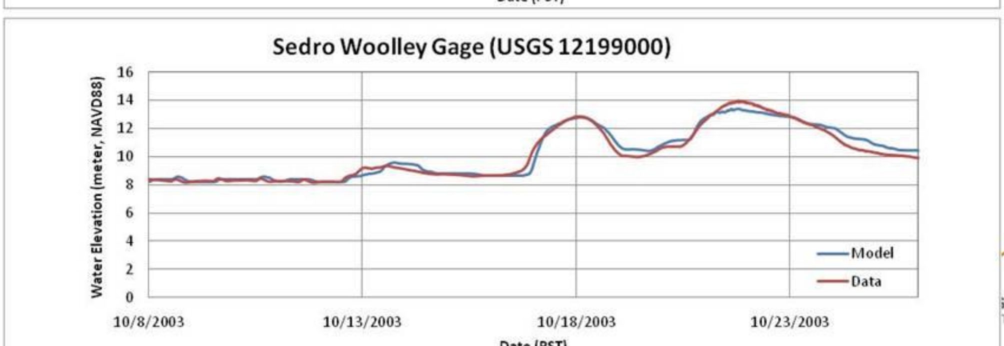
Model Validation for Water Level





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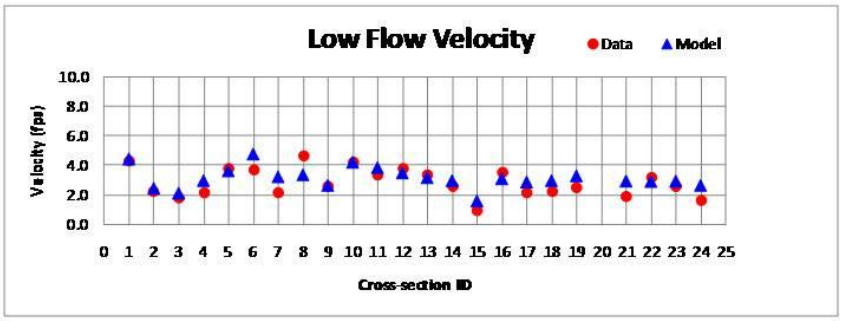
Model Validation for Velocity – Low Flow

- Comparison of cross-section averaged velocities
- Error statistics
  - Mean Error = 0.3 ft/s
  - Mean Absolute Error = 0.53 ft/s
  - Root Mean Square Error = 0.64 ft/s



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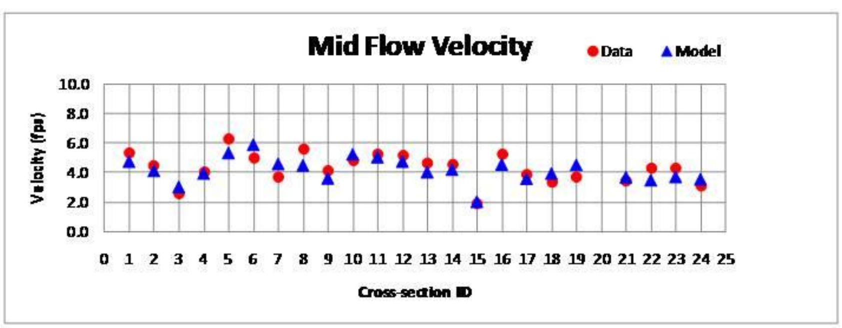
Model Validation for Velocity – Mid Flow

- Comparison of cross-section averaged velocities
- Error statistics
  - Mean Error = -0.10 ft/s
  - Mean Absolute Error = 0.54 ft/s
  - Root Mean Square Error = 0.60 ft/s



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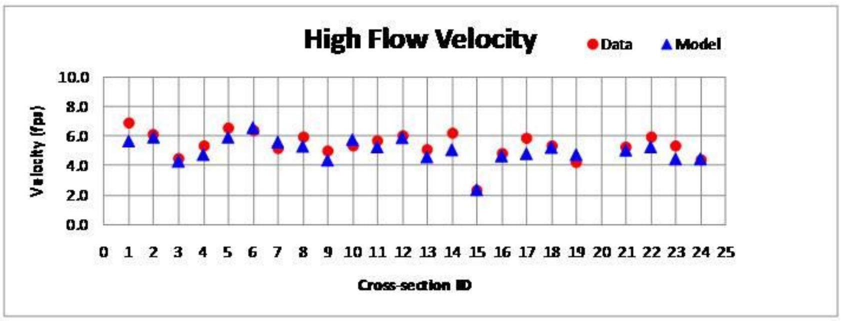
Model Validation for Velocity – High Flow

- Comparison of cross-section averaged velocities
- Error statistics
  - Mean Error = -0.33 ft/s
  - Mean Absolute Error = 0.48 ft/s
  - Root Mean Square Error = 0.59 ft/s



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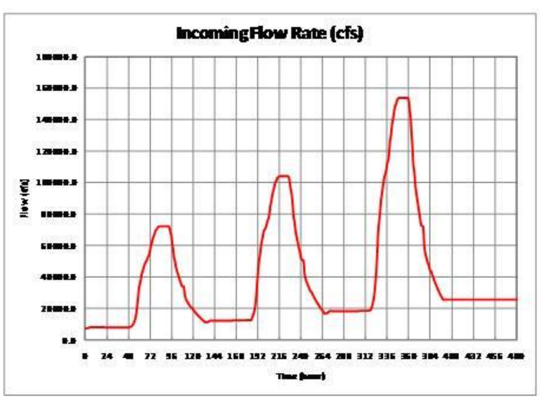
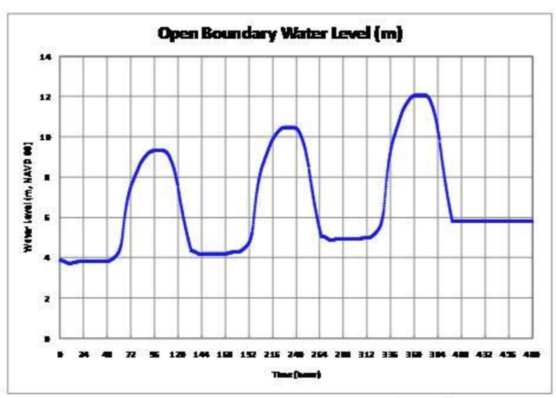
Simulation of Flood Scenarios

- Three flood flow conditions
  - 2-year flood: 72,500 cfs
  - 5-year flood: 104,000 cfs
  - 25-year flood: 154,000 cfs





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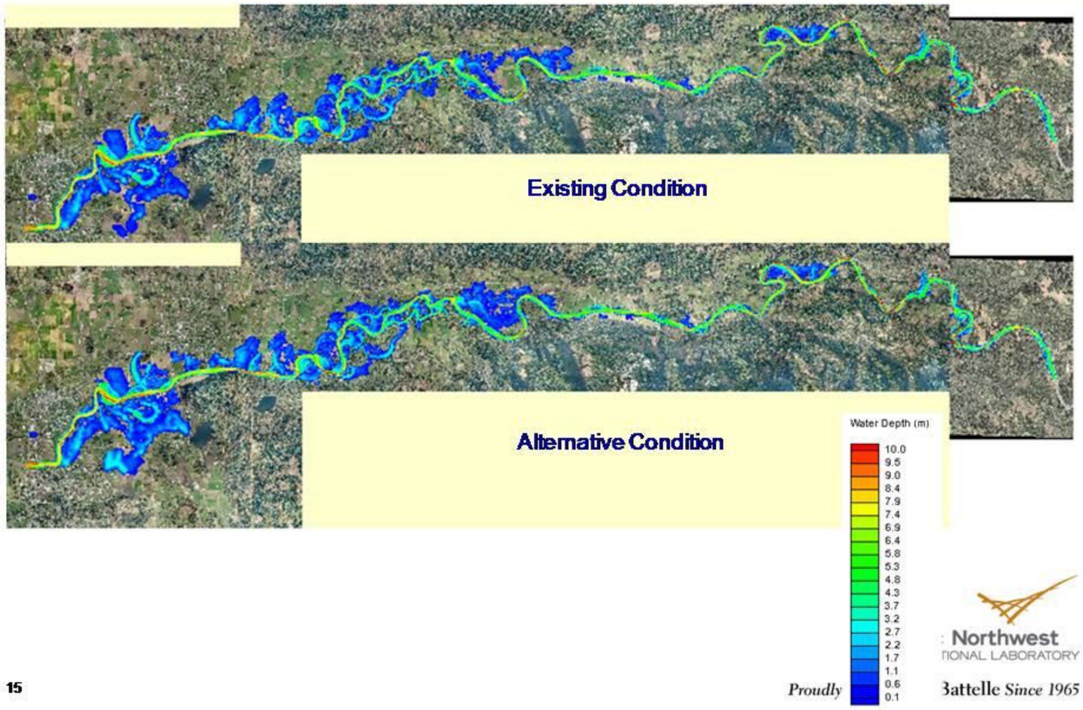
Flooding Areas for Existing and Alternative Conditions for a 2-year Flow (72,500 cfs)



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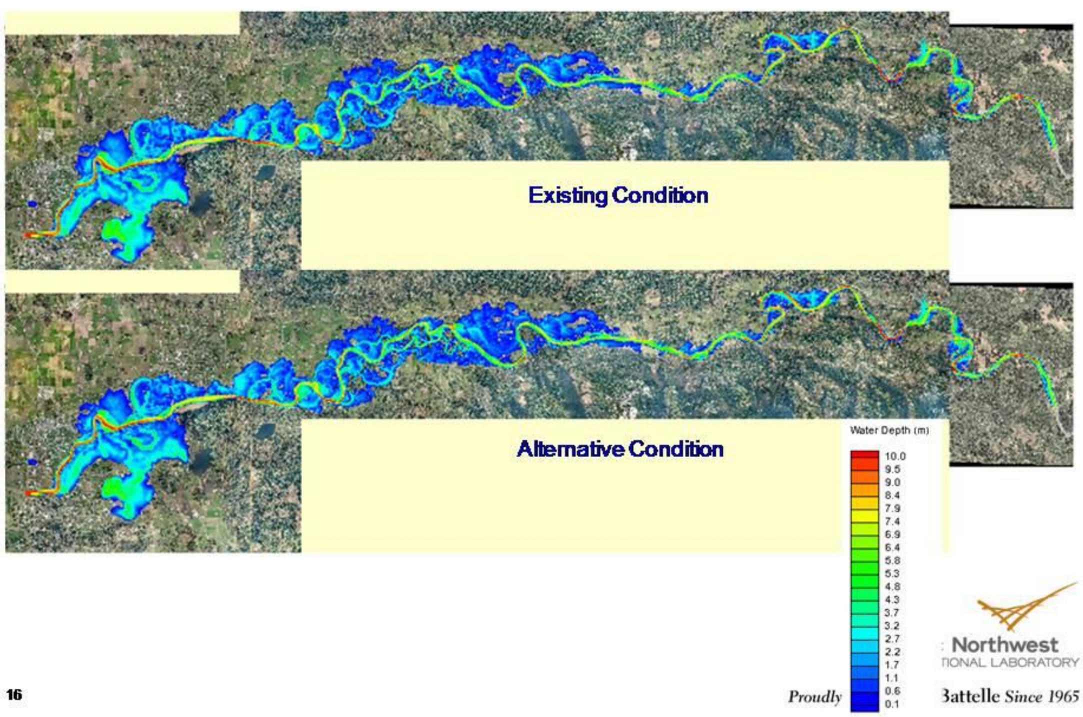
Flooding Areas for Existing and Alternative Conditions for a 5-year Flow (104,000 cfs)



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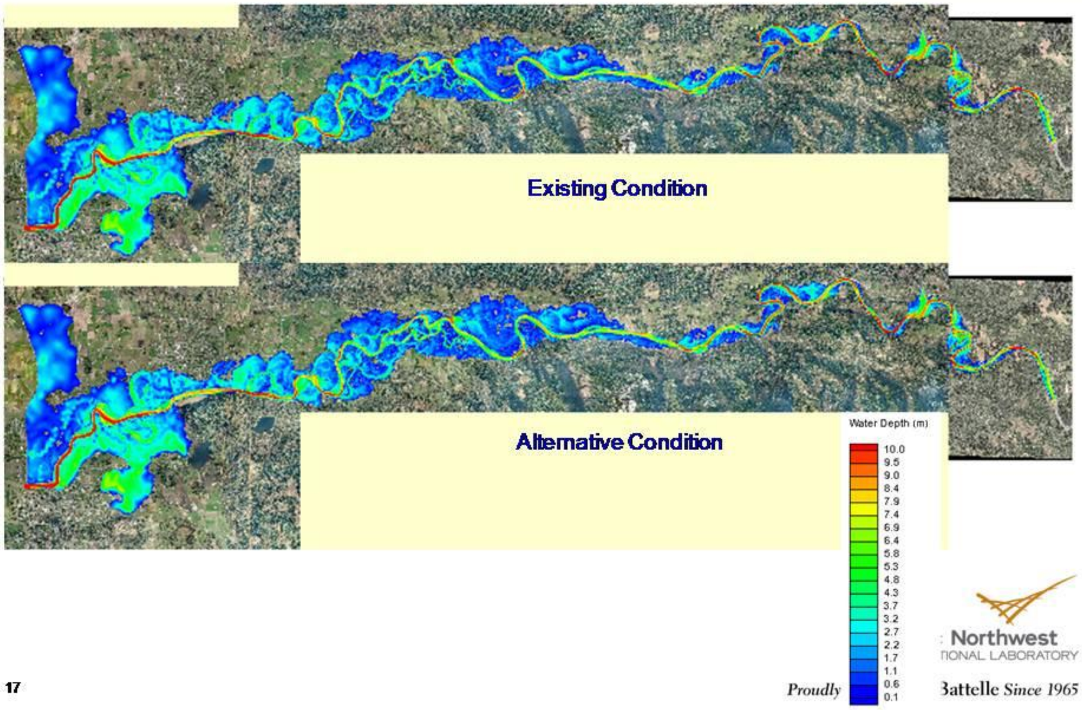
Flooding Areas for Existing and Alternative Conditions for a 25-year Flow (154,000 cfs)



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Summary

- Update and extension of middle Skagit floodplain model to the confluence of Skagit and Saulk Rivers
- Model validation with PSE velocity data for three different flow conditions
  - RMSE = 0.61 ft/s (for all data)
- Application to three flood flows for existing and alternative (without hydro-mod) conditions
  - 2-year flood: 72,500 cfs
  - 5-year flood: 104,000 cfs
  - 25-year flood: 154,000 cfs
- Provide model results for habitat mapping under existing and alternative conditions with different flood flows

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APPENDIX B Simulation Modeling of Juvenile Chinook Salmon Habitat

Simulation Modeling of Juvenile Chinook Salmon Habitat for the Middle Skagit River Assessment

Prepared for:
Skagit Watershed Council

Prepared by:
Ed Connor
Seattle City Light
April 1, 2011

Introduction

The Middle Skagit Assessment Project was conducted by the Skagit Watershed Council (SWC) in part to identify the most important areas for protecting and restoring the habitat of Chinook salmon in the 43.2-mile section of the Skagit River between the town of Sedro Woolley and the confluence of the Sauk River. The middle Skagit River was identified by the Skagit Chinook Recovery Plan (SRSC and WDFW 2005) as one of the most limiting regions of the Skagit watershed for the production of Chinook salmon. Scientists with the Northwest Fisheries Science Center also identified the middle Skagit as one of the two areas in the Skagit basin where habitat restoration and protections areas should be prioritized. The Skagit Watershed Council identified both the estuary/delta and the middle Skagit as the highest priority areas for restoration, protection, and ESA recovery efforts for Chinook salmon (SWC 2010).

The greatest constraint to Chinook productivity in Skagit River basin is quantity and quality of juvenile rearing habitat (SRSC and WDFW 2005), and the areas within the watershed where rearing habitat is most limiting are the middle Skagit and the freshwater tidal delta and estuary. Juvenile rearing habitat has been lost in the middle Skagit due to the widespread construction of dikes, levees, roads, culverts, and other structures that have isolated floodplain from the river (SRSC and WDFW 2005). Levees and bank armoring has resulted in the channelization of several areas the middle Skagit, resulting in a confined mainstem channel that lacks natural edge and bank morphology and vegetation. These hydromodifications can have reduced the availability of the low-velocity habitats required by juvenile Chinook salmon and steelhead that rear along the mainstem Skagit. Habitat has been further degraded by land development throughout floodplain of the middle Skagit, resulting in the loss of riparian habitats and wetlands. These areas greatly improve invertebrate production in floodplain channels and along the margins of the mainstem river, thus improving the growth and survival of juvenile Chinook.

One of the main objectives of Skagit Watershed Council's assessment project is to identify the most important reaches (or "hotspots") in middle Skagit for juvenile Chinook under current conditions. The assessment also had the complimentary objective of identifying those reaches that could provide abundant and high quality juvenile Chinook rearing habitat provided that major hydromodifications were removed and natural channel and floodplain processes restored. The first objective seeks to identify the most important reaches within the middle Skagit for conservation land purchases for habitat protection, while the second objective seeks to identify the most important reaches for habitat restoration.

The mainstem and floodplain habitats of large rivers historically provided abundant natal and non-natal habitat for juvenile Chinook salmon. The middle Skagit is an important spawning area for Chinook salmon, and supports the majority of fall-run Chinook spawners in the watershed (SRSC and WDFW 2005; NOAA 2005). The middle Skagit provides natal rearing habitat for the majority of these fish. It also provides non-natal rearing habitat for juveniles originating from upper areas of the watershed, including the Upper Skagit, Cascade, Suiattle, and Sauk rivers. However, the middle Skagit can no longer support the number of juvenile Chinook that migrate through this section of the river. The maximum production of the riverine rearing juvenile Chinook is presently about 2.2 million fish (Zimmerman et al. *In Prep*), with the number of smolts produced from riverine habitats declining when spawner abundance exceeds approximately 10,000 adults. The decline in smolts that originate from river rearing juveniles indicates that the habitat capacity of the mainstem river is being exceeded, and that the survival rate of juvenile Chinook that rear in these areas is declining (Zimmerman et al. *In Prep*). Reduced survival rates of juvenile Chinook rearing in the middle Skagit would likely result from competition due to the lack of suitable rearing habitat, and reduced growth rates in these areas due to limited food resources.

I employed a set of hydraulic and habitat simulation models to determine the availability of juvenile Chinook rearing habitat among the different reaches of the middle Skagit River. This modeling approach was used to identify those areas and major habitat types, which provided the most suitable rearing conditions for juvenile Chinook. This modeling approach assumed that two physical habitat variables, depth and velocity, were the primary factors limiting the availability of juvenile rearing habitat in the middle Skagit. The hydraulic and habitat simulation modeling was based upon transect data collected in the middle Skagit by Puget Sound Energy (PSE) as part of an instream flow study of the middle Skagit completed for the Baker Hydroelectric Project relicensing (R2 Resource Consultants 2008). PSE provided the transect data to the Skagit Watershed Council for the purpose of identifying conservation land acquisition and restoration projects for salmon in the middle Skagit.

Methods

The middle Skagit River was delineated into nine reaches for the SWC's assessment project. These reaches were based upon those originally defined in the Skagit Chinook Recovery Plan (SRSC and WDFW 2005), and were based upon the channel types and hydromodifications defined in the recovery plan. The reaches were modified for the purposes of the Middle Skagit River Assessment Project to reflect longitudinal changes in river channel morphology, including meander pattern, channel form, floodplain confinement, and gradient. The nine reaches of the middle Skagit delineated for the purposes of the assessment project are described in Table 1. Transect data was collected by PSE in the six reaches downstream of the confluence of the Baker River. Recent transect data was not available for the three reaches of the middle Skagit upstream of the Baker River, so these reaches were not included in the hydraulic and habitat simulation modeling described in this report.

Tab1e 1. Reaches of the middle Skagit River used in the Middle Skagit Assessment Project (river miles obtained from USGS topography; channel length, channel pattern, and floodplain width values were obtained from SRSC 2011).

Reach Number	Reach Name	Starting River Mile	Ending River Mile	Channel Length (mi)	Channel Pattern Type	Floodplain Width (ft)
1	Skiyou	24.3	28.5	4.7	Straight	5,975
2	Ross Island	28.5	35.0	6.2	Island-Braided	8,840
3	Cockreham	35.0	42.5	7.7	Meandering	6,179
4	Savage	42.5	47.4	4.7	Straight	2,247
5	Cape Horn	47.4	52.2	4.8	Meandering	2,939
6	Baker	52.2	56.6	4.8	Straight	992
7	Jackman	56.6	60.5	3.7	Island-Braided	2,724
8	Aldon	60.5	64.0	3.2	Straight	988
9	Rockport	64.0	67.2	3.4	Straight	1,658

Simulation modeling of juvenile Chinook salmon habitat was conducted using the Physical Habitat Simulation System (PHABSIM), an integrated set of hydraulic and habitat simulation models developed by the U.S. Geological Survey. PHABSIM predicts the amount of suitable habitat available to specific species and life stages of fish based at different stream and river flows, and is the habitat simulation component of the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service, the most widely used river habitat simulation model in the United States (Stalnaker et al. 1995; Milhous and Bartholow 2006). Modeling habitat with PHABSIM involves several steps (Bovee et al. 1998), including:

- Collecting velocity, depth, and substrate data across a number of cross-sectional transects established with each study reach of a stream or river for one or more flows conditions;
- Collecting water surface elevations at a minimum of three flows at each transect;
- Completing a calibrated hydraulic model which is used to predict velocities, depths, and substrate types across river channel for up to 100 different flows;
- Development of habitat suitability index (HSI) curves which describe the velocities, depths, and substrate types preferred by a given species and life stage of fish; and
- Complete habitat simulation modeling runs using the output of the hydraulic model and the HSI curves to estimate the availability of suitable habitat for a given species and life stage across each transect;
- Combining the results of the habitat simulation modeling runs for the individual transects based upon the length of river channel represented by each transect, and then generating a weighted usable area (WUA) versus flow curve for every study reach.

The resulting habitat area versus flow curves can then be used in conjunction with daily river flow to calculate a time-series of daily habitat values for a period of analysis. For this study, daily habitat values were calculated for the rearing period of juvenile Chinook salmon in the middle Skagit River, which was established to be March 1 through June 30 based upon smolt outmigration numbers and growth rates observed at the WDFW smolt trap in the lower Skagit River (Kinsel et. al 2008).

Transect Data Collection

Puget Sound Energy (PSE) collected data from 23 transects located in the middle Skagit River between August 2002 and March 2003 (R2 Resource Consultants 2008). A total of 10 transects were established in the Skagit River between the towns of Concrete and Hamilton (Figure 1), and 13 transects were established between the towns of Hamilton and Sedro Woolley (Figure 2). The transects were established to represent the range of channel types found in the middle Skagit, including straight, sinuous, and island-complex habitats, as well as natural and hydromodified sections of the river (Table 2). Several of the transects were divided into two segments in order to model hydraulic and habitat conditions in areas where the mainstem river was divided by an island (transects 6,8, and 10), or in the Ross Island reach where the river separates into multiple mainstem channels (transects 16 through 20). These transect segments were modeled independently, since they had unique water surface elevations and flow regimes. Consequently, a total of 28 hydraulically independent transects were employed in the study. These transects did not extend into the independent side channels, sloughs, and tributaries of the floodplain. Consequently, the results of this study apply to mainstem river habitats only, and do not describe the rearing habitat provided by off-channel habitats in the floodplain.

Velocity, depth, and substrate-type values were measured across each transect at intervals that ranged between 5 ft and 20 ft, with the greater intervals applied to the longer transects. Velocity and depth measurements were recorded with an acoustic Doppler current profiler across sections of the river channel that had a depth greater than 2.5 ft, and with a stadia rod and current meter in shallow areas near the river banks (R2 Resource Consultants 2008). Water surface elevations were measured at each transect using a total station, and were measured relative to a local survey benchmark established near each transect. Velocity, depths, substrate types, and water surface elevation data were measured at three flow conditions at each transect: approximately 4,000 cfs (low); 11,000 cfs (medium); and 26,000 cfs (high).

Hydraulic Modeling

Hydraulic and habitat simulation modeling of the middle Skagit was completed using PHABSIM for Windows (Waddle 2001). PSE provided copies of the transect data files to SWC in Excel spreadsheet format. These data were then converted for each of the 28 transects into the format required by the PHABSIM hydraulic simulation model IFG4. These data files were then calibrated to accurately predict velocities and depths across each transect cross-section for flows ranging from 3,000 to 50,000 cfs. Calibration the data files involved two steps: calibrating stage-discharge functions at each transect, and then velocities across each transect.

A stage-discharge relationship was calculated and calibrated at each transect using a log-stage versus log-flow regression. The water surface elevations predicted by the model were compared with water surface elevations measured at each transect under low, medium, and high flows. The stage-discharge relationships were following calibration procedures recommended by USGS (Waddle 2001) until the best goodness-of-fit in the stage-discharge relationship was achieved for each transect. The calibration procedures resulted in an excellent goodness-of-fit value at all transects (the regression R-Square value exceeded 99.0 in all cases).

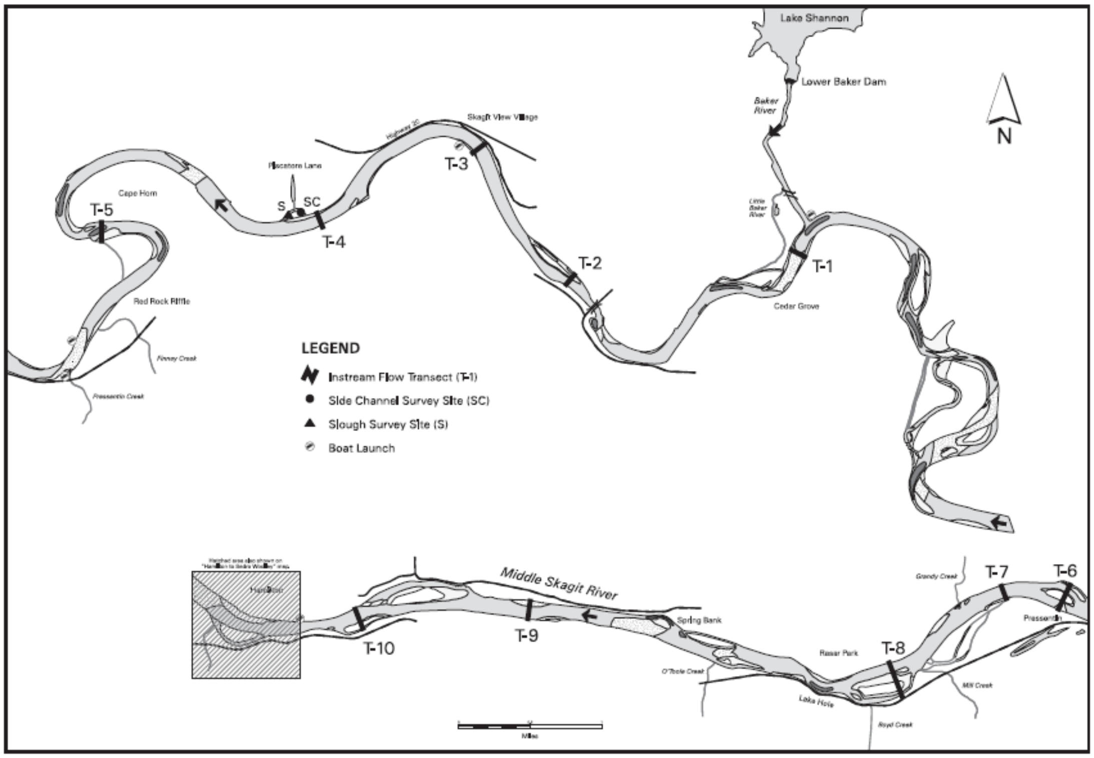

Figure 1. Middle Skagit River from Concrete to Hamilton, showing instream flow transects 1 through 10 (source: R2 Resource Consultants 2008).

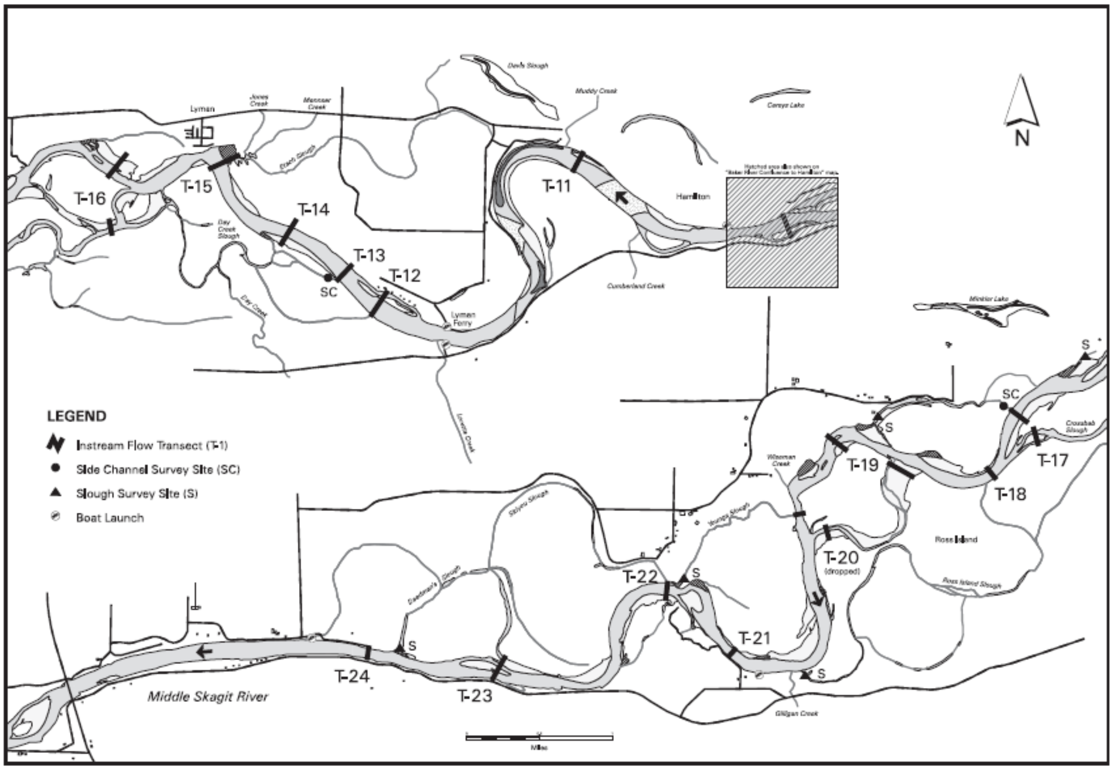

Figure 2. Middle Skagit River from Hamilton to Hamilton, showing instream flow transects 11 through 24 (source: R2 Resource Consultants 2008).

The IFG4 hydraulic simulation model was then calibrated to accurately predict velocities across each transect for the full range of simulation flows. This involved two modeling procedures. First, velocities were predicted for low to medium flows (3,000 to 24,000 cfs) using the velocity-flow regression approach preferred for river habitat simulation studies by the Wash. Dept. of Fish and Wildlife and Wash. Dept. of Ecology (WDFW and WDOE 2008). Calibration involved comparing predicted and measured velocities across each transect for each of the three calibration flows (i.e., flows under which data was collected in field), and minimizing the difference between the predicted and measured velocities. Second, a separate "high flow" model was completed to model velocities across each transect for flows greater than 24,000 cfs (the highest flow for which velocities were measured in the river). The high flow model predicted velocities across each transect using channel roughness coefficients (Manning's N values) calculated at each transect interval. Calibration involved modifying individual channel roughness coefficients across each transect following IFG4 protocols (Waddle 2001). The calibrated high flow model reasonably predicted velocities across each transect for flows ranging from 26,000 to 50,000 cfs.

Tab1e 2. Location and description of instream flow transects used for middle Skagit habitat simulation model (channel location and type obtained from R2 Resource Consultants 2008).

Transect	Reach	River Mile	Channel Type	Channel Planform	Right Bank	Left Bank
1	6	56.2	Single, symmetric	Straight	Natural Bar	Natural Bar
2	6	53.9	Island	Straight	Natural Bank	Natural Bank
3	6	52.6	Single, asymmetric	Bend	Natural Bank	Natural Bank
4	5	51.3	Single, asymmetric	Bend	Natural Bar	Natural Bank
5	5	48.9	Single, asymmetric	Bend	Natural Bar	Modified Bank
6	4	46.6	Island	Bend	Natural Bar	Natural Bank
7	4	46.2	Single, asymmetric	Straight	Modified Bank	Natural Bar
8	4	45.2	Island	Bend	Natural Bank	Natural Bar
9	4	42.6	Single, asymmetric	Straight	Natural Bar	Natural Bank
10	3	41.5	Complex	Bend	Modified Bank	Natural Bar
11	3	39.8	Single, asymmetric	Bend	Natural Bar	Natural Bar
12	3	37.1	Divided	Bend	Modified Bar	Natural Bank
13	3	36.8	Single, asymmetric	Straight	Natural Bar	Natural Bank
14	3	36.4	Single, asymmetric	Bend	Natural Bank	Natural Bar
15	3	35.6	Alcove	Bend	Natural Backwater	Natural Bar
16	2	34.8	Multi Channel	Bend	Natural Bar	Natural Bank
17	2	33.1	Multi Channel	Bend	Natural Bank	Natural Bar
18	2	32.7	Multi Channel	Bend	Natural Bank	Natural Bar
19	2	31.5	Multi Channel	Bend	Natural Bank	Natural Bar
21	1	29.3	Single, asymmetric	Bend	Natural Bank	Modified Bank
22	1	28.6	Single, asymmetric	Bend	Natural Bank	Natural Bar
23	1	27.0	Complex	Straight	Natural Bar	Modified Bank
24	1	26.0	Single, symmetric	Straight	Modified Bank	Modified Bank

A tributary and groundwater inflow model was then developed to estimate flow values occurring within each reach of the middle Skagit relative to flows at the USGS gaging station in Concrete (Dalles Gage). This model was based upon differences in daily flows measured between Concrete and Mount Vernon USGS gaging stations during the juvenile Chinook rearing period (March 1 through June 30), and calculated inflows predicted within each reach based upon cumulative basin area estimates. This model accounted for inflows from major tributaries, including Finney Creek and Day Creek, as well as groundwater inflows. The inflow model was used to predict daily flows at each transect based upon the daily flows measured at the Dalles Gage.

The final step to hydraulic simulation modeling was to develop a method to predict the separation of river flows for sites where the mainstem Skagit River split into multiple channels. Most of these sites were located in the Ross Island Reach (Figure 2). A log-log regression model was completed that predicted flows in each split channel based upon total river flow. The resulting model accurately predicted flows among channels in island complex sites for total river flows ranging from 3,000 to 50,000 cfs.

Suitability Curves

Habitat suitability index (HSI) curves were used to describe the velocities and depths that juvenile Chinook salmon would prefer in the middle Skagit. HSI curves were constructed from habitat suitability curves for large rivers developed Washington (WDFW and WDOE 2008), and from HSI curves developed for juvenile Chinook rearing by the U.S. Fish and Wildlife Service (Raleigh et al. 1986). HSI curves are scaled from 0.0 to 1.0, with a zero value expressing that the a particular velocity or depth value is highly unsuitable for a given species and life stage of fish, and a 1.0 value expressing the most preferred habitat conditions (Bovee et al. 1998). The HSI curves constructed for this study were verified by comparing the velocities and depths predicted as suitable habitat by the curves with the mean and range of velocity and depth values measured for juvenile Chinook in the Skagit River by SRSC and the Northwest Fisheries Science Center (Beechie et al. 2005; Hayman et al. 1996).
The velocity curve constructed for the middle Skagit Assessment show that mean column velocities between 0.4 and 1.5 feet per second (fps) provide the most suitable habitat conditions for juvenile Chinook salmon (Figure 3). Velocities become less suitable for juvenile Chinook as they approach zero. Also, habitat becomes progressively less suitable when velocities increase beyond 1.5 fps. Mean column velocities greater 3.6 fps are assumed to have no value as juvenile Chinook rearing habitat by this model. A study of microhabitat use by Chinook fry in the middle Skagit found that most fish were associated with slow-velocity habitats located along the margin of the mainstem river, with an average velocity of 0.5 fps (Beechie et al. 2005). Few Chinook fry were observed at velocities greater than 1.5 fps in this study. Studies of microhabitat use suggest that habitat use by juvenile Chinook declines when velocities decline below 0.4 fps (Raleigh et al. 1986; WDFW and WDOE 2008). Juvenile Chinook avoid zero-velocity habitats, especially if those areas are occupied by juvenile coho salmon (Taylor 1996).

The depth curve shows that a minimum depth of 0.45 ft is required for juvenile Chinook salmon habitat use (Figure 4). Depths become rapidly more suitable for juvenile Chinook as they increase beyond 0.5 ft. The curve assumes that depths greater than 1.5 ft are not limiting as habitat to juvenile Chinook. Velocity, not depth, is assumed to be the primary factor limiting the distribution and habitat use of juvenile Chinook in the mainstem Skagit river.

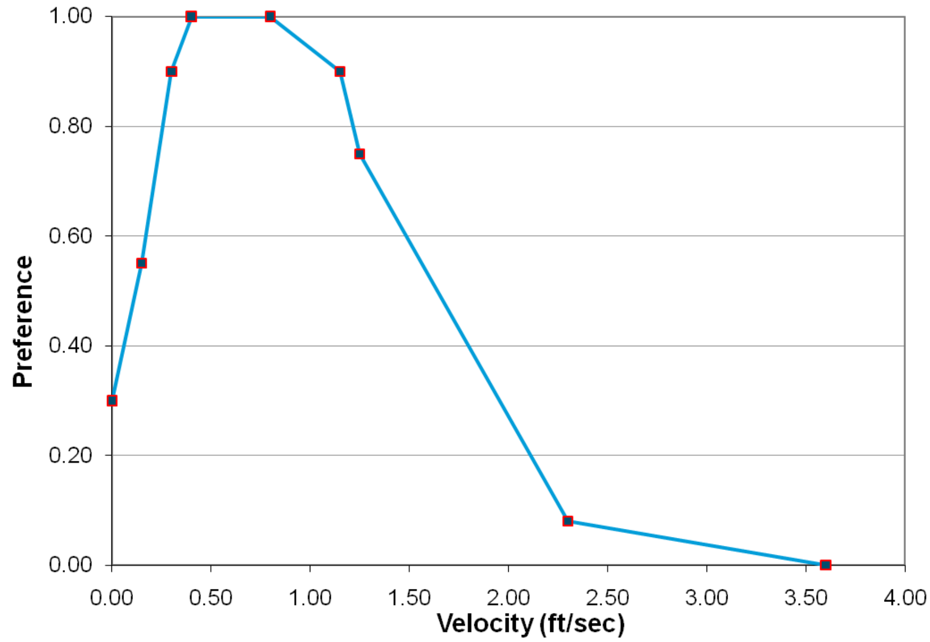

Figure 3. Velocity preference curve for juvenile Chinook salmon employed in for the middle Skagit assessment mainstem habitat simulation model.

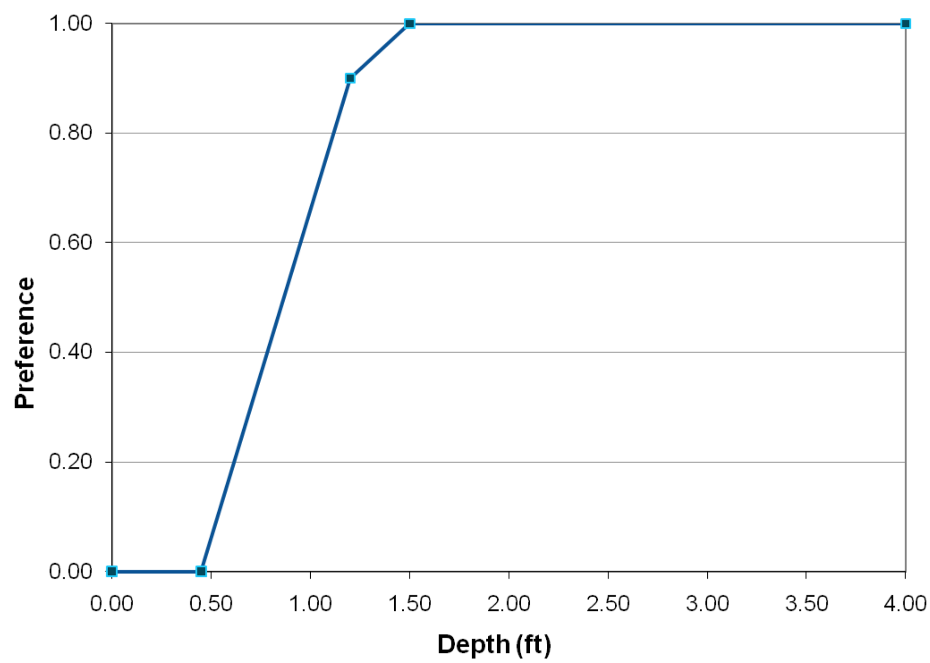

Figure 4. Depth preference curve for juvenile Chinook salmon employed in for the middle Skagit assessment mainstem habitat simulation model.

Habitat Simulation Modeling

Weighted usable area (WUA) versus flow curves were calculated at each transect using the habitat simulation program HABTAE (Waddle 2001). This program combined the data output from the hydraulic simulation model with the juvenile Chinook HSI curves to calculate the total width of each transect that provided suitable habitat conditions for juvenile Chinook for each simulation flow. WUA values were calculated at each transect for flows ranging from 3,000 to 50,000 cfs, in increments of 2,000 cfs. The WUA versus flow curves for all transects within a given reach were then combined based upon a weighting factor calculated for each transect. This weighting factor measured the proportion of habitat (e.g., straight channel with hydromodified banks) represented by a given transect. The habitat types present within a given reach, and the total length of mainstem channel habitat represented by each transect, were delineated from orthophotos of the middle Skagit study area using ArcMap GIS software.

The WUA curves in each reach were thus combined to yield a habitat area versus flow curve for the entire reach. The habitat area versus flow curves where then compared to identify the reaches, which provide the most amount of habitat for juvenile Chinook salmon rearing. The habitat area versus flow curves where then combined with daily flow values measured at the Dalles Gage. Daily flow data from 2007, 2008, and 2009 was used to produce a time-series record of daily habitat conditions occurring within each reach of the middle Skagit. The resulting plots were used described the total amount of habitat produced over the spring rearing period of juvenile Chinook salmon. These plots allowed us to identify those reaches of the middle Skagit producing the greatest and least amount of juvenile Chinook rearing habitat over time.

Results

Habitat Availability and Flow

The habitable width and area of the mainstem river channel was calculated for each of the six reaches by the habitat simulation model. Ross Island (Reach 2) was found to have the greatest mean habitable width (Figure 5), and provide the greatest habitable area (Figure 6) for juvenile Chinook in the middle Skagit River over the range of flows modeled. The habitable width of the Ross Island reach was 160 ft under low flow conditions of 3,000 cfs, declined to 82 ft at 10,000 cfs, and then progressively increased to 220 ft at 35,000 cfs (Figure 5). The habitable width remained stable at between flows of 35,000 and 50,000 cfs. Ross Island provided 120 acres of juvenile Chinook habitat area under low flow conditions (3,000 cfs), declining to 62 acres of habitat at 10,000 cfs (Figure 6). The habitat area in this reach progressively increased to 165 acres at a flow of 35,000 cfs, and then remained stable up to 50,000 cfs.

The Cochreham reach (Reach 3) was second to Ross Island in having the greatest habitable width and area for juvenile Chinook salmon rearing over the range of flows modeled. Cochreham had a mean habitable width of 95 ft under low flows (3,000 cfs), steadily declining to 50 ft at 40,000 cfs (Figure 5). The habitable width increased slightly to 55 ft from 40,000 to 50,000 cfs. This reach provided 90 acres of rearing habitat at 3,000 cfs, with habitat declining to 45 acres at 40,000 cfs (Figure 6). Habitat area then increased to 60 acres at 45,000 cfs, remaining stable to 50,000 cfs.

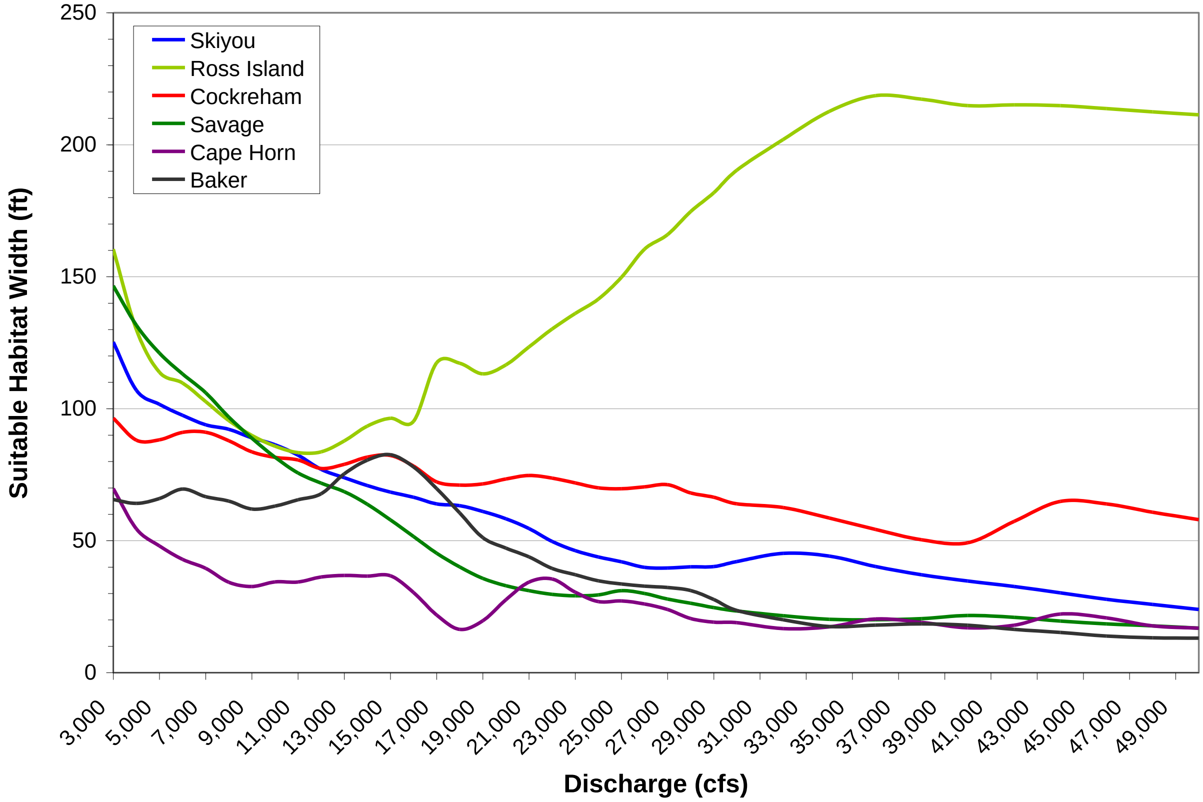

Figure 5. Juvenile Chinook salmon habitat width versus flow relationships six modeled reaches of the middle Skagit River.

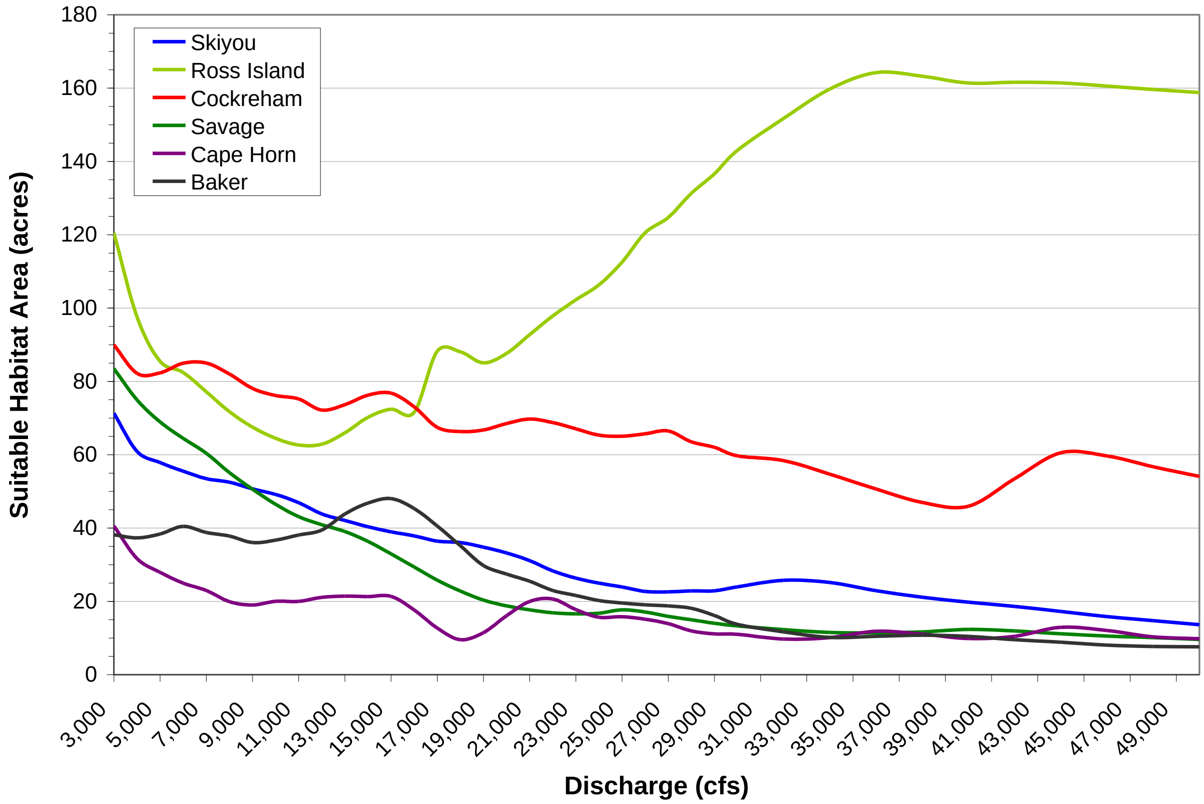

Figure 6. Juvenile Chinook salmon habitat area versus flow relationships six modeled reaches of the middle Skagit River. These plots shows the amount of rearing habitat available in the mainstem channel of the Skagit River within each reach for flows ranging from 3,000 to 50,000 cfs.

The Skiyou reach (Reach 1) provided the third greatest habitat width and area values over the range of flows modeled. The mean habitable width of this reach was greatest (125 ft) under low flow conditions (3,000 cfs), and progressively declined to 25 ft at 50,000 cfs (Figure 5). This reach has a habitat area 90 acres at 3,000 cfs, and then progressively declined to 15 acres at 50,000 cfs (Figure 6).

The Savage reach (Reach 4) ranked fourth in terms of habitat width and area over the range of flows modeled. The mean habitat width of this reach was highest (148 ft) under the low flow modeled (3,000 cfs), steadily declined to 20 ft at 30,000 cfs, and then remained fairly stable to flows of 50,000 cfs (Figure 5). Savage provided 84 acres of juvenile rearing habitat at 3,000 cfs, with suitable habitat declining to 10 acres at 35,000 cfs, and then remaining constant at 10 acres to 50,000 cfs (Figure 6).

The Baker reach (Reach 6) ranked fifth in terms of habitat width and area over the range of modeled flows. This reach had a mean habitat width of 58 ft at the lowest flows modeled (3,000 cfs), with habitat widths remaining stable through 12,000 cfs and then increasing to a maximum value of 75 ft at 15,000 cfs (Figure 5). The mean habitable width of this reach then progressively declined to 10 ft at 50,000 cfs. This reach provided almost 40 acres of habitat at 3,000 cfs, with habitat remaining steady through 12,000 cfs and then increasing to

45 acres at 15,000 cfs (Figure 6). The amount of suitable habitat provided by the Baker reach then steadily declined to 5 acres at 50,000 cfs.

Cape Horn (Reach 5) had the narrowest habitat width and smallest habitable area for juvenile Chinook salmon of the six reaches modeled. This reach had a mean habitable width of 70 ft at 3,000 cfs, which then declined to 15 ft at 18,000 cfs (Figure 5). The habitable width then increased to 30 ft at 22,000 cfs, but progressively declined to 15 ft again at 32,000 cfs. The habitable width then remained fairly constant up to 50,000 cfs. The habitat area provided by this reach was highest (40 ft) at 3,000 cfs, and then remained fairly stable at 20 ft between 8,000 and 15,000 cfs (Figure 6). The habitable areas of this reach dropped to 10 acres at 18,000 cfs, increased to 20 acres at 22,000 cfs, and steadily declined with increasing flow to 10 acres at 50,000 cfs.

The habitat curves were combined to produce a cumulative habitat area versus flow plot for all six reaches (Figure 7). The plot shows the total amount of habitat provide by the six reaches of the middle Skagit for flows from 3,000 to 50,000 cfs. The plot also shows the proportion of the total habitat provided by each reach at any given flow. The greatest amount of Chinook rearing habitat in the middle Skagit was 440 acres, which occurred under the lowest flows modeled (3,000 cfs). Total habitat area values rapidly declined to 250 acres at 20,000 cfs, but then remained relatively constant with increasing flows up to 50,000 cfs. Ross Island provided the greatest amount of habitat over all flows, and increased in habitat area with increasing flows above 18,000 cfs. Cochreham was second to Ross Island in the amount of habitat produced from 3,000 to 50,000 cfs, with habitat area slightly declining at flows above 18,000 cfs. The habitat area provided by the four remaining reaches – Skiyou, Savage, Cape Horn, and Baker – substantially declined with increasing flows above 18,000 cfs.

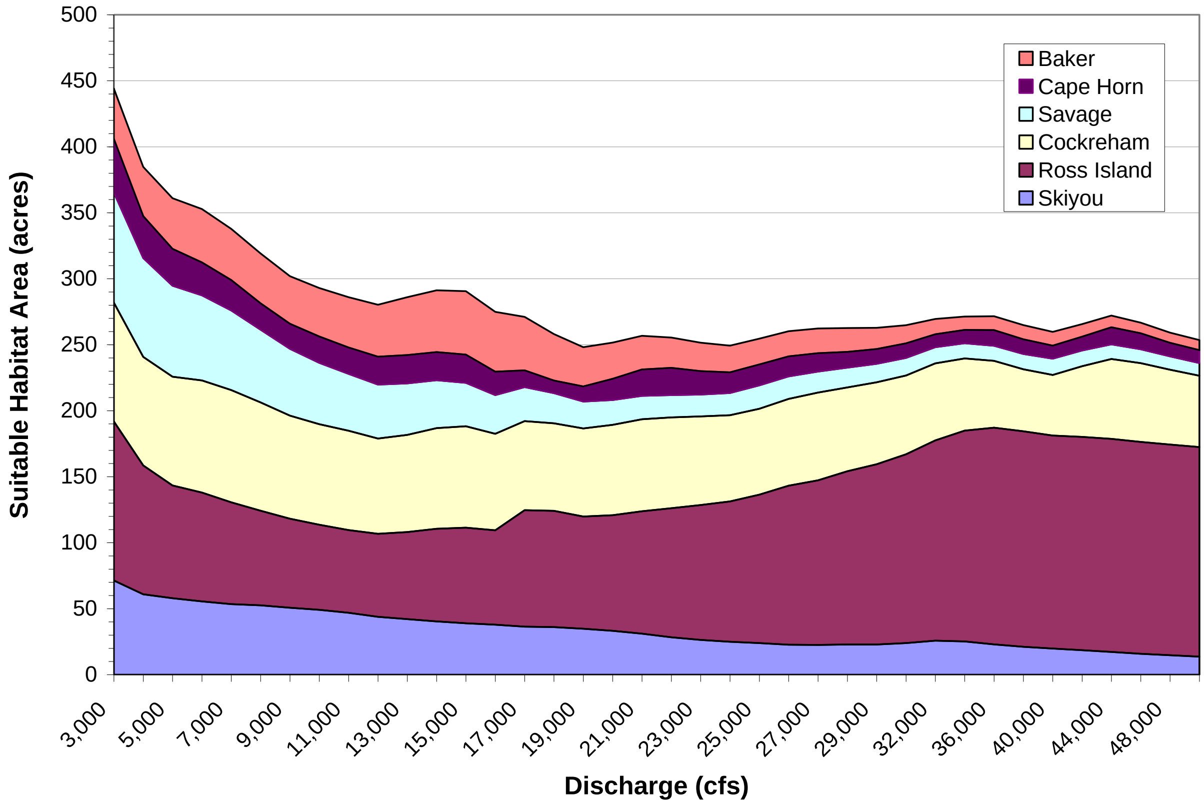

Figure 7. Cumulative habitat area versus flow relationships for juvenile Chinook salmon in the six modeled reaches of the middle Skagit River. The plot shows the total amount of rearing habitat provided in the six reaches of the middle Skagit for flows ranging from 3,000 to 50,000 cfs. The plot also shows the proportion of habitat provided by each reach at any given flow in this range.

Habitat Availability over Time

The habitat area versus flow functions for the six modeled reaches (see Figure 6) was combined with daily flow values to produce a time series of daily habitat values for the spring rearing period of juvenile Chinook in the Skagit River. Daily habitat values were calculated under flow conditions recorded at the USGS gage at Concrete for the years 2007, 2008, and 2009. These three years had very different flow characteristics during the spring rearing period of juvenile Chinook salmon in the middle Skagit (Figure 8). The spring of 2007 included two early high flow events, with flows increasing to 60,000 cfs and again to 52,000 cfs in March. Flows remained relatively higher during the 2007 juvenile Chinook rearing period. In contrast, flows in during spring 2008 remained relatively low from March through early May, and then increasing to a spring peak flow of 48,000 cfs in mid-May. Flows remained relatively high through the end of the snowmelt runoff period in June. Finally, flows during the spring of 2009 were lowest all (under 10,000 cfs) through mid-March, and then increased to approximately 20,000 cfs by mid-May. Flows then increased steadily through early June to a seasonal maximum flow of 30,000 cfs, after which flows gradually declined to 20,000 cfs. Unlike 2007 and 2008, no peak flow events were observed in 2009. Mean flows during the juvenile Chinook rearing period were 21,200 cfs in 2007, 15,600 cfs in 2008, and 15,000 cfs in 2009.

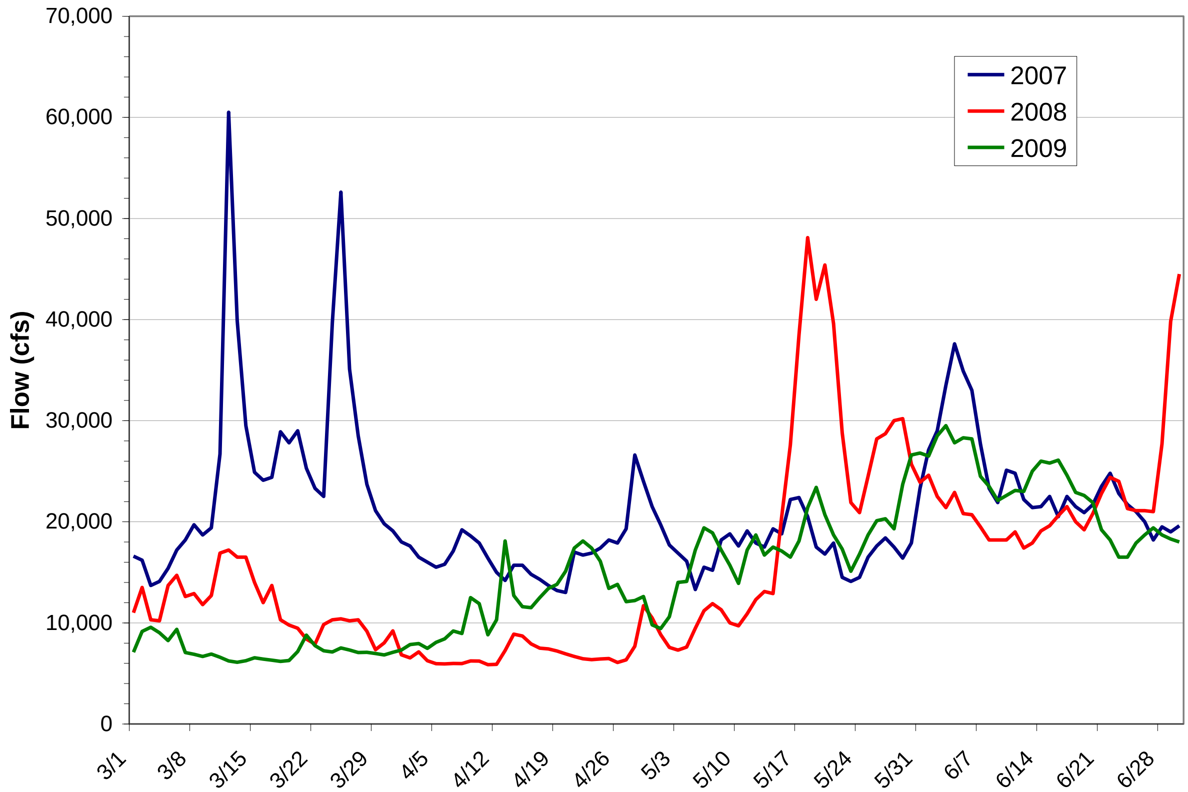

Figure 8. Daily flows in the middle Skagit River at Concrete during the Chinook salmon rearing period (March 1 through June 30) of 2007, 2008, and 2009 (source: USGS gaging station records).

Ross Island (Reach 2) provided the greatest amount of juvenile Chinook habitat in the middle Skagit during the spring rearing period. The habitat area suitable for juvenile Chinook rearing was substantially greater in the Ross Island reach in 2007 compared to the other reaches (Figure 9), especially during the high flow conditions observed in March and June. Cochreham (Reach 3) was second to Ross Island and providing habitat for rearing Chinook throughout the spring of 2007. The habitat area available for Chinook rearing declined during peak flow events observed during March and June, but not to the extent of the Baker and Skiyou reaches. The Skiyou, Salvage, Cape Horn, and Baker reaches provided substantially less habitat than Ross Island and Cockreham during the spring of 2007. The Skiyou, Savage, and Baker reaches provided the most habitat during low flow conditions, but rapidly declined in habitat value when flows increased above 15,000 cfs. The Cape Horn reach provided the least amount of habitat throughout the spring 2007 rearing period.

The Cochreham reach provided slightly more habitat than Ross Island during the low flow conditions (less than 10,000 cfs) that persisted from early March through mid-May in 2008 (Figure 10). However, the habitat area provided by Ross Island became substantially than Cockreham when flows increased above 15,000 cfs from mid-May through June 30. Savage and Skiyou were the third and fourth most important reaches, respectively, in terms of habitat area during the low flow conditions observed from early March through mid-May 2008. Baker provided substantially lower habitat area than Skiyou and Savage during this period, and Cape Horn provided the lowest amount of habitat of all six reaches. Habitat area values declined considerably in the Skiyou, Savage, Cape Horn, and Baker reaches during when flows increased above 15,000 cfs from mid-May through late June in 2008.

The amount of Chinook rearing habitat provided by the six reaches over the spring of 2009 was similar to that observed in 2008. Cochreham initially provided the greatest amount of habitat during the low flow conditions that occurred from early March through mid-April 2009 (Figure 11). Ross Island provided the greatest amount of habitat when flows increased above 15,000 cfs starting in mid-May. Savage ranked third in terms of habitat productivity during low flow conditions observed between early March and mid-May 2009. During higher flow conditions observed from mid-May through late June, Skiyou yielded slightly more habitat than Savage. Baker ranked fifth in habitat area produced during 2009, and Cape Horn again ranked last. The amount of habitat available in the Skiyou, Savage, Cape Horn, and Baker reaches substantially declined when flows increased above 20,000 cfs in June 2009.

Daily statistics for the habitat area values predicted for the six reaches during 2007, 2008, and 2009 are shown in Table 3. The mean habitat area for Ross Island ranged from 84.4 to 94.4 acres during the three years modeled. Cochreham ranked second in terms of mean habitat values, ranging from 67.4 to 73.6 acres during these three years. Skiyou ranked third, with mean habitat values ranging from 32.1 to 40.9 acres. Savage ranked fourth, with mean habitat values ranging from 21.9 to 36.2 acres. Baker ranked fifth, with mean habitat values ranging from 30.6 to 34.5. Finally, Cape Horn ranked sixth with mean habitat area values ranging from 15.2 to 18.7 acres. The total amount of rearing habitat available for juvenile Chinook rearing in for the six reaches ranged from a mean value of 263.5 acres to 290.2 acres for the three years modeled.

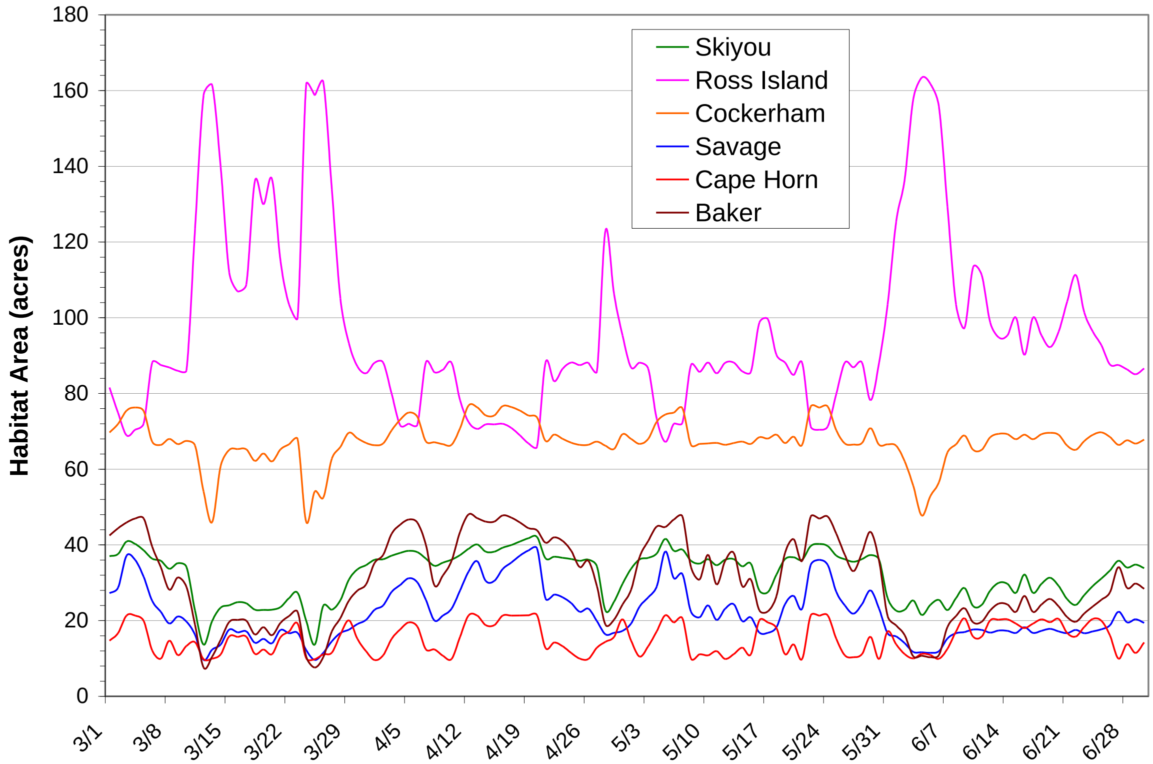

Figure 9. Time series plots of juvenile Chinook habitat availability in the middle Skagit under daily flows measured from March 1 through June 30, 2007.

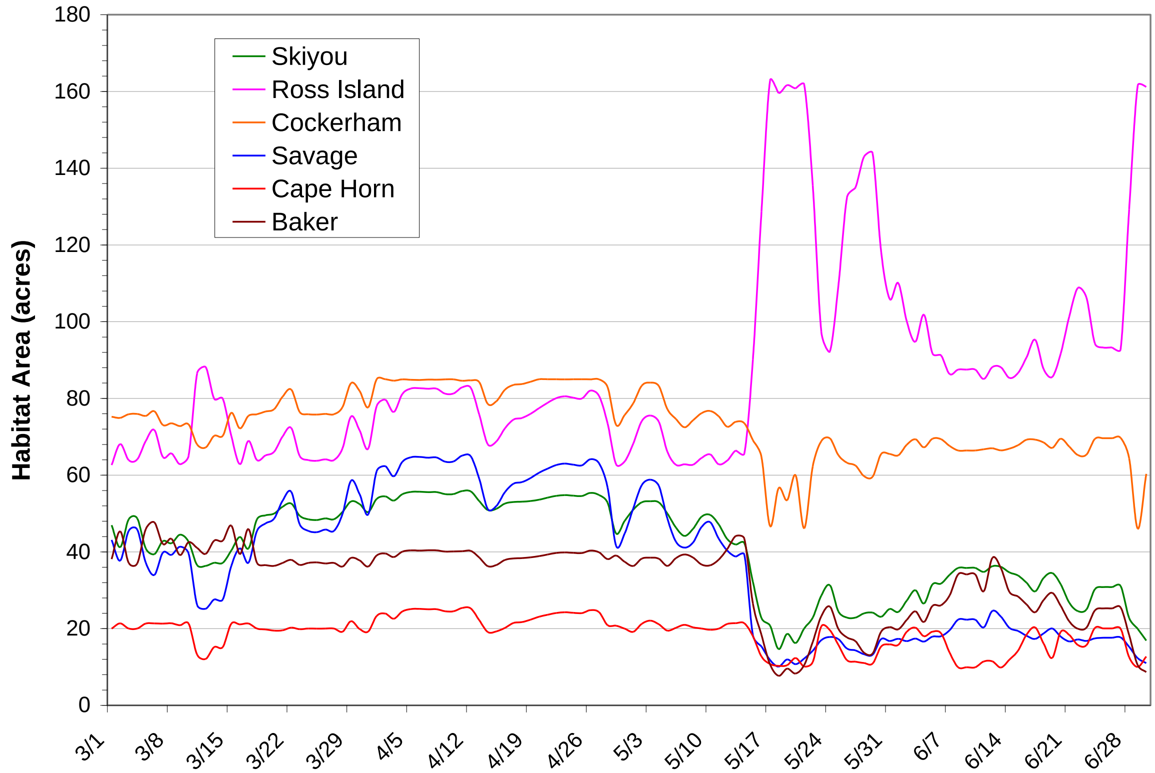

Figure 10. Time series plots of juvenile Chinook habitat availability in the middle Skagit under daily flows measured from March 1 through June 30, 2008.

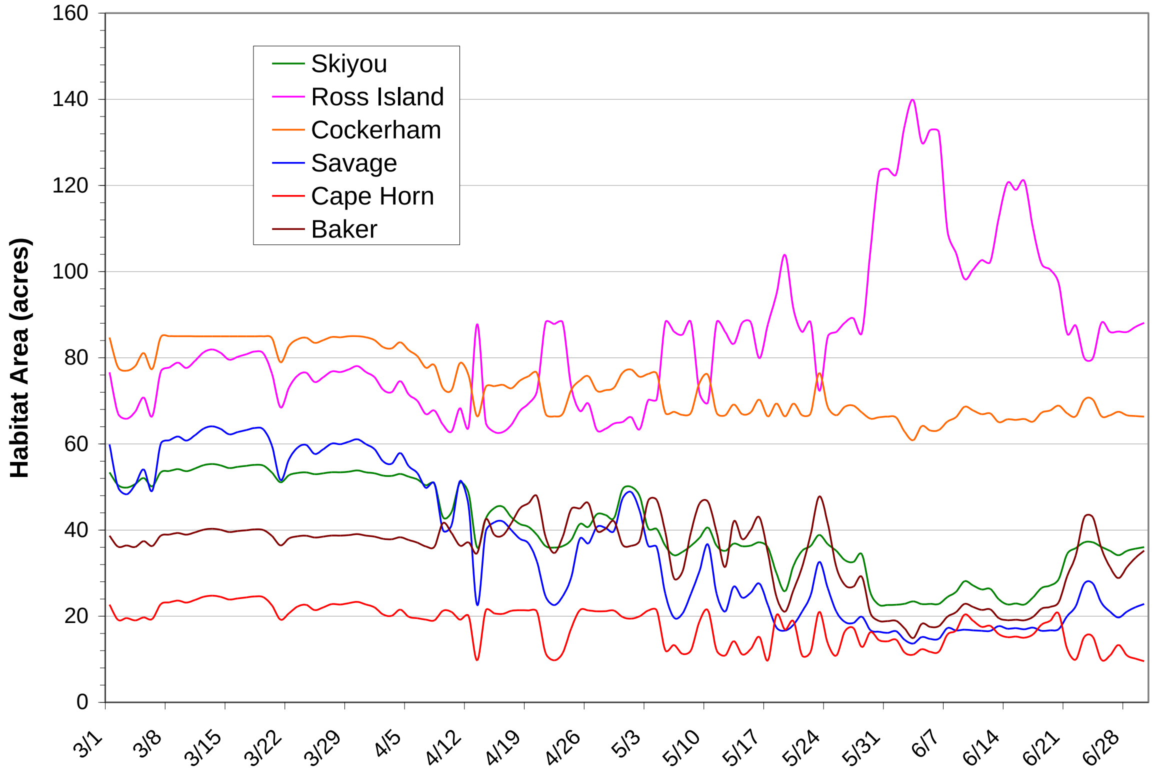

Figure 11. Time series plots of juvenile Chinook habitat availability in the middle Skagit under daily flows measured from March 1 through June 30, 2009.

Table 3. Daily habitat statistics for six reaches of the middle Skagit River during the juvenile Chinook rearing period, 2007 – 2009.

Acres Suitable Habitat - 2007							
Statistic	Skiyou	Ross Island	Cockreham	Savage	Cape Horn	Baker	Total
Mean	32.1	96.4	67.4	21.9	15.2	30.6	263.5
Maximum	42.1	163.4	76.8	39.1	21.4	48.0	390.8
Median	34.5	88.1	67.3	20.1	14.9	29.4	254.4
7-Day Minimum	21.9	69.7	57.9	13.1	11.1	13.7	187.4

Acres Suitable Habitat - 2008							
Statistic	Skiyou	Ross Island	Cockreham	Savage	Cape Horn	Baker	Total
Mean	40.9	86.8	73.4	37.4	18.7	32.8	290.2
Maximum	55.9	162.8	85.0	65.1	25.4	47.7	441.8
Median	43.1	80.4	74.1	40.1	20.0	37.1	294.7
7-Day Minimum	19.4	63.5	55.7	12.3	10.6	11.7	173.3

Acres Suitable Habitat - 2009							
Statistic	Skiyou	Ross Island	Cockreham	Savage	Cape Horn	Baker	Total
Mean	40.5	84.4	73.6	36.2	17.8	34.5	287.0
Maximum	55.3	139.8	85.0	64.1	24.8	47.8	416.7
Median	38.9	80.5	72.5	32.6	19.2	37.9	281.5
7-Day Minimum	22.8	65.1	63.6	15.1	11.4	17.6	195.6

Discussion

Ross Island was found to be the most important reach for juvenile Chinook rearing habitat in the middle Skagit, and was the only reach to provide increasing habitat area when flows increased above 15,000 cfs. The habitat area available for rearing Chinook salmon increased in the Ross Island reach with increasing flow up to 35,000 cfs, and sustained high habitat area values as flow increased to 50,000 cfs. Cockreham was found to be the second most important reach for juvenile Chinook, as the reach provided fairly high and relatively consistent habitat area values throughout the spring rearing period. In contrast to the Ross Island and Cochreham reaches, rearing habitat area value in the Skiyou, Savage, and Baker substantially declined as flows increased above 15,000 cfs during spring runoff period when Chinook salmon rear in the middle Skagit. The Cape Horn reach provided the lowest habitat benefits to rearing juveniles, maintaining consistently low habitat area values throughout the spring rearing period.

The ranking of the six reaches of the middle Skagit in terms of their habitat benefits to rearing juvenile Chinook is directly related to the channel and floodplain characteristics of each reach, and to amount of hydromodification (e.g., levee construction and bank armoring) that has occurred in each reach. The findings of the habitat simulation analysis can be summarized as follows:

- Reaches with complex islanded mainstem channels (often referred to as anabranching channels) provide the greatest amount of habitat for juvenile Chinook over the range of flows that occur during the spring. These reaches are found in naturally broad and low gradient floodplains that are conducive to the formation of multiple channels, and which sustain frequent channel migrations. The complex morphology of these reaches have extensive channel margin areas that provide the low velocity conditions that rearing Chinook require. Flows are also distributed through a broad network of channels, resulting in lower velocities throughout the reach. Ross Island Slough is an example complex island reach that has not been significantly altered by hydromodification structures. Skiyou was formerly an islanded mainstem reach, but has been artificially confined by levees along the north bank, and by the South Skagit Highway along the south bank.

- Sinuous channels (also referred to as meandering channels) in broad floodplains are second in importance with regard to the amount of habitat they provide for juvenile Chinook. These reaches are sustained by broad and low gradient floodplains that are not constrained by dikes, levees, roads, and other hydromodifications. The curvature of these channels provides for the formation of natural channel margin features including backwaters, side pools, secondary channels, and lateral gravel bar areas that provide the low velocity habitat conditions required by juvenile Chinook salmon. Cochreham provides and example of a sinuous reach in an naturally unconfined floodplain, though the habitat benefits of this reach are substantially constrained by a levee that extend along much of the northern bank of the reach.

- Straight channels with natural banks are the third most important habitat areas for Chinook salmon rearing in the middle Skagit. The best habitat areas in these reaches for juvenile Chinook are islands, backwater pools, connected side channels, and shallow lateral pools associated with broad gravel bars. Savage and Baker are both examples of straight channel reaches.

- The lowest habitat benefits for rearing Chinook salmon are found in reaches with extensively armored or disturbed banks. These areas possess relatively little low velocity habitat along the margins of the channel, which is caused by the lack of backwater areas, lateral gravel bars, connected side channels, and other habitat features important to juvenile Chinook. The Cape Horn reach has banks that are highly degraded by extensive bank disturbance resulting from a combination of steep banks and adjacent land-disturbance. The narrow low-velocity areas found along the banks of this reach, when combined with a lack of suitable natural cover (i.e., live root wads, overhanging vegetation, log jams, large cobbles, and boulders), results in poor habitat conditions for rearing Chinook.

The Ross Island reach provides an additional benefit that is not provided by the other reach, and this benefit makes it the “keystone” reach of the middle Skagit in terms of Chinook rearing habitat. In addition to possessing the most extensive habitat area for rearing Chinook, the Ross Island reach has the unique characteristic of providing more habitat area with increasing flow. This may be of great importance to juvenile Chinook in the middle Skagit. Flows typically become higher in the middle Skagit during the latter parts of the rearing period as a result of snowmelt runoff. Habitat area subsequently declines in the reaches above Ross Island during May and June. As a result of the declines in habitat area, juvenile Chinook in the upper reaches are likely displaced by competitive pressures, and would then be expected to move downstream in search of suitable habitat areas for rearing. The Ross Island reach, by providing more habitat as flows become progressively higher, may provide the habitat area that is required by fish that are displaced from shrinking habitats in the upper reaches. The Ross Island reach therefore compensates for habitat loss in the upper reaches, and may be important for sustaining juvenile Chinook production in the middle Skagit.

The availability of low velocity habitat is a major constraint to juvenile Chinook in the middle Skagit. Large rivers intrinsically don't have abundant juvenile habitat, since much of the channel cross-section has velocities that are too high for small fish. The results of this study suggest that there low-velocity habitats area present in the middle Skagit, but are concentrated in reaches complex (islanded) mainstem channels, and sinuous channels found in broad and unaltered floodplains. Large rivers like the middle Skagit may provide abundant habitat for adult spawners, but lack the amount of habitat required for the juveniles produced by these spawners. This results in a "juvenile bottleneck" to population productivity, which is common in freshwater fish (Werner 1986). This bottleneck is evident in the middle Skagit from juvenile Chinook outmigration data that has been collected at the WDFW smolt trap for almost two decades (SRSC and WDFW 2005; Kinsel et al. 2008; Zimmerman *In Prep*). Protecting the best existing habitat areas for juvenile Chinook, especially the Ross Island reach, and restoring reaches that formerly provided rearing habitat including the Cochreham and Skiyou, will be necessary for sustaining and improving the productivity of Chinook in the Skagit River.

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APPENDIX C Project Identification Maps