

Landscape Assessment and Conservation Prioritization of Freshwater and Nearshore Salmonid Habitat in Kitsap County



Christopher W. May, Ph.D. and Gretchen Peterson

Prepared for Kitsap County

2003 KITSAP SALMONID REFUGIA REPORT

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EXECUTIVE SUMMARY

The goal of this project is to *identify* and *characterize* potential salmonid conservation and restoration areas located within Kitsap County. After identification of these areas, a primary objective of this project was to analyze and prioritize these *salmonid refugia* to assist in conservation, enhancement, and restoration efforts. A major aim of the project is to support the early salmon recovery actions necessary to preserve the remaining areas of high-quality salmonid spawning and rearing habitat in the region. Protection of these “last best places” is likely an essential part of the salmon recovery process, but alone will not be sufficient to ensure the restoration of natural runs of native salmonids.

Definition of Salmonid Refugia

“Salmonid” means “of the salmon family.” Salmonids in the study area include coho, chum, chinook, and pink salmon, as well as steelhead and cutthroat trout. This report is based upon a multi-species approach and does not give special consideration to any individual species of salmon.

One ecological definition of *refugia* is an area where special environmental circumstances have enabled a species or community of species to survive after decline or extinction in surrounding areas. For the purpose of this report, *salmonid refugia* can be defined as “habitats or environmental factors that provide spatial and temporal resistance and/or resilience to aquatic communities impacted by natural and anthropogenic disturbances”

Refugia can be stream corridors, watersheds, or shoreline areas. No single factor leads an area to be designated as refugia, rather it is a convergence of several ecological (physical and biological) factors.

Areas that qualify as *refugia* typically have habitat features such as intact streamside forests, undeveloped floodplains, wetlands, and natural shorelines. Refugia are used intensively by salmon compared to non-refugia areas—they are biological “hot-spots.”

Refugia areas are important for maintaining *populations* of salmon. Refugia act to “re-seed” nearby areas after natural or man-made disturbances. Figure ES-1 shows how a “core population” on the mainstem of a river can be a source for naturally re-stocking outlying populations. For wild salmon to continue to survive, these core populations (and their habitat) must remain viable. It is from these core populations found in refugia areas that salmon populations will recover and begin to use less ideal habitat, forming “satellite populations.”

The refugia concept is similar to the thinking that led to the formation of the National Wildlife Refuge System. Migratory waterfowl and other wildlife benefited and thrived during the last century because key habitat was protected.

Refugia areas are not only important for salmon but also for other wildlife and plant communities.

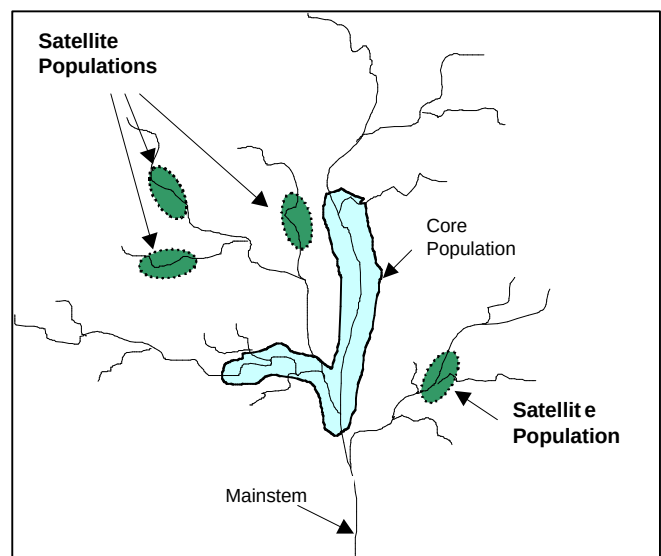


Figure ES-1: Refugia concept showing core populations and satellite populations.

Why was this study undertaken?

This study was undertaken because refugia are critical for wild salmon to survive and funds to recover salmon are limited. One of the first crucial steps to cost-effectively maintain or restore wild salmon populations is to identify areas that are critical for wild salmon. This study, in conjunction with more detailed Limiting Factors Analyses, comprise the initial steps in a comprehensive, long-term salmon recovery process.

Refugia areas identification and categorization process

To determine if a watershed, stream corridor, or marine shoreline is a refugia area, the study looked at several “landscape-centered” factors and several “fish-centered” factors. Examples of “landscape-centered” data used:

- LandSat images showing watershed conditions such as the amount of development and forest cover.
- LandSat images showing the amount and quality of streamside forests and floodplain development.
- Nearshore marine conditions such as bulkheads and presence of eelgrass.

Examples of “fish-centered” data used:

- Records related to salmon presence, abundance, diversity, and productivity.
- Field data about the condition of instream habitat (such as the amount of large woody debris, the quality of spawning gravels, and the stability of streambeds).

Figure ES-2 shows how the freshwater refugia scores were determined. Since some factors are more important than others, each factor (top line of boxes) was given a certain “weight” (depicted by the pie charts in the middle of the graphic) before incorporating it into a “fish score,” a “watershed score,” and a “riparian score.” These three scores were combined to come up with a “final score.” Based upon each refugia’s final score (and interjecting best professional judgment to make modifications as necessary) the author assigned a category to each refugia. A similar process was used to categorize shoreline refugia (see ES-3).



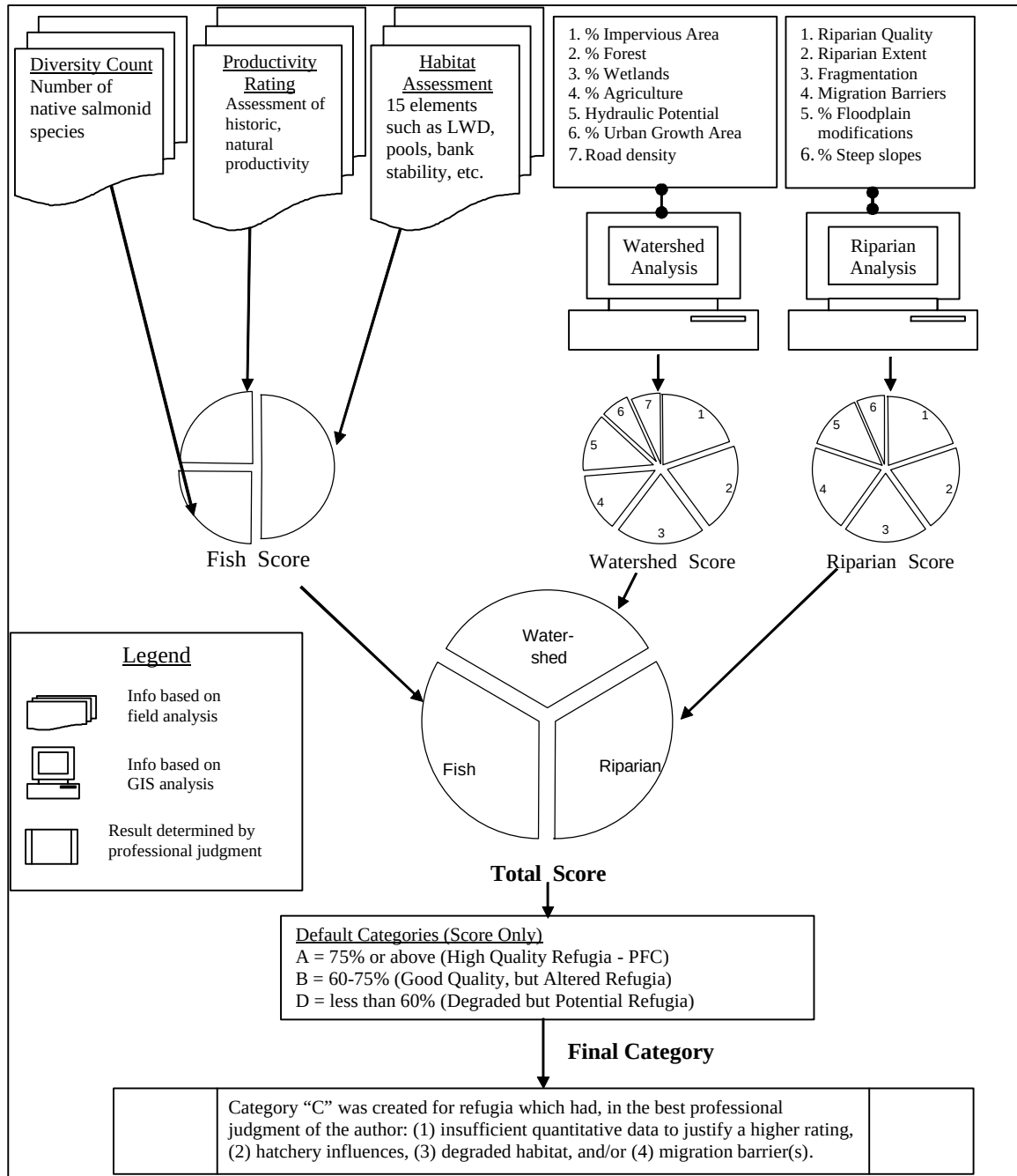


Figure ES-2: Freshwater Refugia Scoring and Categorization Process.



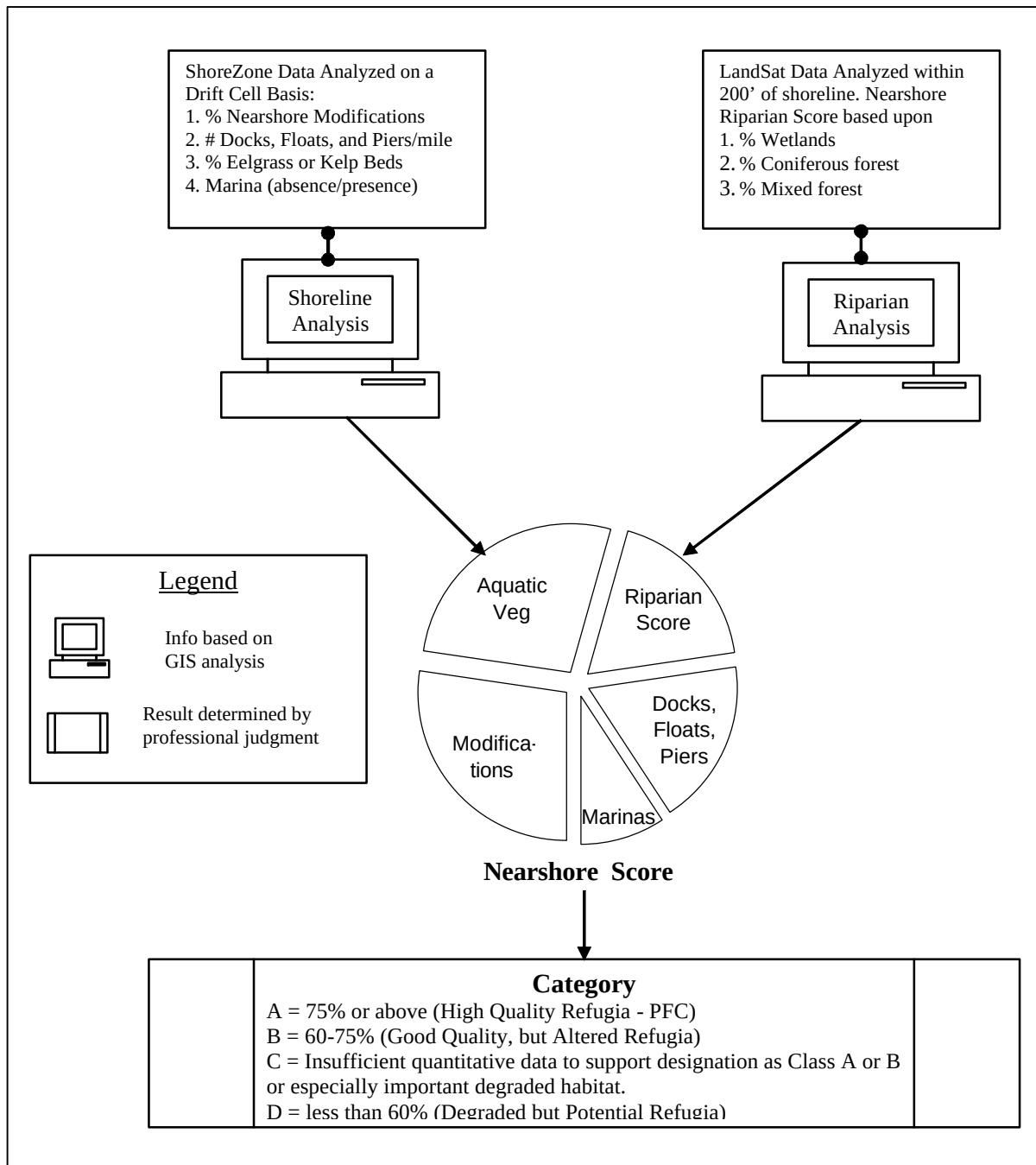


Figure ES-3: Nearshore and Estuarine Refugia Scoring and Categorization Process.



Definition of Refugia Categories

Category “A” means: “Priority refugia with natural ecological integrity.” While not necessarily pristine, these areas are nearly intact, relatively undisturbed, and generally exhibit *properly functioning conditions*. These are generally in excellent condition.

Category “B” means: Primary refugia with altered ecological conditions.” These are refugia with somewhat disturbed conditions, but which still support natural assemblages of native salmon. These are generally in good condition.

Category “C” means: “Secondary refugia with altered ecological integrity.” These areas may belong in Category “A” or “B” if not for hatchery influences, migration barriers and/or degraded habitat. These are generally in fair condition. The author also placed in this category refugia that did not support a higher rating due to a lack of quantitative data. This could be called “Possible refugia.”

Category “D” means: “Potential refugia with altered ecological integrity.” These areas are best described as “potential future refugia” due to significantly degraded habitat conditions. These areas were likely historically important for salmon, but today do not support anywhere near natural levels of salmon productivity.

Areas that did not meet these criteria were considered non-refugia.



Stavis Creek Estuary. Stavis Watershed is watershed with the highest score in the study area.





The Lower Reach of the Denawatto River is the stream reach with the highest score (88%). It is part of a Category A Focal Sub-Watershed Refugia.



The South Fork of Dogfish Creek is the stream reach with the lowest score (37%). It is designated as a Category D Nodal Riparian Corridor refugia.



The Point No Point nearshore is the shoreline with the highest Nearshore-Estuarine score (83%). It is designated as a Category A Nearshore-Estuarine Refugia.



Sinclair Inlet is the shoreline with the lowest Nearshore-Estuarine score (19%). It is designated as a Category D Nearshore-Estuarine Refugia.



Types of Refugia

The report delineates freshwater refugia as one of two types: (1) “Focal Sub-Watershed” (FSW); or (2) “Nodal-Riparian Corridor” (NRC). Generally, a “Focal Sub-Watershed” designation is more appropriate for headwater areas, while a “Nodal-Riparian Corridor” designation is more appropriate for lower reaches of a stream, or streams that are confined within steep-sloped valleys. One type is not necessarily “better” than the other; it is more a matter of which type of refugia fits the specific situation in the field and which type will be more effective for conserving salmon habitat.

For marine areas, the report delineates “Nearshore and Estuarine” (NSE) refugia for those stream estuaries, nearshore migration corridors, and shoreline areas that provide refuge habitat for migrating and rearing salmon. Nearshore and Estuarine refugia are based upon *drift cells*. Drift cells are reaches of shoreline where waves move sediment from eroding “feeder” areas (such as bluffs) to “deposition” areas (such as sand spits).

“Critical Contributing Area” (CCA) is a fourth area delineated by the report (these areas are not shown on the map). The Critical Contributing Area itself is not itself a refugia area, but directly influences downstream refugia with stream flows and/or water quality. Natural conditions such as seasonal flow or natural barriers typically prevent these areas from supporting viable salmon populations. There is typically one or more CCA associated with a Nodal Riparian Corridor. All seasonal streams draining to Nearshore and Estuarine refugia are considered Critical Contributing Areas.

Results

The map (Figure ES-4) shows the results of the study. A complete listing of refugia can be found in Table 16, pages 91-93.

Importance of non-refugia areas

Based upon the findings of this report, areas not proposed for refugia status should not be considered unimportant for regional salmon recovery efforts. Every watershed, stream, and nearshore area deserves protection and stewardship to some degree. Even the smallest watershed or nearshore area has some salmon habitat value, which may be critical to the survival of a population of fish. By the same token, degraded watersheds, streams, or nearshore areas may also still retain some measure of habitat value and therefore should be managed appropriately.



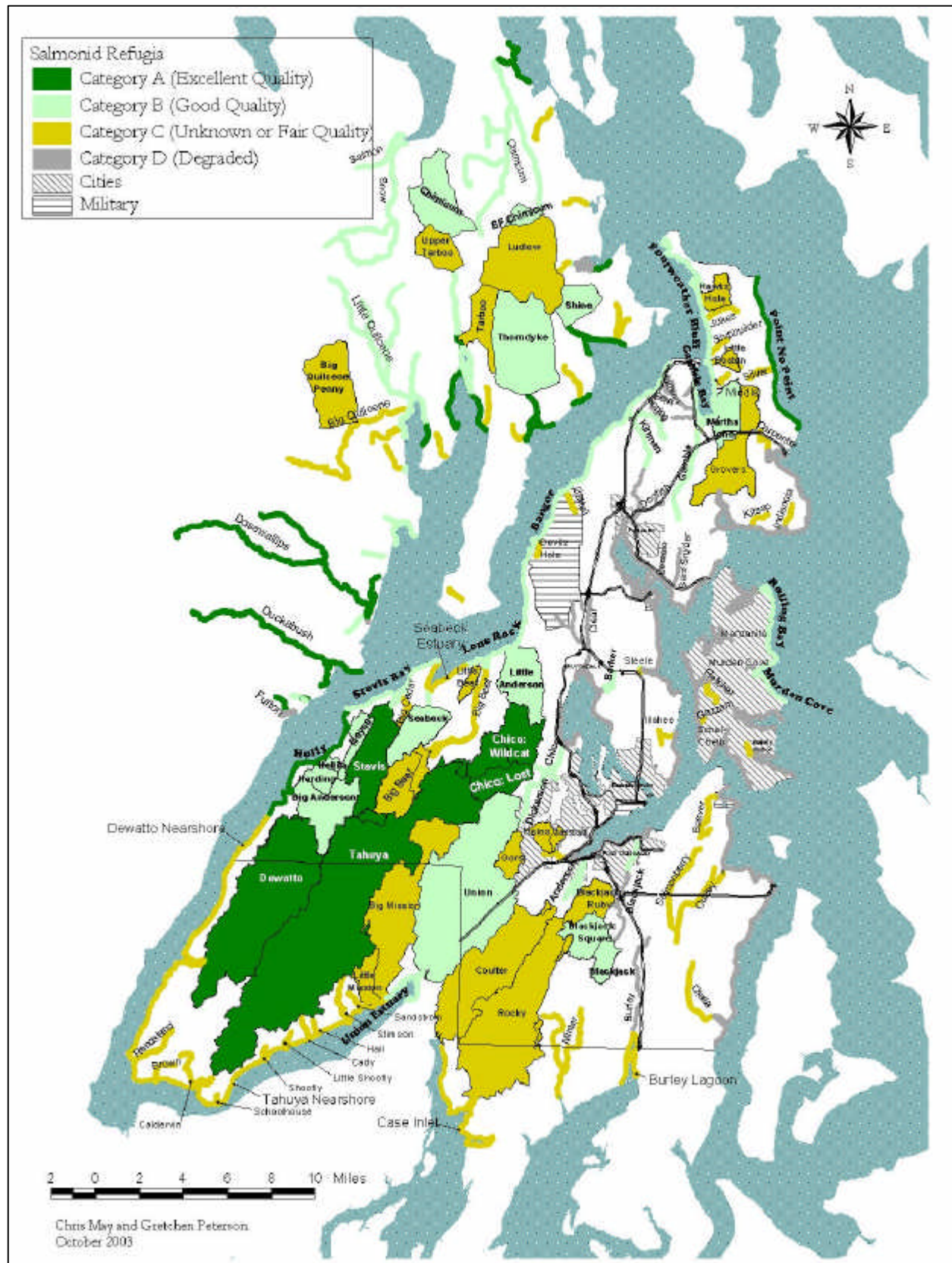


Figure ES-4: Map of Kitsap Focal Sub-Watershed, Nodal-Riparian Riparian Corridor and Nearshore-Estuarine Refugia.



Highest quality refugia and range of refugia scores

The 26 streams and nearshore areas that contain Category A & B refugia are shown in Table ES-1. There are five nearshore areas and 26 streams and in Category C. In Category D there are 18 streams and 16 nearshore areas. There were 44 streams analyzed that were deemed to be non-refugia and were not assigned to Categories A-D.

The highest freshwater refugia score was 88% for the lower reaches of the Dewatto River (the overall average for the Dewatto watershed is 82%). The lowest score was 37% for the South Fork of Dogfish Creek.

For nearshore areas the high score was 83% for the Point No Point Nearshore; the low was 19% for Sinclair Inlet.

Number of Refugia

Report classified a total of 160 individual sub-watersheds, stream reaches, and nearshore areas as refugia. The breakdown of these refugia by Category and type is shown in Table ES-2.

Interim nature of nearshore results

At the present time, our knowledge of nearshore salmonid utilization is relatively basic and is rapidly expanding. In addition, the database on nearshore salmonid habitat conditions is also relatively sparse. Therefore, this assessment of nearshore salmonid conditions should be considered as “interim” until more and better data is developed.

Prioritizing habitat conservation vs. habitat restoration

It is generally understood that it is more successful and much more cost-effective to prevent habitat degradation rather than restore damaged areas. Protecting the “last best places” is an essential part of the salmon recovery process. This report is designed to identify where to focus resources to efficiently and cost-effectively protect key areas.

Where habitat conditions have been degraded, restoring natural runs of native salmon will require that stream corridors, watersheds, and nearshore areas be brought back to a higher quality condition.

Highest Category for this Stream	Stream/Nearshore Name	Average Score for this Stream
A	Point-No-Point Nearshore	83%
A	Stavis Creek	83%
A	Dewatto River	82%
A	Holly Nearshore	79%
A	Tahuya River	78%
A	Chico Creek	71%
B	Murden Cove Nearshore	75%
B	Harding Creek	74%
B	Big Anderson Creek	74%
B	Nellita Creek	73%
B	Union River	72%
B	Boyce Creek	72%
B	Foulweather Bluff	69%
B	Stavis Bay Estuary	69%
B	Martha John Creek	69%
B	Seabeck Creek	67%
B	Lone Rock Nearshore	67%
B	Rolling Bay Nearshore	66%
B	Little Anderson Creek	64%
B	Port Gamble Bay	64%
B	Union Estuary	63%
B	Kinman Creek	61%
B	Gamble Creek	61%
B	Blackjack Creek	59%
B	Barker Creek	56%
B	Steele Creek	54%

Table ES-1: Category A and B refugia.

	FWS	NRC	NSE	Total
Category A	6	0	2	8 (5%)
Category B	10	18	8	36 (23%)
Category C	14	45	5	64 (40%)
Category D	0	36	16	52 (32%)
Total	30 (19%)	99 (62%)	31 (19%)	160

Table ES-2: Frequency of Refugia by Type and Category.



This study does not imply that protection of the designated refugia areas alone is ecologically sufficient to support salmon recovery or even to maintain current conditions within the region. Maintaining refugia is considered a necessary first step in a comprehensive, long-term ecosystem conservation program.

Conclusions

The available data indicate several common problems throughout the study region. These include (in no specific order):

- Natural stream ecological processes have been significantly altered due to the cumulative effects of watershed land-use practices and human encroachment into the stream-riparian ecosystem.
- There has been a significant shift in the natural hydrologic regime of many watersheds, especially those undergoing urbanization. This is characterized by increases in peak flow frequency, duration, and magnitude due to increased stormwater runoff from lands that have been converted from native forest and wetlands to developed landscapes dominated by impervious surfaces.
- Streambed stability and spawning gravel quality have been degraded by high stormflow scour and fine sediment deposition. Major fine sediment sources include logging roads, construction sites, and agricultural fields.
- Stream channel morphological changes have resulted from direct alterations such as agricultural channelization or floodplain diking. In addition, streambank erosion has increased in frequency and extent due to higher stormflows, loss of natural vegetation cover, and subsequent streambank armoring.
- There is a general lack of adequate large woody debris (LWD) in streams, particularly large, stable coniferous “key” pieces that are critical to forming pools, providing cover for juvenile fish, retaining organic matter, and maintaining instream habitat complexity. In addition, there is a general lack of adequate, high-quality rearing habitat (pools) for juvenile salmonids and the lack of deep “holding” pools for adult salmon migration.
- There has been a significant degradation and loss of natural floodplain processes in our rivers and larger stream systems, including the loss of functional off-channel wetland habitat. This is mainly due to dredging, bank armoring, and stream channelization. Past and current agricultural land-use has had a significant impact on floodplain and riparian processes in a number of lowland watersheds. In addition, development has also continued this process of stream channel manipulation.
- Almost all local streams have experienced a loss of natural riparian function due to removal or alteration of natural riparian forest vegetation. This degrades water quality, increases streambank erosion, reduces shade needed for water temperature regulation, and impacts instream habitat conditions through the decline in LWD recruitment.



Example of a Kitsap stream with altered riparian vegetation, a lack of LWD, and an altered stream channel.



- Stream-riparian corridor fragmentation is a major problem in many watersheds. This fragmentation has impacted the structure and function of our stream-riparian ecosystems. In addition, there are a significant number of culverts, diversion dams, and other fish passage barriers throughout these same watersheds.
- Estuarine and nearshore processes have been significantly impacted by physical alteration of nearshore ecological structure and function. These impacts include extensive shoreline bulkhead construction, loss of shoreline forest and large woody debris recruitment, loss of shoreline riparian cover and shade, and degraded water quality. In addition, natural sediment transport and beach nourishment processes have been disrupted as nearshore drift-cells have been altered by shoreline armoring, dock construction, and other human activities. All of these modifications have impacted salmonid habitat in the nearshore environment to some extent.
- Other impacts (e.g. hatcheries and harvest) have also significantly affected salmonid populations, however those issues are beyond the scope of this report.

Recommendations

Throughout the report, the author makes several general recommendations, including:

- Protection and restoration activities should be prioritized to focus on critical watersheds, streams, or reaches that have the potential to protect and reestablish core populations at strategic locations within mainstem river systems, estuaries, and tributaries.
- Preserve native vegetation as much as possible in critical nearshore areas, estuaries, and sensitive (steep banks and landslide-prone) shorelines.
- Reduce to negligible levels the impacts of shoreline development in all Nearshore and Estuarine refugia areas.
- Investigate Category C refugia where insufficient quantitative data existed to justify a Category A or B rating.
- Integrate monitoring and feedback with management so that conservation efforts may be continually refined ("*adaptive management*").
- Develop integrated watershed plans to manage current and future human activities in a way that minimizes our impacts on the natural environment. This is necessary to sustain our natural resources and protect our own quality of life.

The report concludes with the following recommendations:

- Continue to evaluate freshwater habitat conditions throughout watershed and correct identified salmonid habitat limiting factors.
- Develop salmonid habitat conservation programs that include protective purchases, conservation easements, and voluntary stewardship elements.
- Because salmonids are adapted to spatially and temporally varied local habitat conditions, it does not make sense to manage for the same conditions at all locations, or to expect



conditions to remain constant at any one location. A “one-size-fits-all” solution is rarely appropriate in the case of salmonid habitat conservation and restoration.

- Evaluate all known and potential adult and juvenile salmonid migration barriers in the watershed. Prioritize and correct all migration barriers as necessary.
- Protect stable natural hydrology within the watershed. Conserve native forest cover throughout the watershed and minimize impervious surfaces in all developed areas.
- Restore floodplain function, natural channel configuration, and stream channel migration zone. This should include consideration of dike and levee removal, road and residential relocation, and restoration of off-channel and historic slough habitat.
- Develop and implement a forest road management plan to reduce erosion and other impacts from logging roads. Ensure timber harvest operations are conducted with long-term sustainability as a goal. The principles of ecosystem management should guide all logging activities.
- Protect and enhance natural estuarine structure and function. Maintain connectivity with the adjacent nearshore.
- Restore natural riparian integrity throughout the watershed; encourage conifer regeneration in deciduous stands that historically had a conifer component, particularly in disturbed areas. This effort should include planting conifers (cedar, hemlock, and spruce), reducing riparian corridor fragmentation, and the establishment of ecologically appropriate riparian buffer zones.
- Reconnect and restore historic riparian wetlands and other off-channel habitat, where possible.
- Develop and implement a short-term large woody debris strategy until full riparian function is restored.
- Reduce impacts of roads and road crossings, including increased stormwater runoff to surface waters, non-point source water quality impacts from stormwater runoff, and increased fine sediment delivery from road surfaces and associated ditch maintenance. Correct all fish passage barriers as soon as practicable.
- Reduce habitat impacts from hobby farms and agricultural lands, including development and implementation of farm plans that restore stream functions; identify and correct areas in the watershed that have unrestricted livestock access.
- Implement a long-term biological monitoring program for the creek using the macroinvertebrate-based benthic index of biotic integrity (B-IBI). Biological monitoring is an excellent tool for diagnosing and qualifying watershed health and is a good way to involve citizens in the assessment process.
- Implement an exotic vegetation management program in the watershed.
- Identify and correct sources of known water quality problems. Continue to monitor for water quality problems.



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ACRONYMS

AFS: American Fisheries Society

ASTER: Advanced Spaceborne Thermal Emission and Reflection Radiometer

B-IBI: Benthic Index of Biotic Integrity

CCA: Critical Contributing Area

CFS: Cubic Feet per Second

CMZ: Cannel Migration Zone

DAIS: Digital Airborne Imaging System

DB: Database

DEM: Digital Elevation Model

DNR: (Washington) Department of Natural Resources

EDT: Ecosystem Diagnosis and Treatment

EF: East Fork

EPA: Environmental Protection Agency

ESA: Endangered Species Act

ESU: Evolutionarily Significant Unit

ETM: Enhanced Thematic Mapper

FEMA: Federal Emergency Management Agency

FEMAT: Northwest Forest Ecosystem Management and Assessment Team

FIRM: Flood Insurance Rate Map

FSW: Focal Sub-Watershed (Refugia)

GIS: Geographic Information System

HB: House Bill

HCCC: Hood Canal Coordinating Council

HCSC: Hood Canal Summer Chum

HCSEG: Hood Canal Salmon Enhancement Group

HSI: Habitat Suitability Index

HSM: Habitat Suitability Model



IMST: (Oregon) Independent Multidisciplinary Science Panel

JNRC: (Governor's) Joint Natural Resources Cabinet

KCD: Kitsap Conservation District

LAMIRD: Local Area of More Intensive Rural Development

LFA: Limiting Factors Analysis

LIDAR: Light Detection And Ranging

LULC: Land Use/Land Cover

LWD: Large Woody Debris

MCDA: Multi-Criteria Decision Analysis

MDN: Marine-Derived Nutrients

MPI: Matrix of Pathways and Indicators

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NPS: Non-Point Source Pollution

NRC: National Research Council

NRC: Nodal-Riparian Corridor (Refugia)

NRCS: Natural Resources Conservation Service

NSE: Nearshore and Estuarine (Refugia)

NWI: National Wetlands Inventory

NWIFC: Northwest Indian Fisheries Commission

PFC: Properly Functioning Condition

PNPTC: Point No Point Treaty Council

PNW: Pacific Northwest

PS: Puget Sound

PSC: Puget Sound Chinook

PSL: Puget Sound Lowlands

RBER: Rapid Biotic and Ecological Response

RM: River Mile



SF: South Fork

SPTH: Site-Potential Tree Height

SRF Board: Salmon Recovery Funding Board

SSHEAR: Salmonid Screening Habitat Enhancement and Restoration

SSHIAP: Salmon and Steelhead Habitat Inventory and Assessment Program

SZ: Shorezone

TFW: Timber, Fish, and Wildlife

TIA: Total Impervious Area

TIGER: Topologically Integrated Geographic Encoding and Referencing

TPL: Trust for Public Lands

UGA: Urban Growth Area

UGB: Urban Growth Boundary

USDA: US Department of Agriculture

USFS: US Forest Service

USFWS: US Fish & Wildlife Service

USGS: US Geological Survey

UW: University of Washington

VSP: Viable Salmonid Population

WAU: Watershed Administrative Unit

WCC: Washington Conservation Commission

WDFW: Washington Department of Fish & Wildlife

WDNR: Washington Department of Natural Resources

WDOE: Washington Department of Ecology

WRIA: Water Resource Inventory Area



“The richest values of wilderness lie not in the past, nor even the present, but rather in the future.”

ALDO LEOPOLD, 1956

INTRODUCTION

The goal of this project is to identify and characterize potential salmonid conservation and restoration areas in the watersheds of Water Resource Inventory Area 15 (WRIA-15) located within Kitsap County, Washington and the watersheds of Water Resource Inventory Area 16 (WRIA-16) and 17 (WRIA-17) located within East Jefferson County, Washington. After identification of these areas, a primary objective of this project was to analyze and prioritize these *salmonid refugia* to assist in conservation, enhancement, and restoration efforts. Results of this effort have been integrated into a geographic information system (GIS) database for use by local decision-makers, regional natural resource agencies, state and tribal fisheries biologists, watershed stewardship groups, and the general public. This project, along with concurrent projects in other parts of the Puget Sound Region evolutionarily significant unit (ESU), represents an initial, rapid assessment of high-priority salmon habitat for conservation action.

A major aim of the project is to support the early salmon recovery actions necessary to preserve the remaining areas of high-quality salmonid spawning and rearing habitat in the region. Protection of these “last best places” is likely an essential part of the salmon recovery process, but alone will not be sufficient to ensure the restoration of natural runs of native salmonids. Many key watersheds and nearshore areas were historically important for salmonids, but are currently in need of rehabilitation work in order to restore them to a more natural, high-quality condition in support of long-term salmon recovery efforts. These historically important areas are also identified and assessed in this report.

One ecological definition of *refugia* is an area where special environmental circumstances have enabled a species or community of species to survive after decline or extinction in surrounding areas. For the purpose of this report, *salmonid refugia* can be defined as “habitats or environmental factors that provide spatial and temporal resistance and/or resilience to aquatic communities impacted by natural and anthropogenic disturbances” (Sedell et al., 1990).

The ultimate goal of the regional salmonid recovery effort, of which this refugia project is a key component, is to restore aquatic habitat to a natural, self-sustaining condition known as *properly functioning condition* (PFC). PFC represents the range of characteristics found in natural ecosystems that generally support healthy, native salmonid populations over the long term.

The success of achieving this salmon recovery goal is very much dependent on both the number and quality of discrete refugia that can be preserved, enhanced, and/or restored (Sedell et al., 1990; Frissell, 1998; Beechie and Bolton, 1999). This concept is based on recent ecological studies that have identified the critical importance of spatially distributed refugia for the long-term persistence and recovery of stream fish populations (Sedell et al., 1990; Niemi et al., 1990; Schlosser, 1995; Spence et al., 1996; Frissell, 1998; Lichatowich et al., 2000; Dewberry, 2001; Montgomery et al., 2003). This theory also holds true for other species that, like salmon, are thought to exist as interactive populations and are very closely affected by landscape-level changes, habitat fragmentation, and



perturbations in their natural disturbance regime (Opdam, 1991; Andren, 1994; Wahlberg et al., 1996; Fahrig, 1997; Fagen, 2002).

Identification of historic and existing, functional refugia is recognized as one of the crucial, initial steps in a comprehensive, long-range salmon recovery process. This has been documented as a necessary phase in the conservation and restoration of salmonid populations in watersheds of the PNW (Sedell et al., 1990; Reeves and Sedell, 1992; Frissell, 1993; FEMAT, 1993; Li et al., 1995; Reeves et al., 1995; NRC, 1996; Spence et al., 1996; Frissell, 1998; Beechie and Bolton, 1999; Lichatowich et al., 2000; Dewberry, 2001; Beechie et al., 2003). However, habitat conservation and restoration alone will not be not enough to ensure salmon recovery in the Puget Sound (PS) region or the Pacific Northwest (PNW). To be successful, salmon regional recovery efforts must also address other human impacts on salmon (e.g. dams and other migration barriers, poor hatchery operations, and over-harvest of salmon resources). This is as much a matter of societal values as it is science (Scarnecchia, 1988).

If the people of the PNW region are to preserve natural resources, including salmon, and protect our own quality of life, we must learn to coexist with nature on a mutually sustainable level (Naiman and Turner, 2000). An important part of this long-term process is the assessment of current conditions and the development of a comprehensive plan to manage current and future human activities so as to minimize their impact on the natural environment. In the case of aquatic resources such as streams and the salmon they support, a *watershed approach* has been recognized as the optimum strategy for conservation efforts (Naiman, 1992; Naiman and Bilby, 1998; Beechie and Bolton, 1999). Monitoring and feedback must be integrated with management so that conservation efforts may be continually refined. This process is known as *adaptive management* (NRC, 1992; Thom, 1997; Thom, 2000). As such, this report should be considered a work in progress. As new data is obtained or existing information is refined, management plans should be adjusted to reflect this updated knowledge base.



“...a thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it does otherwise.”

ALDO LEOPOLD, 1956

BACKGROUND

Historically, the rivers and streams of the Pacific Northwest (PNW) have been productive salmon-bearing waters. This is particularly true of the lowland rivers, streams, and wetlands of the Puget Sound region (Stouder et al., 1997). These aquatic ecosystems provide important spawning and rearing habitat for several species of native salmonids. Salmonid species utilizing these waters include both resident and sea-run cutthroat trout (*Oncorhynchus clarki*), steelhead trout (*O. mykiss*), coho salmon (*O. kisutch*), chinook salmon (*O. tshawytscha*), sockeye salmon (*O. nerka*), chum salmon (*O. keta*), and pink salmon (*O. gorbuscha*). Figure 1 shows the typical life history of PNW salmon.

Wild salmon and trout have significant scientific, cultural, and economic value to the people of the PNW region (Scarnecchia, 1988). Ecologically, they are a keystone species in our aquatic and forest ecosystems (Willson and Halupka, 1995; Lichatowich, 1999; Gende et al., 2002). Salmon are also one of the primary indicators of the ecological integrity of the greater ecosystems humans also inhabit. The cultural value of salmon to our region is also extremely important. In addition, salmon are an indicator of our quality of life and represent an important component of the PNW economy (Scarnecchia, 1988).

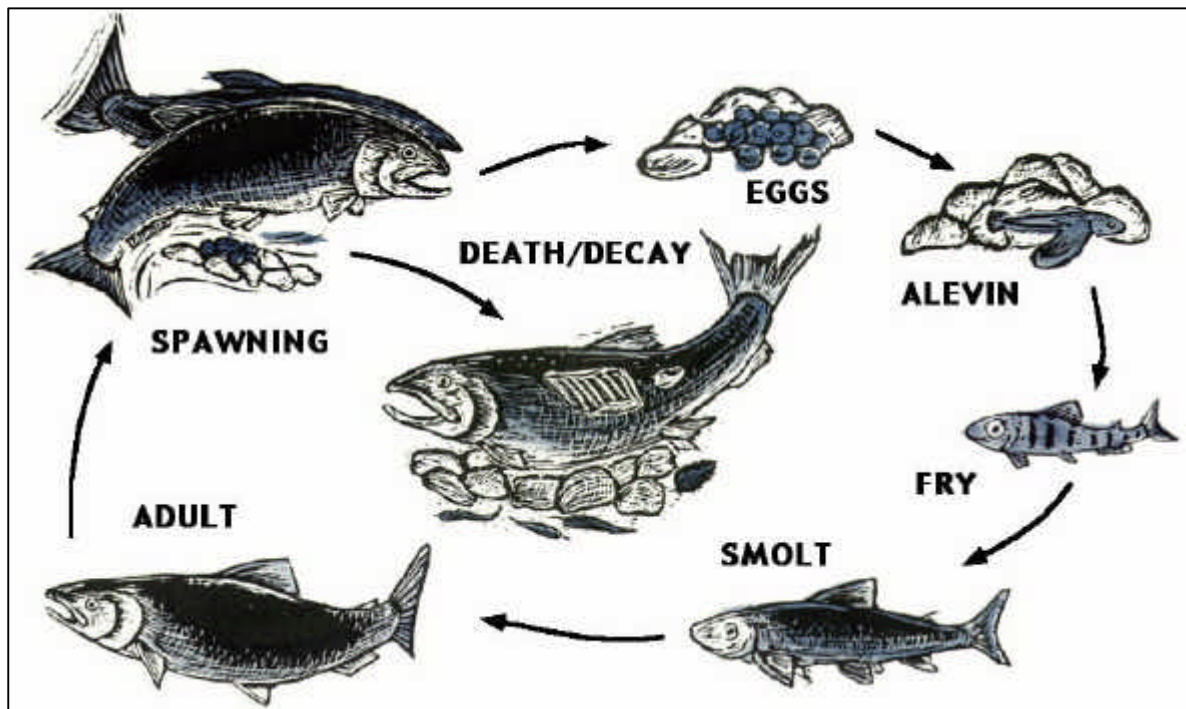


Figure 1: Typical Salmonid Life Cycle (modified from drawing by N. McClure).



In spite of the important scientific, cultural, and socio-economic value of these organisms, many genetically unique salmon populations are in danger of being lost forever (Naiman and Turner, 2000). Figure 2 illustrates this trend in the PNW region. This is especially true in the Puget Sound Lowland (PSL) eco-region, where rapid population growth and widespread development are putting pressure on the remaining natural resource areas that support native salmonids (May et al., 1997). The Kitsap County and East Jefferson County study areas are located in the PSL eco-region. The recent listing of Puget Sound chinook and Hood Canal summer chum under the Endangered Species Act (ESA; 16 U.S.C. 1531-1544) has emphasized the severity of the so-called “salmon crisis”. Based on its location in the Puget Sound region, Kitsap and Jefferson Counties are experiencing many of the problems associated with population growth and watershed development, while still retaining much of their high-quality aquatic resources. In addition, economically important resource extraction land-uses such as timber harvest, mining, and agriculture are also still an active part of the economy of both counties. In spite of these pressures, many streams in Kitsap and East Jefferson County still support healthy, productive runs of native salmonids. In addition, despite widespread habitat degradation, there are many watersheds within the study areas of WRIA-15, 16, and 17 that still retain a significant portion of their historic high-quality, natural salmonid habitat. It is widely acknowledged that recovery of Puget Sound wild salmon populations will require the preservation and protection of these remaining functional habitat areas (NRC, 1996; Frissell, 1998; Beechie and Bolton, 1999; Lichatowich, 1999; TPL, 2000; Lichatowich et al., 2000; Dewberry, 2001; Montgomery et al., 2003).

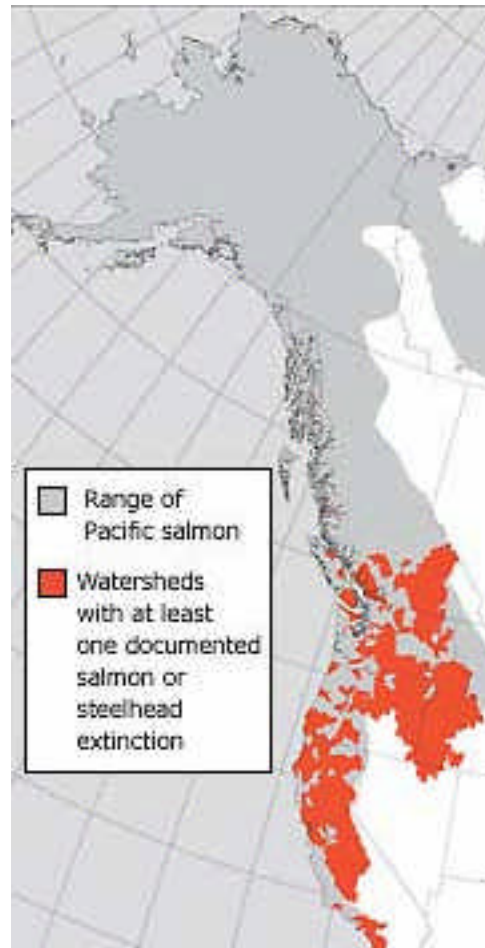


Figure 2: PNW Salmon Extinction Map
(based on Nehlsen et al., 1991).

Prior to non-indigenous settlement of the region, each salmonid species consisted of abundant, geographically isolated populations (Groot and Margolis, 1991). Each native population, or *stock*, maintained inherited genetic traits that were advantageous for survival and persistence in the environment of its home watershed (Groot and Margolis, 1991; Stouder et al., 1997; Lichatowich, 1999; Levin and Schiewe, 2001). These unique, evolved traits can include genetic, morphological, and physiological characteristics as well as behavioral patterns such as spawning run timing or rearing habitat preference. Diversity in these traits, both within and among stocks, has allowed wild salmonids to utilize available resources and habitat most efficiently, and to persist in a changing environment over a long period of time (Groot and Margolis, 1991; Stouder et al., 1997; Lichatowich, 1999). Conservation of this native *biodiversity*, both the unique salmon genetics and the associated physical habitat, is a major goal of overall salmon recovery efforts in the region and an underlying goal of this project as well.

Based on the complex life history (see Figure 1) of each salmonid species, there is a need to protect spawning, rearing, and migration habitat within the freshwater and nearshore marine environment (Bisson, 1995; NRC, 1996; Stouder et al., 1997). Research has demonstrated that



effective conservation should encompass the whole life history of each salmon species and not simply focus attention on so-called “bottlenecks” to production (Healy, 1994).

In addition to the scientific and social rationale discussed above, there are regulatory reasons for conservation of native salmonid resources. The Endangered Species Act (ESA) requires that *critical habitat* for threatened or endangered species be identified and protected. According to the ESA, critical habitat includes areas that contain ecological features that are essential to the conservation of the species and that require special management considerations or protection. For migratory species, such as anadromous salmonids, critical habitat can be quite extensive.

Based on the underlying principles of conservation biology (Noss and Cooperrider, 1994) and the natural history of salmonids (Groot and Margolis, 1991), a few basic assumptions were used in this study as a guide to identifying potential salmon refugia. These scientific assumptions provided a template for identifying and classifying refugia areas during this project. The State of Oregon Salmon Recovery Program, Independent Multidisciplinary Science Team (IMST, 1999 & 2002) identified these basic scientific concepts to guide salmon recovery efforts. Each concept is consistent with generally accepted scientific theory. The concepts are as follows:

- Wild salmonids are a natural part of the ecosystem of the PNW, and they have co-evolved with it. The contemporary geological landscape of the PNW was established with the formation of the river and stream basins of the region, approximately two to five million years ago. The salmonid species of the region largely developed from that time (Lichatowich, 1999). The abundance of these species at the time of Euro-American migration to the PNW is a reflection of more than 10,000 years of adaptation to the post-glacial environment and 4,000 to 5,000 years of adaptation to contemporary climatic and forest patterns, as well as the activities of indigenous peoples. There is also some indirect evidence from anthropological studies that salmon in the region may not have reached the high levels of abundance that the first Euro-Americans saw until about 1,000 to 2,000 years ago (Lichatowich, 1999). The main point is that the salmonid stocks of today co-evolved with the natural environment of the PNW over a relatively long period compared with the length of time since non-indigenous peoples entered the landscape. These species, although highly adaptable to environmental change, are affected by disturbance patterns, both natural and human-induced.
- High quality habitat for wild salmonids was the result of naturally occurring processes that operated across a landscape scale and over a relatively long time period. These processes still occur today, but humans have altered the extent, frequency, and intensity of the natural disturbance regime. Humans will continue to exert a dominant force on the landscape of the PNW. Our land-use activities have generally simplified and degraded the natural mosaic of salmonid habitat. For recovery to be successful, current ecosystems need to better reflect the range of natural ecological conditions (IMST, 1999 & 2002). The *natural disturbance regime* is quite different from most human disturbances in a variety of ways. Natural disturbance events, such as floods or seismic events tend to be relatively infrequent and localized events, whereas human disturbances, such as agriculture, timber harvest, or development tend to be relatively continuous and widespread activities. This shift in disturbance regime and the rapid pace of environmental change is difficult for salmonids and other species to successfully adapt to (Noss and Cooperrider, 1994; NRC, 1996; Lichatowich, 1999).



- The environment and habitat of salmonids is dynamic, not static. In any given watershed, there will be periods of time when habitat conditions are better and times when habitat conditions are worse. At any given time, there also will be geographic locations where habitat is better and locations where it is worse. Over time the location of high-quality habitat has shifted and will continue to do so. Salmonid habitat in the region has been and will be a continuously shifting mosaic of naturally disturbed and undisturbed habitats. One of the legacies of salmonid evolution in this changing environment is the ability to colonize new or recovered habitat. The widespread presence of adequate refugia areas is critical to this recolonization process (FEMAT, 1993; Noss and Cooperrider, 1994; NRC, 1996; Spence et al., 1996; Lichatowich, 1999).
- Wild salmonid stocks historically accommodated changes in their environment through a combination of strategies. Long-term adaptation produced the highly varied life-history forms of these species, providing the genetic diversity needed to accommodate a wide range of changing conditions (Lichatowich, 1999). Genetic and life history diversity among populations of native salmonids vary with the spatial and temporal landscape patterns of their aquatic habitats (Nehlsen et al., 1991). High levels of salmonid abundance distributed in multiple locations (the “stock” theory) have increased the likelihood that populations and their gene pools would survive (Stouder et al., 1997). Occupation of higher quality refugia habitat allowed for recolonization of poor habitat as its condition improved over time. Since the mid 1850s, the rate and extent to which habitat conditions changed sometimes exceeded the ability of these species to adapt; therefore, stock abundance currently is greatly reduced (Nehlsen et al., 1991). Although a small number of high-quality refugia still exist, populations of wild salmonid stocks are seriously depressed because of a variety of factors. These factors are often referred to as the so-called “4-H’s”; harvest, hydropower dams, hatchery influences, and habitat alteration, including cyclical ocean-climate conditions. These factors together, tend to limit the rate and extent to which recolonization can occur. In addition, some harvest and hatchery practices have diminished the genetic diversity of salmonids, limiting their ability to cope with climate fluctuations (NRC, 1996). It is the combination of these factors and their *cumulative effects* that have led to the current situation (FEMAT, 1993; NRC, 1996; Lichatowich, 1999).
- The historic range of ecological conditions in the PNW, both of habitat and of salmonid stocks, is important because it provides a framework for developing policy and management plans for the future. The success and persistence of salmonid populations, both in terms of abundance and distribution, under historic ecological conditions is evidence that these habitats were compatible with salmon reproduction and survival. Borrowing from the disciplines of conservation biology and landscape ecology, a key principle of *ecosystem management* is that native species have evolved within a context of natural disturbance regimes and the spatial patterns of habitats that were the result of those regimes (Franklin, 1980). Therefore, the potential for survival of any given species may be reduced if spatial and temporal patterns of habitat shift outside the natural range of variation, especially if the shift is too rapid to allow for adaptation or migration. Land uses resulting in non-historical ecological conditions may support productive salmonid populations, but the evidence for recovery of salmonids under these circumstances is neither extensive nor compelling (IMST, 1999 & 2002). Therefore, the goal of aquatic resource management and policy should be to emulate natural processes within their historic range (Spence et



al., 1996). The recovery of wild salmonid stocks is an iterative process. Just as policy and management have changed in the past they will have to continue to change in the future, guided by what is learned from science and from experience. Recovery of wild salmonids requires, among other things, habitat that is functional across the broader landscape (Frissell, 1993). This means that management plans, regulations, and voluntary actions must also work across the landscape. A policy framework that incorporates landscape perspectives and makes regulation, management, and voluntary actions possible at this scale is needed (FEMAT, 1993; NRC, 1996; Spence et al., 1996; IMST, 1999; IMST, 2002). Ecosystem management that recognizes the “natural range of habitat variation” is a scientifically defensible approach to conserving native species diversity and maintaining natural ecological processes (Beechie and Bolton, 1999).



"Leave nature as it is...the ages have been at work on it and man can only mar it"

THEODORE ROOSEVELT, 1916

SALMONID REFUGIA THEORY

The refugia concept is built on the premise that the remaining native populations of salmonids can benefit most if conservation and restoration efforts are concentrated on those areas that still retain a functioning level of ecological integrity. These areas are critical, supportive habitat components of the total salmon life history. This scientific theory considers both salmonid life-history requirements (see Figure 1) and critical watershed processes in its analytical approach (Beechie and Bolton, 1999). Simply put, refugia are the last, best places for salmon survival and recovery. The national park system and the network of national wildlife refuges are examples of this theory in every-day practice. Based on conservation biology principles, these wildlife refuges are defined as refugia that are under protected status (Noss and Cooperrider, 1994).

The idea of *refuges, sanctuaries, or conservation reserves* for salmon is not a new one. At the American Fisheries Society (AFS) annual meeting in 1892, Livingston Stone, an early advocate of fisheries conservation, spoke of the impending demise of salmon and called for the establishment of "salmon parks" to protect native stocks (Stone, 1892).

"We must provide some refuge for salmon, and provide it quickly, before complications arise which make it impractical, or at least very difficult.... if we procrastinate and put off our rescue mission too long, it may be too late to do any good. After the rivers are ruined and the salmon gone, they cannot be reclaimed.... All the power of the United States cannot restore salmon to rivers after the destruction is complete..."

Stone argued that Pacific salmon were caught between the exploitation of fisherman and the destructive forces of civilization. He reminded his AFS colleagues at the meeting of the fate of Atlantic salmon (*Salmo salar*) on the east coast of North America and in Europe (Stone, 1892).

"It was the mills, the dams, the steamboats, the manufacturers injurious to the water, and similar causes, which, first making the streams more and more inhabitable for salmon, finally exterminating them altogether."

Obviously these prophetic words were not heeded, but instead the exploitation of salmonid stocks for economic gain has continued, along with an over-reliance on technological "fixes" such as hatchery production to make up for our destruction of natural habitat (NRC, 1996; Lichatowich, 1999; Lichatowich et al., 2000). Although the idea of salmon sanctuaries never really caught on in the PNW, it has been considered and was even implemented for a short time. In 1892, Stone himself recommended that the Uganik River, on Afognak Island, Alaska (a small island near Kodiak Island) be designated as a salmon sanctuary. This refuge was established, but fishing pressure and political maneuvering eventually led to its demise by 1923 (Lichatowich, 1999). In 1895 the Klamath River in Oregon was recommended as a salmon preserve, but was never established (Lichatowich, 1999). In 1928, the citizens of Oregon were asked to decide whether the Deschutes, Umpqua, and Rouge Rivers should be protected as fish sanctuaries. This petition was defeated at the polls and the idea



died (Lichatowich, 1999). Washington State also considered the idea of establishing salmon refuges as early as 1932, but failed to act on the concept (Lichatowich, 1999). Ironically, during this same period of time, the National Wildlife Refuge Program gained momentum with politicians and the public in an effort to conserve the dwindling waterfowl populations. As a result, this network of wildlife refuges was at least partially responsible for the recovery of migratory waterfowl populations, while salmon continued to decline in abundance and diversity (Lichatowich, 1999).

To-date, the recovery efforts in the PNW have not been successful. Native salmonid stocks have been extirpated from almost half of their natural range (Nehlsen et al., 1991). Although the overall decline of salmon populations can be attributed to a combination of factors including over-harvest, hatchery conflicts, and the natural variability of ocean conditions, one of the single most influential factors has been the loss and degradation of critical habitat (Nehlsen, et al., 1991; NRC, 1996; Spence et al., 1996; Stouder et al., 1997; Lichatowich, 1999). Because of this, the need for salmon refuges has become ever more critical (Rahr, et al., 1998). The watersheds of the PNW continue to become more degraded and fragmented, while the remaining productive salmonid habitat also declines. Therefore, one of the most important factors influencing the recovery and persistence of native salmonids must be the conservation of high quality spawning, rearing, and migrating habitat (Nehlsen et al., 1991; FEMAT, 1993; Huntington et al., 1996; NRC, 1996; Spence et al., 1996; Stouder et al., 1997). A clear correlation exists between habitat loss or degradation and the decline of salmonid populations in general (FEMAT, 1993; NRC, 1996; Spence et al., 1996; Stouder et al., 1997; May et al., 1997). Additionally, there is also a strong connection between habitat quality and salmon abundance and diversity (FEMAT, 1993; Frissell, 1993; Huntington et al., 1996; NRC, 1996; Stouder et al., 1997; May et al., 1997; Lichatowich, 1999).

In summary, over the past 100+ years since Livingston Stone originally called for the establishment of salmon reserves, the need for protected refuges for native salmonids has grown as the pressures on these valuable resources have grown. The remaining productive salmonid habitat is disappearing or declining in quality at a rapid pace as the human population of the PNW region increases. Habitat loss or degradation is a major factor in the decline of just under 90% of the native salmonid stocks designated as “at risk” or of “special concern” in the region (Nehlsen et al., 1991). In addition, over 90% of the “healthy” stocks of native PNW salmonids are considered threatened by the multiple stressors that cause habitat degradation (Huntington et al., 1996). It is also well established that many of the remaining stocks of native salmonids that can be considered highly productive are found only in watersheds that have some level of protective status, such as the rivers of the Olympic National Park or those watersheds protected under the Wildness Act and National Wild and Scenic Rivers Program (Lichatowich, 1999).

For the purposes of this report, a *salmonid refugia*, can be defined as a watershed patch or nearshore area that contains one or more of the following:

- Adequate quantities of functional, complex, and connected habitat, as well as the biological, chemical, geologic, and physical processes that maintain natural conditions over the long-term (Sedell et al., 1990). It must contain habitats that support salmonid spawning, rearing, and migration life history phases (Lichatowich et al., 2000).
- Diverse, native populations of salmonid species and life-history stages and/or biological “hot-spots” that can serve as source areas for the recolonization of surrounding watersheds (Frissell, 1993). These areas are also often called “anchor habitats” or a biological “oasis” (Dewberry et al., 1998).



- A level of protection that ensures the persistence of salmonid populations over an extended period of time, even in the face of natural disturbance regimes (Reeves et al., 1995). These refuges should be managed to ensure that salmonid populations and critical habitats are maintained within the “natural range of habitat variability” for the long-term. These refuge areas may require greater protection than is currently the norm under existing laws and regulations (Lichatowich et al., 2000).

Refugia are not identified solely by physical criteria, but rather represent a convergence of ecological (physical and biological) conditions that create a critical *patch* of habitat supporting life-stages of one or more salmonid populations (Frissell, 1998). From a geographic perspective, it may also be necessary to rehabilitate damaged habitat to provide refugia areas in key watersheds. This is necessary because the spatial distribution of refugia must be such that salmonid population dynamics are supported and so that ecological connectivity is maintained. The quantity and quality of refugia habitat will also change due to natural or human-induced disturbances. Based on this reasoning, adequate refugia habitat must be provided to compensate for localized losses due to disturbance events, both natural and human induced.

From a scientific perspective, refugia can span a broad extent of geographic sizes, shapes, and forms (Sedell et al., 1990). Salmon refugia can range from entire watersheds that retain much of their natural landscape of forest cover, diversity of aquatic biota, and intrinsic hydrologic function, to tributary stream-floodplain segments that function as islands of naturally complex and diverse habitat, to micro-habitat “patches” or stream reaches that function as temporal refugia during periods of disturbance. This interdependent or “nested” hierarchy of refugia habitat is a vital component of the natural salmonid landscape of the PNW (Frissell, 1998). As an example, “key watersheds” have been identified as critical to the overall recovery of numerous species, both terrestrial (spotted owl and marbled murrelet) and aquatic (salmon and trout) that inhabit the forests of the region (FEMAT, 1993).

Based on the complexity and variety of salmonid life-history stages, their survival depends on functional refugia existing throughout the full extent of a stream or river system, from headwater tributaries to the estuary and associated nearshore areas (Sedell et al., 1990; Schlosser, 1995; Frissell, 1998). Because the various life stages of salmonids (see Figure 1) require different physical habitat features, spatial heterogeneity and connectivity of habitat patches is critical for completion of their life cycles and long-term persistence of the population (Schlosser, 1995). The term “habitat complementation” refers to the spatial proximity of different habitat types (i.e., LWD or deep holding pools) or unique resources (food, cover, etc.) required by a particular species. A landscape where these unique habitat types are in close proximity and are natural redundant will generally support larger and more robust populations (Schlosser, 1995). If the spatial arrangement among different habitat types is temporally in a state of natural dynamic equilibrium, increased habitat complementation can result in enhanced population stability and persistence (Dunning et al., 1992). Habitat *complementation* will therefore increase persistence of salmonid populations by increasing the probability that fish of various life stages will find appropriate habitat types during critical life history stages (e.g. fall or winter spawning habitat, over-winter rearing habitat, spring or summer feeding habitat, etc.).

Therefore, it should be clear that *refugia habitat* cannot be identified by a single physical characteristic or single scale of measure, but rather these areas represent the convergence of a number of ecological conditions that together allow a particular area to “support the vital ecological functions necessary for the long-term survival of native species” (Frissell and Bayles, 1996).



From an aquatic resources management perspective, it is generally recognized that a *watershed-based approach* is the optimum strategy for salmon conservation (FEMAT, 1993; Spence et al., 1996; Stouder et al., 1997; Naiman and Bilby, 1998; WA-JNRC, 2001). To be considered a refugia area, a watershed must be able to support diverse, locally adapted populations of salmonids and the habitat matrix necessary to sustain them over the long-term. Due to the cumulative impacts of past land-use practices many watersheds do not meet these criteria, but are nonetheless important from an historic perspective (i.e. salmon productivity and/or diversity). These watersheds can be considered as potential or future salmon refuges, and should be the primary focus of restoration and rehabilitation activities.

To function as an effective refuge, not only must the habitat be of high enough quality (or have the potential to be restored to that level) and of adequate extent, but it must also be accessible to the species of concern during one or more life stages. In other words, there must be sufficient opportunity for a self-sustaining portion of the population to gain access to the refugia during critical life-history stages (Lichatowich et al., 1995). In the case of wild salmonids, refugia habitat is needed to support upstream adult migration, spawning and incubating, nearshore adult and juvenile migration, juvenile rearing during all seasons, downstream smolt migration, and estuarine/nearshore rearing. Some of this refugia habitat may coincide, but some may be unique to each life-stage and may vary considerably between species (Stouder et al., 1997). Even species that share similar habitat needs may have subtle differences in their ability to exploit potential refugia based on differences in population distribution, dispersal capabilities, and other aspects of physiology or behavior. Therefore, the geographic location, temporal accessibility, and ecological function of the habitat are all critical to the structure and function of refugia. The ecological value and quality of the refugia is determined by all these factors combined (Li et al., 1995; Frissell and Bayles, 1996; Frissell, 1998; Lichatowich et al., 2000). As was discussed earlier, there also needs to be enough refugia habitat within a region to support native populations and allow for the natural disturbance regime to function.

Because of the frequency, intensity, and diversity of the region's natural disturbance regime (flooding, fire, landslides, etc.), no single refugia is likely to maintain its structure or function indefinitely (Reeves and Sedell, 1992; Reeves et al., 1995; Frissell, 1998). Human activities in the watershed tend to increase the frequency and magnitude of environmental disturbance. This is especially true for aquatic ecosystems of the Puget Sound region that are undergoing watershed development (May et al., 1997). Based on these facts, the potential network of salmon refugia identified by this study was geographically distributed over the natural "salmonid landscape" based on the historically productive and diverse habitats of the region. This natural distribution of refugia should help to ensure the long-term persistence of salmon populations within the region over several decades or even longer.

The need for refugia habitat to be managed as some form of conservation area arises from the extensive human-induced disturbance that has impacted the landscape over the past century (Frissell and Bayles, 1996; Lichatowich et al., 2000; Dewberry, 2001). The widespread, cumulative impacts of human land-use activity in the watershed have left relatively few areas that approach their natural, historic abundance or diversity of salmonid populations or habitat (Naiman and Turner, 2000). This is especially true in lowland areas where a history of timber harvest and agricultural activity has been followed by watershed development (May et al., 1997; Horner and May, 1999; Booth et al., 2001). In the Puget Sound lowlands resource extraction land use (timber harvest, mining, and agriculture) is still a significant part of the disturbance profile of many watersheds. If our land-use practices and natural resource management activities significantly improve over the next century, it is hoped that the need for dedicated salmonid refuges may diminish (Frissell, 1993; Reeves et al., 1995; Frissell, 1998). However, if long-term salmon recovery efforts fall short, continued stewardship of refugia areas based on the principles of adaptive management would be prudent.



Recent scientific studies and publications have made a persuasive argument for ecologically functional refugia as the cornerstone of a long-term aquatic resource conservation plan (Sedell et al., 1990; Frissell, 1993; Noss and Cooperrider, 1994; Li et al., 1995; Rapp, 1997; Frissell, 1998; Lichatowich et al., 2000; Dewberry, 2001). This is certainly applicable on a regional scale to any proposed Puget Sound salmon recovery program. The refugia strategy is also appropriate for salmon conservation on the sub-regional and watershed scales involved in this study. Tributary watersheds and stream corridors are vital landscape components for the survival and persistence of wild salmonids and many other native species. Identification of current and/or historic watersheds and highly productive stream-riparian corridors is likely crucial to the long-term aquatic biodiversity of the region. These areas and other critical habitat “patches” (such as riparian corridors) are important because they provide a disproportionately large share of regional salmon productivity and diversity. Because of the extensive, high quality habitat, these areas also tend to provide refuge from natural disturbance events, such as large floods, extended droughts, and other major disturbance events.

Because these areas currently support or historically supported large, diverse populations of salmonids, refugia can also be considered biological “hot-spots” or source areas for the repopulation of locally extirpated stocks. In this capacity, they are the primary recolonization sources for adjacent watersheds and stream systems. Over time and with a dedicated effort, habitat in these surrounding watersheds should improve as a result of restoration activities. Salmonids from refuge watersheds should then repopulate these areas through natural “straying” or via augmentation programs (Young, 1999). This basic approach to recovery came out of the Northwest Forest Ecosystem Management and Assessment Team (FEMAT) process and has been referred to as the Rapid Biotic and Ecological Response (RBER) strategy (Doppelt et al., 1993).

The FEMAT process also identified the concept of “key” watersheds (FEMAT, 1993). This strategy delineates relatively undisturbed watersheds on a large geographic scale as refuges for salmonids on a regional scale. The key watershed approach was proposed for prioritizing recovery efforts within a large geographic region such as the Columbia River, the PNW coastal eco-region, or the Puget Sound basin. This strategy allocates scarce resources among river basins or stream sub-watersheds within the key watershed of interest. A scaled-down version of this approach could also work on smaller regional levels as well. Within the designated Puget Sound Evolutionary Significant Unit (ESU) there are sub-regions such as the Hood Canal that contain potential refugia habitat that should be identified and managed for the benefit of the region as a whole.

The relatively new conservation strategy of *ecosystem management* should also be a key component in the overall salmonid recovery effort. The conceptual foundation for this strategy is based on the principles of *landscape ecology* (Foreman, 1997; Farina, 1998; Turner et al., 2001) and *conservation biology* (Wilson, 1992; Noss and Cooperrider, 1994; Wilson, 2001). This strategy involves managing aquatic ecosystems for the protection of native biodiversity (Naiman and Bilby, 1998) and assumes that the protection of ecosystem structure and function will result in the protection of all species including those already listed as threatened or endangered. A key component of this strategy is that humans are recognized as an integral part of the ecosystem and the success of conservation efforts is highly dependent on understanding of human influences on ecological processes and landscape patterns (Naiman and Bilby, 1998). Therefore, ecosystem management on the scale of refugia is not just scientific theory; rather it is an integrated program of scientific, socio-political, cultural, and economic values designed to achieve long-term ecosystem conservation.



"There is no final ecological truth. All knowledge is a current approximation, and each addition to that knowledge is but a small, incremental step toward understanding. Not only are ecosystems more complex than we think; they may be more complex than we can think."

JACK WARD THOMAS, USFS, 1992

SALMONID POPULATION THEORY

In general, scientists agree that watershed or landscape-level characteristics, as well as instream habitat conditions, play a significant role in influencing salmonid population dynamics and population persistence (Sedell et al., 1990; Frisell, 1993; Schlosser, 1995; McElhany et al., 2000). Functional interactions at the terrestrial-aquatic eco-tone (stream-riparian corridor) are at least as significant as aquatic processes within the stream (flow, water quality, etc.) for the long-term survival of salmonids (Gregory et al., 1991; Schlosser, 1995; Naiman and Bilby, 1998). Watershed conditions also directly or indirectly influence instream habitat characteristics and population dynamics (e.g. the hydrologic regime or instream water quality). Because of these factors, in areas where the watershed landscape is being modified by human land-use, refugia will likely be critical to maintaining natural population distribution and interactions (Sedell et al., 1990). The idea that salmon population management should focus on the watershed scale is not a new concept. In 1939, based on many years of research in the PNW, Professor Willis Rich of Stanford University concluded that each species of Pacific salmon was composed of many unique, local, watershed-based populations (Lichatowich, 1999). According to Rich, each watershed and its unique salmon population should be the fundamental unit of management. He stated his principles as follows (quoted in Lichatowich, 1999):

"In the conservation of any natural biological resource it may, I believe, be considered self-evident that the population must be the unit to be treated. By population, I mean an effectively isolated, self-perpetuating group of organisms of the same species regardless of whether they may or may not display distinguishing characters and regardless of whether these distinguishing characters, if present, be genetic or environmental in origin. Given a species that is broken up into a number of such isolated groups or populations, it is obvious that the conservation of the species as a whole resolves into the conservation of every one of the component groups or populations and that the success of efforts to conserve the species will depend, not only on the results obtained with any one population, but with the total of individuals in the species that is contained within all the populations affected by the conservation measures."

The National Marine Fisheries Service (NMFS) defines a viable salmonid population (VSP) as "an independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation, local environmental variation (natural and anthropogenic), and genetic diversity changes over a 100-year timeframe" (McElhany et al., 2000). This NMFS report (McElhany et al., 2000) provides "the basis for a general approach to performing salmon conservation assessments" using salmonid population theory as the foundation. The first step in this VSP analysis is the identification of ecologically important salmonid populations. This can be done at the evolutionarily significant unit (ESU) level, but may be more appropriate at a smaller, more regional scale, because independent salmonid populations likely exist at a smaller scale than the



entire Puget Sound ESU (Waples, 1991; Allendorf et al., 1997; McElhany et al., 2000). This provides another scientific justification for the refugia approach to salmonid conservation.

There are several major parameters that are important when evaluating biological population status. These include species abundance, productivity (or population growth rate), population spatial structure, and biological diversity (McElhany et al., 2000). These factors reflect the general processes that are important to populations in all species, not just salmonids (Waples, 1991; Policansky and Magnuson, 1998; McElhany et al., 2000).

All else being equal, smaller populations are generally at greater risk of extinction than large populations, primarily because both environmental and genetic influences operate differently in small as opposed to large populations. Therefore population size is an important consideration in the refugia process. Population size or abundance is important to maintain a VSP based on both demographic and genetic reasons. Low population size can result in inadequate reproductive output, inbreeding depression, and loss of genetic diversity (McElhany et al., 2000). Population growth rate or productivity over the entire salmonid life cycle is also an important factor to consider. NMFS has developed guidelines for evaluating VSP status with regard to population size and productivity (McElhany et al., 2000). These include the following:

- A population should be large enough to have a high probability of surviving environmental variation based on historical patterns observed in the study area.
- A population should have sufficient abundance for compensatory processes to provide resilience to environmental and anthropogenic disturbances.
- A population should be sufficiently large to maintain its genetic diversity over the long-term.
- A population should be sufficiently abundant so as to provide important ecological functions (such as nutrient enrichment from spawned-out carcasses) throughout its life cycle.
- A population's natural (wild) productivity should be sufficient to maintain its abundance at or above the minimum VSP level.
- A population should not exhibit sustained declines in abundance over multiple generations and should exhibit sufficient productivity during freshwater life-history phases so as to maintain a VSP even during poor ocean conditions.

The long-term genetic and ecological interactions within species are critical to the process of identifying populations for protection (Li et al., 1995). Salmonid populations are believed to exist in some form of *meta-population*, or a "population of populations" (Cooper and Manger, 1999; Dunham and Reiman, 1999; McElhany et al., 2000). This is a major factor in the designation of the Puget Sound ESU under the ESA (Waples, 1995). These meta-populations are composed of geographically isolated, genetically unique populations. Under this survival strategy, species persist in the long-term and over wide geographic areas because recolonization follows episodic extinctions of local populations (Hanski and Gilpin, 1991; Policansky and Magnuson, 1998; McElhany et al., 2000). This results in a continuously shifting species distribution pattern. In pure meta-populations, each local population is equal in size and relative importance to the overall array of populations (Harrison, 1991). This is illustrated in Figure 3A. In reality, most species that exist as meta-populations do so as some modified form (Harrison, 1991). Some species may exist as "core-satellite" populations (see Figure 3B), while others could better be described as "patchy" populations (see Figure 3C). Patchy



population dynamics characterize mobile taxa in spatially heterogeneous, temporally variable habitats, where several complementary habitats are required for the persistence of the population. Core-satellite populations have one or more sub-populations that have a greater potential for emigration than the others (see Figure 3B). The core populations are larger and usually occupy the more extensive and productive habitats. Under natural conditions, the core population is expected to persist indefinitely. Satellite populations often occupy marginal habitat (Harrison, 1991). Their abundance may fluctuate in response to changes in climate, and they may go extinct after severe disturbance events. Dispersal of individuals from the large core population will often colonize vacant habitat, reestablishing satellite populations and generally minimizing the possibility of total extinction of the meta-population (Harrison 1991). If core areas associated with core populations can be identified, it would be critical to protect those habitats to prevent the extinction of the meta-population and ensure the possibility of recovery. This also points out the importance of having adequate satellite habitat, even habitat areas that go under-utilized for periods of time, so that the meta-population has refuge habitat as a “hedge” against disturbance events. It is generally believed that salmonids exist as hybrid meta-populations (see Figure 3D) that are a combination of the patchy and core-satellite models (Schlosser and Angermeier, 1995). Figure 4 shows this meta-population concept as it might be viewed from a watershed perspective.

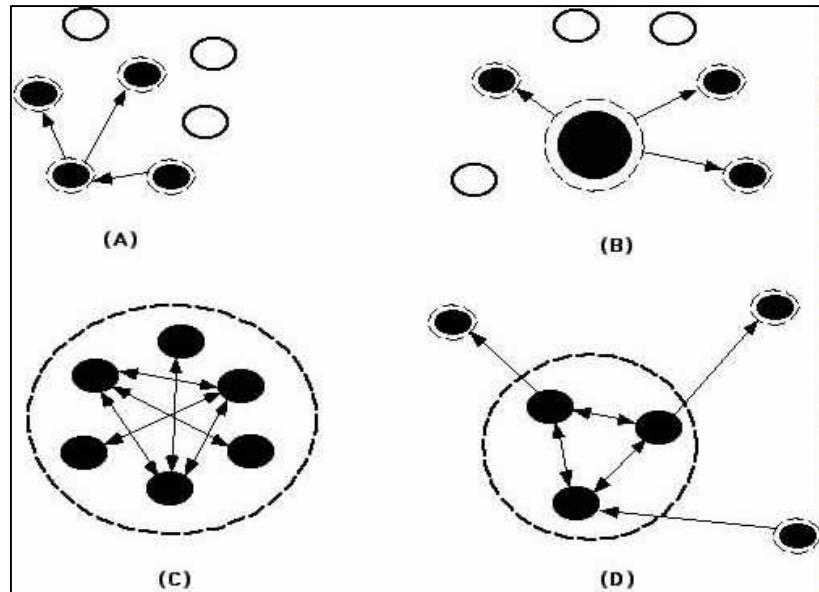


Figure 3: Diagram of Meta-population Models (modified from Schlosser and Angermeier, 1995). Solid shapes indicate occupied habitat patches and local populations. The open shapes indicate vacant patches. Arrows indicate generalized recolonization or straying pathways. The dashed lines show population boundaries. Population models: (A) pure meta-population (B) core-satellite population (C) patchy population (D) hybrid meta-population.

Meta-population theory also directly links populations to the natural disturbance regimes that shape landscape structure and function (Policansky and Magnuson, 1998; Cooper and Manger, 1999; Dunham and Reiman, 1999; McElhany et al., 2000). The linkage is the balance between the extinction of local populations after severe habitat disturbance and the subsequent recolonization of previously disturbed habitats as they recover. This extinction-colonization balance depends on the dispersal of individuals and the connectivity between habitats occupied by populations making up the meta-population (Fagan, 2002). If the frequency of disturbance, whether human caused or natural, that degrades critical habitat exceeds its ability to maintain a balance between extinction and recolonization, the local populations and eventually the entire meta-population will likely go extinct (Hanski and Gilpin, 1991; Harrison 1991; Li et al., 1995; Fagan, 2002).

A landscape or watershed approach to salmonid recovery is consistent with the concepts of meta-population dynamics. According to the meta-population concept, species occur as discrete local populations on networks of idealized habitat patches. Groups of populations that are linked by



migration of individuals are considered to be meta-populations. Local or regional disturbance events can cause extinction of local populations, but long-term persistence of meta-populations is due to asynchrony, local population dynamics, and the ability of individuals to re-colonize habitats (Harrison, 1991; Hanski and Gilpin, 1991; Hanski, 1998).

Meta-population theory has been applied to many groups of organisms, leading to the development of multiple theories or models (IMST, 2002). These meta-population models differ according to the relative size of

populations, relative rates of extinction and recolonization, and relative habitat quality (Hanski, 1991; Harrison, 1991; Li et al., 1995; Schlosser and Angermeier, 1995; Rieman and Dunham, 2000).

In core-satellite model (see Figures 3 & 4), a large (core) population is less prone to extinction and provides a source of immigrants to smaller (satellite) populations (Hanski and Gilpin, 1991; Harrison, 1991; Li et al. 1995). In this model, the core population is generally stable, while the smaller, satellite populations may fluctuate in abundance as a result of demographic processes, genetic processes, and changing environmental conditions (IMST, 2002). In the case of salmon, these environmental changes may include variations in climate and ocean conditions, or changes in local habitat conditions. In this model, the persistence of the core population is therefore critical not only to the survival of the satellites, but to the persistence of the entire meta-population as well.

Frissell (1993) concluded that core populations were closely associated with lowland streams that had high levels of ecological function and high habitat quality. However, the dynamic nature of aquatic systems results in salmonid habitat quality that can be highly variable, both spatially and temporally (Reeves et al., 1995). Therefore, we would expect that core populations of salmon would not remain static over time and space, and that the location of high-quality, “core” habitat areas would change with time. Successful management would need to anticipate and respond to these changes (IMST, 2002).

A similar model to the core-satellite model is the source-sink model. The source-sink model emphasizes that habitat quality varies enough among areas to cause differences in productivity among populations (Harrison, 1991). Variation in habitat quality may be due to natural processes or human disturbance (Pulliam, 1988). In the source-sink model, source populations occupy high quality

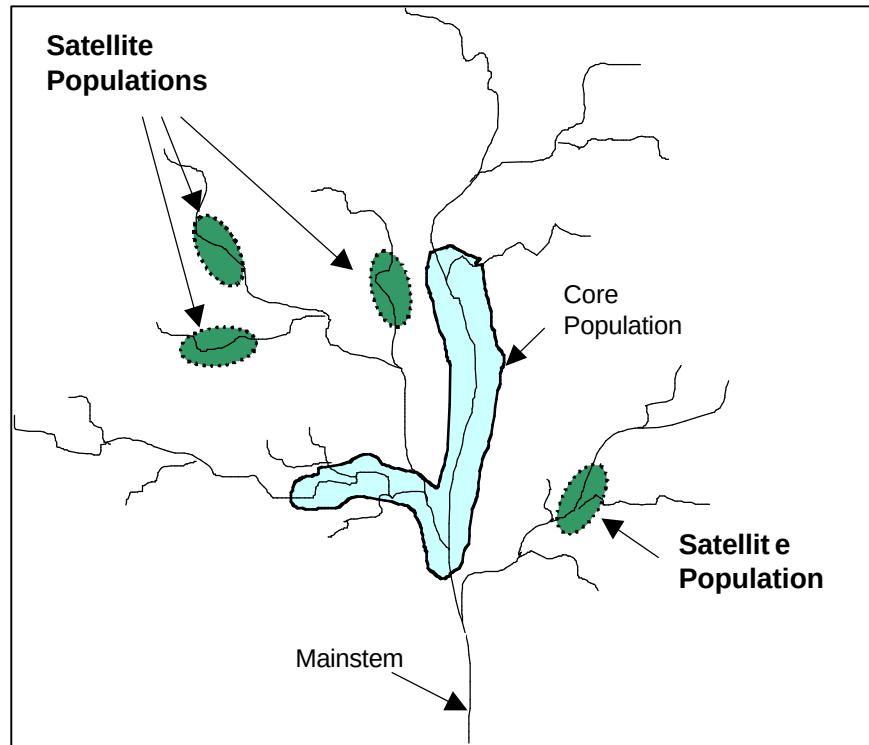


Figure 4: Diagram of Meta-population on the Watershed Scale (IMST, 2002).



habitat, leading to enhanced survival and reproduction (Pulliam, 1988). Salmonids that disperse into lower quality habitat form sink populations. However, because habitat quality is lower, sink populations are less likely to persist if source populations are extirpated (Pulliam, 1988). In a source-sink system, protection of source populations is critical because smaller populations are not self-sustaining in the absence of the source population. In contrast, in the core-satellite model, satellite populations might serve as refugia if a core population went extinct.

Another model, the patchy population model (see Figure 3C), consists of a number of populations that are highly connected by dispersal (Harrison, 1991). Salmon also exhibit some characteristics of patchy populations (Reeves et al., 1995). Like other species that exhibit this pattern, salmon exist in a dynamic environment with variable patch quality and have strong dispersal capabilities (Harrison, 1991). In this case, the presence of multiple habitat patches and the potential for dispersal among patches is important to salmon persistence and recovery (Harrison, 1991; Reeves et al., 1995; Schlosser and Angermeier, 1995).

At present, scientists have little data to determine which, if any, of the models is most appropriate to describe demographic processes in individual salmonid species or populations (IMST, 2002). Furthermore, population size and dispersal rates vary among species and runs. Regardless of differences among models, meta-population structure was likely a key strategy by which salmonids survived and adapted to changes in their environment.

Meta-population theory has only recently been used to formulate salmon management strategies (Li et al., 1995, Mundy et al., 1995, Schlosser and Angermeier, 1995, NRC 1996, IMST, 2002), but it can provide important guidance to recovery efforts. Local populations, even an entire meta-population, are more prone to extinction in fragmented landscapes having little connectivity (Fagan, 2002). Given the dynamic nature of critical salmonid habitats, currently unoccupied habitats may be critical for long-term survival (Hanski, 1997). Recovery strategies, to be successful, need to consider meta-population structure within and among watersheds, the scale thought to be relevant to salmonid meta-population dynamics (Li et al., 1995; Schlosser and Angermeier, 1995; Reeves et al., 1995; IMST, 2002).

PNW salmonid populations are generally considered hybrid meta-populations mainly due to cohabitation during their ocean phase and the occurrence of “straying” within and between local populations (Quinn, 1993). An independent population is that group of sub-populations found within a distinct geographic range. They do not usually interact with other regional populations, but the actual independence of populations is not fully understood. The importance and extent of straying is also not well understood (Quinn, 1993). It is generally believed that independent populations are smaller than an entire ESU, and will be associated with major river basins or geographically defined areas such as Hood Canal or the Kitsap Peninsula.

Aside from the purely scientific value of meta-population theory, a solid understanding of salmon population dynamics is needed to identify and manage refuge areas that support species conservation (Policansky and Magnuson, 1998; Cooper and Manger, 1999; Dunham and Reiman, 1999; McElhany et al., 2000). Habitat fragmentation can have a significant impact on meta-populations (Hess, 1996; Wahlberg et al., 1996; Fahrig, 1997; Hiebel, 2000; Fagan, 2002). In highly disturbed regions, identification and protection of “core” populations could be critical to the overall success of a recovery program. Location and assessment of critical, life-stage habitat “patches” or satellite habitat (see Figure 4) could also influence the designation of refugia areas. It is also important to characterize the dispersal dynamics and migration corridors of the species of interest if we are to design our reserve network to support species persistence or recovery. In most cases, meta-



populations require a relatively large number of closely spaced, interconnected refugia to lower the risk of extinction to a level that is acceptable (Sedell et al., 1990; Li et al., 1995; Fagan, 2002).

The exact geographic distribution of independent populations required to maintain VSP conditions within an ESU has also not been determined. Spatial structure in spawning salmonids is a natural consequence of their ability to home to natal watersheds, natal tributaries within watersheds, and (potentially) natal reaches within tributaries (Quinn, 1993). Homing provides a mechanism for maintaining a hierarchy of reproductive isolation among groups of fish that reflects the dendritic structure of watersheds (Policansky and Magnuson, 1998). Straying (i.e., the return of individuals to freshwater habitats other than that in which they were born) offsets both the demographic and genetic isolation of such groups (Quinn, 1993). In general, the frequency of straying tends to decrease with distance from the natal patch (Quinn, 1993). Based on this, “patch spacing” is the primary factor determining “migration corridors” in salmonids. If habitat patches are too widely spaced, then patch extinction or destruction may outpace colonization (Sedell et al., 1990; Fagan, 2002; Policansky and Magnuson, 1998).

Therefore, the spatial arrangement of habitat patches must be considered when assessing spatial structure, because it affects the probability that colonization can occur should empty (but suitable) habitat become available (McElhany et al., 2000). In an empirical study of a bull trout meta-population, Dunham and Reiman (1999) found a decrease in patch occupancy with increasing distance from an occupied patch. Populations may also “stray” or expand into new habitat patches during times of high productivity (for example during periods of high ocean survival). This may occur even if the quality of adjacent patches is lower than in the “core” or “source” patch. These “marginal” patches may still contribute to population abundance during favorable years and thus help buffer the population from extinction (McElhany et al., 2000). However, if patches are too far apart, populations may not be able to expand to new patches in times of high productivity. Thus, the spacing of habitat patches that rarely contain fish may affect population viability (McElhany et al., 2000).

NMFS has developed guidelines for evaluating VSP status with regard to population spatial structure (McElhany et al., 2000). These include the following:

- Habitat patches should not be destroyed faster than they are naturally created. Salmonid habitat is dynamic in nature, with suitable habitat being continually destroyed and created by natural processes and disturbances. Human activities should not result in an overall decrease in habitat abundance, availability, or accessibility.
- Natural rates of straying among sub-populations should not be substantially impacted by human activities. Therefore, habitat patches should be close enough together to allow appropriate exchange of spawners and the expansion of populations into unused habitat during times of high abundance.
- Habitat patches that appear to be suitable or marginally suitable, but do not currently support salmonid populations should also be protected. In the dynamics of natural populations, there may be a time lag between habitat abandonment and colonization. If human activity is allowed to degrade suitable, unoccupied or under-occupied habitat, the larger population as a whole may not be sustainable over time.
- Habitat patches differ in quality and this is reflected in productivity differences among sub-populations. Some habitat patches are naturally more productive than



others. These “source” populations must be maintained. It should also be recognized that spatial processes are dynamic and source areas may shift over time.

There are several reasons why diversity is an important salmonid population trait. This natural variation has important implications for population viability (McElhany et al., 2000). Some of these diversity traits include population age structure, life-span, fecundity, morphology (body size and shape), adult spawner run-timing, spawning behavior, juvenile rearing behavior, egg/embryo development rate, smolt timing, ocean distribution patterns, and genetics. Many of these traits may be adaptations to local conditions or may help protect a population from environmental variations. In general, a combination of genetic and environmental factors is responsible for species diversity.

In a spatially and temporally varying environment, there are three general reasons why diversity is important for species and population viability. First, diversity allows a species to use a wider array of environments than they could without it. For example, varying adult run and spawn timing allows several salmonid species to use a greater variety of spawning habitats than would be possible without this diversity. Second, diversity protects a species against short-term spatial and temporal changes in the environment. Fish with different characteristics have different likelihoods of persisting—depending on local environmental conditions. Therefore, the more diverse a population is, the more likely it is that some individuals would survive and reproduce in the face of environmental variation. Third, genetic diversity provides the raw material for surviving long-term environmental changes. Salmonids regularly face cyclic or directional changes in their freshwater, estuarine, and ocean environments due to natural and human causes, and genetic diversity allows them to adapt to these changes (McElhany et al., 2000).

NMFS has developed guidelines for evaluating VSP status with regard to population diversity (McElhany et al., 2000). These include the following:

- Human-caused factors (such as habitat degradation, harvest pressure, hatchery influences, and hydro-modifications) should not substantially alter variations in diversity traits such as run timing, age structure, fecundity, body size or shape, spawning or rearing behavior, and genetic characteristics.
- Natural processes of dispersal should be maintained. Straying rates should not be significantly altered by human activities. This is critical to population persistence from a genetic perspective.
- Natural environmental processes that result in ecological variation should be maintained. In general, the natural disturbance regime must be maintained.

The distribution and sizes of local populations can also impact population persistence and overall genetic diversity. Therefore skewed population distributions that result from significant differences in habitat carrying capacities or habitat quality can result in an increased probability of extinction (McElhany et al., 2000). This implies that protection, rehabilitation, or enhancement of the biggest or the most culturally important populations may not always be the optimum course of action in the long run. Protection and recovery of small local populations may also be required, and may in fact be critical to the persistence of a population (Schlosser, 1995). The bottom-line is that we do not know enough to say which sub-populations are most important and which are not (Policansky and Magnuson, 1998; Cooper and Manger, 1999; Dunham and Reiman, 1999; McElhany et al., 2000; Fagan, 2002). In addition, because of the inherent heterogeneity of salmonid habitat, it is generally accepted that the more geographically distributed a population is, the more resistant it is to extinction due to regional or local catastrophes, as well as being more resilient to disturbance in general (Frissell,



1997; Dunham and Reiman, 1999; McElhany et al., 2000). This supports protection of a large number of geographically dispersed sub-populations as the most conservative approach to ensuring the persistence of a given population. It follows then, that any loss of apparent “redundancy” or range within a network of populations, is likely to compromise the overall long-term survival of that population (Sedell et al., 1990; Bisson, 1995; Frissell, 1997; McElhany et al., 2000; Dewberry, 2001).

Understanding how salmonid populations interact with one another highlights the importance of identifying individual populations, maintaining connectivity among habitat patches, and designing habitat restoration strategies to support multiple self-sustaining populations. A better understanding of critical parameters of salmonid populations, such as dispersal among basins (straying) and productivity, can help to design more effective recovery strategies (IMST, 2002).

Although it is not within the scope of this report to discuss in detail the impacts of hatchery fish and aqua-culture on wild salmonids, it is generally and widely recognized by the scientific community that the ecological effects of hatchery fish are predominately negative due to intra- and inter-species competition, as well as other significant problems (Hilborn, 1992; Meffe, 1992; NRC, 1996; Mahnken et al., 1998; Lichatowich et al., 1999; Flagg et al., 2000; Naylor et al., 2000; Levin et al., 2001; Levin and Williams, 2002). Most hatcheries are operated as “production” hatcheries, supplying salmonids to the “common property fishery” to benefit commercial, tribal, and sport fishers with little regard for the impact on wild stocks. In some cases, however, hatchery influences may not be entirely negative if used ecologically (McElhany et al., 2000) or operated as “conservation” hatcheries with a minimal impact on the survival of wild salmonids (Flagg et al., 2000). There is evidence that recovery of some extirpated or low-abundance populations may be aided by selective inputs of hatchery stocks to artificially increase the rate of recolonization (White, 1995; Grant, 1997; Young, 1999; Flagg and Nash, 1999; Hamm and Pearsons, 2001). This is a component of the overall salmon recovery strategy that should be investigated further. However, with only a few exceptions, this is generally not how hatcheries are currently operated. Federal (USFWS), state (WDFW), and tribal hatcheries in the Puget Sound region are currently being examined by an independent scientific review team (The Hatchery Scientific Review Group). Although the report was not available for inclusion in this study, the findings and recommendations of this panel should provide scientific guidance for improving hatchery operations in support of salmon recovery. However, for the purposes of this report, the overall impact of a *production hatchery* located within a potential refugia area was considered to be negative.

In addition to hatcheries, the impact of harvest operations on salmonid populations, while also not within the scope of this report should be considered as part of the overall salmonid recovery process. Ocean conditions also play a significant role on salmonid productivity (Lawson, 1993) and should be a component in the recovery planning process.



"Almost every aspect of modern human society in the Pacific Northwest has played some part in the decline of the wild salmon and the degradation of salmon habitat..."

BROWN, 1982

STUDY APPROACH

The Salmonid Refugia Project was designed to evaluate the current ecological condition of salmonid resources in the East Jefferson County and Kitsap County, Washington study areas. This report can be considered as the first step in the overall, long-term salmon recovery process. The report also makes recommendations for resource conservation, enhancement, and restoration.

The study area includes streams that drain into Hood Canal and west-central Puget Sound (see Figures 5 & 6). The study area encompasses parts of Water Resource Inventory Area (WRIA) 15, 16, and 17. This project can be described as a rapid identification and evaluation of high-priority areas for conservation of salmonid resources in our region. The study is a synthesis of existing data, scientific information, field surveys, and professional opinion. The report draws from what is known, published and described by "local experts" within agencies, tribes and watershed groups having direct knowledge of these ecosystems and populations. The assessment provides a prioritized listing of the most ecologically significant freshwater and nearshore habitats for salmon in the study area. This prioritized list of refugia, together with the summarized information and compiled sources, can be used to help guide cost-effective conservation decision-making in the near term for the benefit of salmon.



Figure 5: Location of Refugia Project Study Area.

A modified version of the refugia methodology developed by Frissell (1998 and 1999) was used to identify salmonid refugia habitat. The best available scientific data was utilized, including both quantitative and qualitative habitat data on each stream system, salmonid abundance data, and stock assessments, as well as historic and current watershed conditions on multiple landscape scales. Our approach is a modification of the Rapid Biological and Ecological Response (RBER) protocols (Doppelt et al., 1993), a watershed-based strategy developed during the FEMAT (1993) process. The scientific foundation for this approach can also be found in basic conservation reserve design principles (Noss and Cooperrider, 1994) and is grounded on the principle of "best available science" (Smallwood et al., 1999).

The State of Washington published guidance on *watershed assessment* to support salmon conservation efforts (WA-JNRC, 2001). This guidance document characterizes the watershed assessment process as being composed of three overlapping stages, each more detailed and



scientifically rigorous than the next. Watershed assessment is recognized as a critical early component in the overall salmon recovery process (Beechie, et al., 2003). The Salmonid Refugia Project covers the first stage of this overall process. The “Limiting Factors Analysis” (LFA), which was conducted within the same time period of this study, covers the second stage of the watershed assessment process as defined by the guidance document (WA-JNRC, 2001). The detailed watershed assessment process, which is currently underway in the study area, should cover the third and final stage of the overall process. Each of these studies involves different levels of effort and different levels of detail, but the overall goals of each are very complimentary and supportive of the next stage. The initial stage of the watershed assessment process, as outlined in the Washington guidance document (WA-JNRC, 2001), consists of characterizing the watershed, describing current habitat conditions, summarizing salmonid stock status and trends, and synthesizing this information into a summary report. The guidance document recommends using existing data as much as possible and utilizing the local expertise of scientists who are familiar with the watersheds under assessment. It is important to note that detailed, quantitative instream habitat assessment is not a part of this stage in the watershed assessment process, nor was it a part of the refugia project.

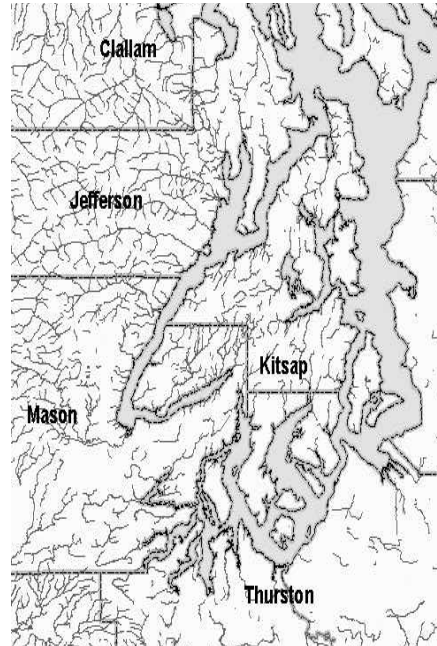


Figure 6: Boundaries of Refugia Project Study Area.



"We must work together to restore the integrity of our landscape and our native fishes, riparian areas, forests, and streams. The health of our watersheds depends upon the developing a proper land ethic, upon conducting ourselves in a manner consistent with the principles of that ethic, and upon correcting damage from past actions. The challenge is not an easy one, but one that is worthy of our best fight."

BRUCE BABBITT, SECRETARY OF THE INTERIOR, 1997

LANDSCAPE APPROACH TO PROTECTION AND RESTORATION

Protection of aquatic resources involves preventing anthropogenic alterations to the structure and function of the ecosystem (NRC, 1992). Ideally, this would involve protection of biological, chemical, and physical processes that maintain salmonid habitat. The mechanisms for protection include regulation, acquisition, conservation easements, and stewardship. These are mainly policy issues and will not be addressed in this report. However, the scientific information outlined in this report can be used to make informed decisions about where protection may be an effective tool.

In contrast, restoration involves improving aquatic functions and related physical, chemical, and biological characteristics of riparian and aquatic systems. Restoration may involve reconstruction of previous physical conditions, adjusting physio-chemical processes, removal of invasive or exotic species, and/or biological re-introduction of extirpated species (NRC, 1992). Aquatic restoration activities often include improvements in water quality, water quantity, fish passage, and riparian vegetation (IMST, 2002).

Different types of restoration activities vary in the amount of human intervention involved and represent a continuum of "passive" to "active" restoration (NRC, 1996). The term restoration is typically used broadly to encompass activities that are sometimes classified as "rehabilitation", "enhancement", or "mitigation" (NRC, 1992). Figure 7 illustrates these concepts. As used in this report, watershed restoration is defined as the process of restoring systems and processes to the point they can

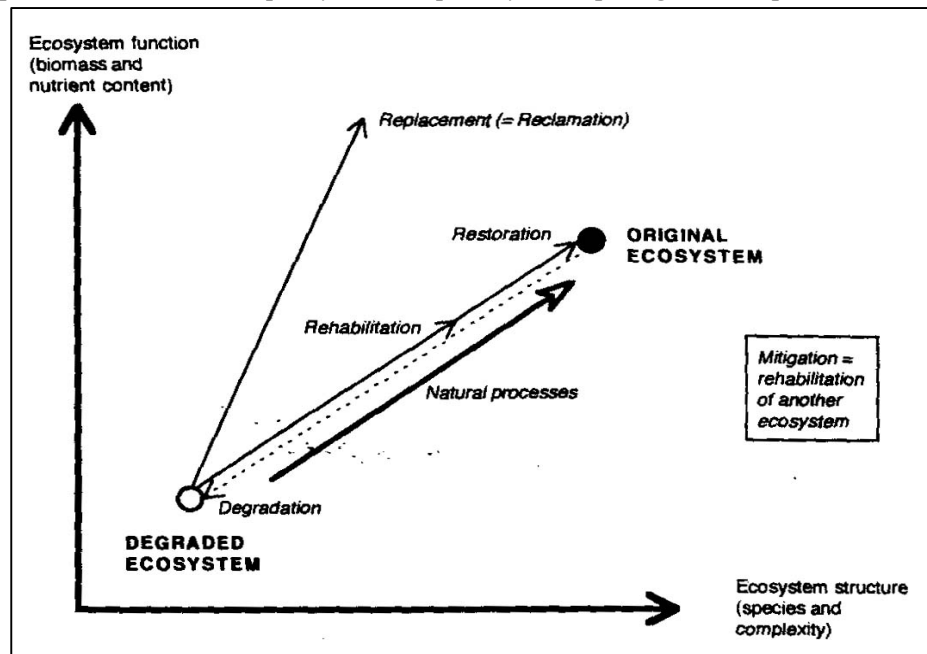


Figure 7: Resource management Concept Diagram (Bradshaw, 1983).



provide the natural materials and ecological functions that create habitat (IMST, 2002). In this report, protection and restoration of ecological function is emphasized. However, it should be acknowledged that enhancement and mitigation activities may have a role to play in salmonid recovery.

Rehabilitation has been defined as re-establishment of naturally self-sustaining or properly functioning aquatic-riparian ecosystems to the extent possible while acknowledging that irreversible human changes might permit only partial restoration of ecological functions (NRC, 1996). In the PNW, the restoration of pre-Euro-American settlement aquatic conditions and functions across entire watersheds is not usually feasible because of societal constraints and/or irreversible landscape changes. However, at individual sites or in specific sub-watersheds, restoration to pre-Euro-American settlement conditions may be possible and even desirable (IMST, 2002).

Enhancement focuses on improving selected habitat characteristics, and may involve technological approaches or artificial structures that mimic habitat elements, as well as natural methods (NRC, 1992). Mitigation describes a range of activities with the intent to, avoid, reduce, or compensate for the effects of environmental damage (NRC 1992). Based on this definition, one can see that mitigation is not designed to be 100% effective in protecting natural ecosystem structure and function.

Protection or restoration projects are usually applied to only a small portion of a watershed and may not provide measurable increases in salmonid production at the larger, watershed level (Roni et al., 2002). Most of these efforts have been conducted in upland reaches and on the site scale rather than the landscape or watershed scale (Frissell and Ralph, 1998). Common restoration activities, including barrier removal and in-channel restoration, are typically constrained to an individual site and protection efforts are often limited in scope by the availability of willing landowners to sell key parcels and/or a limited budget. One of the greatest challenges of recovery planning is selecting site-specific protection and restoration activities without losing the landscape perspective (Roni et al., 2002). To overcome this challenge, decision-making within a landscape approach needs to be informed by research and planning at the appropriate scales (IMST, 2002).

Productive salmonid ecosystems require a mosaic of favorable, interconnected habitats that are maintained by natural physical (geomorphic and hydrologic), chemical, and biological processes within a watershed. These habitats are linked in both space and time and support diverse salmonid life histories (Bisson, 1995; Reeves et al., 1995; IMST, 2002). Salmonid habitat is dynamic on several scales. Disturbances, such as wildfires, landslides, and floods produce a mosaic of habitats in different successional stages (Reeves et al., 1995). This dynamic mosaic argues for identification, protection, and restoration of habitat throughout the landscape, including floodplains, wetlands, and surrounding watersheds. Preservation of habitat fragments may not be sufficient to maintain natural diversity in aquatic ecosystems (Harding et al., 1999), and restoration may be effective only if watersheds are protected from land-use practices that disrupt fundamental ecological processes in streams (IMST, 2002). A watershed approach to salmonid recovery that considers the varied spatial and temporal distribution of key habitats needed by anadromous salmonids to complete their life histories has been recognized as necessary to the long-term recovery of salmonid stocks (NRC 1992; NRC 1996; IMST 1999; IMST 2002). The State of Oregon has undertaken an effort to designate critical, high-quality Salmon Habitat and Diversity Watersheds. These Salmon Habitat and Diversity Watershed designations could be used by agencies, private landowners, and watershed councils to prioritize assessments, monitoring, protection, and restoration efforts to most effectively to help in salmonid recovery (IMST, 2002).



“Water is the driver of all nature...”

LEONARDO DA VINCI

WATERSHED ASSESSMENT AND PRIORITIZATION

The role of this project in the overall watershed planning and assessment process to support salmon recovery is that of a screening tool. Identification of salmonid refugia areas and a description of their current conditions is the primary objective of the study. The report can serve as a basis for prioritizing preservation and restoration efforts in the study area. This includes identification of potential conservation areas, justification for obtaining salmon recovery project funding, and for evaluating potential risk of future land-use activities. The Limiting Factors Analysis (LFA) can be used in conjunction with the refugia report to identify problem areas that are impacting salmonid production and distribution, as well as to prioritize restoration or rehabilitation projects developed to correct these problems. This report provides information that can and should be used in the development of salmonid habitat protection and restoration strategies. It should be considered a living document, with additional habitat assessment data incorporated as information becomes available.

According to Washington guidance (WA-JNRC, 2001), the key objectives of the initial stage of watershed assessment include the following:

- Establish the current conditions of each watershed on a landscape scale.
- Describe the unique characteristics of each watershed, both natural and land-use related.
- Describe how current watershed conditions diverge from what is expected in a healthy, natural watershed.
- Establish the current salmonid habitat conditions in each stream ecosystem.
- Describe how current habitat conditions differ from properly functioning conditions (PFC).
- Where possible, identify the salmonid species found in each watershed
- Describe the current status of salmonid species, as well as the historic distribution, diversity, and productivity.
- Describe the extent of human-caused factors impacting salmonid habitat conditions.
- Describe the habitat-forming processes in the watershed.
- Identify data gaps, limitations of current data, and uncertainty of information.



Watershed assessment is an on-going process of compiling and analyzing technical information on watershed conditions, and the effect of human activities on those conditions. It is the first step in a long-term *ecosystem management* program (Montgomery et al., 1995). Ultimately, watershed management, including conservation and restoration efforts, will be a key local component in integrated regional ecosystem management efforts. Because data availability and technical resources vary across geographic areas, the way watershed assessment tasks are approached and the time frame for accomplishing them varies. A single assessment method or tool will likely not provide all the information needed to effectively manage a watershed based on multiple beneficial uses. However, a standardized assessment framework is needed to bring together different assessment elements, improve consistency, and synthesize data for more effective watershed management (WA-JNRC, 2001).

A science-based watershed assessment analyzes the past and current state of the watershed, captures its unique physical, chemical, and biological characteristics, and compares these conditions to those in natural “reference” watersheds. It should explicitly identify uncertainty of information and be supported by written records that provide a basis for decision-making. Assessments help us determine how well a watershed is functioning and how it responds to natural and human disturbances (see Figure 8). They should help us understand how a watershed “works” and how a watershed has changed as a result of human activities.

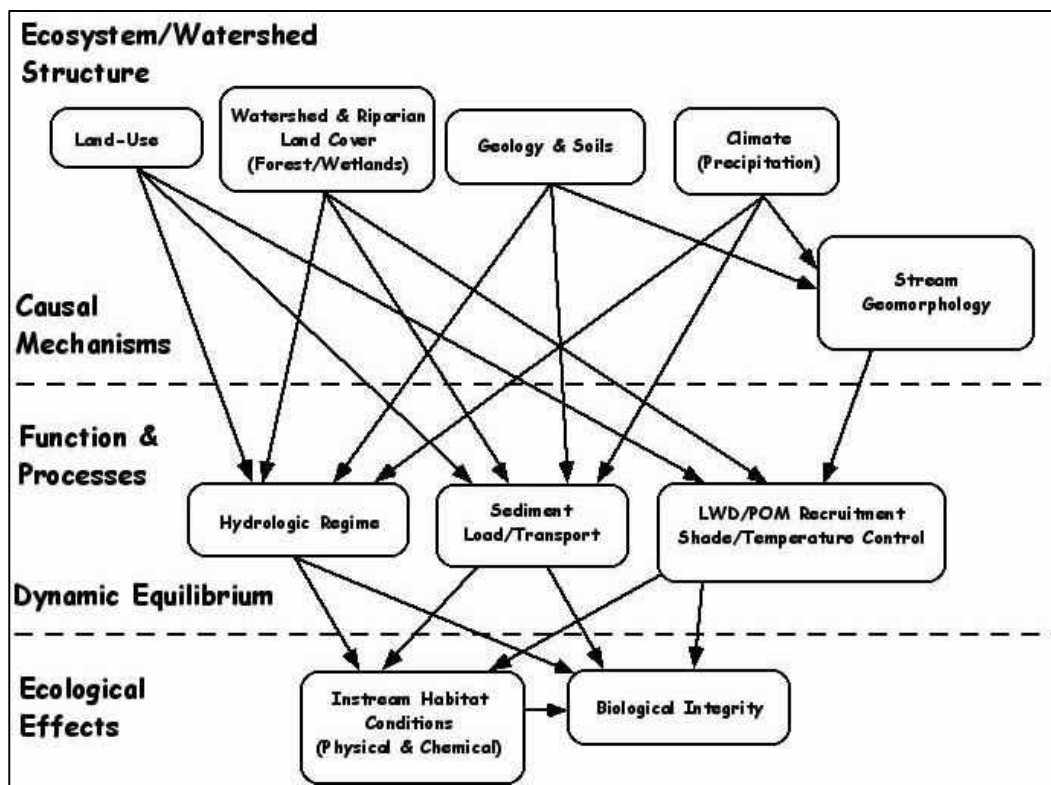


Figure 8: Conceptual Diagram of Watershed Structure and Function.



The key components generally involved with watershed assessment include the following (USEPA, 2000):

- 1) Describe the general physical, biological, and chemical attributes of the watershed (i.e. geology, climate, topography, hydrology, and soil structure). This can be done at a qualitative or quantitative level.
- 2) Identify and describe factors within the watershed, both natural and human-caused, that affect the physical, biological, and chemical attributes of the watershed. This includes analysis of:
 - Hydrologic conditions - low flows, peak flows, water use, land cover, land-use, and impervious surfaces.
 - Soil erosion and sediment load and sources—roads, construction sites, landslides.
 - Natural vegetation patterns and characteristics—riparian corridors, upland forests, and other native vegetation.
 - Wetland, floodplain, and nearshore/estuary conditions within or adjacent to the watershed.
 - Biological communities – aquatic and terrestrial biota.
 - Water quality conditions – chemical characteristics and pollutants of concern.
- 3) Identify and describe human-caused factors existing outside of the watershed that affect the physical, biological, and chemical attributes of the watershed; (e.g., an upstream dam that regulates flow or modifies water temperature, a source of chemical pollution or turbidity, or degraded aquatic habitat).
- 4) Classify and subdivide the watershed into sub-watersheds to facilitate comparative assessment of existing conditions and prioritization of management prescriptions.
- 5) Identify data gaps that need to be filled to reduce uncertainty in the development of recommendations to address problems.

As a general principle, preservation and protection of intact, functional aquatic habitats should be the first priority (NRC, 1992; NRC, 1996; Beechie and Bolton, 1999; IMST, 2002; Roni et al., 2002). Maintaining high quality habitat is typically much easier than restoring degraded habitat (Roni et al., 2002). As an initial step in the recovery process, high quality areas that maintain healthy and diverse salmonid populations (refugia) should be protected from further human-caused disturbance that degrades habitat or biological conditions (Sedell et al., 1990; Frissell, 1993; Bisson, 1995; Nehlsen, 1997). Relatively intact habitat patches, including reaches, riparian corridors, sub-watersheds, or entire watersheds, that still sustain wild, native salmonid populations are a source of individuals to repopulate other areas (Niemi et al., 1990; Sedell et al. 1990; Frissell, 1993). These protected areas can also serve as “reference areas” or “templates” for restoration of already degraded habitat. These areas can provide fundamental information on natural processes and ecosystem structure, enable evaluation of temporal and spatial changes, and provide a basis for estimating attainable future conditions for restoration (Hughes et al., 1986).



Along with protecting refugia areas, a secondary priority should be to restore a system of habitats connected or adjacent to these protected watersheds. Salmonids have the capacity to recover, if enough favorable habitats are provided (Sedell et al. 1990). Although much salmonid life history diversity has been lost, there is evidence that this diversity can be reestablished as well (Nehlsen et al., 1991; Healey and Prince, 1995; Huntington et al. 1996). Areas with a high potential and opportunity for restoration should be selected, including habitats that historically had high productivity and diversity (Frissell et al., 1993; Nehlsen, 1997; Lichatowich et al., 1999). Restoration activities that emphasize reconnection of high quality habitats should also be strongly emphasized (Roni et al., 2002). Finally, rehabilitation of all habitat types across the entire landscape is needed, including habitats now used by anadromous salmonids and those not used but having potential for use (Roni et al., 2002).

The type of protection and restoration activities can be prioritized according to their likelihood for longevity of response and probability of success. However, the effectiveness of various restoration techniques to increase salmonid production is not always well known (Roni et al. 2002). Inherent variability in ecological data can make it difficult to detect real change. Long-term monitoring data is often needed to evaluate restoration success (Roni et al., 2002). Lack of effective monitoring, including an emphasis on physical rather than biological factors, has limited our understanding of salmonid response to restoration (Roni et al., 2002).

The location of protection and restoration activities can also be prioritized according to their probability of being effective. Prioritization can be conducted at multiple spatial scales such as basin, watershed, and sub-watershed scales. Many criteria may be weighed when prioritizing restoration and preservation of key habitats (NRC, 1992; Bradbury et al., 1995; Li et al., 1995; Nehlsen, 1997; Whidden and Lichatowich, 1999). These criteria include factors such as historical and current productivity (Whidden and Lichatowich, 1999), habitat quality (Li et al. 1995; Nehlsen, 1997; Roni et al., 2002), meta-population structure and dispersal rates (Rieman and Dunham 2000), hydrologic function (Reeves et al., 1995), riparian processes (Beechie and Bolton, 1999), and life history diversity (Nehlsen, 1997).

During prioritization of restoration activities within a watershed, landscape position is an important factor to consider. Some research indicates that restoration should proceed from headwater reaches downstream, largely because human disturbances proceeded from the river mouth into headwater areas (Sedell et al., 1990; Stanford and Ward, 1992; Stanford et al., 1996). As a result, headwater tributaries, often in forested areas and in federal ownership, are the often most intact (Frissell, 1993). Furthermore, successful preservation and restoration of any riverine habitat depends on upstream processes and upland land use (Sedell et al., 1990). Minimizing adverse impacts on small streams and restoring their ecological connections are of critical importance to the improvements downstream (NRC, 1996). Often, the effects of disturbances such as floods are magnified as they progress downstream. In addition, stream restoration without modification of upslope land-uses could be ineffective (Doppelt et al., 1993).

Nevertheless, headwater streams alone are not capable of producing large numbers of salmonids compared with more productive lowland systems (IMST, 2002). In addition, lowland streams and rivers provide connectivity with estuarine and nearshore habitat areas important to the completion of salmonid life cycles (Williams and Thom, 2001). Restoring habitats in lowland streams and rivers, which historically were more productive than headwater tributaries, is critical for increasing life history diversity and production (Sedell et al., 1990; Lichatowich et al., 1999; Nehlsen, 1997; Roni et al., 2002). Protection and restoration activities should be prioritized to focus on critical watersheds, streams, or reaches that have the potential to protect and reestablish core populations at strategic locations within mainstem river systems, estuaries, and tributaries (IMST, 1999; IMST, 2002; Roni et



al., 2002). Protection and restoration activities should be spread across the landscape to include all habitats within a watershed that historically supported salmonids (Healey and Prince, 1995; Williams et al., 1997; IMST, 2002; Roni et al., 2002).

Management strategies can then be developed based on the guiding principles of ecosystem management and the specific results of watershed assessments. Watershed management is continuous and needs a multi-disciplinary, flexible approach. A watershed management framework that supports community partnering, uses sound science, and takes well-planned actions should achieve positive results. Some would argue that we lack sufficient knowledge about the way in which watersheds work to implement an ecosystem-based management strategy. On the contrary, even if no further research were done, the current level of knowledge is adequate to do a much better job of aquatic resource conservation than has been done in the past. In general, watershed protection is more effective than restoration or rehabilitation. Therefore, conservation efforts should move forward and should not be delayed while awaiting “better” data. It must be acknowledged that science will never answer all the questions. Science is a process, not an endpoint. Rather than being paralyzed by the unknown as more ecosystems are degraded or more species are lost, action should be taken to apply the *best available science* toward conservation of the remaining functioning habitat. In conjunction with this conservation action, scientific research should continue so that the level of knowledge improves and *adaptive management* is supported in the long term. This also should reinforce the *precautionary principle*, in that watersheds and aquatic resources should not be managed right to the limit of their functional capacity, but instead should be managed conservatively (Franklin, 1993).



“When we try to pick out anything on earth by itself, we find it hitched to everything else in the universe...”

JOHN MUIR

REFUGIA ASSESSMENT METHODS

The salmonid refugia identification and evaluation process consists of two independent, parallel paths. These mutually supportive, concurrent paths both have the goal of identifying potential salmon refuge habitat and assessing the ecological integrity of that habitat on a quantitative basis. These two complementary paths will be referenced in this report as the *fish-centered approach* and the *landscape-centered approach* (based on the methodology of Frissell et al., 1999). This phased, parallel-path approach is similar to the protocol being used in other parts of the Puget Sound region to identify key salmonid habitat for protection or restoration (IPL, 2001). Figure 9 illustrates the two approaches and the general project flow-path. The fish-centered approach relies heavily on historical records of salmonid utilization, abundance, distribution, and instream habitat conditions, as well as the “local knowledge” of area biologists and natural resource managers. The landscape-centered approach utilizes landscape-scale data and a geographic information system (GIS) to perform assessment and rankings of watersheds within the study area.

The two independent assessment methods provide complementary information that can be used to help frame conservation efforts. The landscape-centered approach yields a relatively coarse-grained, but comprehensive assessment of factors that may influence the ecological integrity of salmonid streams and salmonid populations across the study area. By contrast the fish-centered approach rests on field data or accounts from local biologists on habitat conditions in specific stream segments and salmonid populations in individual stream systems, which is by nature more fine-scaled (e.g. reach level data).

For various reasons, the results of these two analyses generally correspond relatively well. Many areas are recognized as having value under both the landscape and fish-centered approaches. These are likely to be of unqualified conservation value and, where they remain unprotected, should be high priority for immediate conservation action. Areas identified as having relatively high ecological integrity on the landscape scale, but not identified during the fish-centered approach, may have significant ecological data gaps and should be targeted for further analysis and instream surveys to determine the status of their salmon populations.

Areas scoring low in the landscape analysis but high in the fish-centered assessment also merit concern. Some of these may represent populations at risk, destined to future decline as the effects of current and future land-use disturbances become fully realized, unless conservation action is taken quickly. Others may represent critical “hot-spots” of biodiversity where salmon habitat has remained exceptionally resilient or robust even with the cumulative impacts of past human perturbations. In these latter two cases, restoration and protection efforts may be warranted, but to be effective will need to be carefully crafted to fit the local ecological, historical, and social circumstances (Booth et al., 2001).



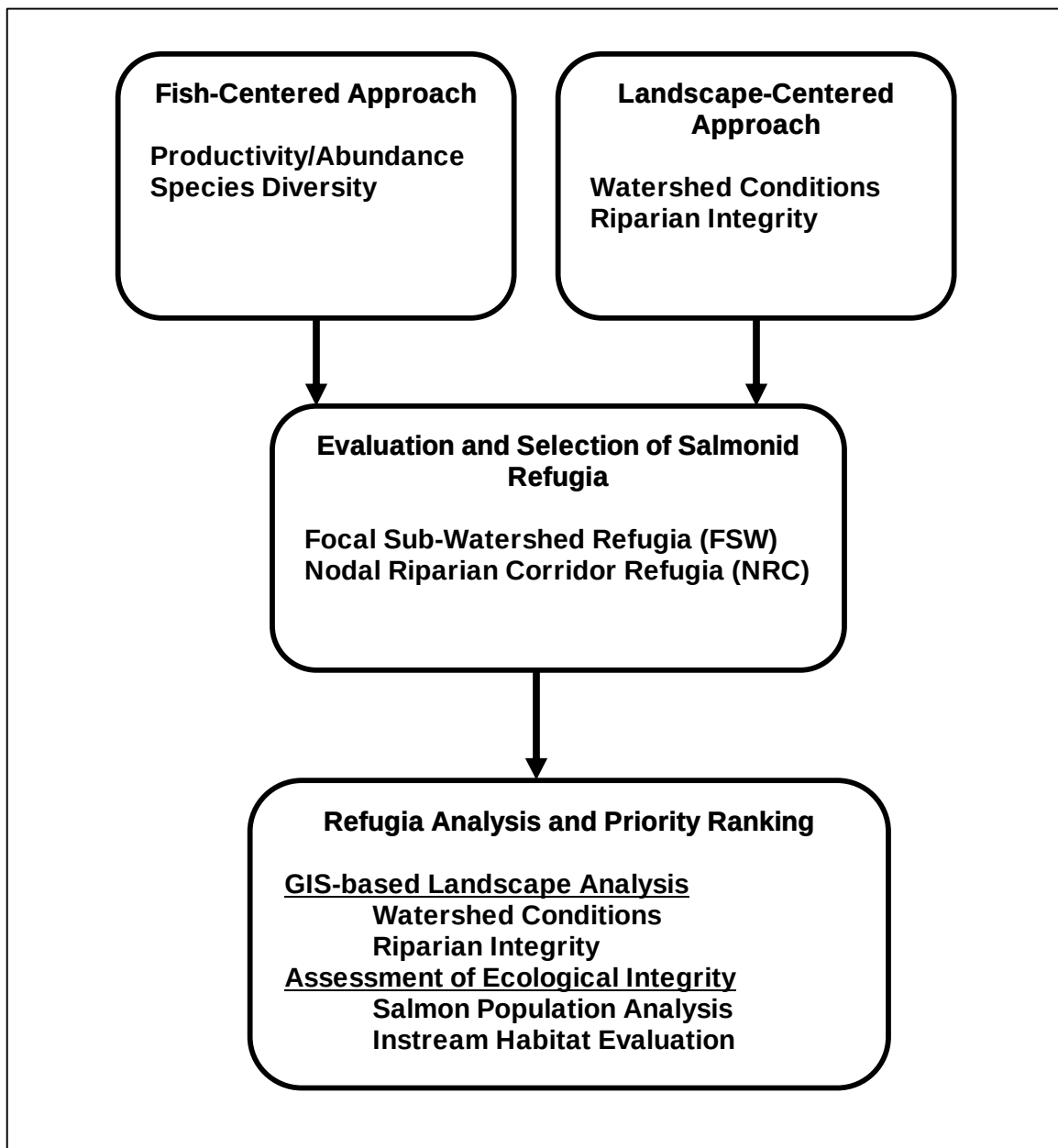


Figure 9: Refugia Project Study Approach and Project Flow Path.



“Conservation is a state of harmony between men and the land. By land it is meant all things on, over, or in the earth. Harmony with land is like harmony with a friend...”

ALDO LEOPOLD, 1949

FISH-CENTERED APPROACH

To identify key watersheds within the study area that are important to native salmonids, the *fish-centered approach* developed by Frissell (1989) was used. In this methodology, rivers, streams, and nearshore areas were evaluated based on the following general attributes:

- Historically productive and/or diverse salmonid resources.
- Large proportion of the historic species assemblage still intact.
- Current utilization by multiple salmonid species.
- Stable, productive populations of native, wild salmonids.
- Significant patches of the properly functioning instream habitat.
- Habitat supporting multiple salmonid life-history stages.
- Functional habitat forming and watershed-ecosystem processes.
- Relatively high level of stream-riparian corridor integrity.
- Potential for recovery of ecosystem structure and function.

During the process of identifying candidate refugia areas as part of this segment of the study, ecological “hot-spots” were also identified (Frissell, 1998 and 1999). These areas include those sub-watersheds, streams, or stream segments that currently support healthy, self-sustaining runs of native wild salmonids due to the convergence of high-quality habitat, accessibility, and watershed conditions supportive of salmonid habitat-forming processes. As can be seen from the above list, stream ecosystems with significant historic populations were also included as refugia candidates, as were ecosystems that currently support highly productive salmonid populations. In addition to streams with a large proportion of relatively intact natural, high-quality salmonid habitat, those with a high potential for rehabilitation were also selected for consideration as refugia.

The focus of this approach was not only ESA-listed species, but instead, a *multi-species approach* was taken so that all salmonid species native to the area were considered in the process. This approach is supported by basic conservation biology theory and by the ecosystem management strategy outlined earlier in this report (Noss, 1983). The refugia selection framework was based on the need for refugia habitat connectivity required to support all salmonid species and all phases of



salmonid life history. Including life history diversity provides a spatial and temporal framework to deal with the complexities of habitat connectivity while allowing the inclusion of integrated populations where they coexist (Frissell, 1998).

As was already discussed, the suite of habitat conditions necessary for the long-term survival of salmonid populations is often referred to as “properly functioning conditions” (PFC). Providing for PFC throughout the study region was a guiding principle in the selection of potential refugia and the foundation of the instream habitat assessment used in this project. The PFC concept is based on the matrix of “pathways and indicators” (MPI) guidelines originated by the National Marine Fisheries Service (NMFS) Habitat Conservation Branch (NMFS, 1996). This MPI guidance was further refined by the NMFS (1999) and the Washington Conservation Commission (WCC, 1999) for use in assessing salmonid habitat conditions for use in the *limiting factors analysis* (LFA) process. The basis for this guidance is that premise that salmonid survival in the wild depends on the proper functioning of certain ecosystem processes, including habitat formation and maintenance. Retaining or restoring functional habitats depends largely on allowing natural processes to increase their ecological function, while at the same time removing adverse impacts of current human activities (Stouder et al., 1997). These habitat-altering actions continue to affect salmonid populations, mostly in a negative manner (NMFS, 1996). PFC is defined as the sustained presence of natural habitat-forming processes in a watershed (e.g. natural hydrologic regime, riparian community succession, LWD recruitment, bedload transport, and channel migration) that are necessary for long-term persistence of species through the full range of environmental variation. PFC constitutes the physical habitat component of the salmonid biological requirements (NMFS, 1999).

The fish-centered approach utilizes available information on current salmonid habitat conditions, species diversity, salmonid distribution data, salmon productivity data, and other related data. Available salmonid data related to fish utilization, abundance, and diversity was obtained from federal, state, local, and tribal agencies. In addition, all available quantitative habitat assessment data was obtained from the same sources. Examples of data on salmonid distribution and species diversity include the historical references such as the Washington Department of Fish and Wildlife (WDFW) *Stream Catalog* (WDFW, 1975) and current sources such as the on-going Washington Conservation Commission (WCC) “Limiting Factors Analysis” (WCC, 2001, 2002, & 2003). Instream habitat survey data are also available for several streams within the study area, although some of this data is somewhat dated and is often based on methodologies that are no longer in use or are not in a standardized format. All physical habitat data were analyzed in relation to current standards and PFC guidelines.

There has been a significant amount of work done by USFWS and WDFW habitat biologists, habitat biologists from local Native American Tribes and the Point-No-Point Treaty Council (PNPTC), Kitsap Land Trust, Jefferson County Land Trust, the Jefferson Conservation District (JCD), the Kitsap Conservation District (KCD), citizen groups such as the Hood Canal Salmon Enhancement Group (HCSEG), North Olympic Salmon Coalition (NOSC) and Wild Olympic Salmon (WOS), and the technical team of the Hood Canal Coordinating Council (HCCC) on identifying and evaluating water resources in the region for potential conservation and restoration projects. This report builds on these efforts as summarized in the *Salmon Habitat Recovery Strategy for the Hood Canal and Eastern Strait of Juan de Fuca* (HCCC, 2001).

To verify and update recorded information, numerous resource professionals were interviewed as a primary source of information on fish distribution, population status, and habitat conditions (see Table 1).



- Peter Bahls, Habitat Biologist, Northwest Watershed Institute (NWI), Portland OR.
- Lee Bode, Habitat Biologist, Hood Canal Salmon Enhancement Group (HCSEG), Belfair WA.
- Ginna Correa, Washington Conservation Commission (WCC), Hood Canal Limiting Factors Analysis (LFA) Project Coordinator, Olympia WA.
- Jennifer Cutler, Northwest Indian Fisheries Commission (NWIFC) Geographic Information System (GIS) Database Manager, Olympia WA.
- Monica Daniels, Kitsap County Salmon Restoration Coordinator.
- Jeff Davis, WDFW Habitat Biologist, Port Orchard WA.
- Marty Ereth, Skokomish Tribal Habitat Biologist, Belfair WA.
- Christopher Frissell, University of Montana, Kalispell MT.
- Glenn Gately, Jefferson Conservation District (JCD).
- Jeff Heinis, Skokomish Tribal Habitat Biologist, Belfair WA.
- Ron Hirschi, Habitat Biologist, Port Townsend WA.
- Randy Johnson, WDFW Fisheries Biologist, Port Angeles, WA.
- Thom Johnston, WDFW Habitat Biologist, Discovery Bay WA.
- Ted Labbe, Port Gamble S'Klallam Tribal Habitat Biologist, Hansville WA.
- Al Latham, Jefferson Conservation District (JCD).
- Paula Mackrow, North Olympic Salmon Coalition (NOSC).
- Mark McHenry, US Forest Service (USFS) Habitat Biologist, Quilcene WA.
- Byron Rot, Habitat Biologist, Jamestown S'Klallam Tribe, Port Townsend WA.
- Doris Small, WDFW Habitat Biologist, Port Orchard WA.
- Steve Todd, Point-No-Point Treaty Council (PNPTC) Habitat Biologist, Hansville WA

Table 1: Salmonid Refugia Project Informational Interview Sources

SALMONID DISTRIBUTION MAPPING

Establishing the presence or absence of salmonids within a watershed can be problematic. A stream may have historically supported an assemblage of salmonid species, but one or more of those species may no longer utilize that stream due to natural habitat changes or because of human influences. These changes can affect all phases of the salmon life history (see Figure 1). For example, a passage barrier such as a poorly designed culvert or water-diversion dam could impact adult migration. The loss or degradation of spawning habitat can cause a contraction of spawning distribution. Rearing habitat can also be lost or degraded such that a stream segment no longer supports juvenile life-stages of particular species. A good example of this is the lack of instream large woody debris (LWD), which has particularly adverse impact on juvenile coho survival during the freshwater rearing life-stage (Maser et al., 1988). If any of these changes have occurred over the past 50-100 years, there may be no formal record of historic salmonid utilization. Few streams have long-term fish abundance or distribution data. In addition, salmonids are known to sometimes make only short-term, temporary use of streams, stream segments, or habitat patches based on changes in climatic or environmental conditions. Furthermore, there can be seasonal or year-to-year changes in habitat suitability and utilization based on fluctuations in flow regime or due to other environmental factors. Obviously, spatial and temporal variations in habitat conditions can complicate the verification of salmonid distributions and utilization.

The refugia project utilized the most current quantitative instream habitat data and *Limiting Factors Analysis* (LFA) information to develop baseline conditions for the streams, wetlands, and watersheds under consideration for refugia status. The LFA process has led to the development of the most comprehensive fish distribution maps currently available. These maps were used, along with the WDFW *Stream Catalog* (WDFW, 1975) as the basis for species distribution determination in this project. Because of the inherent uncertainties involved with salmonid distribution and utilization within natural ecosystems, a conservative approach to mapping salmonid distribution was taken for this project. As a starting point, records documenting current salmonid distribution and historic anadromous fish utilization were compiled (including known extirpated populations). Sources of this



data included LFA and WDFW records, Tribal records, data from the on-going Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP), WDFW Stream-Net data, WDFW Priority Habitat & Species Maps (2001), and other verifiable sources. These records were then combined with information on salmonid distributions gained during interviews with local aquatic biologists to determine the *known* or *historic* salmonid distributions in regional streams. Appendix B contains the current LFA fish distribution maps for the study region.

Species and life-stage habitat suitability criteria were used to identify the *potential* fish distributions. These areas are those with no definitive record of fish use, but conform to species and life-stage habitat criteria. These areas were evaluated based on their potential as salmonid habitat. For this project a modified version of the SSHIAP salmonid habitat criteria was used to identify *potential* salmonid habitat in study area streams (see Tables 2 & 3). This method is based on geomorphologic principles, a hierarchical view of stream systems, and standard stream delineation theory (Frissell et al., 1986; Montgomery and Buffington, 1993; SSHIAP, 1999). The standard Washington Watershed Administrative Unit (WAU) protocols are used as background for the SSHIAP delineation. This identifies the stream within the standard Water Resource Inventory Area (WRIA). Most standard stream assessment protocols delineate streams into segments based on gradient, valley-channel confinement, and habitat type (i.e. streams, wetlands, and lakes). This delineation technique is designed, in part, to recognize the inherent capacity of the stream to support a variety of salmonid species. For the refugia study a “gradient-confinement” matrix was developed to identify potential spawning and rearing habitat for each salmonid species (Tables 2 & 3). In the absence of definitive information on salmonid utilization (current or historic), the criteria in these Tables were used to determine *potential* salmonid species utilization.

In summary, this project took a more conservative approach than other parallel efforts (e.g. LFA) to identification of salmonid habitat within the study region. For the purposes of refugia assessment, current, historic, and potential salmon habitat were considered as potential refugia areas. In addition, watersheds were considered to support a species if any portion of that watershed was utilized during any life history stage. This approach is based on the precautionary principle outlined earlier in this report. While this is a conservative approach it is nonetheless scientifically sound in that water resources within a watershed are interconnected hydrologically, chemically (water quality), and biologically. Appendix B contains details on the species distribution of native salmonids in study area streams used in this project.

ESA-LISTED SPECIES CONSIDERATIONS

Currently Puget Sound chinook (PSC) and Hood Canal Summer chum (HCSC) are “listed” under the Endangered Species Act (ESA). Although no special consideration was given to these two species within this report, the status of these “threatened” species is worth noting. There are chinook salmon, spawning naturally in some Puget Sound streams, are not presently assigned to what the NMFS Technical Review Team has defined as an independent chinook population (NMFS, 2001). These streams are not considered “primary spawning habitat”, but are still utilized at certain times by wild chinook (NMFS, 2001). There are two main reasons why naturally spawning chinook may not have been assigned to a population. First, spawning adults are known to occur intermittently in certain streams, spawning in groups of tens to hundreds of fish in some years and none in others (NMFS, 2001). A plausible biological explanation for intermittent occurrence of chinook in some streams is that those adults are part of a larger independent population that uses “secondary” or alternative spawning habitats only during years of high abundance or favorable habitat conditions. The streams that intermittently harbor spawning adults could contain fish from more than one independent population. The locations of the streams relative to the primary spawning areas of independent populations dictate how many populations might contribute fish to these “spillover” spawning areas (NMFS, 2001). Second, it is possible that some streams presently containing chinook



never supported naturally spawning chinook historically. In many of these instances, the origin of the naturally spawning chinook currently present is most likely due to strays from nearby hatchery production (NMFS, 2001). Some streams may therefore contain chinook solely because of the presence of a hatchery, and they would not have represented historical (primary) chinook spawning habitat. As more information becomes available, it is possible that chinook in some intermittently used streams can be clearly associated with one or more populations, and their assignment will change to reflect their association with a particular population. Critical habitat and PSC outside of currently recognized independent population areas may still be important for overall Puget Sound ESU viability (NMFS, 2001).

In summary, there are only a few streams in the study area that could be considered as true chinook streams in the classic sense. However, this supposes that streams can be classified as “chinook streams” or “coho streams” for management purposes. This sort of classification scheme is really not supported by the ecosystem management perspective, which looks at streams from a more holistic point of view. The dynamic nature of ecosystems and salmonid populations does support a more flexible approach to classifying streams in relation to salmonid utilization. Several streams in the study area do support limited populations of Puget Sound chinook (PSC), but for the most part, chinook currently found in the study are believed to be wild or hatchery strays. However, many study area streams have gradient and channel characteristics that would support chinook spawning and rearing, but are limited in their chinook productivity by water flow. Some scientists believe that a mean annual flow of approximately 20 CFS is required to support a self-sustaining chinook population, but this has not been scientifically verified as yet. However, based on what we do know of salmonid population dynamics, it is highly likely that chinook would stray into “marginal” habitat (streams with adequate, but not ideal habitat), especially during higher rainfall or flow periods. In addition, in years when returning runs were especially large, it is also likely that more chinook would seek out alternative spawning areas in these “marginal” streams. It cannot be stated conclusively that this behavior is not critical to long-term survival of PSC (NMFS, 2001). Perhaps these small chinook streams also provide some unique refuge habitat during specific environmental disturbances that may make them “critical” habitat. Alternatively, these less than ideal chinook streams may also be very important from a genetic diversity perspective. In addition to spawning adults, juvenile chinook have been observed in the estuaries of several small streams throughout the Hood Canal (Hirschi, 2002). This habitat utilization may be related to a specific life-history adaptation of some populations of PSC. More information is needed to determine the true ecological value of smaller streams for chinook and other salmonid species.

Finally, there are several streams within the study area that likely supported historic runs of chinook as well as other salmonids not currently found in those watersheds. Based on the information found in this study, several potential refugia watersheds were identified as supportive of chinook. A scientifically conservative approach to salmonid protection necessitates this action. In addition to PSC, several study area streams also support Hood Canal Summer Chum (HCSC). Regional biologists have identified these streams and rivers as being of special importance to the overall salmon recovery effort (PNPTC & WDFW, 1999). It should be noted, however, that ESA-listed species were given no additional weight in the overall refugia model. The basis for this study was a multi-species, ecosystem approach and therefore all native salmonids were treated equally.



Channel Confinement	Gradient					
	<2%	2-4%	4-8%	8-12%	12-20%	>20%
Unconfined (VW>4CW)	Coho Chum chinook Steelhead Cutthroat	Coho Chinook Steelhead Cutthroat	Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A
Moderately Confined (2CW<VW<4CW)	Coho Chum chinook Steelhead Cutthroat	Coho Chinook Steelhead Cutthroat	Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A
Confined (VW<2CW)	Coho chinook Steelhead Cutthroat	Coho Chinook Steelhead Cutthroat	Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A

Note: VW = Valley Width and CW = Channel (bankfull) Width

Table 2: Potential Salmonid Rearing Habitat (modified from SSHLAP).

Channel Confinement	Gradient					
	<2%	2-4%	4-8%	8-12%	12-20%	>20%
Unconfined (VW>4CW)	Chum Cutthroat	Coho Chinook Steelhead Cutthroat	Coho Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A
Moderately Confined (2CW<VW<4CW)	Chum Cutthroat	Coho Chinook Steelhead Cutthroat	Coho Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A
Confined (VW<2CW)	Chum Cutthroat	Coho Chinook Steelhead Cutthroat	Steelhead Cutthroat	Steelhead Cutthroat	Cutthroat	N/A

Note: VW = Valley Width and CW = Channel (bankfull) Width

Table 3: Potential Salmonid Spawning Habitat (modified from SSHLAP).

Note: Pink and Sockeye are not included in these Tables due to lack of historic information and their generally low historic presence in the study area. Pink have similar habitat requirements as chum and chinook. Sockeye require a lake for rearing. See Appendix B for details on salmonid habitat requirements.



SALMONID DIVERSITY

Salmonid diversity was measured as the number of salmonid species that currently, historically, or could potentially utilize a given watershed. The maximum number of species that could be associated with a watershed is eight (8). The majority of the streams in the study area are relatively small in watershed size. These streams generally support coho and chum salmon, as well as cutthroat trout. Many of the larger streams and rivers in the study region, especially those draining to the Hood Canal, support other salmonid species, including chinook and steelhead. Appendix B contains details on the species distribution of native salmonids in study area streams used in this project.

SALMONID PRODUCTIVITY

As was the case with mapping salmonid distribution, evaluating and quantifying *productivity* of each watershed was also quite difficult. Productivity, as used in this report, is a measure of the relative mean annual abundance of salmonids produced by each stream system and does not refer to harvest levels associated with each stream. However, productivity does relate to the idea that large numbers of salmon returning to their natal streams does influence the overall productivity of the ecosystem in the form of marine-derived nutrient (MDN) inputs (Cederholm and Peterson, 1985; Cederholm et al., 1989; Willson and Halupka, 1995; Willson et al., 1998; Lichatowich, 1999; Cederholm et al., 2000; Lichatowich et al., 2000). This measure was added to the refugia model to account for the fact that larger watersheds generally, but not always, have the potential to produce larger numbers of salmonids (HCCC, 2001).

As was stated earlier, very few streams have long-term salmonid abundance data. Furthermore, seasonal or long-term changes in habitat suitability and utilization based on human impacts or other fluctuations in environmental factors can greatly influence productivity. Complicating this assessment are the cumulative impacts of harvest and hatchery operations. For this project, all available (WDFW and Tribal) salmonid abundance data was used to evaluate productivity. Based on this data and discussions with regional/local biologists, a “productivity rating” was assigned to each watershed being considered for refugia status. The criteria used to assign these productivity scores is shown in Table 4. Basically, watersheds were classified as high productivity, moderate productivity, or low productivity habitat based on historic and current habitat conditions, as well as watershed. The “raw” scores from the salmonid diversity and productivity scoring criteria were then converted to “synthetic” scores for use in the refugia model (see GIS

5 = Natural, unimpaired system currently at or near historically or potentially high level of productivity. No natural barrier(s) that limit access or productivity and no man-made access barriers or hatchery influences.

4 = Historically or potentially a high productivity system, but currently producing at a reduced level due to a combination of human impacts, including degraded habitat, man-made migration barriers, and/or hatchery influences.

3 = Moderate productivity system, naturally limited by small watershed size and/or natural barrier(s). Currently at or near historic or potential level of productivity. No man-made access barriers or hatchery influences.

2 = Moderate productivity system, naturally limited by small watershed size and/or natural barrier(s). Currently producing at a reduced level due to a combination of human impacts, including degraded habitat, man-made migration barriers, and/or hatchery influences.

1 = Low productivity system, due to one or more of the following:

- Natural barrier(s)
- Small watershed size
- Man-made barrier(s)
- Hatchery influences
- Degraded habitat conditions

Table 4: Salmonid Productivity Criteria



modeling methods section for details). Appendix B of this report contains both the diversity and productivity scores for each watershed and stream segment that was evaluated.

SALMONID HABITAT ASSESSMENT

A variety of instream habitat assessment protocols are in use in the PNW (see Table 5). Some of these “stream survey” guidelines are more quantitative than others. The Northwest Indian Fisheries Commission (NWIFC), Timber, Fish, and Wildlife (TFW) Ambient Monitoring Protocols are generally considered the “benchmark” for quantitative instream habitat assessment in the PNW (Schuett-Hames et al., 1999). Most of the tribes and government agencies in the region utilize these protocols or a modified version of the TFW protocols (see Table 6). Several government agencies have their own habitat assessment techniques, but most of these are at least as rigorous as the TFW Ambient Monitoring Protocols (i.e. USFWS, WDFW, and Washington Trout). Based on our primary study objective of identifying salmonid refugia and prioritizing them for conservation action, no extensive TFW-level habitat assessments were undertaken, but when available, TFW data were utilized in the assessment process.

For this project, all available quantitative habitat data was obtained for the most recent ten-year period. This data was evaluated for quality in comparison to the TFW standards. Data that was of sufficient scientific quality was used to score candidate refugia areas. Data that was not comparable to the TFW standards was used only after “qualitative” field surveys were conducted to verify the data or discussions with local habitat biologists indicated that the data reflected current conditions. In all cases, even when the most recent quantitative (TFW-level) data was available, local habitat biologists were consulted to verify the accuracy and applicability of the data. In addition, all candidate refugia were “field-checked” to ensure a representative assessment of habitat conditions for the stream was obtained.

- 1) *Timber, Fish, and Wildlife (TFW) Ambient Monitoring Manuals* (Schuett-Hames et al., 1999).
- 2) *Aquatic Habitat Indicators and their Application to Water Quality Objectives within the Clean Water Act*. US-EPA-910-R-99-014 (Bauer and Ralph, 1999).
- 3) *Fish and Fish Habitat Standard Inventory Procedures Handbook*. USDA, Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report #346 (Overton et al., 1997).
- 4) *Rapid Bio-assessment Protocols*. US-EPA-841-B-99-002 (Plafkin et al., 1999).
- 5) *Methods for Evaluating Stream, Riparian, and Biotic Conditions*. USDA, Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report (Platts et al., 1983).
- 6) *Monitoring Wilderness Stream Ecosystems*. USDA, Forest Service, Rocky Mountain Research Station, General Technical Report (Davis et al., 2001).
- 7) *Monitoring Guidelines to Evaluate the Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska*. US-EPA-910/9-91-001 (MacDonald et al., 1991).
- 8) *Stream Inventory Level II Handbook*. USDA, Forest Service Region 6 (USDA-FS, 1994).
- 9) *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*. USDA, Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report #245 (Harrelson et al., 1994).
- 10) *Applied River Morphology*. (Rosgen, 1996).
- 11) *Stream-keepers Field Guide. Adopt-a-Stream Foundation* (Murdoch et al., 1996).
- 12) *Stream visual Assessment Protocol*. USDA, Natural Resource Conservation Service, Technical Note 99-1 (USDA-NRCS, 1999).
- 13) *Monitoring Urban Streams: Strategies and Protocols for Humid-Region Lowland Systems*. University of Washington, Center for Urban Water Resources Management. (Scholz and Booth, 1998).
- 14) *Aquatic Habitat Assessment: Common Methods*. American Fisheries Society (AFS, 1999).
- 15) *Aquatic Inventory Project: Training Materials and Methods for Stream Habitat Surveys*. Oregon Department of Fish and Wildlife (ODFW, 1999).
- 16) *Nature mapping for Fish and Streams*. Washington Department of Fish and Wildlife (WDFW, 1997).

Table 5: PNW Salmonid Habitat Assessment Protocols.



Protocol Name and Number	Protocol Citation
1. TFW Method Manual for the Large Woody Debris Survey	Shuett-Hames, D., A. E. Pleus, J. Ward, M. Fox, and J. Light. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-004. DNR #106. March. 33 pp.
2. TFW Method Manual for the Habitat Unit Survey	Pleus, A. E., D. Shuett-Hames, and L. Bullchild. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-003. DNR #105. June. 31 pp.
3. TFW Method Manual for the Salmonid Spawning Gravel Composition Survey	Shuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-001. DNR #101. March. 48 pp.
4. TFW Method Manual for the Salmonid Gravel Scour Survey	Shuett-Hames, D., A. E. Pleus, and D. Smith. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-008. DNR #110. December. 41 pp.
5. TFW Method Manual for the Salmonid Spawning Habitat Availability Survey	Shuett-Hames, D., A. E. Pleus, and D. Smith. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-007. DNR #119. November. 32 pp.
6. TFW Method Manual for the Reference Point Survey	Pleus, A. E., D. Shuett-Hames. 1998. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-008. DNR #002. May. 31 pp.
7. TFW Method Manual for Wadable Stream Discharge Measurement	Pleus, A. E. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-009. DNR #111. June. 13 pp.
8. TFW Method Manual for the Stream Temperature Survey	Pleus, A. E. 1999. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-005. DNR #107. June. 35 pp.
9. TFW Method Manual for Stream Segment Identification	Pleus, A. E., D. Schuett-Hames. 1998. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-98-001. DNR #103. May. 39 pp.
10. TFW Riparian Stand Survey	Smith, D. 1998. Northwest Indian Fisheries Commission. Olympia, WA. September. 12 pp.

Table 6: Timber, Fish, and Wildlife (TFW) Habitat Assessment Protocols.



The most current quantitative habitat data for each stream is summarized in the watershed description for each salmon stream, which can be found in Appendix A of this report. A detailed discussion of salmonid habitat requirements is also included in Appendix C. Based on the limited TFW-level data available and the requirements of this project, only the following “key” physical habitat parameters were utilized:

- 1) Large Woody Debris (LWD) quantity and quality.
- 2) Pool (rearing) habitat quantity and quality.
- 3) Riffle (spawning) habitat quantity and quality.
- 4) Canopy cover, shade, and temperature data.
- 5) Stream channel geomorphology data.

Based on a combination of field surveys conducted as part of this project, available quantitative habitat data, and input from local habitat biologists, each stream segment was then scored using a standard scoring criteria (see Figure 10 and Appendix C). This habitat assessment scoring criteria is based on the NMFS Habitat MPI Matrix discussed earlier (NMFS, 1999). This is basically the same matrix used in the LFA process (WCC, 1999). When no quantitative habitat data were available, the qualitative approach alone was adopted to get a basic, “reconnaissance-level” assessment of instream habitat conditions. Local habitat biologists were also consulted for their input. Like the salmonid diversity and productivity scores discussed earlier, the “raw” scores from the qualitative habitat scoring criteria were then converted to “synthetic” scores for use in the refugia model (see GIS modeling methods section for details). The salmonid habitat scores and scoring criteria are included in Appendix C to this report. The qualitative habitat assessment score sheet used in this project is shown below (Table 7). A brief description of the habitat assessment parameters included in this index is included as well.



Physical Habitat Assessment Qualitative Scoring Criteria	
1. Migration Access	This habitat parameter is used to assess the relative accessibility of the stream or stream segment to all species and life-stages of salmonid (juvenile and adult). The metric is graded based on the percentage of usable salmonid habitat that was blocked by artificial barriers such as culverts, dams, and water diversion structures.
2. Floodplain Conditions	This parameter is based on the degree of alteration of the natural floodplain and channel migration zone (CMZ). The metric also included an evaluation of off-channel wetlands as well as floodplain areas.
3. Spawning Habitat Quantity	This parameter measured the quantity of riffle habitat suitable for spawning throughout the stream or stream segment. A balance of rearing habitat (pools) and spawning habitat (riffles) is generally the optimum condition (see NMFS/WCC Habitat matrix in Appendix C).
4. Spawning Habitat Quality	This parameter measured the quality of spawning habitat (riffles) located within the stream or stream segment. This evaluation focused on the quality of spawning gravels as well as the level of fine sediment deposition and substrate embeddedness. The degree to which boulders, cobble, or gravel are surrounded by fine sediment indicates suitability of the stream substrate as habitat for benthic macroinvertebrates and for salmonid spawning and egg incubation. Embeddedness is evaluated by visual observation of the average degree to which larger particles are surrounded by sediment. A variety of substrate material sizes are also typically desirable. The presence of cobble and gravel in PSL streams is generally considered the most desirable habitat. Bottom substrate is evaluated and rated by observation of dominant substrate.
5. Rearing Habitat Quantity	This parameter measured the quantity of rearing (pool) habitat suitable for juvenile salmonid rearing throughout the stream or stream segment. A balance of rearing habitat (pools) and spawning habitat (riffles) is generally the optimum condition (see NMFS/WCC Habitat matrix in Appendix C).
6. Rearing Habitat Quality	This parameter measured the quality of rearing habitat (pools) located within the stream or stream segment. Pool quality is determined by a number of variables including residual pool depth (RPD) and pool type. A complex and diverse array of pool types is generally desired, including deep holding pools, plunge pools, scour pools, backwater pools, side-channel pools, off-channel wetland pools, dam pools, and beaver ponds. Pool quality is also evaluated based on the quantity and quality of cover on the pool. Large Woody Debris Quantity = The quantity of large woody debris (LWD) within the active stream channel and especially in and around pools is observed and tallied for this parameter.
7. Large Woody Debris Quantity	The quantity of large woody debris (LWD) within the active stream channel and especially in and around pools observed and tallied for this parameter.
8. Large Woody Debris Quality	In addition to the abundance of LWD, the complexity and diversity of LWD is also evaluated. Large (diameter > 0.5 m) LWD (especially coniferous) is highly desirable for its stability and longevity.



9. Streambank Stability	The degree of streambank erosion and streambank stability is rated by observing existing or potential detachment of soil from the upper and lower stream bank and its potential movement into the stream. Steeper banks are generally more subject to erosion and failure, and may not support stable vegetation. Streambank vegetation is also a major factor contributing to streambank stability. Bank soil is generally held in place by plant root systems and perennial vegetation. Erosional protection may also be provided by boulder, cobble, or gravel material, as well as LWD. An estimate of the coverage density of streambank vegetation provides a good indication of streambank stability.
10. Streambed Stability	These parameters relate to the destruction of instream benthic habitat resulting from excessive scour and/or aggradation. Characteristics to observe are scoured substrate and degree of siltation in pools and riffles. Scouring results from high velocity flows. The potential for scouring is increased by channelization and higher stormwater runoff volumes. Deposition and scouring result from the transport of sediment and may be an indication of larger scale watershed degradation. Deposition and scouring is rated by estimating the percentage of an evaluated reach that is scoured.
11. Channel Form	Stream flow relates to the ability of a stream to provide and maintain a relatively stable aquatic environment within the normal range of flows typical of a stream system. The quality of the aquatic habitat can therefore be evaluated, in part, in terms of a velocity and depth relationship. Combinations of slow/fast and deep/shallow flows zones are desirable. Habitat quality is reduced in the absence of one or more of these flow categories. Complexity and diversity are the keys. The character of a natural stream channel includes sinuosity, shape, and floodplain area. Channelization decreases stream sinuosity, thereby increasing stream velocity and the potential for scouring. Upstream impacts may cause channel widening and or incision due to higher peak flows and altered sediment loads.
12. Riparian Extent	The width of the riparian buffer and continuity of the riparian corridor (# of breaks for roads, utility lines, and other stream-crossings) is estimated by visual observation. A relatively wide, continuous riparian corridor is desirable. In general, one site-potential tree height (SPTH) is used as a gage of an ecologically functional buffer width.
13. Riparian Quality	The successional stage or stand-age is estimated by visual observation. A mature forest is more desirable than a clear-cut or young riparian forest.
14. Dominant Riparian Vegetation	The dominant riparian vegetation within 50 meters of the stream is observed and evaluated. Coniferous or mixed (coniferous and deciduous) forest is desired. Brush, shrubs, or grass are less desirable.
15. Canopy Cover	Typical small PSL streams are well shaded. This naturally dense canopy cover provides excellent temperature regulation, keeping PSL streams cool in the summer and insulated in the winter. A qualitative estimation for canopy cover was made based on visual observation.

Table 7: Physical Habitat Assessment Qualitative Scoring Criteria



REFUGIA PROJECT HABITAT ASSESSMENT SCORE SHEET			
STREAM: _____		REACH: _____	
		DATE: _____	
<u>Habitat Parameter</u> (Score)	<u>Optimal</u> (4)	<u>Good</u> (3)	<u>Fair</u> (2)
1. Migration Access (Artificial Barriers)	All Habitat Accessible	<10% Blocked	10-20% Blocked
2. Floodplain Conditions (Habitat & Connectivity)	Natural Floodplain	<25% Area Altered or Lost	25-50% Area Altered or Lost
3. Spawning Habitat Quantity (% Riffles)	40-60% Balanced P-R	30-40% Few Riffles	20-30% Sparse Riffles
4. Spawning Habitat Quality (%Fines & Embeddedness)	<10% Cobble/Gravel	10-15% Gravel/Sand	15-20% Sand/Gravel
5. Rearing Habitat Quantity (% Pools)	40-60% Balanced P-R	30-40% Few Pools	20-30% Sparse Pools
6. Rearing Habitat Quality (Depth & Cover)	Frequent Deep Pools w/Cover	Some Deep Pools and Good Cover	Few Deep Pools Little Cover
7. LWD Quantity (Large Woody Debris)	Abundant Complex	Moderate Spotty	Sparse Infrequent
8. LWD Quality (Large Woody Debris)	Coniferous Large (Key)	Mixed Medium	Deciduous Small
9. Streambank Stability (Bank Erosion)	Stable (>90%) Fully Vegetated	75-90% Patchy Vegetation	Stable Sparse Vegetation
10. Streambed Stability (Scour and Fill)	Stable Natural Changes	Localized Scour and Fill	Degradation Aggradation
11. Channel Form (Shape/Sinuosity)	Natural Diverse/Complex	Flow-impacted Meandering	Flow Incised or Constrained
12. Riparian Buffer Width (w/in SPTH)	Wide/ Intact Continuous	Some Encroachment	Narrow Fragmented
13. Riparian Quality (Stand-Age)	Mature Forest > 20" dbh	Mixed Forest 12-20" dbh	Young Forest <12" dbh
14. Dominant Vegetation (w/in 50m)	Conifer Dominated	Mixed Conifer/Deciduous	Deciduous Dominated
15. Canopy Cover (Temperature Control)	Dense/Shaded Natural Temp	Filtered Sunlight Periodic Hi Temp	Sparse/Broken Frequent Hi Temp

Total Score: _____ (Minimum of 15 / Maximum of 60)

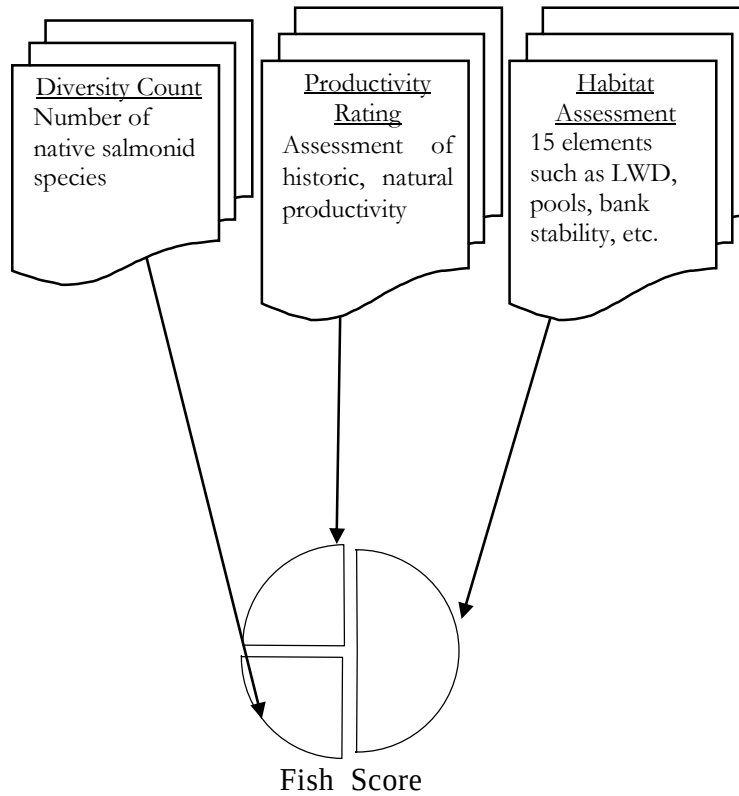
Note: Habitat Parameters derived from NMFS Properly Functioning Conditions (PFC) Matrix

Figure 10: Refugia Project Habitat Assessment Score Sheet



In summary, the fish-centered approach of this project includes the following components:

- 1) Salmonid Diversity Score
- 2) Salmonid Productivity Score
- 3) Salmonid Habitat Quality Score



These three independent scores are combined within the overall refugia model with the landscape metrics to produce a final refugia score. The landscape model components are described in detail in the following section.



“Nature, the earth herself, is the only panacea.”

HENRY DAVID THOREAU, 1859

LANDSCAPE-CENTERED APPROACH

The landscape-centered approach utilizes geographic information system (GIS) data to evaluate landscape-level parameters or GIS *map layers* in all watersheds and nearshore areas. Research in the PSL eco-region and elsewhere has shown that salmonid habitat and ecological integrity decline as landscape-level conditions are altered by human activities (Beechie et al., 1994; NRC, 1996; Richards et al., 1996; May et al., 1997; Horner and May, 1999; Booth et al., 2001). In many cases, the decline in salmonid abundance and diversity in the PNW, along with habitat quality can be directly related to the degree of watershed modification (Pess et al., 2002). During the “landscape” phase of the refugia project, GIS data was used to independently evaluate all watersheds for conditions that would be supportive of native salmonid populations or the processes that maintain salmonid habitat. The landscape-centered approach also served to verify potential refugia identified by the fish-centered approach, identify possible refugia that may have been overlooked by the fish-centered approach, and to make an initial quantitative evaluation of each candidate refugia on a landscape scale. The results of this assessment are based on analysis of multiple digital coverages.

The landscape approach is based on the principles of *landscape ecology*. Landscape ecology is based on the premise that landscape-level patterns at many spatial scales influence ecosystem structure and processes (Noss, 1983; Noss and Cooperrider, 1994; Richards et al., 1996; Abbruzzese and Leibowitz, 1997; Forman, 1997; Naiman and Bilby, 1998). This “ecological signature” of land-use and land-cover (LULC) patterns consists of landscape characteristics on spatial scales that correspond to specific ecological processes. In short, the structure of the landscape determines, in large part, the functionality of the ecosystems encompassed by its boundaries. In the case of native salmonid populations, genetic and life history diversity varies with spatial and temporal patterns of their aquatic habitat. Pacific salmonids have evolved within the framework of the natural disturbance regimes of the PNW and their habitats are also formed by those same natural disturbance patterns (Stouder et al., 1997). Therefore, a multi-scale assessment of LULC characteristics and landscape patterns is essential to understanding ecosystem function.

To understand why landscape-level analysis is a necessary component in salmonid habitat assessment, a graphical representation or *conceptual model* is often useful. A conceptual model expresses ideas about components and processes deemed to be important in an ecosystem, and our current understanding of how the components and processes are connected (Gentile et al., 2001). They are also useful in conveying information to decision-makers and the general public. The basic framework of conceptual model used in this project is shown in Figure 11.



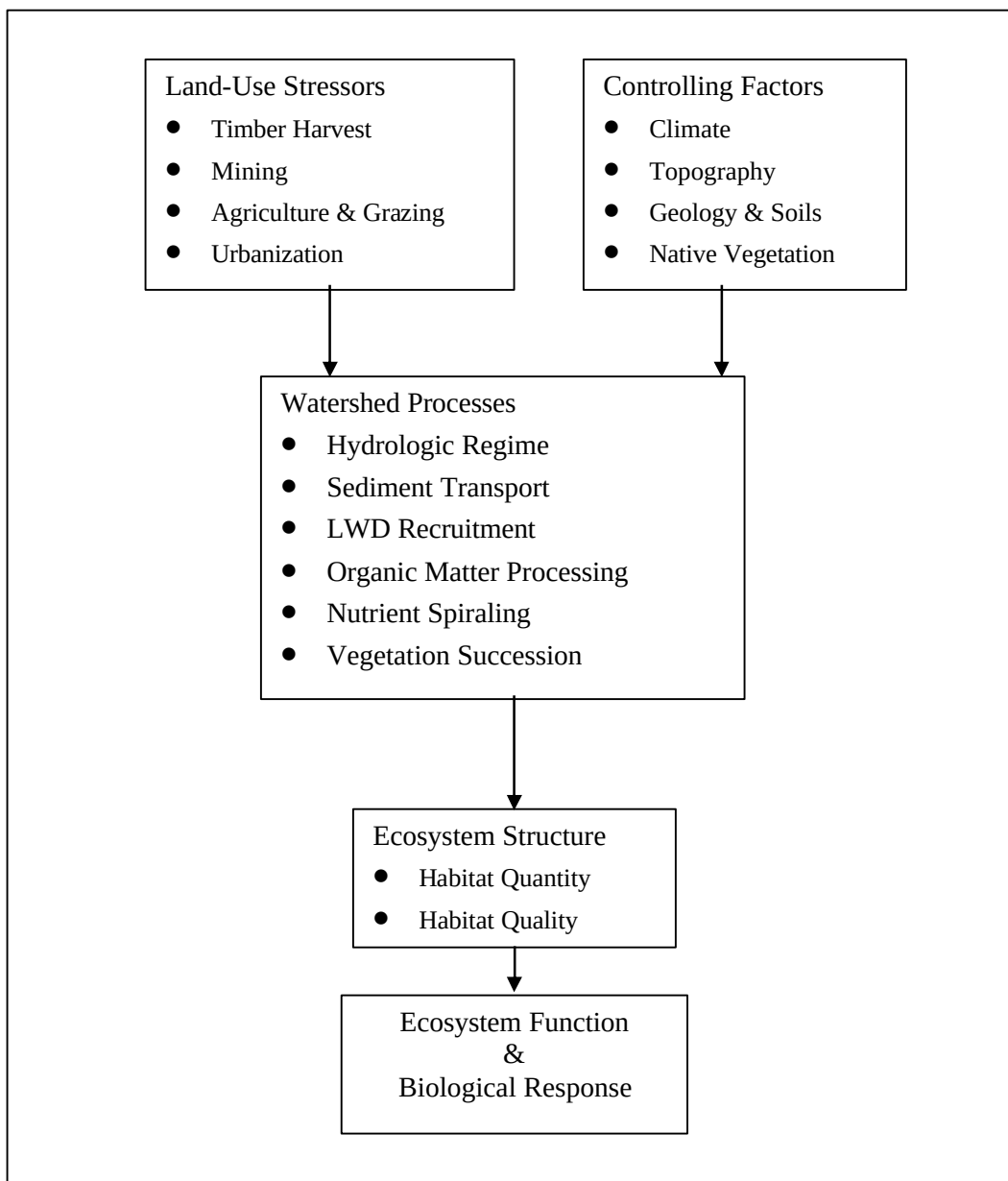


Figure 11: Conceptual Model Framework

The conceptual model approach suggested here is based on an ecosystem-based design. As was discussed earlier, salmon are adapted to local environmental conditions (including associated temporal and spatial variability). In most watersheds, a combination of natural landscape controlling factors and land-uses (human stressors) affect ecosystem processes (e.g., hydrology, sediment transport, riparian function, etc.), which shape the local habitat characteristics (ecosystem structure) on which salmon rely. Salmon and other biota respond to these habitat conditions (quantity and quality), as does overall ecosystem function. Thus an approach to habitat recovery that focuses on preserving and/or restoring ecosystem processes should provide quality salmon habitat over the long term. An advantage of this approach is that it is not species-specific and could provide benefits to the entire ecosystem. This may help to reduce conflicting management objectives and actions when



dealing with multiple natural resources. Each type of land-use activity (e.g. timber harvest, agriculture, and urbanization) tends to have a different level of affect on aquatic ecosystems, both in terms of the severity of degradation and the persistence of the cumulative impacts (Figure 12). These inherent differences often require different management and recovery strategies.

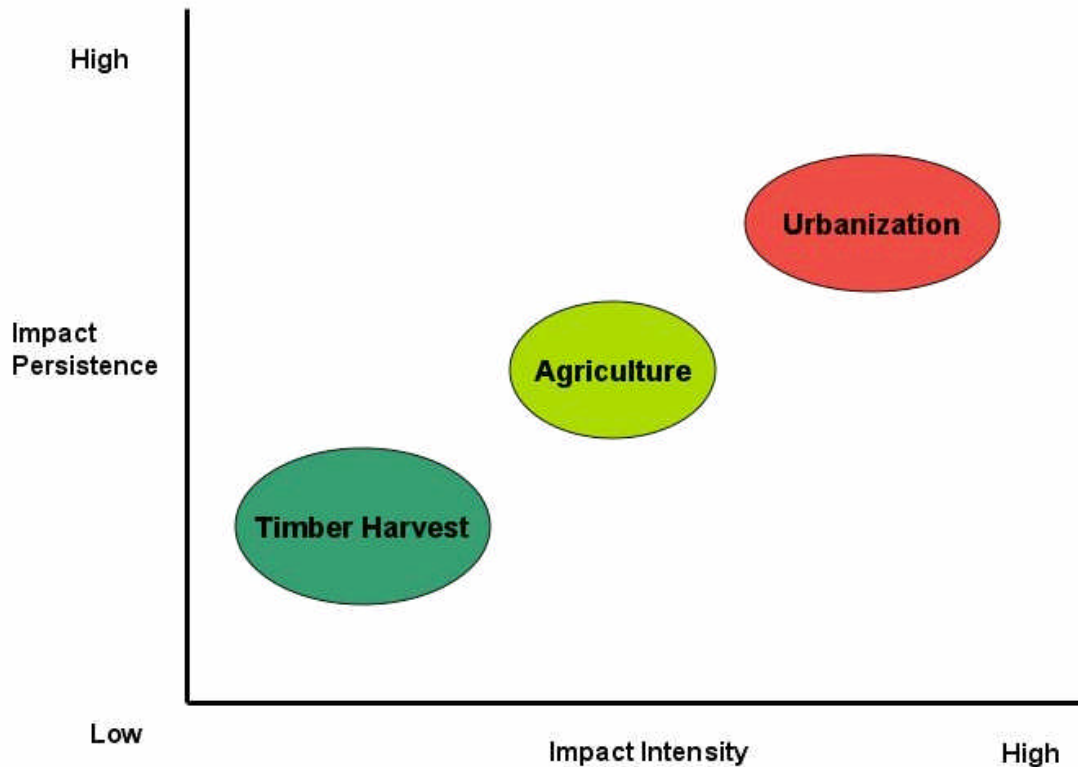


Figure 12: Land-Use Impact Matrix.

Habitat changes resulting from human stressors (e.g. land-use activities) can alter the abundance, productivity, spatial structure, and life history diversity of individual salmon populations (Beechie et al., 2003). At the landscape scale, watershed-based analyses can be conducted to quantify relationships among landscape attributes, land uses, and effects on salmon. Comparisons between historic (reference or optimal) and current habitat conditions can help assess potential productivity, diversity, and viability of salmon populations. Currently in the PNW, the most accepted methods include GIS-based analyses that predict the amount of habitat potentially available to salmonids and the Ecosystem Diagnosis and Treatment (EDT) model (Beechie et al., 2003). Both methods typically utilize data relevant to a specific watershed. GIS-based analyses rely on relationships derived from empirical data and expert opinion combined in a landscape-level model, whereas EDT relies on expert opinion, existing survival estimates, and biological rules in a mathematical model (Mobernd et al., 1997).

In the GIS model used in this report, land use practices associated with habitat losses can be correlated with salmon abundance to identify potential causes for decline. This information can then be used to identify the causes of habitat loss or degradation in the watershed, as well as to identify actions that can be taken to restore habitat-forming processes to their natural range. In addition, model results can be used to identify areas of high habitat quality sufficient to sustain viable



populations. Results can also suggest areas where further or more detailed research should be conducted at the watershed level to gain a more complete understanding of factors affecting salmon viability. The use of a GIS-based landscape model to evaluate ecological conditions in watersheds has been used extensively in the PNW and other regions (Strittholt et al., 1999; Frissell et al., 2000; Staus and Strittholt, 2001; Pess et al., 2002). The methodology used in this project is also similar to the framework outlined by Hyman and Leibowitz (2000 & 2001).

Map layers considered for inclusion in the salmonid refugia model were selected to best represent those watershed factors considered to influence salmonid habitat conditions and stream utilization in the study region (May et al., 1997; Horner and May, 1999; Beechie et al., 2003). All of the map layers considered are ecologically significant in that they either directly or indirectly influence physical and/or biological conditions in streams or nearshore areas. In addition to ecological relevance, map layers were considered for inclusion in the model only if adequate data coverage existed for the entire study area. The selection of habitat map layers to measure at the reach scale was based on known relationships between those habitat features (e.g. LWD, pools, etc.) and salmonid utilization, diversity, and productivity (May et al., 1997). The selection of landscape-level map layers used in this project is based on empirical relationships between specific watershed characteristics and physical habitat conditions, as well as known watershed characteristic linkages with habitat-forming processes (Abbruzzese and Leibowitz, 1997; May et al., 1997; Beechie et al., 2003). In general, these landscape-scale relationships fall into three scales of analysis. These are the *watershed, riparian, and nearshore scales*. Tables 8, 9, and 10 list the potential landscape indices considered for use in this project. The final selection process for map layers used in the GIS refugia model is discussed in the following section.



Landscape Map layer	Definition	Potential GIS Data Source
Total Forest Cover	The percent of area with native forest cover.	Landsat 7 TM
Mature Forest Cover	The percent of area with mature or old growth forest cover.	Landsat 7 TM
Coniferous Forest Cover	The percent of area with conifer-dominated forest cover.	Landsat 7 TM
Deciduous Forest Cover	The percent of area with deciduous-dominated forest cover.	Landsat 7 TM
Mixed Forest Cover	The percent of area with mixed forest cover. Mixed forests have both conifers and deciduous tree species with neither type dominating.	Landsat 7 TM
Forest Clear-cut Cover	The percent of area clear-cut.	Landsat 7 TM
Wetland Area	The percent of area designated as wetlands per the NWI.	National Wetlands Inventory (NWI)
Developed Land-Use	The percent of area with anthropogenic/developed land-use. Anthropogenic alterations are represented by numerous categories.	Landsat 7 TM
Agricultural Land-Use	The percent of area with row-crop or grazing land-use.	Landsat 7 TM
Total Impervious Area (%TIA)	Calculated using Standard %TIA conversion factors for the region.	Landsat 7 TM
Mass Wasting/Steep Slopes	The percent of area with steep slopes. Steep slopes are defined as greater than 30%.	DEM based on USGS topography
Road Density	The ratio of road length (km) to the watershed area.	U.S. Department of Commerce Bureau of the Census Geography Division Tiger Roads
Drainage Density	Natural drainage density consists of the length of stream channel normalized by watershed area. Developed drainage density includes roads, stormwater conveyances, and other anthropogenic alterations to the environment that provide drainage routes to streams.	U.S. Department of Commerce Bureau of the Census Geography Division Tiger Roads Layer. Washington Department of Natural Resources (WDNR) Hydro-layer.
Basin Slope	Average Watershed Terrain Slope	DEM based on USGS topography
Soil Type	Soil Type Data	NRCS Soil Survey Data
Hydrologic Potential	Basin Area multiplied by Mean Annual Rainfall	DEM based on USGS topography and precipitation data

Table 8: Watershed landscape map layers considered for inclusion in the Refugia Model.



Landscape Map layer	Definition	Potential GIS Data Source
Riparian Forest Cover	The percent of riparian buffer area with forest cover.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Wetland Cover	The percent of riparian buffer area classified as wetlands.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM National Wetlands Inventory (NWI)
Riparian Coniferous Forest Cover	The percent of riparian buffer area with conifer-dominated forest cover.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Deciduous Forest Cover	The percent of riparian buffer area with deciduous-dominated forest cover.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Buffer Mixed Forest Cover	The percent of riparian buffer area with mixed forest cover. Mixed forests have both conifers and deciduous tree species with neither type dominating.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Buffer Shrub Cover	The percent of riparian buffer area with shrub cover.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Buffer Grass Cover	The percent of riparian buffer area with grass or turf cover.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Riparian Land Use	The percent of riparian buffer area with anthropogenic/developed land-use. Anthropogenic alterations are represented by numerous categories.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Stream Crossing Density	The ratio of the number of times a road, forest road, railroad, abandoned railroad, or trail crosses any stream within the total length of stream channel.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM U.S. Department of Commerce Bureau of the Census Geography Division Tiger Roads Layer.
Floodplain Modification	The area of floodplain modified by anthropogenic activities.	Washington Department of Natural Resources (WDNR) Hydro-layer. Landsat 7 TM
Barriers to Salmonid Migration	The number of anthropogenic barriers to salmonid migration. Anthropogenic barriers include culverts, dams, or water diversion structures that prohibits adult or juvenile salmonids from migrating either upstream or downstream.	Washington Department of Natural Resources (WDNR) Hydro-layer. Washington Department of Fish and Wildlife (WDFW) Data.
Length of Streams Blocked	Length of Type 1, 2, and 3 streams blocked by a salmon migration barrier relative to the total length of Type 1, 2, and 3 (WAC 222-16-031) streams within the watershed.	Washington Department of Natural Resources (WDNR) Hydro-layer. Washington Department of Fish and Wildlife (WDFW) Data.

Table 9: Riparian landscape map layers considered for inclusion in the Refugia Model.



Landscape Map layer	Definition	Potential GIS Data Source
Nearshore Habitat Type	The percent of shoreline area of each habitat type.	DNR Shore-Zone Inventory
Nearshore Modifications	The percent of shoreline area with anthropogenic alterations such as bulkheads or shoreline armoring.	DNR Shore-Zone Inventory County Records
Density of Docks, Piers, Wharfs, floats, and Boat Ramps	The ratio of the number of docks, piers, wharfs, and boat-ramps to the total length of shoreline.	DNR Shore-Zone Inventory County Records
Number of Marinas	Number of commercial or private marinas with boat maintenance facilities and/or sewage pump-out stations.	DNR Shore-Zone Inventory County Records
Aquatic Vegetation	The percent of nearshore area with native aquatic vegetation (eel grass, kelp, etc.).	DNR Shore-Zone Inventory
Shoreline Riparian Forest Cover	The percent of shoreline riparian buffer area with native forest cover.	Landsat 7 TM

Table 10: Nearshore landscape map layers considered for inclusion in the Refugia Model.



“There are some who can live without wild things and some who cannot. Like winds and sunsets, wild things were taken for granted until progress began to do away with them. Now we face the question whether a still higher standard of living is worth its cost in things natural, wild, and free”

ALDO LEOPOLD, 1949

GIS LANDSCAPE MODEL

A landscape-level (GIS) model measuring a variety of watershed, riparian, instream, and nearshore salmonid habitat factors was created in order to identify and rank the best salmonid habitat within the study area. The spatial data input, storage, analysis, modeling and output capabilities of GIS were used to display and rank salmonid refugia in the study area. Refugia ranks were computed via a model comprising all known and measurable criteria relating to salmonid habitat quality. Data were gathered from existing datasets, analyzed and then combined. The model was developed using concepts from habitat suitability modeling and multi-criteria decision analysis (MCDA) and implemented within the GIS framework (Malczewski, 1999).

Habitat suitability modeling is a formal process of identifying locations that are best suited for life and growth of a particular species and is often carried out in a GIS environment. The GIS environment is well suited to analysis of landscape patterns (Wickham and Norton, 1994). These GIS-based models can also be designed to produce a ranked set of sites from most suitable to least suitable. Common components include a set of standardized input data, weighting schema accounting for the relative importance of each dataset, and an algorithm to combine the weights and data (frequently of a weighted linear summation type). Because suitability is often a matter of opinion, but is measured in a systematic way, the suitability scores can be both subjective and quantitative. Many habitat suitability models use Landsat data and other satellite derived imagery as base data for the models. A review of satellite imagery products and their usefulness in environmental models can be found in Klemas (2001).

The MCDA method, first developed as an alternative to traditional neo-classical planning techniques, is a structured method of reaching a goal with an assigned decision-maker and a specified set of evaluation criteria (Chankong and Haimes, 1983; Carver 1991; Malczewski, 1999). It also involves a set of alternatives (e.g. refugia) and possible outcomes (rankings). The algorithms, decision-making techniques and methods of deriving standardized maps and weighting schemes of MCDA contribute to the success of a habitat suitability model. Using the terms of MCDA, the refugia model is considered a single objective, multi-attribute analysis. In this case, the decision maker is a scientist who represents the composite of available knowledge on freshwater and nearshore salmonid habitat in the study area, through the use of current literature, best available scientific data, and the inputs of local habitat biologists.

The East Jefferson and Kitsap County refugia models described here are adapted from the original Kitsap County Refugia Study (Kitsap County, 2000). Some additions and refinements to the original methodology were incorporated into the existing algorithm to produce the current study. Additional criteria were added to more accurately reflect habitat conditions. These were made possible by the acquisition of data that were not available for the original Kitsap study such as flood-prone zones and aquatic vegetation. The methods of computing some of the map layers were refined to reflect newer data and additional knowledge of habitat conditions. An update to the



Kitsap County refugia model was conducted concurrently to the Jefferson County refugia model and map layers for both studies were combined before being converted to synthetic scales. Results are reported for refugia and nearshore zones in both study areas.

HABITAT SUITABILITY MODELING

Habitat suitability modeling (HSM) techniques and case studies are covered in both the natural resources journals and the GIS literature. Examples of these models are numerous. In the United Kingdom, for instance, suitability modeling has been used to determine appropriate sites for radioactive waste disposal. The power of automating suitability modeling within a GIS was illustrated by the thousands of potential locations that were evaluated through automated GIS routines. The waste disposal study also showed that suitability modeling within a GIS provides a rational, objective and non-biased approach to determining the best sites for an activity (Carver, 1991).

A common suitability modeling technique is the use of proportions as a basis for quantifying land cover influence in a watershed or riparian zone. In Illinois, where urban and agricultural land uses dominate the state, prioritization of the remaining forest and wetland areas for preservation has received considerable attention. Because many of the intact natural areas are concentrated in riparian zones, a recent study sought to analyze the potential habitat within riparian zones in order to rank them for conservation. Using multiple land cover datasets including Landsat as well as wetland and watershed boundaries, grassland, forest and mixed successional vegetation types were identified. The proportion of each land cover within a buffer distance of the streams was calculated and from these a score of relative habitat quality was assigned (Iverson et al., 2001).

Another HSM application, incorporating an aquatic habitat component, conducted by NOAA in Casco and Sheepscot Bays, Maine, involved development of a HSM for several aquatic species. The study integrated the environmental variables of temperature, salinity, depth and substrate into a suitability algorithm that combined the four variables in a manner consistent with their collective roles in the aquatic species' habitat. The authors concluded that the model results were generally successful in delineating habitat for the selected species. Furthermore, maps produced from the NOAA model corresponded closely to sampling data and expert knowledge of the species distributions (Brown et al., 2000).

Some suitability models venture beyond the computation of feasible sites to include the ranking of all the suitable sites and/or quantifying the effects of model inputs on the resultant sites. For example, a ranked habitat suitability model was created by the Florida Marine Research Institute to identify and delineate fish habitats off the coast of Florida. The resultant predicted distribution map broke fish habitat into four categories: optimum, high, medium and low (Rubec et al., 1998). In another example, a habitat suitability model was constructed to determine the effects of individual habitat factors on the overall quality of wild pig habitat in California. This wild pig model quantified the influence of environmental factors (such as hunting) on the suitability of habitat and species abundance (Davis et al., 1997). HSM outputs such as these are sometimes referred to as a Habitat Suitability Index (HSI). A multitude of HSI models have been developed for freshwater and marine fish species (Brown et al., 2000; Rubec et al., 1998; Malczewski, 1999; Vadas and Orth, 2001).

The set of alternatives (sites) identified through HSI modeling can also be reduced and/or ordered using MCDA techniques (Malczewski, 1999). MCDA is not generally thought of as a core capability of GIS. It can, however, be implemented within a GIS through the use of algorithms applied to the GIS databases as well as applying MCDA techniques to decision making processes (Malczewski, 1999). This incorporation of HSM and MCDA within a GIS is an effective method of



minimizing the trade-offs and uncertainties involved in the modeling process (Carver, 1991; Jankowski, 1995; Malczewski, 1999; Store and Kangas, 2001).

The benefit of embedding MCDA in GIS is that it allows for the evaluation of various land areas on the basis of multiple criteria (Carver 1991). This could be accomplished solely within a GIS through an iterative habitat suitability analysis by reducing the set of alternatives in a step-by-step manner. The reduction would be achieved by applying Boolean logic at each step. In this way, an area would be accepted or rejected based on an ever-tightening threshold value. The longer an area remains "accepted", the higher its overall rank. Imprecise threshold values, however, could lead to loss of information or error propagation (Store and Kangas 2001). A less problematic and more rapid approach is the use of MCDA techniques (such as weighted linear summation) within the GIS (Jankowski 1995). An example of this integration is illustrated in the following red squirrel habitat analysis.

The Mount Graham red squirrel habitat evaluation criteria (e.g., maximize number of conifers, maximize number of large trees) were identified and the corresponding data obtained (e.g., land cover, tree diameter at breast height). The habitat criteria and data selection were based on expert opinion and then combined into a suitability model. Various MCDA techniques were used including a method of quantifying the expert knowledge of red squirrel habitat factors in order to produce meaningful criteria measurement data (criterion maps). The results of the final model were found to accurately predict habitat use when compared with data on actual habitat use (Pereira and Duckstein, 1993).

Prioritization of entire watersheds, as opposed to individual habitat units, is also feasible with the integration of habitat suitability modeling, GIS and MCDA. For example, in Gujarat, India, a model with the objective of minimizing excess runoff to prevent poor crop yields was needed (Sharma et al., 2001). By combining a GIS with the two modeling techniques mentioned above, this model could evaluate entire watersheds based on multiple criteria such as soil erosion and low moisture. Once the areas of concern were identified, alternative land use and management practices were input into the model to quantify their potential impact. The result of this alternative-future analysis showed a decrease in runoff from the pre-conservation value (Sharma et al., 2001). In another example a GIS-based model was used in Pennsylvania to predict fish distributions based on landscape-level indices (Argent et al., 2003).

The model examples described above could have been accomplished through a habitat suitability modeling process without the incorporation of MCDA. Without the decision-making techniques and data standardization protocols of MCDA, however, they may not have been as successful (Hopkins, 1977). The US-EPA Research Station in Corvallis Oregon has also developed a framework for prioritizing landscape features such as wetlands using a GIS-based MCDA-HSM model (Abbruzzese and Leibowitz, 1997; Hyman and Leibowitz, 2000; Hyman and Leibowitz, 2001).

An example of the use of MCDA and GIS-based techniques in evaluating salmon habitat in the PNW is the NMFS study of coho salmon in the Snohomish River of western Washington (Pess et al., 2002). This study used a GIS-based spatially explicit statistical model to correlate land-use and land-cover (LULC) variables (forest cover, wetland occurrence, local geology, agricultural land-use, and others) with measures of coho salmon abundance. The study found that median adult coho densities were 1.5 to 3.5 times as dense in forest-dominated sub-watersheds as they were in sub-basins where rural, urban, and agricultural land-uses dominated the landscape (Pess et al., 2002). This study and the others discussed above demonstrate the utility of GIS-based MCDA methods for identification, assessment, and prioritization of salmonid habitat for conservation and restoration activities.



REFUGIA GIS MODEL

One of the key components of the salmon recovery strategy in the PNW is the development of a better quantitative understanding of the relationship between watershed conditions, instream habitat, and salmonid population levels (Holtby and Scrivener, 1989). There have been numerous methods developed for relating salmonid population response to changes in instream habitat conditions (Reeves et al., 1989). However, until recently there have been only a few studies that have quantified the relationship between watershed-scale characteristics (LULC), salmonid habitat, and salmonid population diversity and abundance (Beechie et al., 1994; May et al., 1997; Montgomery et al., 1999; Pess et al., 2002). This project builds on those previous studies and expands the process using GIS and the MCDA techniques described above.

Multi-criteria decision analysis (MCDA) requires that habitat suitability modeling (HSM) begin with a definition of the objective and associated attributes. From there, criterion maps are produced that reflect the measurement of each attribute over the spatial extent. The terms "evaluation criteria" and "objectives" are used interchangeably. The terms "raw data" and "attributes" are also equal as are "criterion maps" and "map layers." The process of identifying evaluation criteria, determining relevant raw data, creating criterion maps, standardizing the criterion maps and combining them within a weighted algorithm constituted the habitat suitability model.

Two habitat types were evaluated: *freshwater* habitat (watershed-based) and *nearshore* (including estuarine) habitat. The overall goal of the refugia study was to quantify the suitability of each watershed and nearshore unit within the study area with respect to salmonid habitat quality. Watershed units and nearshore zones were evaluated separately to reflect the different habitat requirements of each. For example, flood-prone zone analysis was only relevant to the freshwater habitat while shoreline modifications were only relevant to the nearshore areas.

Objectives were developed using expert knowledge of salmon habitat requirements retrieved from recent literature and local expertise. They describe the components of salmon habitat in their idealized state. The datasets involved in measuring the extent to which each objective is achieved are referred to as attributes. Multiple attributes are sometimes needed in order to measure an objective. Whether or not an objective is measured through the use of one attribute or the combination of attributes, each objective is ultimately represented with a single map layer that is then input into the mathematical function. Because map layers have differing levels of effect on habitat quality, they are combined through a modified additive weighting algorithm rather than simply added together. The output of the map layer algorithm is a map of relative salmon habitat quality that then fulfills the goal identified for the model. See Figures 13 and 14 for illustrations of the relationships among goals, objectives and attributes in both the freshwater and nearshore models. Figures 15 and 16 illustrate the freshwater and nearshore model flow-paths.

The decision-maker (in the case of the refugia project, an ecologist familiar with the study region) chose the evaluation criteria to best represent those landscape-level watershed and nearshore factors that influence salmonid habitat conditions in the Puget Sound lowland eco-region. They are based on current research on the cumulative impacts of development on aquatic ecosystems in the region and the sum of local knowledge of salmon habitat requirements. A total of 20 *objectives* were identified: 15 freshwater criteria and 5 nearshore criteria (see Tables 11 & 12). Every effort was made to ensure that the evaluation criteria, as a group, would provide a comprehensive measure of salmonid habitat quality.

The objectives can be split up into four categories, watershed, riparian, instream, and nearshore (see Tables 11 & 12). All of the objectives are ecologically significant in that they either directly or indirectly affect physical and/or biological conditions within the stream or nearshore ecosystem.



Watershed-level criteria included hydrologic potential, total impervious surface area, agricultural land-use, road density, wetlands, urban development (including rural, suburban, and urban land-uses), and native forest cover. Many of these criteria have been identified as having a significant influence on watershed conditions and salmonid habitat (Beechie et al., 1994; May et al., 1997; Pess et al., 2002). Some map layers are measures of human influence (i.e. total impervious area, agricultural land-use, and roads). Some of the map layers selected also represent the natural landscape conditions found in the Puget Sound lowland eco-region prior to human disturbance (i.e. forest cover, wetlands, and riparian quality).

Riparian-based evaluation criteria included measures of riparian fragmentation (road and utility line crossings), riparian corridor extent/width, riparian vegetation quality, floodplain modification, salmonid migration barriers (blocking culverts, dams, and hatchery weirs), and mass wasting potential (slope stability). These measures represent measures of the *Riparian Integrity* of the stream ecosystem (May and Horner, 2000). Instream factors included salmonid diversity, salmonid productivity, and instream habitat quality. The instream factors represented directly measured stream conditions and other effects on population dispersal. The nearshore objectives of shoreline modifications, small boating related structures, marinas, marine vegetation and nearshore riparian vegetation comprise the known impacts to salmonid habitat in the nearshore zone.

In summary, the selection of the freshwater and nearshore *metrics* included in the model was based on the ecological significance of the map layers and their influence on the processes that create and maintain salmonid habitat. The selected metrics also represent multiple spatial scales of influence with regard to salmonid habitat quality (watershed, riparian, and nearshore) as well as influence on multiple life stages (migrating, spawning, and rearing). All watersheds and nearshore areas within Kitsap and East Jefferson Counties were evaluated using the selected GIS model metrics. The following section discusses the details of the scoring process. Based on the overall model scores, refugia areas were selected and classified.



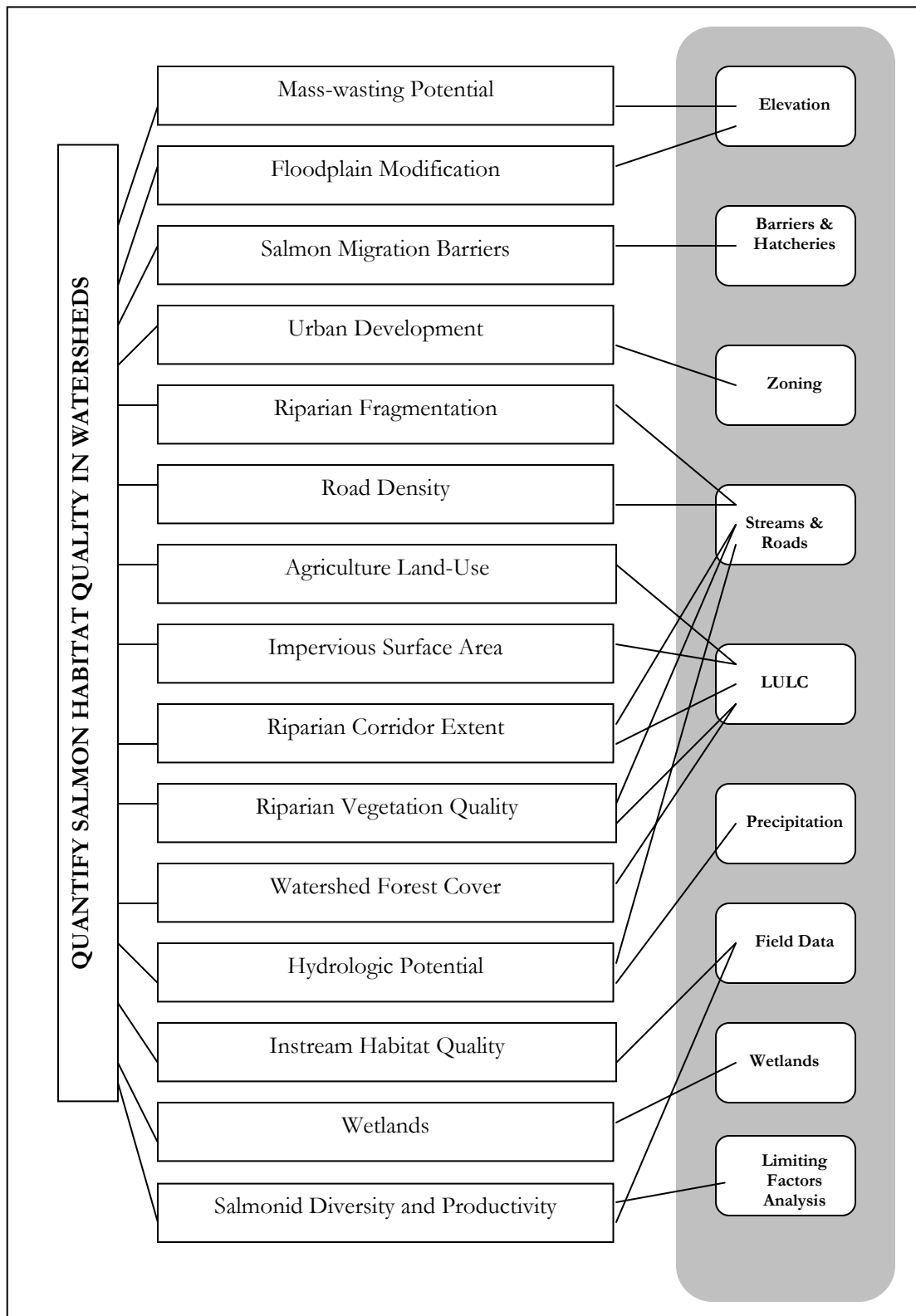


Figure 13: Freshwater Model Landscape Goals, Objectives, and Attributes.



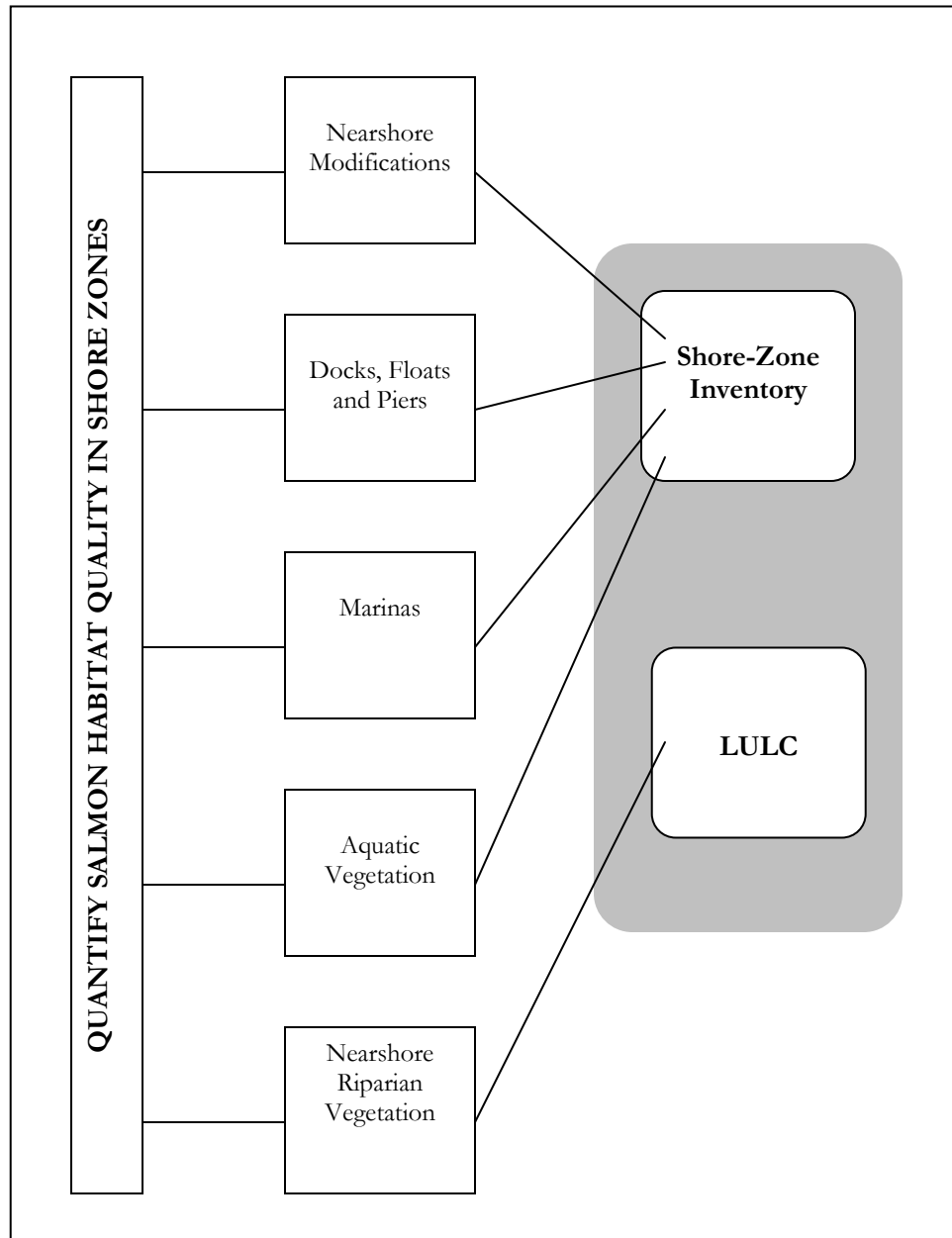


Figure 14: Nearshore Goals, Objectives, and Attributes.



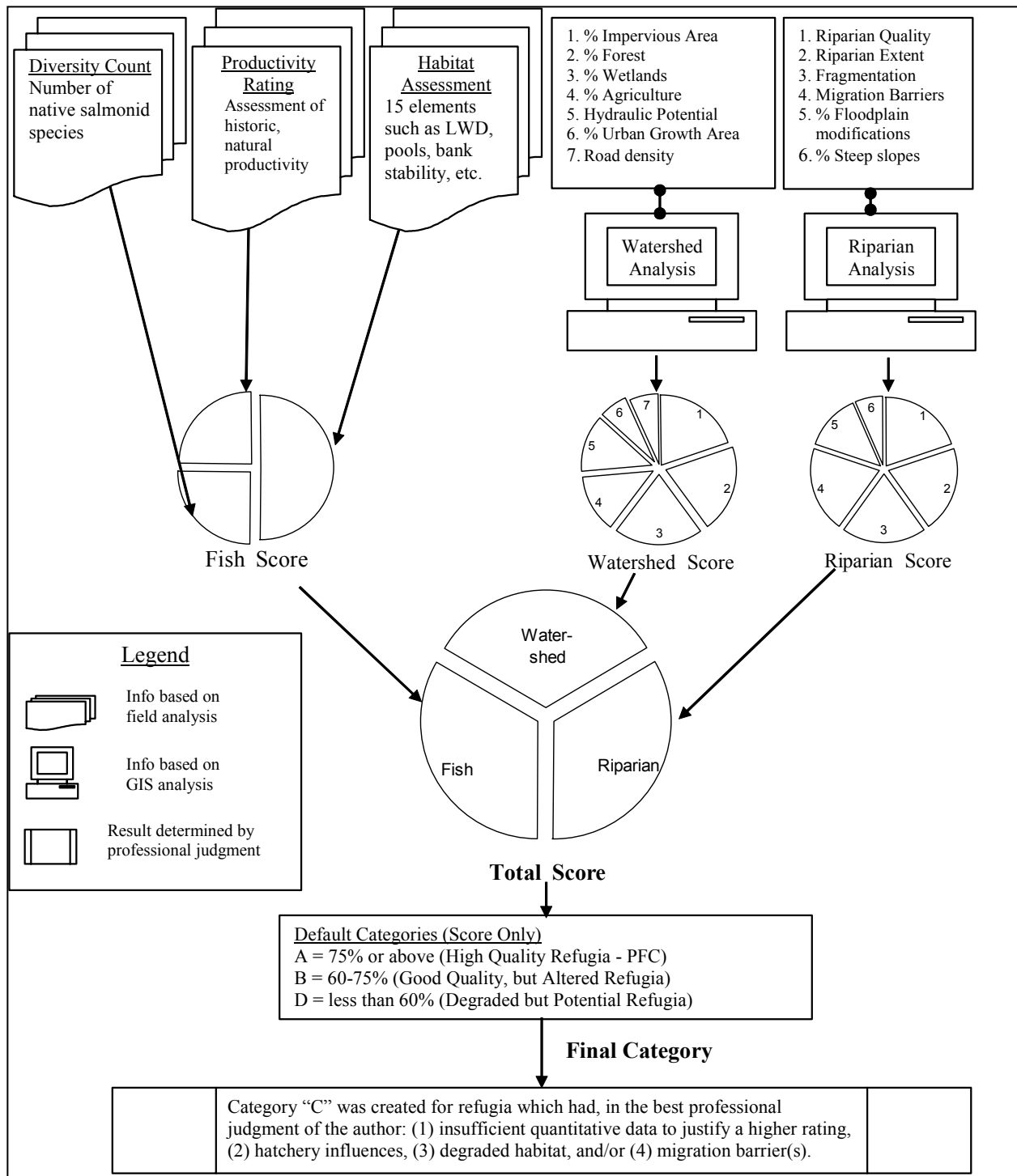


Figure 15: Freshwater Refugia Model Flow-Path.



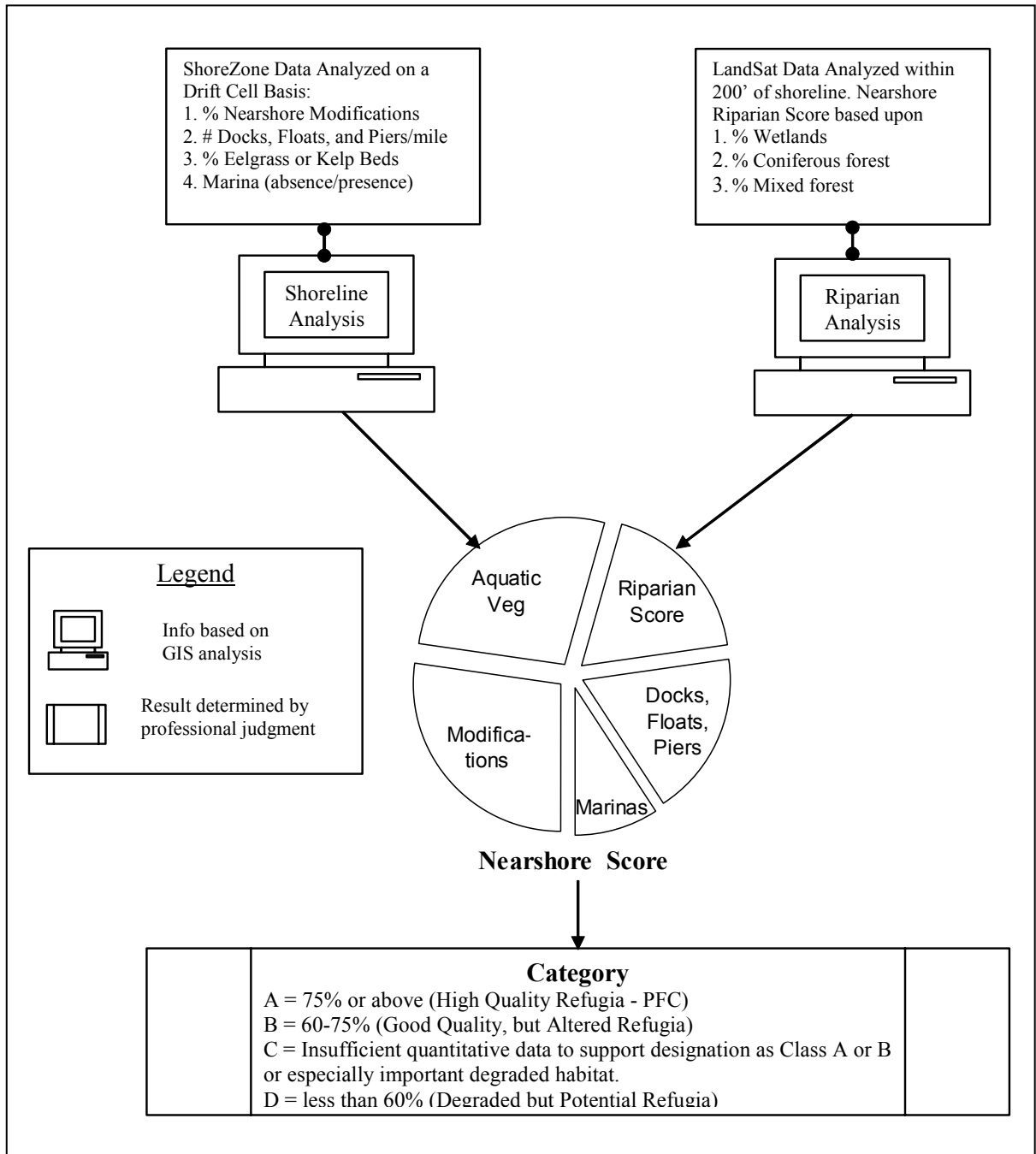


Figure 16: Nearshore Refugia Model Flow-Path.



GIS Layer	Calculation of Metric	Units	Main Data Source
Riparian Fragmentation	Road & utility stream crossings / stream mile	#	Roads Utility Lines Streams
Riparian Corridor Extent	Forest area / buffer area	%	Land use/land cover Streams
Riparian Vegetation Quality	Coniferous and mixed forest area / buffer area	%	Land use/land cover Streams
Mass Wasting Potential	Area of slopes greater than 30 degrees / watershed area	%	Elevation
Hydrologic Potential	Weighted addition of basin area (2) + drainage density (1) + average rainfall (3)	N/A	Precipitation Streams
Total Impervious Surface Area	Rural residential area (.1) + low intensity residential (.35) + high intensity residential (.6) + commercial (.9)	%	Land use/land cover
Agriculture Land-Use	Agriculture area / watershed area	%	Land use/land cover
Road Density	Miles of road / watershed area	km	Roads
Wetlands	Wetland area / watershed area	%	Wetlands
Urban Development	Urban development area / watershed area	%	Zoning
Salmon Migration Barriers	Blocked stream length / stream length	%	Barriers Hatcheries
Instream Habitat Quality	1 to 5, with 5 representing the best habitat quality	N/A	Field Data
Salmonid Productivity and Diversity	1 to 5, with 5 representing high salmonid productivity	N/A	Limiting Factors Analysis Field Data
Flood-prone Zone Modification	Human-modified flood-prone zone area / total flood-prone zone area	%	Elevation
Forest Cover	Weighted addition of clear-cut area (1) + deciduous forest area (2) + mixed forest area (3) + coniferous forest area (4)	%	Land use/land cover

Table 11: GIS layers selected for inclusion in the Freshwater Refugia Model.

GIS Layer	Calculation of Metric	Units	Main Data Source
Nearshore Modifications	Human-modified nearshore area / nearshore area	%	Land use/land cover
Docks, Floats, and Piers	Docks, floats, and piers / nearshore segment mileage	#	Shore-Zone Inventory
Marinas	Presence or absence of marinas	Yes/No	Shore-Zone Inventory
Eel Grass or Kelp Beds	Aquatic vegetation score / nearshore segment length	%	Shore-Zone Inventory
Nearshore Riparian	Wetland, coniferous, and mixed forest area / shoreline segment buffer area	%	Shore-Zone Inventory

Table 12: GIS layers selected for inclusion in the Nearshore Refugia Model.



GIS Data and Map-Layer Descriptions

Attribute data pertinent to the selected evaluation criteria were examined early in the study for completeness, accuracy, and timeliness. This section includes a description of specific datasets that were evaluated for inclusion or exclusion as well as datasets that were created when no adequate data were available. Table 13 contains a comprehensive listing of all the digital data used in the model.

	Scale/Resolution	Source
Salmon Migration Barriers	All culverts and dams inventoried to-date	Washington Department of Fish and Wildlife SSHEAR database representing unresolved fish passage problems outside of the Olympic National Forest
Elevation	10 meter DEM	Kitsap County, originating with U. S. Geological Survey
Digital Ortho-photos	1:24,000	Year 2000 quadrangles obtained from the Washington State Department of Natural Resources
Flood-prone Zones	Not applicable	Created for the current project
Instream Habitat Quality	Not applicable	Created for the current project
Land use/land cover	30 meter	Created for the current project
Limiting Factors Analysis	1:24,000	Draft for WRIAs16 & 17 from the Northwest Indian Fisheries Commission
Marine Vegetation	0.5 mile	Washington Shore-zone Inventory from the Washington State Department of Natural Resources
Precipitation	1.25 arc-minutes (~2 km)	Developed by the University of Oregon and Oregon State University
Refugia	1:24,000	Created for the current project
Roads	1:100,000	2000 U. S. Bureau of the Census TIGER database
Shoreline Modifications	0.5 mile	Washington Shore-zone Inventory from the Washington State Department of Natural Resources
Stream Types	1:24,000	Washington Department of Natural Resources hydro-geography
Streams	1:24,000	Washington Department of Natural Resources hydro-geography
Topography	1:24,000	Quadrangles obtained from GIS Data Depot, originating with U. S. Geological Survey
Hatchery Operations	Yes or No	Washington Department of Fish and Wildlife
Utility lines	1:50,000	Created for the current project
Watersheds	6th field	Olympic National Forest 6th field hydrologic units
Wetlands	1:24,000	USFWS National Wetlands Inventory
Drift Cells	1:24,000	Washington State Department of Ecology
Zoning	Unknown	County zoning theme

Table 13: GIS Refugia data

Multiple *map layers* were required as inputs to the salmonid habitat suitability model (HSM). These layers were either *collected* via field inventories and expert knowledge or *produced* from existing data through the use of spatial functions and analysis. An example of a “collected” layer is the instream habitat quality map that was created by converting field data to a digital spatial database. An example of a “produced” layer is the forest cover map that was created by interpreting Landsat satellite imagery to locate forest areas, and then calculating the amount of forest area within each watershed. Most of the map layers needed for the model are of the *produced* type.

A further distinction is made between map layers that measure objectives directly and those that are considered *proxy* map layers. A direct scale, such as habitat diversity (number of salmon species in the stream), measures the achievement of its associated objective directly. Other map layers, such



as mass-wasting potential, measure the degree to which its associated objective is met through an assumed indicator. For example, in the case of mass-wasting potential, the measurement of percentage of slopes greater than 30 degrees within each watershed was used as a proxy to indicate potential slope instability.

As was discussed earlier in this report, the selection of the freshwater and nearshore metrics or map layers included in the model was based on the ecological significance of the measured parameters and their influence on the processes that create and maintain salmonid habitat (Pess et al., 2002). The selected metrics also represent multiple spatial scales of influence with regard to salmonid habitat quality (watershed, riparian, and nearshore) as well as influence on multiple life stages (migrating, spawning, and rearing). In addition, sensitivity analysis was conducted with various combinations of potential metrics to determine which metrics were best suited for inclusion in the GIS model.

Freshwater Map Layers

Riparian Fragmentation

Landscape fragmentation is recognized as a significant factor in determining ecosystem structure and function (Sedell et al., 1990; Wahlberg et al., 1996; Hiebler, 2000). In the Puget Sound lowland (PSL) region riparian fragmentation is a common by-product of watershed development, beginning with rural-agricultural land-use and continuing through suburban and urban development (Figure 17). This riparian fragmentation metric correlates well with declining biological integrity in PSL streams (Figure 18). GIS code was written to automate the process of determining the intersections

of roads and utility lines with streams. The resultant points of intersection where summed for each watershed and then divided by total watershed stream miles. The metric is defined as road and utility stream crossings per stream mile. The 1:100,000 scale TIGER roads data were determined to be most appropriate for the road-utility stream crossing analysis than the other road datasets described above. The use of this data minimized the occurrence of extraneous road-stream crossings upon examination of the analysis results.

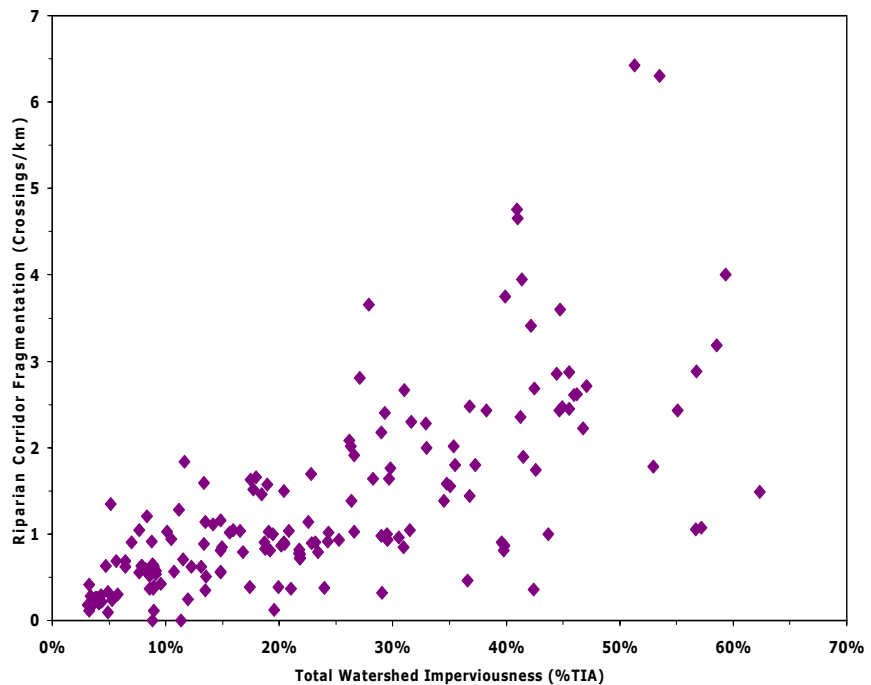


Figure 17: Riparian Fragmentation in Puget Sound Lowland Watersheds (May and Horner, 2000).



Riparian Corridor Extent

Like the longitudinal fragmentation of the riparian corridor, the lateral extent of the riparian zone has been shown to be a significant factor in the ecological integrity of PSL streams (May et al., 1997; May and Horner, 2000; Booth et al., 2001). Figures 19 and 20 show this relationship for PSL streams. Based on the established relationship between stream ecosystem quality and riparian extent, this metric was selected for inclusion in the GIS model. The total area of all forest types (coniferous, deciduous, and mixed) within a 200-foot stream buffer (both sides of the stream) was calculated. A 200-foot buffer was used because this distance approximates one site-potential tree height (SPTH) for the study area of interest. In general, one SPTH is considered an ecologically significant riparian width in forested watersheds (FEMAT, 1993; Spence et al., 1996; Knutson and Naef, 1997; Naiman and Bilby, 1998). The total forested area within stream buffers and a total buffer area were derived for each watershed and then divided. The metric is defined as forested area per total buffer area.

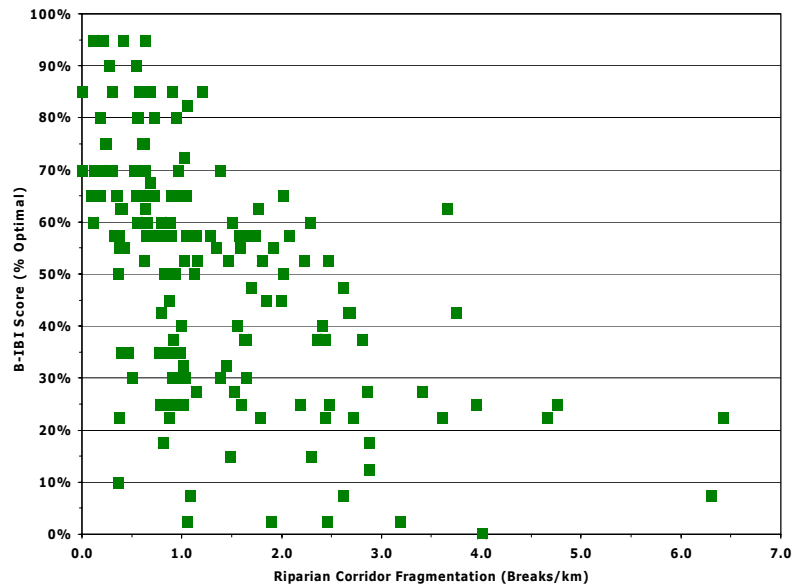


Figure 18: Riparian Fragmentation in Puget Sound Lowland Watersheds (May and Horner, 2000).

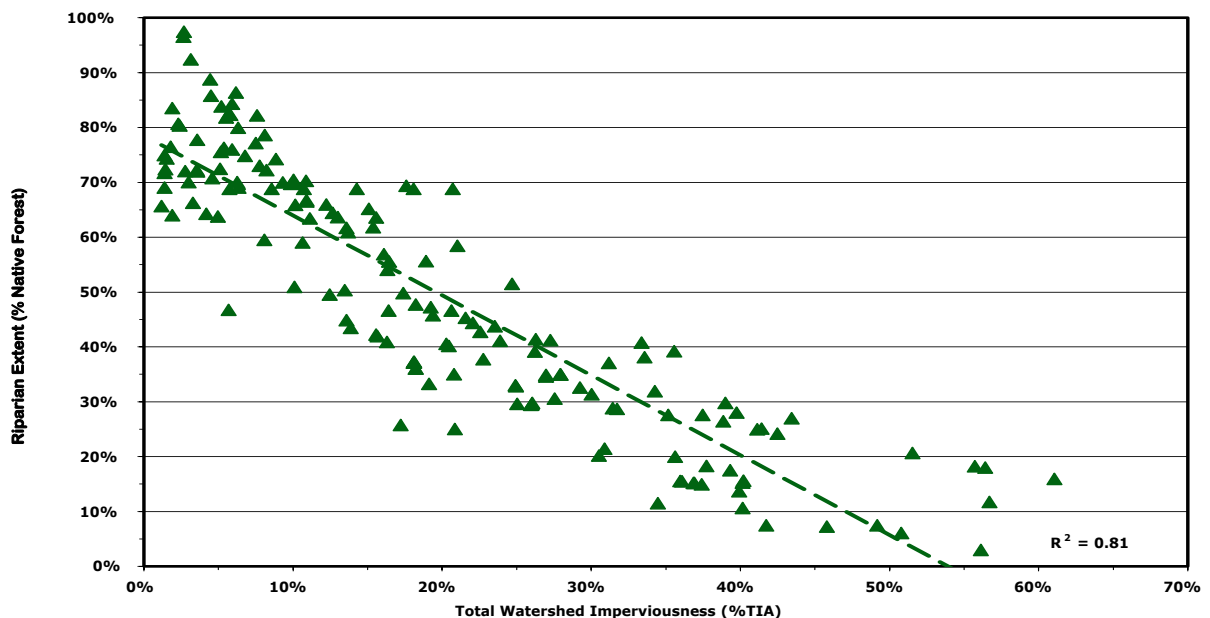


Figure 19: Riparian Corridor Extent in Puget Sound Lowland Watersheds (May and Horner, 2000).



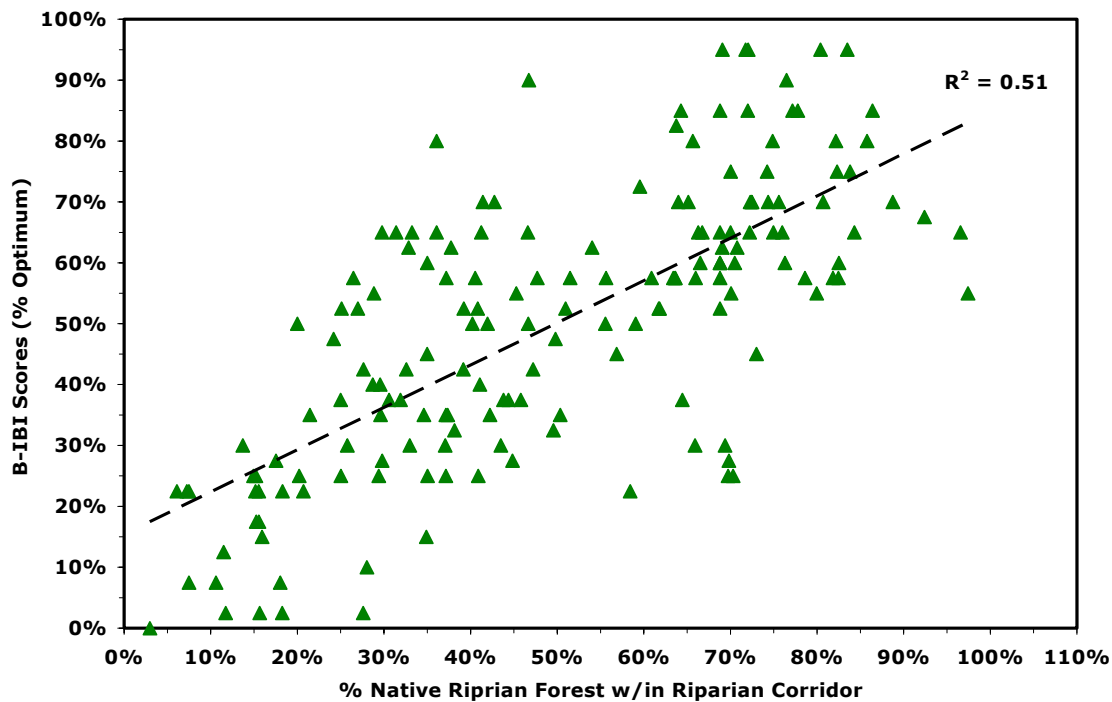


Figure 20: Riparian Corridor Extent in Puget Sound Lowland Watersheds (May and Horner, 2000).

Riparian Vegetation Quality

The total area of coniferous and mixed forest types within each 200-foot stream buffer was calculated. In general, coniferous and mixed forest is considered the most representative of pre-development conditions within the riparian zones of forested watersheds in the PNW (Naiman and Bilby, 1998). In the case of rivers and larger streams, the lower mainstem floodplain areas were often dominated by pioneer vegetation (mostly deciduous species) as a result of frequent flooding disturbance events that inhibit the forest succession process common to upland areas (Naiman and Bilby, 1998). For most lowland streams, the natural riparian corridor of streams in the PNW contain a mosaic of forest types (Naiman and Bilby, 1998), with coniferous forests (mixture of cedar, hemlock, and spruce) being the most common. Therefore, for this study *riparian quality* was defined as both coniferous and deciduous forest. A total coniferous and mixed forest area within stream buffers and a total buffer area were derived for each watershed and then divided. The metric is defined as total coniferous and mixed forest area per total buffer area.

Mass Wasting Potential

A land slope map was created from the digital elevation model (DEM) after sinks were filled. Slopes greater than 30 degrees were selected and their areas calculated. This value was selected based on current guidance from the Washington Department of Natural Resources (WDNR) on potential slope instability in forested watersheds (WDNR, 1995). The metric is defined as area of slopes greater than 30 degrees per total watershed area.



Hydrologic Potential

The *hydrologic potential* analysis used in this study is a composite of three independent analyses: watershed area, drainage density, and average annual precipitation. This metric was designed to quantify the streamflow potential of each watershed. In general, the greater the streamflow or hydrologic potential, the greater the available salmonid habitat area. The *watershed area* is simply the surface area of the watershed. The *drainage density* was computed by totaling the stream channel length per watershed area. The *average annual precipitation* was determined by intersecting the rainfall contours (precipitation) with the watershed map and then summing the total area of each resultant polygon, multiplied by its precipitation average. The watershed area measurement was then multiplied by two (2), drainage density was multiplied by one (1), and average annual precipitation was multiplied by three (3), then combined for a total metric score. The metric is defined as a synthetic score comprising the weighted addition of basin area (2) plus drainage density (1) plus average rainfall (3).

Land Use and Land Cover

Since eight out of the 23 objectives required land use/land cover (LULC) information for their measurement, it was important to acquire the most current and accurate data possible. To that end, a Landsat 7 ETM+ (30 meter pixel resolution) satellite image was classified into several LULC categories. Care was taken to use similar classification methods to those employed for the original Kitsap County Refugia Report (2000). Ortho-photo quarter quadrangles, DEM, digital raster graphics and ASTER satellite imagery were used as supporting data for the classification. ASTER data from the multi-spectral sensor of the TERRA satellite was chosen as a supporting dataset because of the additional spectral resolution it provided. The digital ortho-photo quadrangles were used primarily to provide ground truth information. It should be noted that higher resolution remote-sensing data are available from a variety of sources (e.g. digitized aerial photos, LIDAR, etc.). However, many of these various data sources were not available for all parts of the study area. Therefore, it was determined that the 2001 Landsat 7 ETM+ would be used as the primary LULC classification source. LULC data was used to determine both watershed and riparian scale landscape map layers.

Total Impervious Surface Area

The effects of watershed development on PSL streams are well documented (Booth, 1990; Booth, 1991; Booth and Reinelt, 1993; Horner et al., 1997; May et al., 1997; Horner and May, 1999; Booth et al., 2002). They include extensive changes in basin hydrologic regime, channel morphology, and physiochemical water quality. The cumulative effects of these alterations have produced an instream habitat that is significantly different from that in which salmonids and associated fauna have evolved. In addition, development pressure has a negative impact on riparian forests and wetlands, which are essential to natural stream functioning.

The most obvious manifestation of watershed development is the increase in impervious surface area and the corresponding loss of natural vegetation. Land clearing, soil compaction, encroachment on riparian corridors, and modifications to the surface-water drainage network all typically accompany human land uses. Total impervious area (%TIA) is the most commonly used measure of watershed development currently in use. In developing areas, imperviousness typically increases at the expense of native forest cover (see Figure 21). Although impervious surfaces themselves do not generate pollution, they are the major contributor to the change in basin hydrologic regime that drives many of the physical changes affecting stream ecosystems (Schueler, 1994). Figures 22 and 23 show the relationship between watershed development (as measured by %TIA) and selected measures of ecological integrity in the Puget Sound region. These relationships generally hold for most measures of ecological integrity (biotic integrity, physical habitat, water quality, etc.).



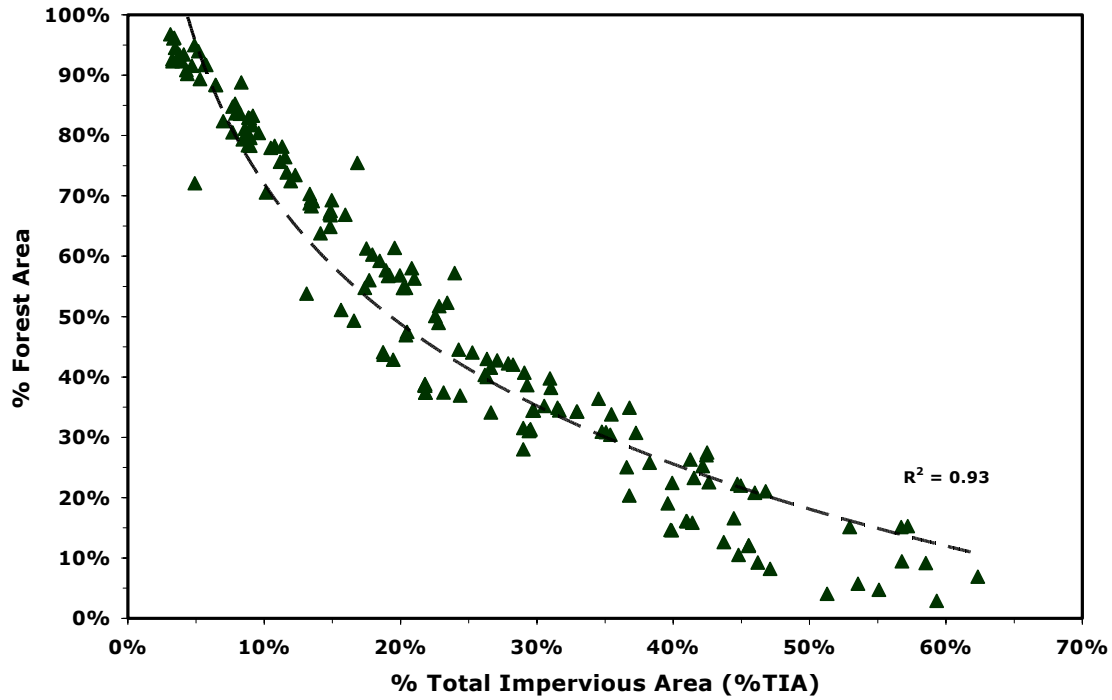


Figure 21: Forest Cover and Total Impervious Area in PSL Watersheds (May et al., 1997).

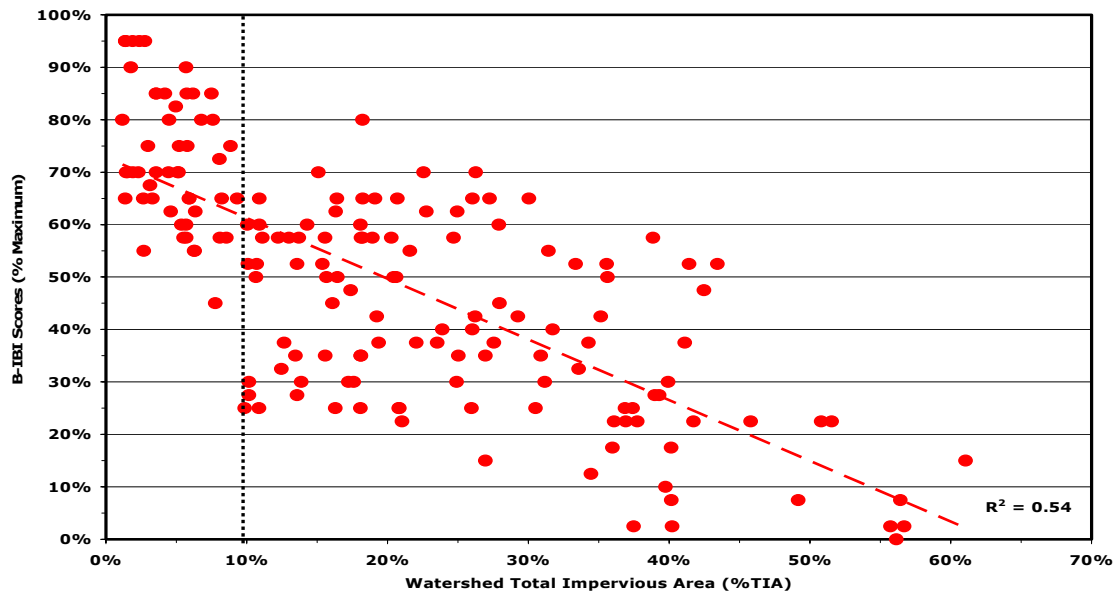


Figure 22: Relationship between Watershed Development in PSL Watersheds and Ecological Integrity (May et al., 1997).



WMI Puget Sound Habitat Assessment

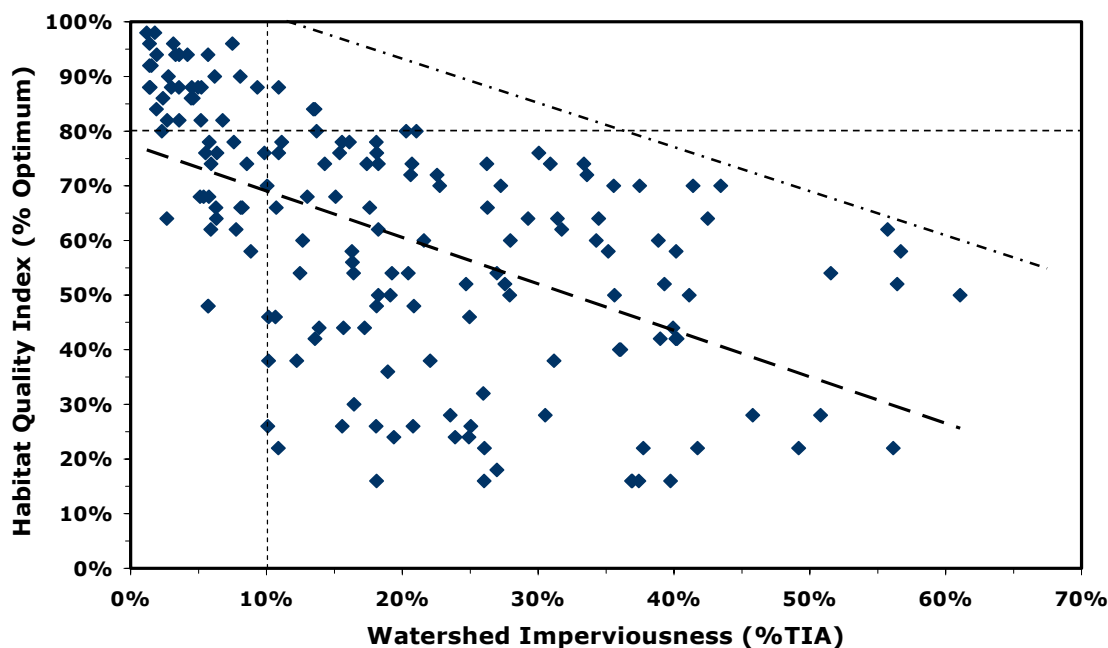


Figure 23: Relationship between Watershed Development in PSL Watersheds and Ecological Integrity (May et al., 1997).

As a landscape metric, watershed imperviousness (%TIA) generally is able to explain most of the cumulative impacts associated with stream ecosystem decline. A wide *range* of stream conditions, however, can be associated with any given level of imperviousness, particularly at lower levels of development. Land development that eliminates hydrologically mature forest cover and undisturbed soil can result in significant changes to the natural stream flow regime and, in turn, to the physical stability of stream channels, as well as to instream habitat conditions. These changes are manifested in altered stream flow patterns with higher volumes of storm flow, leading to accelerated channel erosion and habitat simplification. These hydrologic changes cannot be completely mitigated with structural stormwater control and treatment measures (Horner and May, 2001). Although factors other than hydrologic change (*e.g.*, declining water quality, riparian encroachment) can undoubtedly affect the magnitude of urban impacts, the breadth of the existing data suggest that improvements in these other factors can never fully mitigate the hydrologic consequences of watershed development (Booth et al., 2002).

Four impervious surface area categories were differentiated in the Landsat classification scheme: rural residential, low intensity residential, high intensity residential, and commercial/industrial. The total area of each type was computed in each watershed and then multiplied by its corresponding percent impervious factor: 0.10, 0.35, 0.60 and 0.90 respectively (May et al., 1997). The four adjusted area measurements were then summed and divided by total watershed area to compute percent total impervious area (%TIA). The metric is defined as rural residential area (.1) plus low intensity residential (.35) plus high intensity residential (.6) plus commercial (.9) combined into %TIA.



Forest Cover

It is generally understood that native forest cover is the most desirable LULC category for watersheds that support salmonids (Booth et al., 2002). In addition, mature forests are generally more desirable than young forests with regard to salmonid ecological requirements (Naiman and Bilby, 1998). Under the typical rural land use patterns found in the Puget Sound region, the magnitude of observed forest-cover losses affects watershed flow regime as much as, or more than, associated increases in impervious area (Booth et al., 2002). It should come as little surprise that the progressive loss of forest cover has been linked to declining stream quality indicators, given that forested watersheds are often routinely used to define natural reference conditions for streams (Booth *et al.*, 2001). Forest maturity is recognized as an important characteristic of the landscape in the PNW (Kruckeberg, 1991). For aquatic ecosystems, forest maturity or stand age is important from both a hydrologic and ecological perspective (Naiman and Bilby, 1998). Mature forest is also considered to be the main benchmark for defining pre-development hydrology within watersheds (WDNR, 1995). Consequently, forest cover is perhaps the most powerful indicator to predict the quality of streams within the lower end of the development spectrum (Booth *et al.*, 2001), as is found throughout the study area of East Jefferson and Kitsap Counties (see Figure 21).

Clear-cut logging area, deciduous forest area, mixed forest area, and coniferous forest area were identified as the main forest cover categories in the Landsat classification process. Each “forest-type” was summed separately per watershed and then weighted from an ecological basis. The weights were: 1 for clear-cut, 2 for deciduous, 3 for mixed forest, and 4 for coniferous forest. The metric is defined as a synthetic score comprising the weighted addition of clear-cut area (1) plus deciduous forest area (2) plus mixed forest area (3) plus coniferous forest area (4).

In addition, native forest age was identified as a contributing factor in the forest cover categories. A coniferous seral stage classification was thus derived from the land use/land cover classification. This was accomplished by overlaying an existing seral stage database covering forest service areas with DEM, Landsat ETM+ satellite imagery, Landsat band-4 forest texture and ASTER satellite imagery. The overlay provided enough information to derive unique spatial and spectral signatures for each stand age class. These signatures were then used to derive the classes through a supervised classification and modeling process. Four seral stages were thus mapped for the Jefferson County study area only: late seral, mid seral, early seral and recent clear cuts. However, in order to remain consistent with the original Kitsap refugia study, seral stage data were not incorporated into the GIS model, but is available for use in future refugia analysis updates and for use in other projects.

Urban Development

Urban areas were summed by totaling the area of certain zoning categories and any areas lying within designated urban growth boundaries (UGB). From the Clallam zoning theme, those categories were: general commercial, industrial, rural center, rural commercial, Sequim, Sequim urban residential, urban residential low, and Jamestown S'Klallam. From the Jefferson County zoning theme, those categories were: convenience crossroads, neighborhood crossroads, general crossroads, heavy industrial, light industrial, Port Townsend Urban Growth Area (UGA), rural village centers (Port Ludlow), airport, waste management, and all the MPR zoning types. Also included were the areas of the current Tri-Area proposed UGA for Jefferson County and the expanded commercial areas for Brinnon, Quilcene, and Port Hadlock. For Kitsap County, the following zoning themes were included: Kitsap County UGA, Joint Planning Areas, Local Areas of More Intense Rural Development (LAMIRD), public facilities, airports, and industrial. The metric is defined as total urban development area per total watershed area and is included as a measure of potential development pressure.



Agriculture Land-Use

Agriculture, like urbanization and timber harvest, is considered a significant landscape altering land-use (NRC, 1996). In the study area grazing and row-crop agricultural activity are both quite common. For this study, impervious was used to measure development and clear-cuts were used as a measure of recent logging activity. Likewise, agricultural lands were identified in the Landsat classification and summed within each watershed. The metric is defined as agriculture area per total watershed area and is expressed as a fraction (% agricultural land-use).

Wetlands

Wetlands are a significant ecological landscape feature both hydrologically and from a salmonid habitat perspective (Naiman and Bilby, 1998). Wetlands were identified using the National Wetlands Inventory (NWI). Wetland area within each watershed was then calculated. All NWI wetland types were included. The metric is defined as wetland area per total watershed area.

Flood-prone Zones

Floodplain location data exist in the form of Federal Emergency Management Act (FEMA) flood insurance rate maps (FIRMS). The FEMA FIRMS in the study area were last updated in 1998. The FEMA maps were developed for flood insurance purposes and do not adequately represent floodplain area from a salmonid habitat perspective. Floodplain areas are important to the stream-riparian ecosystem for hydrologic and ecological reasons. In general, the natural floodplain of streams in the PNW contains a mosaic of forests and wetlands (Naiman and Bilby, 1998). Floodplain areas provide storage for excess streamflows during extreme flooding events. In addition, they dissipate the energy of floodwaters and capture nutrient-rich sediments carried by the floodwaters. Salmonid habitat features found within the floodplain area include small tributary channels, off-channel wetlands, side-channels, and beaver pond wetlands (Stouder et al., 1997).

Therefore, new data showing *flood-prone zones* were created through an extensive analysis utilizing best available elevation data, known historical flood events, field verification and expert knowledge of known obstructions. The term *flood-prone zone* was coined to differentiate the area identified in this analysis from the existing FEMA floodplain areas already designated. The analysis built upon the methodology described in Garono and Brophy (2001). A description of the process steps involved in creating the flood-prone zones follows. The intended use of the dataset is for watershed comparison purposes within the context of this study and not for determining floodplain boundaries at greater than a 1:24,000 scale.

The *flood-prone zone* analysis began with an analysis of slopes within the study area. To this end, digital elevation models (DEM) at a 10-meter resolution were used as input into the GIS slope algorithms. Following a sensitivity analysis of various slope categories, it was decided that slopes of 0-5 degrees adequately reflected the flood-prone zones most applicable to salmon habitat. Once these areas were identified, any areas of less than 1.5 hectares were considered irrelevant and excluded from the analysis. Areas not coinciding with high flow locations (i.e., rivers and streams) were also excluded. Expert knowledge of plateau areas, as well as obstructions such as culverts or bridges, was utilized prior to incorporation into the analysis. Finally, any remaining areas in question were examined in the field to determine actual flood-prone area extents. Data on historical flows were also considered in the last portion of the analysis. The resultant digital flood-prone area delineations were used as input data for the flood-prone area modification criterion and are helpful in determining which watersheds contain the most flood-prone area modifications and which contain the least.

The flood-prone area was delineated using the methods described earlier in this report. The human land-uses, as identified in the Landsat classification, were then selected within the defined



flood-prone area. The total of human land-use areas within flood-prone zone was then computed and divided by the total area of the flood-prone zone. The metric is defined as the human-modified flood-prone zone area divided by the total flood-prone zone area.

Roads and Road Density

Road data for the study area exist in multiple databases. An evaluation of the many road layers was conducted early in the study. Although two of the existing databases: the Olympic National Forest road layer and the County road layers contained detailed road information, neither layer covered the entire study area. A third road layer, the 2000 U. S. Bureau of the Census TIGER database, was not as detailed as the Olympic National Forest layer but was comprehensive of the study area. Initially, a combination of the two datasets - using the ONF data in national forest lands and TIGER data in non-forest lands - was considered. However, it was determined that the TIGER database underrepresented logging-type roads in the study area and therefore a combination of the two datasets would create a bias between national forest watersheds and non-forest watersheds. In other words, watersheds within a national forest would receive a lower score than those outside of the national forest even if they contained the same amount of roads. Also, since the road databases were derived via dissimilar collection methods, the representation of roads versus reality could have been different in each database, therefore potentially raising or lowering a watershed's overall rank artificially.

The 1:100,000 scale TIGER roads data were determined to be most appropriate for the road-utility stream crossing analysis than the other road datasets described above. The use of this data minimized the occurrence of extraneous road-stream crossings upon examination of the analysis results. Major utility lines were also digitized from current ortho-photos. Locations where forest clearings were visible in long, narrow swaths were digitized and their locations verified as current utility line paths.

Road density was the metric used to quantify road impact on the watershed scale. The length of all roads within each watershed was calculated and divided by the watershed area. The road density metric is defined as total miles of road per watershed area in square miles (see Figure 24).

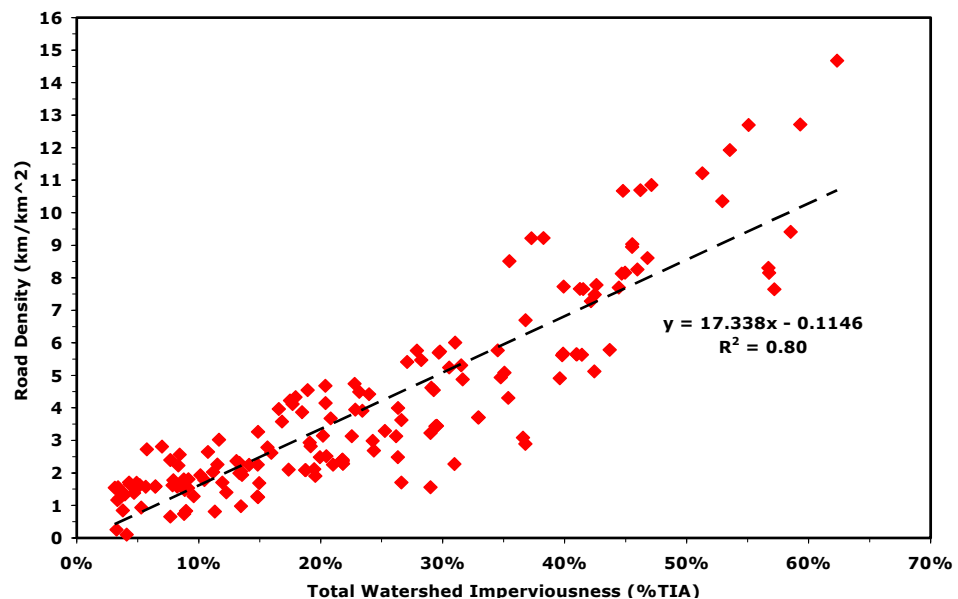


Figure 24: Relationship between Watershed Development and Road Density in PSL Watersheds (May et al., 1997).

Salmon Migration Barriers

The Salmonid Screening Habitat Enhancement and Restoration Database (SSHEAR database) was used to locate barriers in the study area. It is comprehensive of the study area and updated continually by the Washington Department of Fish and Wildlife. These data represent culverts and



dams inventoried to-date and do not include fish-ways. Barrier data was collated for all type 1-3 streams. The total length of type 1-3 streams upstream of a barrier was then computed and summed for each watershed. The metric is defined as blocked stream length per total stream length for all potentially fish-bearing streams in the watershed.

Instream Habitat Quality

Field data for several salmonid habitat characteristics (spawning, rearing, migration, canopy, LWD, water quality, streambank erosion, and riparian integrity) were collected and averaged to come up with an overall habitat quality score. The habitat quality metric is defined as a synthetic score from one to five, with five representing the best habitat quality (see previous section for detailed explanation).

Salmonid Productivity and Diversity

Data for salmonid diversity data were gathered from existing records as well as from interviews and from the on-going Limiting Factors Analysis (LFA) process. The diversity metric represents the combined number of fish species currently present in the stream, the number historically present in the stream, and the number that could potentially use the stream based on stream geomorphic characteristics. The maximum number of salmonid species found in the study area is seven (chinook, coho, fall/winter chum, summer chum, pink, steelhead, and cutthroat). The diversity metric is defined as a synthetic score from one to five, with five representing the highest salmonid diversity possible (see previous section for detailed explanation).

Productivity was scored using the qualitative criteria discussed in an earlier section of this report. The productivity metric is defined as a synthetic score from one to five, with five representing high salmonid productivity (see previous section for detailed explanation).

Nearshore Map Layers

A GIS-based landscape of the nearshore area was conducted for the first time during this project. The selection of landscape metrics was based on the current understanding of what factors are ecologically significant with respect to nearshore salmonid habitat (Williams and Thom, 2001). At the present time, our knowledge of nearshore salmonid utilization is relatively basic and is rapidly expanding. In addition, the database on nearshore salmonid habitat conditions is also relatively sparse. Therefore, this assessment of nearshore salmonid conditions should be considered as “interim” until more and better data is developed. Regardless of this limitation, the analysis presented here is scientifically sound and is based on the best available information. In addition to providing a foundation for future nearshore assessments, it provides decision-makers data on where potential nearshore refugia are located and what their current condition is based on the following criteria.

Nearshore Modifications

The percent modification data from Shore-zone data was used to create this map layer. Percent modification is the percentage of the Shore-zone segment that has been modified with wood, metal, or concrete bulkheads, riprap, landfill, or boat-ramps. The length of the nearshore segment was also calculated. This percentage was translated into percentage of the nearshore segment for use in the refugia model. The metric is defined as the percent of nearshore segment modified and is included as a measure of human impact along the shoreline (Williams and Thom, 2001).

Docks, Floats, and Piers

Using the Shore-zone data, the sum of piers, docks, small slips, large slips, and boat ramps was calculated for each nearshore segment. The length of the nearshore segment was also calculated.



The metric is defined as the number of docks, floats, and piers per mile of nearshore segment and is included as a measure of human impact along the shoreline (Kelty and Bliven, 2003).

Marinas

Presence or absence of a marina in each of the study area's watersheds was recorded for this project via a list of marinas. A list of known marinas was obtained from each county. It included any marina with at least one of the following services: fueling operations, human waste management and/or haul-out facilities. The following marinas were identified in East Jefferson County: Boat Haven, Port Hudson, Port Hadlock, Quilcene, Port Ludlow, and Pleasant Harbor. Marinas in Kitsap County include the following: Blake Island Marina (Yukon Harbor), Kitsap Marina (Sinclair Inlet), Port Orchard Marina (Sinclair Inlet), Port Orchard Yacht Club (Sinclair Inlet), Port Washington Marina (Dyes Inlet), Port of Bremerton, Bremerton Yacht Club Marina (Dyes Inlet), Port of Keyport (Liberty Bay), Port of Poulsbo (Liberty Bay), Liberty Bay Marina (Liberty Bay), Poulsbo Yacht Club (Liberty Bay), Port of Winslow (Eagle Harbor), Harbour Marina (Eagle Harbor), Eagledale Marina (Eagle Harbor), Seabeck Marina (Hood Canal), Driftwood Key Marina (Hood Canal), Port of Brownsville, Port of Kingston, and Port of Silverdale.

The total number of marinas with least one of the following services: fueling, human waste management, haul-out facilities was computed. The metric is defined as a synthetic score representing the presence or absence of marinas and is included as a measure of human impact along the shoreline (Kelty and Bliven, 2003).

Eel Grass or Kelp Beds

Using the Shore-zone kelp and eelgrass designations of absent, patchy and continuous, a synthetic score for each nearshore segment was computed. The metric is defined as the aquatic vegetation score divided by nearshore segment length.

Nearshore Riparian

A 200-foot interior buffer along the shoreline was created and the sum of estuarine intertidal wetlands, coniferous forest, and mixed forest area was computed per shore-zone segment. The metric is defined as the total wetland, coniferous, and mixed forest area per shoreline segment buffer area.

GIS REFUGIA MODEL ANALYSIS

The GIS analysis phase of the refugia model began with the creation of standardized map layers and weighting the criteria. Once these pre-processing steps were performed, weights and map layers were combined using a *value function*. The GIS assists in these tasks by performing the data standardization and generating results from the user-defined algorithm. Details concerning the pre-processing steps and the specifics of the algorithm are described in this section.

Each map layer described previously contains its own scale of measurement. For example, instream habitat quality is depicted via an integer number representing the relative habitat quality as assigned by the decision maker while the wetland map layer is measured as the percentage of wetlands within each watershed. An integral part of habitat suitability modeling and MCDA involves the transformation of values from the various criterion map layers into comparable units. In other words, the scales must be made commensurate in order for the map layers to be combined in a reasonable manner (i.e., before the map layers are input into the algorithm). This ensures that all the maps, some of which may consist of nominal or ordinal measurements, are converted to a common, interval value, scale. It also allows for the possible non-linearity between the raw (original map layer) and synthetic (transformed map layer) scales (Pereira and Duckstein, 1993).



The method of deriving non-linear synthetic scales usually involved the application of a classification called natural breaks to the raw data of each map layer. The natural breaks classification identifies breakpoints between classes using the Jenk's Optimization statistical formula. Simply put, this method minimizes the sum of the variance within the classes, finding groupings and patterns inherent in the data (Jenks, 1977). Raw data were transformed into a one to nine integer scale using the natural breaks classification computed in the GIS. Graphs of the raw and synthetic values for selected map layers are shown in Figure 25.

Even though all the map layer data were converted to the commensurate, synthetic scale through the above methodology, they could not yet be combined due to differences in their relative importance to salmonid habitat. For example, the salmon migration barrier criterion was identified by the decision-maker as having more effect on salmon habitat than the urban development criterion. A weighting scheme for the model was developed in order to represent this disparity between map layers. A *weight* is defined as the value assigned to each map layer to signify its importance relative to the other map layers (Malczewski, 1999).

The trade-off method was used to determine the weights. In the trade-off method, the decision-maker assesses trade-offs between pairs of criteria based on best available science (Malczewski 1999). In other words, the map layers were examined and a choice was made as to whether map layer *A* was preferred to map layer *B*, map layer *B* was preferred to map layer *A*, or whether the two map layers had equal importance relative to salmon habitat. In general, those map layers that most directly influence habitat (such as riparian conditions) were weighted the highest and those with somewhat less direct influence, or those that have an indirect impact (such as future land-use), were weighted lower. This rationale was justified based on current best available science relating watershed landscape alteration to salmonid habitat conditions. In general, there were three categories of map layers: watershed, riparian, and instream, as well as the nearshore map layers.

The weights derived via the trade-off analysis resulted in three coefficients for both the freshwater map layers and the nearshore map layers. Weights were normalized in order that their sum would equal 1. Both instream map layers were weighted equally (7.5 each) so that their sum would be equal to the sum of the riparian map layers (15) or the sum of the watershed map layers (15). This was done to reflect the decision maker's emphasis of equal importance for each of the three categories of analysis. It follows that instream map layers comprised a third of the overall rank, riparian map layers another third, and watershed map layers the remaining third. For the freshwater portion of the model, the map layers with three times the importance of the other map layers were multiplied by the coefficient 3/45. Those with two times the importance were multiplied by the coefficient 2/45 and those with one time the importance were multiplied by the coefficient 1/45. Similarly, the nearshore coefficients were: 3/11, 2/11 and 1/11. Once the weights were assigned and the coefficients derived, they were multiplied to the map layer's synthetic measurement values accordingly. Tables 14 and 15 summarize this information.

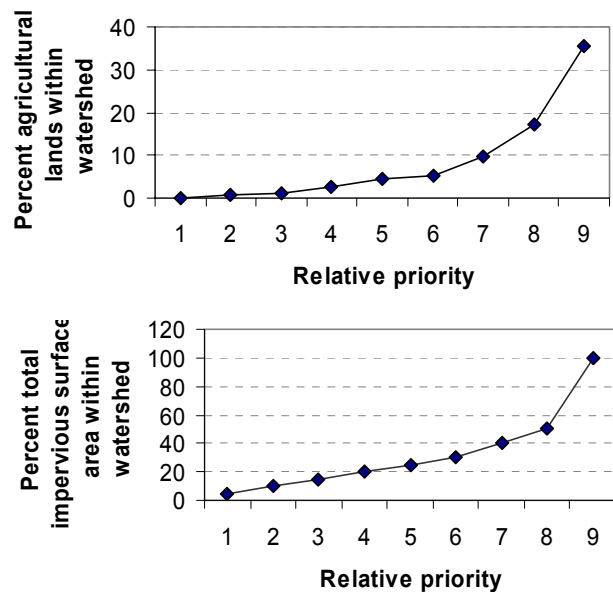


Figure 25: Priority functions as derived by the Natural Breaks Method.



Criterion	Relative Importance	Factor
<i>Instream</i>	--	.334
Salmonid diversity and productivity	7.5	.167
Instream habitat quality	7.5	.167
<i>Riparian Corridor</i>	--	.335
Salmon migration barriers	3	.067
Riparian fragmentation	3	.067
Riparian corridor extent	3	.067
Riparian vegetation quality	3	.067
Flood-prone zone	2	.045
Mass wasting	1	.022
<i>Watershed</i>	--	.335
Forest cover	3	.067
Total impervious surface area	3	.067
Wetlands	3	.067
Agriculture	2	.045
Hydrologic potential	2	.045
Road density	1	.022
Urban development	1	.022

Table 14: Freshwater Landscape Map Layers and Weighting Factors.

Criterion	Relative Importance	Factor
Nearshore modifications	3	0.2727
Aquatic vegetation	3	0.2727
Docks, floats, piers	2	0.1818
Nearshore riparian	2	0.1818
Marinas	1	0.0909

Table 15: Nearshore Map Layers and Weighting Factors

Evaluation criteria, standardized map layers and decision-maker preferences (weights) were combined into two algorithms (one for the freshwater ranking and one for the nearshore ranking) using multi-criteria decision rules. An additive decision rule, called a value function, was the method used for ranking the refugia in descending order of importance. The landscape refugia prioritization algorithm, adapted from Chrisman (1997) is written as follows:

$$R_l = \sum_m w_m v_{ml}$$

where R_l refers to the rank of each landscape refugia l , w_m refers to the weight assigned to each map layer m so that $\sum_m w_m = 1$, v_{ml} refers to the value of each landscape refugia l with respect to the m th map layer. The watershed characterized by the highest value of R_l has the best salmon habitat. The range of R_l is an integer scale from one to nine.



Similarly, the nearshore prioritization algorithm is represented as follows:

$$R_n = \sum_m w_m v_{mn}$$

where R_n refers to the rank of each nearshore zone n , w_m refers to the weight assigned to each map layer m so that $\sum_m w_m = 1$, v_{mn} refers to the value of each nearshore zone n with respect to the m th map layer. The nearshore zone characterized by the highest value of R_n has the best salmon habitat. The range of R_n is an integer scale from one to nine.

Once the landscape refugia and nearshore zones were ordered via the above algorithm, the rankings were translated into a percentage scale. For example, a refugia area with a final rank of 5.5 received a 61% score (or $5.5/9.0 = 61\%$). Both the one-to-nine scale and the percentage scores are reported for landscape refugia and nearshore zones in the results section and in Appendix G of this report. The frequency of freshwater refugia falling within each percentage category is shown in Figure 26. The mean of the percentage scores is 64.5 and the standard deviation is 11.0. The frequency of nearshore zones falling within each percentage category is also shown in Figure 26. The mean of the percentage scores is 65.5 and the standard deviation is 17.5.

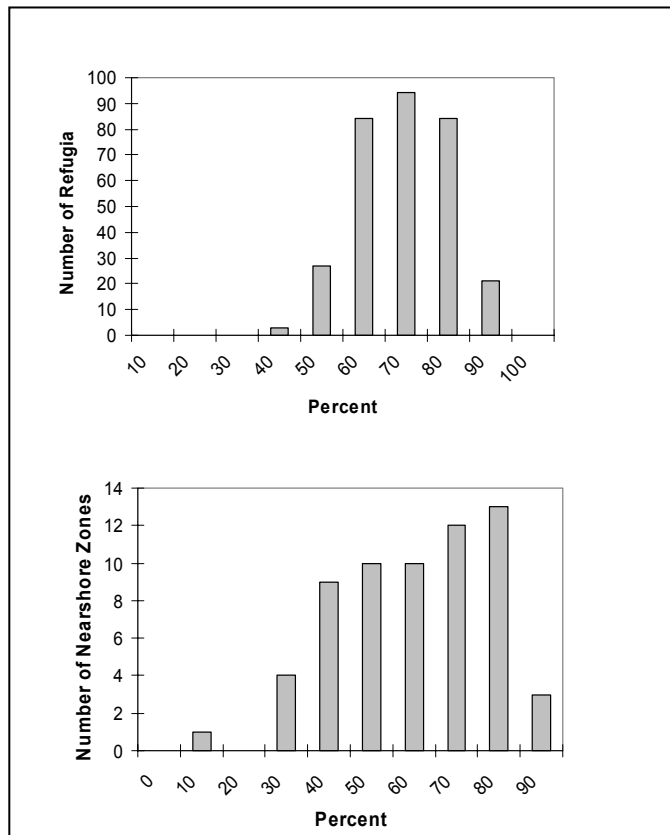


Figure 26: Frequency of Freshwater and Nearshore Refugia falling within each percentage category.



"We abuse the land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we begin to use it with love and respect."

ALDO LEOPOLD, 1956

REFUGIA IDENTIFICATION

Viewed from the perspective of native salmon or trout, the environment of the PNW is a mosaic of complex habitats. In this "fish landscape" there are salmon-friendly areas, where diversity and productivity is high, and there are other areas where just the opposite is true and salmon survival is low. These areas are constantly changing in quantity and quality on both a temporal and spatial scale. Such is the nature of ecosystems. As was discussed earlier, a large body of research indicates that protection and restoration of these salmon-friendly areas or *refugia* is one of the keys to regional salmon recovery (Sedell et al., 1990; Niemi et al., 1990; Doppelt et al., 1993; Schlosser, 1995; Spence et al., 1996; NRC, 1996; Frissell, 1998; Lichatowich, 1999; Lichatowich, 2000; Levin and Schiewe, 2001; Dewberry, 2001; IMST, 2002).

Salmonid refugia, in general, represent habitat patches that currently or historically function to provide a disproportionately large share of native salmonid productivity and diversity within the overall salmon landscape. These refugia areas can be critical for the persistence of native salmonid populations during major disturbances, both natural (flooding, drought, or fire) and human-induced (timber harvest, agriculture, or development). Refugia also function as sources of recolonization when adjacent or nearby watersheds experience a loss of native populations for whatever reason.

There is a degree of uncertainty in the refugia evaluation and selection process. As such, all watersheds in the study area (see Figure 27) that support populations of native salmonids were considered for refugia status. It was decided not to distinguish between each of the proposed refugia during the early phases of the evaluation process, but to wait until the entire process was

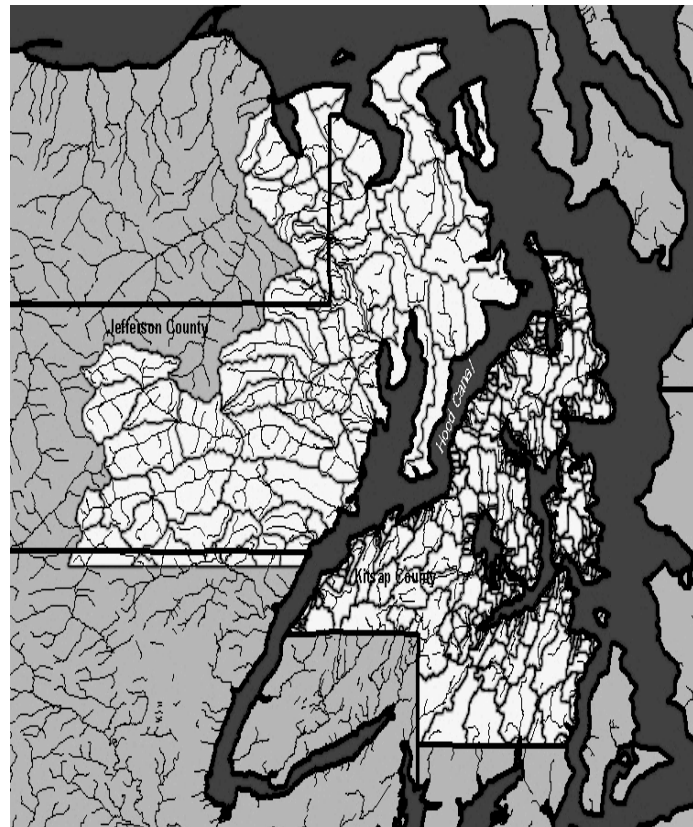


Figure 27: Study Area Watersheds.



complete before prioritizing. This included the *fish-centered approach* described in the previous section and the *landscape-centered approach* described in this section.

It is also important to recognize that the evaluation and selection criteria are not all-inclusive. Based on the findings of this report, areas not proposed for refugia status should not be considered unimportant with respect to regional salmon recovery efforts. Every watershed, stream, and nearshore area deserves protection and stewardship to some degree. Even the smallest watershed or nearshore area has some salmonid habitat value, which may be critical to the survival of a population or populations of fish. By the same token, degraded watersheds, streams, or nearshore areas may also still retain some measure of habitat value and therefore should be managed appropriately. It should also be reiterated that this study does not imply that protection of the designated refugia areas alone is ecologically sufficient to support salmon recovery or even to maintain current conditions within the region. This action is considered a necessary, but not sufficient, first step in a comprehensive, long-term ecosystem conservation program.

REFUGIA DELINEATION

Natural hydro-geographic features were generally used to delineate refugia boundaries. Watershed boundaries derived from the GIS digital elevation model (DEM) were used where appropriate based on hydrologic and ecological considerations. Ecologically significant, natural boundaries, such as ravines or floodplains, were also used to delineate refugia boundaries for stream-riparian corridors. For nearshore and estuarine refugia areas, natural shoreline features and drift-cells were the primary determinants of refugia boundaries. In delineating refugia areas, the size of the refugia was also a major consideration. Every effort was made to include sufficient area to encompass the migratory, spawning, and rearing needs of all salmonid species under consideration for refugia status. It is a basic principle of landscape ecology and conservation biology that larger refuge areas are preferable to smaller, fragmented reserves whenever possible (Sedell et al., 1990; Noss and Cooperrider, 1994; Foreman, 1997; Dewberry, 2001). This principle applies for a number of reasons, including the scale of ecological processes and the structure of the ecosystem being protected.

The following categories were utilized for delineating salmonid refugia areas in this report (modified based on Frissell, 1998 and 1999):

- Focal Sub-Watersheds (FSW)
- Nodal -Riparian Corridors (NRC)
- Nearshore and Estuarine Refugia (NSE)
- Critical-Contributing Areas (CCA)

The delineation of refugia areas is based primarily on hydro-geographic features and ecological considerations. Because natural features were primarily used to delineate refugia, the different categories of refugia are less critical. Therefore, a focal sub-watershed (FSW) refugia area is not necessarily “better” than a nodal-riparian corridor (NRC) refugia area. It is more a matter of which type of refugia fits the specific conditions in the field and which type will be most effective for conservation or restoration of salmonid habitat. For instance, consider a refugia area located within the lower, mainstem stream flowing through a ravine or narrow valley. That refugia area is likely more suited to NRC status whereas the headwater tributary area of the same watershed may be more suited to being delineated as a FSW. Both may be equally important in the overall scheme of protecting salmonid resources within the larger watershed that both are part of, but each is more



suited to different types of refugia. An area designated as a critical contributing area (CCA) is not in itself a refugia area, but is an area that can significantly influence water flows and water quality of downstream refugia. The refugia categories utilized in this report are described below in detail.

FOCAL SUB-WATERSHEDS

The term “focal watershed” was developed by Frissell (1998) to describe key or critical catchment areas (whole watersheds or “nested” sub-basins) that contain relatively unimpaired ecological structure and function in support of a significant number of salmonid species and life-stages. The refugia designation of *focal sub-watershed* (FSW) is used in this study to identify stream-ecosystem, whole watershed, or tributary sub-watershed-level refugia. The scale of these refugia is typically on the order of 10-100 square kilometers. These areas are analogous to the “key watersheds” designated under the FEMAT (1993) process, but at a local rather than regional scale. The typical FSW refugia include anadromous migration corridors, as well as spawning and rearing habitat for a number of species and populations of salmonids.

In most cases, watersheds in the study area have experienced a variety of human impacts, which have resulted in some degree of degradation. There are few watersheds that can be considered “pristine” or completely natural, therefore it will be important to maintain, enhance, or restore natural watershed processes within designated FSW refugia to create a complex, diverse landscape pattern of habitats favorable to the native salmonid community. Maintaining connectivity between high-quality *habitat patches* within each FSW is also critical to the success of the refugia. Although an entire watershed could be designated as a FSW refugia, the FSW designation is typically used to identify refugia within the broader watershed level. An example of this would be the designation of a tributary sub-basin within a larger stream watershed. In general, a FSW is disproportionately important within the larger watershed for providing critical salmonid spawning and rearing habitat.

In general, the FSW classification of refugia is also used to designate those areas that still have a low level of human impact (i.e. timber harvest, mining, agriculture, and development) and retain a significant amount of natural forest cover, wetland area, and intact riparian corridor. Most designated FSW refugia have maintained a relatively natural hydrologic regime and have very few, if any, water-quality problems. Most importantly, however, to be designated as a FSW, a watershed must also retain a significant degree of natural salmonid productivity and species diversity. At the very least, a FSW should support at least one wild spawning population of salmonid. A FSW should also be resilient to disturbance and be able to function as a recolonization source for local or regional salmonid population recovery. In summary, the key characteristics of FSW include:

- Support relatively unimpaired biological and physical processes.
- Support a significant diversity of salmonid species and are relatively productive.
- Function as “zones of convergence” (Frissell, 1998) for multiple life-history stages of salmonids.
- Retain natural water quality and a natural hydrologic regime.
- May serve as migratory corridors.
- Have relatively low levels of human land-use activities.
- Have relatively intact, natural riparian corridors.



Most FSW refugia are typically not “pristine”, but still have a significant proportion of natural landscape (forest and wetlands), intact segments of high quality riparian corridor, and functional instream habitat. FSW designation is concentrated on those watersheds that have the greatest potential for full recovery to a natural condition. Clearly, as was discussed earlier, the preponderance of research indicates that an ecosystem or watershed focus is the optimum approach to aquatic resource protection (Noss and Cooperrider, 1994; Spence et al., 1996; Stouder et al., 1997; Naiman and Bilby, 1998). Designation of FSW refugia recognizes this and will rely heavily on innovative, “fish-friendly” land-use management to conserve the remaining aquatic resources. In addition, rehabilitation and restoration efforts will also be required as part of the overall watershed-based conservation strategy.

NODAL-RIPARIAN CORRIDORS

According to current refugia theory, nodal-riparian corridors (NRC) are those stream segments where refugia occur in the form of complex mosaics of instream habitat, off-channel wetlands, floodplain complexes, and natural riparian forests (Sedell et al., 1990; Stanford et al., 1996; Naiman and Bilby, 1998). These areas have also been referred to as “riparian reserves” in some scientific literature (Noss and Cooperrider, 1994) and were originally called nodal corridors by Frissell (1998). As with FSW refugia areas, NRC refugia also tend to sustain a disproportionately heavy use by numerous salmonid species and typically support several life-stages of salmonids.

The NRC refugia designation is used in this report in situations where a portion of a stream system or stream segment is designated as a refugia area, as opposed to the entire watershed or tributary sub-watershed. In many cases, rivers and streams within the study area flow through a steep ravine or narrow valley, with few tributaries. These are natural delineations for NRC refugia areas. NRC refugia also include riverine reaches, valley-bottoms, or floodplain segments where salmonid refuges occur in the form of complex stream channel and off-channel wetland mosaics (Frissell, 1998). NRC Refugia almost always include the entire floodplain area, or channel migration zone (CMZ), and any associated wetlands critical to their structure and function (Sedell et al., 1990; Stanford et al., 1996; Frissell, 1998). Many NRC refugia have high groundwater levels, unconfined near-surface aquifers, or extensive hyporheic zones that interact with surface waters in complex paths that help control stream temperatures, hydrologic flows, and nutrient flux (Sedell et al., 1990; Stanford et al., 1996; Knutson and Naef, 1997; Frissell, 1998). The availability of groundwater and frequent inundation of floodplain areas also encourages natural riparian succession and recovery of native vegetation (Gregory et al. 1991).

These NRC refugia can also include small “patches” of intact salmonid habitat that provide critical ecological functions, also known as “hot-spots” (Doppelt et al., 1993). In general, NRC refugia are areas where instream habitat complexity is high, off-channel habitat is accessible and functional, riparian corridor integrity is high, and/or important tributary connections are present. NRC can also provide linkage or access to other refugia areas and have a degree of local resistance to external disturbances and a level of natural resilience. The key characteristics of NRC refugia include (Frissell, 1998):

- Used by a significant diversity of salmonid species.
- Serve as “nodes” for multiple salmonid life histories.
- Serve as salmonid migratory corridors.
- Provide significant “patches” of juvenile salmonid habitat.



- Consist of complex channel and wetland mosaics with off-channel and floodplain habitats.
- Are dominated by the riparian corridor and its physical and biological processes.
- May be impacted by human land-use.

In addition to the above description of a typical NRC, this refugia designation is also used in areas where development already exists and watershed-level cumulative impacts have already occurred, but some degree of natural ecosystem structure and function still remains. In this situation, it is assumed that full protection on a watershed scale is not currently feasible in these areas due to present and future human land-use activities. The basic hypothesis is that, although not as holistically effective as the watershed approach, a riparian reserve or NRC refugia strategy will be effective for the long-term conservation of salmonid resources in areas of continued watershed development and future human activity. For this report, NRC refugia may be designated as either a short segment (“patches”) of exceptional stream-riparian habitat or as a continuous riparian corridor within a developing watershed, which is still in relatively good condition. These NRC typically are disproportionately important within the developed or developing watershed as a whole for supporting native salmonids (May and Horner, 2000).

The NRC refugia approach assumes that protecting a high quality instream and riparian habitats along the stream-riparian corridor is a critical step in “buffering” the stream from the effects of land-use and human activities in the watershed. Research in the Puget Sound region indicates that protecting a nearly continuous forested corridor around the stream ecosystem can be effective in maintaining ecological integrity under some watershed conditions (May et al., 1997; May and Horner, 2000; Booth et al., 2001). Based on current research, it is likely that human activities in the watershed will also need to be managed so as to reduce the cumulative impacts on hydrology, water quality, instream habitat conditions, and other environmental factors.

In general, “riparian reserves” or NRC refugia tend to have a degree of local resistance to external disturbances and maintain a level of natural resilience. The inclusion of the entire floodplain area, channel migration zone (CMZ), and any associated off-channel wetland areas is critical to the structure and function of these riparian reserves (Sedell et al., 1990; Stanford et al., 1996; Frissell, 1998). Many riparian corridors have high groundwater levels, unconfined near-surface aquifers, or extensive hyporheic zones that interact with surface waters in complex paths that help control stream temperatures, hydrologic flows, and nutrient flux (Sedell et al., 1990; Stanford et al., 1996; Knutson and Naef, 1997; Frissell, 1998). The accessibility of off-channel wetlands and frequent inundation of floodplain areas also encourages natural riparian succession and recovery of native vegetation (Gregory et al., 1991). A detailed discussion of the benefits of protecting stream-riparian ecosystems is included in Appendix E to this report.

NEARSHORE AND ESTUARINE REFUGIA

Designated *nearshore-estuarine refugia* (NSE) include stream estuaries, nearshore migration corridors, and marine shoreline areas that provide refuge habitat for migrating and rearing salmonids. The typical NSE refugia will encompass the entire nearshore zone, which is usually defined as that area between the lower limit of the “photic” zone (i.e. the zone of sunlight penetration to the bottom) and the upland-aquatic interface (i.e. the shoreline riparian ecotone). This category of refugia was not part of the original refugia methodology (Frissell, 1998), but was added due to the recognized importance of the nearshore area to salmonid recovery in particular (Williams and Thom,



2001) and to the conservation of marine resources in general (Beck, 2001). The NSE refugia designation is the marine equivalent of the FSW and NRC refugia in the freshwater environment.

The NSE refugia concept was developed to address the ecologically important marine environment that is critical to the survival of several salmonid species, including the Puget Sound chinook (PSC) and Hood Canal summer chum (HCSC), both ESA listed species. Although most salmonids spend a significant portion of their life history spawning and rearing in freshwater, all the anadromous species utilize saltwater areas for the majority of their existence. An important period in the typical salmonid life history (see Figure 1) is spent in the transitional area of the nearshore environment (Groot and Margolis, 1991). This is a critical rearing area for juvenile salmonids of all species, but it is especially important to sea-run cutthroat trout, as well as chinook, chum, and pink salmon (Stouder et al., 1997).

Nearshore and estuarine areas provide protection from waves, winds, and storms to salmonids and other species that use the habitat. Although most salmonids spend a significant portion of their life history spawning and rearing in freshwater, all of the anadromous species utilize saltwater areas for the majority of their existence. These areas also provide foraging habitat, critical refuge habitat for adult and juvenile salmonids from predators, a physiological transition zone for smolts moving from the freshwater to the marine environment, and a migration corridor to and from the ocean environment (Simenstad *et al.* 1982). Juvenile salmonids remain in nearshore habitats for varying residence periods depending on the species, their size at smolt migration from freshwater, the time of year of transition to the marine environment, and the habitat conditions in the nearshore/estuary areas. A detailed discussion of the utilization of the nearshore environment by salmonids is included in Appendix F to this report.

The delineation of NSE refugia areas is based on the “drift-cell” concept. Littoral *drift cells* in nearshore areas are analogous to watersheds in the freshwater environment. A drift cell typically includes a source of sediment, such as a “feeder bluff” or other naturally erosive area. The prevailing long-shore currents then transport this sediment through the nearshore environment to a depositional area. Within a drift cell there may be a variety of nearshore habitats that support salmonids (Williams and Thom, 2001). In general, NSE refugia were delineated based primarily on drift-cells and significant geographic or ecological features. River and stream estuaries are among the most important transitional habitat areas for salmonids and therefore are prominent among the designated NSE refugia. NSE refugia can also have associated CAA. The upland shoreline, low-order streams, seasonal/intermittent channels, and areas directly upslope should be considered as CCA. The condition of the CCA adjacent to NSE refugia can directly affect salmonid habitat. Key characteristics of NSE refugia include:

- Provide juvenile and adult salmonid migratory habitat and access to estuarine wetlands and tributaries.
- Provide refuge from predators to juvenile and adult salmonids.
- Provide juvenile and adult salmonid foraging habitat.
- Provide juvenile rearing habitat.
- Can be adversely affected by human modifications such as tide-gates, dikes, levees, docks, seawalls, bulkheads, marinas, and boat ramps.
- Can be adversely affected by point and non-point source pollution.



Based on understanding of the importance of nearshore ecotones to almost all salmonid species and our less than complete knowledge of these critical marine habitat areas, our protection efforts should be very conservative. A protective strategy similar to that established for riparian areas on streams should also be established for nearshore refugia. Native vegetation should be preserved as much as possible in critical nearshore areas, estuaries, and sensitive (steep banks and landslide-prone) shorelines. The impacts of development within the nearshore “riparian zone”, including structures, septic systems, docks, bulkheads, and roads should also be reduced to negligible levels in all NSE refugia areas.

For this report, the designation of NSE refugia areas, although based on the current best available information, is considered as “interim” to acknowledge the rudimentary and evolving level of knowledge with regard to these important ecosystems. Until such time as our understanding of these critical habitat areas improves, a conservative resource protection strategy should be established for NSE refugia areas. In summary, our modification of the “nearshore landscape” has diminished the ability of salmonid species to effectively utilize one of their critical rearing and migration habitats (Broadhurst, 1998). Recovery of sustainable salmonid populations will require extensive protection, enhancement, and restoration efforts in our designated nearshore refugia (NRC, 1996; Broadhurst, 1998; Williams and Thom, 2001).

CRITICAL-CONTRIBUTING AREAS

A *critical contributing area* (CCA) is not in itself a refugia area, but has important hydrologic and/or water-quality influences on refugia (FSW, NRC, and NSE) that are located downstream. For various reasons (e.g. natural barriers, ephemeral flows, etc.), these areas typically do not contain viable salmon populations, but are of recognized importance to maintaining the ecological integrity of downstream areas that do contain salmon habitat and populations. There are usually one or more critical contributing areas associated with each focal sub-watershed (FSW) or nodal-riparian corridor (NRC) refugia. In addition, the adjacent shoreline, any low-order streams or seasonal/intermittent channels, and areas directly up-slope from nearshore-estuarine refugia (NSE) should also be considered as critical contributing areas (CCA). These areas typically consist of the shorelines and small streams that drain directly into the nearshore areas. Management of these areas will be one of the keys to restoring and preserving our nearshore salmonid habitat.

Although critical contributing areas are not by themselves refugia and typically do not directly provide habitat for anadromous salmonids, they do contribute indirectly to downstream habitat. These areas, including seasonal and intermittent streams or wetlands, are hydrologically connected to associated riparian corridors. Also included in the CCA category are steep slope areas, which are prone to mass-wasting events and can be significant sources of sediment to downstream refugia. In addition to protecting downstream refugia from hydrologic and erosional impacts, there are also chemical water quality concerns that justify the designation of an area as a critical contributing area. Furthermore, gravel and/or LWD recruitment from a CCA may also be significant as a habitat-forming process.

Critical Contributing Areas protect downstream refugia from hydrologic, erosional, and water quality impacts; thus they are critical to maintaining the ecological integrity of downstream habitat and have the following key characteristics:

- Linked by topography and hydrology to FSW or NRC refugia.
- Can include tributary and upland habitats including wetlands, lakes, and beaver ponds.



- May include areas prone to mass wasting due to steep slopes.
- May include seasonal and intermittent streams.

In summary, the purpose of the CCA designation is to call attention to upland and tributary areas that may be of critical importance in maintaining ecological integrity of downstream refugia habitat. Restoration efforts, such as improved stormwater treatment or rehabilitation of roads within the CCA may be especially important to protecting or enhancing downstream refugia habitat (Frissell, 1998).

REFUGIA CLASSIFICATION

In addition to the actual refugia scores produced by the model, those areas identified for refugia status were also placed into one of the following categories based on their combined refugia model score, as well as their unique salmonid habitat characteristics. Because of the inherent uncertainty in determining a single numerical score that encompasses all natural ecosystem attributes, refugia were placed into classification categories with watersheds of similar quality. This classification scheme serves to group refugia based on their overall condition to further aid in conservation or restoration prioritization, as well as management focus. The rationale in doing this is two-fold. First, there may be specific characteristics of a refugia area that make it a better “fit” in another management classification than its model score alone would indicate. Second, the difference between two refugia model scores may or may not be significant from an ecological perspective. For example, a refugia scored as 7.50 (83% of maximum) by the model is likely not significantly “better” than one scored as 7.00 (78% of maximum). This reasoning is based on sensitivity analysis conducted during this study. However, the difference between refugia scored as 5.40 (60% of maximum) and one scored as 6.75 (75% of maximum) is ecologically significant and measurable.

CATEGORY A

Priority Refugia with Natural Ecological Integrity. Category “A” designated refugia contain the most abundant natural salmonid populations and most nearly intact native assemblages of salmon relative to their historic conditions. In most of these areas, while not pristine, natural conditions have been relatively undisturbed by major environmental alterations. In most cases these areas are not completely undisturbed, but ecological recovery from historic disturbances has advanced significantly. Salmonid habitat conditions are generally properly functioning.

Basically, category “A” areas are those that: (1) support nearly natural levels salmonid productivity and diversity; (2) have a relatively undisturbed, forested watershed and an intact riparian corridor or natural estuarine-nearshore environment; and (3) have a high level of ecological integrity and salmonid habitat quality. Unfortunately, due to the cumulative effects of human activities (both historical and current), very few refugia of this category were identified within the study area.

CATEGORY B

Primary Refugia with Altered Ecological Integrity. Those areas with somewhat disturbed watershed conditions and those areas that have less than natural riparian, instream, or nearshore habitat, but still support natural assemblages of native salmonids, were rated as category “B” refugia. Although the salmonid populations and habitat quality (riparian, instream, and nearshore) in these areas are not at historic levels or conditions, they have shown some resistance to degradation. Some also tend to be in an early stage of recovery due to some level of natural resilience. These refugia are not pristine, but frequently constitute the “next-best” remaining salmonid habitat and generally support the largest remaining salmonid populations in their geographic sub-region. In addition to



land conservation and aquatic resource protection, rehabilitation measures will likely be required to maintain or enhance the ecological integrity of these category “B” refugia areas.

In summary, category “B” designated refugia have been altered from natural conditions, but at least some salmonid populations appear to be self-sustaining and resilient. These areas are not pristine, but frequently constitute the best of what salmon habitat remains within moderate to highly developed watersheds and generally contain adequate functional habitat.

CATEGORY C

Secondary Refugia with Altered Ecological Integrity. Category “C” designated areas are where there is an indication, based on salmonid population and instream habitat information that the refugia might belong in Category “A” or “B”. However, because of limited quantitative habitat data, lack of information on salmonid utilization, diversity, or abundance, and/or lack of information altogether, the higher category classification is not fully justified. These areas should be a high priority for field surveys, stock assessments, and further investigation. In all likelihood, these areas could be reclassified as category “A” or “B” refugia after further analysis based on quantitative habitat assessments and with a concerted rehabilitation effort. In addition, some “C” refugia areas are geographically positioned such that they may be only salmonid refugia within a critical sub-region, thus further emphasizing the need for further evaluation and conservation efforts. These areas are sometimes called “possible” refugia.

Also included in category “C” refugia are those streams with relatively good habitat conditions, but due to significant downstream fish-passage barriers (i.e. dams or culverts that are partial migration barriers) and/or hatchery operations (e.g. weirs, fish-racks, and fish releases) that may negatively impact wild salmonid populations, do not fully support native salmonid populations. The future ability of these areas to fully support wild salmonid populations may be speculative, but they warrant recognition because of their historic productivity, functional habitat conditions, and/or their potential for higher ecological integrity. If migration barriers were removed and/or hatchery operations modified to support wild salmonids, these areas could be reclassified.

In summary, most category “C” refugia areas may contain functional habitat but have limited native, anadromous fish due to artificial downstream barriers such as dams, impassable culverts, or hatchery facilities. In all likelihood, the removal of barriers should restore access to upstream habitat for future, newly colonizing salmon populations.

CATEGORY D

Potential Refugia with Altered Ecological Integrity. Category “D” refugia are simply those areas that can best be described as “potential” or future refugia, either because the area was historically important habitat, but has been degraded over time, or because the refugia is completely blocked to fish access by an impassable, man-made barrier. The first type includes areas of watersheds that historically contained the most productive and diverse salmonid habitats, but habitat has been degraded by land-use activities. This type of refugia is most often associated with low gradient valley floodplains that historically contained a diversity of side-channels and complex wetland habitats critical to the life history of many salmonid species. Most of these floodplain systems have been highly modified by drainage modifications, channelization, and conversion for agricultural or residential purposes. These once productive areas are potential refugia that are usually good restoration candidates, but do not generally qualify for outright protective status.

In most cases, category “D” refugia areas were likely historically important salmonid resource areas, but typically have significantly degraded watershed and instream habitat conditions that do not



currently support natural levels of ecological integrity or abundant, diverse salmonid populations. Also included in this category are NSE refugia areas that have been significantly modified or degraded by human activities, such that they no longer function naturally or support historic levels of native salmonid populations.



“A river, with its waterfalls and meadows, a lake, a hill, a cliff, or individual rocks, a forest, and ancient trees standing singly...If the inhabitants of a community were wise, they would seek to preserve these things, though at a considerable expense; for such things educate far more than any hired teachers or preachers, or any present recognized system of school education. I do not think him fit to be the founder of a state or a town who does not foresee the use of these things....”

HENRY DAVID THOREAU, 1861

REFUGIA DESIGNATION

The designation of Kitsap County salmonid refugia was a multi-step process. Initially, all potential refugia areas (watersheds, sub-watersheds, and stream-segments) were scored using the combined fish and landscape GIS model. See Tables 16 and 17 for a summary of scores for all potential refugia for Kitsap County. Figures 28-42 show the overall refugia model results for each geographic sub-region within Kitsap County. Tables 18, 19, and 20 summarize the refugia areas by type for the entire study area.

The refugia classification categories were assigned to specific “bins” based on the refugia scores developed in the combined Kitsap-Jefferson GIS model. The values assigned to these bins were determined using statistical considerations and based on ecologically significant “breaks” in the model results. In other words, some professional judgment was used to assign the bin-values after statistical analysis was used to determine the most logical data bins. The following model result bins were assigned to each refugia category:

- Category A = >75%
- Category B = 60-75%
- Category C = N/A
- Category D = <60%

Table 16 shows the categories assigned to each category C refugia area based solely on the GIS model scores, and explains why the final classification differs. A map of Kitsap’s refugia by category is in the Executive Summary; see Figure ES-4 page ES-6.

Next, each potential refugia area was reviewed individually to determine if the “scored” refugia classification category should be changed based on specific information compiled about that river, stream, or stream segment. This included a review of salmonid diversity and productivity data as well as the salmonid habitat data available. This is also where any unique biological features or ecological characteristics that were identified during field surveys and interviews were incorporated into the refugia evaluation. Based on this information the classification of some potential refugia areas was “adjusted” to reflect this information. The most common adjustment was to shift refugia from a category “B” refugia to a category “C” because of a lack of quantitative data or even good “local knowledge” on salmonid utilization, instream habitat, species diversity, and/or productivity (see the



discussion of category “C” refugia in the previous section). In addition, some potential refugia areas were shifted from category “B” to a category “C” or “D” based on artificial barriers that significantly restrict salmonid utilization. Some potential refugia areas were also “adjusted” from category “B” to category “A” (or “D” to “B”) based on unique and/or important salmonid-supporting characteristics. See the “Reason not Category A/B/D” column in Table 16 for a summary of these changes.

As was discussed in detail earlier, category “A” areas are those that: (1) support nearly natural levels salmonid productivity and diversity; (2) have a relatively undisturbed, forested watershed and an intact riparian corridor or natural estuarine-nearshore environment; and (3) have a high level of ecological integrity. Unfortunately, due to the cumulative effects of human activities (both historical and current), very few refugia of this category were identified within the study area. The category “B” designated refugia have been altered from natural conditions, but at least some salmonid populations appear to be self-sustaining and resilient. These areas are not pristine, but frequently constitute the best of what salmon habitat remains within moderate to highly developed watersheds. This refugia category of refugia comprised the bulk of all areas identified.

Category “C” designated areas are where there is a good indication, based on salmonid population and instream habitat information that the refugia might belong in Category “B”. However, because of limited quantitative habitat data, lack of information on salmonid utilization, diversity, or abundance, and/or lack of information altogether, a category “B” classification is not fully justified. These areas should be a high priority for field surveys, stock assessments, and further investigation. Also included in category “C” refugia are those streams with relatively good habitat conditions, but due to significant downstream fish-passage barriers (dams or culverts that are partial migration barriers) or hatchery operations (weirs, fish-racks, etc.) that negatively impact wild salmonid populations, do not fully support native salmonid populations.

In most cases, category “D” refugia areas were likely historically important salmonid resource areas, but typically have significantly degraded watershed and instream habitat conditions that do not currently support natural levels of ecological integrity or abundant, diverse salmonid populations. Category “D” refugia are simply those areas that can best be described as “potential” or future refugia, either because the area was historically important habitat, but has been degraded over time, or because the refugia is completely blocked to fish access by an impassable, man-made barrier. The first type includes areas of watersheds that historically contained the most productive and diverse salmonid habitats, but have been degraded by land-use activities. This type of refugia is most often associated with low gradient valley floodplains that historically contained a diversity of side-channels and complex wetland habitats critical to the life history of many salmonid species. Most of these floodplain systems have been highly modified by drainage modifications, channelization, and conversion for agricultural or residential purposes. These once highly productive and diverse areas of the watershed are potential refugia that should be given high priority for restoration efforts, but do not generally qualify for conservation/protection.

Finally, refugia areas were designated and the “refugia type” (FSW or NRC) was assigned to each designated refugia area based on the criteria discussed in the previous section of this report (see Table 16 for refugia type assignments). The delineation of refugia areas is based primarily on hydro-geographic features and ecological considerations. In this respect, a FSW refugia is not necessarily “better” than a NRC refugia, but it is more a matter of which type of refugia fits the specific conditions in the field. For instance, consider a watershed with the lower, mainstem stream flowing through a ravine or narrow valley. That refugia area is likely more suited to NRC status whereas a headwater tributary of the same watershed may be more suited to being delineated as a FSW. Both may be equally important in the overall scheme of protecting salmonid resources with the larger



watershed that both are part of, but each is more suited to different types of refugia. In addition, a CCA is not in itself a refugia area, but is an area that can significantly influence water flows and water quality of downstream refugia. Therefore, it should not be implied that a FSW designation is somehow “better” than a NRC. The designation of a refugia area as a NRC or FSW is based on which configuration is judged to be most effective for protection. The conservation priority of the refugia area should be judged based primarily on the refugia classification and on the overall refugia model score.



Refugia Area	Description
Category A Focal Sub-Watershed Refugia (FSW)	
Chico Creek	Lost and Wildcat tributaries
Dewatto River	
Stavis Creek	
Tahuya River	
Category A Nearshore-Estuary Refugia (NSE)	
Holly Nearshore	w/CCA
Point-No-Point	w/CCA
Category B Focal Sub-Watershed Refugia (FSW)	
Big Anderson Creek	
Blackjack Creek	Headwaters, Square tributary
Boyce Creek	
Harding Creek	
Little Anderson Creek	
Martha John Creek	
Nellita Creek	
Seabeck Creek	Headwaters
Union River	
Category B Nodal Riparian Corridor Refugia (NRC)	
Anderson Creek	
Barker Creek	w/CCAs
Blackjack Creek	Mainstem
Chico Creek	Mainstem, Dickerson tributary (w/CCA) & Kitsap tributary
Gamble Creek	
Kinman Creek	w/CCA
Seabeck Creek	Mainstem w/CCA
Steele Creek	w/CCAs
Category B Nearshore-Estuary (NSE) Refugia	
Bangor Nearshore	w/CCA
Foul-Weather Bluff	w/CCA
Lone Rock Nearshore	w/CCA
Murden Cove	w/CCA
Port Gamble Bay	w/CCA
Rolling Bay	w/CCA
Stavis Bay Estuary	w/CCA
Union Estuary	w/CCA



Category C	Refugia Type and Reason not Category A
Big Beef Creek	FSW: Headwaters. NRC. Mainstem. Hatchery Influences
Big Mission Creek	FSW. Need Habitat Data
Caldervin Creek	NRC. Need Habitat Data
Coulter Creek	FSW. Hatchery Influences
Little Mission Creek	FSW. Need Habitat Data
Rendsland Creek	NRC. Need Habitat Data
Rocky Creek	FSW. Need Habitat Data
Category C	Refugia Type and Reason not Category B
Beaver Creek	NRC. Need Habitat Data
Big Cedar Creek	NRC. Need Habitat Data
Blakely Harbor Creek	NRC. Need Habitat Data
Brown Creek	NRC. Need Habitat Data
Cady Creek	NRC. Need Habitat Data
Carpenter Creek	NRC w/CCA. Need Habitat Data
Cattail Creek	NRC. Migration Barriers
Curley Creek	NRC. Need Habitat Data
Devils Hole Creek	NRC. Migration Barriers
Fletcher Creek	NRC. Need Habitat Data
Gazzam Creek	NRC. Need Habitat Data
Gorst Creek	NRC: Mainstem. FSW: Headwaters, Jarstad & Heins tribs. CCA. Hatchery Influences
Grovers Creek	FSW: Hatchery Influences
Hall Creek	NRC. Need Habitat Data
Hawks Hole Creek	FSW. Need Habitat Data
Illahee Creek	NRC w/CCAs. Need Habitat Data
Indianola Creek	NRC. Need Habitat Data & Culvert
Jukes Creek	NRC. Need Habitat Data
Kitsap (North) Creek	NRC. Need Habitat Data & Culvert
Little Beef Creek	FSW. Need Habitat Data
Little Boston Creek	FSW. Need Habitat Data & Barrier
Middle Creek	NRC. Need Habitat Data & Barrier
Little Shoofly Creek	NRC. Need Habitat Data.
Minter Creek	NRC. Hatchery Influences & Habitat
Olalla Creek	NRC. Need Habitat Data
Reservation Creek	NRC. Need Habitat Data & Barrier
Salmonberry Creek	NRC. Need Habitat Data
Schoolhouse Creek	NRC. Need Habitat Data
Shipbuilder Creek	NRC. Need Habitat Data
Shoofly Creek	NRC. Need Habitat Data
Silver Creek	NRC. Need Habitat Data
Stimson Creek	NRC. Need Habitat Data
Sundstrom Creek	NRC. Need Habitat Data



Category C	Refugia Type and Reason not Category D
Blackjack Creek	FSW. Ruby Creek. Significant Spawning & Rearing Habitat.
Gamble Creek	NRC. Mainstem. Significant Migration Corridor with Degraded Habitat.
Gorst Creek	NRC. Mainstem. Significant Migration Corridor with Degraded Habitat.
Steele Creek	NRC. South Fork. Significant Spawning & Rearing Habitat.
Seabeck Bay Estuary	NSE: Significant Migration Corridor with Degraded Habitat.

Category C: NSE Refugia With Insufficient Data to Classify “A” or “B”	
Burley Lagoon	Dewatto Nearshore
Case Inlet	Tahuya Nearshore

Category D (“Potential Refugia”) Nodal-Riparian Corridors	Reason Category D
Bjorgen	Degraded Habitat
Blackjack (middle reaches)	Degraded Habitat
Burley (Mainstem)	Degraded Habitat
Clear (mouth; East Fork, West Fork, Mountainview, and Bangor tribs) w/CCA	Degraded Habitat
Cougar	Migration Barrier(s)
Cowling	Degraded Habitat
Dogfish (mainstem, East Fork, South Fork)	Degraded Habitat
Fern	Migration Barrier(s)
Hudson	Migration Barrier(s)
Laudine DeCouteau	Migration Barrier(s)
Lemolo	Migration Barrier(s)
Machias	Migration Barrier(s)
Manzanita	Degraded Habitat
Murden Cove	Degraded Habitat
Sam Snyder	Migration Barrier(s)
Schel-Chelb	Degraded Habitat
Spring	Migration Barrier(s)
Todhunter	Migration Barrier(s)
Wright	Degraded Habitat

Category D (“Potential Refugia”) Nearshore-Estuary (NSE) (all have an associated CCA)	
Agate Passage Nearshore	Indianola Nearshore
Brownsville Nearshore	Liberty Bay
Colvos Passage	Lynwood Nearshore
Dyes Inlet East	Manzanita Bay
Dyes Inlet West	Miller Bay
Eagle Harbor	Port Blakely Harbor
Fletcher Bay	Port Madison Bay
Illahee Estuary	Sinclair Inlet

Table 16: Kitsap County Refugia Designations



Refugia Area	Type	Score	% Max
Stavis Creek	FSW	7.45	83%
Little Mission Creek	FSW	7.44	83%
Dewatto River	FSW	7.37	82%
Big Beef Creek RM 6.5-HW	FSW	7.38	82%
Chico Creek Lost Tributary	FSW	7.25	81%
Big Mission Creek	FSW	7.19	80%
Big Beef Creek RM 6.0-6.5	FSW	7.21	80%
Chico Creek Wildcat Tributary RM 2.5-4.5	FSW	7.19	80%
Rocky Creek	FSW	7.13	79%
Big Beef Creek RM 0.0-1.0	NRC	7.09	79%
Big Beef Creek RM 1.0 -5.5	NRC	7.09	79%
Tahuya River	FSW	7.03	78%
Coulter Creek	FSW	6.98	78%
Chico Creek Wildcat Tributary RM 4.5-HW	FSW	6.86	76%
Rendsland Creek	NRC	6.74	75%
Caldervin Creek	NRC	6.74	75%
Harding Creek	FSW	6.70	74%
Big Anderson Creek	FSW	6.68	74%
Big Cedar Creek	NRC	6.68	74%
Gorst Creek Jarstad Tributary	FSW	6.58	73%
Nellita Creek	FSW	6.58	73%
Chico Creek Dickerson Tributary	NRC	6.57	73%
Union River	FSW	6.52	72%
Anderson Creek East Fork	NRC	6.51	72%
Anderson Creek West Fork	NRC	6.51	72%
Boyce Creek	FSW	6.45	72%
Gorst Creek RM 1.0-HW	FSW	6.44	72%
Curley Creek	NRC	6.39	71%
Seabeck Creek RM 1.0-HW	FSW	6.32	70%
Seabeck Creek RM 0.0-0.5	NRC	6.32	70%
Chico Creek Kitsap Tributary	NRC	6.31	70%
Gorst Creek Heins Tributary	FSW	6.26	70%
Martha John Creek	FSW	6.25	69%
Kitsap Creek	NRC	6.22	69%
Olalla Creek RM 0.0-1.5	NRC	6.19	69%
Blackjack Creek Square Tributary	FSW	6.17	69%
Seabeck Creek RM 0.5-1.0	NRC	6.15	68%
Little Beef Creek	FSW	6.12	68%
Gorst Creek RM 0.75-1.0	NRC	6.10	68%
Gamble Creek RM 1.5-HW	NRC	6.09	68%
Indianola Creek	NRC	6.04	67%
Grovers Creek	FSW	5.95	66%
Barker Creek RM 0.0-0.5	NRC	5.90	66%
Barker Creek RM 0.5-1.0	NRC	5.90	66%



Refugia Area	Type	Score	% Max
Minter Creek Huge Tributary	NRC	5.89	65%
Minter Creek RM 0.0-1.5	NRC	5.89	65%
Blackjack Creek RM 0.0-1.5	NRC	5.86	65%
Anderson Creek RM 0.0-0.5	NRC	5.85	65%
Carpenter Creek RM 0.0-1.0	NRC	5.79	64%
Chico Creek RM 1.25-2.5	NRC	5.78	64%
Little Anderson Creek	FSW	5.77	64%
Big Beef Creek Lake Symington RM 5.5-6.0	NRC	5.76	64%
Kinman Creek RM 0.0-0.5	NRC	5.74	64%
Kinman Creek RM 0.5-HW	NRC	5.74	64%
Minter Creek RM 1.5-HW	NRC	5.73	64%
Steele Creek RM 0.0-0.5	NRC	5.67	63%
Blackjack Creek RM 5.5-HW	FSW	5.62	62%
Carpenter Creek RM 1.0-1.5	NRC	5.62	62%
Olalla Creek RM 1.5-HW	NRC	5.52	61%
Chico Creek RM 0.75-1.25	NRC	5.44	60%
Kinman Creek South-Lofall Tributary	NRC	5.41	60%
Illahee Creek North Fork RM 1.0-1.5	NRC	5.40	60%
Illahee Creek RM 0.0-1.0	NRC	5.40	60%
Salmonberry Creek	NRC	5.38	60%
Clear Creek West Fork RM 1.0-2.0	NRC	5.32	59%
Chico Creek RM 0.0-0.75	NRC	5.28	59%
Steele Creek South Fork RM 0.5-1.0	NRC	5.18	58%
Clear Creek Mountainview Tributary	NRC	5.14	57%
Carpenter Creek RM 1.5-HW	NRC	5.12	57%
Dogfish Creek East Fork RM 0.0-1.0	NRC	5.12	57%
Dogfish Creek East Fork RM 1.0-HW	NRC	5.12	57%
Blackjack Creek Ruby Tributary	FSW	5.09	57%
Barker Creek RM 1.0-1.5	NRC	5.06	56%
Burley Creek RM 0.0-0.5	NRC	5.05	56%
Burley Creek RM 0.5-1.5	NRC	5.05	56%
Blackjack Creek RM 1.5-3.0	NRC	5.03	56%
Gorst Creek RM 0.5-0.75	NRC	5.02	56%
Gamble Creek RM 0.0-1.0	NRC	4.93	55%
Dogfish Creek RM 1.0-3.0	NRC	4.86	54%
Dogfish Creek RM 3.0-HW	NRC	4.86	54%
Steele Creek Crouch Tributary	NRC	4.83	54%
Steele Creek North Fork RM 0.5-HW	NRC	4.83	54%
Clear Creek West Fork RM 0.0-0.5	NRC	4.82	54%
Clear Creek West Fork RM 0.5-1.0	NRC	4.82	54%
Burley Creek RM 1.5-HW	NRC	4.72	52%
Gorst Creek RM 0.0-0.25	NRC	4.69	52%
Gorst Creek RM 0.25-0.5	NRC	4.69	52%
Clear Creek East Fork RM 1.0-2.0	NRC	4.64	52%
Clear Creek East Fork RM 2.0-HW	NRC	4.64	52%



Refugia Area	Type	Score	% Max
Dogfish Creek RM 0.0-0.5	NRC	4.62	51%
Dogfish Creek RM 0.5-1.0	NRC	4.62	51%
Barker Creek RM 1.5-HW	NRC	4.56	51%
Clear Creek West Fork RM 2.0-HW	NRC	4.32	48%
Blackjack Creek RM 3.0-5.5	NRC	4.28	48%
Clear Creek RM 0.0-1.0	NRC	4.16	46%

Table 17: Kitsap County Refugia Model Results



Focal Sub-Watershed (FSW) Refugia	Score	% Max
Stavis Creek	7.45	83%
Little Mission Creek	7.44	83%
Big Beef Creek Headwaters (Upper)	7.38	82%
Dewatto River	7.37	82%
Chico Creek Lost Tributary	7.25	81%
Big Beef Creek Headwaters (Lower)	7.21	80%
Big Mission Creek	7.19	80%
Chico Creek Wildcat Tributary (Upper)	7.19	80%
Rocky Creek	7.13	79%
Tahuya River	7.03	78%
Coulter Creek	6.98	78%
Chico Creek Wildcat Tributary (Lower)	6.86	76%
Harding Creek	6.70	74%
Big Anderson Creek	6.68	74%
Gorst Creek Jarstad Tributary	6.58	73%
Nellita Creek	6.58	73%
Union River	6.52	72%
Boyce Creek	6.45	72%
Gorst Creek Headwaters	6.44	72%
<i>Shine Creek Headwaters</i>	6.38	71%
Seabeck Creek Headwaters	6.32	70%
Gorst Creek Heins Tributary	6.26	70%
Martha John Creek	6.25	69%
<i>Thorndyke Creek Headwaters</i>	6.24	69%
Blackjack Creek Square Tributary	6.17	69%
<i>Big Quilcene River Penny Tributary</i>	6.13	68%
Little Beef Creek	6.12	68%
<i>Ludlow Creek Headwaters</i>	6.02	67%
Grovers Creek	5.95	66%
Little Anderson Creek	5.77	64%
<i>Chimicum Creek East Fork Headwaters</i>	5.72	64%
<i>Tarboo Creek Coyle Tributary</i>	5.71	63%
Blackjack Creek Headwaters	5.62	62%
<i>Tarboo Creek Headwaters</i>	5.54	62%
<i>Chimicum Creek West Fork Headwaters</i>	5.40	60%
Blackjack Creek Ruby Tributary	5.09	57%

Table 18: Focal Sub-Watershed (FSW) Refugia Scores

Note: East Jefferson County watersheds in *italics* and Kitsap County watersheds in **bold**.



Nodal Riparian Corridor (NRC) Refugia	Score	% Max
<i>Dosewallips River RM 2.5-5.5</i>	7.81	87%
<i>Dosewallips River RM 5.5-11.5</i>	7.64	85%
<i>Duckabush River RM 2.5-4.5</i>	7.43	83%
<i>Duckabush River RM 4.5-7.5</i>	7.36	82%
<i>Fulton Creek</i>	7.30	81%
Big Beef Creek RM 0.0-1.0	7.09	79%
Big Beef Creek RM 1.0 -5.5	7.09	79%
<i>Dosewallips River RM 0.0-2.5</i>	7.05	78%
<i>Duckabush River RM 0.0-2.5</i>	6.76	75%
<i>Rocky Brook Creek</i>	6.75	75%
<i>Thorndyke Creek RM 0.0-1.0</i>	6.74	75%
Rendsland Creek	6.74	75%
Caldervin Creek	6.74	75%
<i>Tarboo Creek RM 0.0-1.0</i>	6.71	75%
<i>Shine Creek RM 0.0-1.0</i>	6.71	75%
Big Cedar Creek	6.68	74%
<i>Camp Discovery Creek</i>	6.60	73%
Chico Creek Dickerson Tributary	6.57	73%
<i>Little Quilcene River RM 0.8-3.0</i>	6.55	73%
Anderson Creek East Fork	6.51	72%
Anderson Creek West Fork	6.51	72%
<i>Big Quilcene River RM 2.8-7.8</i>	6.39	71%
Curley Creek	6.39	71%
<i>Nordstrom Creek</i>	6.38	71%
<i>Devils Lake Creek</i>	6.36	71%
<i>Ludlow Creek RM 0.0-0.5</i>	6.35	71%
Seabeck Creek RM 0.0-0.5	6.32	70%
Chico Creek Kitsap Tributary	6.31	70%
<i>Howe Creek</i>	6.29	70%
<i>Big Quilcene River RM 0.7-2.5</i>	6.26	70%
<i>Little Quilcene River RM 0.0-0.8</i>	6.22	69%
<i>Little Quilcene River RM 3.0-6.0</i>	6.22	69%
Kitsap Creek	6.22	69%
Olalla Creek RM 0.0-1.5	6.19	69%
Seabeck Creek RM 0.5-1.0	6.15	68%
<i>Snow Creek RM 0.0-1.0</i>	6.13	68%
<i>Snow Creek RM 3.5-6.5</i>	6.13	68%
Gorst Creek RM 0.75-1.0	6.10	68%
Gamble Creek RM 1.5-HW	6.09	68%
<i>Snow Creek Andrews Tributary</i>	6.06	67%
<i>Fisherman's Harbor</i>	6.05	67%
<i>Little Thorndyke Creek</i>	6.05	67%
Indianola Creek	6.04	67%
<i>Indian George Creek</i>	6.02	67%
<i>Chimicum Creek RM 0.0-1.0</i>	5.96	66%
<i>Snow Creek RM 1.0-3.5</i>	5.96	66%



Nodal Riparian Corridor (NRC) Refugia	Score	% Max
<i>Salmon Creek RM 0.8-2.0</i>	5.95	66%
Barker Creek RM 0.0-0.5	5.90	66%
Barker Creek RM 0.5-1.0	5.90	66%
<i>Ripley Creek</i>	5.89	65%
Minter Creek Huge Tributary	5.89	65%
Minter Creek RM 0.0-1.5	5.89	65%
Blackjack Creek RM 0.0-1.5	5.86	65%
<i>Ludlow Creek RM 0.5-1.0</i>	5.85	65%
Anderson Creek RM 0.0-0.5	5.85	65%
Carpenter Creek RM 0.0-1.0	5.79	64%
Chico Creek RM 1.25-2.5	5.78	64%
<i>Lindsay Creek</i>	5.77	64%
<i>Big Quilcene River RM 0.0-0.7</i>	5.76	64%
Big Beef Creek Lake Symington RM 5.5-6.0	5.76	64%
Kinman Creek RM 0.0-0.5	5.74	64%
Kinman Creek RM 0.5-HW	5.74	64%
Minter Creek RM 1.5-HW	5.73	64%
<i>Bones-Hubbard Creek</i>	5.71	63%
Steele Creek RM 0.0-0.5	5.67	63%
Beaver Creek RM 0.0-0.5	5.65	63%
Beaver Creek RM 0.5-HW	5.65	63%
<i>Chimicum Creek RM 1.0-2.0</i>	5.62	62%
Carpenter Creek RM 1.0-1.5	5.62	62%
<i>Salmon Creek RM 0.0-0.8</i>	5.61	62%
<i>Donovan Creek</i>	5.55	62%
<i>Tarboo Creek RM 2.5-4.0</i>	5.54	62%
<i>Spencer Creek</i>	5.53	61%
Olalla Creek RM 1.5-HW	5.52	61%
Chico Creek RM 0.75-1.25	5.44	60%
Kinman Creek South-Lofall Tributary	5.41	60%
<i>Chimicum Creek Naylors Tributary</i>	5.40	60%
Illahee Creek North Fork RM 1.0-1.5	5.40	60%
Illahee Creek RM 0.0-1.0	5.40	60%
Salmonberry Creek	5.38	60%
<i>Mats Mats Creek</i>	5.37	60%
<i>Little Goose Creek</i>	5.37	60%
<i>Leland Creek</i>	5.37	60%
<i>Tarboo Creek RM 1.0-2.5</i>	5.37	60%
Clear Creek West Fork RM 1.0-2.0	5.32	59%
Chico Creek RM 0.0-0.75	5.28	59%
<i>Chimicum Creek East Fork Mainstem</i>	5.22	58%
Steele Creek South Fork RM 0.5-1.0	5.18	58%
Clear Creek Mountainview Tributary	5.14	57%
Carpenter Creek RM 1.5-HW	5.12	57%
Dogfish Creek East Fork RM 0.0-1.0	5.12	57%
Dogfish Creek East Fork RM 1.0-HW	5.12	57%
Barker Creek RM 1.0-1.5	5.06	56%



Nodal Riparian Corridor (NRC) Refugia	Score	% Max
Burley Creek RM 0.0-0.5	5.05	56%
Burley Creek RM 0.5-1.5	5.05	56%
Blackjack Creek RM 1.5-3.0	5.03	56%
Gorst Creek RM 0.5-0.75	5.02	56%
Gamble Creek RM 0.0-1.0	4.93	55%
<i>Chimicum Creek RM 2.8-9.0</i>	<i>4.90</i>	<i>54%</i>
Dogfish Creek RM 1.0-3.0	4.86	54%
Dogfish Creek RM 3.0-HW	4.86	54%
Steele Creek Crouch Tributary	4.83	54%
Steele Creek North Fork RM 0.5-HW	4.83	54%
Clear Creek West Fork RM 0.0-0.5	4.82	54%
Clear Creek West Fork RM 0.5-1.0	4.82	54%
<i>Chimicum Creek RM 2.0-2.8</i>	<i>4.79</i>	<i>53%</i>
Burley Creek RM 1.5-HW	4.72	52%
Gorst Creek RM 0.0-0.25	4.69	52%
Gorst Creek RM 0.25-0.5	4.69	52%
Clear Creek East Fork RM 1.0-2.0	4.64	52%
Clear Creek East Fork RM 2.0-HW	4.64	52%
Dogfish Creek RM 0.0-0.5	4.62	51%
Dogfish Creek RM 0.5-1.0	4.62	51%
Barker Creek RM 1.5-HW	4.56	51%
Clear Creek West Fork RM 2.0-HW	4.32	48%
Blackjack Creek RM 3.0-5.5	4.28	48%
Clear Creek RM 0.0-1.0	4.16	46%

Table 19: Nodal Riparian Corridor (NRC) Refugia Scores

Note: East Jefferson County streams in *italics* and Kitsap County streams in **bold**.



Nearshore-Estuary Refugia	Score	% Max
<i>Kala Point South</i>	8.82	98
<i>Quilcene Bay</i>	8.27	92
<i>Chimacum North</i>	8.18	91
<i>Dabob Bay East</i>	8.09	90
<i>Duckabush North</i>	8.00	89
<i>Dabob Bay West</i>	7.82	87
<i>Shine South</i>	7.82	87
<i>Nordstrom Estuary</i>	7.55	84
<i>Thorndyke South</i>	7.55	84
<i>Thorndyke North</i>	7.55	84
<i>Chimacum South</i>	7.45	83
Point-No-Point	7.45	83
<i>McDonald North</i>	7.27	81
<i>Duckabush South</i>	7.27	81
<i>Dosewallips North</i>	7.27	81
<i>Ludlow East</i>	7.27	81
Holly Nearshore	7.09	79
<i>Shine North</i>	7.00	78
<i>Kala Point North</i>	6.91	77
<i>Thorndyke Estuary</i>	6.82	76
<i>Shine Estuary</i>	6.82	76
<i>Chimacum Estuary</i>	6.82	76
<i>Kala Point Lagoon</i>	6.82	76
<i>Quilcene Bay Head</i>	6.73	75
Murden Cove	6.73	75
<i>Devil's Lake Estuary</i>	6.64	74
<i>Jackson Cove North</i>	6.55	73
<i>Dabob Bay Head</i>	6.45	72
Bangor Nearshore	6.27	70
Foul-Weather Bluff	6.18	69
Stavis Bay	6.18	69
<i>Jackson Cove South</i>	6.09	68
<i>McDonald South</i>	6.00	67
Lone Rock Nearshore	6.00	67
Rolling Bay	5.91	66
Port Gamble Bay	5.73	64
Union Estuary	5.64	63
<i>Discovery Bay</i>	5.55	62
<i>Fulton Estuary</i>	5.36	60
Port Blakely Harbor	5.27	59
Seabeck Bay	5.27	59
Dewatto Nearshore	5.09	57
Indianola Nearshore	5.00	56
Fletcher Bay	4.82	54
<i>Dosewallips South</i>	4.73	53
Colvos Passage	4.73	53
Lynwood Nearshore	4.73	53
Agate Passage Nearshore	4.64	52
<i>Port Ludlow Bay</i>	4.45	49



Nearshore-Estuary Refugia	Score	% Max
Brownsville Nearshore	4.36	48
Miller Bay	4.18	46
Burley Lagoon	4.09	45
Illahee Estuary	4.09	45
Dyes Inlet East	4.00	44
Port Madison Bay	3.91	43
Dyes Inlet West	3.64	40
Manzanita Bay	3.64	40
Tahuya Nearshore	3.45	38
Case Inlet	3.36	37
Eagle Harbor	3.27	36
Liberty Bay	2.91	32
Sinclair Inlet	1.73	19

Table 20: Nearshore-Estuarine (NSE) Refugia Scores

Note: East Jefferson County nearshore areas in *italics* and Kitsap County nearshore areas in **bold**.



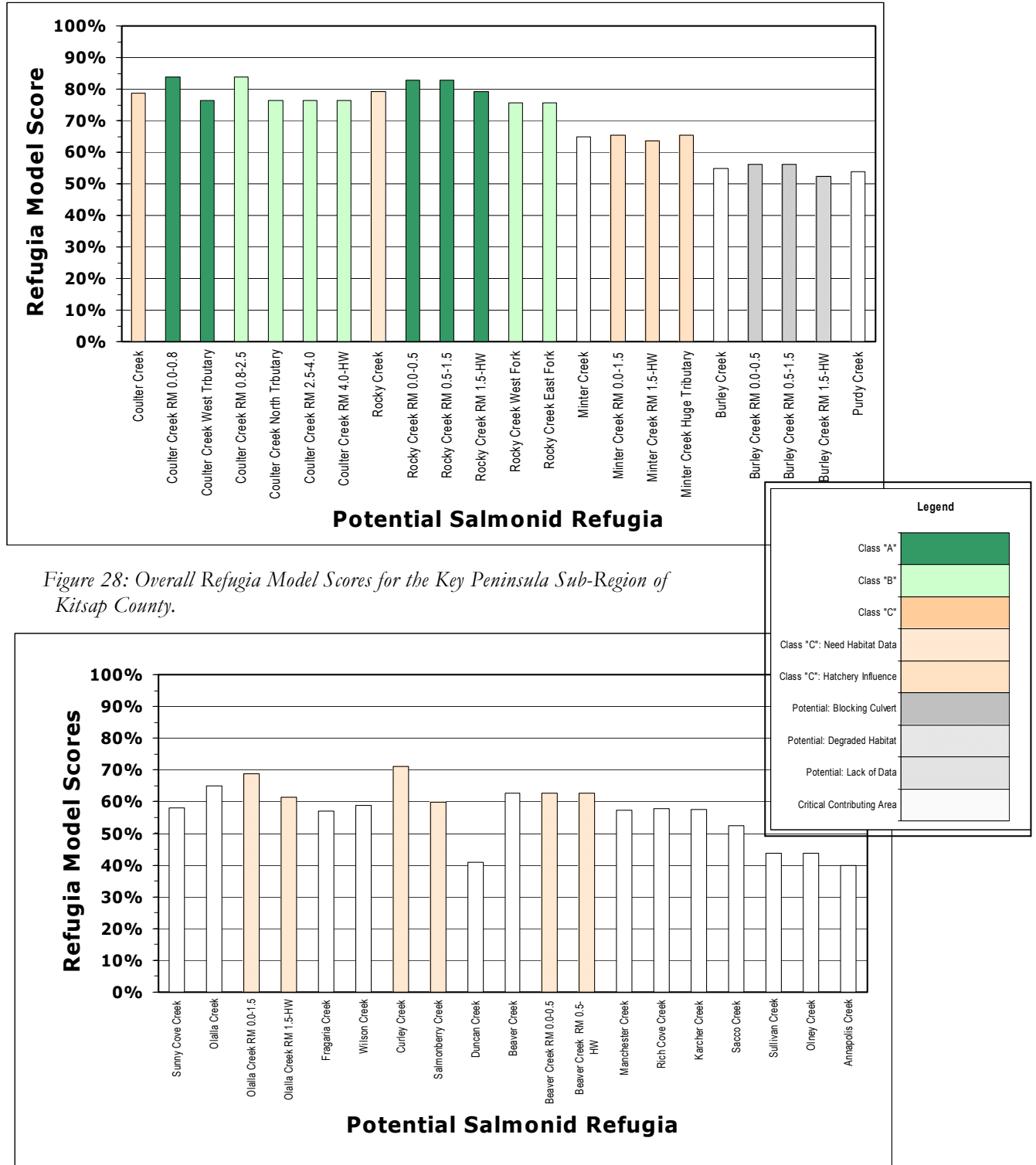


Figure 28: Overall Refugia Model Scores for the Key Peninsula Sub-Region of Kitsap County.

Figure 29: Overall Refugia Model Scores for the South Kitsap Sub-Region of Kitsap County



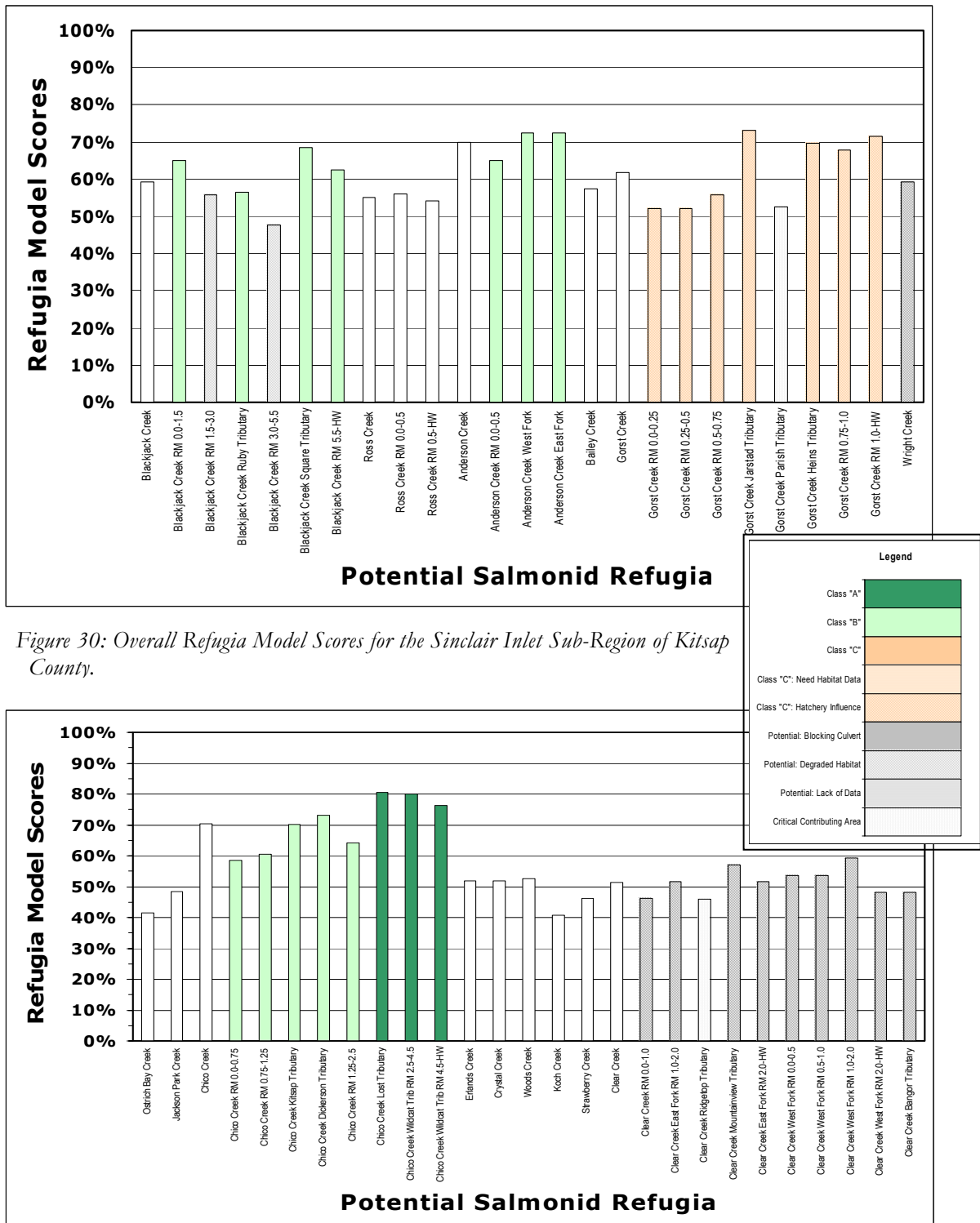


Figure 31: Overall Refugia Model Scores for the Western Dyes Inlet Sub-Region of Kitsap County.



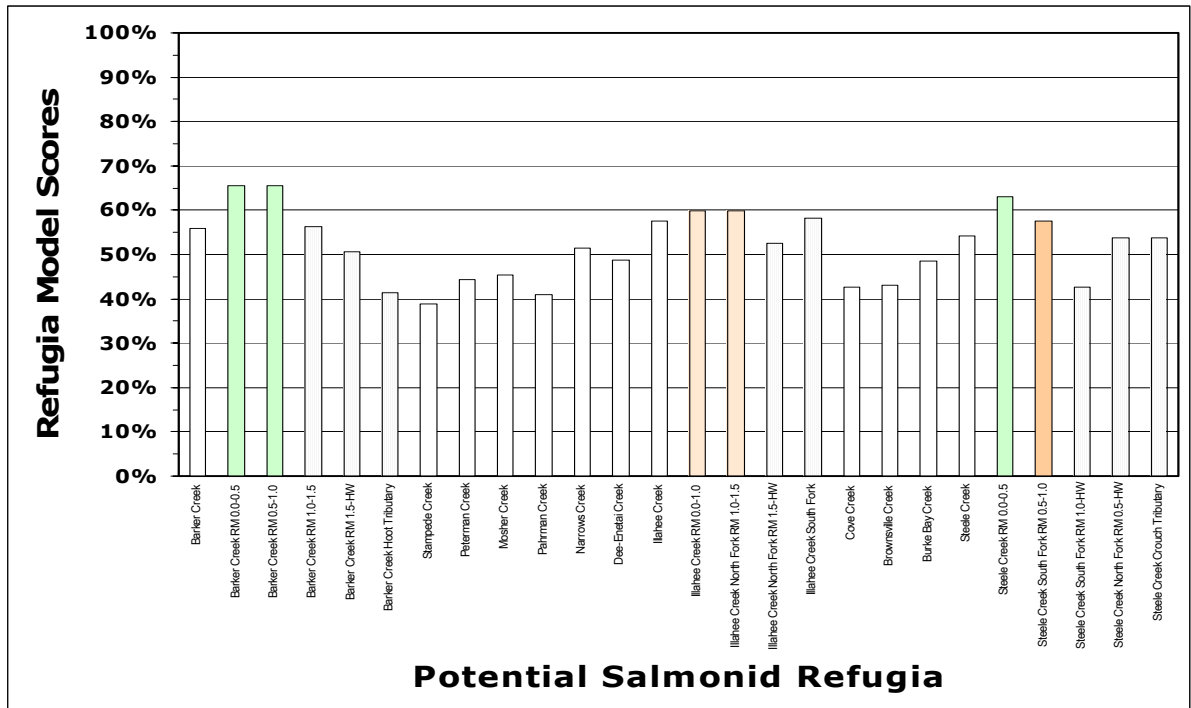


Figure 32: Overall Refugia Model Scores for the Eastern Dyes Inlet Sub-Region of Kitsap County.

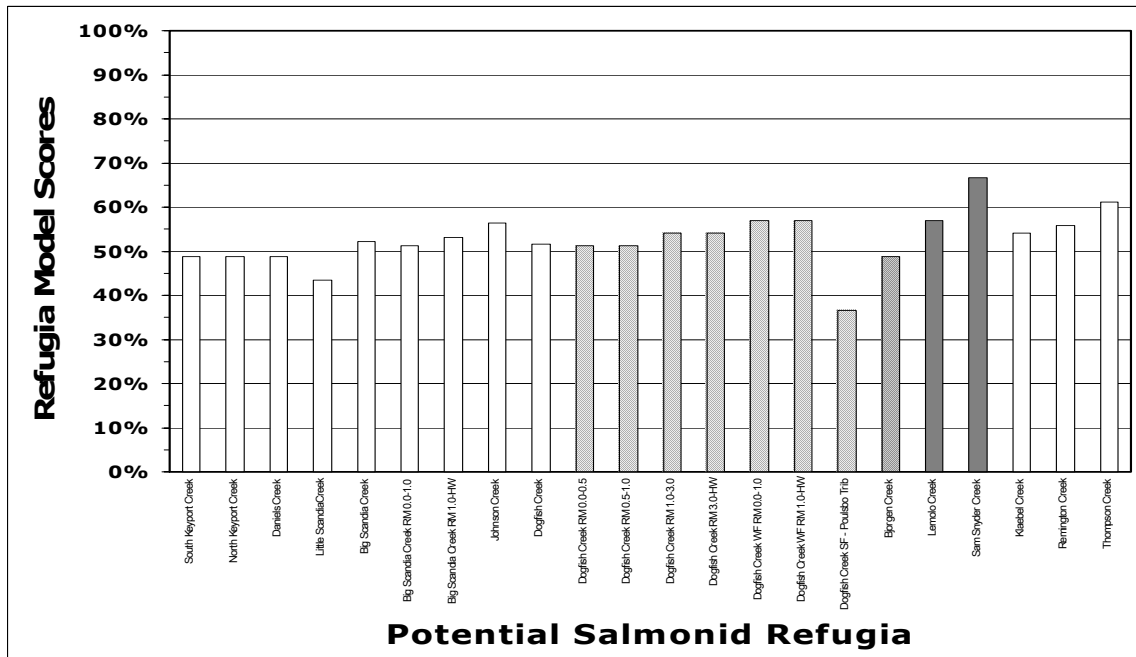


Figure 33: Overall Refugia Model Scores for the Liberty Bay Sub-Region of Kitsap County.



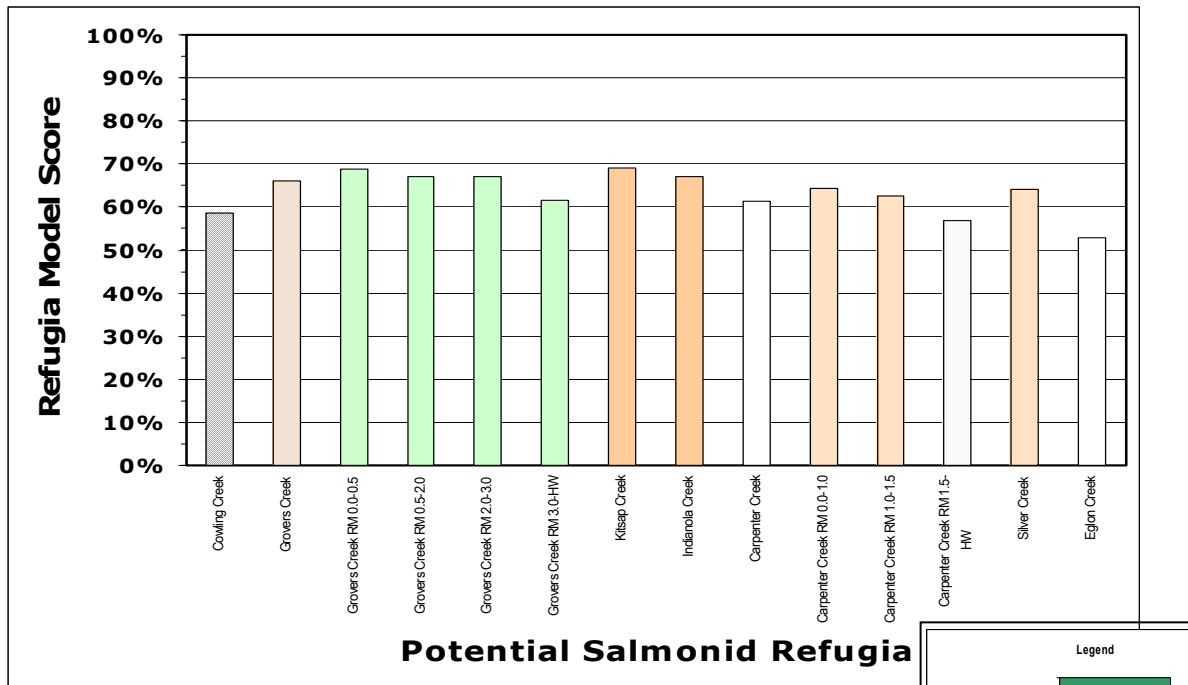


Figure 34: Overall Refugia Model Scores for the Kingston Sub-Region of Kitsap County.

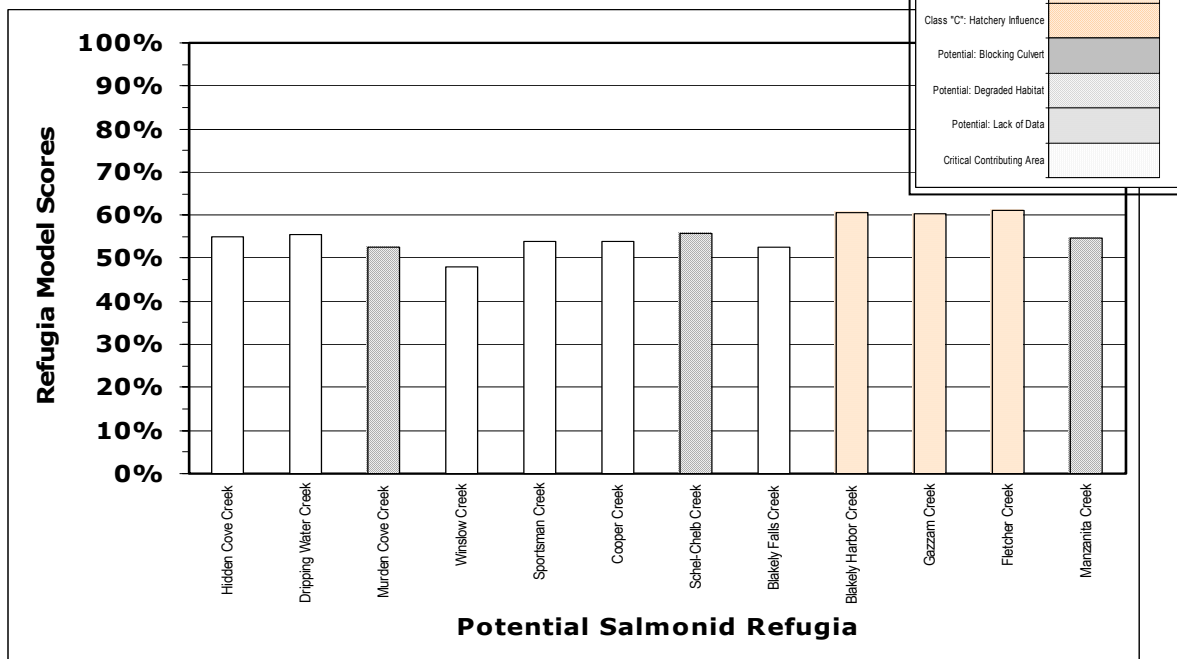


Figure 35: Overall Refugia Model Scores for the Bainbridge Island Sub-Region of Kitsap County.



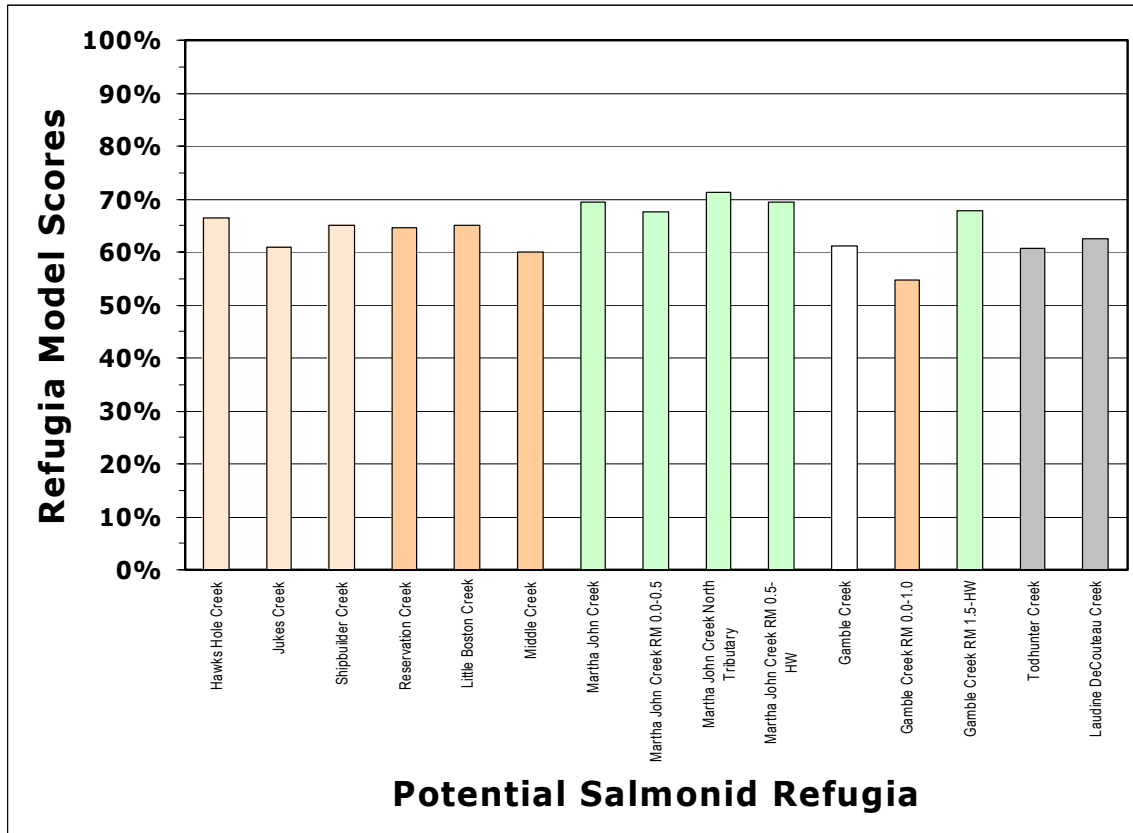


Figure 36: Overall Refugia Model Scores for the Gamble Bay Sub-Region of Kitsap County.

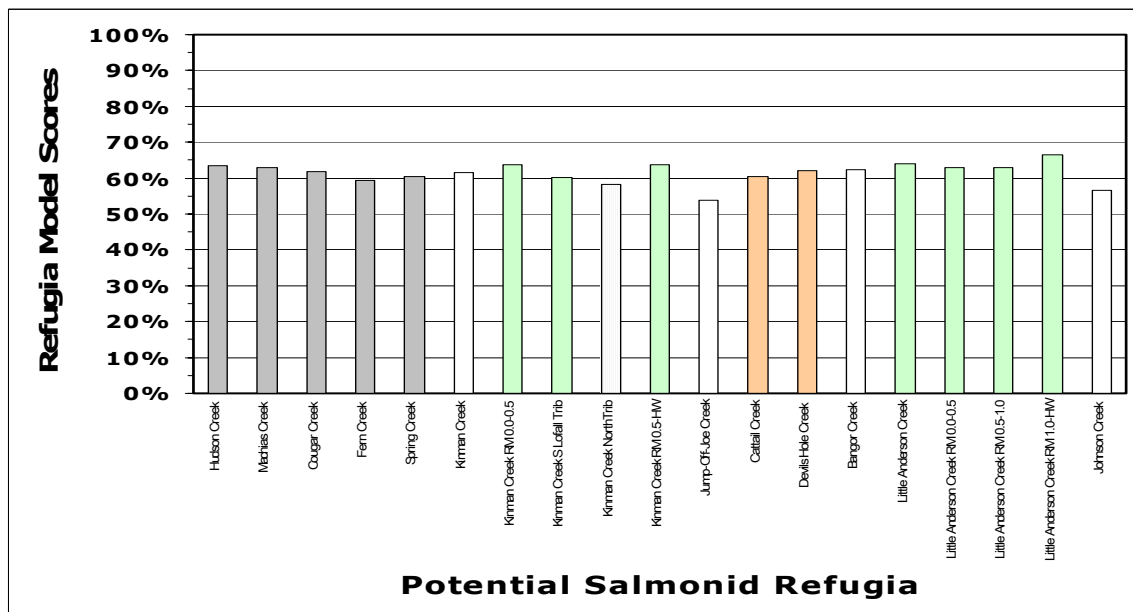


Figure 37: Overall Refugia Model Scores for the North Hood Canal Sub-Region of Kitsap County.



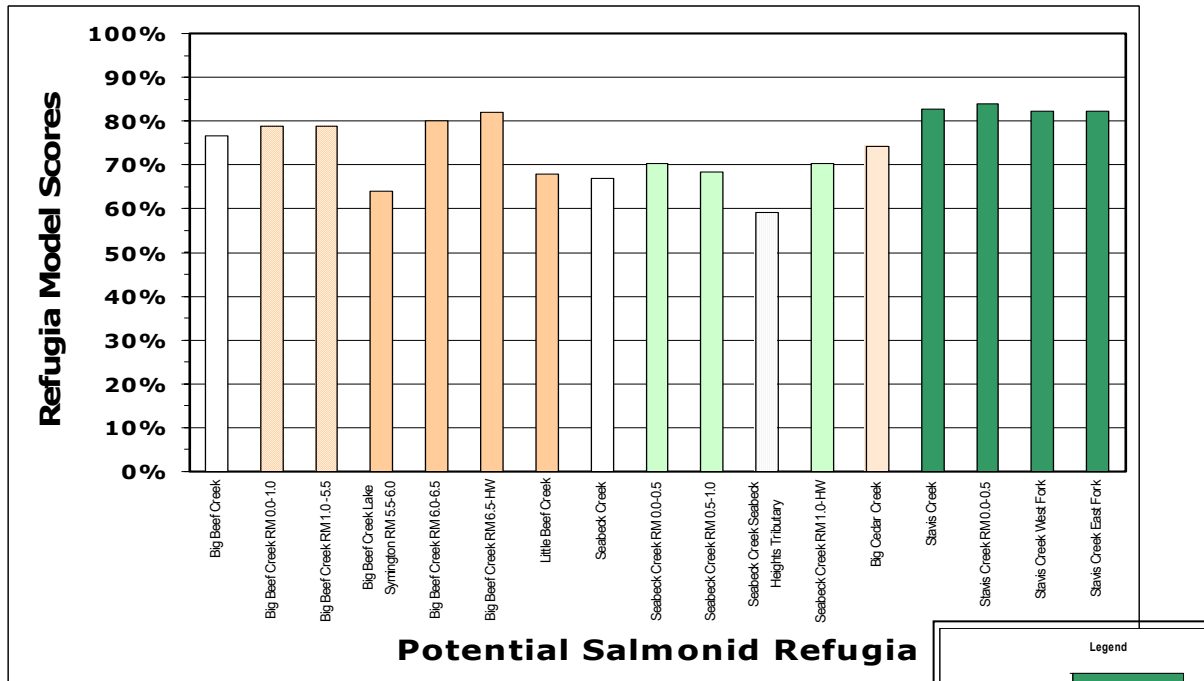


Figure 38: Overall Refugia Model Scores for the Seabeck Sub-Region of Kitsap County.

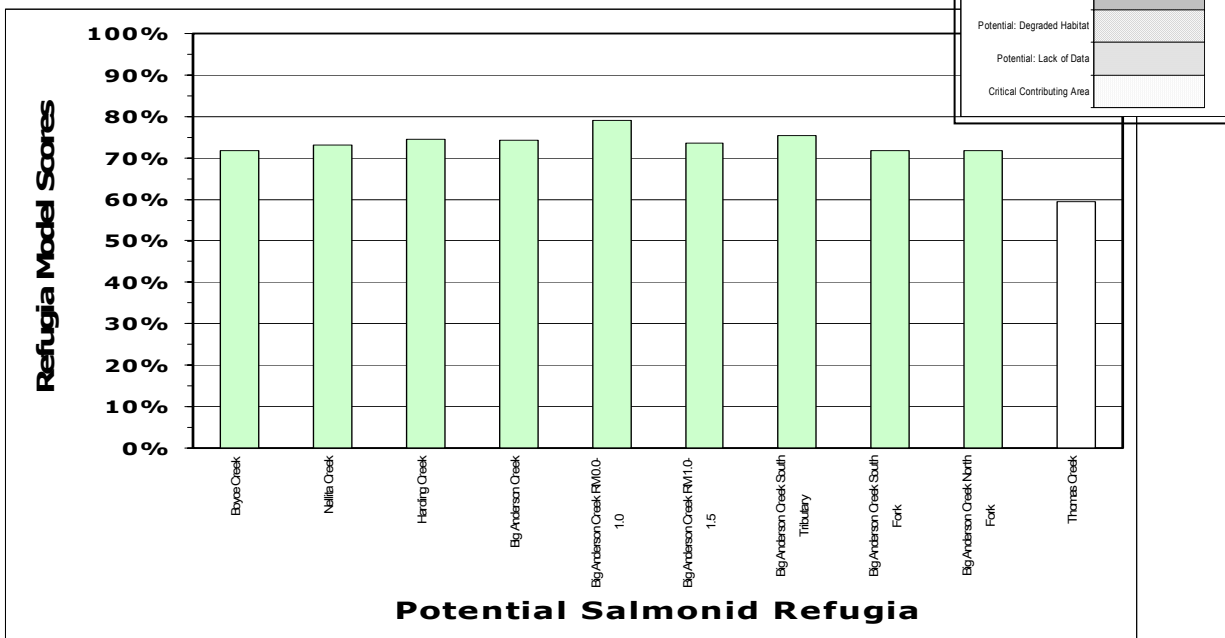


Figure 39: Overall Refugia Model Scores for the Holly Sub-Region of Kitsap County.



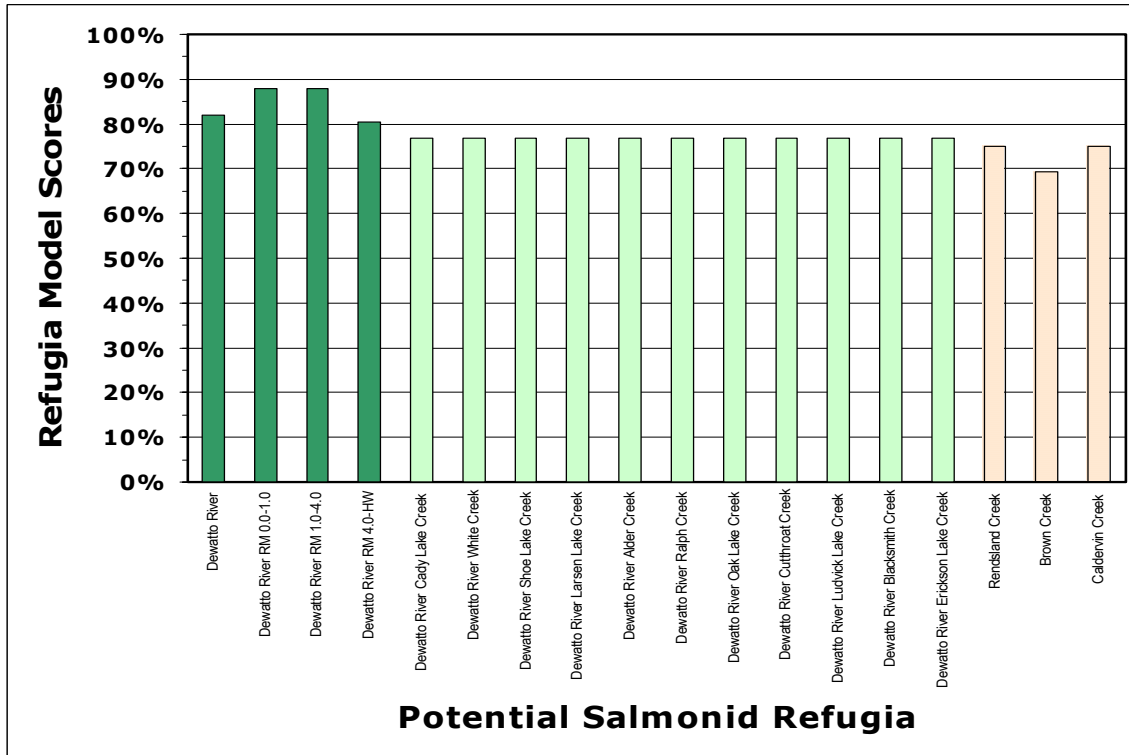


Figure 40: Overall Refugia Model Scores for the Devatto Sub-Region of Kitsap County.

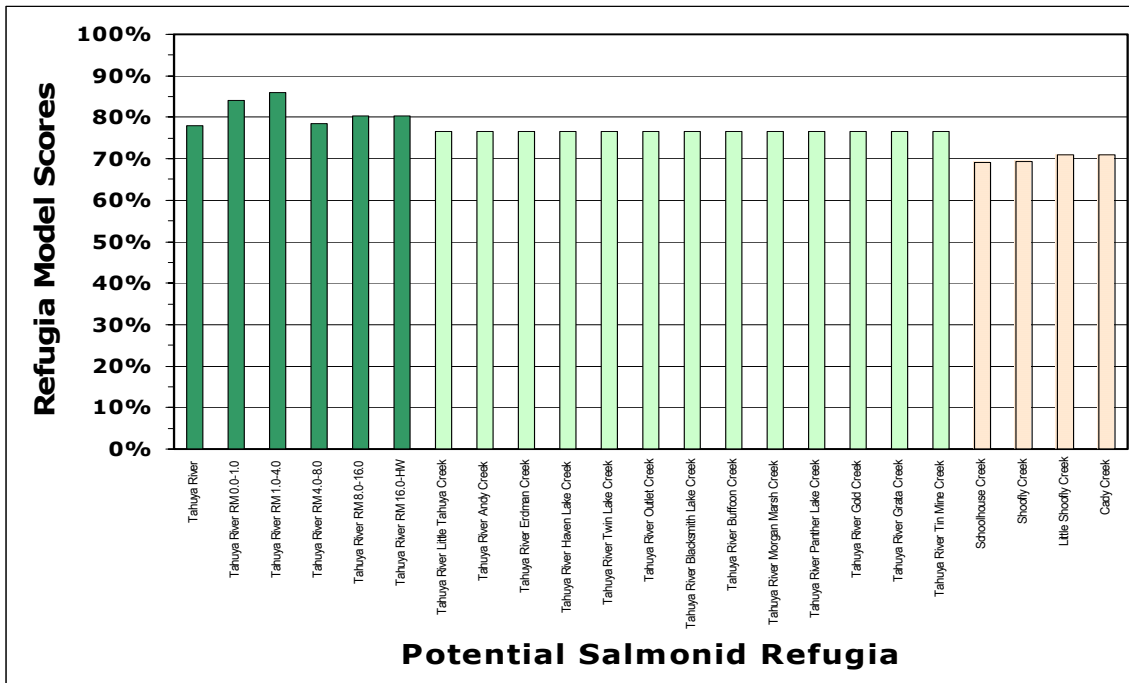


Figure 41: Overall Refugia Model Scores for the Tahuya Sub-Region of Kitsap County.



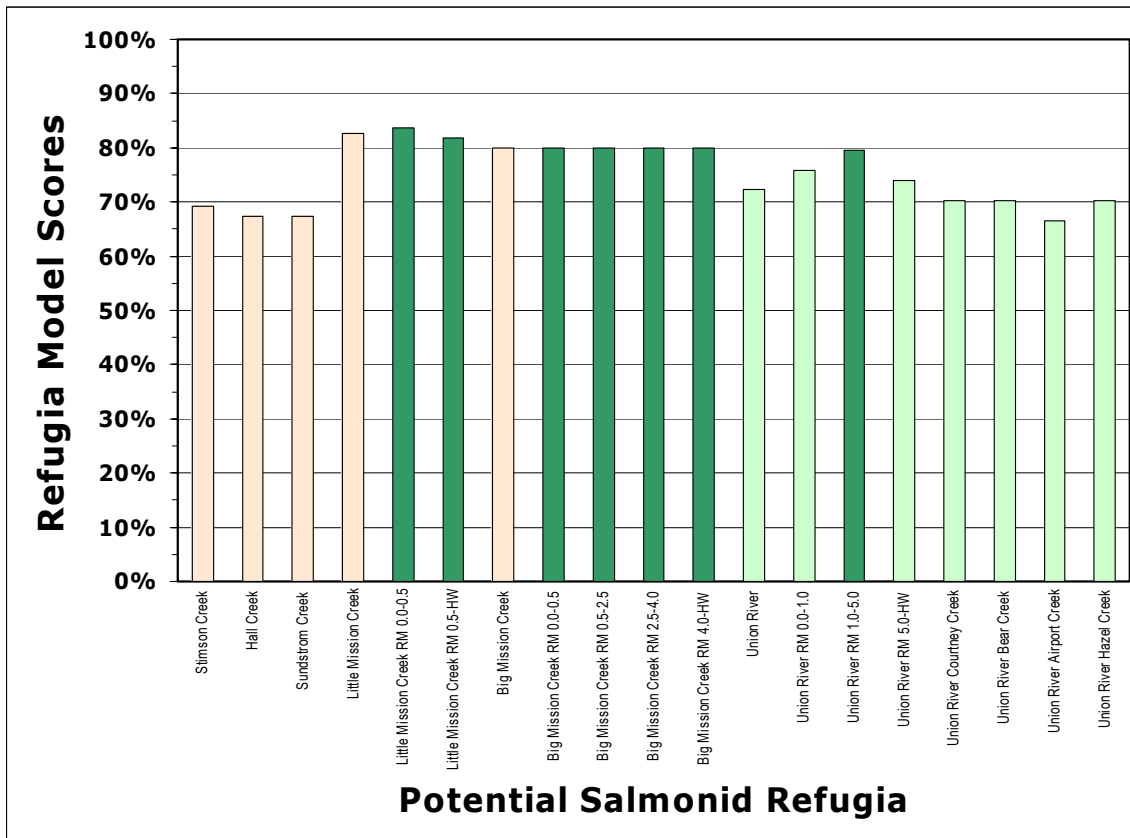
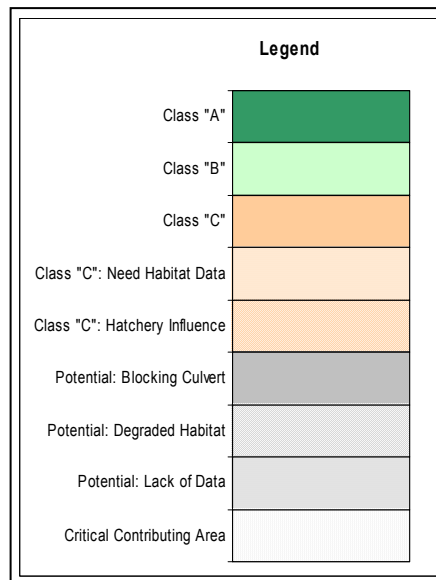


Figure 42: Overall Refugia Model Scores for the Union Sub-Region of Kitsap County.



“One cannot be pessimistic about the west. This is the native home of hope. When it fully learns that cooperation, not rugged individualism, is the quality that most characterizes and preserves it, then it will have achieved itself and outlived its origins. Then it has a chance to create a society to match its scenery.”

WALLACE STEGNER, 1992

REFUGIA DESCRIPTIONS

This section contains brief descriptions of freshwater refugia areas, including a summary of model scores. Details on the model scoring can be found in Appendix G (see Table G-1). More detailed descriptions of each watershed, including instream habitat data, can be found in Appendix A.

EAST KITSAP FRESHWATER REFUGIA

COULTER CREEK

WRIA#: 15.0002

Project ID#: CLT-FSW-01

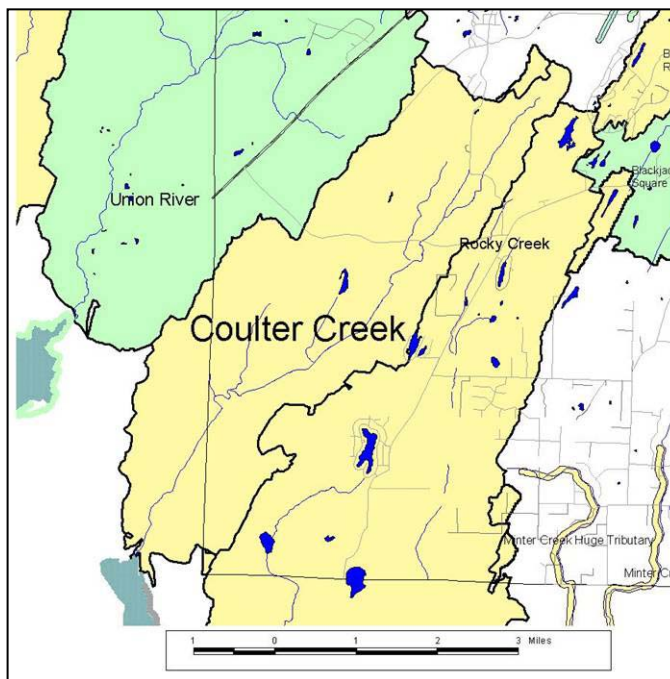
Designation: Coulter Creek FSW

Classification: C (78%)

Salmonid Diversity: Coho,
Chinook, Fall Chum, Steelhead,
& Cutthroat

Description:

Coulter Creek focal sub-watershed (FSW) refugia area encompasses the entire Coulter Creek stream system. Despite a relatively high refugia model score, the Coulter Creek FSW is classified as a class “C” refugia because of the presence of the WDFW hatchery near the mouth. The hatchery influences salmonid access to the creek and impacts the native, wild salmonid populations. Without the hatchery, this watershed would rate as a class “A” refugia. Landscape and instream habitat conditions in Coulter Creek are generally good, although timber harvest activities have had some impact on forest maturity, forest patterns, and instream LWD recruitment. In general, the overall lack of development and the responsible stewardship by the primary landowner in the watershed has helped maintain salmonid habitat conditions in the stream system from the estuary to the headwaters.



ROCKY CREEK

WRIA#: 15.0015

Project ID#: RKY-FSW-01

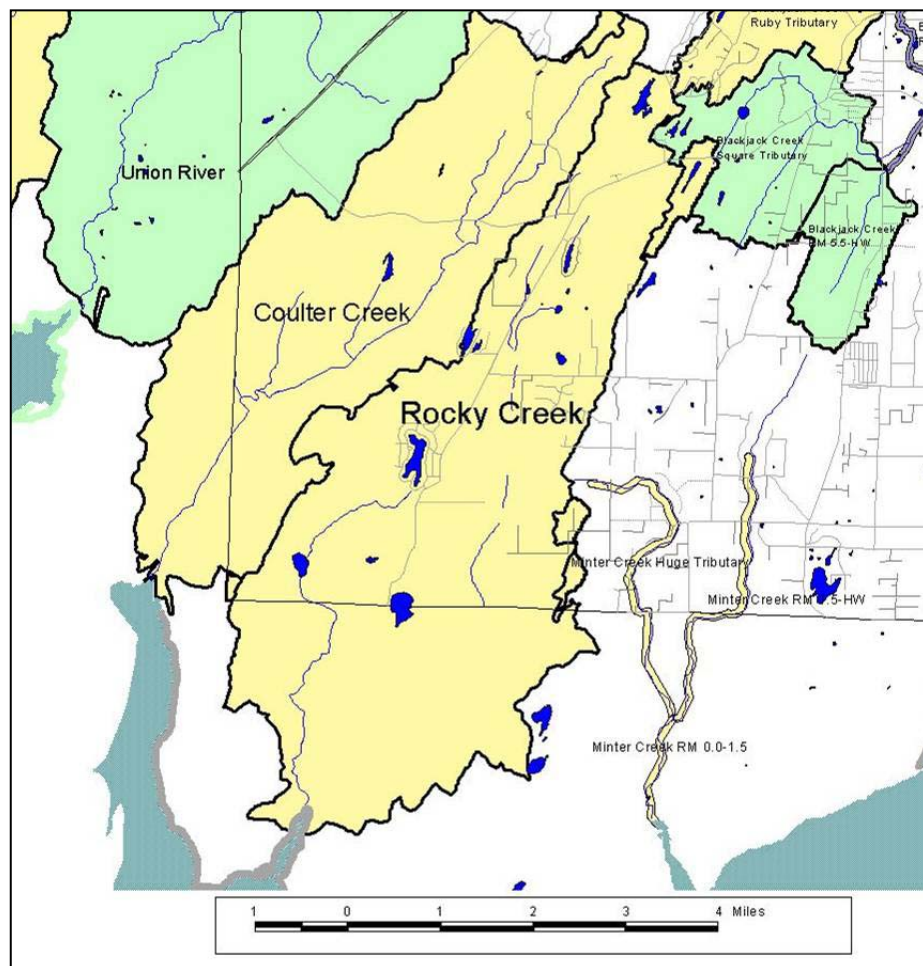
Designation: Rocky Creek FSW

Classification: C (79%)

Salmonid Diversity: Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:

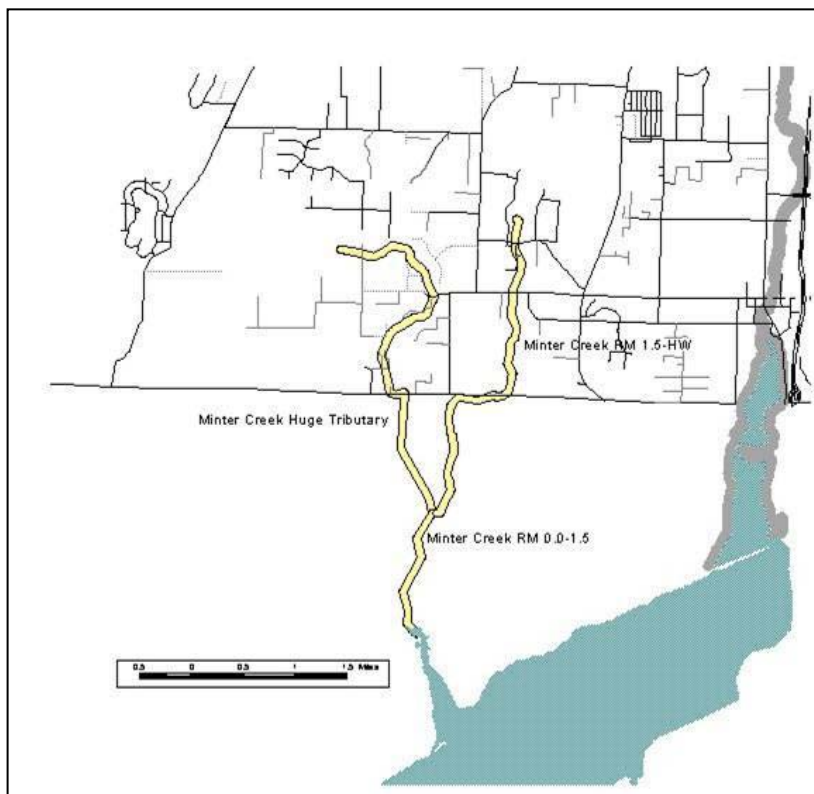
Rocky Creek focal sub-watershed (FSW) refugia area encompasses the entire stream system of Rocky Creek. Landscape conditions in the Rocky Creek watershed are generally good. Instream habitat conditions in Rocky Creek are also believed to be good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, Rocky Creek FSW is designated as a class “C” refugia. In general, the overall lack of watershed development has helped maintain relatively good salmonid habitat conditions in the stream system from the estuary to the headwaters.



MINTER CREEK

WRIA#:	15.0048
Project ID#:	MTR-NRC-01
Designation:	Lower Minter Creek NRC
Classification:	C (65%)
Project ID#:	MTR-NRC-02
Designation:	Upper Minter Creek NRC
Classification:	C (64%)
Project ID#:	MTR-NRC-03
Designation:	Huge Creek NRC
Classification:	C (65%)
Salmonid Diversity:	Coho, Chinook, Fall Chum, Steelhead, & Cutthroat
Description:	

Minter Creek nodal-riparian corridor (NRC) refugia area encompasses the entire stream system of Minter Creek. Instream habitat conditions in Minter Creek are believed to be generally good, although no quantitative habitat assessments have been performed on the stream in recent years. In addition there is a WDFW hatchery located in the lower watershed. The hatchery influences salmonid access to the creek and impacts the native, wild salmonid populations. For these reasons, Minter Creek NRC is designated as a class "C" refugia area. Huge Creek (WRIA 15.0052) is the major headwater tributary of Minter Creek and is included in the NRC refugia area.



OLALLA CREEK

WRIA#: 15.0107

Project ID#: OLA-NRC-01

Designation: Lower Olalla Creek NRC

Classification: C (69%)

Project ID#: OLA-NRC-02

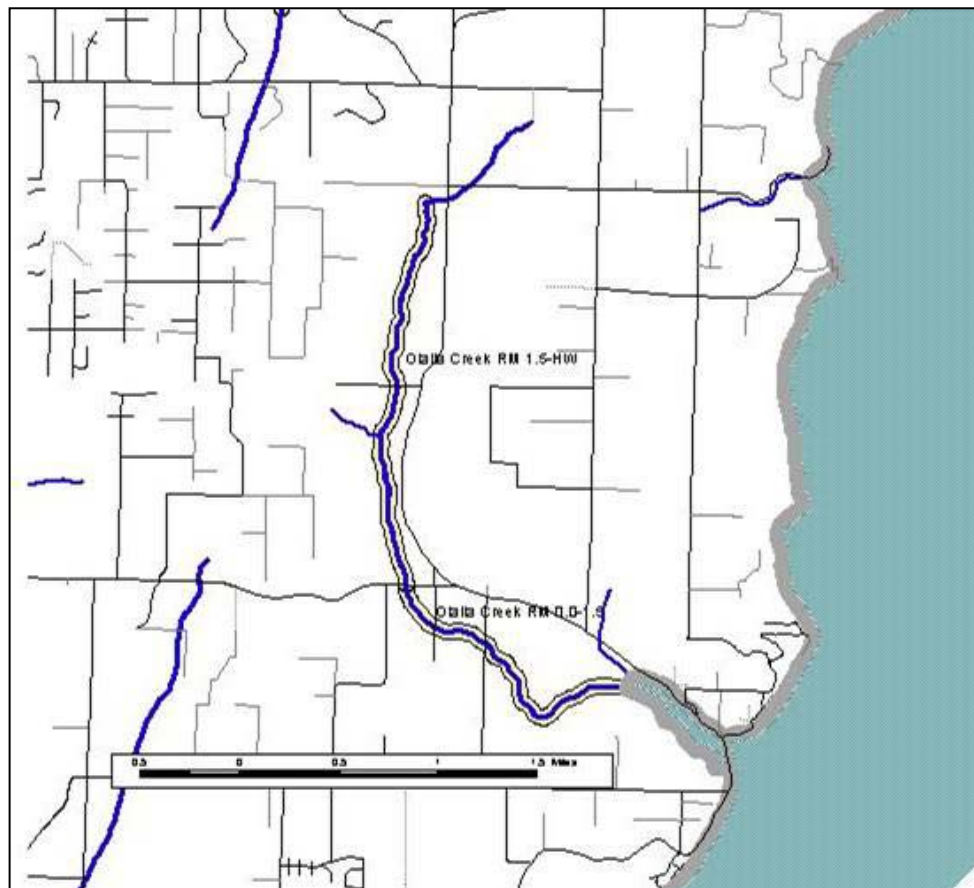
Designation: Upper Olalla Creek NRC

Classification: C (61%)

Salmonid Diversity: Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:

The Olalla Creek nodal-riparian corridor (NRC) refugia area encompasses both the lower mainstem and headwaters of Olalla Creek. Instream habitat conditions in the creek are believed to be generally good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, Olalla Creek NRC is designated as a class “C” refugia.



CURLEY CREEK

WRIA#: 15.0185

Project ID#: CUR-NRC-01

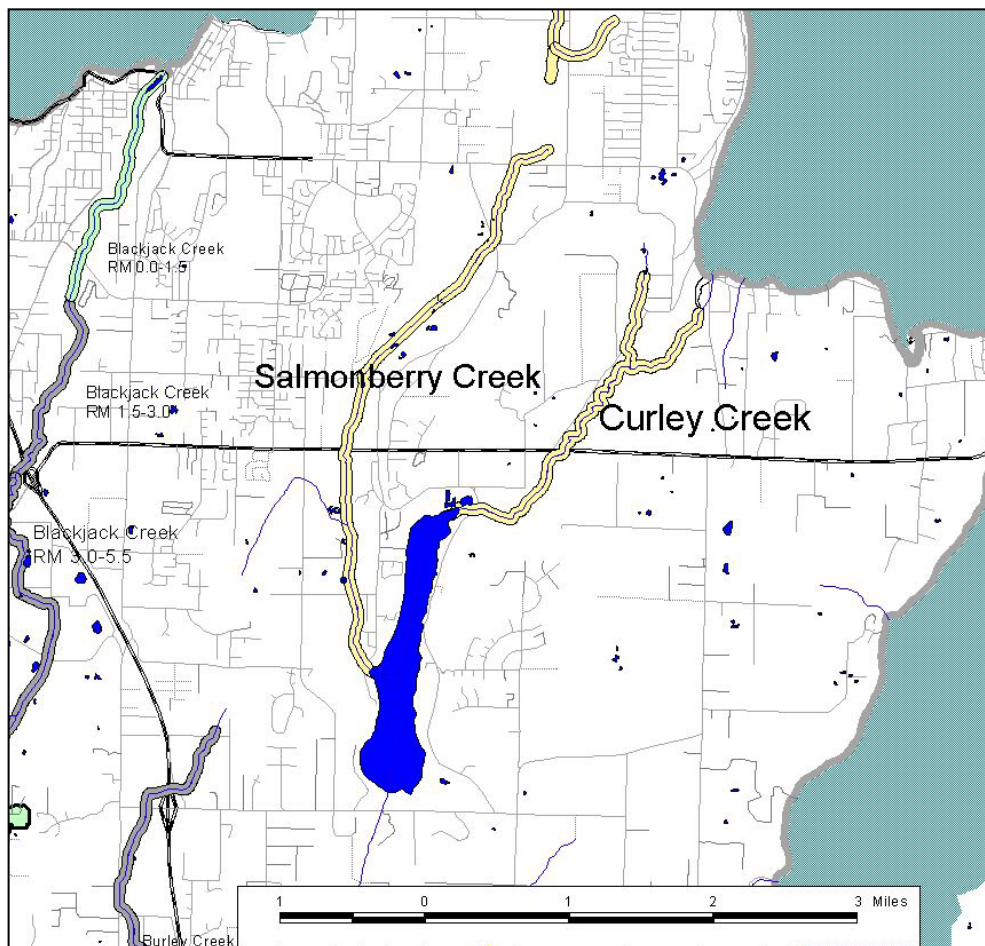
Designation: Curley Creek NRC

Classification: C (71%)

Salmonid Diversity: Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:

The Curley Creek nodal-riparian corridor (NRC) refugia area encompasses the lower mainstem of Curley Creek from the estuary at Yukon Harbor to the outlet of Long Lake. Instream habitat conditions in the creek are believed to be generally good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, Curley Creek NRC is designated as a class “C” refugia.



SALMONBERRY CREEK

WRIA#: 15.0188

Project ID#: SLB-NRC-01

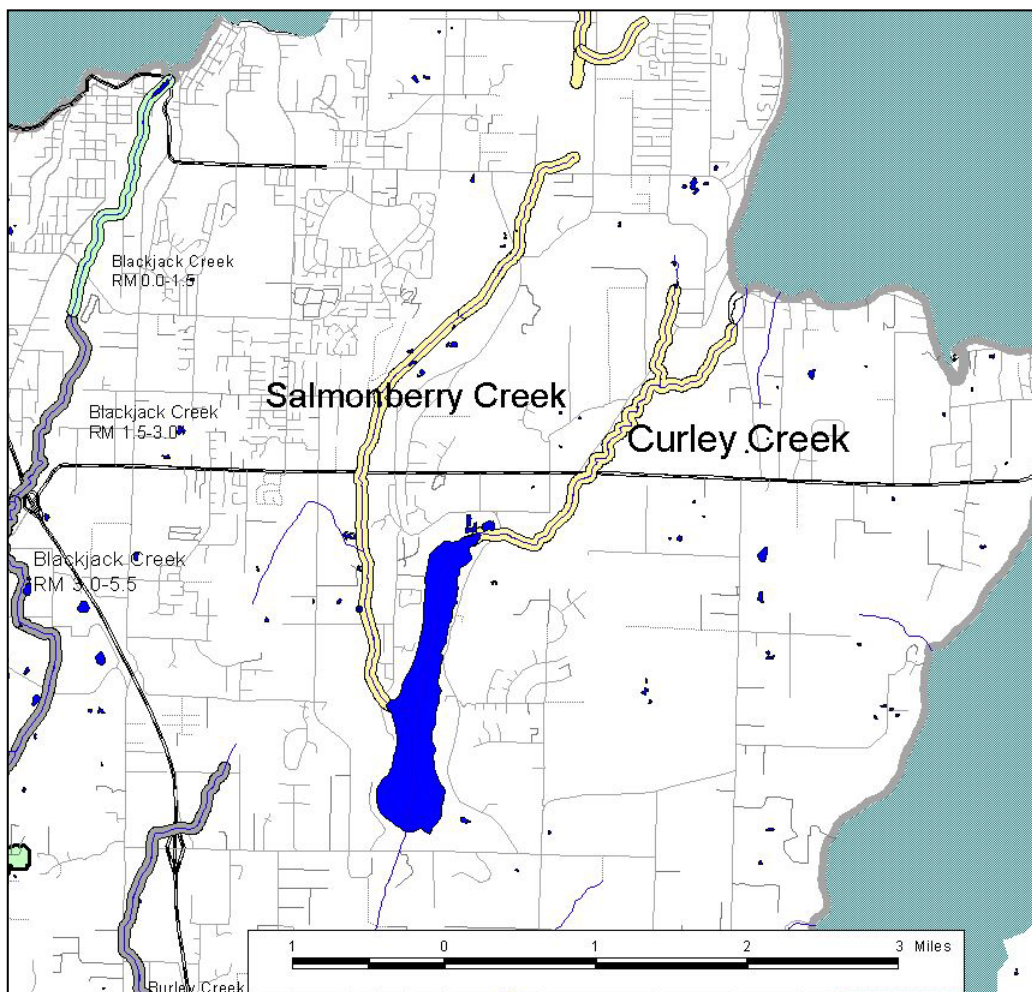
Designation: Salmonberry Creek NRC

Classification: C (60%)

Salmonid Diversity: Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Salmonberry Creek nodal-riparian corridor (NRC) refugia area encompasses the entire length of Curley Creek from the headwaters to the mouth of the creek at the inlet to Long Lake. Instream habitat conditions in the creek are believed to be fair to good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, Salmonberry Creek NRC is designated as a class "C" refugia.



BEAVER CREEK

WRIA#: 15.0192

Project ID#: BVR-NRC-01

Designation: Lower Beaver Creek NRC

Classification: C (63%)

Project ID#: BVR-NRC-02

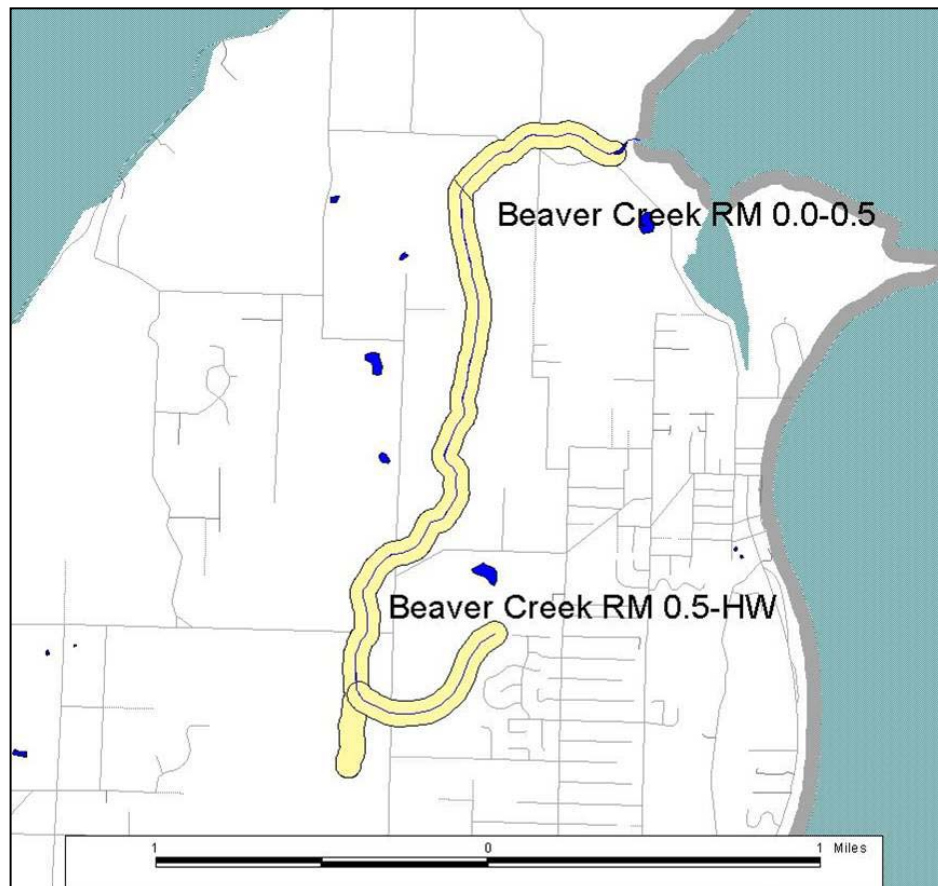
Designation: Upper Beaver Creek NRC

Classification: C (63%)

Salmonid Diversity: Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Beaver Creek nodal-riparian corridor (NRC) refugia area encompasses both the lower mainstem and headwaters of Beaver Creek. Instream habitat conditions in the creek are believed to be generally good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, Beaver Creek NRC is designated as a class “C” refugia.



BLACKJACK CREEK

WRIA#: 15.0203

Project ID#: BLJ-NRC-01

Designation: Lower Blackjack Creek NRC

Classification: B (65%)

Project ID#: BLJ-NRC-02

Designation: Middle Blackjack Creek NRC

Classification: D (56%)

Project ID#: BLJ-NRC-03

Designation: Upper Blackjack Creek NRC

Classification: D (48%)

Project ID#: BLJ-FSW-01

Designation: Blackjack Creek Headwaters FSW

Classification: B (62%)

Project ID#: BLJ-FSW-02

Designation: Ruby Creek FSW

Classification: C (57%)

Project ID#: BLJ-FSW-03

Designation: Square Creek FSW

Classification: B (69%)

Salmonid Diversity: Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:

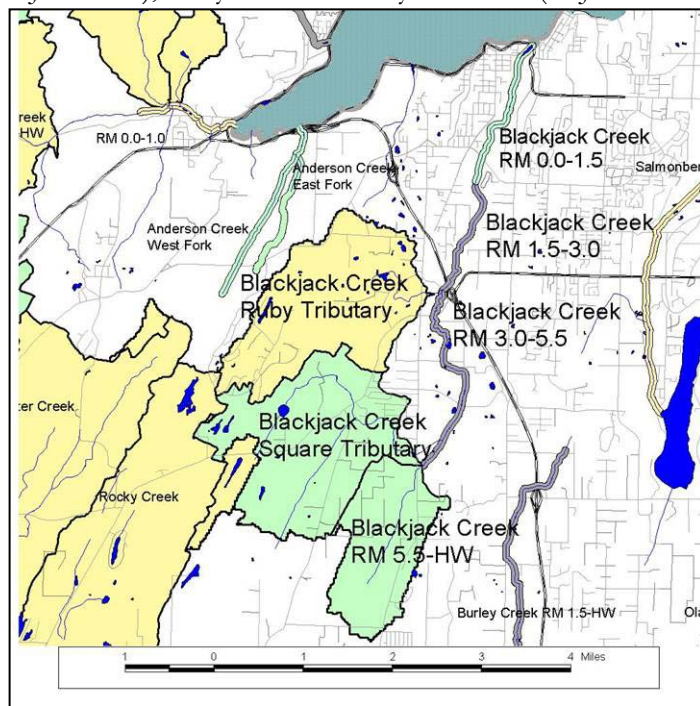
Blackjack Creek is one of the largest and most productive watersheds in the south Kitsap sub-region. The mainstem of Blackjack Creek flows northerly from a broad valley into a naturally incised ravine within the City of Port Orchard prior to entering Sinclair Inlet at the east end of the City of Port Orchard. The lower portion of the watershed within the city limits is generally developed, although the creek is located within a deep, naturally forested ravine. The upper watershed is dominated by rural residential and agricultural land use. Blackjack Creek has two major tributaries: Ruby Creek (WRIA 15.0205) and Square Creek (WRIA 15.0207), which present some of the best



opportunities for habitat protection/restoration in the south Kitsap area. These two tributaries are relatively productive salmon streams. Several habitat protection/restoration actions have already been implemented in the headwaters of Square and Ruby Creeks, and the benefits of these actions would be complemented by additional restoration actions throughout the rest of the watershed. Instream habitat conditions are typical of other Puget Sound lowland streams that are experiencing development pressures. These include riparian encroachment, lack of instream LWD, and fine sediment deposition in spawning gravels. The Blackjack Creek estuary is severely degraded and constrained by development along the shoreline of downtown Port Orchard. This is undoubtedly a limiting factor for salmonid productivity and diversity within the Sinclair Inlet nearshore and for the creek as a whole. Overall, the natural characteristics of the Blackjack Creek estuary have been highly altered. Designated refugia in the Blackjack Creek watershed include nodal-riparian corridors (NRC) in the lower and middle watershed and focal sub-watersheds (FSW) in the headwaters.

The lower Blackjack NRC (BLJ-NRC-01) begins at the estuary and includes the lower mainstem of the creek located within the ravine (RM 0-1.5). Salmonid habitat conditions are generally good within the lower mainstem ravine segment and the NRC is designated as a class “B” refugia. The lower mainstem segment is the primary chum spawning area within the Blackjack system. The middle Blackjack NRC (BLJ-NRC-02) has been significantly by rural-residential development and agricultural land-use (RM 1.5-3.0), including channelization, riparian encroachment, and degradation of instream habitat. Although significantly degraded, this segment of the creek is a critical salmonid migration corridor and is therefore designated a class “C” refugia. The upper Blackjack Creek NRC (BLJ-NRC-03) is designated a class “C” refugia. Rural-residential development and agricultural land-use (RM 3.0-HW), including channelization, riparian encroachment, and degradation of instream habitat, has degraded conditions in this segment of the creek. However, this segment of the creek is a critical salmonid migration corridor and is therefore worthy of refugia status. Lower Blackjack Creek supports chinook (likely wild and/or hatchery stocks that have strayed into the creek), fall & winter chum, coho, steelhead, and cutthroat, as well as a unique run of early (summer) chum.

The Blackjack Creek headwater sub-basin (BLJ-FSW-01), Ruby Creek tributary sub-basin (BLJ-FSW-02), and Square Creek tributary sub-basin (BLJ-FSW-03) are all designated as focal sub-watershed (FSW) refugia areas. These areas are the primary spawning and rearing habitat for coho, steelhead, and cutthroat in the Blackjack system. Ruby and Square Creeks are the primary headwater tributaries of Blackjack Creek. According to WDFW and Suquamish Tribal records, these streams support significant populations of coho, cutthroat, and (historic) steelhead. Both of these sub-watershed areas are generally only sparsely developed, and should be high on the priority list for conservation and protection activities. Square Creek supports a relatively healthy coho and cutthroat population and has good instream habitat conditions (class “B” refugia). Ruby Creek is somewhat more degraded but is still an important spawning and rearing area for coho and cutthroat (class “C” refugia).



ANDERSON CREEK

WRIA#: 15.0211

Project ID#: ANG-NRC-01

Designation: Lower Anderson Creek NRC

Classification: B (65%)

Project ID#: ANG-NRC-02

Designation: West Fork Anderson Creek NRC

Classification: B (72%)

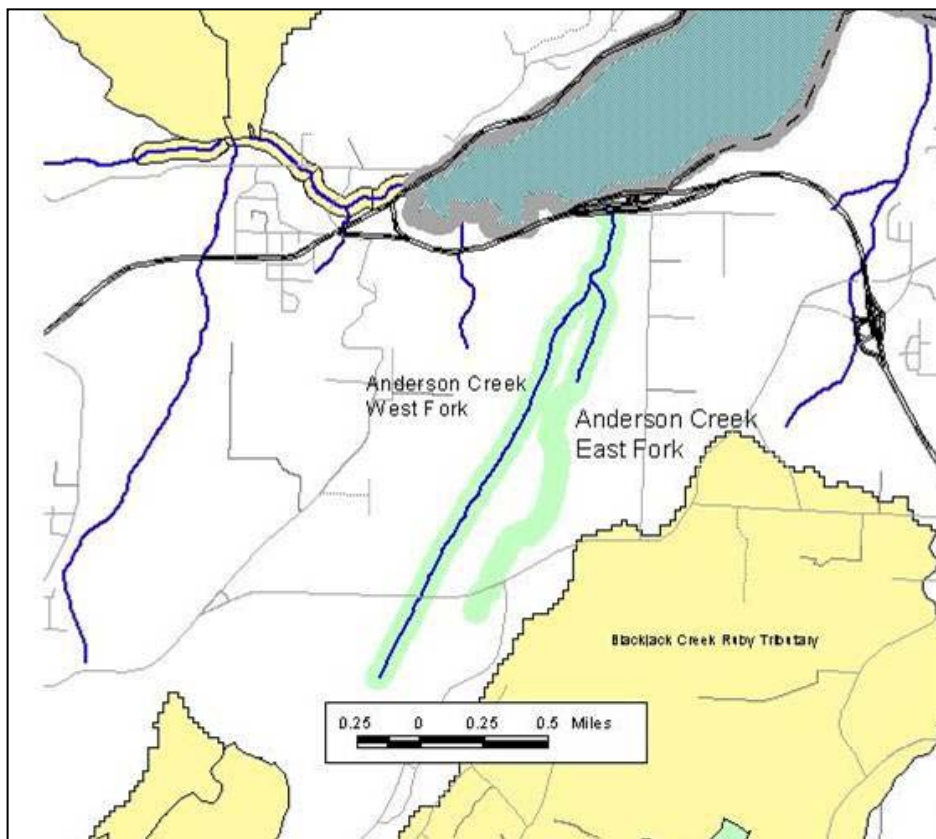
Project ID#: ANG-NRC-03

Designation: East Fork Anderson Creek NRC

Classification: B (72%)

Salmonid Diversity: Coho, Fall Chum, Steelhead, & Cutthroat

Description:



The Anderson Creek Nodal-Riparian Corridor (NRC) refugia area encompasses the entire stream system of Anderson Creek. Landscape and instream habitat conditions in Anderson Creek are generally good, although residential and commercial development have begun to impact conditions in the watershed. In general, the overall low level of development in the watershed has helped maintain salmonid habitat conditions in the stream system.

Most of the historic estuarine function at the mouth of Anderson Creek has been eliminated by the containment of lower Anderson Creek in culverts under the SR-16 crossings. Spawning and rearing habitat, as well as LWD is lacking in the section of the creek just above the highway crossing. This is mainly due to channelization through the Bremerton water supply wellhead area, including a concrete channel and flume structure. Flow through the diversion flume inhibits fish passage at certain flows. This flume severely constricts the channel and floodplain and eliminates all suitable habitat conditions within the flume. This structure should be removed and the stream channel should be naturalized.

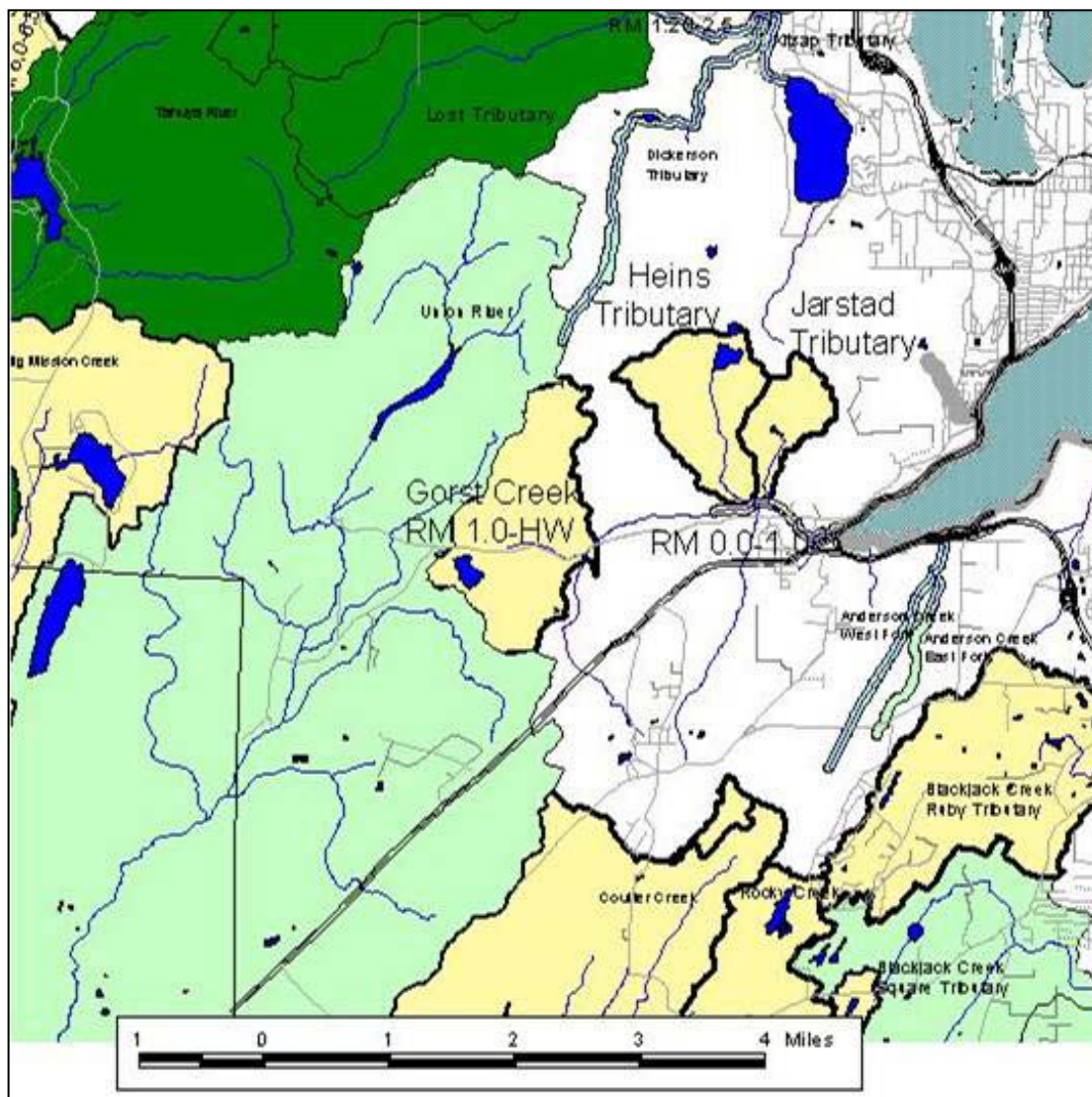
Above the flume structure, the creek branches into two forks (east and west), which flow parallel to each other through two moderately deep ravines. These segments of the creek are in relatively good condition, with stable instream habitat and a wide riparian corridor (although mature conifers are lacking in some reaches). The east and west forks provide the primary spawning and rearing habitat in the watershed. The headwaters (extensive wetlands and beaver ponds) of both forks lie in within a developing area and are sensitive to disturbance. While no anadromous salmonids are present in the headwaters, these areas are critical to the ecological integrity of all downstream areas and provide habitat for resident cutthroat. The headwaters should be protected and enhanced if possible.



GORST CREEK

WRIA#:	15.0216
Project ID#:	GOR-NRC-01
Designation:	Lower Gorst Creek NRC
Classification:	C (52%)
Project ID#:	GOR-NRC-02
Designation:	Lower Gorst Creek NRC
Classification:	C (52%)
Project ID#:	GOR-NRC-03
Designation:	Middle Gorst Creek NRC
Classification:	C (56%)
Project ID#:	GOR-NRC-04
Designation:	Upper Gorst Creek NRC
Classification:	C (68%)
Project ID#:	GOR-FSW-01
Designation:	Gorst Creek Headwaters FSW
Classification:	C (72%)
Project ID#:	GOR-FSW-02
Designation:	Jarstad Creek FSW
Classification:	C (73%)
Project ID#:	GOR -FSW-03
Designation:	Heins Creek FSW
Classification:	C (70%)
Project ID#:	GOR -CCA-01
Designation:	Parish Creek CCA
Salmonid Diversity:	Coho, Chinook, Fall Chum, Steelhead, & Cutthroat



Description:

Gorst Creek is one of the largest and most productive watersheds in the east WRIA-15 sub-region. The creek flows from a largely forested watershed prior to entering Sinclair Inlet near the community of Gorst. A majority of the watershed lies within the City of Bremerton's urban growth boundary, although the likelihood of future development is low due to the protection of the watershed as a drinking water supply. The watershed lies almost entirely within the City of Bremerton's water supply, with associated restricted entry. The city conducts selective timber harvests in portions of the basin. The three major tributary streams to Gorst Creek include Parish, Heins, and Jarstad Creeks. The Suquamish Tribe operates a chinook hatchery in the lower mainstem. Strays from this hatchery are the likely source of chinook found in the Gorst Creek system, although the creek may have historically supported wild chinook. The existence of a hatchery in the lower watershed may conflict with wild salmonid management efforts in the basin. Therefore, all refugia in the Gorst Creek system are designated as class "C" refugia. Without the hatchery influence, portions of this watershed would likely qualify as a class "B" refugia.

The Gorst Creek estuary is in relatively good condition, although the surrounding nearshore area is heavily impacted by commercial development and the SR-3 road right-of-way. Historic natural



estuarine characteristics upstream of the lower SR-3 culverts have been eliminated due to channelization and confinement of the lower creek through the commercial core of Gorst. The lower mainstem also lies within the commercial area of Gorst, which is heavily developed. The creek is channelized with armored streambanks and little or no riparian corridor. The lower mainstem of Gorst Creek historically supported heavy spawning activity by chum salmon, however this segment, more than any other in the stream system has been affected by development and land-use encroachment. Instream habitat conditions in the lower nodal-riparian corridor (NRC) refugia (GOR-NRC-01 & 02) of Gorst Creek are generally poor; however these segments are critical migration corridors to the upper watershed. Restoration and protection efforts in the lower mainstem are vital to long-term salmonid recovery in the Gorst Creek system.

The middle (GOR-NRC-03) and upper (GOR-NRC-04) NRC refugia of Gorst Creek are in better condition than the lower segments, but they are far from natural. A major channel restoration project was completed in 2001 for the middle segment of the creek that passes through Jarstad Park. Above the park, the creek is relatively natural, although there is a lack of channel complexity and LWD due to past land-use practices in the lower watershed. The hatchery is also located within the middle mainstem segment of the creek, along with its associated water diversion structure and fish ladder. Hatchery operations impact this segment of the creek and the migration of wild salmonids into the upper watershed.

The upper watershed is dominated by timber harvest and water management land uses. Most of the upper Gorst Creek (GOR-FSW-01), Jarstad Creek (GOR-FSW-02), and Heins Creek (GOR-FSW-03) focal sub-watershed (FSW) refugia are owned and managed by the City of Bremerton for forestry and protection of the city water supply. As a result, significant riparian buffers have been retained and riparian quality conditions are generally good. Instream habitat in these FSW refugia areas is also generally good. Development in the Sunnyslope area has impacted the headwaters of Parish Creek tributary. The Parish Creek sub-watershed (GOR-CCA-01) is designated as a critical contributing area (CCA) because of water quality and quantity concerns.



CHICO CREEK

WRIA#:	15.0229
Project ID#:	CCO-NRC-01
Designation:	Lower Chico Creek NRC
Classification:	B (60%)
Project ID#:	CCO-NRC-02
Designation:	Middle Chico Creek NRC
Classification:	B (60%)
Project ID#:	CCO-NRC-03
Designation:	Upper Chico Creek NRC
Classification:	B (64%)
Project ID#:	CCO-NRC-04
Designation:	Kitsap Creek NRC
Classification:	B (70%)
Project ID#:	CCO-NRC-05
Designation:	Dickerson Creek NRC w/CCA
Classification:	B (73%)
Project ID#:	CCO -CCA-01
Designation:	Upper Dickerson Creek CCA
Project ID#:	CCO-FSW-01
Designation:	Lost Creek FSW
Classification:	A (81%)
Project ID#:	CCO-FSW-02
Designation:	Wildcat Creek FSW
Classification:	A (80%)
Project ID#:	CCO-FSW-02

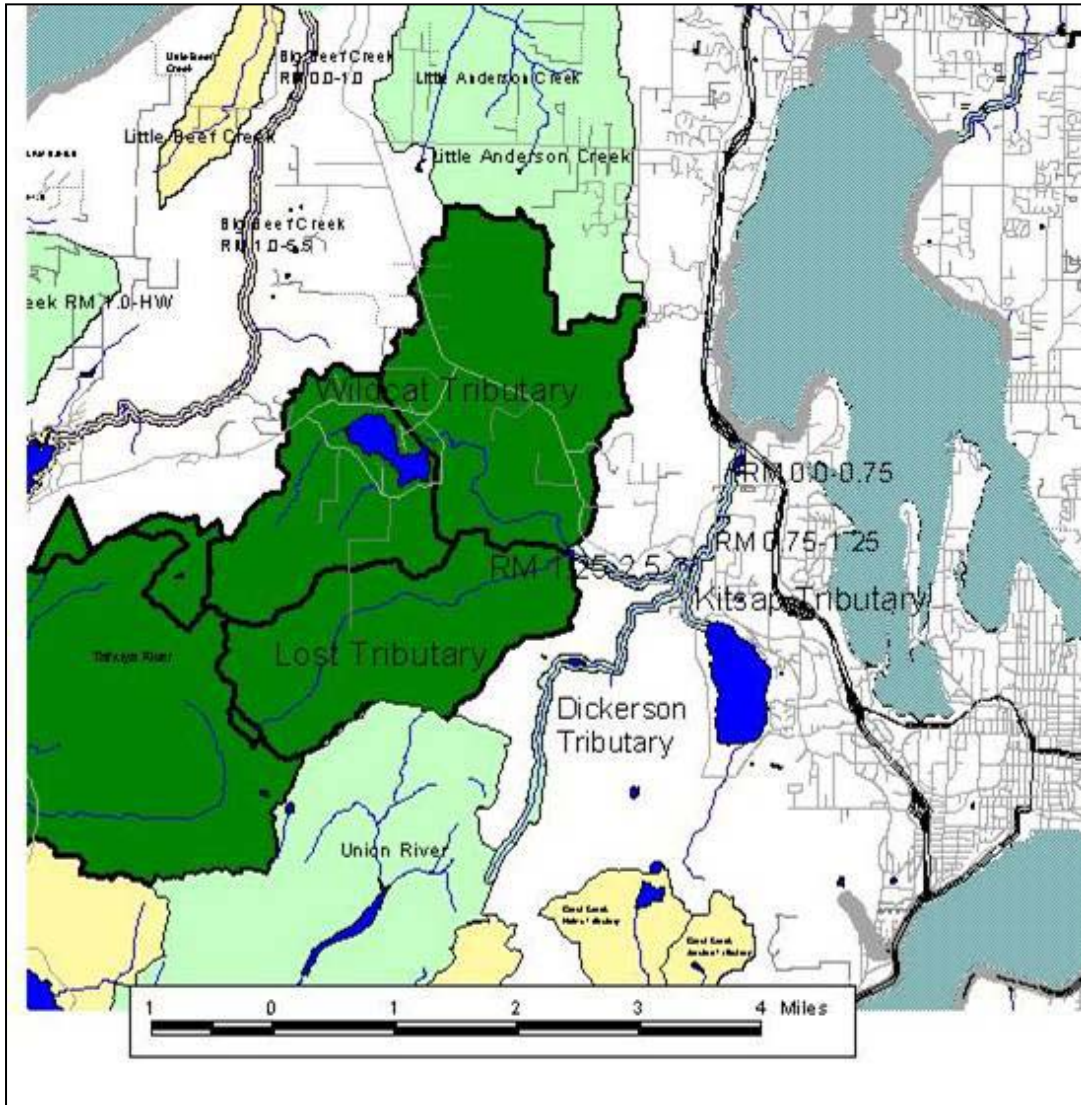


Designation: Wildcat Creek Headwaters FSW

Classification: A (76%)

Salmonid Diversity: Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:



Chico Creek is one of the largest and most productive watersheds in the east WRIA-15 sub-region. Chico Creek enters Chico Bay on the western shore of Dyes Inlet near the community of Chico. The four major tributary streams to Chico Creek include Kitsap, Dickerson, Lost, and Wildcat Creeks. There are also two ecologically important lakes in the watershed, Kitsap and Wildcat lakes. The Chico Creek estuary is in relatively good condition, although the surrounding nearshore has been encroached upon and degraded by development and the extent of estuarine influence is limited by the routing of the creek through a confined culvert near the mouth. Migration and braiding was likely more active in the lower segment of the creek before the highway culverts were installed. The concrete box culverts at the SR-3 crossing are velocity barriers at high flows. In addition, the Washington State, Department of Transportation maintains a “trash rack” upstream of the highway



crossing to intercept logs and other debris that might clog the SR-3 culvert downstream. The instream structure covers the full width of the channel, limiting natural channel function. It is a partial to complete barrier to fish passage when clogged with accumulated debris. Replacement of the SR-3 culvert with a bridge should be a high restoration priority.

The Chico Creek lower mainstem (CCO-NRC-01 & 02) nodal-riparian corridor (NRC) refugia support heavy spawning activity by chum salmon, even though these segments, more than any other in the stream system has been affected by development and land-use encroachment. Chico Creek is channelized and contained within riprap dikes from the mouth to the golf course (~RM 1.25). Instream habitat conditions are generally only fair and there are few resting areas in this reach for adult and juvenile fish during high flows. Several road-crossing culverts (including the main SR-3 culvert) in the lower mainstem segment of the creek need to be upgraded to allow for natural migration access at all flow conditions. Restoration of floodplain, riparian forest, and off-channel habitat will be key to restoring full ecological function to this section of the creek. The triple box culvert at the Golf Club Hill Road crossing is a passage barrier at low flows or when the culverts are periodically blocked with debris. Replacement of these culverts with a bridge would provide natural substrate at the crossing and would pass debris, eliminating the need for regular maintenance of the current weir system. Riparian conditions on Chico Creek from the mouth to the golf course are generally poor due to encroachment of development and lack of mature, diverse riparian vegetation.

In general, watershed, riparian, and instream habitat (LWD, rearing habitat, and spawning habitat) conditions are markedly better upstream of the Navy railroad crossing for all tributaries of Chico Creek. This includes the upper mainstem Chico Creek NRC refugia (CCO-NRC-03). The middle mainstem corridor contains the Mountaineers property and other patches of natural riparian forest habitat. This segment supports significant chum spawning and is a key migratory pathway for coho and steelhead moving into the headwaters to spawn.

Kitsap Creek (WRIA 15.0230), between Kitsap Lake and the mainstem of Chico Creek, is critical habitat for chum, steelhead, and coho. The lower segment of Kitsap Creek (downstream of Kitsap Lake) is prime chum spawning habitat. The lake and the Kitsap Creek upstream of the lake, including the headwater wetlands are prime spawning and rearing habitat for coho and steelhead. The full length of Kitsap Creek is designated as a class "B" NRC refugia (CCO-NRC-04) from confluence with Chico Creek to the headwaters (including Kitsap Lake).

Dickerson Creek (WRIA 15.0231) is also prime chum spawning habitat. In addition, coho, steelhead, and cutthroat utilize the creek. Dickerson Creek is designated as a class "B" NRC refugia from the confluence with Chico Creek to the natural anadromous barrier falls (CCO-NRC-05). Upper Dickerson Creek (upstream of the falls) is designated as a critical contributing area (CCA) for water quality and quantity purposes, as well as for potential resident cutthroat habitat.

The headwaters of Chico Creek, within Lost (WRIA 15.0234) and Wildcat (WRIA 15.0238) tributaries are important spawning and rearing habitat for coho and steelhead, as well as resident cutthroat. The upper watershed is largely forested, with only rural development concentrated around Wildcat Lake. Patches of mature forest remain surrounded by second growth commercial timber. Extensive headwater wetlands exist above Wildcat Lake and in the upper reaches of Lost Creek. Fish presence in Lost Creek extends upstream to a natural cascade. In general, riparian and instream habitat conditions in Lost and Wildcat Creeks are good. Lost Creek (CCO-FSW-01) and Wildcat Creek (CCO-FSW-02 & 03), including Wildcat Lake, are designated as focal sub-watershed refugia (FSW) areas.



BARKER CREEK

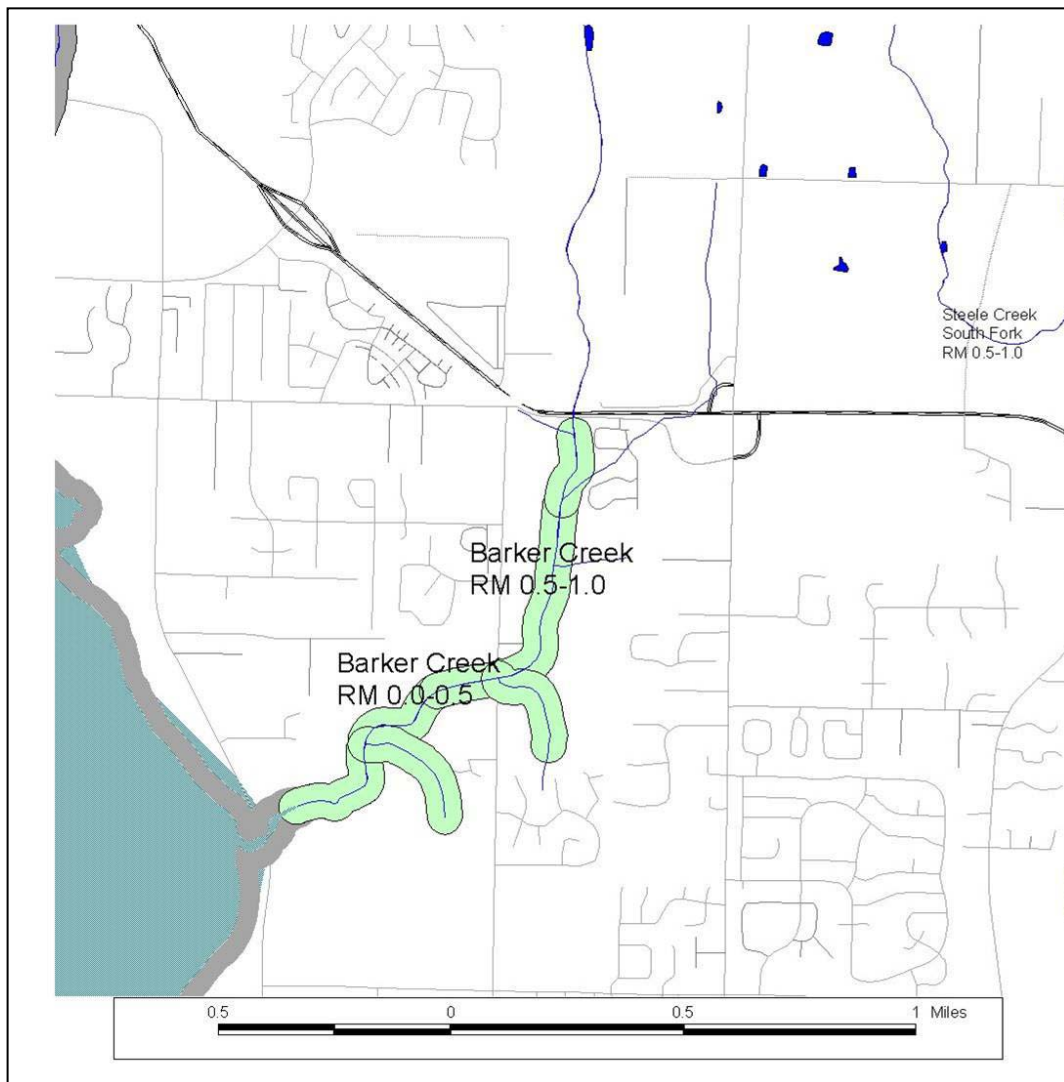
WRIA#:	15.0255
Project ID#:	BRK-NRC-01
Designation:	Lower Barker Creek NRC
Classification:	B (66%)
Project ID#:	BRK-NRC-02
Designation:	Middle Barker Creek NRC
Classification:	B (66%)
Project ID#:	BRK-CCA-01
Designation:	Upper Barker Creek CCA
Project ID#:	BRK-CCA-02
Designation:	Barker Creek Headwaters CCA
Project ID#:	BRK-CCA-03
Designation:	Hoot Creek CCA
Salmonid Diversity:	Coho, Chinook, Fall Chum, Steelhead, & Cutthroat
Description:	

The Barker Creek (BRK-NRC-01 & 02) nodal-riparian corridor (NRC) refugia area encompasses the entire lower mainstem of Barker Creek. Instream habitat and riparian conditions in the lower creek are generally good. The upper watershed and headwater tributaries are designated as critical contributing areas (CCA). Barker Creek supports runs of chum and coho salmon, as well as cutthroat trout. There is also limited, but consistent utilization by chinook salmon and steelhead trout reported in the lower mainstem. The origin of this chinook run is not clear (hatchery plants and/or wild strays), but due to its size/flow, the stream still has a limited potential to support chinook, as well as steelhead.

Barker Creek, an independent, low gradient stream, flows into a small estuarine area in Dyes Inlet near Silverdale. The culvert at the Tracyton Boulevard crossing constricts the estuary at the mouth of the creek, but there is still some natural tidal exchange between the creek and the estuary. However, this undersized culvert does restrict tidal influence upstream of the culvert, affecting normal sediment transport to Dyes Inlet and estuarine productivity. The culvert also has eliminated historic estuarine/salt-marsh conditions upstream and downstream of the road. This culvert should be replaced with a bridge or culvert of sufficient size to restore full tidal influence upstream of the highway. Replacement of the culvert with a bridge would help restore natural estuarine function.



The lower mainstem of Barker Creek is contained within a relatively deep ravine in the lower-most segment of the creek. Instream habitat conditions between Barker Creek Road and Nels Nelson Road (BRK-NRC-01) are generally very good. There is a balanced pool-riffle channel configuration and a moderate level of instream LWD and habitat complexity, especially for an urbanizing stream such as Barker Creek. Streambank stability is generally good, with only minor fine sediment deposition in spawning gravels. The riparian corridor in this segment of the creek is mainly intact, with several stands of mature conifers (cedars and hemlocks) located throughout the riparian zone. From Nels Nelson Road to Waaga Way (BRK-NRC-02), there is generally good spawning and rearing habitat. The riparian corridor is largely intact, although encroachment by development and road-crossings has degraded habitat conditions. LWD is lacking in this section of the creek. The floodplain of Barker Creek, upstream of Nels Nelson Road, is also impacted by development including areas where the streambanks have been bulkheaded. This area historically was a broad wetland zone (patches of riparian wetland still remain), but encroachment has likely eliminated access to most historic floodplain areas. Riparian condition is generally good from Nels Nelson Road to Waaga Way. This NRC refugia area also includes the Pinsch and Waldo Creek tributaries. Upper Barker Creek (upstream of Waaga Way) and the Hoot Creek tributary are designated as critical contributing areas (CCA).

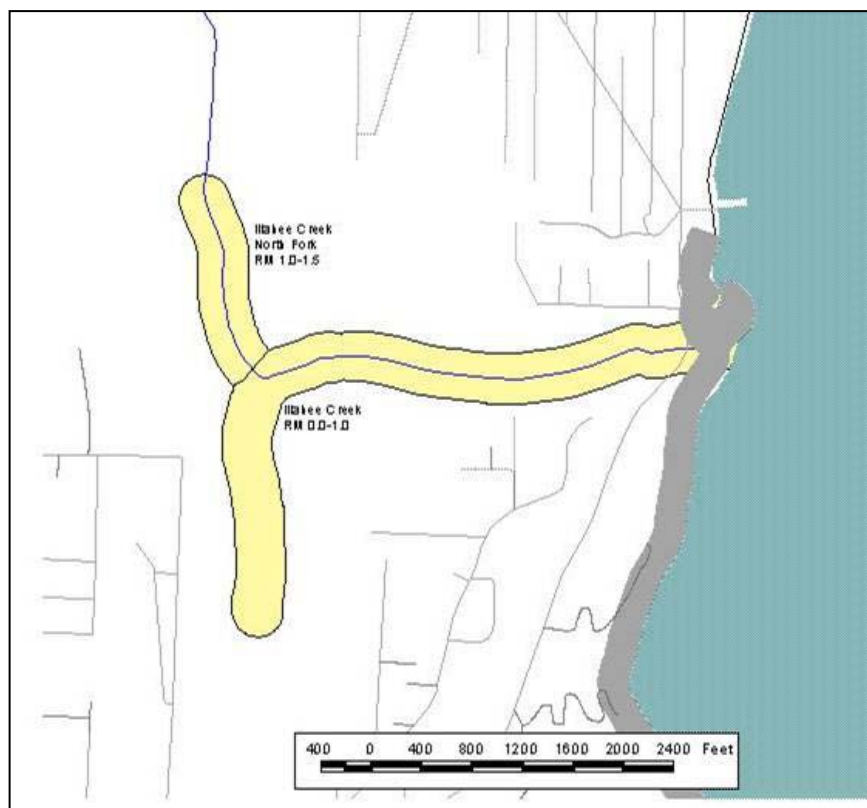


ILLAHEE CREEK

WRIA#:	15.0266
Project ID#:	ILL-NRC-01
Designation:	Lower Illahee Creek NRC
Classification:	C (60%)
Project ID#:	ILL-NRC-02
Designation:	Lower North Fork Illahee Creek NRC
Classification:	C (60%)
Project ID#:	ILL-CCA-01
Designation:	North Fork Illahee Creek Headwaters CCA
Project ID#:	ILL-CCA-02
Designation:	South Fork Illahee Creek CCA
Salmonid Diversity:	Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Illahee Creek (BRK-NRC-01) nodal-riparian corridor (NRC) refugia area encompasses the entire lower mainstem of Illahee Creek. The lower segment of the North Fork Illahee Creek is also included in an NRC refugia (ILL-NRC-02). The mainstem of Illahee Creek and two tributary forks are located in a relatively narrow valley that provides good spawning habitat. Instream habitat in Illahee Creek is generally fair to good and the riparian corridor is largely intact,



with a mixed mature forest found in most reaches. No quantitative instream habitat assessments have been conducted in the Illahee Creek watershed, therefore all refugia areas are designated as class “C” refugia.

The upper watershed and headwater tributaries, including the entire South Fork Illahee Creek, are designated as critical contributing areas (CCA). Illahee Creek supports runs of chum and coho salmon, as well as cutthroat trout. There is also limited, but consistent utilization by steelhead trout reported in the lower mainstem. There is a well-developed and relatively functional estuary at the mouth of Illahee Creek. The estuary currently has little shoreline armoring, although there have been some filling and dredging activities that have occurred in the past. There is also a small, intact salt marsh at the outer end of the estuary. The shallow intertidal delta likely provides good rearing and migration habitat for natal salmonids and other fish passing through the area. There are few such estuaries along this section of the East Kitsap nearshore zone, making even small estuarine areas valuable as salmonid rearing and migration refuges.



STEELE CREEK

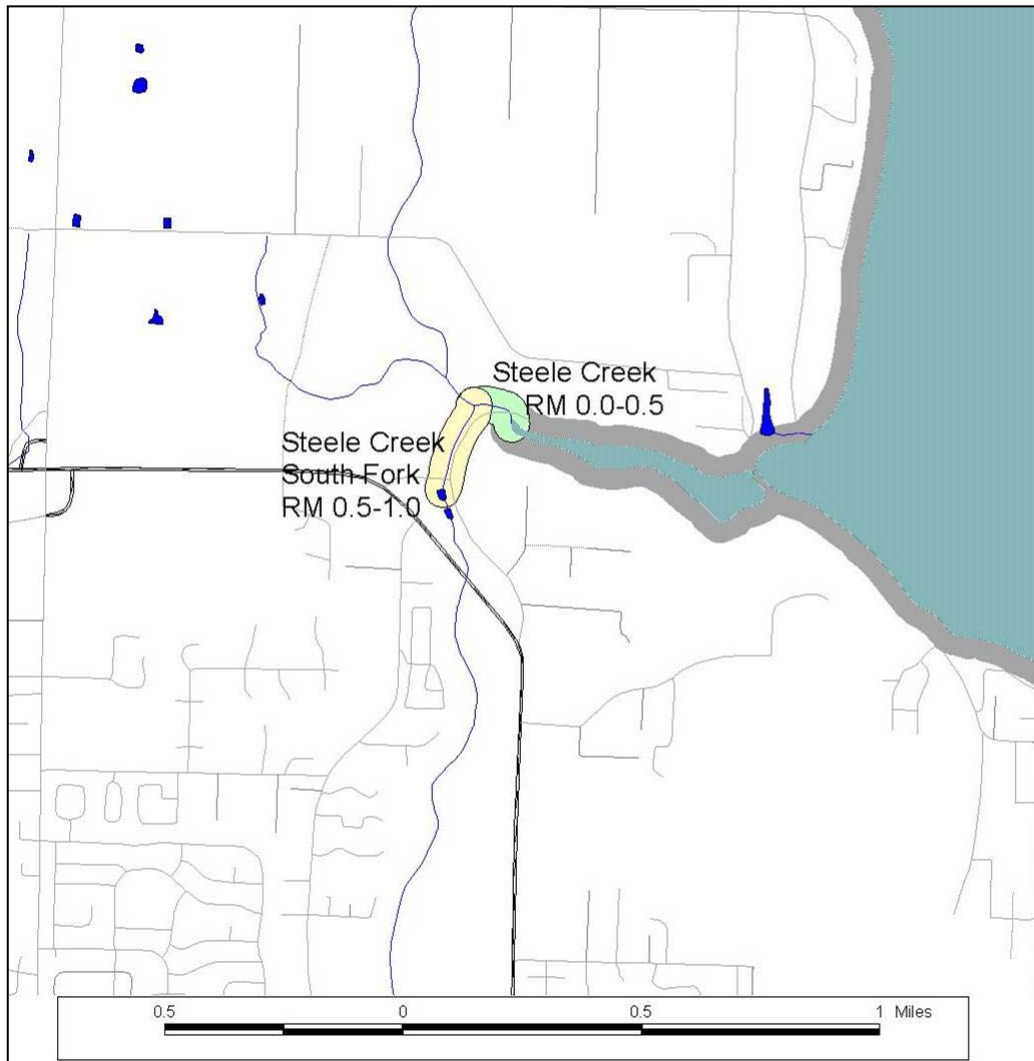
WRIA#:	15.0273
Project ID#:	STL-NRC-01
Designation:	Lower South Fork Steele Creek NRC
Classification:	B (63%)
Project ID#:	STL-NRC-02
Designation:	Middle South Fork Steele Creek NRC
Classification:	C (58%)
Project ID#:	STL-CCA-01
Designation:	Upper South Fork Steele Creek CCA
Project ID#:	STL-CCA-02
Designation:	North Fork (Royal Valley) Steele Creek CCA
Project ID#:	STL-CCA-03
Designation:	Crouch Creek CCA
Salmonid Diversity:	Coho, Chinook, Fall Chum, Steelhead, & Cutthroat
Description:	

The Steele Creek (STL-NRC-01 & 02) nodal-riparian corridor (NRC) refugia areas encompass the entire lower mainstem of Steele Creek, from the estuary to Gluds Pond. Instream habitat and riparian conditions in the lower creek are generally good. The upper watershed and headwater tributaries are designated as critical contributing areas (CCA) due to their ecological importance, but degraded habitat conditions. Steele Creek supports runs of chum and coho salmon, as well as cutthroat trout. There is also limited utilization by chinook salmon and steelhead trout reported in the lower mainstem. The origin of this chinook run is not clear (hatchery plants and/or wild strays), but due to its size/flow, the stream still has only limited potential to support chinook, as well as steelhead. The Steele Creek system consists of three main branches. The South Fork (SF) of Steele Creek is the largest tributary and drains a largely suburban watershed. The North Fork (also known as Royal Valley Creek) watershed consists of primarily rural-residential and agricultural land-use. Crouch Creek is the smallest of the three branches and is located in the north end of the watershed, running parallel to the Royal Valley Creek.

The Steele Creek NRC lies within a relatively deep, forested ravine. The riparian zone is largely intact except where the Brownsville Road constrains the stream. The riparian corridor consists of young and mature deciduous forest, with several patches of conifers. Instream habitat in the lower mainstem is generally good, but conditions could benefit from more LWD and habitat complexity. Riparian vegetation in the NRC is generally lacking in mature conifers. The NRC segment is



channelized downstream of Gluds Pond Road along the Brownsville Road, where the creek is confined in a rock-lined channel between Gluds Pond on one side and the Brownsville Road on the other. The creek lacks suitable habitat elements in this confined reach. There are two culverts and a failed fish-way that have been identified as fish passage barriers, all in the vicinity of the junction of Gluds Pond Road and Brownsville Road. The local stream stewardship group has been operating an adult fish-trap and passage operation at this location since 1996. Adult coho and chum are being effectively passed upstream of the trap and above the two impassable culverts to a location on the upstream side of the Gluds Ponds dams to spawn. Juvenile downstream migrants have also been trapped and enumerated from this stream for two consecutive years (SCORE and WDFW). This artificial migration barrier should be corrected as soon as possible to allow unrestricted access to the upper watershed for all native salmonids.



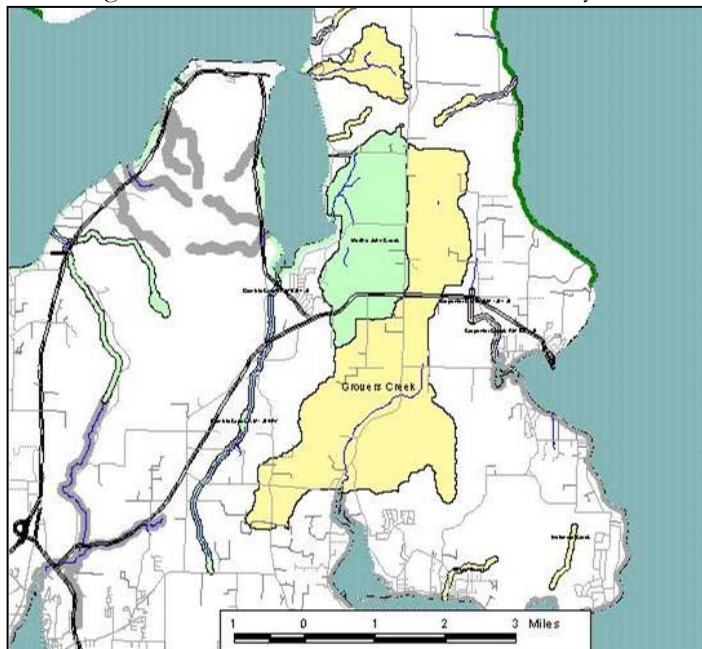
GROVERS CREEK

WRIA#:	15.0299
Project ID#:	GRV-FSW-01
Designation:	Grover's Creek FSW
Classification:	C (66%)
Salmonid Diversity:	Coho, Chinook, Fall Chum, Steelhead, & Cutthroat

Description:

The Grover's Creek focal sub-watershed (FSW) refugia area encompasses the entire stream system of Grover's Creek. Instream habitat conditions in the creek are believed to be generally good, although no quantitative habitat assessments have been performed on the stream in recent years. In addition there is a Suquamish Tribal Fish Hatchery located near the mouth of the creek. The hatchery influences salmonid access to the creek and impacts the native, wild salmonid populations. Because of the lack of quantitative instream habitat data and the presence of the hatchery, Grover's Creek FSW is designated as a class "C" refugia. Grover's Creek supports wild runs of chum, coho, and cutthroat, with the potential for steelhead as well. Hatchery chinook salmon are also present up to the hatchery weir. The presence of the hatchery has a significant influence on native salmon populations. This is especially true for chum salmon, which tend to utilize the lower segments of a stream system for spawning. The impact on coho and cutthroat has likely been minimal due to the location of the hatchery near the mouth of the creek.

Miller Bay, at the mouth of Grover's Creek, provides good-excellent estuarine and nearshore habitat. Because of its enclosed configuration, the wave energy and nearshore transport of sediment are both limited within Miller Bay, and that the nearshore habitat remains in generally good condition, with pockets of excellent habitat. Eelgrass beds are common within Miller Bay and the shoreline riparian zone is in relatively good condition. The lower and middle segments of Grover's Creek have been degraded by timber harvest, agriculture, rural development, and peat mining, as well as land-use encroachment into the riparian corridor. However, instream habitat conditions are still generally fair to good. The upper watershed is relatively undeveloped, although agricultural, rural residential development and road crossings have impacted the ecological integrity of the stream as a whole. There are also extensive wetland and beaver pond (rearing habitat) complexes in the middle and upper reaches of Grover's Creek.



KITSAP (NORTH) CREEK

WRIA#: 15.0305

Project ID#: KIT-NRC-01

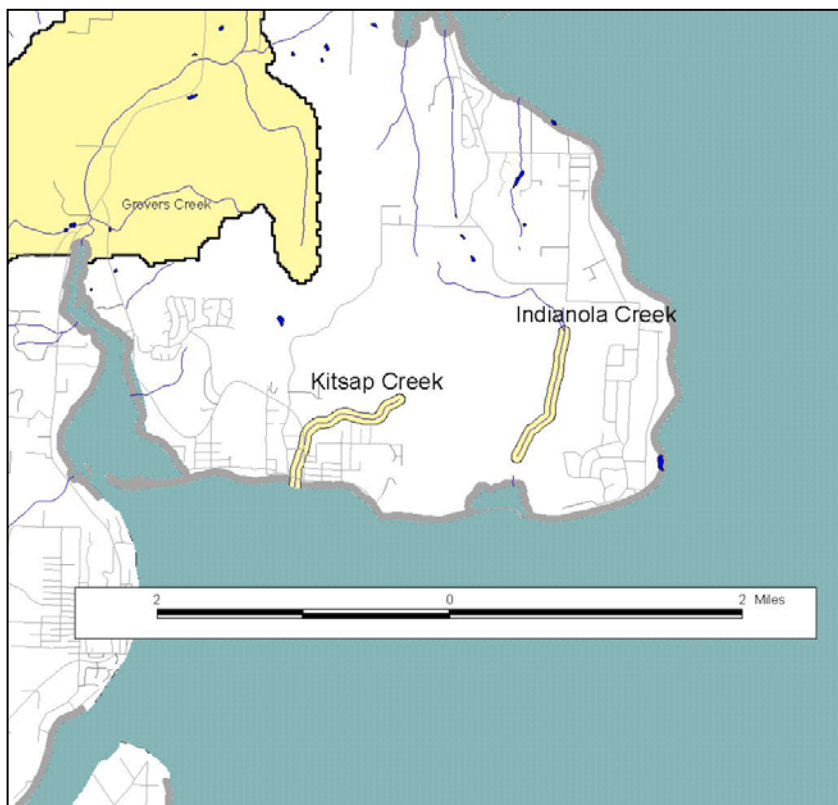
Designation: Kitsap Creek NRC

Classification: C (69%)

Salmonid Diversity: Coho, Fall Chum & Cutthroat

Description:

Kitsap Creek (WRIA 15.0305) is a small independent stream located near Indianola. The creek currently supports coho and chum salmon, as well as cutthroat trout. The culvert under Indianola Road is a complete passage barrier. The culvert at Shore Drive is a velocity barrier at certain flows, but does allow partial fish passage. Under peak flow conditions the Shore Drive culvert is undersized and causes water to back up upstream and deposit material. There are natural higher stream gradient areas downstream of Indianola Road that may naturally limit salmon access upstream. No estuarine habitat exists as this system discharges directly into Port Madison Bay marine waters, along a high-energy shoreline. The nearshore has been residentially developed, although no bulkheads exist in the immediate vicinity of the stream outlet. From the mouth to Shore Drive, residential development encroaches to the edge of the stream, with poor riparian conditions. Upstream of Shore Drive, instream and riparian conditions are generally good where the stream is confined in an undeveloped ravine, which is naturally vegetated and provides adequate room for channel dynamics and recruitment of large woody debris (LWD). There is maturing second growth further upstream as well. No quantitative information is available regarding habitat conditions in the creek. It is recommended that an integrated stream assessment program, including quantitative habitat, salmonid utilization, and bio-monitoring surveys, be implemented.



INDIANOLA CREEK

WRIA#: 15.0305a

Project ID#: IND-NRC-01

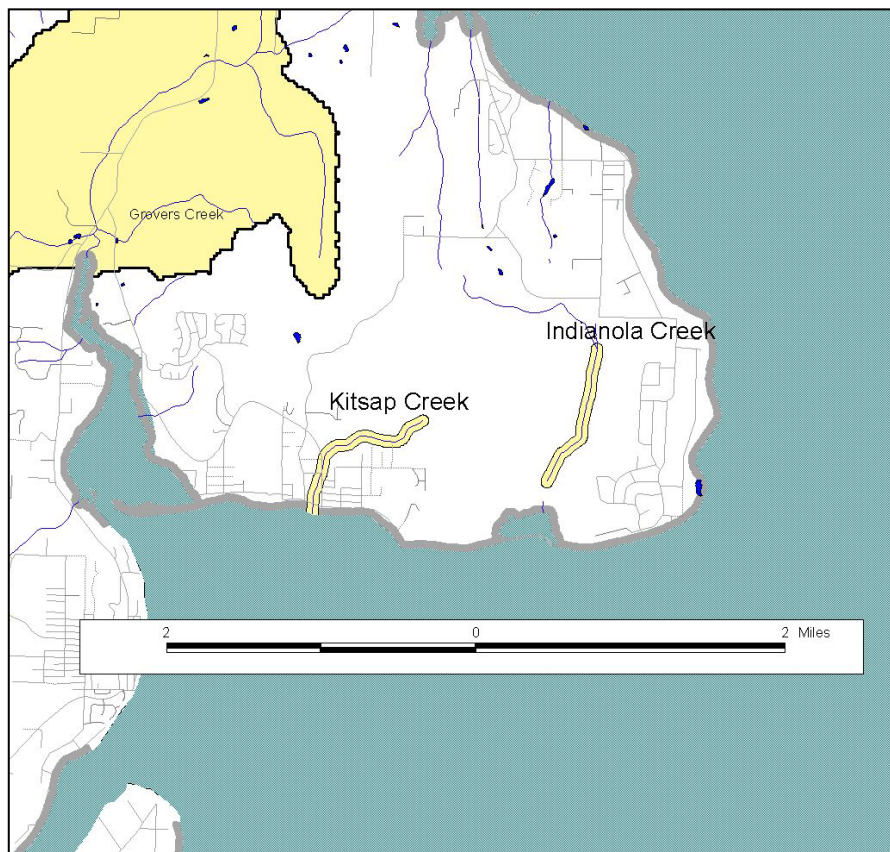
Designation: Indianola Creek NRC

Classification: C (67%)

Salmonid Diversity: Coho, Fall Chum & Cutthroat

Description:

Indianola Creek (WRIA 15.0305a) is a small independent stream located near Indianola. The creek currently supports coho and chum salmon, as well as cutthroat trout. Significant modification (bulkhead construction) of the natural shoreline exists to the west of the stream outlet. Shoreline residential development has eliminated the natural beach berm and nearshore riparian vegetation in the surrounding area near the mouth of the creek. There are several fish passage barriers on the lower mainstem, including a complete barrier at Indianola Road, which blocks 1.5 miles of habitat from anadromous use. The creek is located within a moderately deep ravine for much of its length. Riparian conditions are generally fair to good, as are instream habitat conditions. However, the watershed has been platted for development, and the cumulative impacts of lot clearing are beginning to encroach on the riparian corridor and degrade riparian quality in some places. A 20-acre parcel, including both sides of the creek upstream of Indianola Road, has been placed in conservancy status, which will provide long-term riparian and habitat protection. No quantitative information is available regarding habitat conditions in the creek. It is recommended that an integrated stream assessment program, including quantitative habitat, salmonid utilization, and bio-monitoring surveys, be implemented.



CARPENTER CREEK

WRIA#:	15.0309
Project ID#:	CAR-NRC-01
Designation:	Lower Carpenter Creek NRC
Classification:	C (64%)
Project ID#:	CAR-NRC-02
Designation:	Middle Carpenter Creek NRC
Classification:	C (63%)
Project ID#:	CAR-CCA-01
Designation:	Upper Carpenter Creek CCA
Salmonid Diversity:	Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Carpenter Creek (CAR-NRC-01 & 02) nodal-riparian corridor (NRC) refugia areas encompass the entire lower mainstem of the creek, from the estuary to SR-104 and includes Carpenter lake wetland complex. Instream habitat and riparian conditions in the lower creek are generally good, although no quantitative habitat assessments have been conducted on the creek. Therefore, the Carpenter Creek NRC areas are designated as class "C" refugia. The upper watershed and headwater tributaries are designated as critical contributing areas (CCA) due to their ecological importance, but degraded habitat conditions. The Carpenter Creek watershed consists mainly of rural-residential land-use and is still mainly forested, especially in the headwaters. Carpenter Creek supports runs of chum and coho salmon, as well as cutthroat trout. There is also limited utilization by steelhead trout reported in the lower mainstem.

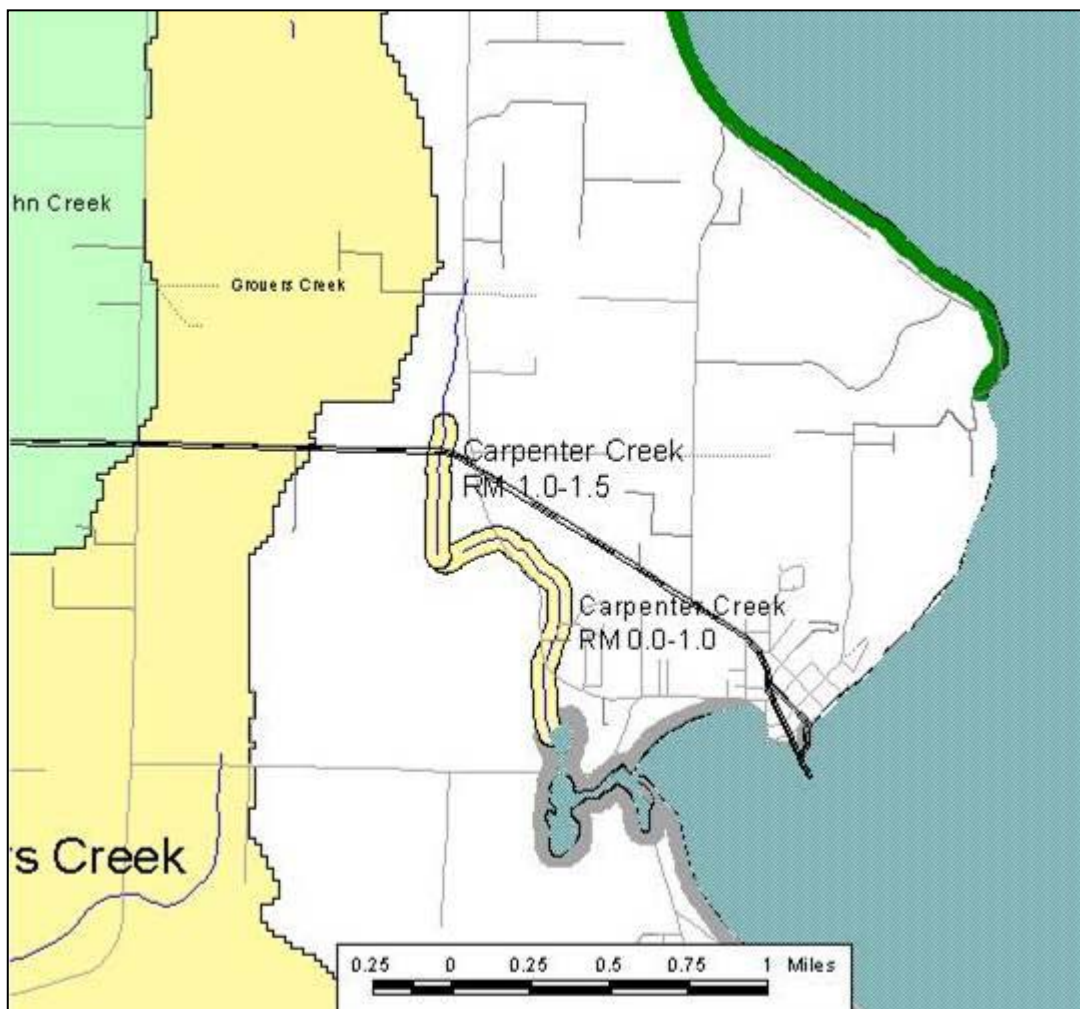
The Carpenter creek estuary is relatively natural except for the presence of road crossing culverts that restrict tidal exchange. The culvert at West Kingston Road, at the mouth of the creek, is not a fish passage barrier, but does restrict saltwater exchange to the historic inner estuarine area upstream of the culvert, and also inhibits natural sediment transport to the outer estuary. This disruption of natural estuarine and hydrologic functions has resulted in a conversion of historic saltwater estuary habitat to a low-gradient freshwater emergent marsh habitat. In addition to the West Kingston Road culvert, the box-culvert that connects the stream system to Appletree Cove (South Kingston Road) restricts tidal interaction within the outer estuary. In general, the estuary riparian area is relatively intact except near road crossings. The upper part of the inner estuary is in public ownership as a county open-space area. This portion of the estuary consists of high salt marsh and forested wetland dominated by Sitka spruce. The outer estuary has been developed, but still retains a good measure of natural ecological integrity. These culverts should be replaced by bridges as soon as is practicable.

The lower mainstem NRC (CAR-NRC-01), from the inner estuary to Carpenter Lake is predominantly riparian wetland habitat. Mature alders dominate the riparian forest in this area and beaver activity is common. There is a lack of mature conifers within the riparian corridor in this



section of the creek. Carpenter Lake consists of open water surrounded by a “bog” type wetland. While the creek and the lake have always been hydrologically connected via groundwater and surface water within the floodplain area, the original main surface flow of the creek may have bypassed the lake/bog. Regardless of historic channel conditions, the lake is an integral component of the Carpenter Creek ecosystem, providing habitat for waterfowl wildlife, salmonids, and other aquatic biota. There is also a very large beaver dam complex just below the lake, which provides good rearing habitat for coho and cutthroat.

The middle mainstem NRC (CAR-NRC-02) runs from Carpenter Lake to just upstream SR-104. There are few pools and little habitat diversity throughout this section of the creek. LWD is generally absent in the middle mainstem segment of the creek and the riparian zone is minimal, with reed canary grass common throughout the channel and floodplain area. In spite of these conditions, anadromous salmonids can migrate through the SR-104 culvert under most flow conditions. The SR-104 culvert is listed as a partial fish passage barrier. This section of the creek has high restoration potential, including re-meandering the stream channel and re-establishing the riparian corridor. This segment of the creek still provides spawning and rearing habitat for coho and cutthroat.



SILVER CREEK

WRIA#: 15.0311

Project ID#: SIL-NRC-01

Designation: Silver Creek NRC

Classification: C (64%)

Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

The Silver Creek Nodal-Riparian Corridor (NRC) refugia areas encompass the entire Silver Creek watershed. Little is known about habitat conditions in the creek, however there are extensive beaver-pond wetlands in the headwaters that may provide significant rearing habitat.



BAINBRIDGE ISLAND FRESHWATER REFUGIA

WRIA#:	15.0321
Project ID#:	MUR-NRC-01
Designation:	Murden Cove Creek NRC
Classification:	D (53%)
WRIA#:	15.0325
Project ID#:	SCL-NRC-01
Designation:	Schel-Chelb Creek NRC
Classification:	D (56%)
WRIA#:	15.0331
Project ID#:	BLH-NRC-01
Designation:	Blakely Harbor Creek NRC
Classification:	C (61%)
WRIA#:	15.0332
Project ID#:	GAZ-NRC-01
Designation:	Gazzam Creek NRC
Classification:	C (60%)
WRIA#:	15.0340
Project ID#:	FLT-NRC-02
Designation:	Fletcher Creek NRC
Classification:	C (61%)
WRIA#:	15.0344
Project ID#:	MNZ-NRC-01
Designation:	Manzinita Creek NRC
Classification:	D (55%)
Salmonid Diversity:	Coho, Fall Chum, & Cutthroat



Description:

There are numerous small, independent stream-watersheds on Bainbridge Island. Several of these small streams support salmonid populations, mainly coho and chum salmon. Almost all also have sea-run and/or resident populations of cutthroat trout and some may support limited numbers of steelhead trout. Very little is known about salmonid utilization, abundance, or habitat conditions in the Bainbridge Island streams. These small streams may provide important refuge habitat from disturbances in adjacent larger creeks or river systems, but little is known about their salmonid populations or how important these creeks are to the overall Bainbridge Island ecosystem. Undoubtedly, these streams and their estuaries provide transitional habitat for salmonids from their own watershed, but some may also provide migratory refuge areas for fish moving along the Puget Sound nearshore zone. Based on a conservative approach to habitat protection, the largest of these small stream watersheds were identified here as potential salmonid refugia areas.



WEST KITSAP FRESHWATER REFUGIA

HANSVILLE AREA CREEKS

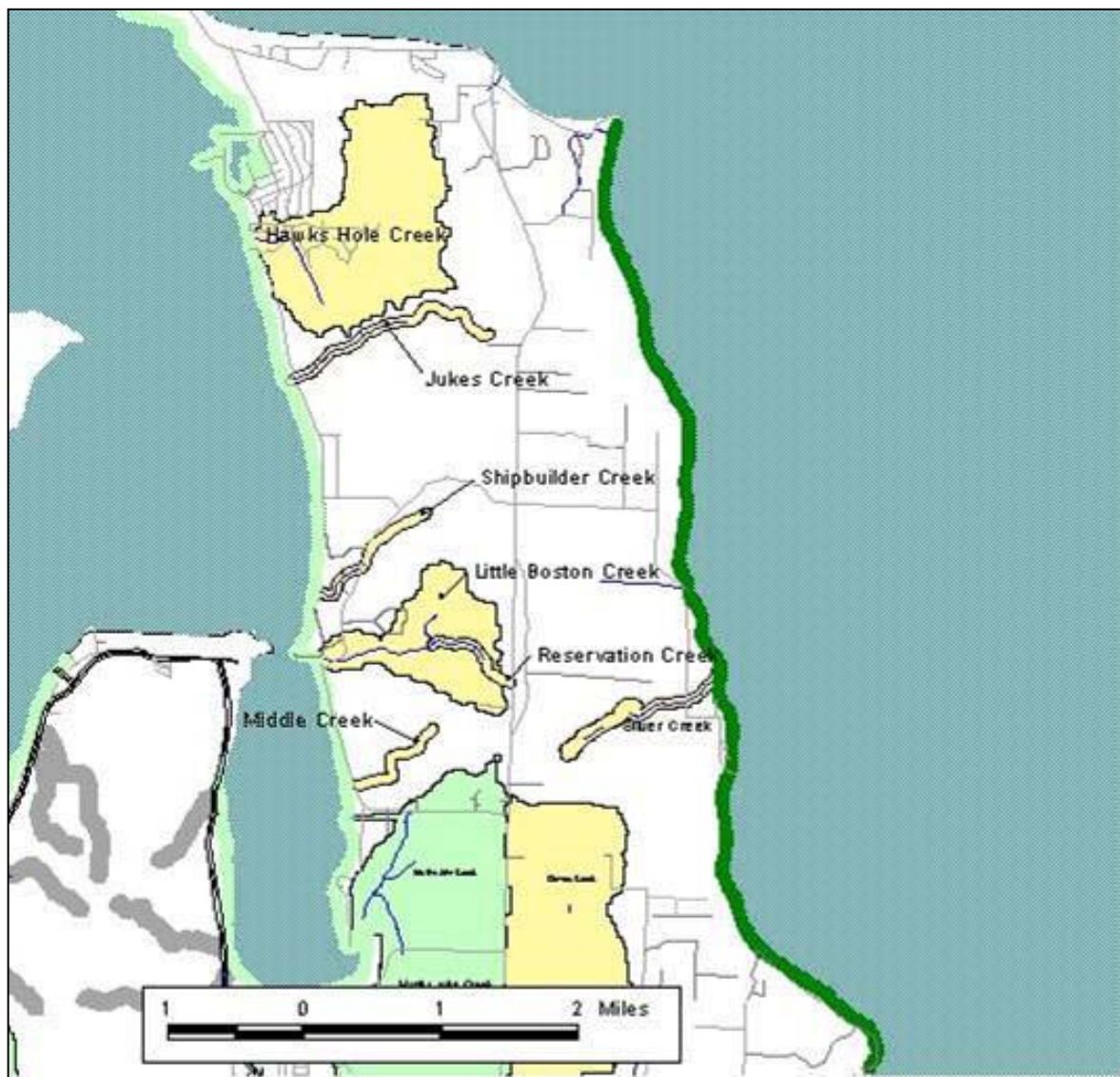
WRIA#:	15.0345
Project ID#:	HWK-FSW-01
Designation:	Hawks Hole Creek FSW
Classification:	C (66%)
WRIA#:	15.0348
Project ID#:	JKS-NRC-01
Designation:	Jukes Creek NRC
Classification:	C (60%)
WRIA#:	15.0349
Project ID#:	SHP-NRC-01
Designation:	Shipbuilders Creek NRC
Classification:	C (60%)
WRIA#:	15.0350
Project ID#:	LBS-NRC-01
Designation:	Little Boston Creek FSW
Classification:	C (65%)
WRIA#:	15.0351
Project ID#:	RES-NRC-01
Designation:	Reservation Creek NRC
Classification:	C (60%)
WRIA#:	15.0352
Project ID#:	MID-NRC-01
Designation:	Middle Creek NRC
Classification:	C (63%)



Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

There are numerous small, independent stream-watersheds along the western shoreline of Hood Canal. Several of these small streams support salmonid populations, mainly coho and chum salmon. Almost all also have sea-run and/or resident populations of cutthroat trout and some may support limited numbers of steelhead trout. These small streams may provide important refugia habitat from disturbances in adjacent larger creeks or river systems, but little is known about their salmonid populations or how important these creeks are to the overall Hood Canal ecosystem. Undoubtedly, these streams and their estuaries provide transitional habitat for salmonids from their own watershed, but some may also provide migratory refuge areas for fish moving along the Hood Canal nearshore zone.



MARTHA JOHN CREEK

WRIA#: 15.0354

Project ID#: MJN-FSW-01

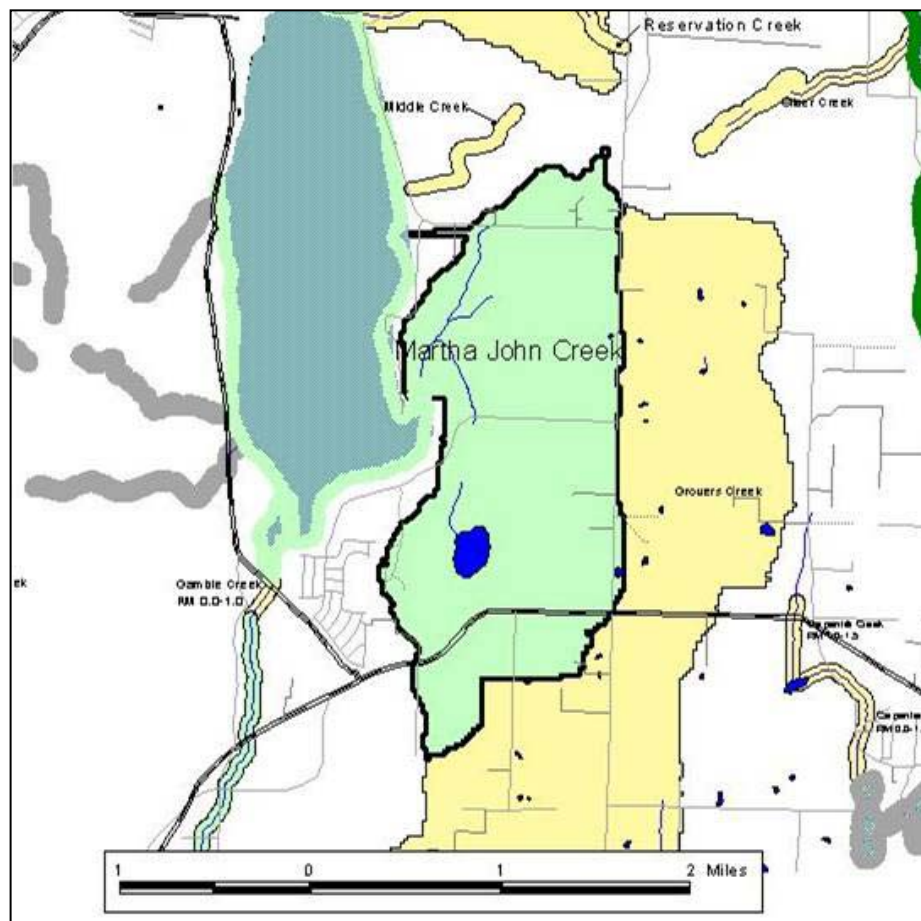
Designation: Martha John Creek FSW

Classification: B (69%)

Salmonid Diversity: Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Martha John Creek focal sub-watershed (FSW) is designated a class "B" refugia area (MJN-FSW-01). Martha John Creek is a small independent watershed enters Hood Canal within Gamble Bay. Most of the combined watershed area is forested, with little development impact. Extensive headwater wetlands (Miller Lake) and beaver ponds provide stable flows and relatively natural water quality. The creek flows through a series of beaver ponds and wetlands in the lower mainstem, with



gravel-bed channels common in upstream segments. Riparian vegetation is relatively good except where rural development has encroached on the stream. The riparian corridor consists mainly of alder, maple, and second growth fir, with patches of mature conifers. Extensive off-channel wetlands provide good rearing habitat. Miller Lake is one of the more pristine lake environments remaining on the Kitsap Peninsula. The lake has a wide, relatively intact second growth, mature coniferous riparian zone. Anadromous salmonids may have access to Miller Lake but this is not known for certain. In general, instream salmonid habitat conditions in Martha John Creek are good.

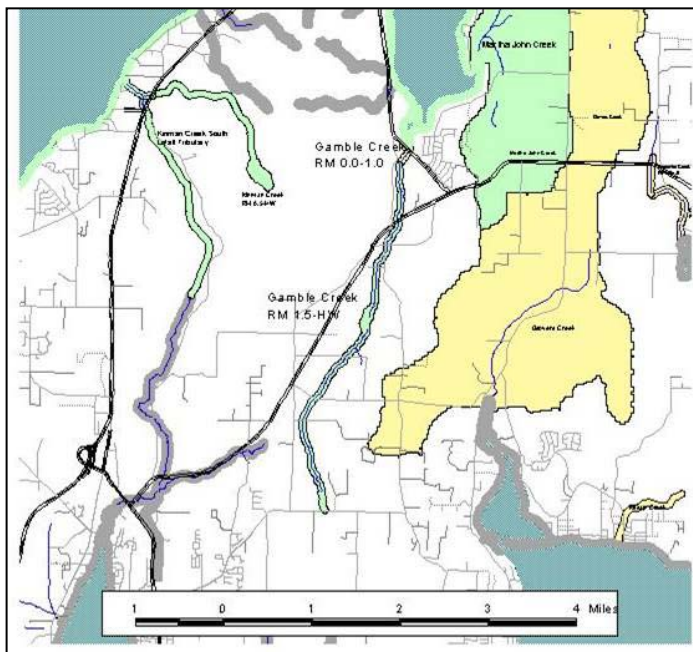


GAMBLE CREEK

WRIA#:	15.0356
Project ID#:	GMB-NRC-01
Designation:	Gamble Creek NRC
Classification:	C (55%)
Project ID#:	GMB-NRC-02
Designation:	Gamble Creek NRC
Classification:	B (68%)
Salmonid Diversity:	Coho, Fall Chum, Steelhead, & Cutthroat

Description:

The Gamble Creek nodal-riparian corridor (NRC) refugia area extends from the estuary to approximately RM 1.0 (GMB-NRC-01). This refugia area is designated as a class “C” refugia because of its importance as a migration corridor and as chum spawning habitat, even though the instream habitat conditions have been degraded by surrounding land-use activities (timber harvest, agriculture, and rural residential development). The Gamble Creek nodal-riparian corridor (NRC) is designated a class “B” refugia area (GMB-NRC-02) and includes the upper watershed and headwaters of the Gamble Creek.



Gamble Creek is a small independent watershed enters Hood Canal within Gamble Bay. Most of the combined watershed area is forested, with little development impact. Gamble Bay is the largest sub-estuary area in the northwest part of Hood Canal. Gamble Bay estuary includes the estuaries for Middle, Little Boston, Martha John, Gamble, and Todhunter Creeks, along with numerous unnamed streams. The western shoreline of the bay contains some of the most natural nearshore habitat in the upper Hood Canal watershed. The eastern shoreline is significantly impacted by development around the Port Gamble community, with natural nearshore habitat remaining in patches along the eastern shoreline. Net pens located in Port Gamble Bay to raise and release coho salmon for commercial harvest at adult return restrict natural wild escapement to the stream. Pollution from this site may also degrade the nearshore area in the bay. In general, instream salmonid habitat conditions in lower Gamble Creek are poor, while conditions in upper Gamble Creek are good.



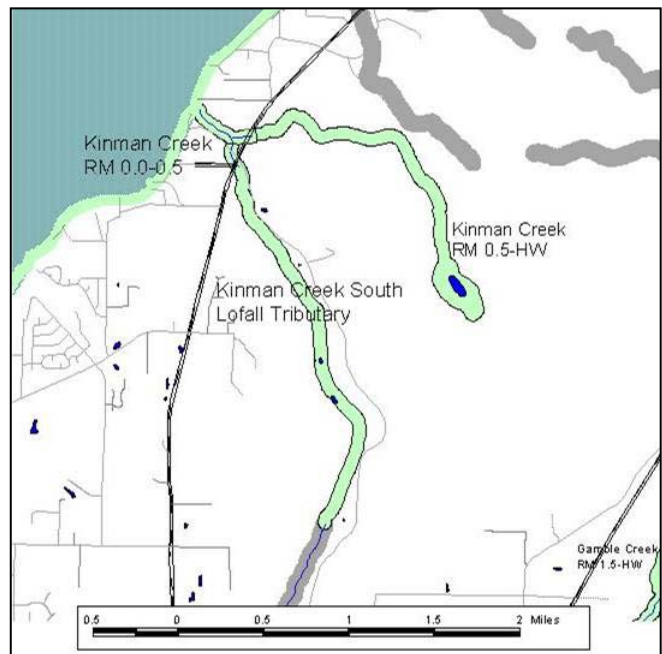
KINMAN CREEK

WRIA#:	15.0367
Project ID#:	KIN-NRC-01
Designation:	Lower Kinman Creek NRC
Classification:	B (64%)
Project ID#:	KIN-NRC-02
Designation:	Upper Kinman Creek NRC
Classification:	B (64%)
Project ID#:	KIN-NRC-03
Designation:	Lofall Creek Tributary NRC
Classification:	B (60%)
Project ID#:	KIN-CCA-01
Designation:	North Fork Kinman Creek CCA

Salmonid Diversity: Coho, Fall Chum,
Steelhead, & Cutthroat

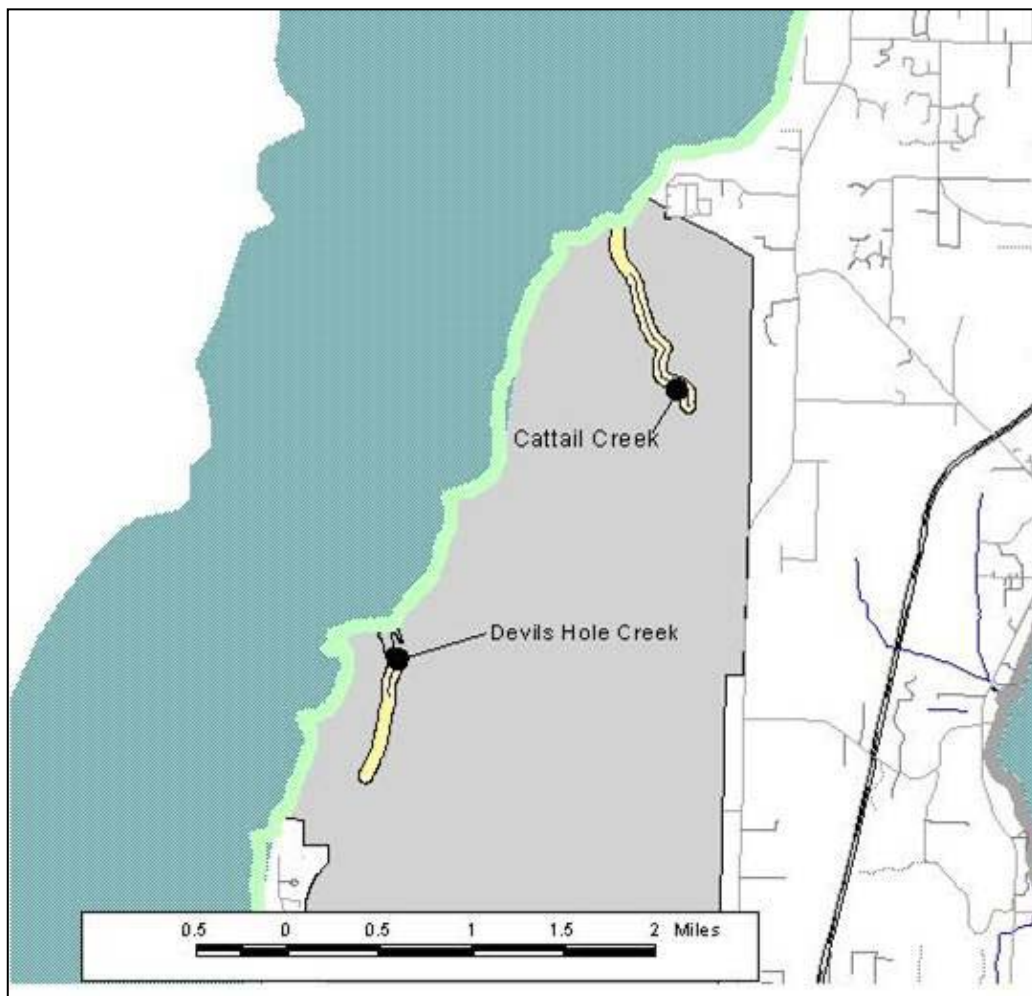
Description:

The Kinman Creek (KIN-NRC-01 & 02) nodal-riparian corridor (NRC) refugia areas encompass the entire mainstem of the creek, from the estuary to the headwaters. The Lofall Creek NRC (KIN-NRC-03) includes the entire length of this spring-fed tributary. Instream habitat and riparian conditions in Kinman Creek are generally good. Therefore, the Kinman Creek NRC areas are designated as class "B" refugia. The south fork tributary of Kinman Creek is designated as a critical contributing area (CCA) due to their ecological importance, but degraded habitat conditions. This tributary is important from a water quality and quantity perspective, as well as providing habitat for resident cutthroat. Kinman Creek watershed consists mainly of rural-residential land-use and is still mainly forested, especially in the headwaters. Kinman Creek supports runs of chum and coho salmon, as well as cutthroat trout. There is also limited utilization by steelhead trout reported in the lower mainstem.



BANGOR CREEKS

WRIA#: 15.0373
Project ID#: CAT-NRC-01
Designation: Cattail Creek NRC
Classification: C (60%)
WRIA#: 15.0374
Project ID#: DVH-NRC-01
Designation: Devils Hole Creek NRC
Classification: C (62%)
Salmonid Diversity: Coho, Chinook, Fall Chum, & Cutthroat
Description:



The Cattail Creek nodal-riparian corridor (NRC) refugia area encompasses both the mainstem and headwaters of Cattail Creek (CAT-NRC-01). The creek is currently blocked to anadromous salmonid access by a shoreline road and perched culverts. The creek is believed to have supported runs of chum and coho salmon, as well as cutthroat trout. Cattail Creek watershed is located on the east shore of Hood Canal and is completely within the boundary of the Bangor Naval Submarine Base. The University of Washington completed separate fish use and watershed mapping studies for this stream in 2001. Recommendations for habitat recovery have been assessed and documented. Included in these recommendations is the removal of the current shoreline road, replacing it with a causeway or bridge that would allow for restoration of the stream estuary and full access to all salmonid species.

The Devils Hole Creek nodal-riparian corridor (NRC) refugia area encompasses both the mainstem and headwaters of Devils Hole Creek (DVH-NRC-01). A fish ladder at the mouth of the creek is a barrier to most salmonids except under certain flow and tidal conditions. Instream habitat conditions in the creek are generally good and the Devils Hole Creek NRC is designated as a class "C" refugia. The creek supports runs of chum and coho salmon, as well as cutthroat trout. Devils Hole Creek watershed is located on the east shore of Hood Canal and is completely within the boundary of the Bangor Naval Submarine Base. The University of Washington and the WDFW completed separate fish use and watershed mapping studies for this stream in 2001. Recommendations for habitat recovery have been assessed and documented. Included in these recommendations is the removal of the current shoreline road and fish-way and replacing it with a causeway or bridge that would allow for restoration of the stream estuary.



LITTLE ANDERSON CREEK

WRIA#: 15.0377

Project ID#: LAN-FSW-01

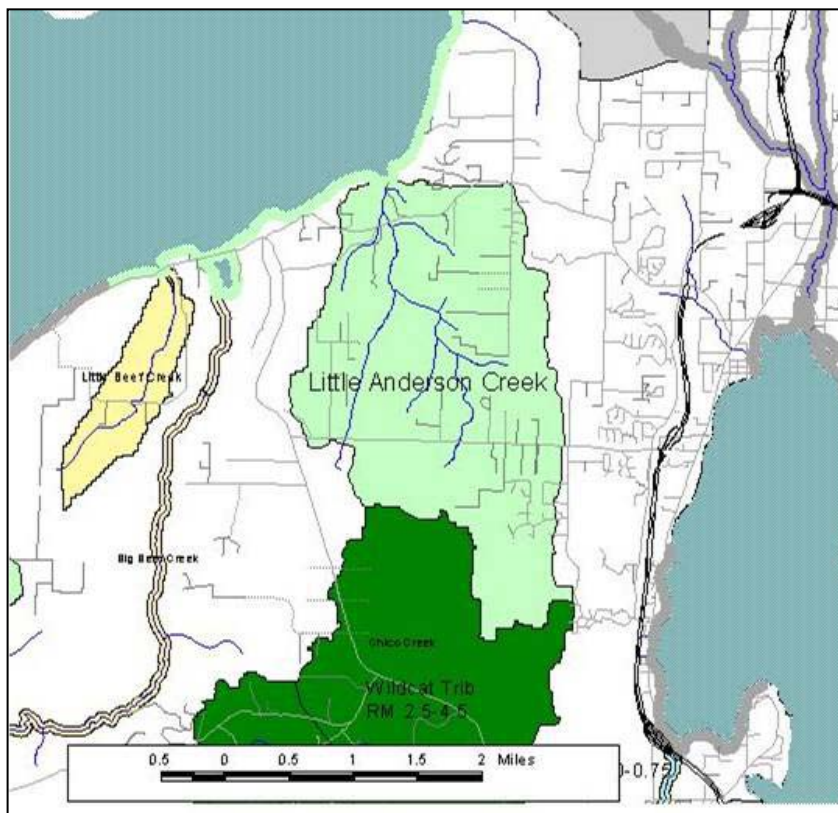
Designation: Little Anderson Creek FSW

Classification: B (64%)

Salmonid Diversity: Coho, Summer Chum, Fall Chum, Steelhead, & Cutthroat

Description:

The Little Anderson Creek focal sub-watershed (FSW) encompasses the entire stream system from the estuary to the headwaters (LAN-FSW-01). Landscape and instream habitat conditions in Little Anderson Creek are generally good. Little Anderson Creek (WRIA 15.0377) supports coho, fall-winter chum, steelhead, and cutthroat. There is also limited use by and steelhead reported in the lower mainstem. WDFW has trapped and enumerated downstream migrant salmonids from this basin since 1992. Little Anderson Creek is a small, low-gradient stream located near Lone Rock on Hood Canal. The Little Anderson Creek estuary is protected as an open-space county park and is in relatively natural condition, although past channel dredging and agricultural activity in the floodplain have left residual impacts. The culvert at Anderson Hill Road was a complete barrier to upstream salmon migration until replaced by a bridge during the summer of 2002. The long-term impact of this fish passage barrier will likely be felt for years to come, but with time, natal salmon populations should recover. The Little Anderson Creek watershed consists mainly of rural-residential land-use and is still mainly forested, especially in the headwaters, although development along the Newberry Hill Road corridor is beginning to impact the creek in the form of stormwater runoff and riparian encroachment. In spite of these impacts, the stream still retains much of its natural ecological structure and function. A moderately degraded riparian corridor, high stormflows, streambank erosion, lack of instream cover (LWD), low summer baseflows, and fine sediment deposition appear to be the major limiting factors for salmonid productivity.



BIG BEEF CREEK

WRIA#: 15.0389

Project ID#: BBF-NRC-01

Designation: Lower Big Beef Creek NRC

Classification: C (79%)

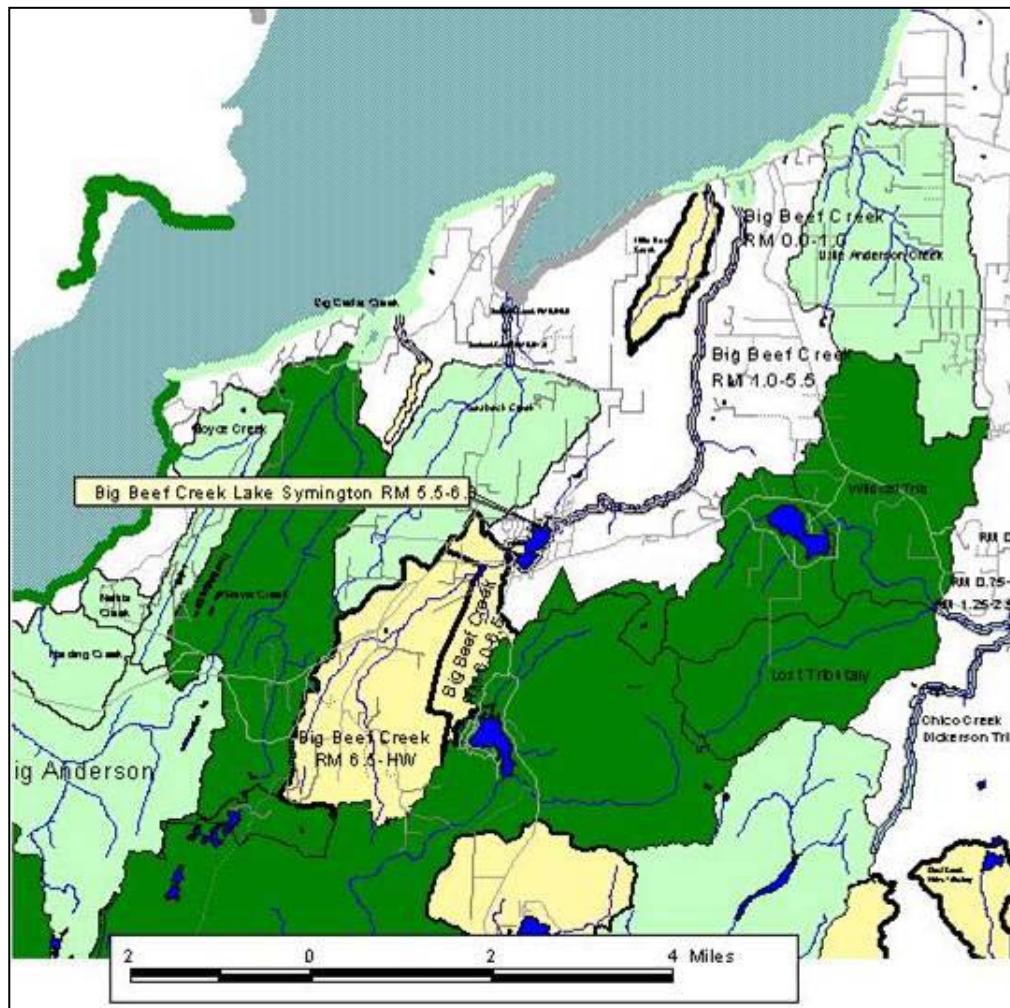
Project ID#: BBF-FSW-01

Designation: Upper Big Beef Creek FSW

Classification: C (81%)

Salmonid Diversity: Coho, Chinook, Summer Chum, Fall Chum, Steelhead, & Cutthroat

Description:



Big Beef Creek is the largest and most productive salmon stream on the northeast shore of Hood Canal. The Big Beef Creek refugia area includes the entire Big Beef stream system. Big Beef Creek is designated as a class “C” refugia, due to the presence of the UW research hatchery and WDFW counting weir near the mouth of the creek, as well as the Lake Symington Dam. Due to its relatively natural conditions and generally good salmonid habitat quality, the creek would likely be a class “A” refugia without these influences. The creek supports coho, fall/winter chum, steelhead, and cutthroat. A summer chum salmon reintroduction program is presently underway in this basin (WDFW and HCSEG). There is also limited use by chinook reported in the lower mainstem. The chinook run is hatchery stock released at the creek over many years as part of a supplementation program and wild production from adults spawning downstream of the study weir/or wild strays.

Big Beef Creek is a large, lowland stream located between the communities of Lone Rock and Seabeck on the east shore of Hood Canal. The Big Beef Creek watershed is still mainly forested, especially in the headwaters and lower mainstem. Pockets of rural and suburban development exist in the watershed, with the most significant development located in the central watershed, around Lake Symington (a man-made impoundment with a fish ladder). In spite of development pressures and logging activity in the watershed, the stream still retains a high level of natural ecological structure and function.

The Big Beef estuary has been modified to support a causeway for Seabeck Highway. The causeway at Big Beef has likely had a significant adverse impact on the natural structure and function of the lower creek and the estuary. These changes have likely had a significant impact on migrating salmonids, as well as juveniles rearing in the estuarine environment. Adult intertidal spawning may also have also been impacted by these changes. Both the bridge and associated fill have significantly degraded the estuary. The current causeway and bridge should be replaced with a raised causeway or bridge at the earliest opportunity. The creek was also channelized just upstream of the mouth during the late 1960s. However, the lower stream channel has, over the years, regained much of its natural properties. Recent removal of portions of the dike and road on the upper research station grounds will allow the stream to meander in a more natural manner. Portions of the historic estuarine salt marsh and freshwater wetland habitat have been lost due to erosion and sediment build up in the upper and lower estuary. There is an excellent opportunity to restore stream-riparian connectivity with the estuary. In addition, rehabilitation work will need to restore the lower floodplain and riparian corridor, as well as the historic delta in order to maximize the opportunity for full creek-tidal water exchange and circulation.

The University of Washington (UW) and Washington Department of Fish and Wildlife (WDFW) co-manage a fish-count weir and fisheries research station in the lower-most reach of the creek. The lower mainstem of the creek, from the estuary to just upstream of weir is typical of many lowland streams in that channelization and encroachment have restricted the natural channel migration zone (CMZ). The research facility, road, bridge construction and sediment aggradation near the mouth of the stream have decreased the quality and amount of the sub-estuarine habitat that is most immediately available to emigrating salmonid smolts. The fish counting weir tends to act as a channel constriction and sediment trap, affecting upstream channel conditions and sediment transport processes into the estuary. The lower mainstem channel has also been significantly impacted by upstream land-use practices, with concurrent reductions in survival in all salmonid life stages. The segment of stream from the mouth to Lake Symington is generally in good condition as far as instream and riparian habitat, although sediment inputs from upstream sources continue to impact this part of the creek. In particular, the Kid Haven Road area is known to be a significant problem. This lower segment is part of the Hood Canal Salmon Sanctuary. Although the riparian forest is generally quite natural, it is dominated by alders and is lacking in large conifers (cedars and hemlocks) and associated LWD recruitment is only moderate. Also illegal removal of LWD from the lower



stream in the mid-1980s and storm runoff from the Lake Symington area have reduced pool area of the lower stream.

Lake Symington is a large, shallow (man-made) impoundment that was built in an area of historic meandering stream channel, riparian wetlands, and beaver ponds located in the center of the watershed. Lake Symington has had a primary impact on the lower stream system. The temperature in Lake Symington in late summer is often too high for salmonid survival and impacts the stream for several kilometers downstream. The outlet dam has a fish ladder that allows coho, steelhead, and cutthroat to move upstream to spawn, but likely prevents most juvenile migration upstream and may inhibit downstream migration of juveniles under certain flow conditions. Exotic, warm-water fish are also present in the lake, which has created a predation problem for rearing and migrating juvenile salmonids. A long-term solution to this problem will likely include removal of the dam and lake or a significant modification of flow through the lake. The lake should be managed for water quality (temperature, nutrients, and FC) as well as exotic fish species and aquatic vegetation in a manner that protects salmonid habitat conditions in the lake and downstream.

Directly above the lake and downstream of the Holly Road crossing there is a segment of the creek that is a “hot-spot” for coho rearing. Habitat in this reach is relatively natural, with good instream LWD levels, and rearing pools. The upper Big Beef watershed consists of several headwater wetland and beaver pond complexes that offer outstanding coho rearing habitat. In addition, several small tributaries provide the majority of spawning reaches in the upper watershed. Extensive headwater wetlands tend to mitigate summer low-flow conditions that limit salmonid productivity in many Kitsap streams. This portion of the watershed also has hydrologic linkages to Stavis Creek and the Tahuya River. Several high-quality headwater wetlands still remain (most notable being Morgan Marsh), although rural residential development has begun to encroach upon these critical habitat areas. The upper Big Beef watershed should be a high-priority area for protection, enhancement, and rehabilitation.



LITTLE BEEF CREEK

WRIA#: 15.0399

Project ID#: LBF-FSW-01

Designation: Little Beef Creek FSW

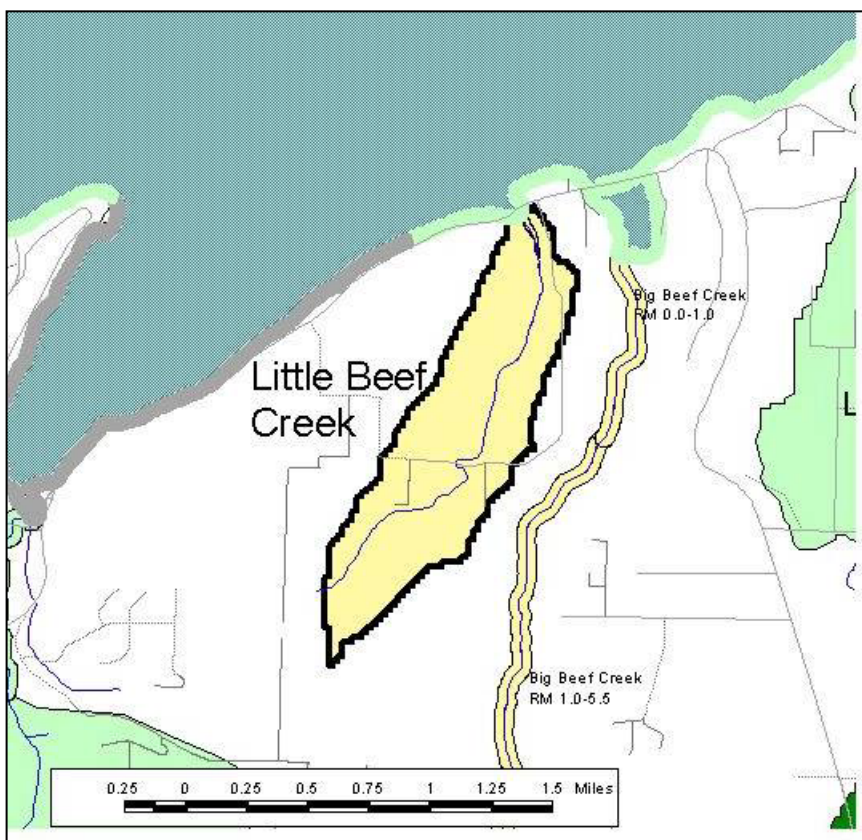
Classification: C (68%)

Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

The Little Beef Creek focal sub-watershed (FSW) encompasses the entire stream system from the estuary to the headwaters (LBF-FSW-01). Landscape and instream habitat conditions in the Little Beef Creek watershed are generally good, although no quantitative habitat assessments have been performed on the creek in recent years. The creek supports coho, fall-winter chum, and cutthroat. Little beef Creek FSW is designated as a class “C” refugia due to the lack of instream habitat data.

Little Beef creek is a small stream located just south of Big Beef Creek in central Hood Canal. Little is known about instream conditions in Little Beef Creek, but its estuary is known to provide refuge for juvenile chinook and chum salmon. The estuary is in a relatively natural condition and is a good candidate for protection. The Little Beef Creek watershed is still mainly forested, especially in the headwaters and adjacent to the lower mainstem. Pockets of rural development exist in the watershed. In spite of development pressures, the stream still retains a high level of natural ecological structure and function.



SEABECK CREEK

WRIA#:	15.0400
Project ID#:	SEA-NRC-01
Designation:	Lower Seabeck Creek NRC
Classification:	B (70%)
Project ID#:	SEA-NRC-02
Designation:	Middle Seabeck Creek NRC
Classification:	B (68%)
Project ID#:	SEA-FSW-01
Designation:	Upper Seabeck Creek FSW
Classification:	B (70%)
Project ID#:	SEA-CCA-01
Designation:	Seabeck Heights Tributary CCA
Salmonid Diversity:	Coho, Summer Chum, Fall Chum, Steelhead, & Cutthroat

Description:

Seabeck Creek supports coho, fall/winter chum, steelhead, and cutthroat. Juvenile chinook have been found rearing in the estuary of the creek. Limited survey data for summer chum indicate that the summer chum population has been extirpated. However, extreme low summer and fall flow conditions are not conducive to summer chum. Seabeck Creek is within close proximity to adjacent watersheds that have supported summer chum, making it a likely candidate for summer chum restoration. WDFW has operated a downstream migrant trap on this system since 1994 enumerating all downstream migrants.

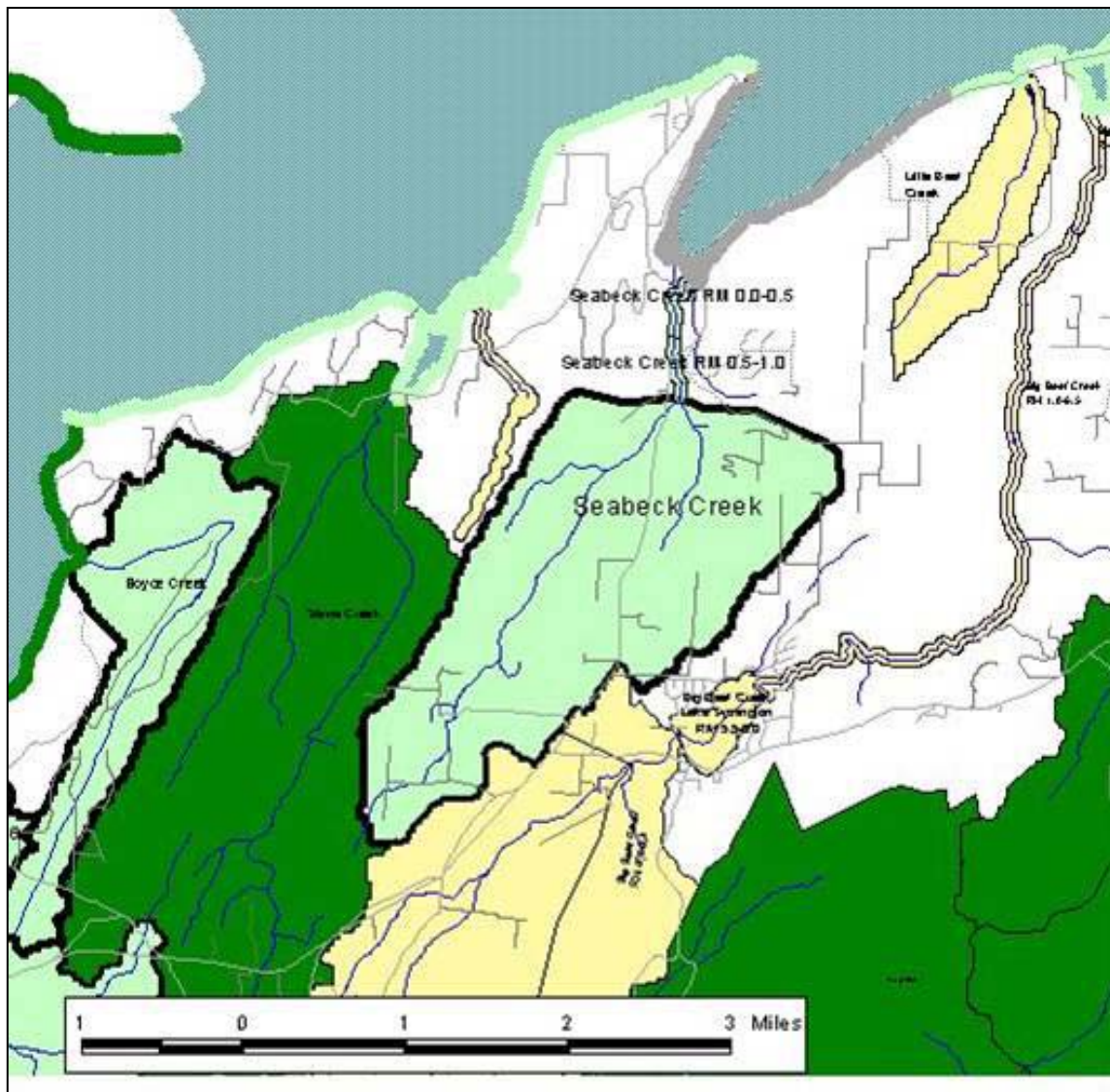
The lower Seabeck creek nodal-riparian corridor (NRC) refugia area (SEA-NRC-01) is designated as a class "B" refugia, as is the middle Seabeck Creek NRC (SEA-NRC-02). The Seabeck Heights tributary is designated as a critical contributing area (CCA) for water quality and quantity reasons. The upper watershed of Seabeck Creek is designated as a class "B" focal sub-watershed (FSW) refugia (SEA-FSW-01).

Seabeck Creek is a small, lowland stream located just south of the community of Seabeck on Hood Canal. Seabeck Creek watershed is still mainly forested, especially in the headwaters. Pockets of rural and suburban development exist in the watershed, with the most significant development located in the lower watershed. The lower watershed has been impacted by past land-use practices (timber harvest) and current development along the Seabeck Highway corridor. The Seabeck Heights development has had significant impacts on the tributary channel draining this sub-basin, including channel erosion, incision, and high flows. The upper watershed has little development except around



the community of Hite Center and along the Seabeck-Holly Road. The stream retains a relatively high level of natural ecological structure and function. Lack of high-quality LWD, extreme summer low flows, fragmentation of the riparian corridor, and fine sediment deposition are the major limiting factors for the creek.

Seabeck Creek originates in headwater wetlands located on a flat glacial till plain south of Hite Center Road. The mainstem then flows in a northerly direction in steep tightly confined ravines for approximately two miles. In the middle mainstem, the channel gradient moderates and is unconfined, eventually emerging into a relatively broad floodplain in the lower mainstem before flowing into a small estuary at Seabeck Bay. A small tributary to the east of the mainstem also feeds into the estuary. The Seabeck Creek estuary has a comparatively narrow delta that is heavily encroached upon by residential development on the east side. Associated bulkheads and armoring have also impacted the nearshore area. Although the Seabeck marina is located on the outer margins of the stream delta, the associated docks do not appear to directly impact the delta because of their position over deeper water. The Nick's Lagoon area of Seabeck Bay provides especially productive rearing habitat for juvenile salmonids.



BIG CEDAR CREEK

WRIA#: 15.0403

Project ID#: BAC-NRC-01

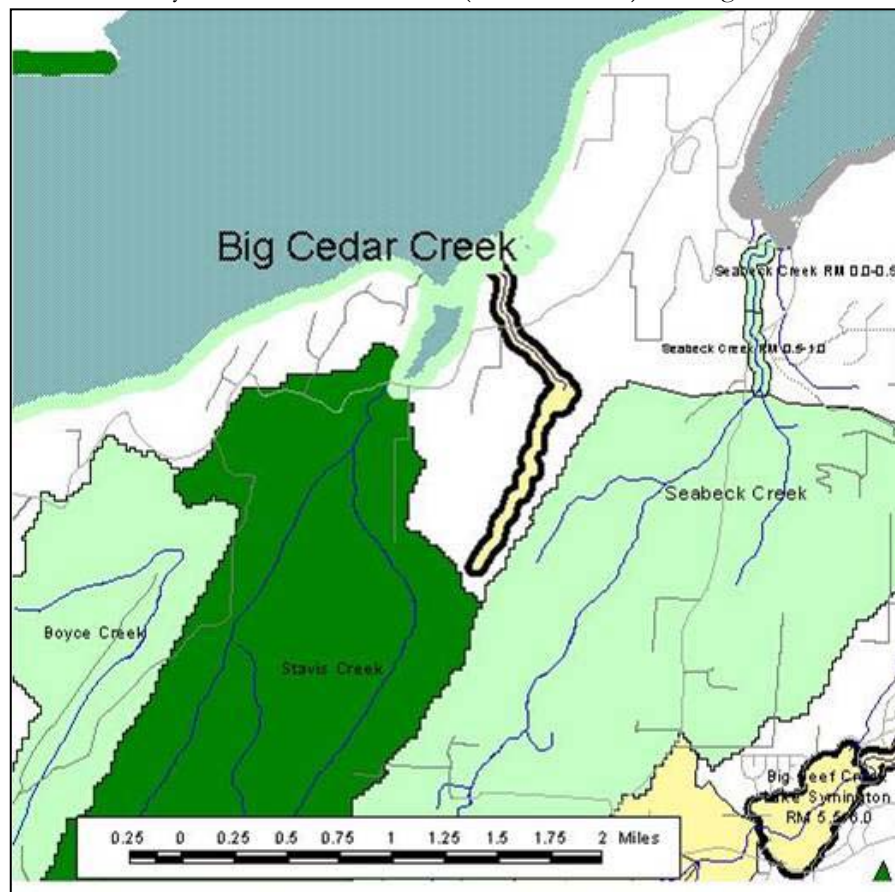
Designation: Big Cedar Creek NRC

Classification: C (74%)

Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

Big Cedar Creek is located on the east shore of Hood Canal near Stavis Creek. The watershed is mainly forested, with stands of mature conifers common, although past logging operations and roads have impacted the over quality of the forest. Riparian conditions are also generally good except where historic logging has encroached into the riparian corridor. The creek supports coho and chum salmon, as well as cutthroat trout. The creek flows into a high quality estuary lagoon just north of Stavis Bay. This area provides excellent rearing habitat for several species of salmonids, including migrating chinook. The Big Cedar Creek nodal-riparian corridor (NRC) refugia area encompasses the entire length of Big Cedar Creek from the headwaters to the estuary. Instream habitat conditions in the creek are believed to be fair to good, although no quantitative habitat assessments have been performed on the stream in recent years. For this reason, it (BAC-NRC-01) is designated as a class "C" refugia.



STAVIS CREEK

WRIA#:	15.0404
Project ID#:	STV-FSW-01
Designation:	Stavis Creek FSW
Classification:	A (83%)
Salmonid Diversity:	Coho, Summer Chum, Fall Chum, Steelhead, & Cutthroat

Description:

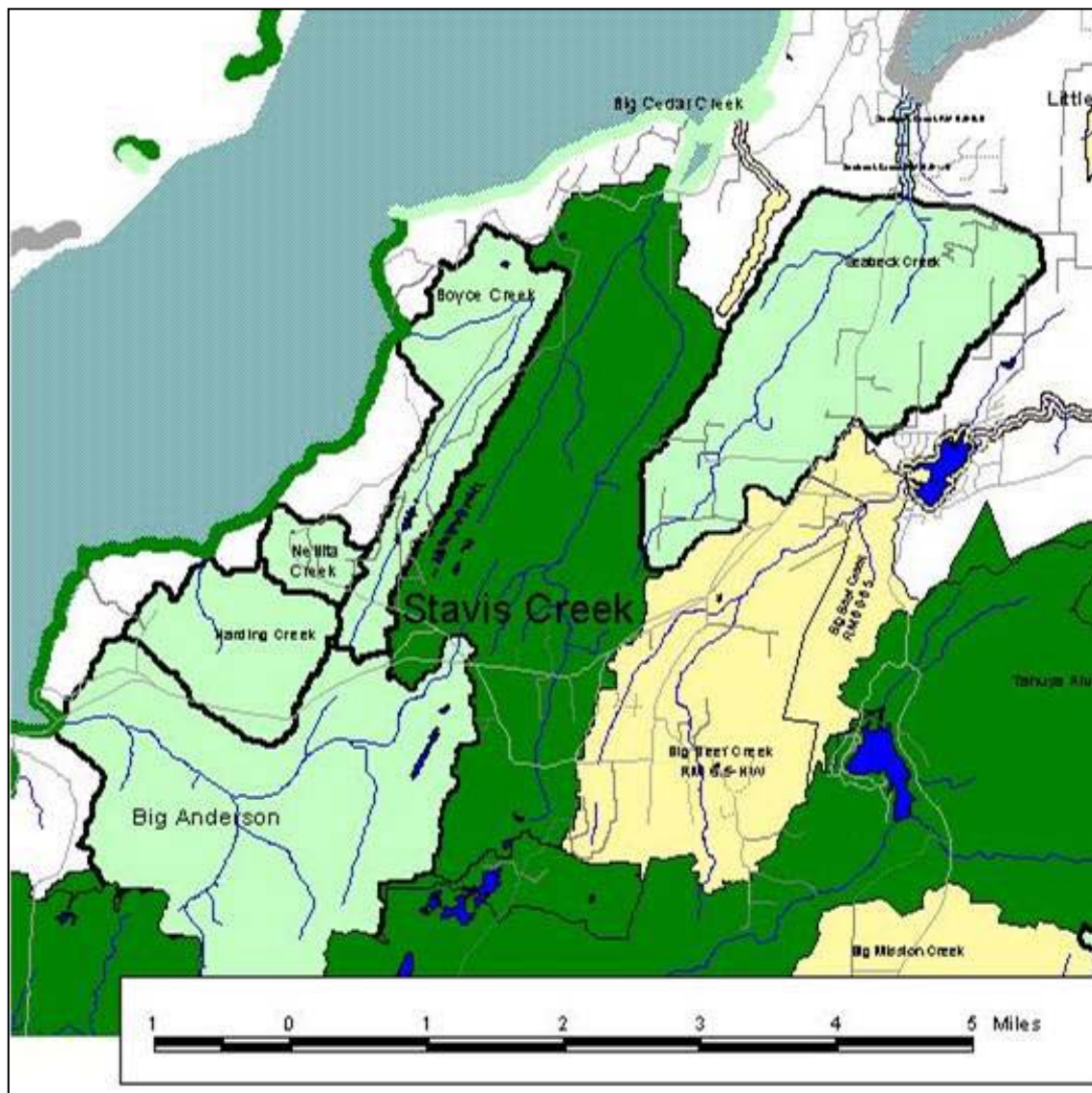
The Stavis Creek focal sub-watershed (FSW) encompasses the entire watershed from the estuary to the headwaters of both branches (STV-FSW-01). The Stavis Creek FSW contains some exceptional habitat and is designated a class “A” refugia. Stavis Creek supports coho, fall/winter chum, summer chum, steelhead, and cutthroat. There is also limited use by chinook reported in the estuary and lower mainstem of the creek. The chinook run is likely wild strays rather than a distinct population natal to Stavis Creek. Stavis Creek supports relatively healthy runs of coho and fall/winter chum. WDFW has operated a downstream migrant salmonid trap on this stream since 1994 documenting juvenile salmonid production. Juvenile chinook salmon have been found rearing in the estuary of the creek. Limited survey data for summer chum indicate that the summer chum population has been extirpated. However, suitable habitat and stable late summer flow conditions appear conducive to summer chum and it is probable that summer chum did historically occupy the watershed. Stavis Creek is also within close proximity to adjacent watersheds that have supported summer chum, making it a likely candidate for summer chum restoration.

Stavis Creek is a medium-sized, moderate-gradient stream located between Stavis and Scenic Beach on Hood Canal. The Stavis Creek watershed is mostly forested, with pockets of rural residential development throughout the sub-basin. The lower mainstem extends from the estuary to the main channel fork and includes the majority of the development in the watershed. This segment and a small left bank tributary contain most of the chum-spawning habitat. The existing development is confined to the upland area, leaving the riparian corridor relatively natural. However, the lower riparian zone is dominated by alders and is in need of conifers. In addition, several sediment sources and mass-wasting sites exist where logging roads encroach into the stream-riparian corridor. Commercial timber harvest is the dominant land-use in the watershed. For the most part, the stream retains a measure of its natural ecological structure and function. However, there is a lack of large woody debris (LWD) throughout the creek, especially stable, “key” pieces of LWD, removed illegally in the 1980s. Excessive landslides, streambank erosion, lack of instream cover, and fine sediment deposition appear to be the limiting factors for salmonid productivity in Stavis Creek. According to the Hood Canal Coordinating Council (HCCC), the Hood Canal Salmon Sanctuary (HCSS), and the Hood Canal Salmon Enhancement Group (HCSEG), the Stavis Creek watershed is a high-priority area for protection and restoration. A portion of the Stavis Creek watershed has been designated by WDNR as a Natural Area Preserve; WDNR is considering classifying much of the watershed as a Natural Resources Conservation Area. This may be some of the best mature forest remaining in this part of the peninsula.

Stavis Creek originates as two branches (east and west forks) in a series of beaver ponds, forested and emergent wetlands located on a flat glacial till plain. The forks then flow parallel to each other in a northeasterly direction in steep, tightly confined. Below the junction of the forks, the channel



gradient moderates and is unconfined, eventually emerging into a relatively broad floodplain before flowing into a relatively high quality estuary and Stavis Bay. The Stavis Bay estuary is the most unique feature of the local nearshore area. The estuary area provides migration, foraging, and rearing habitat for multiple salmonid species and other marine wildlife. This nearshore area also includes the estuaries of several low-order seasonal, coastal streams. The Stavis shoreline is only lightly impacted by development, with long stretches of natural nearshore habitat remaining intact. Protection efforts are underway within the Stavis creek estuary and should be extended to include other critical portions of the bay.

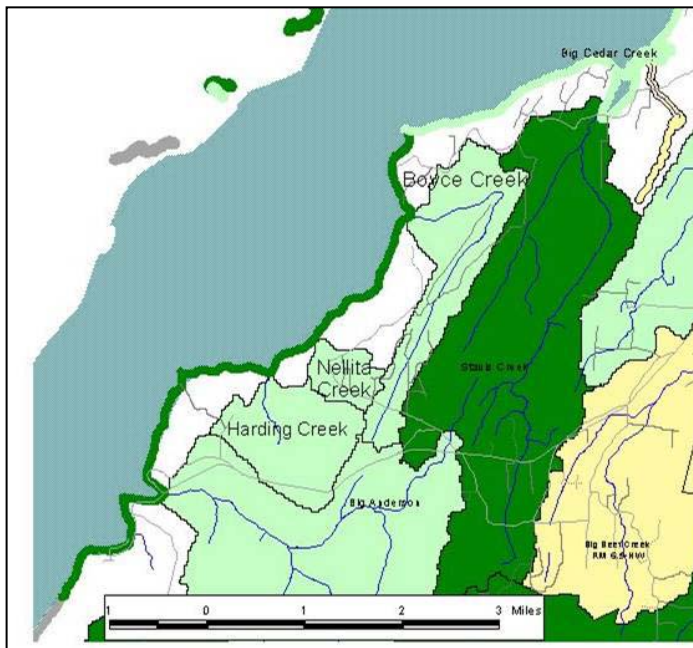


BOYCE, HARDING, AND NELLITA CREEKS

WRIA#:	15.0407
Project ID#:	BOY-FSW-01
Designation:	Boyce Creek FSW
Classification:	B (72%)
WRIA#:	15.0407a
Project ID#:	NEL-FSW-01
Designation:	Nellita Creek FSW
Classification:	B (73%)
WRIA#:	15.0408
Project ID#:	HRD-FSW-01
Designation:	Harding Creek FSW
Classification:	B (74%)
Salmonid Diversity:	Coho, Fall Chum, & Cutthroat

Description:

These focal sub-watersheds (FSW) encompass the entire watershed from the estuary to the headwaters of all three watersheds. All three of these FSW are designated as class “B” refugia. The creeks support coho, fall/winter chum, and cutthroat. Boyce, Harding, and Nellita watersheds are located on a remote section of the east shore of Hood Canal between Holly and Scenic Beach. All three of these basins are almost totally undeveloped and generally contain a high percentage of natural forest cover and intact riparian corridors, although past timber harvest activities have resulted in some significant problems, including landslides, road failures, and riparian encroachment. Instream salmonid habitat conditions in these creeks are generally good.



BIG ANDERSON CREEK

WRIA#:	15.0412
Project ID#:	BAN-FSW-01
Designation:	Big Anderson Creek FSW
Classification:	B (74%)
Salmonid Diversity:	Coho, Chinook, Summer Chum, Fall Chum, Steelhead, & Cutthroat

Description:

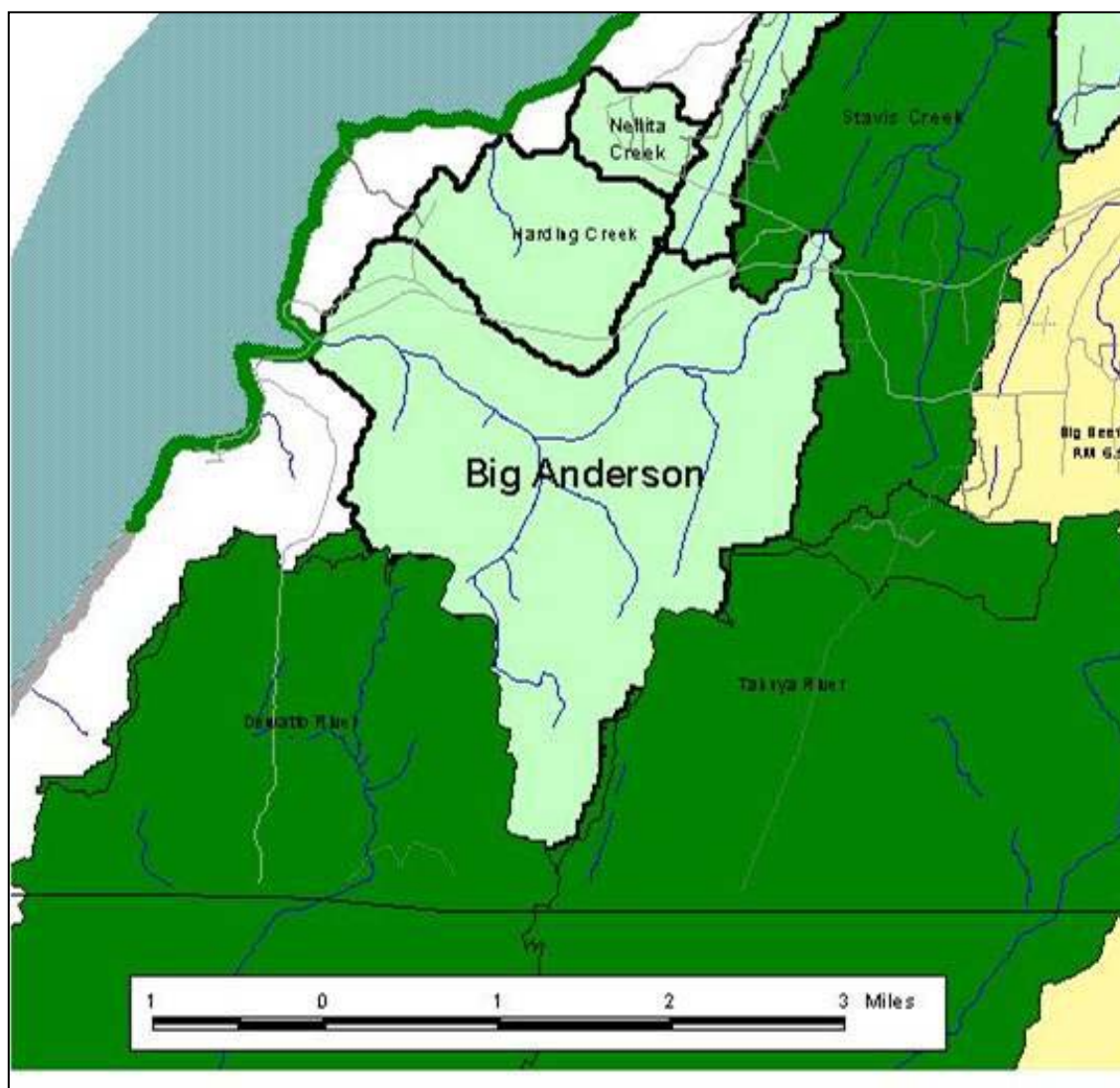
The Big Anderson Creek focal sub-watershed (FSW) encompasses the entire watershed from the estuary to the headwaters (BAN-FSW-01) and is designated as a class “B” refugia. Big Anderson Creek supports coho, fall/winter chum, summer chum, steelhead, and cutthroat. There is also limited use by chinook reported in the estuary and lower mainstem of the creek. The chinook run may be wild strays rather than a distinct population natal to the system, although the streamflow of Big Anderson Creek is normally adequate to support chinook spawning in the early fall. Juvenile chinook salmon have been found rearing in the estuary of the creek. Limited survey data for summer chum indicate that the summer chum population has been extirpated. However, suitable habitat and stable late summer flow conditions appear conducive to summer chum and it is possible that prior to current spawning surveys summer chum did historically occupy the watershed. Big Anderson Creek is also within close proximity to adjacent watersheds that have supported summer chum, making it a likely candidate for summer chum restoration. According to the Hood Canal Coordinating Council (HCCC) and the Hood Canal Salmon Enhancement Group (HCSEG), this watershed is a high-priority area for protection and restoration.

The stream enters Hood Canal approximately one-half mile north of the small community of Holly. Similar to other streams on the Kitsap Peninsula, Big Anderson Creek originates in headwater wetlands and flows through a confined ravine before flowing into a broad floodplain in the lower mainstem. The Big Anderson Creek estuary includes a large intertidal delta enclosed within Anderson Cove. The area around Big Anderson estuary was historically a seasonal fishing camp for local indigenous peoples, including both the Twana and S’Klallam Tribes. Land-use in the watershed is primarily commercial forestry operations conducted by several large landowners and the Washington Department of Natural Resources (WDNR). Logging in the Big Anderson most likely began in 1920’s continues to the present. The cumulative impact of these logging cycles is that riparian and instream habitat in the Big Anderson Creek watershed has been significantly degraded from natural conditions, especially the loss of channel complexity and LWD recruitment.

There is little development within the watershed, except for a few homesteads in the lower part of the watershed. A logging road built within the floodplain of the creek serves as an access road for these homes and significantly constrains the channel migration zone (CMZ) as well as limiting floodplain processes. This floodplain road should be removed and existing development access relocated. Aggradation and fine sediment deposition coming from the floodplain road and erosion in the upper watershed have negatively impacted the lower section of the creek. Although the riparian corridor is largely intact, the residual affects of logging encroachment and “stream-cleaning” have reduced the number of conifers in the riparian zone and left the instream habitat lacking in abundant LWD. The lower mainstem of the creek includes extensive off-channel wetlands, side channels, and



beaver ponds. This area of the creek provides excellent rearing habitat for a variety of salmonids, including coho, chum, chinook, and cutthroat. The middle mainstem of the creek has been channelized and there is some streambank armoring (“rip-rap”) present. Compared to historical levels, the channel is degraded, but is in comparatively better condition than many other watersheds in the region. However, the channel is also somewhat unstable, with high sediment loading and peak flow problems. It is expected that channel condition will deteriorate for at least the next several decades due to the poor riparian condition and mass wasting in the upper watershed, but will eventually recover. The upper watershed and tributaries of Big Anderson Creek are in much the same condition as the mainstem, although instream LWD tends to be slightly more plentiful and sediment deposition is not as severe a problem. However, the riparian corridors on tributary streams tend to be even narrower than the mainstem and also show a distinct lack of conifers, especially mature trees. This is likely a remnant of past logging practices. Several of the upper tributary channels are incised from logging road runoff as well. Coho utilize all of these tributary streams for spawning and rearing.



DEWATTO RIVER

WRIA#: 15.0420

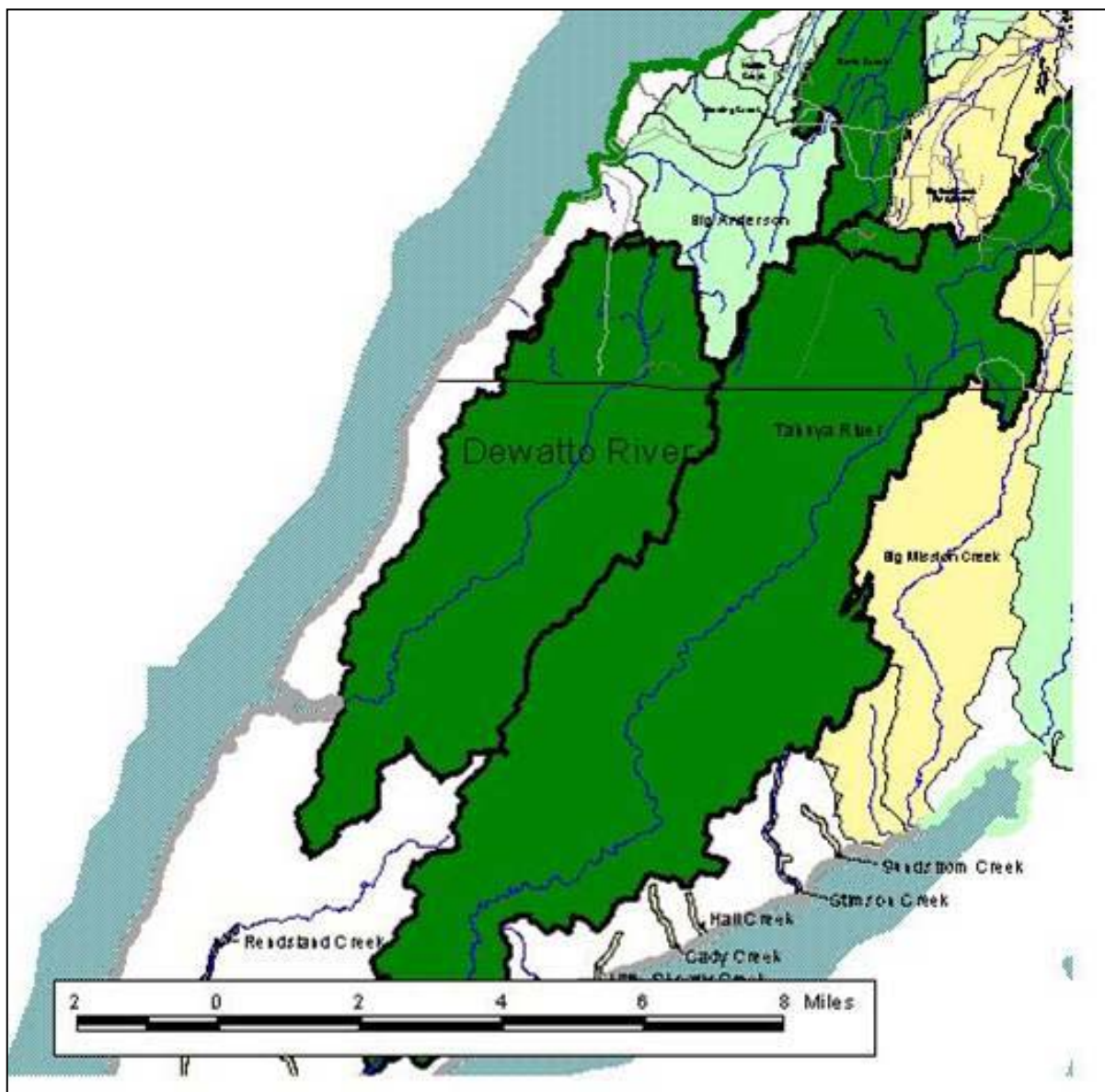
Project ID#: DWT-FSW-01

Designation: Dewatto River FSW

Classification: A (82%)

Salmonid Diversity: Coho, Chinook, Pink; Summer, Fall & Winter Chum; Steelhead, and Cutthroat

Description:



Although only the headwaters of the Dewatto River are located within Kitsap County, the entire watershed is designated as a class “A” focal sub-watershed (FSW) refugia area (DWT-FSW-01). The Dewatto River supports chinook, pink, coho, fall-winter chum, summer chum, steelhead, and cutthroat. The Dewatto River contains some of the best remaining salmonid habitat on the east side of Hood Canal.

Although the Dewatto is by no means pristine, it is in excellent condition relative to other Puget Sound lowland streams. The watershed is sparsely developed, with timber harvest as its primary land-use. Land cover in the watershed is still dominated by native coniferous forest and the riparian corridors are generally in a relatively natural condition, although the cumulative effects of multiple timber harvest cycles and WDFW “stream-cleaning” operations likely had an impact on forest maturity and large woody debris (LWD) recruitment potential.

The chum salmon populations of the Dewatto River are recognized by WDFW as unique. Three distinct stocks of chum utilize the stream at different times of the year and spawn in different segments of the river. The earliest run (summer chum) typically enters the river in late September and spawns in the lower part of the river. A second run (fall chum) enters in November and spawns primarily in the lower river tributaries and middle mainstem areas. The third run (winter chum) enters the Dewatto in the December-January timeframe and spawns in the inter-tidal zone and lower mainstem of the river. There appears to be little overlap in these runs. It is also likely that Dewatto River supported a wild chinook run, owing to the typically strong late summer flows and the proximity of the creek to other chinook streams in Hood Canal (i.e. Union, Skokomish, Tahuya, Dosewallips, Hamma Hamma, and Duckabush Rivers). Steelhead, cutthroat, and coho utilize the many tributary creeks for spawning and its headwater wetland areas for rearing. Pink salmon are also known to occasionally utilize the lower Dewatto River.

Overall habitat quality in the Dewatto River was rated as good and in a state of recovery from historic logging practices, especially in comparison with adjoining watersheds (PNPTC, 2000). The estuary is an example of a high quality system that provides abundant transitional areas for adults and rearing habitat for juveniles.



RENDSLAND CREEK

WRIA#: 15.0439

Project ID#: RND-NRC-01

Designation: Rendsland Creek NRC

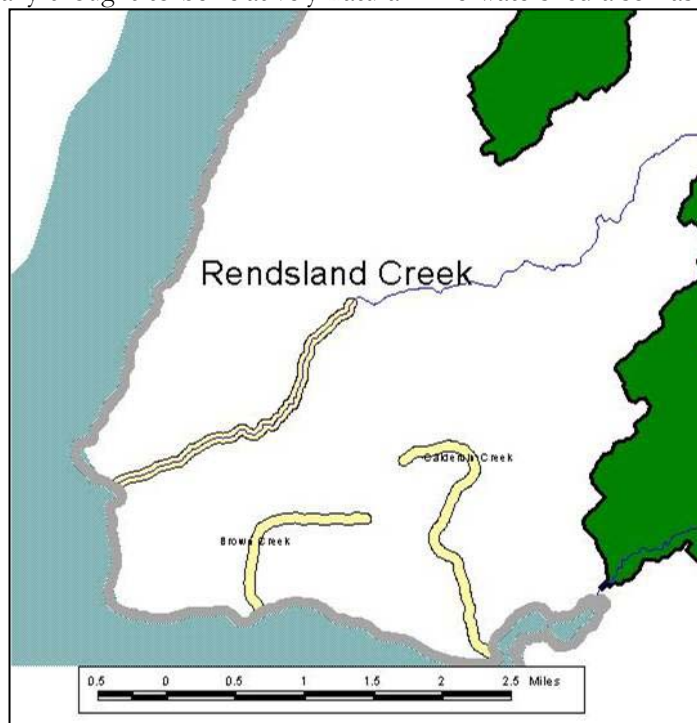
Classification: C (75%)

Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

The Rendsland Creek nodal-riparian corridor (NRC) refugia area includes the entire watershed from the estuary to the headwaters (RND-NRC-01) and is designated as a class “C” refugia due to lack of habitat data. Rendsland Creek supports coho, fall/winter chum, summer chum, steelhead, and cutthroat. Limited use by steelhead has also been reported. The watershed is sparsely developed, with timber harvest as its primary land-use. Land cover in the watershed is still dominated by native coniferous forest and the riparian corridors are generally in a relatively natural condition, although the cumulative effects of multiple timber harvest cycles have had an impact on forest maturity and large woody debris (LWD) recruitment potential. Rendsland Creek coho mainly utilize its tributary creeks for spawning and its headwater wetland areas for rearing. Historically, summer chum salmon may have occasionally utilized the lower segment of the creek. Rendsland Creek has extensive headwater wetland complexes. Major tributary streams include Lone Duck, Tee Lake, Wild Berry, and Homestead Creeks.

Little is known about the Rendsland Creek watershed, but the stream is generally low-moderate gradient with no impassable barriers to salmonid migration in the lower watershed. Riparian conditions and upland forests are generally thought to be relatively natural. The watershed also has intact headwater wetland/lakes that provide year-round flow to downstream reaches, although the creek often goes hyporheic in late summer in the lower reaches. The estuary has been significantly impacted by the encroachment of shoreline development. Aside from the common development-related stream-riparian impacts in the lowest reaches of the stream and in the estuary, Rendsland Creek has generally good instream salmonid habitat throughout the watershed, although no quantitative habitat assessments have been conducted on the creek in recent years. The limiting factor is intermittent stream flows during the summer months, making rearing habitat less than optimal.



CALDERVIN CREEK

WRIA#: 15.0445

Project ID#: CLD-NRC-01

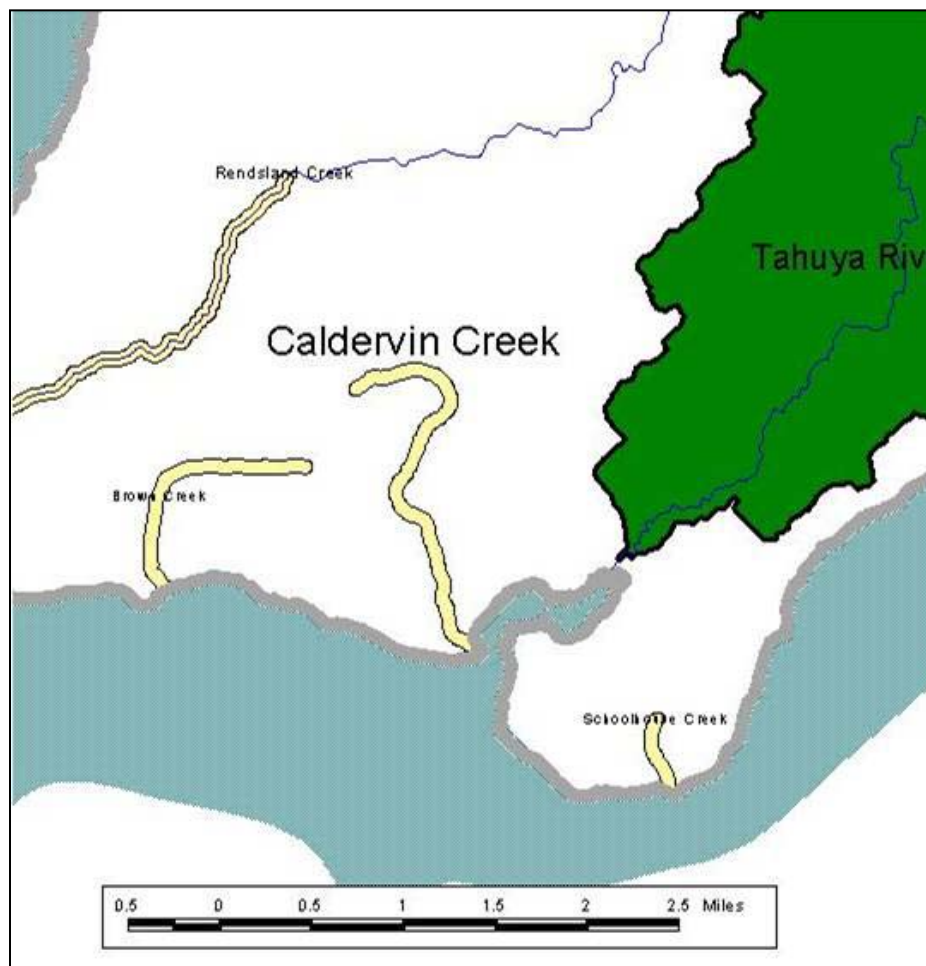
Designation: Caldervin Creek NRC

Classification: C (75%)

Salmonid Diversity: Coho, Fall Chum, & Cutthroat

Description:

The Caldervin Creek nodal-riparian corridor (NRC) refugia area includes the entire watershed from the estuary to the headwaters (CLD-NRC-01). The Caldervin NRC is designated as a class "C" refugia due to lack of habitat data. The watershed is mainly forested, although past logging operations and residential development have impacted the over quality of the forest. Riparian conditions are also generally good except where logging and development has encroached into the riparian corridor. The creek supports coho and chum salmon, as well as cutthroat trout and perhaps limited steelhead. Little is known about habitat conditions in the creek. It is recommended that habitat and salmonid utilization surveys be conducted on the creek.



TAHUYA RIVER

WRIA#: 15.0446

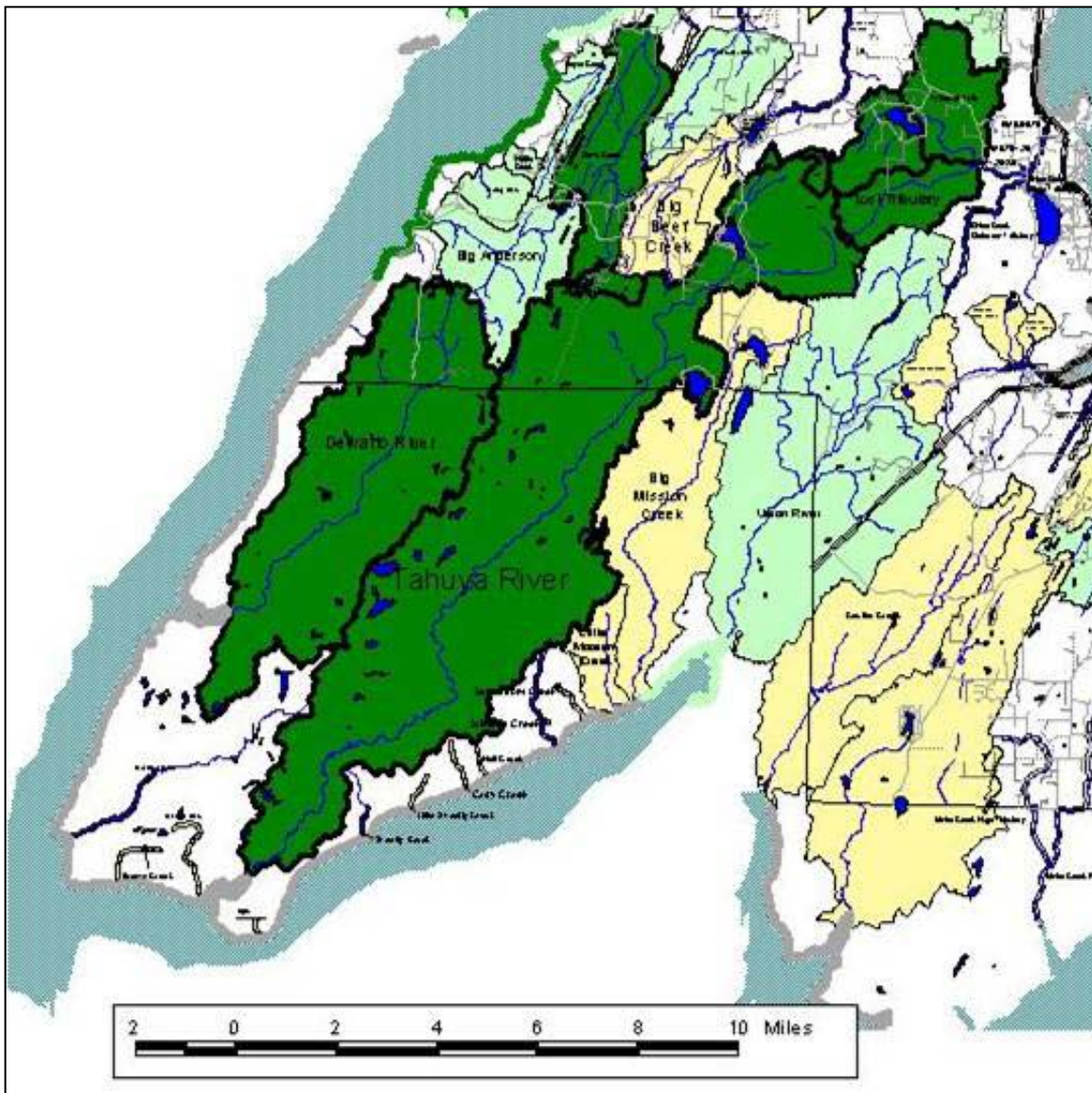
Project ID#: THY-FSW-01

Designation: Tahuya River FSW

Classification: A (78%)

Salmonid Diversity: Coho, Chinook, Pink; Summer, Fall, and Winter Chum; Steelhead, and Cutthroat

Description:



Although only the headwaters of the Tahuya River are located within Kitsap County, the entire watershed is designated as a class “A” focal sub-watershed (FSW) refugia area (THY-FSW-01). The Tahuya River supports chinook, pink, coho, fall-winter chum, summer chum, steelhead, and cutthroat. The chum populations of the Tahuya are recognized by WDFW as unique (WDFW, 1975). Three distinct stocks of chum utilize the stream at different times of the year and spawn in different segments of the river. The earliest run (summer chum) typically enters the river in late September and spawns in the lower part of the river. A second run (fall chum) enters in November and spawns primarily in the lower river tributaries and middle mainstem areas. The third run (winter chum) enters the Tahuya in the December-January timeframe and spawns in the upper mainstem of the river. There appears to be little overlap in these runs (WDFW, 1975). It is also likely that Tahuya River supported a wild chinook run, owing to the typically strong late summer flows and the proximity of the creek to other chinook streams in Hood Canal (i.e. Union, Skokomish, Dewatto, Dosewallips, Hamma Hamma, and Duckabush Rivers). Tahuya River coho mainly utilize its many tributary creeks for spawning and its headwater wetland areas for rearing. Coho salmon also spawn and rear in the Tahuya mainstem. Pink salmon are also known to occasionally utilize the lower Tahuya River.

Although the Tahuya is by no means pristine, it is in good condition relative to other Puget Sound lowland streams. The Tahuya River watershed land-use is dominated by rural development and industrial forestry. The freshwater habitat overall is in good condition with the majority of the impacts occurring from riparian encroachment by homes and farms in the floodplain as well timber harvest impacts. The cumulative effects of multiple timber harvest cycles and WDFW “stream-cleaning” operations have also had an impact on forest maturity and large woody debris (LWD) recruitment potential. The upper watershed has numerous headwater wetland complexes, providing extensive rearing habitat. It is likely that these headwater wetland areas are hydrologically linked to Big Beef Creek and Chico Creek. Lake Tahuya is a former wetland that has been modified (outlet control structure) to support shoreline development and recreational use. This alteration of hydrologic regime has significantly impacted coho runs and limits the use of upstream spawning and rearing habitat. Correcting this serious problem should be a high priority. The Tahuya River tributaries, which are a major source of coho production in the watershed, include Jiggs, Maggie, Pickers, Erdman, Howell, Little Tahuya, Andy’s, Haven, Blacksmith, Buffoon, Panther, Gold, Grata, and Tin Mine Creeks. The last five contain high-quality headwater wetland complexes. In general, the instream habitat currently appears to be in recovery.

The entire watershed is worthy of special protection based on its relatively natural conditions and the unique salmonid populations supported. Forest retention, riparian protection, and limitations on development will be key to protecting the watershed. The forested mainstem floodplain, combined with the generally high-quality, low gradient tributaries and headwater wetlands, makes the Tahuya River watershed one of the top conservation priorities in the Hood Canal watershed. The upper Tahuya watershed lies within Kitsap County and the lower watershed within Mason County. This will therefore require joint stewardship in support of any conservation efforts.

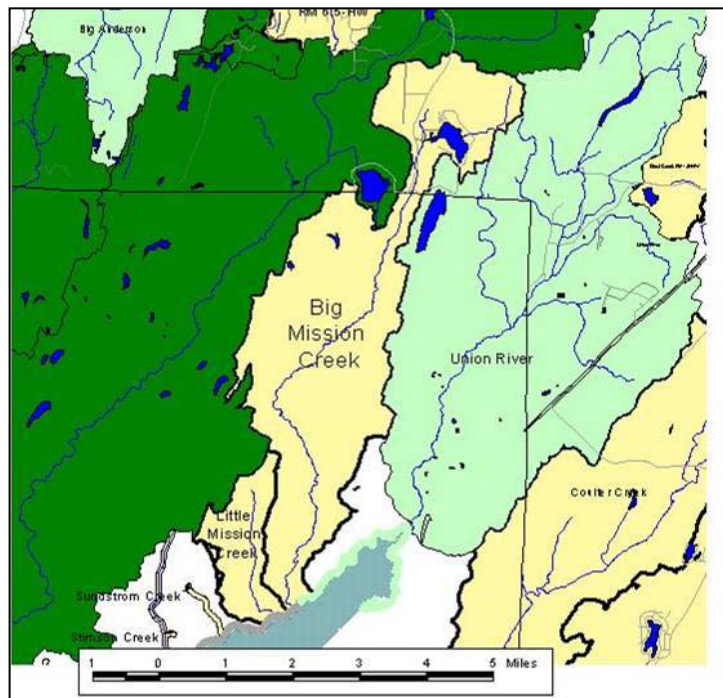


LITTLE AND BIG MISSION CREEKS

WRIA#:	15.0493
Project ID#:	LMS-FSW-01
Designation:	Little Mission Creek FSW
Classification:	C (83%)
WRIA#:	15.0495
Project ID#:	BMS-FSW-01
Designation:	Big Mission Creek FSW
Classification:	C (80%)
Salmonid Diversity:	Coho, Fall Chum, Steelhead, & Cutthroat

Description:

These focal sub-watersheds (FSW) encompass the entire watershed from the estuary to the headwaters of both Little and Big Mission Creeks. Both of these FSW are designated as class “C” refugia due to lack of quantitative habitat assessment data. The creeks support coho, fall/winter chum, and cutthroat. There is also limited use by chinook reported in the lower mainstem of both creeks. Historically, these streams probably supported summer chum salmon as well. Early returning “fall” chum salmon that have been seen in recent years may be a remnant of the summer chum population. Surprisingly for its size, Little Mission Creek often is more productive than its larger brother. Instream salmonid habitat conditions in these creeks are believed to be generally good.



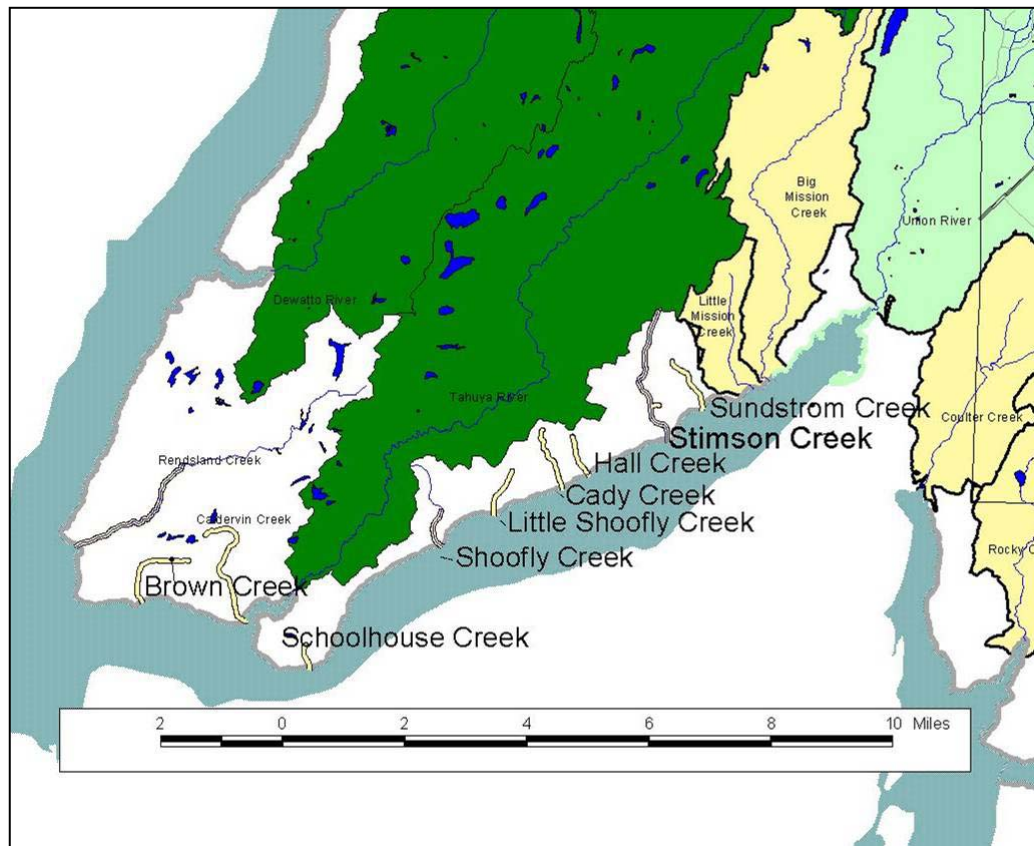
MASON COUNTY HOOD CANAL FRESHWATER REFUGIA

BROWN, STIMSON, SCHOOLHOUSE, SUNDSTROM, LITTLE SHOOFLY, HALL,
SHOOFLY, AND CADY CREEKS

Description:

There are numerous small, independent stream-watersheds located in Mason County, along the northern shoreline of Hood Canal. Several of these small streams support salmonid populations, mainly coho and chum salmon. Almost all also have sea-run and/or resident populations of cutthroat trout and some may support limited numbers of steelhead trout. These small streams may provide important refugia habitat from disturbances in adjacent larger creeks or river systems, but little is known about their salmonid populations or how important these creeks are to the overall Hood Canal ecosystem. Undoubtedly, these streams and their estuaries provide transitional habitat for salmonids from their own watershed, but some may also provide migratory refuge areas for fish moving along the Hood Canal nearshore zone.

Salmonid Diversity: Coho, Fall Chum, & Cutthroat



UNION RIVER

WRIA#:	15.0503
Project ID#:	UNR-FSW-01
Designation:	Union River FSW
Classification:	B (72%)
Salmonid Diversity:	Coho, Chinook, Pink, Summer Chum, Fall & Winter Chum, Steelhead, & Cutthroat

Description:

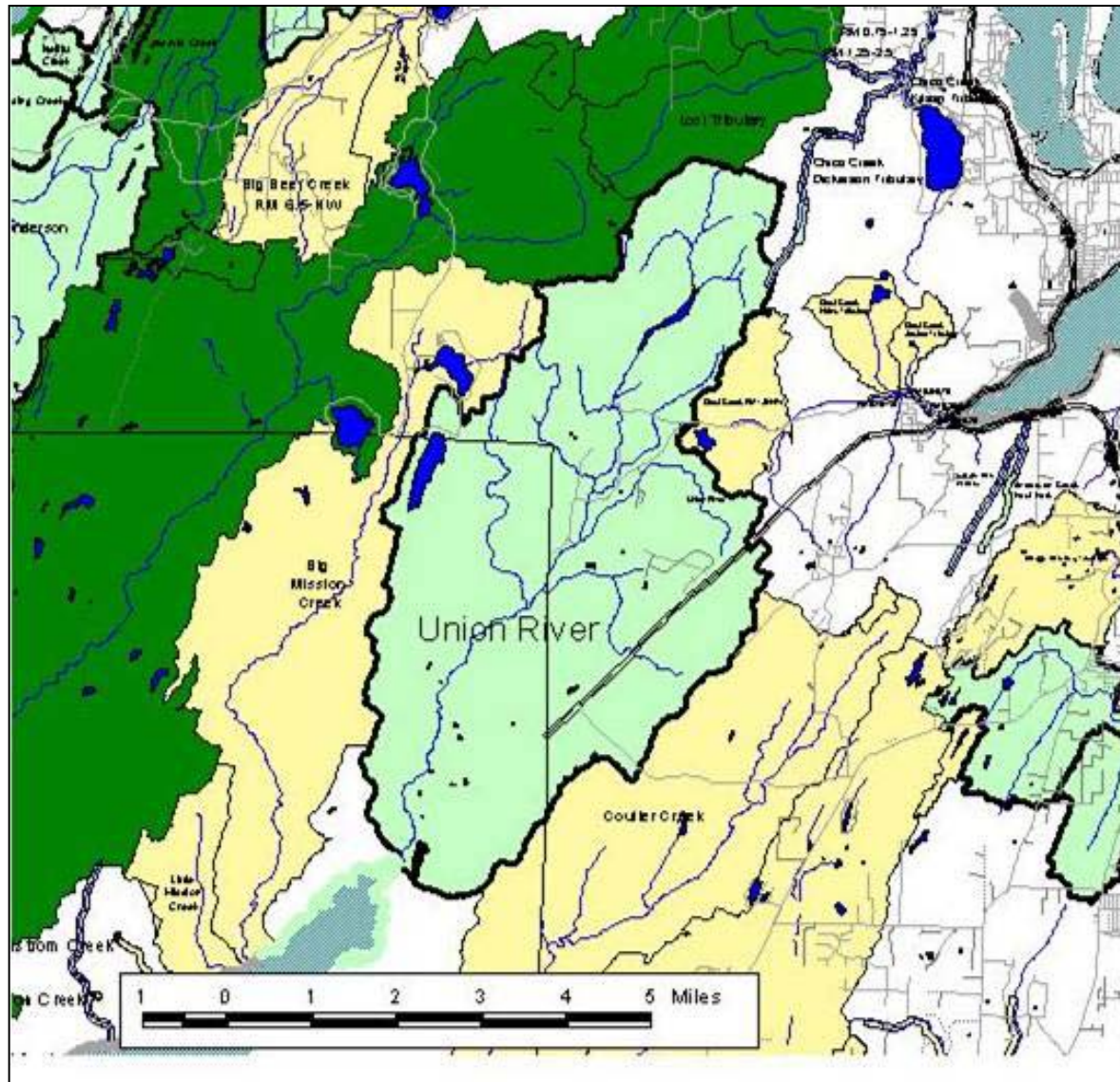
Although only the headwaters of the Union River are located within Kitsap County, the entire watershed is designated as a class “B” focal sub-watershed (FSW) refugia area (UNR-FSW-01). The Union River supports chinook, pink, coho, fall-winter chum, summer chum, steelhead, and cutthroat. The Union River was recommended by the American Fisheries Society for “Aquatic Diversity” status in 1975, although the cumulative impacts of development, logging, and agriculture have significantly degraded the watershed since that time. Rural-suburban residential development, small farms, and industrial forestry currently dominate the Union watershed. The freshwater habitat overall is in good-fair condition with the majority of the impacts occurring from encroachment by homes and farms in the floodplain and dikes and agricultural activities and modifications in the sub-estuary and intertidal areas. The Union River is the only basin on the Kitsap Peninsula to currently have a viable native population of summer chum salmon.

The instream habitat and riparian conditions are generally fair to good. The lower stream corridor has been impacted by development in and around Belfair. The lower Union River (below the falls) lies within a broad floodplain valley and historically contained extensive off-channel, wetland habitat until residential development began encroaching on the CMZ. The east fork of the Union is generally more impacted than the west, due mainly to the influence of development along the SR-3 highway corridor. Major tributaries include Hazel, Bear, Everson, and Courtney creeks. The upper watershed has numerous headwater wetland complexes, providing extensive rearing habitat. McKenna Falls is a natural barrier to fish passage upstream, and is located just downstream of the Union Reservoir dam. The City of Bremerton as a water supply manages this river impoundment.

Currently, Belfair and much of the lower Union River watershed is designated as an Urban Growth Area (UGA) in the Mason County Comprehensive Plan. In addition, the upper watershed is part of the City of Bremerton UGA. The Union River estuary and most of the nearshore marine areas in Hood Canal adjacent to the Union River also have an urban designation under the Mason County Shoreline Master Program. The shoreline is significantly impacted, especially around Belfair, except around the Theler Wetland Preserve and the Klingel wetland complex. The County and other entities should consider acquiring undeveloped estuarine and marine shorelines for permanent protection or acquiring conservation easements from willing landowners. Both existing diked and breached-dike estuarine wetlands are likely limiting the potential for maximal ecological integrity within the estuarine delta. Restoration action in the form of dike breaching, with setback dikes to protect public and private property from flood damage if necessary, and ditch in-filling should be considered as the most proactive approaches to recovering critical summer chum habitat in this sub-estuary. There is a need to evaluate the effectiveness of dikes and the relative impacts on the tidal and freshwater environments and look for restoration opportunities with the landowners. The Hood



Canal Salmon Enhancement Group (HCSEG) has been active in enhancement work in the Union watershed. All culverts suspected of being migration barriers have been inventoried and corrected.

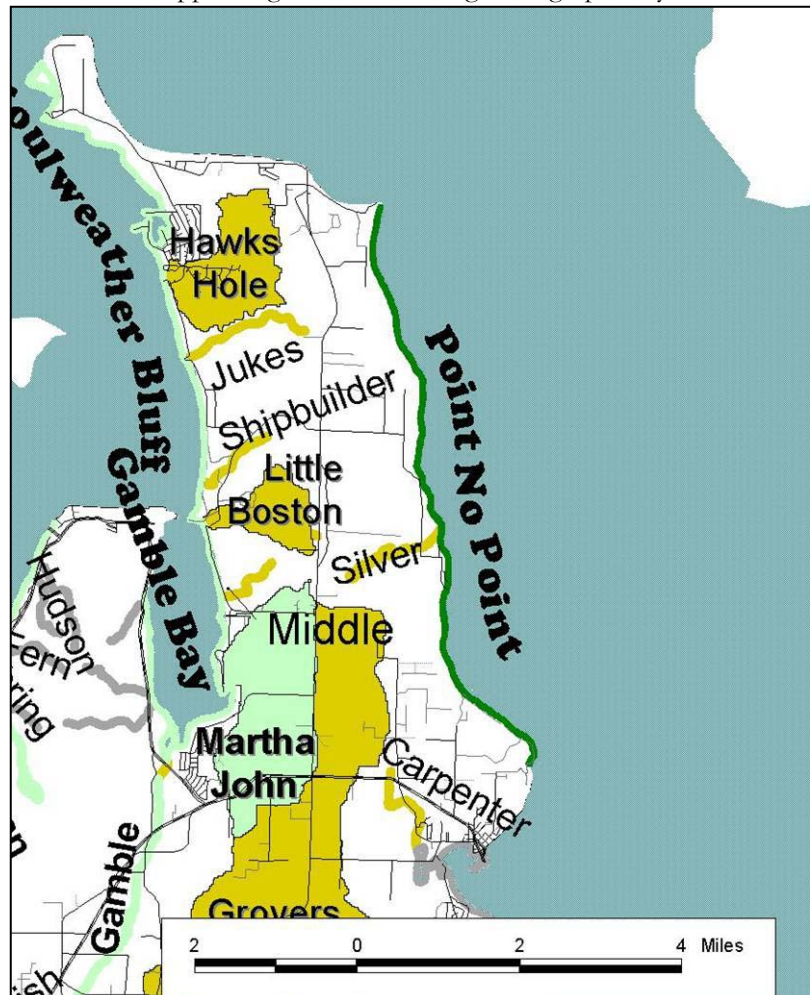


NEARSHORE-ESTUARINE REFUGIA

POINT-NO-POINT NEARSHORE

Project ID#: PNP-NSE-01**Designation:** Point-No-Point NSE**Classification:** A (83%)**Salmonid Diversity:** Coho, Chum, Chinook, & Cutthroat**Description:**

The Point-No-Point (PNP) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. The PNP NSE includes gravel beaches, mud flats, sand spits, and saltwater marshes that provide important nursery habitat for multiple species of salmonids. Much of the shoreline of the PNP NSE area remains forested and nearshore areas remain largely unaltered by human activity. This area represents some of the highest quality nearshore habitat remaining the western side of upper Puget Sound, making it a high priority for conservation in the future.



HOLLY NEARSHORE

Project ID#: HOL-NSE-01

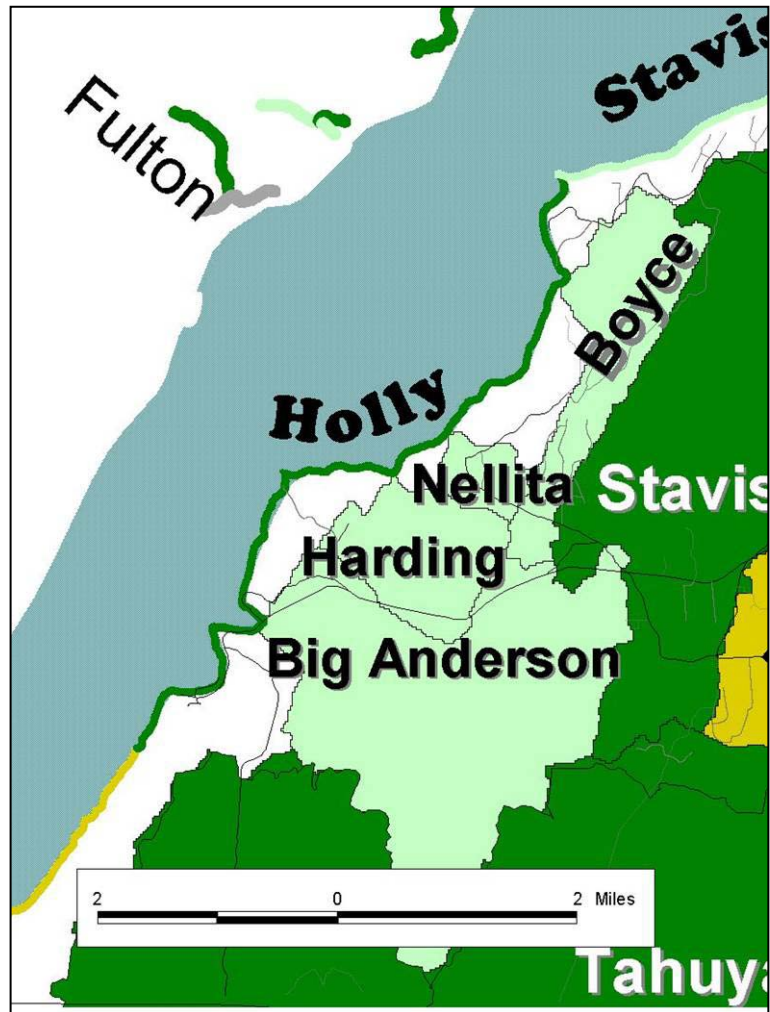
Designation: Holly NSE

Classification: A (79%)

Salmonid Diversity: Coho, Chum, Summer Chum, Chinook, & Cutthroat

Description:

The Holly (HOL) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Much of the shoreline of this NSE area remains forested and nearshore areas remain largely unaltered by human activity. This area represents some of the highest quality nearshore habitat remaining on the eastern side of Hood Canal, making it a high priority for conservation in the future.



MURDEN COVE ESTUARY

Project ID#: MUR-NSE-01

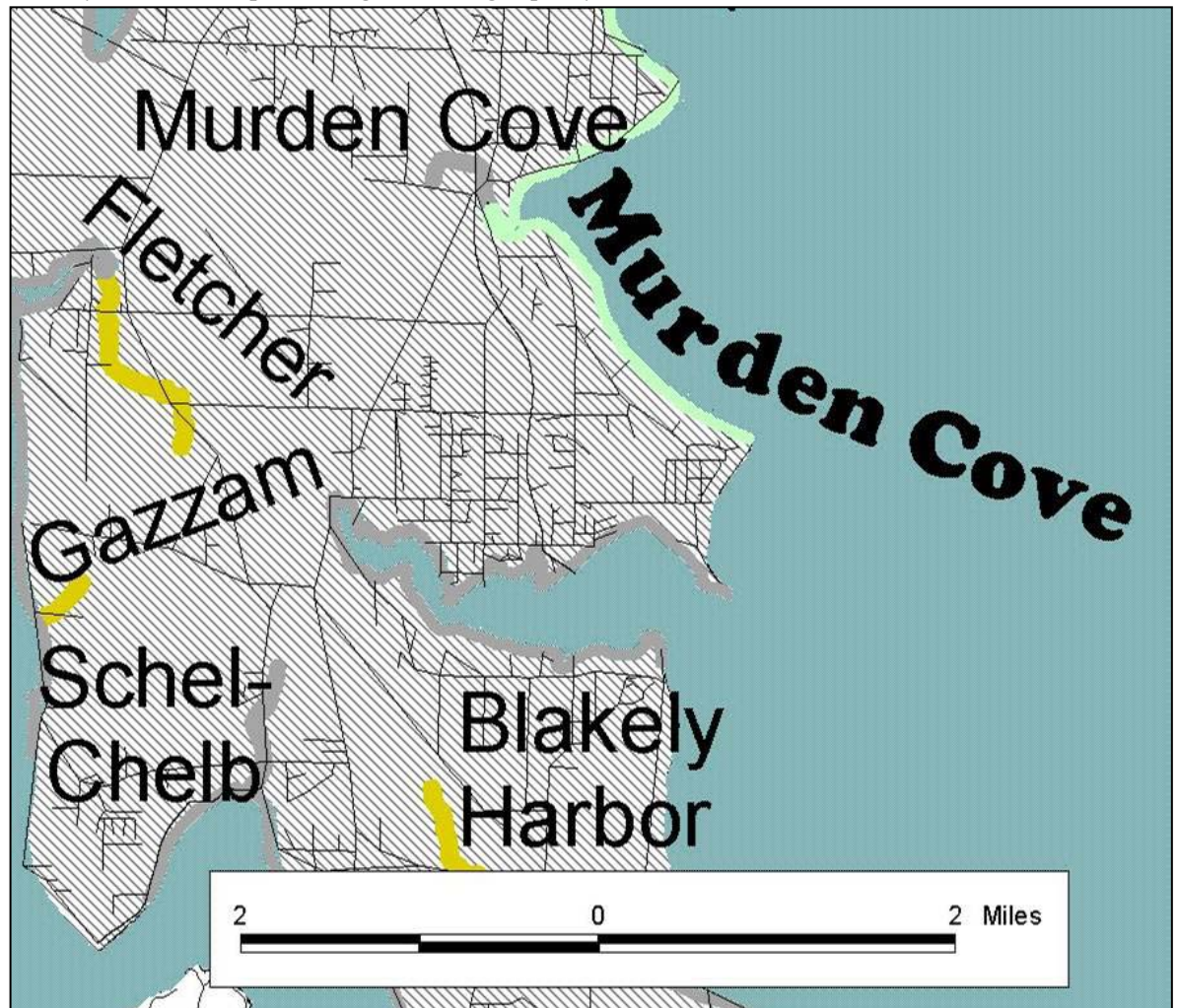
Designation: Murden Cove NSE

Classification: B (75%)

Salmonid Diversity: Coho, Chum, Chinook, & Cutthroat

Description:

Murden Cove NSE is the estuary of Murden Cove Creek on Bainbridge Island. Murden Cove estuary and nearshore areas adjacent to the estuary are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Murden Cove Creek estuary and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration. Although portions of the NSE refugia area has been developed, this enclosed bay continues to provide significant high-quality nearshore salmonid habitat.

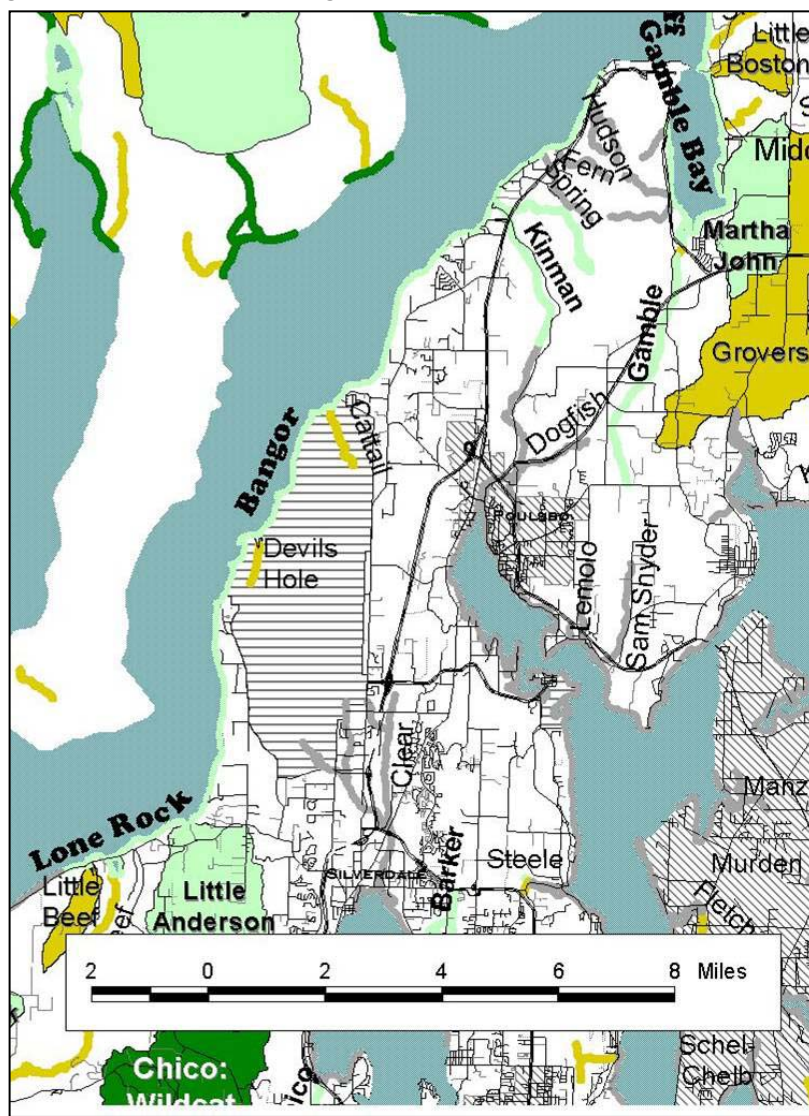


BANGOR NEARSHORE

Project ID#: BNG-NSE-01**Designation:** Bangor NSE**Classification:** B (70%)**Salmonid Diversity:** Coho, Chum, Summer Chum, Chinook, & Cutthroat**Description:**

The Bangor (BNG) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell.

This NSE refugia area extends from just south of the Hood Canal Bridge to just south of the Bangor Naval Base. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. A good portion of the shoreline of this NSE area remains forested and patches of nearshore habitat remain in a natural condition.



FOUL WEATHER BLUFF NEARSHORE

Project ID#: FWB-NSE-01

Designation: Foul Weather Bluff NSE

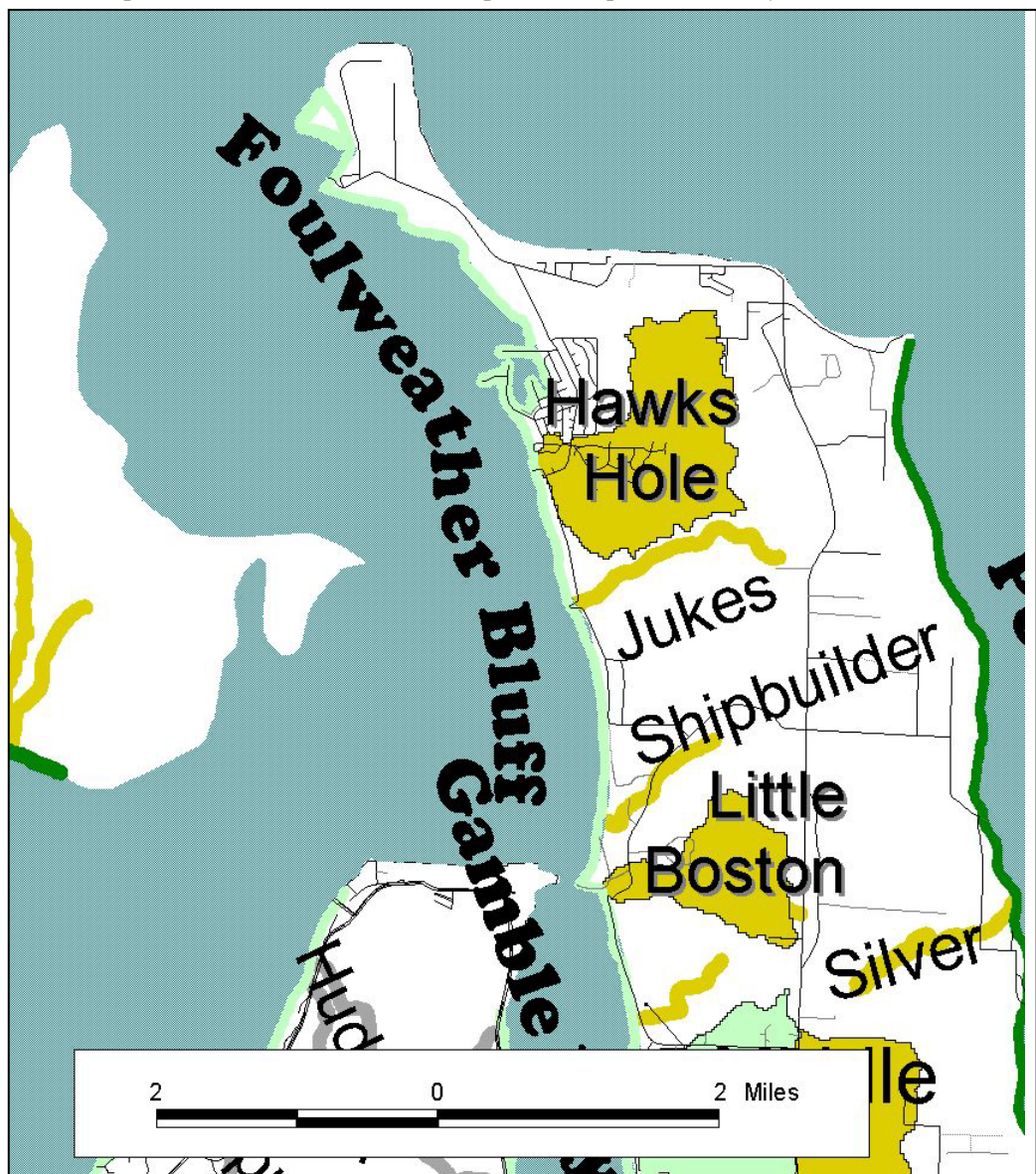
Classification: B (69%)

Salmonid Diversity: Coho, Chum, Chinook, & Cutthroat

Description:

The Foul Weather Bluff (FWB) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. The FWB NSE includes gravel beaches, mud flats, sand spits, and saltwater marshes that provide important nursery habitat for multiple

species of salmonids. Much of the shoreline of the PNP NSE area remains forested and nearshore areas remain largely unaltered by human activity, except in the Hansville area where the shoreline is heavily developed.



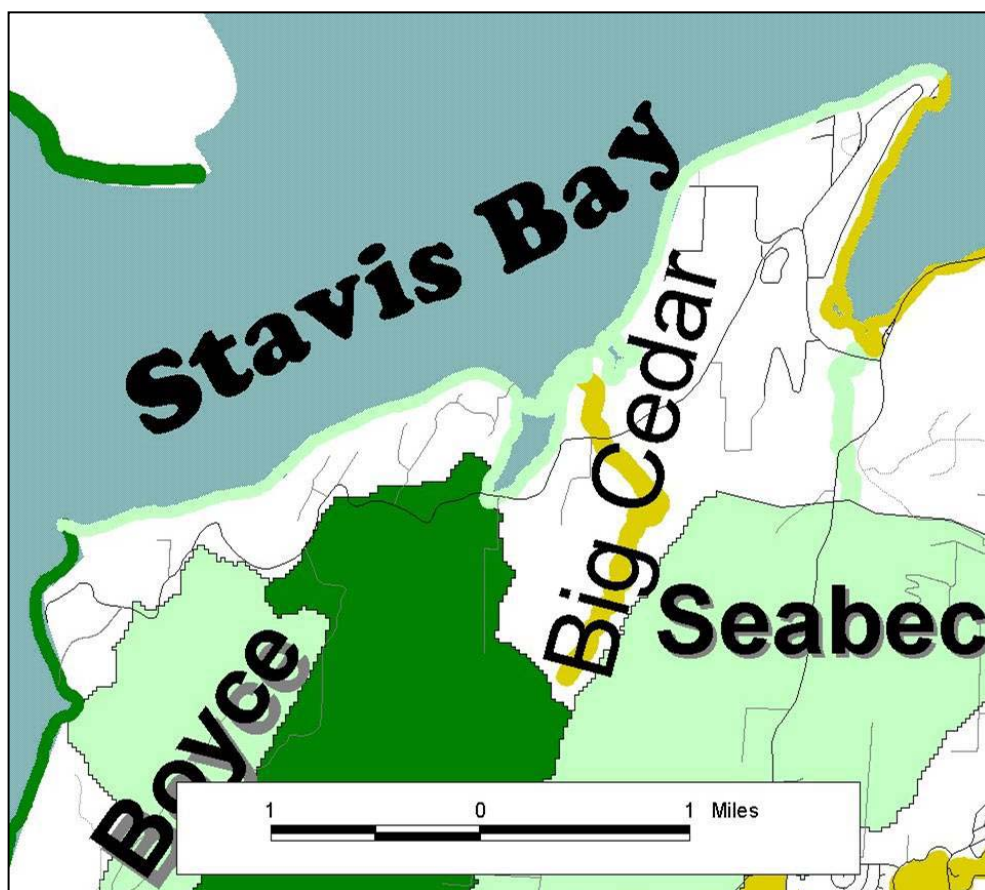
STAVIS BAY ESTUARY & NEARSHORE

Project ID#: STB-NSE-01
Designation: Stavis Bay NSE
Classification: B (69%)

Salmonid Diversity: Coho, Chum, Summer Chum, Chinook, & Cutthroat

Description:

Stavis Bay estuary and nearshore areas adjacent to the estuary are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Stavis and Big Cedar Creek estuaries and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Much of the shoreline of this NSE area remains forested and nearshore areas remain largely unaltered by human activity. This area represents some of the highest quality nearshore habitat remaining on the eastern side of Hood Canal, making it a high priority for conservation in the future.



LONE ROCK NEARSHORE

Project ID#: LRK-NSE-01
Designation: Lone Rock NSE
Classification: B (67%)

Salmonid Diversity: Coho, Chum, Summer Chum, Chinook, & Cutthroat

Description:

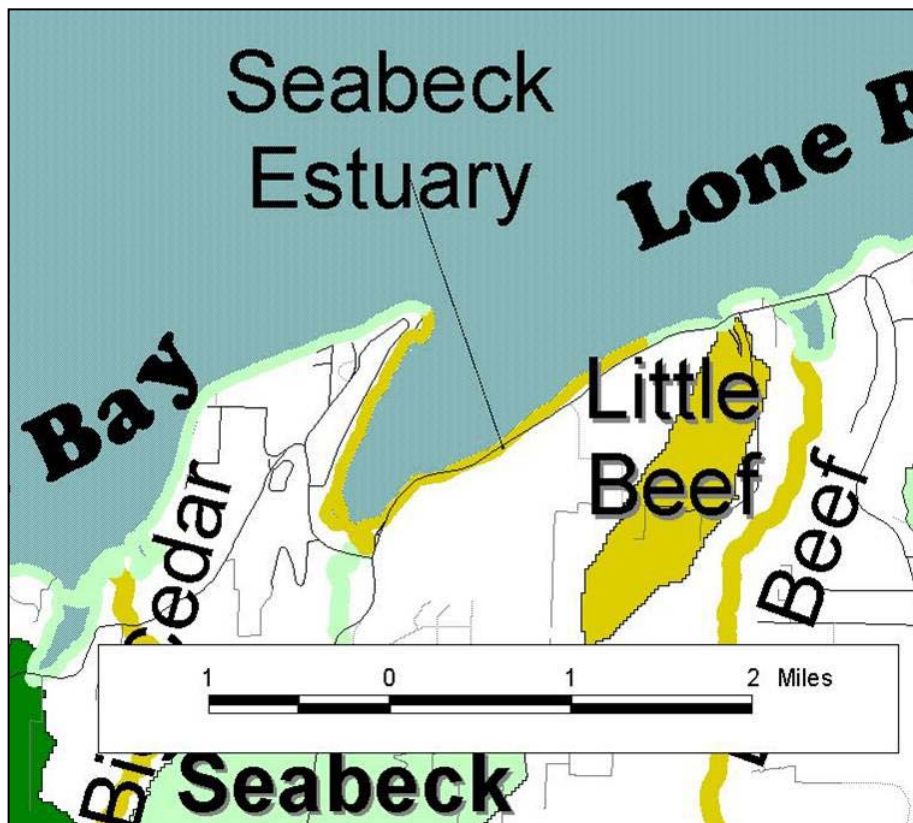
The Lone Rock (LRK) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. This NSE refugia area extends from just south of the Bangor Naval Base to just north of Seabeck. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous streams that provide important nursery habitat for multiple species of salmonids. These include the estuaries of Little Anderson, Big Beef, and Little Beef Creeks. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. A good portion of the shoreline of this NSE area remains forested and patches of nearshore habitat remain in a natural condition.



SEABECK BAY ESTUARY & NEARSHORE

Project ID#: SBB-NSE-01**Designation:** Seabeck Bay NSE**Classification:** C (59%)**Salmonid Diversity:** Coho, Chum, Summer Chum, Chinook, & Cutthroat**Description:**

Seabeck Bay estuary and nearshore areas adjacent to the estuary are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Seabeck Creek estuary and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Although much of the shoreline of this NSE area has been developed there remains patches of natural forested and nearshore areas. This NSE should be a high priority area for restoration activities.



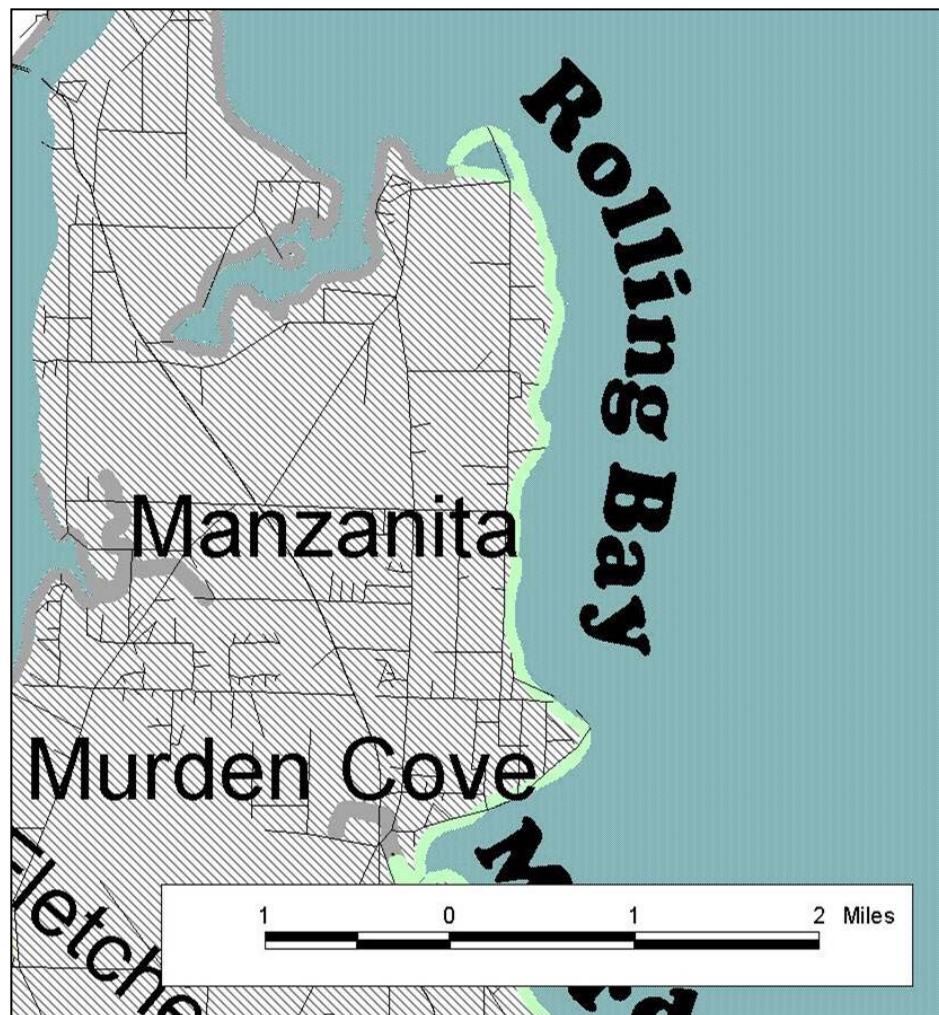
ROLLING BAY NEARSHORE

Project ID#: RBY-NSE-01
Designation: Rolling Bay NSE
Classification: B (66%)

Salmonid Diversity: Coho, Chum, Summer Chum, Chinook, & Cutthroat

Description:

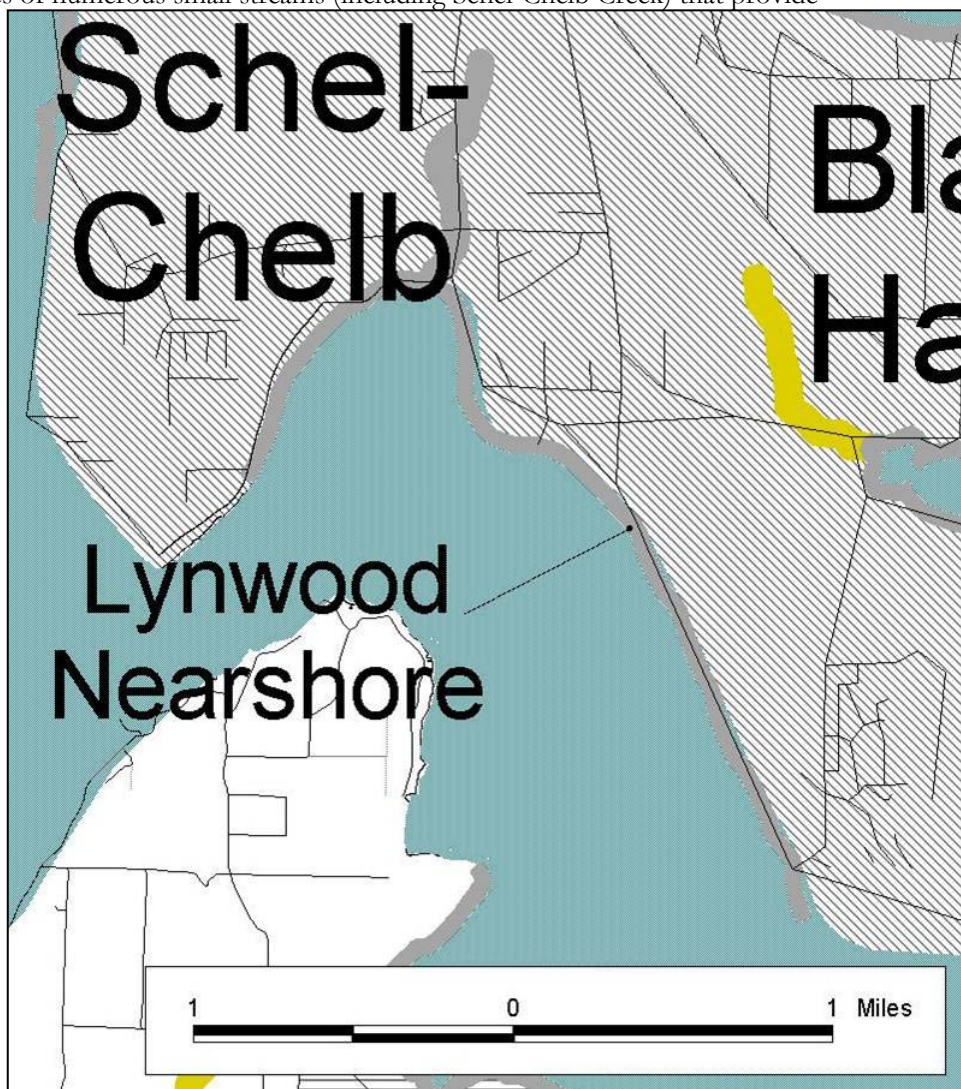
The Rolling Bay (RBY) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. This NSE refugia area is located on the eastern shore of Bainbridge Island. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. A good portion of the shoreline of this NSE area remains forested and patches of nearshore habitat remain in a natural condition.



LYNWOOD NEARSHORE

Project ID#: LYN-NSE-01**Designation:** Lynwood NSE**Classification:** D (53%)**Salmonid Diversity:** Coho, Chum, Chinook, & Cutthroat**Description:**

The Lynwood (LYN) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. This NSE refugia area is located on the southwestern shore of Bainbridge Island. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams (including Schel-Chelb Creek) that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. A good portion of the shoreline of this NSE area remains forested and patches of nearshore habitat remain in a natural condition.



PORT GAMBLE BAY ESTUARY & NEARSHORE

Project ID#: PGB-NSE-01**Designation:** Port Gamble Bay NSE**Classification:** B (64%)**Salmonid Diversity:** Coho, Chum, Summer Chum, Chinook, & Cutthroat**Description:**

Port Gamble Bay estuary and nearshore areas are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Gamble Creek estuary and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell.

Juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the estuary for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of

numerous small streams that provide important nursery habitat for multiple species of salmonids. These small streams include Little Boston, Middle, and other creeks. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Although a good portion of the shoreline of this NSE area has been developed, including the Port Gamble Mill area, there remains patches of natural forested and nearshore areas. This NSE should be a high priority area for restoration activities.



UNION RIVER ESTUARY & NEARSHORE

Project ID#: UNR-NSE-01**Designation:** Union River Estuary NSE**Classification:** B (63%)**Salmonid Diversity:** Coho, Chum, Summer Chum, Chinook, & Cutthroat**Description:**

The Union River estuary and adjacent nearshore areas are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Union River estuary and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. The streams include Stimson, Big Mission, and Little Mission Creeks, as well as several other streams. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Although much of the shoreline of this NSE area has been developed there remains patches of natural forested and nearshore areas. This NSE should be a high priority area for restoration activities.



PORT BLAKELY HARBOR ESTUARY

Project ID#: PBL-NSE-01

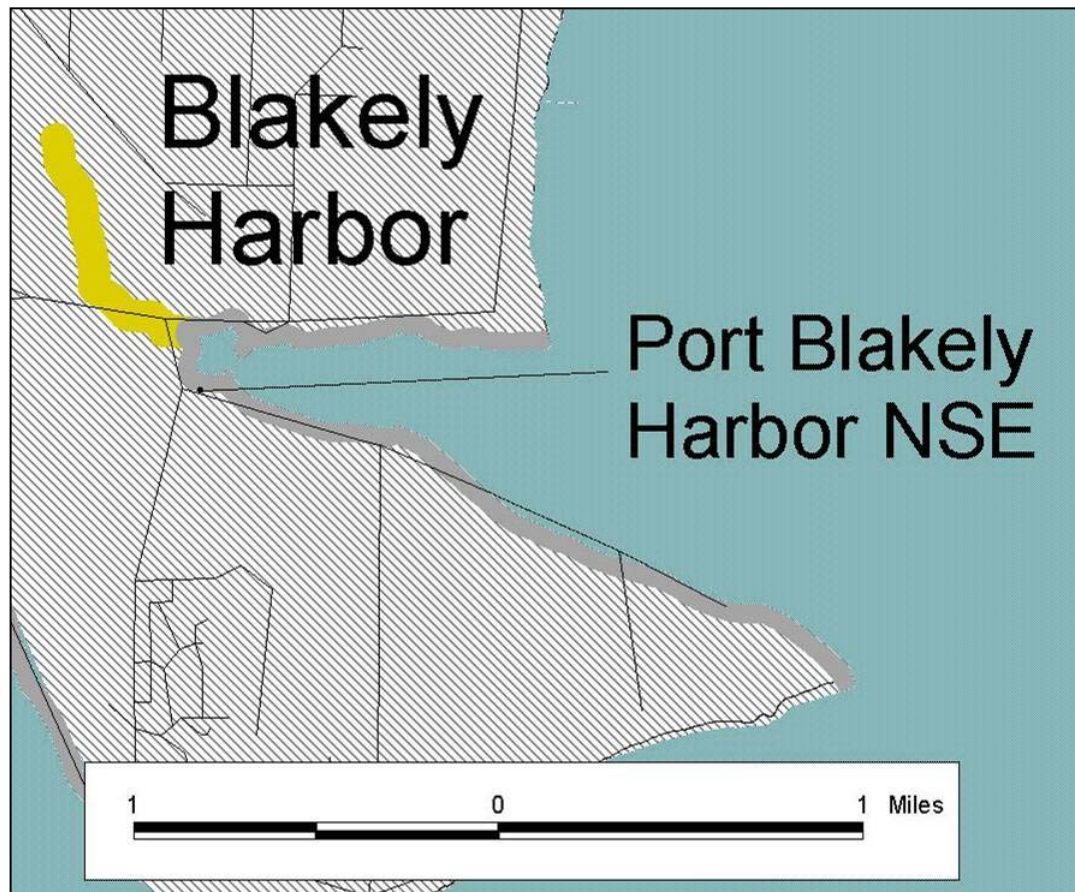
Designation: Port Blakely NSE

Classification: D (59%)

Salmonid Diversity: Coho, Chum, Chinook, & Cutthroat

Description:

Port Blakely Harbor NSE is located at the southeastern end of Bainbridge Island. Port Blakely Harbor and adjacent nearshore areas are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Port Blakely Harbor and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration. Although portions of the NSE refugia area has been developed, this enclosed bay continues to provide significant high-quality nearshore salmonid habitat.

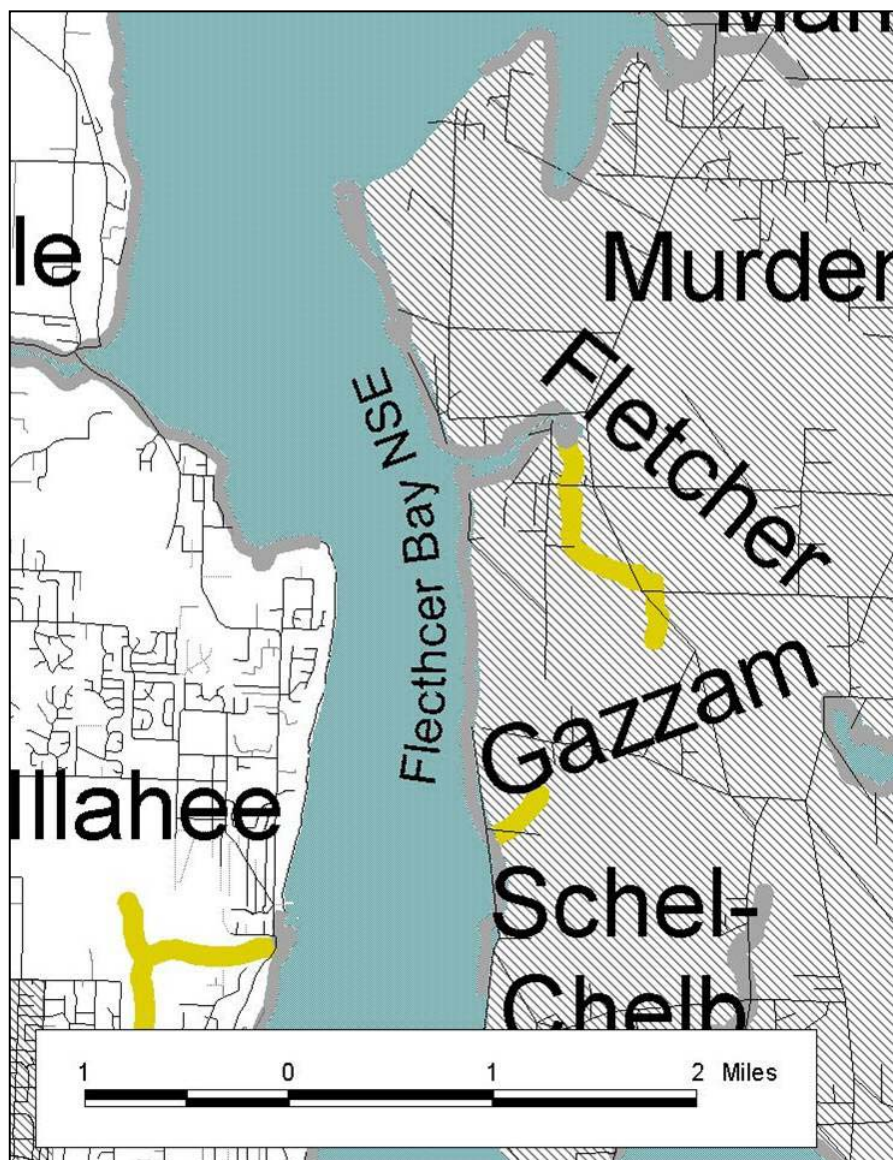


FLETCHER BAY ESTUARY

Project ID#: FLB-NSE-01**Designation:** Fletcher Bay NSE**Classification:** D (54%)**Salmonid Diversity:** Coho, Chum, Chinook, & Cutthroat**Description:**

Fletcher Bay NSE is located the western side of Bainbridge Island. Fletcher Bay and adjacent nearshore areas are important salmonid migration corridors and rearing habitat. The nearshore-estuary (NSE) refugia area includes the Fletcher Creek estuary and the surrounding nearshore areas (see map for refugia boundaries). The nearshore areas are included because of their salmonid habitat value and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat may utilize the estuary for rearing and migration.

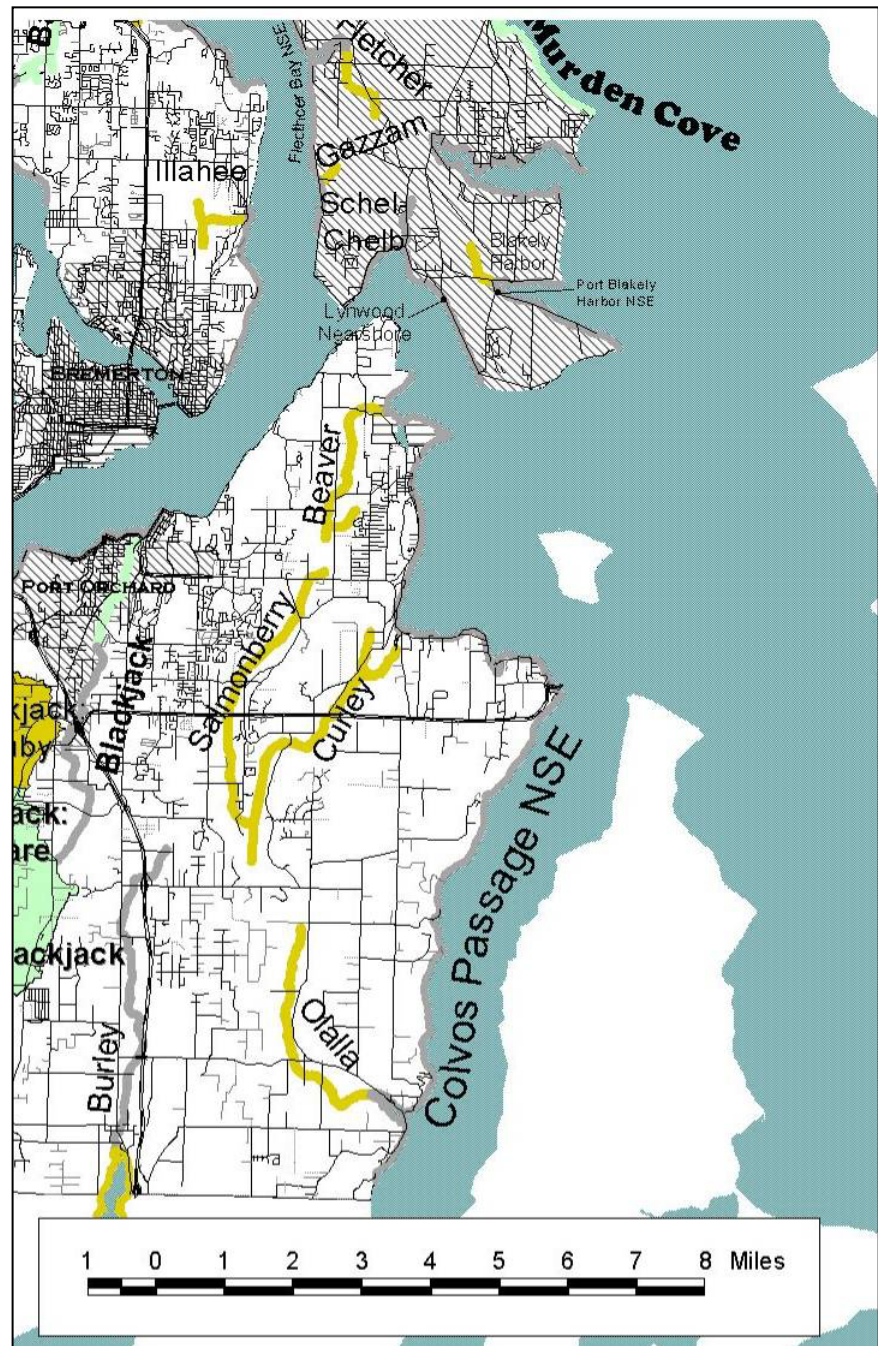
Although portions of the NSE refugia area has been developed, this enclosed bay continues to provide significant high-quality nearshore salmonid habitat.



COLVOS PASSAGE NEARSHORE

Project ID#: COL-NSE-01**Designation:** Colvos Passage NSE**Classification:** D (53%)**Salmonid Diversity:** Coho, Chum, Chinook, & Cutthroat**Description:**

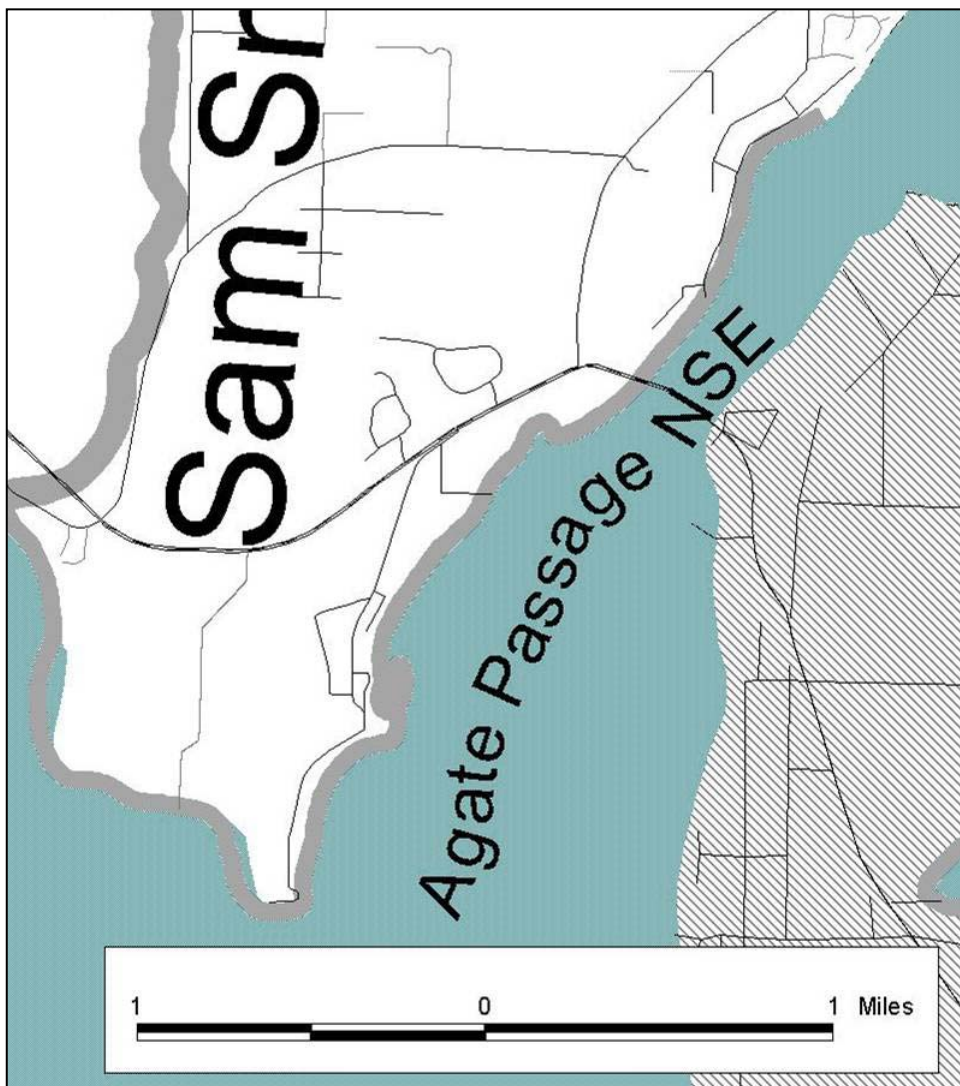
Colvos Passage (COL) nearshore is designated as a NSE refugia area because of its value as salmonid migration habitat and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. Bulkhead construction and associated shoreline development have likely had a negative impact on adult and juvenile salmon migration habitat. These bulkheads also tend to coarsen the dominant beach gravel size and result in a loss of riparian habitat and increase water temperature in the immediate vicinity of the bulkhead, as well as a reduction in organic debris and terrestrial prey organisms to the nearshore. In spite of cumulative impacts of shoreline development along Colvos Passage, there still is a rich diversity of habitats, including intertidal marsh, mud flat, sand spits, and other nearshore features, as well as the estuaries of several streams (Curley, Olalla, and Beaver Creeks).



AGATE PASSAGE NEARSHORE

Project ID#: AGT-NSE-01**Designation:** Agate Passage NSE**Classification:** D (52%)**Salmonid Diversity:** Coho, Chum, Chinook, & Cutthroat**Description:**

Agate Passage (AGT) nearshore is designated as a NSE refugia area because of its value as salmonid migration habitat and their ecological function within the local drift cell. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. Bulkhead construction and associated shoreline development have likely had a negative impact on adult and juvenile salmon migration habitat. These bulkheads also tend to coarsen the dominant beach gravel size and result in a loss of riparian habitat and increase water temperature in the immediate vicinity of the bulkhead, as well as a reduction in organic debris and terrestrial prey organisms to the nearshore. In spite of cumulative impacts of shoreline development in Agate Passage, there still is a rich diversity of habitats, including intertidal marsh, mud flat, sand spits, and other nearshore features.



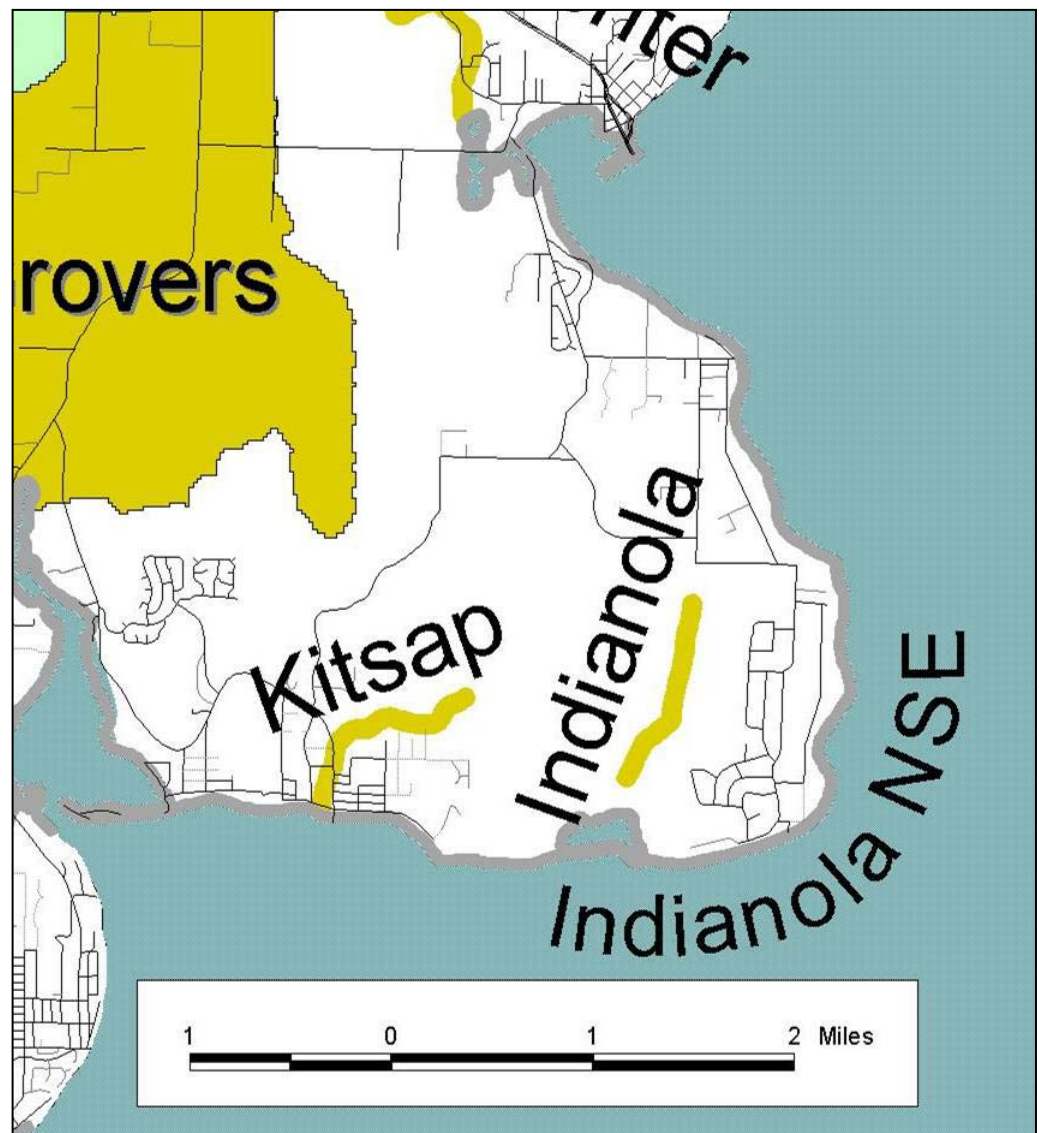
INDIANOLA NEARSHORE

Project ID#: IND-NSE-01
 Designation: Indianola NSE
 Classification: D (56%)

Salmonid Diversity: Coho, Chum, Chinook, & Cutthroat

Description:

The Indianola (IND) nearshore is designated as a NSE refugia area because of its ecological value as salmonid migration and rearing habitat, as well as its ecological function within the local drift cell. This NSE refugia area is located on the northeastern shore of the Kitsap peninsula between Suquamish and Kingston. It is believed that juvenile salmonids, including chinook, coho, chum, and cutthroat utilize the nearshore areas extensively for rearing and migration. This nearshore area includes gravel beaches, mud flats, sand spits, and the estuaries of numerous small streams that provide important nursery habitat for multiple species of salmonids. Recent studies have indicated that small-stream estuarine habitat may be very important as juvenile salmonid rearing, refuge, and migration habitat. High priority should be given to maintaining connectivity with adjacent nearshore habitat and small-stream estuaries. Although much of the shoreline has been impacted by development, a good portion still remains forested and patches of nearshore habitat remain in a natural condition.



“Of all our natural resources, water has become the most precious...in an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of indifference.”

RACHEL CARSON, SILENT SPRING, 1962

PROJECT FINDINGS

This section summarizes the results of the project research, fieldwork, and GIS modeling efforts for the Kitsap County study area. Details on watershed characteristics can be found in Appendix A. Data on salmonid distribution can be found in Appendix B. Available habitat assessment data is compiled in Appendix C. Appendix D contains information on water quality data, including any bio-monitoring that has been conducted in the study area. A summary of best available science related to riparian areas is included in Appendix E and nearshore information is summarized in Appendix F. The GIS data generated during this project can be found in Appendix G.

SALMONID DISTRIBUTION

The distribution of native salmonids in the study area is summarized in Table 21 and is shown on maps contained in Appendix B (WCC, 2002). Salmonid distribution is presented on the watershed scale and is based on both historic and current known salmonid utilization (WDFW, 1975 and WCC, 2002). In addition, salmonid distribution also includes “potential” utilization based on the stream gradient, confinement, and streamflow data discussed earlier in this report. The data utilized in this report reflects the most conservative assessment of salmonid distribution that can be supported by scientific data. Appendix B also contains a discussion of specific habitat requirements and stock status for the populations of each species found in the study area.

In general, all accessible perennial streams within the study area support populations of cutthroat trout and coho salmon. In addition, those streams that drain directly to marine waters also support fall and/or winter chum salmon runs. The other species of salmonid present in the study region require other habitat characteristics in order to be present in a stream. Steelhead are native to almost all the larger streams and river systems. In general, chinook are found only in the major rivers within the study area, including the Dewatto, Tahuya, and Union systems, as well as a few of the larger streams systems (e.g. Coulter, Rocky, Blackjack, Gorst, Chico, Big Beef). Many of these chinook are likely of hatchery origin. Pinks are found only in the Dewatto, Tahuya, and Union Rivers. In addition to these same river systems, summer chum salmon are only found in a limited number of the larger stream systems within the Hood Canal sub-region (e.g. Big Beef, Big Anderson, and Big Mission Creeks).



Watershed Stream	WRIA#	ID	Chinook	Coho	Fall Chum	Summer Chum	Pink	Steelhead	Cutthroat
East Kitsap Streams									
Coulter	15.0002	CLT	X	X	X			X	X
Rocky	15.0015	RKY	X	X	X			X	X
Minter	15.0048	MTR	X	X	X			X	X
Huge	15.0052	HUG	X	X	X			X	X
Burley	15.0056	BUR	X	X	X			X	X
Purdy	15.0060	PUR		X	X				X
Sunny Cove	15.0105	SNY		X	X				X
Olalla	15.0107	OLA	X	X	X			X	X
Fragaria	15.0115	FRA		X	X				X
Wilson (Southworth)	15.0178	WLS		X	X				X
Wilson (Harper)	15.0183	WLH		X	X				X
Curley	15.0185	CUR	X	X	X			X	X
Salmonberry	15.0188	SLB		X	X			X	X
Duncan	15.0191	DUN		X	X				X
Beaver	15.0192	BVR		X	X			X	X
Manchester	15.0193	MAN		X	X				X
Rich Cove	15.0194	RCV		X	X				X
Karcher	15.0195	KAR		X	X				X
Sacco	15.0196	SAC		X	X				X
Sullivan	15.0200	SUL		X	X				X
Olney	15.0201	OLN		X	X				X
Annapolis	15.0202	ANP		X	X				X
Blackjack	15.0203	BLJ	X	X	X			X	X
Ruby	15.0205	RBY		X	X			X	X
Square	15.0207	SQR		X	X			X	X
Ross	15.0209	ROS		X	X			X	X
Anderson	15.0211	ANG		X	X			X	X
Bailey	15.0215	BLY		X	X				X
Gorst	15.0216	GOR	X	X	X			X	X
Jarstad	15.0218	JAR		X	X				X
Parish	15.0220	PAR		X	X				X
Heins	15.0221	HNS		X	X			X	X
Wright	15.0225	WRT		X	X				X
Ostrich Bay	15.0226	OSB		X	X				X
Jackson Park	15.0228	JKP		X	X				X
Chico	15.0229	CCO	X	X	X			X	X
Kitsap	15.0230	KIT		X	X			X	X



Watershed Stream	WRIA#	ID	Chinook	Coho	Fall Chum	Summer Chum	Pink	Steelhead	Cutthroat
Dickerson	15.0231	DCK		X	X			X	X
Lost	15.0234	LST		X	X			X	X
Wildcat	15.0238	WLD		X	X			X	X
Erlands	15.0241	ERL		X	X				X
Crystal	15.0243	CRY		X	X				X
Woods	15.0244	WDS		X	X				X
Koch	15.0245	KCH		X	X				X
Strawberry	15.0246	STR		X	X			X	X
Clear	15.0249	CLR	X	X	X			X	X
Barker	15.0255	BRK	X	X	X			X	X
Stampede	15.0257	STM		X	X				X
Peterman	15.0258	PET		X	X				X
Mosher	15.0259	MSR		X	X				X
Pahrmann	15.0260	PAH		X	X				X
Narrows	15.0262	NAR		X	X				X
Dee-Enetai	15.0265	DEN		X	X				X
Illahee	15.0266	ILL		X	X			X	X
Cove	15.0268	COV		X	X				X
Brownsville	15.0269	BRV		X	X				X
Burke Bay	15.0272	BBY		X	X				X
Steele	15.0273	STL	X	X	X			X	X
South Keyport	15.0276	SKY		X	X				X
North Keyport	15.0277	NKY		X	X				X
Daniels	15.0278	DAN		X	X				X
Little Scandia	15.0279	LSC		X	X				X
Big Scandia	15.0280	BSC		X	X			X	X
Johnson	15.0283	JHN		X	X				X
Dogfish	15.0285	DOG	X	X	X			X	X
Bjorgen	15.0290	BJN		X	X				X
Lemolo	15.0291	LEM		X	X				X
Sam Snyder	15.0293	SAM		X	X				X
Klaebel	15.0294	KLB		X	X				X
Remington	15.0295	REM		X	X				X
Thompson	15.0296	TMP		X	X				X
Cowling	15.0298	COW		X	X				X
Grovers	15.0299	GRV	X	X	X			X	X
Kitsap	15.0305	NKC		X	X				X
Indianola	15.0305a	IND		X	X				X
Carpenter	15.0309	CAR		X	X			X	X
Silver	15.0310	SLV		X	X				X
Eglon	15.0311	EGL		X	X				X



Watershed Stream	WRIA#	ID	Chinook	Coho	Fall Chum	Summer Chum	Pink	Steelhead	Cutthroat
Bainbridge Island Streams									
Hidden Cove	15.0319	HDC		X	X				X
Dripping Water	15.0320	DRW		X	X				X
Murden Cove	15.0321	MRC		X	X				X
Winslow	15.0324	WIN		X	X				X
Sportsmans	15.0325	SPT		X	X				X
Cooper	15.0326	COP		X	X				X
Schel-Chelb	15.0328	SCH		X	X				X
Blakely Falls	15.0330	BLF		X	X				X
Blakely Harbor	15.0331	BLH		X	X				X
Gazzam	15.0332	GAZ		X	X				X
Fletcher	15.0340	FLT		X	X				X
Manzanita	15.0344	MNZ		X	X				X
West Kitsap Streams									
Hawks Hole	15.0345	HWK		X	X				X
Jukes	15.0348	JUK		X	X				X
Shipbuilder	15.0349	RES		X	X				X
Little Boston	15.0350	LTB		X	X				X
Reservation	15.0351	RES		X	X				X
Middle	15.0352	MID		X	X				X
Martha John	15.0354	MJN		X	X			X	X
Gamble	15.0356	GMB		X	X			X	X
Todhunter	15.0360	TDH		X	X				X
Laudine DeCouteau	15.0360a	LAD		X	X				X
Machias	15.0360b	MCH		X	X				X
Hudson	15.0361	HUD		X	X				X
Cougar	15.0362	CGR		X	X				X
Fern	15.0363	FRN		X	X				X
Spring	15.0366	SPR		X	X				X
Kinman	15.0367	KIN		X	X			X	X
Jump-Off-Joe	15.0369	JOJ		X	X				X
Cattail	15.0370	CAT		X	X				X
Devils Hole	15.0374	DVH		X	X				X
Bangor	15.0376	BGR		X	X				X
Little Anderson	15.0377	LAN		X	X	X		X	X
Johnson (Lone Rock)	15.0387	JLR		X	X				X
Big Beef	15.0389	BBF	X	X	X	X		X	X
Little Beef	15.0399	LBF		X	X				X
Seabeck	15.0400	SEA		X	X	X		X	X
Big Cedar	15.0403	BAC		X	X				X
Stavis	15.0404	STV		X	X	X		X	X



Watershed Stream	WRIA#	ID	Chinook	Coho	Fall Chum	Summer Chum	Pink	Steelhead	Cutthroat
Boyce	15.0407	BOY		X	X				X
Nellita	15.0407a	NEL		X	X				X
Harding	15.0408	HRD		X	X				X
Big Anderson	15.0412	BAN	X	X	X	X		X	X
Thomas	15.0417	THM		X	X				X
Dewatto	15.0420	DWT	X	X	X	X	X	X	X
Rendsland	15.0439	RND		X	X				X
Brown	15.0444	BRN		X	X				X
Caldervin	15.0445	CLD		X	X				X
Tahuya	15.0446	THY	X	X	X	X	X	X	X
Schoolhouse	15.0477	SCH		X	X				X
Shoofly	15.0478	SHF		X	X				X
Little Shoofly	15.0483	LSY		X	X				X
Cady	15.0486	CDY		X	X				X
Nursery	15.0487	NUR		X	X				X
Stimson	15.0488	STM		X	X				X
Hall	15.0491	HAL		X	X				X
Sundstrom	15.0492	JBF		X	X				X
Little Mission	15.0493	LMS		X	X			X	X
Big Mission	15.0495	BMS		X	X			X	X
Union	15.0503	UNR	X	X	X	X	X	X	X

Table 21: Kitsap County Salmonid Distribution.

Notes:

- 1) Data represent current, historical, and potential salmonid utilization.
- 2) Most creeks support resident cutthroat and sea-run cutthroat populations.
- 3) Basic population characteristics are included in Appendix B.
- 4) Salmonid distribution maps are also included in Appendix B.
- 5) Data based on interviews with local biologists and available data.

SALMONID DIVERSITY AND PRODUCTIVITY

The qualitative analysis of salmonid diversity and productivity (see methods section of this report) was conducted on the scale of potential refugia areas. In general, this was at the stream-segment or sub-watershed scale. Table 22 summarizes the results of this analysis. The maximum possible diversity score is 7 and the maximum possible productivity score is 5, for a combined maximum total score of 12. The minimum score for this study area was a 4, the maximum was 10, and the median score was 8 for all areas evaluated.



2003 KITSAP SALMONID REFUGIA REPORT

Kitsap Refugia Project Salmonid Diversity & Productivity Scores												
East WRIA-15 Salmonid-Bearing Streams												
Potential Refugia	WRIA ID#	Chinook	Coho	Fall/Winter Chum	Summer Chum	Pink	Sockeye	Steelhead	Cutthroat	Diversity Score	Productivity Score	Total Score
Coulter Creek	15.0002											
RM 0.0-0.8	15.0002	X	X	X				X	X	5	4	9
West Tributary	15.0004		X					X	X	3	2	5
RM 0.8-2.5	15.0002	X	X	X				X	X	5	4	9
North Tributary	15.0007		X					X	X	3	2	5
RM 2.5-4.0	15.0002		X					X	X	3	2	5
RM 4.0-HW	15.0002		X					X	X	3	2	5
Rocky Creek	15.0015											
RM 0.0-0.5	15.0015	X	X	X				X	X	5	4	9
RM 0.5-1.5	15.0015	X	X	X				X	X	5	4	9
RM 1.5-HW	15.0015		X					X	X	3	4	7
West Fork	15.0021		X					X	X	3	2	5
East Fork	15.0016		X					X	X	3	2	5
Minter Creek	15.0048											
RM 0.0-1.5	15.0048	X	X	X				X	X	5	4	9
RM 1.5-HW	15.0048		X					X	X	3	4	7
Huge Creek	15.0052	X	X					X	X	4	4	8
Burley Creek	15.0056											
RM 0.0-0.5	15.0056	X	X	X				X	X	5	4	9
RM 0.5-1.5	15.0056	X	X	X				X	X	5	4	9
RM 1.5-HW	15.0056		X					X	X	3	4	7
Purdy Creek	15.0060		X	X					X	3	2	5
Sunny Cove Creek	15.0105		X	X					X	3	1	4
Olalla Creek	15.0107											
RM 0.0-1.5	15.0107	X	X	X				X	X	5	4	9
RM 1.5-HW	15.0107		X					X	X	3	4	7
Fragaria Creek	15.0115		X					X	X	3	1	4
Wilson Creek(Southworth)	15.0178		X					X	X	3	1	4
Wilson Creek (Harper)	15.0183		X					X	X	3	1	4
Curley Creek	15.0185	X	X	X				X	X	5	4	9
Salmonberry Creek	15.0188		X					X	X	3	4	7
Duncan Creek	15.0191		X	X					X	3	1	4
Beaver Creek	15.0192											
RM 0.0-0.5	15.0192		X	X				X	X	4	2	6
RM 0.5-HW	15.0192		X					X	X	3	2	5
Manchester Creek	15.0193		X	X					X	3	1	4
Rich Cove Creek	15.0194		X	X					X	3	1	4
Karcher Creek	15.0195		X	X					X	3	1	4
Sacco Creek	15.0196		X	X					X	3	1	4
Sullivan Creek	15.0200		X	X					X	3	1	4
Olney Creek	15.0201		X	X					X	3	1	4
Annapolis Creek	15.0202		X	X					X	3	1	4
Blackjack Creek	15.0203											
RM 0.0-1.5	15.0203	X	X	X	X			X	X	6	4	10
RM 1.5-3.0	15.0203		X					X	X	3	4	7
Ruby Creek	15.0205		X					X	X	3	2	5
RM 3.0-5.5	15.0203		X					X	X	3	2	5
Square Creek	15.0207		X					X	X	3	2	5
RM 5.5-HW	15.0203		X					X	X	3	2	5
Ross Creek	15.0209											
RM 0.0-0.5	15.0209		X	X				X	X	4	2	6
RM 0.5-HW	15.0209		X					X	X	3	2	5
Anderson Creek	15.0211											
RM 0.0-0.5	15.0211		X	X				X	X	4	2	6
West Fork	15.0211		X	X				X	X	4	2	6
East Fork	15.0212		X	X				X	X	4	2	6
Bailey Creek	15.0215		X	X					X	3	2	5



Kitsap Refugia Project Salmonid Diversity & Productivity Scores												
East WRIA-15 Salmonid-Bearing Streams												
Potential Refugia	WRIA ID#	Chinook	Coho	Fall/Winter Chum	Summer Chum	Pink	Sockeye	Steelhead	Cutthroat	Diversity Score	Productivity Score	Total Score
Gorst Creek	15.0216											
RM 0.0-0.25	15.0216	X	X	X				X	X	5	4	9
RM 0.25-0.5	15.0216		X	X				X	X	4	4	8
RM 0.5-0.75	15.0216		X	X				X	X	4	4	8
Jarstad Creek	15.0218		X					X	X	3	2	5
Parish Creek	15.0220		X					X	X	3	2	5
Heins Creek	15.0221		X					X	X	3	2	5
RM 0.75-1.0	15.0216		X					X	X	3	2	5
RM 1.0-HW	15.0216		X					X	X	3	2	5
Wright Creek	15.0225		X	X					X	3	2	5
Ostrich Bay Creek	15.0226		X	X					X	3	1	4
Jackson Park Creek	15.0228		X	X					X	3	1	4
Chico Creek	15.0229											
RM 0.0-0.75	15.0229	X	X	X				X	X	5	4	9
RM 0.75-1.25	15.0229	X	X	X				X	X	5	4	9
Kitsap Creek	15.0230		X	X				X	X	4	2	6
Dickerson Creek	15.0231		X	X				X	X	4	2	6
RM 1.25-2.5	15.0229		X	X				X	X	4	4	8
Lost Creek	15.0234		X					X	X	3	4	7
Wildcat Creek RM 2.5-4.5	15.0229		X					X	X	3	4	7
Wildcat Creek RM 4.5-HW	15.0229		X					X	X	3	2	5
Erlands Creek	15.0241		X	X					X	3	1	4
Crystal Creek	15.0243		X	X					X	3	1	4
Woods Creek	15.0244		X	X					X	3	1	4
Koch Creek	15.0245		X	X					X	3	1	4
Strawberry Creek	15.0246		X	X				X	X	4	2	6
Clear Creek	15.0249											
RM 0.0-1.0	15.0249	X	X	X				X	X	5	4	9
East Fork RM 1.0-2.0	16.0249		X	X				X	X	4	4	8
Ridgetop Tributary	15.0253		X					X	X	3	1	4
Mountainview Tributary	15.0254		X					X	X	3	2	5
East Fork RM 2.0-HW	16.0249		X					X	X	3	2	5
West Fork RM 0.0-0.5	15.0250		X	X				X	X	4	4	8
West Fork RM 0.5-1.0	15.0250		X	X				X	X	4	4	8
West Fork RM 1.0-2.0	15.0250		X	X				X	X	4	4	8
West Fork RM 2.0-HW	15.0250		X					X	X	3	2	5
Bangor Tributary	15.0251		X					X	X	3	2	5
Barker Creek	15.0255											
RM 0.0-0.5	15.0255	X	X	X				X	X	5	4	9
RM 0.5-1.0	15.0255	X	X	X				X	X	5	4	9
RM 1.0-1.5	15.0255		X	X				X	X	4	4	8
RM 1.5-HW	15.0255		X					X	X	3	2	5
Hoot Creek Tributary	15.0256		X					X	X	3	1	4
Stampede Creek	15.0257		X	X					X	3	1	4
Peterman Creek	15.0258		X	X					X	3	1	4
Mosher Creek	15.0259		X	X					X	3	1	4
Pahrman Creek	15.0260		X	X					X	3	1	4
Narrows Creek	15.0262		X	X					X	3	1	4
Dee-Enetai Creek	15.0265		X	X					X	3	1	4
Illahee Creek	15.0266											
RM 0.0-1.0	15.0266		X	X				X	X	4	2	6
North Fork RM 1.0-1.5	15.0266		X					X	X	3	2	5
North Fork RM 1.5-HW	16.0266		X					X	X	3	2	5
South Fork	15.0267		X					X	X	3	2	5
Cove Creek	15.0268		X	X					X	3	1	4
Brownsville Creek	15.0269		X	X					X	3	1	4
Burke Bay Creek	15.0272		X	X					X	3	1	4



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Kitsap Refugia Project Salmonid Diversity & Productivity Scores												
East WRIA-15 Salmonid-Bearing Streams												
Potential Refugia	WRIA ID#	Fall/Winter		Summer						Diversity Score	Productivity Score	Total Score
		Chinook	Coho	Chum	Chum	Pink	Sockeye	Steelhead	Cutthroat			
Steele Creek	15.0273											
RM 0.0-0.5	15.0273	X	X	X				X	X	4	4	8
South Fork RM 0.5-1.0	15.0274		X	X				X	X	4	4	8
South Fork RM 1.0-HW	15.0274		X	X					X	3	2	5
North Fork RM 0.5-HW	15.0273		X	X					X	3	2	5
Crouch Creek Tributary	15.0275		X	X					X	3	2	5
South Keyport Creek	15.0276		X	X					X	3	1	4
North Keyport Creek	15.0770		X	X					X	3	1	4
Daniels Creek	15.0278		X	X					X	3	1	4
Little Scandia Creek	15.0279		X	X					X	3	1	4
Big Scandia Creek	15.0280											
RM 0.0-1.0	15.0280		X	X				X	X	4	2	6
RM 1.0-HW	15.0280		X	X				X	X	4	2	6
Johnson Creek	15.0283		X	X					X	3	2	5
Dogfish Creek	15.0285											
RM 0.0-0.5	15.0285	X	X	X				X	X	5	4	9
RM 0.5-1.0	15.0285	X	X	X				X	X	5	4	9
RM 1.0-3.0	15.0285		X					X	X	3	4	7
RM 3.0-HW	15.0285		X					X	X	3	2	5
West Fork RM 0.0-1.0	15.0286		X					X	X	3	4	7
West Fork RM 1.0-HW	15.0286		X					X	X	3	2	5
South Fork - Poulsbo Tributary	15.0287		X					X	X	3	2	5
Bjorgen Creek	15.0290		X	X					X	3	2	5
Lemolo Creek	15.0291		X	X					X	3	2	5
Sam Snyder Creek	15.0293		X	X					X	3	1	4
Klaebel Creek	15.0294		X	X					X	3	1	4
Remington Creek	15.0295		X	X					X	3	1	4
Thompson Creek	15.0296		X	X					X	3	1	4
Cowling Creek	15.0298		X	X					X	3	2	5
Grovers Creek	15.0299											
RM 0.0-0.5	15.0299	X	X	X				X	X	5	4	9
RM 0.5-2.0	15.0299		X	X				X	X	4	4	8
RM 2.0-3.0	15.0299		X					X	X	3	4	7
RM 3.0-HW	15.0299		X					X	X	3	2	5
Kitsap Creek	15.0305		X	X					X	3	2	5
Indianola Creek	15.0305a		X	X					X	3	2	5
Carpenter Creek	15.0309											
RM 0.0-1.0	15.0309		X	X				X	X	4	4	8
RM 1.0-1.5	15.0309		X	X				X	X	4	4	8
RM 1.5-HW	15.0309		X					X	X	3	2	5
Silver Creek	15.0310		X	X					X	3	1	4
Eglon Creek	15.0311		X	X					X	3	2	5
Bainbridge Island Streams												
Hidden Cove Creek	15.0319		X	X					X	3	1	4
Dripping Water Creek	15.0320		X	X					X	3	1	4
Murden Cove Creek	15.0321		X	X					X	3	2	5
Winslow Creek	15.0324		X	X					X	3	1	4
Sportsman Creek	15.0325		X	X					X	3	1	4
Cooper Creek	15.0326		X	X					X	3	1	4
Schel-Chelb Creek	15.0328		X	X					X	3	1	4
Blakely Falls Creek	15.0330		X	X					X	3	1	4
Blakely Harbor Creek	15.0331		X	X					X	3	1	4
Gazzam Creek	15.0332		X	X					X	3	1	4
Fletcher Creek	15.0340		X	X					X	3	2	5
Manzanita Creek	15.0344		X	X					X	3	2	5

Table 22: East Kitsap Salmonid Diversity and Productivity.



Kitsap Refugia Project Salmonid Diversity & Productivity Scores												
West WRIA-15 Salmonid Streams												
Potential Refugia	WRIA ID#	Chinook	Coho	Fall/Winter Chum	Summer Chum	Pink	Sockeye	Steelhead	Cutthroat	Diversity Score	Productivity Score	Total Score
Hawks Hole Creek	15.0345		X	X					X	3	2	5
Jukes Creek	15.0348		X	X					X	3	1	4
Shipbuilder Creek	15.0349		X	X					X	3	1	4
Little Boston Creek	15.0350		X	X					X	3	1	4
Reservation Creek	15.0351		X	X					X	3	1	4
Middle Creek	15.0352		X	X					X	3	1	4
Martha John Creek	15.0353											
RM 0.0-0.5	15.0353		X	X				X	X	4	2	6
North Tributary	15.0354		X	X				X	X	4	2	6
RM 0.5-HW	15.0353		X	X				X	X	4	2	6
Gamble Creek	15.0356											
RM 0.0-1.0	15.0356		X	X				X	X	4	2	6
RM 1.5-HW	15.0356		X	X				X	X	4	2	6
Todhunter Creek	15.0360		X	X					X	3	1	4
Laudine DeCouteau Creek	15.0360a		X	X					X	3	1	4
Machias Creek	15.0360b		X	X					X	3	1	4
Hudson Creek	15.0361		X	X					X	3	1	4
Cougar Creek	15.0362		X	X					X	3	1	4
Fern Creek	15.0363		X	X					X	3	1	4
Spring Creek	15.0366		X	X					X	3	1	4
Kinman Creek	15.0367											
RM 0.0-0.5	15.0367		X	X				X	X	4	2	6
South-Lofall Tributary	15.0367a		X	X					X	3	1	4
North Tributary	15.0368		X	X					X	3	1	4
RM 0.5-HW	15.0367		X	X				X	X	4	2	6
Jump-Off-Joe Creek	15.0369		X	X					X	3	2	5
Cattail Creek	15.0370		X	X					X	3	1	4
Devils Hole Creek	15.0374		X	X					X	3	2	5
Bangor Creek	15.0376		X	X					X	3	1	4
Little Anderson Creek	15.0376											
RM 0.0-0.5	15.0376		X	X				X	X	4	2	6
RM 0.5-1.0	15.0376		X	X				X	X	4	2	6
RM 1.0-HW	15.0376		X	X				X	X	4	2	6
Johnson (Lone Rock) Creek	15.0387		X	X					X	3	1	4
Big Beef Creek	15.0389											
RM 0.0-1.0	15.0389	X	X	X	X			X	X	6	4	10
RM 1.0 -5.5	15.0389		X	X				X	X	4	4	8
Lake Symington RM 5.5-6.0	15.0389		X					X	X	3	4	7
RM 6.0-6.5	15.0389		X					X	X	4	4	8
RM 6.5-HW	15.0389		X					X	X	4	4	8
Little Beef Creek	15.0399		X	X					X	3	2	5
Seabeck Creek	15.0400											
RM 0.0-0.5	15.0400		X	X	X			X	X	5	4	9
RM 0.5-1.0	15.0400		X	X				X	X	4	4	8
Seabeck Heights Tributary	15.0401		X	X				X	X	4	4	8
RM 1.0-HW	15.0400		X	X				X	X	4	4	8
Big Cedar Creek	15.0403		X	X					X	3	1	4
Stavis Creek	15.0404											
RM 0.0-0.5	15.0404		X	X	X			X	X	5	4	9
West Fork	15.0405		X	X				X	X	4	4	8
East Fork	15.0404		X	X				X	X	4	4	8
Boyce Creek	15.0407		X	X					X	3	2	5
Nellita Creek	15.0407a		X	X					X	3	1	4
Harding Creek	15.0408		X	X					X	3	2	5
Big Anderson Creek	15.0412											
RM 0.0-1.0	15.0412	X	X	X	X			X	X	6	4	10
RM 1.0-1.5	15.0412		X	X				X	X	4	4	8
South Tributary	15.0413		X	X				X	X	4	4	8
South Fork	15.0414		X	X				X	X	4	4	8
North Fork	15.0412		X	X				X	X	4	4	8
Thomas Creek	15.0417		X	X					X	3	1	4



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Kitsap Refugia Project Salmonid Diversity & Productivity Scores												
West WRIA-15 Salmonid Streams												
Potential Refugia	WRIA ID#	Chinook	Coho	Fall/Winter Chum	Summer Chum	Pink	Sockeye	Steelhead	Cutthroat	Diversity Score	Productivity Score	Total Score
WRIA-15 Mason Cty												
Dewatto River	15.0420											
RM 0.0-1.0	15.0420	X	X	X	X	X		X	X	7	4	11
RM 1.0-4.0	15.0420	X	X	X	X	X		X	X	7	4	11
RM 4.0-HW	15.0420		X					X	X	3	4	7
Cady Lake Creek	15.0421		X					X	X	3	2	5
White Creek	15.0422		X					X	X	3	2	5
Shoe Lake Creek	15.0424		X					X	X	3	2	5
Larsen Lake Creek	15.0425		X					X	X	3	2	5
Alder Creek	15.0426		X					X	X	3	2	5
Ralph Creek	15.0428		X					X	X	3	2	5
Oak Lake Creek	15.0429		X					X	X	3	2	5
Cutthroat Creek	15.0434		X					X	X	3	2	5
Ludvick Lake Creek	15.0435		X					X	X	3	2	5
Blacksmith Creek	15.0436		X					X	X	3	2	5
Erickson Lake Creek	15.0437		X					X	X	3	2	5
Rendsland Creek	15.0439		X	X					X	3	2	5
Brown Creek	15.0444		X	X					X	3	1	4
Caldervin Creek	15.0445		X	X					X	3	2	5
Tahuya River	15.0446											
RM 0.0-1.0	15.0446	X	X	X	X	X		X	X	7	4	11
RM 1.0-4.0	15.0446	X	X	X	X	X		X	X	7	4	11
RM 4.0-8.0	15.0446		X					X	X	3	4	7
RM 8.0-16.0	15.0446		X					X	X	3	4	7
RM 16.0-HW	15.0446		X					X	X	3	4	7
Little Tahuya Creek	15.0454		X					X	X	3	2	5
Andy Creek	15.0458		X					X	X	3	2	5
Erdman Creek	15.0459		X					X	X	3	2	5
Haven Lake Creek	15.0461		X					X	X	3	2	5
Twin Lake Creek	15.0463		X					X	X	3	2	5
Outlet Creek	15.0466		X					X	X	3	2	5
Blacksmith Lake Creek	15.0468		X					X	X	3	2	5
Buffoon Creek	15.0470		X					X	X	3	2	5
Morgan Marsh Creek	15.0471		X					X	X	3	2	5
Panther Lake Creek	15.0472		X					X	X	3	2	5
Gold Creek	15.0474		X					X	X	3	2	5
Grata Creek	15.0475		X					X	X	3	2	5
Tin Mine Creek	15.0476		X					X	X	3	2	5
Schoolhouse Creek	15.0477		X	X					X	3	1	4
Shoofly Creek	16.0478		X	X					X	3	1	4
Little Shoofly Creek	15.0483		X	X					X	3	1	4
Cady Creek	15.0486		X	X					X	3	1	4
Stimson Creek	15.0488		X	X					X	3	2	5
Hall Creek	15.0491		X	X					X	3	1	4
Sundstrom Creek	15.0492		X	X					X	3	1	4
Little Mission Creek	15.0493											
RM 0.0-0.5	15.0493		X	X	X			X	X	5	4	9
RM 0.5-HW	15.0493		X	X				X	X	4	4	8
Big Mission Creek	15.0495											
RM 0.0-0.5	15.0495		X	X	X			X	X	5	4	9
RM 0.5-2.5	15.0495		X	X				X	X	4	4	8
RM 2.5-4.0	15.0495		X	X				X	X	4	4	8
RM 4.0-HW	15.0495		X	X				X	X	4	4	8
Union River	15.0503											
RM 0.0-1.0	15.0503	X	X	X	X	X		X	X	7	4	11
RM 1.0-5.0	15.0503	X	X	X	X	X		X	X	7	4	11
RM 5.0-HW	15.0503		X					X	X	3	4	7
Courtney Creek	15.0505		X					X	X	3	2	5
Bear Creek	15.0510		X					X	X	3	2	5
Airport Creek	15.0514		X					X	X	3	2	5
Hazel Creek	15.0516		X					X	X	3	2	5

Table 23: West Kitsap Salmonid Diversity and Productivity.



SALMONID HABITAT CONDITIONS

The habitat quality analysis is based on available quantitative habitat assessment data, qualitative habitat surveys conducted as part of this project, and from information provided by local habitat biologists, the so-called “local knowledge” of stream conditions. The analysis of salmonid habitat quality (see methods section of this report) was conducted on the scale of potential refugia areas. In general, this was at the stream-segment scale or “reach” (on the order of a river-mile (RM) or less). In some cases, these analysis units included more than a single stream reach and in other cases the analysis incorporated data from a single sub-watershed. For example, several headwater or tributary sub-watersheds were considered for refugia status and therefore were analyzed as a single unit. Based on the information and data gathered, each potential refugia area was scored using the multi-metric habitat assessment score sheet (see Methods section). Appendix C contains habitat assessment scores for all potential refugia areas.

In general, salmonid habitat within the study area reflected the range of existing conditions found throughout the Puget Sound region. That is to say, there are a few streams that still contain relatively high quality habitat, and many streams that have been significantly degraded from their natural conditions. The level of habitat degradation is generally proportional to the level of landscape alteration, land-use, and human activities that exist within the watershed, as has been observed throughout the Puget Sound region (May et al., 1997). In addition, the historical land-uses and human activities (timber harvest, agriculture, and mining) have had a cumulative impact on salmonid habitat conditions. There has also been direct human manipulation of salmonid habitat, such as the removal of LWD during “stream cleaning” efforts by WDFW in the late 1960 and early 1970’s (Amato, 1996). The legacy of these cumulative impacts is the present degraded condition of many of our streams and rivers. As with many previous assessments, the most significant habitat deficiencies found during this project include:

- More frequent high stream flows in developing watersheds.
- The loss of headwater wetlands and beaver pond habitat.
- Fragmentation of the stream-riparian ecosystem corridor.
- A lack of coniferous trees within the riparian areas.
- A general lack of LWD, especially large “key” pieces of LWD.
- Decreased LWD recruitment potential from riparian zones.
- Little high quality juvenile salmonid rearing habitat (pools).
- Fine sediment deposition in stream spawning gravels.
- Channelized streams, especially in agricultural areas.
- Encroachment of human land-use into the riparian zone.
- A degradation of riparian forest quality and maturity.
- The loss of floodplain and off-channel wetland habitat.



The most significant salmonid habitat problems noted within the Kitsap County study area include the following:

- 1) The general loss of riparian forest and wetland areas on almost all stream systems within the study area due to the encroachment of human land-use activities. In addition, roads and other crossings fragment the stream-riparian corridors of most streams.
- 2) Channelization of streams within historic or current agricultural areas such as the middle-mainstem segments of Burley, Olalla, Salmonberry, Blackjack, Clear, Scandia, Dogfish, Steele, Carpenter, Eglon, Gamble, and Grovers Creeks.
- 3) Disconnection of natural floodplains and off-channel habitat where levees and dikes have been installed to facilitate farming and/or residential development. Examples of this impact can be found on the Tahuya, Dewatto, and Union Rivers.
- 4) Loss of riparian extent and quality, especially the loss of mature conifers that provide long-term LWD recruitment, in areas that have seen several cycles of timber harvest. Examples include the headwaters of Rocky, Chico, Stavis, and Big Anderson Creeks, as well as the Dewatto and Tahuya Rivers.
- 5) Migration barriers in the form of partial or complete blocking culverts on some streams such as Mosher Creek, as well as several small tributary streams.
- 6) The general loss and degradation of high-quality instream rearing habitat and habitat complexity due to the lack of natural levels of LWD, especially large, stable “key” pieces of LWD.
- 7) The loss or degradation of headwater and off-channel wetlands and beaver ponds that traditionally provided seasonal rearing habitat and local refugia for several species of salmonids, most notably coho salmon and cutthroat trout (e.g. Carpenter, Grovers, Dogfish, Clear, and Little Anderson Creeks).
- 8) The degradation of salmonid spawning habitat due to the deposition of fine sediment from logging roads, agricultural runoff, roads, and construction sites.

COMBINED FISH-CENTERED ANALYSIS RESULTS

The combined fish-centered score is the sum of the diversity and productivity scores combined with the salmonid habitat scores for each potential refugia area. Appendix G contains a summary of this data. The use of the data gathered for this report and the specific problems identified above can also provide a starting point for developing potential rehabilitation and enhancement projects to improve salmonid habitat conditions within the study area.

GIS LANDSCAPE MODEL FRESHWATER RESULTS

The results of the GIS landscape analysis are contained in Appendix G to this report (see Table G-1). Table 24 summarizes the GIS landscape metrics used in this model. Figure 43 shows the general relationship between the fish-centered analysis and the landscape-centered analysis. In



Refugia Landscape Analysis GIS Model Components					
Metric#	GIS Layer	Data Type	Source Data	Weighting Factor	Comments
Freshwater Refugia Model					
Riparian Metrics					
1	Stream Crossings/Riparian Fragmentation	Point	LFA Streams & TIGER Roads	3	Measured as # breaks per length of stream channel. Include roads, trails, utility lines, etc.
2	Riparian Corridor Extent/Width	Polygon	LFA Streams & Land-Sat Land-Cover	3	Use SPTH (200 ft) buffer for initial analysis (Also do both > 30 m and > 100 m buffers as a sensitivity analysis). Includes all natural vegetation.
3	Riparian Vegetation Quality	Polygon	LFA Streams & Land-Sat Land-Cover	3	Include Coniferous and Mixed forest as well as wetlands. Use SPTH (200 ft) buffer for analysis.
4	Steep Slopes & Mass Wasting Potential	Polygon	DEM	1	% Riparian Slopes > 30%
5	Floodplain Modification	Polygon	DEM & Land-Sat LULC	2	% Floodplain with human land-use (land-use or roads)
6	Salmon Migration Barriers	Point	SSHEAR DB	3	% stream length with impeded passage due to man-made barriers on type 1, 2, or 3 channels only (<10% = 9, 10-20% = 5, >20% = 3, and >50% = 1). Includes partial & complete barriers.
Watershed Metrics					
7	Hydrologic Condition	Polygon	Watershed DB	2	Combines hydrologic parameters (Annual Precipitation = 3, Basin Area = 2, & Drainage Density=1) into a single metric.
8	Total Impervious Surface Area (%TIA)	Polygon	Land-Sat	3	Use standard conversion factors based on % Urban/Suburban/Commercial/Industrial/Rural
9	% Agricultural Land-Use	Polygon	Land-Sat	2	% Agricultural Land-Use (includes both grazing & row-cropping as well as hobby farms)
10	Road Density	Line	Roads	1	#km of road per km ² Basin Area
11	Wetlands	Polygon	NWI Wetlands	3	% NWI wetland area w/in watershed
12	Urban Development	Polygon	County Zoning DB	1	% within UGA, Rural Centers (Local Areas of More Intense Rural Development LAMIRD), or Commercial Area Boundaries (per Comp Plan)
17	Forest Cover	Polygon	Land-Sat	3	Coniferous = 4, Mixed = 3, Deciduous = 2, & Clear-Cut = 1
Nearshore Refugia Model					
1	Nearshore Modifications	line	Shorezone	3	Includes bulkheads (concrete, rip-rap, & wood), groins and boat-ramps (% of SZ drift-cell).
2	Docks, Floats, and Piers	point	Shorezone	2	Includes all perpendicular over-water structures (# per km of SZ drift-cell).
3	Marinas	point	Shorezone	1	Includes commercial marinas only (# per SZ drift-cell). Marinas are defined as areas where fueling, boat/hull repair, or sewage pump-out operations are performed.
4	Aquatic Vegetation	line	Shorezone	3	Includes all marine vegetation (Eel Grass or Kelp Beds) used as salmonid habitat (% per km of SZ drift-cell). Continuous = 3, Patchy = 2, & None = 1. Forage fish habitat (SZ) also included.
5	Nearshore Riparian	line	Shorezone	3	Use both 30 m & 100m bands corresponding to each SZ drift-cell to test sensitivity. May use SPTH as for FW riparian analysis. Include Coniferous or Mixed and Late or Mid-Seral Stage. Also include any nearshore wetlands.

Table 24: Refugia Landscape Analysis GIS Model Components



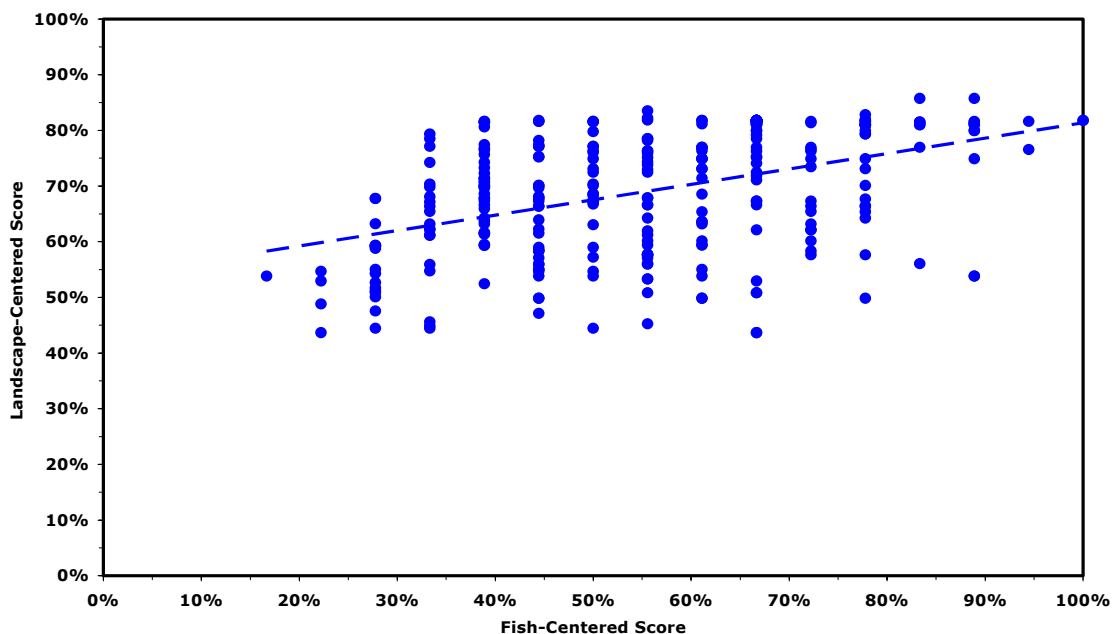
Combined Fish Score vs. Combined Landscape Score

Figure 43: Relationship between GIS Landscape and Fish-Centered Scores for the combined Jefferson and Kitsap County Model.

general, there is a direct relationship between more natural landscape conditions (higher GIS landscape scores) and higher scores from the fish-centered approach. This is to be expected in that instream conditions (i.e. water quality, biological integrity, salmonid habitat, etc.) generally reflect the overall watershed conditions. In most cases, salmonid habitat quality, species diversity, and productivity are higher when natural conditions have been maintained on the watershed and riparian landscape scale. This basic relationship has been demonstrated in other studies as well (Rieman and McIntyre, 1993; Allendorf et al., 1997; May et al., 1997; Beechie and Boulton, 1999; Booth et al., 2001; Pess et al., 2002). However, there are many cases where this correlation is not as strong. There are cases where salmonid habitat quality remains relatively natural and/or where native salmonid populations also remain relatively diverse and/or productive, while landscape conditions have been significantly modified. These areas, while unusual, are also not uncommon. In most cases, unique ecological and/or biological conditions found in these areas have resulted in a higher level of resistance to degradation and resilience to disturbance. Because of their unique conditions, these areas, along with the relatively undisturbed, natural areas, were strongly considered for refugia status.

Tables 18-20 summarize the combined refugia model scores for the combined East Jefferson (WRIA-16 & 17) and Kitsap (WRIA-15) study areas. In general, salmonid habitat conditions are better in East Jefferson County (see Table 25) than in Kitsap County. In addition, habitat conditions in Hood Canal watersheds are generally better than in those draining to the central Puget Sound region (see Table 25). This is likely due to the lower human population levels and resultant lower levels of watershed development

Study Area	Mean GIS Score
Kitsap County	65%
East Kitsap WRIA-15	58%
West Kitsap WRIA-15	72%
East Jefferson County	68%
East Jefferson WRIA-16	77%
East Jefferson WRIA-17	65%

Table 25: Refugia GIS Model Score Summary



found in the western portions of the study area (farther from the commercial-industrial centers of Puget Sound). However, even at relatively low, rural levels of watershed development, human impacts on salmonid habitat quality can be significant. Examples of this include the impacts of timber harvest and agriculture outlined in previous sections of this report.

The relationship between landscape parameters that measured human land-use and those that measure natural land-cover are quite interesting (see Figures 44 through 49). Generally, as development progresses in a watershed, native forest and other natural land-cover features (e.g. wetlands) are lost and replaced with agricultural fields, residential development, roads, and other land-use features. These human land-use features generally have impervious surfaces associated with them (i.e. pavement, rooftops, lawns, pastures, and other non-forested areas). Research has found that the percent total impervious area (%TIA) is a good measure of the cumulative impact of human development within a watershed (Booth, 1991; Booth and Reinelt, 1993; May et al., 1997; Horner et al., 1997; Horner and May, 1999; Booth et al., 2002).

Figure 44 shows the relationship between watershed development (as measured by %TIA) and natural land-cover (as measured by percent forest cover) for all the watersheds analyzed in the combined Kitsap and East Jefferson study area. In analyzing the data displayed in Figure 44, it can be seen that, in general, as watershed development increases, impervious surface area (%TIA) increases and native forest cover is lost. The relationship between the loss of natural forest cover and the increase in impervious surface area is quite strong, especially when development moves from the rural (< 10% TIA) to the suburban and urban ranges (> 30 %). This is the range of development where residential, commercial, and industrial land-uses begin to dominate the landscape and natural land-cover (forests and wetlands) is lost.

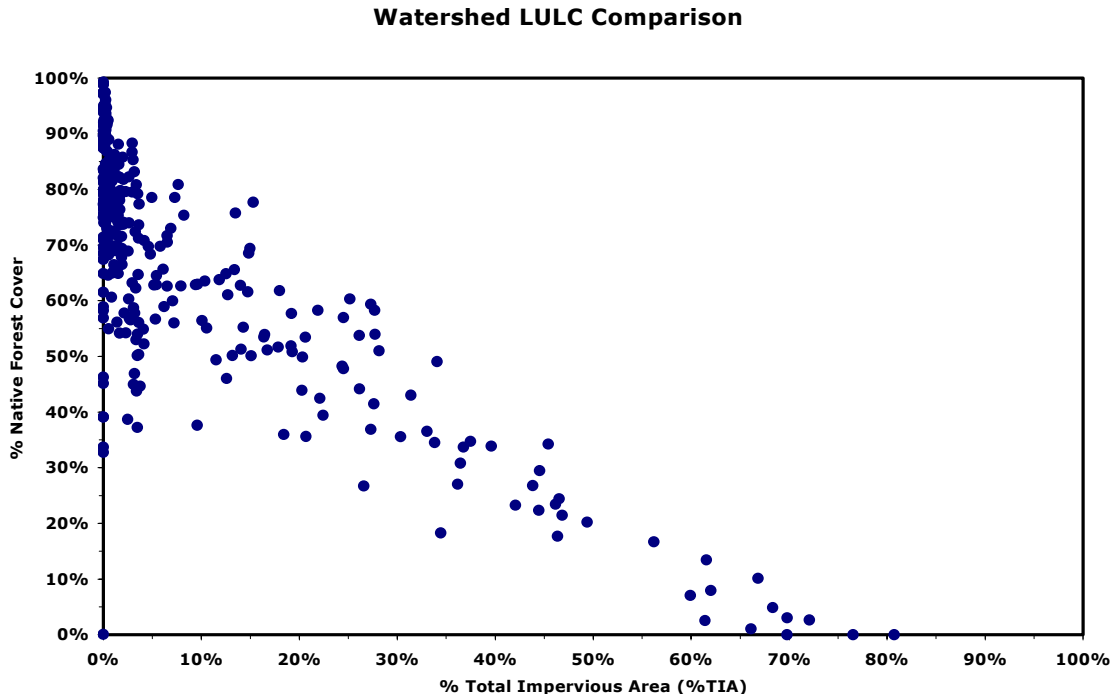


Figure 44: Relationship between Watershed Land-Use and Land-Cover



In the lower end of the impervious spectrum ($<5\%$ TIA), there is a great deal more scatter in the data. This reflects the impact of land-use activities that do not introduce a significant amount of imperviousness, yet do remove natural forest cover. This is primarily agricultural activities (farming or grazing), timber harvest, and rural residential land-uses. The difference between Kitsap County and Jefferson County can be seen in Figure 45, which displays data from both study areas, but differentiates between counties. This shows that Kitsap County is, in general, much more developed than East Jefferson County. A line has been drawn at the 5%TIA level to distinguish the two ranges of land-use discussed above. It can be seen that there is a number of watersheds in both counties with low imperviousness. Within this group, most also have a majority of their native forest land-cover remaining, while a smaller number have lost forest cover to agriculture and timber harvest activities. Another line has been drawn at the 65% forest cover level. This is generally recognized as the level (60-70% forest cover range) at which the natural hydrologic regime of a watershed begins to unravel and instream hydrologic impacts become significant (May et al., 1997; Horner et al., 1997; Horner and May, 1999; Booth et al., 2002). Research in the Puget Sound lowlands (Booth et al., 2002) indicates that at low levels of development (such as the rural levels found throughout Kitsap County), the retention of forest cover is much more significant than the increase in impervious surfaces in maintaining the natural hydrologic regime within a watershed. These results point to the importance of maintaining native vegetation and minimizing imperviousness on the sub-watershed scale. Currently, Kitsap County has several watersheds where stormwater runoff impacts, that tend to result from increased development, have had a significant impact on the natural hydrologic regime or aquatic ecosystems. These include Annapolis, Blackjack, Ross, Wright, Clear, Barker, Mosher, Steele, Bjorgen, and Dogfish Creeks. Retention of natural land cover (native forests and wetlands) is the key to reducing hydrologic impacts at rural levels of development (May et al., 1997; Horner and May, 1999; Booth et al., 2002).

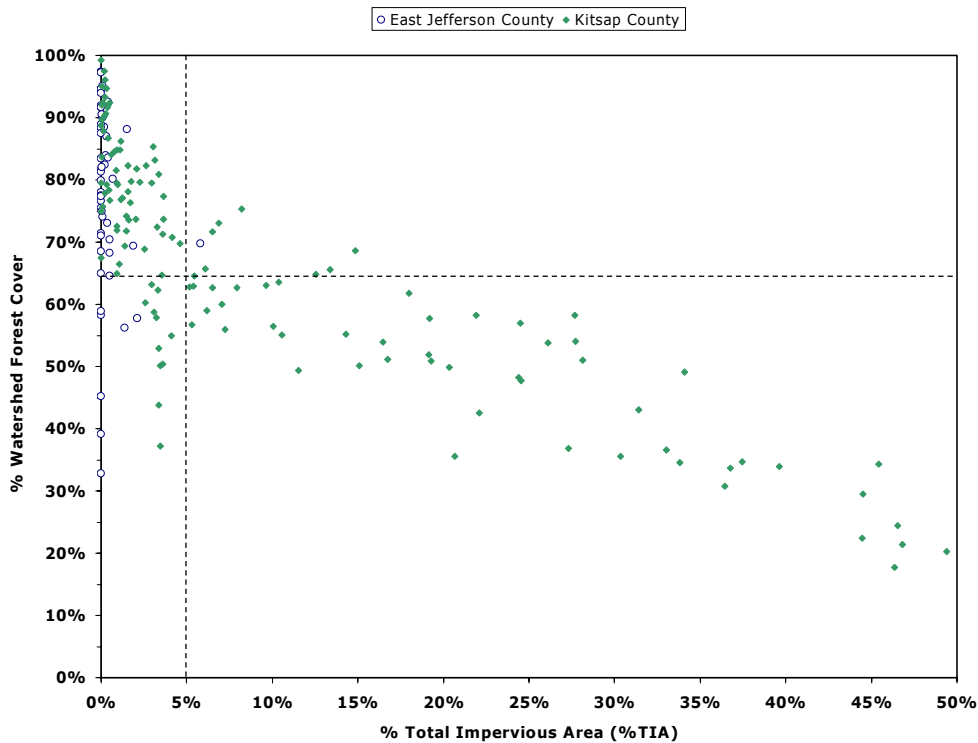


Figure 45: Relationship between Forest Cover and Land Use.



Another interesting relationship is that between imperviousness (%TIA) and the road network within a watershed. Roads are typically a major component of the overall level of imperviousness within a watershed, often exceeding 60% of the total impervious surface area (May et al., 1997; Horner et al., 1997; Horner and May, 1999; Booth et al., 2002). Figure 46 shows this relationship. This points to the importance of limiting the number of roads (paved and unpaved) constructed in a watershed, if impervious surface area is to be controlled and the natural hydrologic regime maintained.

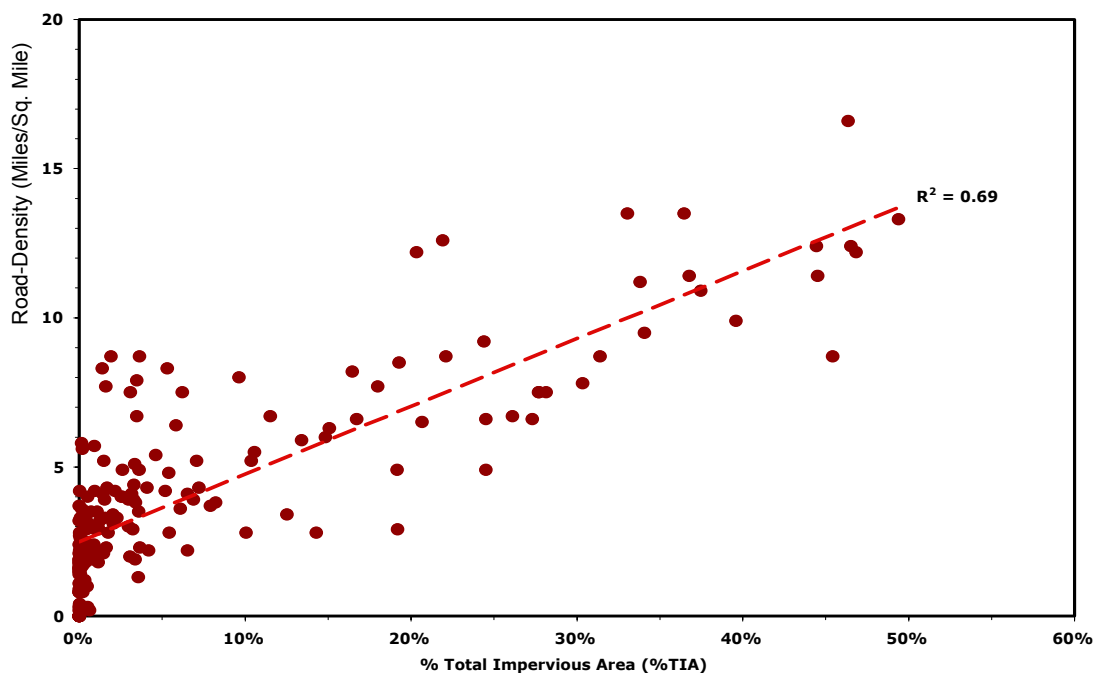


Figure 46: Relationship between Watershed Land-Use and Road Density

Roads also have other impacts on stream systems when they cross a stream or river. These impacts include fragmenting the stream-riparian ecosystem corridor, causing migration barriers (improperly installed culverts), and providing a conduit for fine sediment and other pollutants to enter the stream system with stormwater runoff. Figure 47a-d shows the number of road-crossings per channel length for streams in the Kitsap County study area. In general, a good target for maintaining natural stream-riparian function is to limit stream-crossing frequency to less than 2 per km (May et al., 1997). Numerous Kitsap County streams are well over this target and are highly fragmented. This can lead to hydrologic problems (localized flooding) as well as ecological impacts such as migration barriers.



Kitsap County Riparian Fragmentation

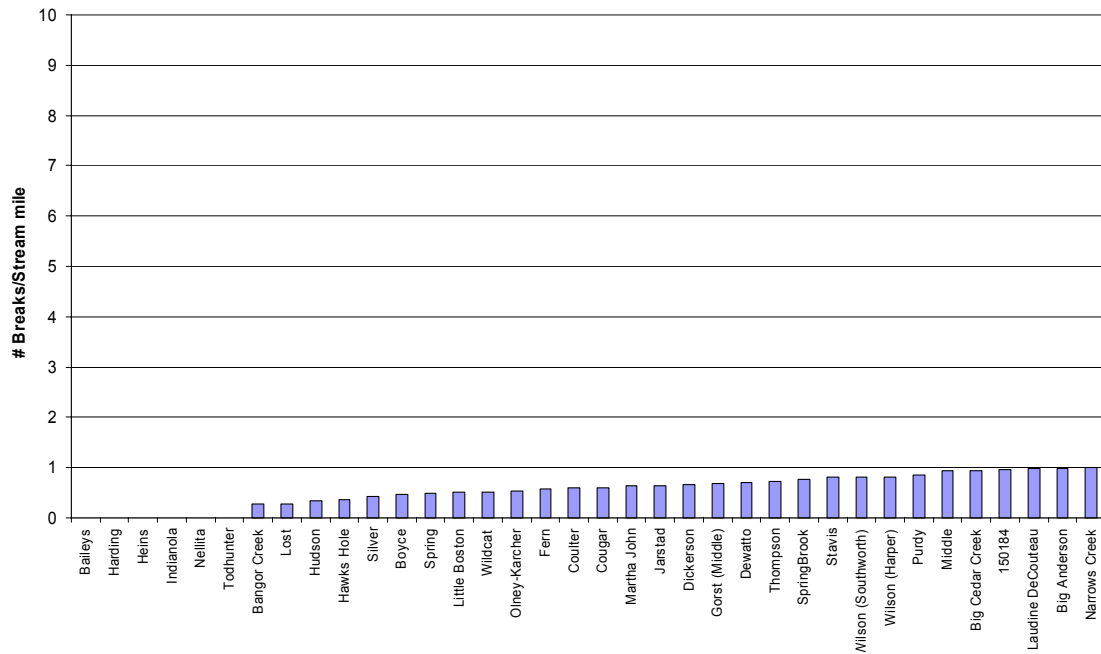


Figure 47a: Stream-Riparian Fragmentation in Kitsap County.

Kitsap County Riparian Fragmentation

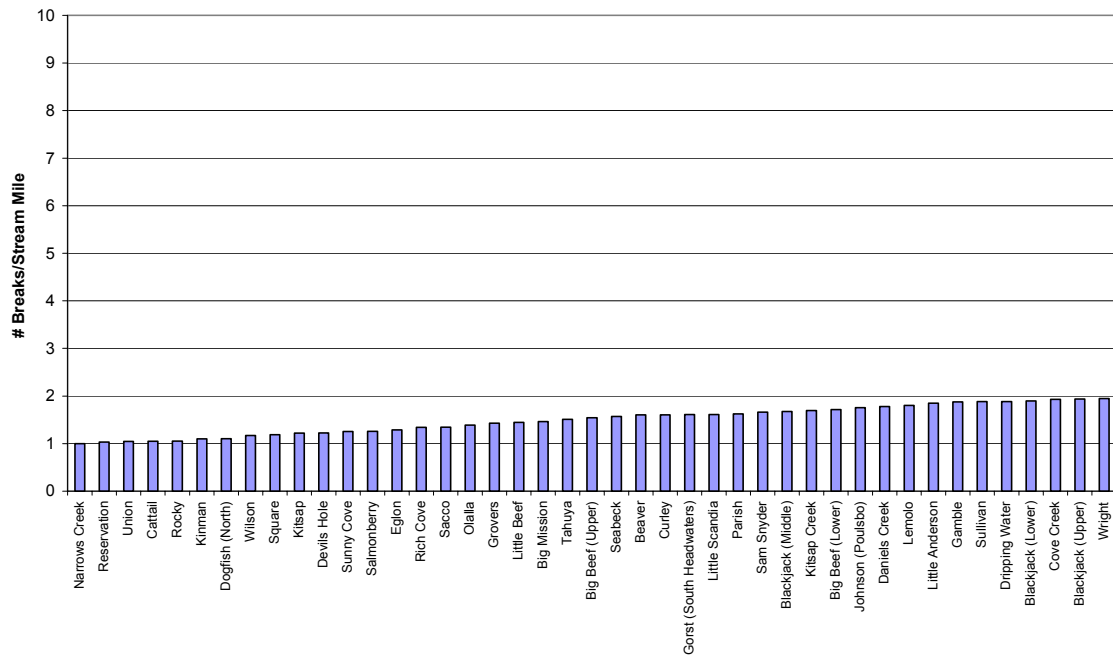


Figure 47b: Stream-Riparian Fragmentation in Kitsap County.



Riparian Fragmentation

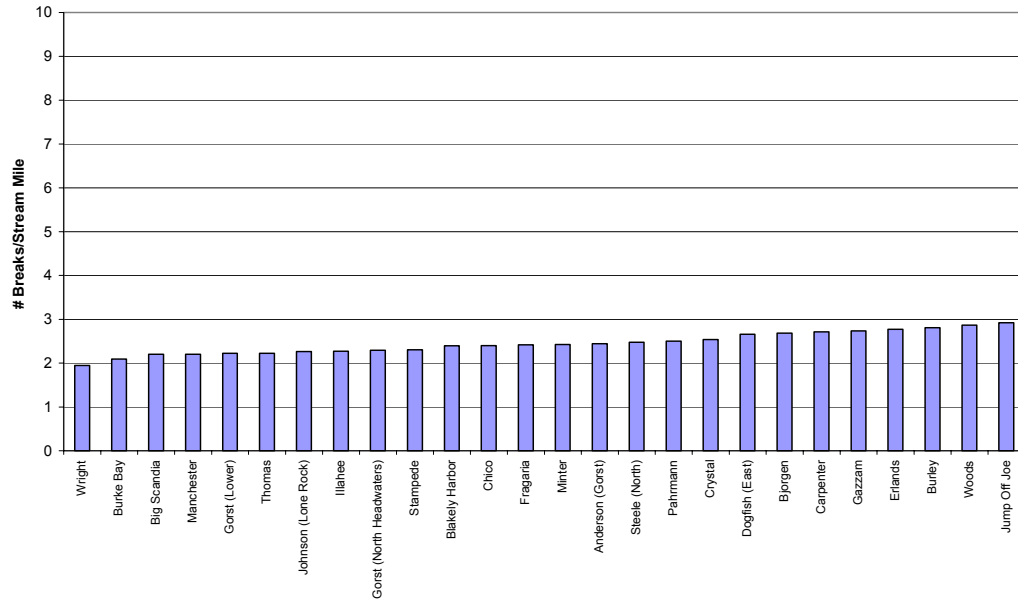


Figure 47c: Stream-Riparian Fragmentation in Kitsap County.

Riparian Fragmentation

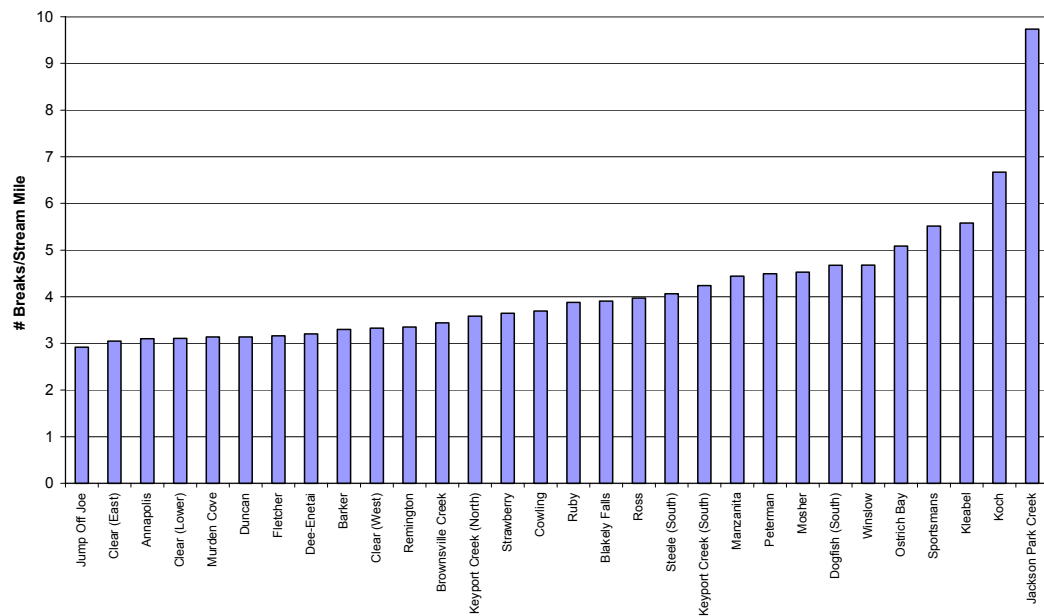


Figure 47d: Stream-Riparian Fragmentation in Kitsap County.



Agricultural (pasture grazing and crop production) is relatively low, but is still a common component of the overall land-use pattern of Kitsap County. Figure 48 shows the level of agricultural land-use found in the study area. In general, hobby farms and horse farms are the major agricultural-related activities, primarily located in the lower valley bottoms of the major stream watersheds (Burley, Olalla, Salmonberry, Blackjack, Dogfish, Steele, Big Scandia, Grovers, Martha John, Kinman, Eglen, Carpenter, and Gamble). Agricultural activities can have several negative impacts on streams, including polluted runoff from fields and pastures, loss of floodplain habitat and ditching of stream channels, and loss of riparian vegetation (NRC, 1996).

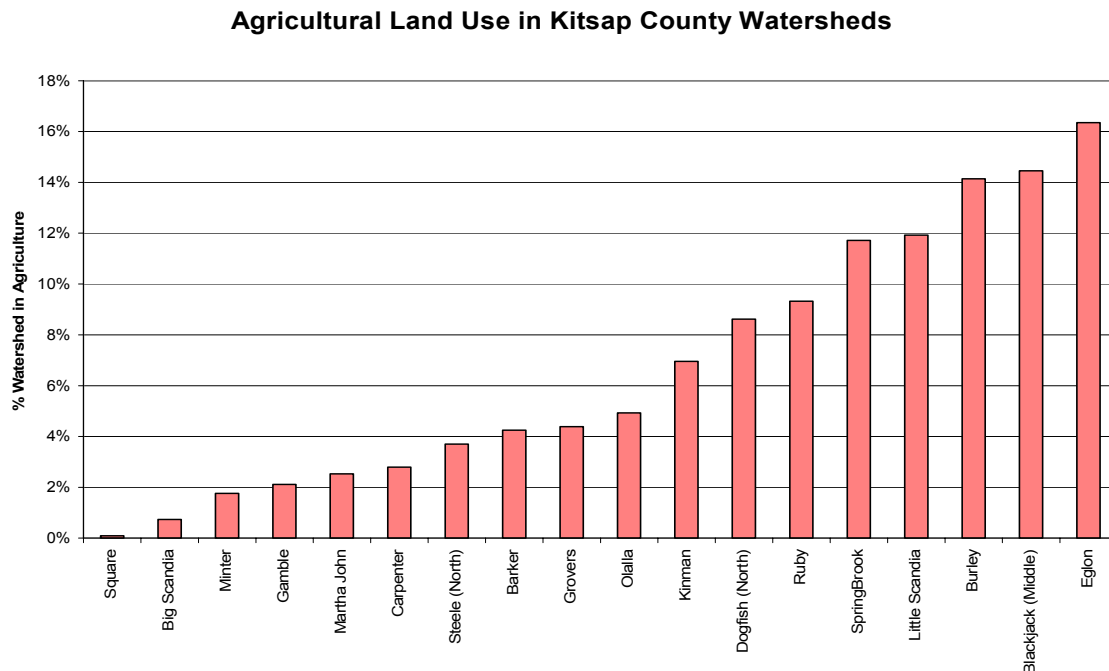


Figure 48: *Agricultural Land Use in Kitsap County Watersheds (other watersheds equal 0%).*

As has been discussed, the urbanization process has numerous impacts on watershed hydrology, water quality, and ecological integrity (May et al., 1997). Floodplain modification is one of those impacts associated with development within floodplain or flood-prone areas (see Figure 49a-b).

Figure 50a-d shows the distribution of impervious cover within the Kitsap study area, indicating that a significant number of watersheds are already at suburban levels of development. In spite of the impacts discussed above, many streams in the Kitsap County study area have retained much of their native forest cover and natural riparian integrity (see Appendix E for details on riparian issues), however a significant number of watersheds have lost much of their native forest cover and riparian integrity. Figure 51a-d shows the distribution of coniferous, deciduous, and mixed forest cover within the study area. Figure 52a-d shows the level of riparian quality (as measured by the percent of the riparian corridor that is composed of native forest cover) for streams in the Kitsap County study area.

The overall GIS landscape scores for the Kitsap County study area are shown in Figure 53a-d. In general, the scores for the Kitsap County study area good, reflecting the low level of watershed development and retention of native forest cover in most watersheds.



Foodplain Modification

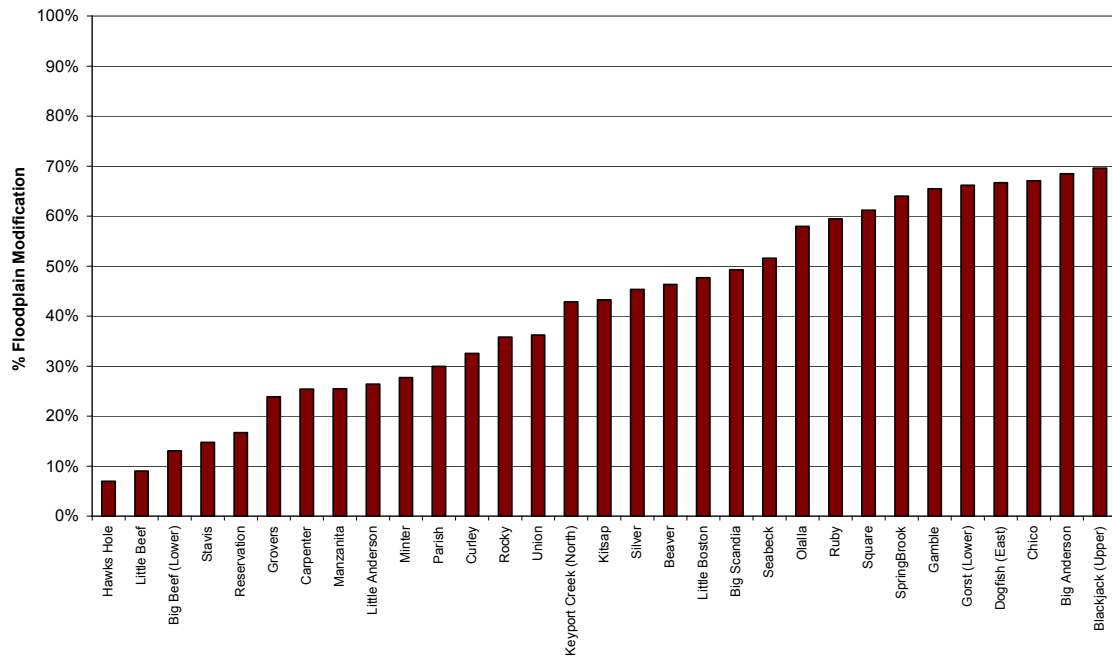


Figure 49a: Floodplain Modification in Kitsap County Watersheds (watersheds not shown have a value of 0%).

Foodplain Modification

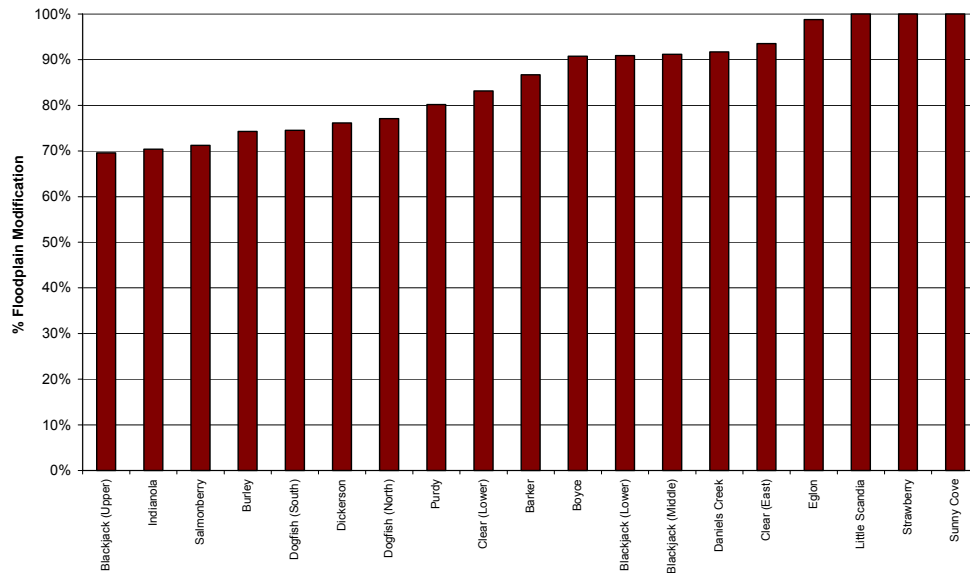


Figure 49b: Floodplain Modification in Kitsap County Watersheds (watersheds not shown have a value of 0%).



Percent Total Impervious Area, Kitsap County Watersheds

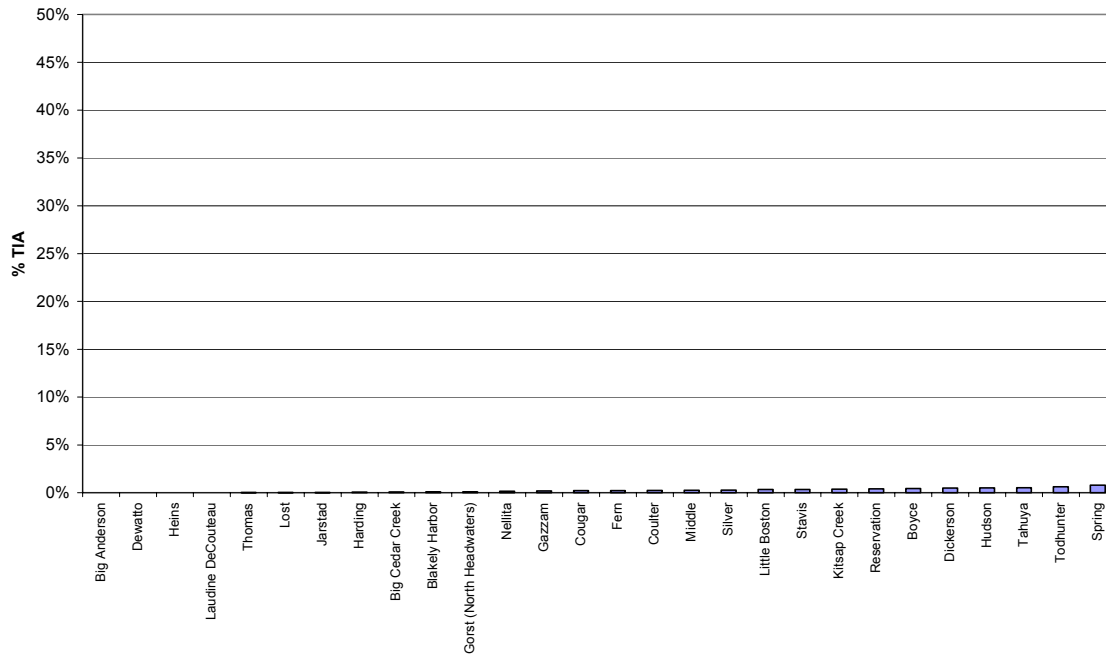


Figure 50a: Percent Total Impervious Area of Kitsap County Watersheds.

Total Impervious Area, Kitsap County Watersheds

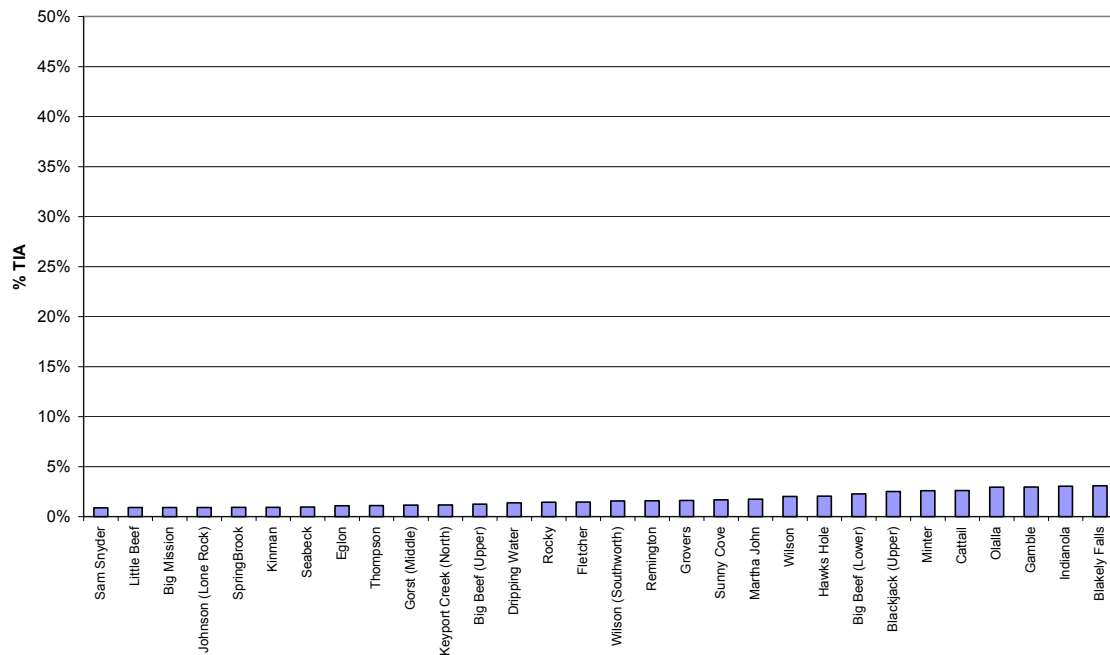


Figure 50b: Percent Total Impervious Area of Kitsap County Watersheds



Percent Total Impervious Area, Kitsap County Watersheds

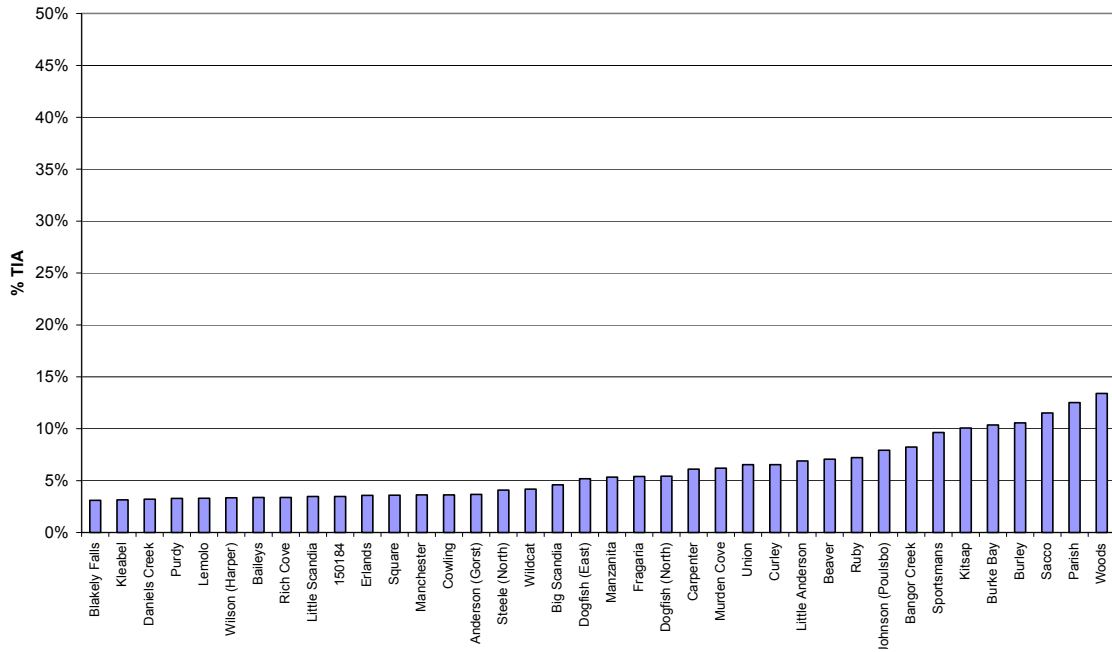


Figure 50c: Percent Total Impervious Area of Kitsap County Watersheds

Percent Total Impervious Area, Kitsap County Watersheds

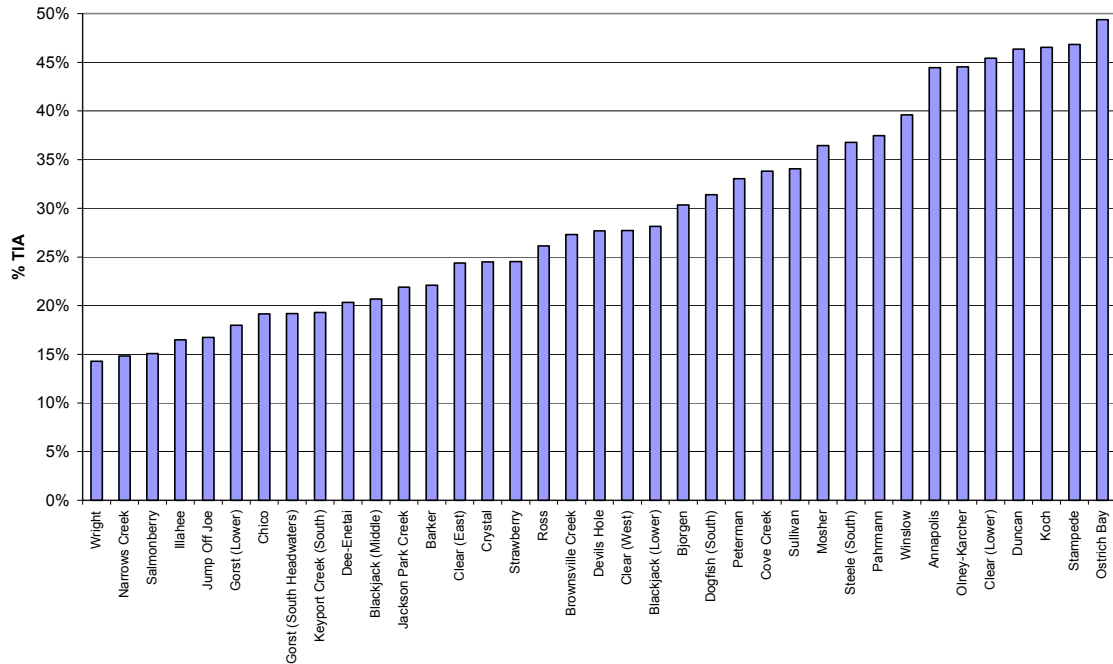


Figure 50d: Percent Total Impervious Area of Kitsap County Watersheds



Percent Forest Cover, Kitsap County Watersheds

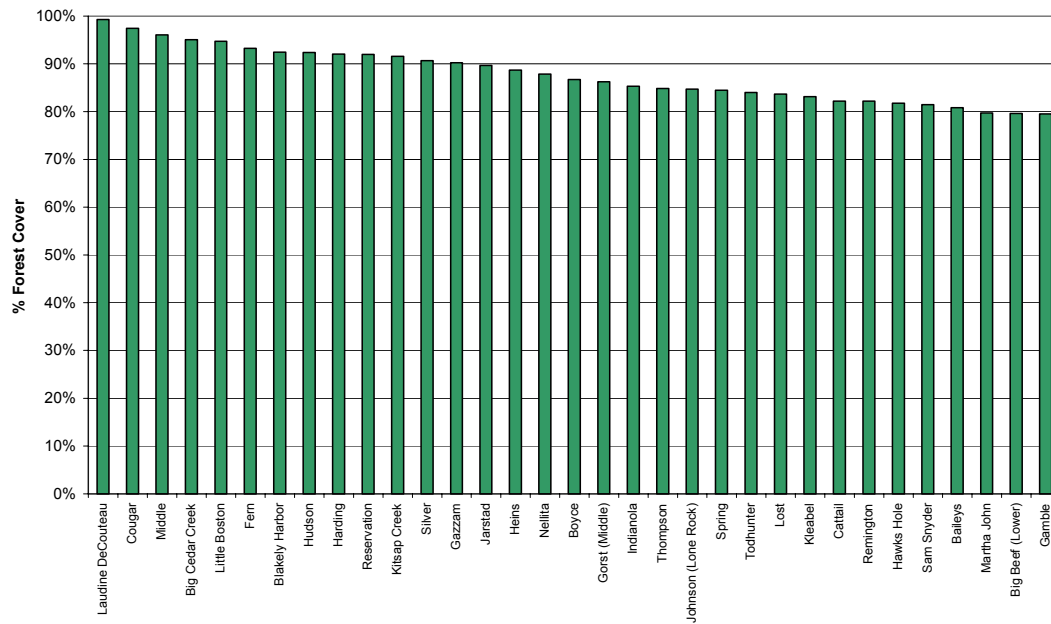


Figure 51a: Percent Forest Cover, Kitsap County Watersheds

Percent Forest Cover, Kitsap County Watersheds

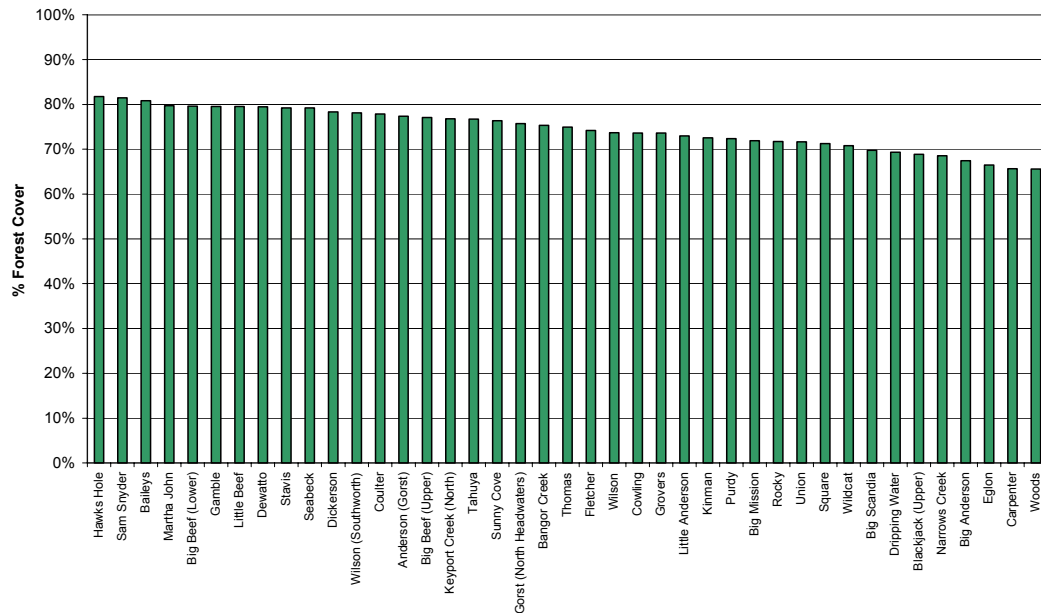


Figure 51b: Percent Forest Cover, Kitsap County Watersheds



Percent Forst Cover, Kitsap County Watersheds

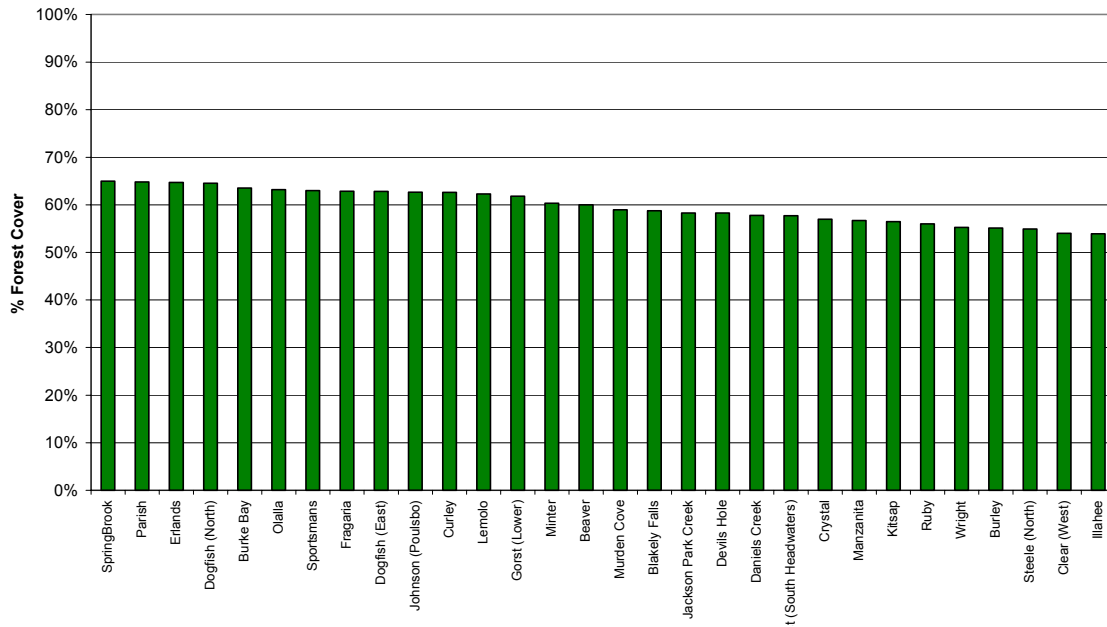


Figure 51c: Percent Forest Cover, Kitsap County Watersheds

Percent Forest Cover, Kitsap County Watersheds

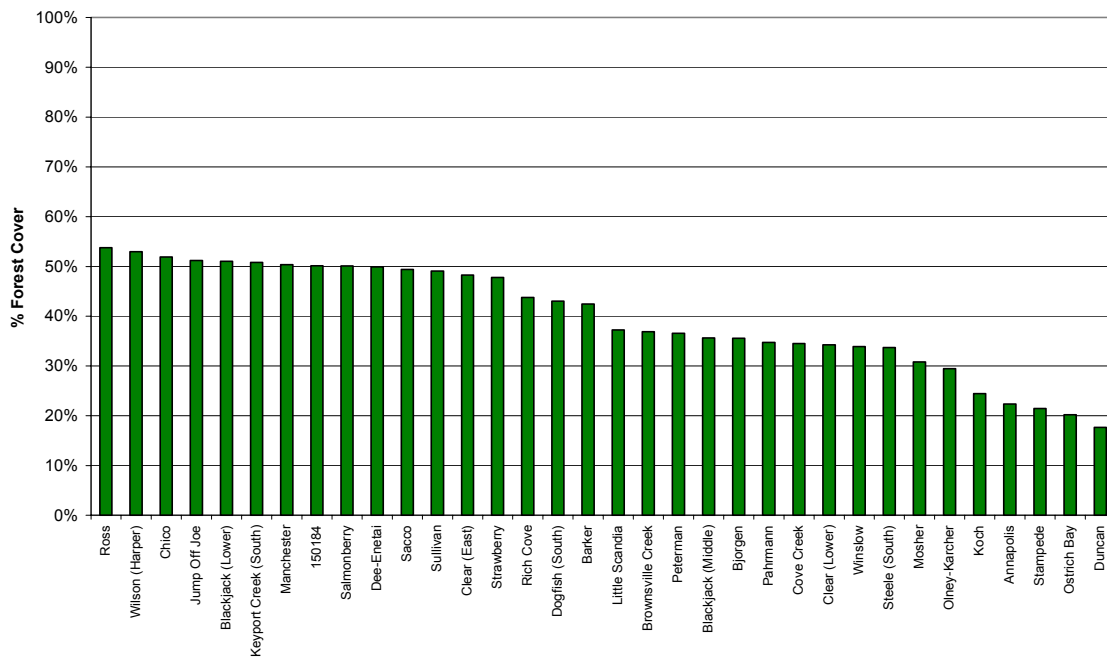


Figure 51d: Percent Forest Cover, Kitsap County Watersheds



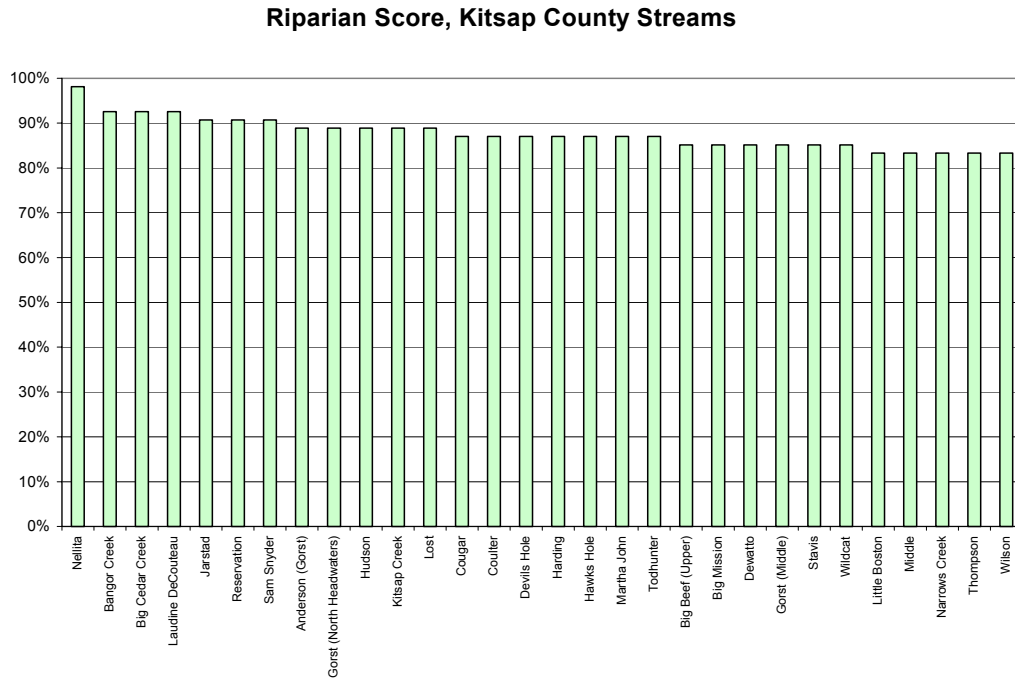


Figure 52a: Riparian Score, Kitsap County Watersheds

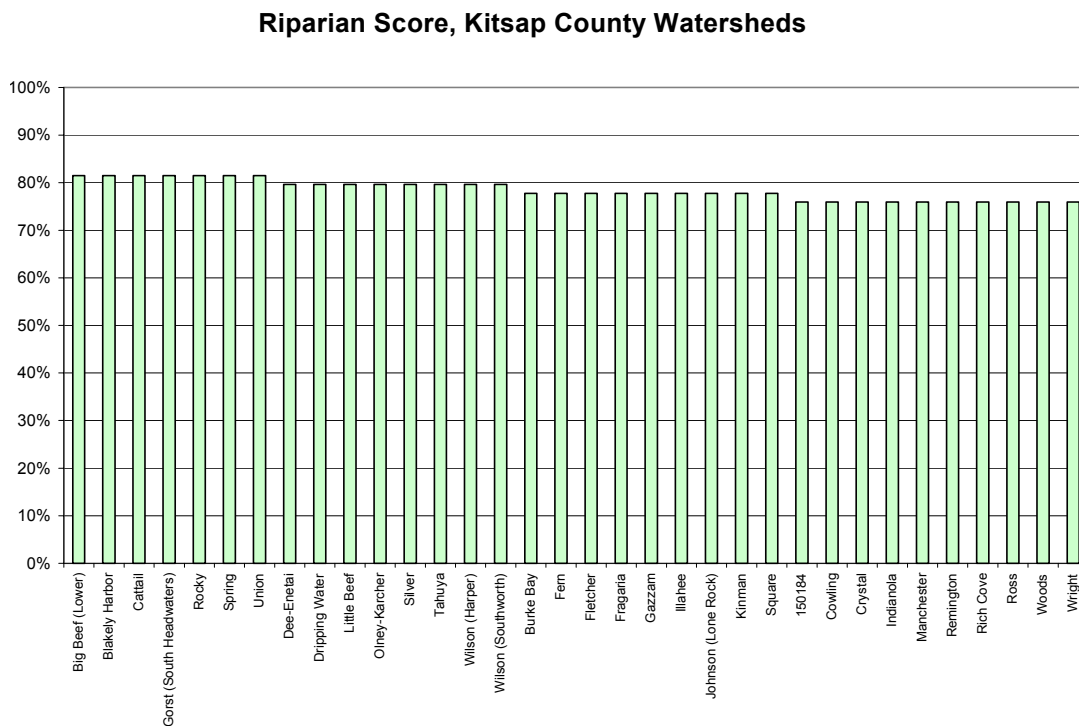


Figure 52b: Riparian Score, Kitsap County Watersheds



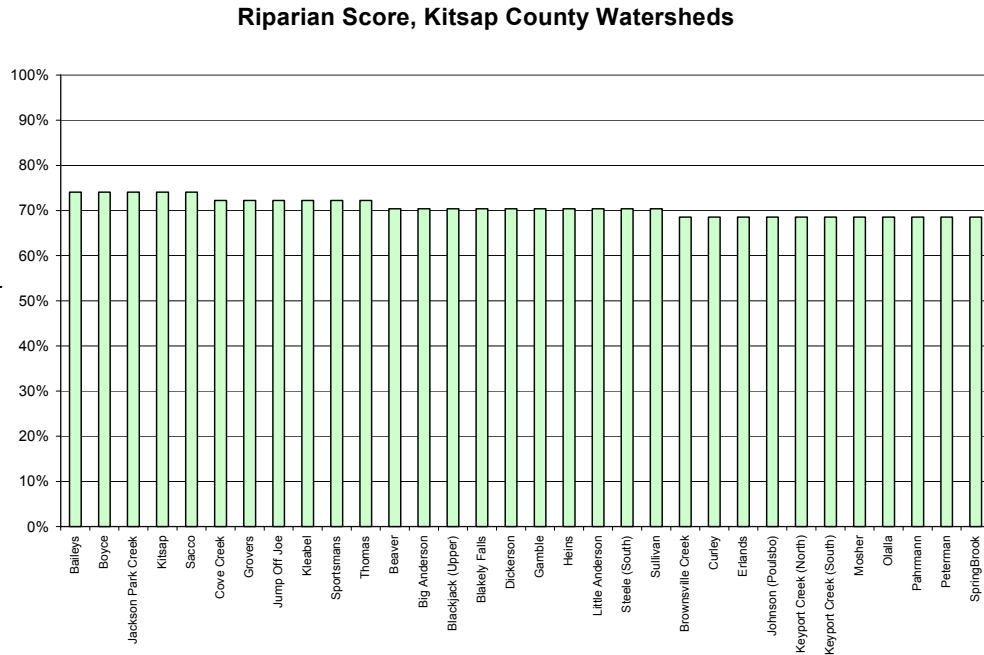


Figure 52c: Riparian Score, Kitsap County Watersheds

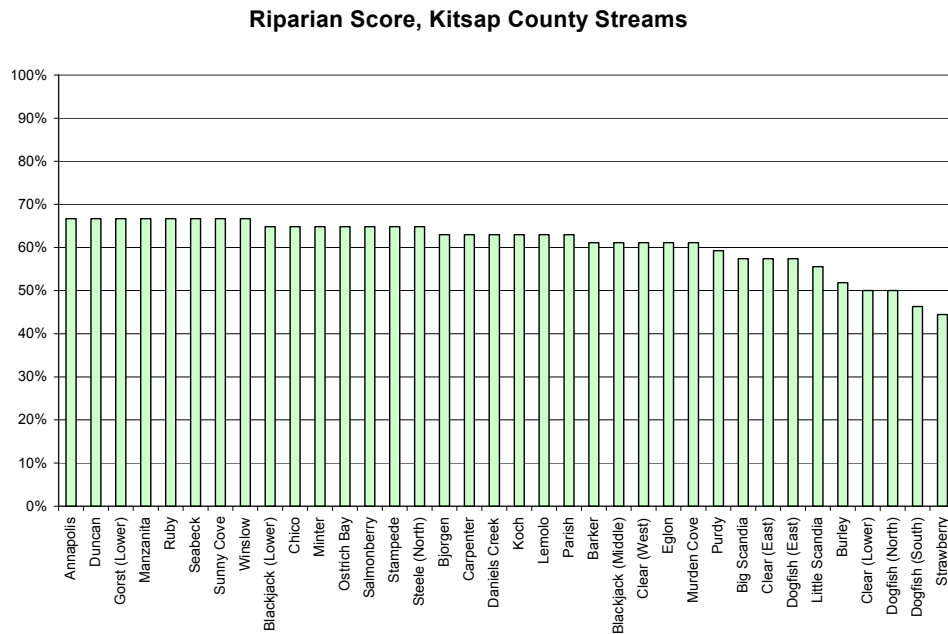


Figure 52d: Riparian Score, Kitsap County Watersheds



Landscape Score Kitsap County Watersheds

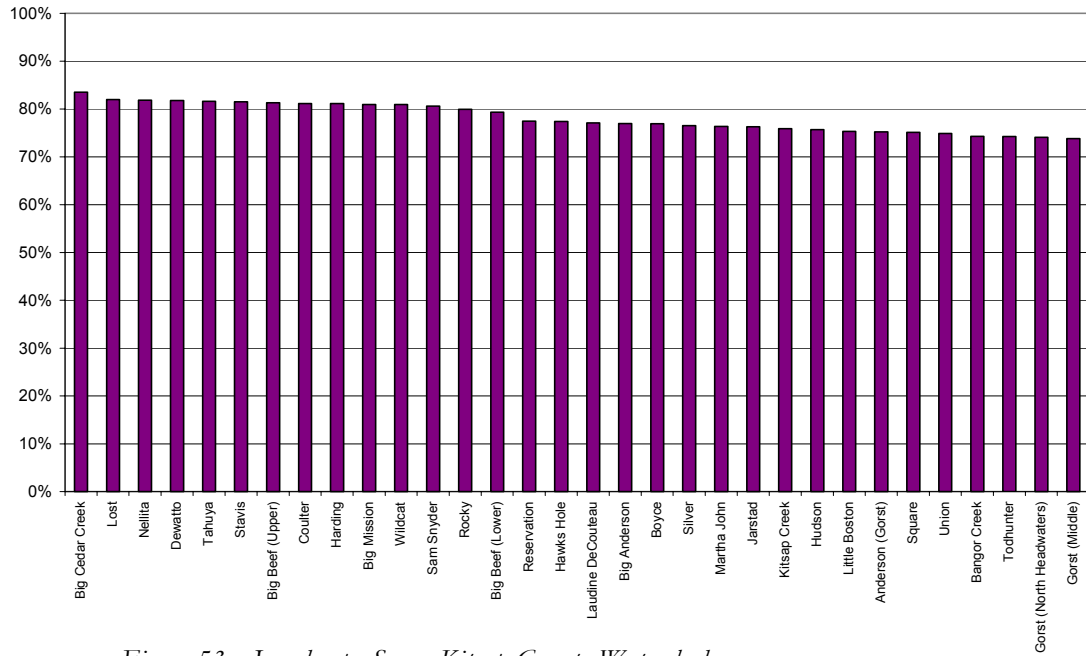


Figure 53a: Landscape Score, Kitsap County Watersheds

Landscape Score Kitsap County Watersheds

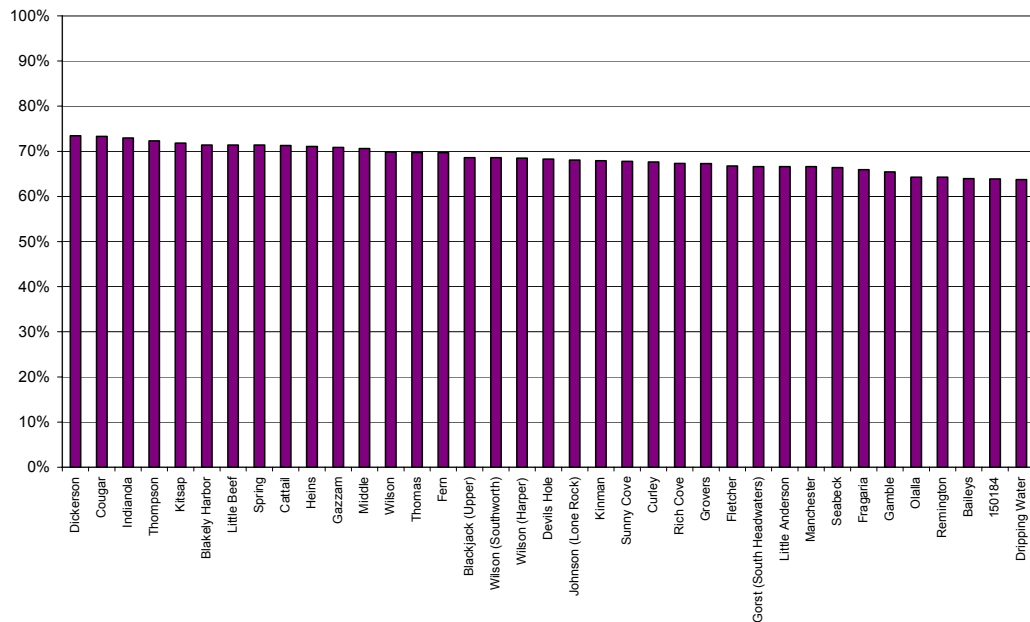


Figure 53b: Landscape Score, Kitsap County Watersheds



Landscape Score Kitsap County Watersheds

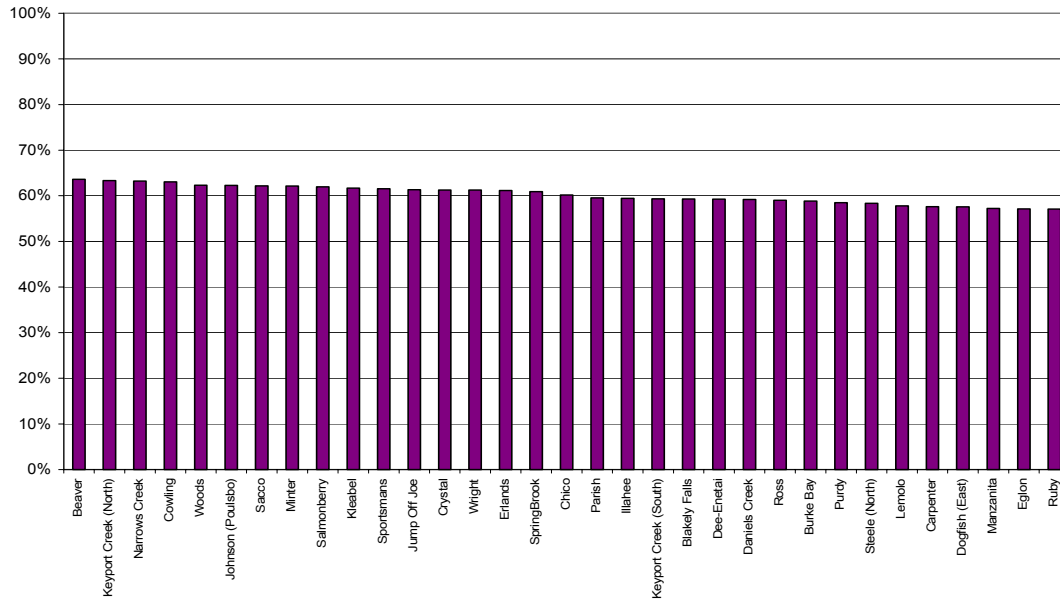


Figure 53c: Landscape Score, Kitsap County Watersheds

Landscape Score Kitsap County Watersheds

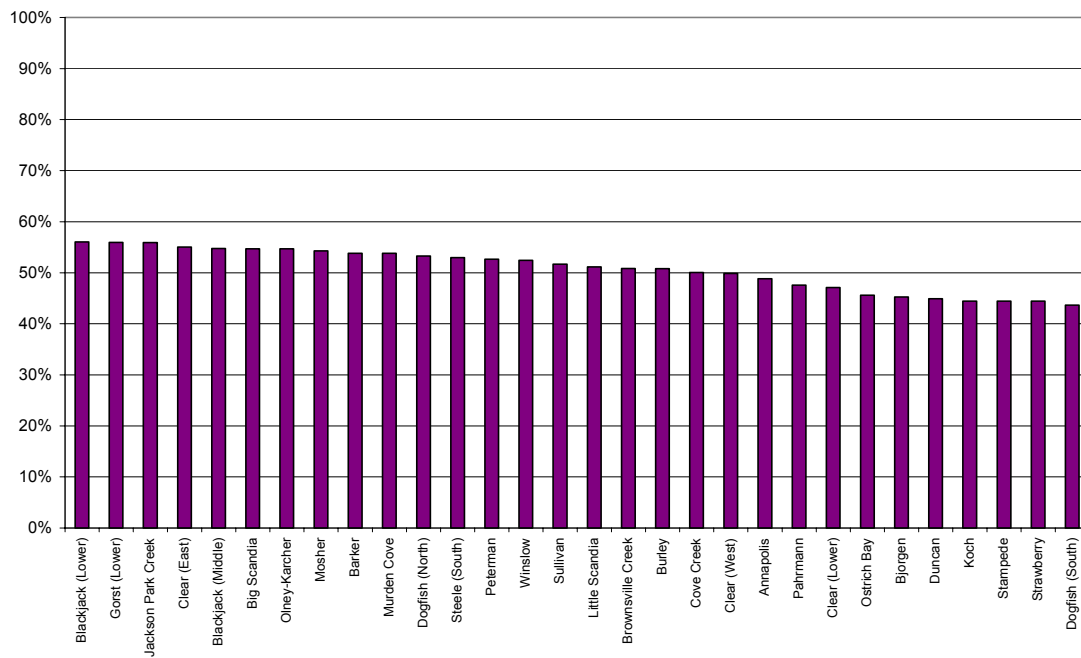


Figure 53d: Landscape Score, Kitsap County Watersheds



GIS LANDSCAPE MODEL NEARSHORE RESULTS

The identification, delineation, and assessment of potential nearshore refugia was based on best available scientific data. There is still a great deal we do not understand about salmonid utilization of the nearshore environment, but the body of knowledge is growing (Williams and Thom, 2001). Other jurisdictions are in the process of conducting detailed nearshore assessments (see King County State of the Nearshore Draft Report and Bainbridge Island Nearshore Assessment Draft Report for examples). The quantity and quality of scientific data available on the nearshore environment within the study area is significantly less than the data available for freshwater salmonid habitat. Therefore, the results of the nearshore refugia analysis should be considered as “interim” until a more thorough and rigorous nearshore assessment can be conducted.

The identification of potential nearshore refugia areas was based on field surveys conducted as part of the refugia project, interviews with local nearshore “experts” (this was primarily conducted in parallel with the WCC limiting-factors nearshore analysis process), and aerial-photo analysis using the most current WDOE shoreline photos (<http://apps.ecy.wa.gov/shorephotos/>). The selection and delineation of nearshore refugia areas was based on the following criteria:

- Known salmonid utilization for juvenile rearing and migration
- Known salmonid utilization for adult migration or feeding
- Presence of aquatic vegetation habitat supportive of salmonids

In addition, the estuaries of major streams and rivers were also included as nearshore refugia areas because of their critical importance in salmonid adult, juvenile, and smolt life history stages for multiple species.

Figure 54 shows a map of nearshore refugia areas in the combined Kitsap County and Kitsap County study area. The results of the GIS nearshore analysis for Kitsap and Jefferson Counties are shown in Figures 55 and 56. In general, nearshore areas in Hood Canal were in a more natural condition than nearshore areas on the east side of the Kitsap Peninsula on Puget Sound. Also, the west shore of the Hood Canal (Jefferson County) has generally more natural nearshore areas than the east shore, with the exception of the Dewatto and Tahuya areas in Mason County, which are among the most natural in the study area. The most significant negative impacts on the nearshore environment were the modification of the shoreline (including bulkheads, docks, marinas, and shoreline roads), the loss of native riparian vegetation, and the filling of estuarine areas for shoreline development.



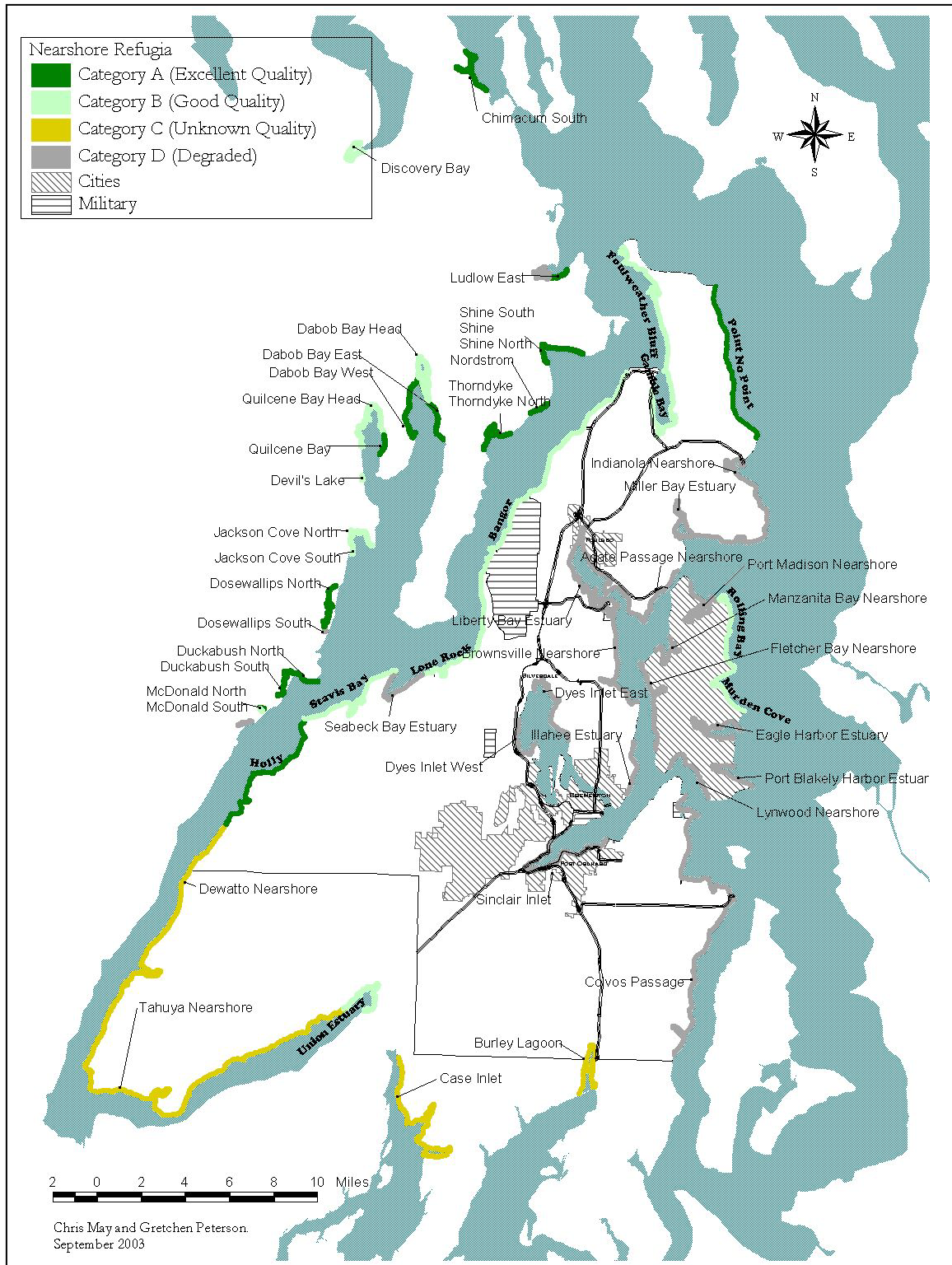


Figure 54: Map of Nearshore Refugia Areas.



Nearshore Scores, Kitsap County

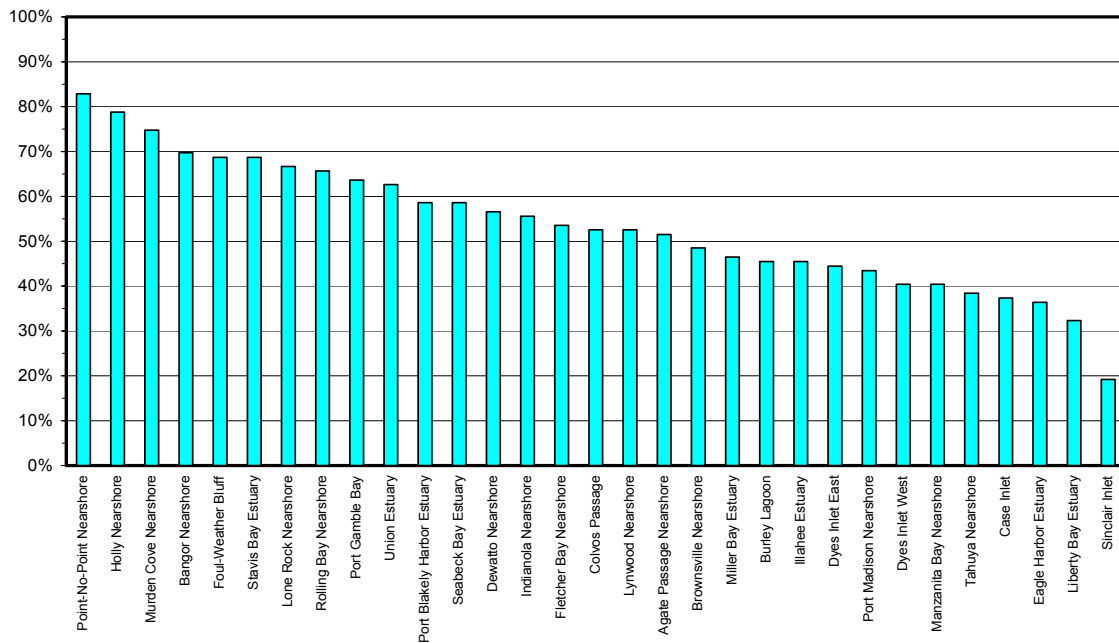


Figure 55: Nearshore Refugia Scores for Kitsap County

Nearshore GIS Model Results, Kitsap & East Jefferson Counties

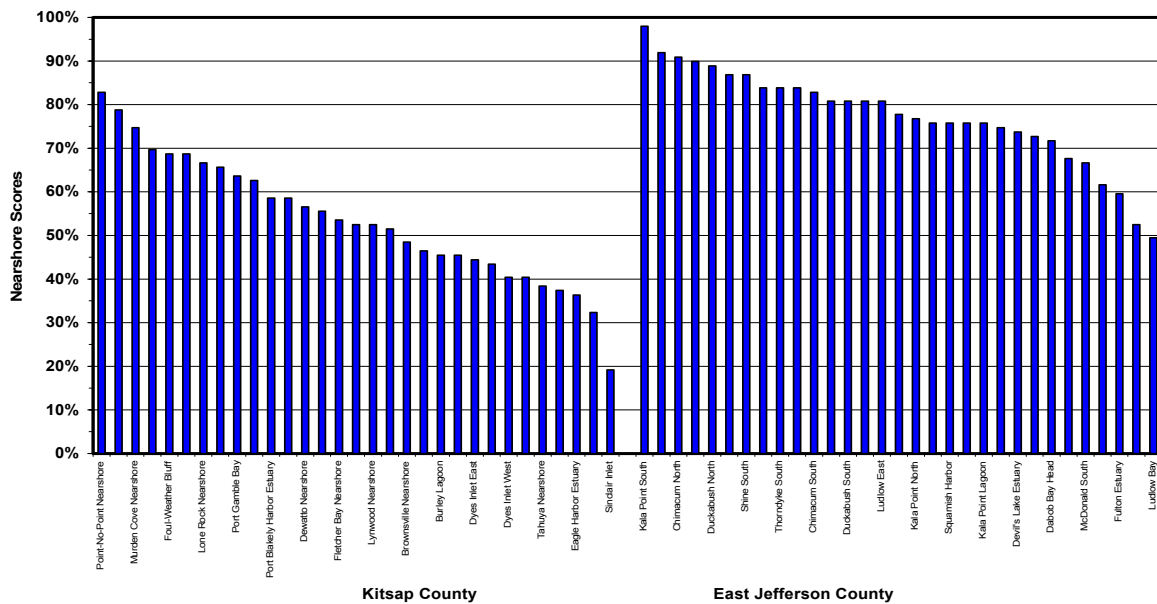


Figure 56: Nearshore Refugia Scores for Kitsap and East Jefferson Counties.



"Many of the things that must be done are little things - small things each citizen can do...things little in themselves, but vital, urgent, and far-reaching in cumulative results. Therefore, the matters here discussed are not to be dismissed lightly as the concerns of scientists, engineers, and government alone. Every citizen must understand the problems and play a part in the solution"

PERSON, 1935

CONCLUSIONS

Native salmon and trout are an important symbol of our connection with the natural landscape of the Pacific Northwest (PNW). What has been said of ecosystems in general is also true for salmon and their ecosystems; they are probably more complicated than we will ever be able to fathom completely. It is true that natural systems are inherently complex and dynamic. No matter how long we study them and how much we learn, there will always be some degree of uncertainty in our understanding of these systems. However, if we are to save our salmonid resources, we will be required to deal with nature as it is, with all its complexities and uncertainties. Saving salmon will require us to try to understand them and their habitats in new ways. Salmon are not predictable parts of a mechanistic system that we can manipulate for predictable results. We do know for certain that the natural ecosystems of the PNW are able to support a diverse and abundant community of organisms, including native salmonids.

Therefore, from both a scientific and common sense perspective, it is logical that we should make conservation of the remaining properly functioning, natural ecosystems a high priority in the overall salmon recovery strategy. This is the basic premise behind the salmonid refugia concept. Protection of these ecosystems as refugia is an excellent first step in the overall protection of native salmonids. The principles of *ecosystem management* should guide land-use activities.

The refugia concept is built on the ecological principle that protecting existing high quality salmon habitats is essential to the long-term survival of salmon. This is not the only action needed, but without conservation or restoration actions to safeguard these areas it may not be possible to recover salmon populations. Moreover, it will be much more expensive, and perhaps infeasible in many respects, to restore high-value habitats should they be further damaged. Long-term protection will require a partnership with the landowners and creative approaches tailored to the local circumstances. In many cases, the priority habitats identified in the assessment only remain intact because of the good stewardship of existing landowners. This history of good stewardship needs to be recognized and supported. In areas where stewardship is lacking or has been poor, public outreach and education should be emphasized to help improve long-term stewardship.

What is also true about our aquatic ecosystems is most are in a degraded condition as a result of many years of abuse and neglect under our stewardship. Salmonid depletion is nearly always the result of cumulative stresses on various parts of its life cycle in freshwater, estuarine-nearshore areas, and in the ocean. Many of these stressors are natural, but many more are the direct or indirect result of human activities. Habitat degradation is not the only stress, but it is one of the most significant in many situations. In a functional, naturally resilient ecosystem, stresses are absorbed with little significant change in ecosystem structure or function. However, as stresses accumulate and intensify,



the natural resiliency and resistance of the ecosystem is gradually degraded or lost altogether. At some point, as more stress is added, the cumulative impacts become too great and the ecosystem begins to unravel or even collapse. This is the case with many of our rivers and streams that historically supported diverse and productive salmonid populations.

As was discussed earlier, data utilized in the preparation of this report include watershed analysis reports compiled by natural resource agencies, formal habitat inventories or studies specifically directed at evaluating fish habitat, other watershed data not specifically associated with fish habitat evaluation, and the body of scientific literature related to salmonid conservation. In addition to scientific literature reviewed, the data and observations used in this report are primarily based on the collective experience of local biologists and ecologists that are actively working in the freshwater drainages and marine nearshore habitats of the study region and have a firsthand knowledge of the watersheds of interest. Although there are a significant number of past studies and reports on these watersheds, a large number of salmonid related “data gaps” remain, which will require additional detailed watershed research and assessment. This is especially true of the nearshore environment, which we are just beginning to fully understand. The available data indicate several common problems throughout the study region. These include (in no specific order):

- Natural stream ecological processes have been significantly altered due to the cumulative effects of watershed land-use practices and human encroachment into the stream-riparian ecosystem.
- There has been a significant shift in the natural hydrologic regime of many watersheds, especially those undergoing urbanization. This is characterized by increases in peak flow frequency, duration, and magnitude due to increased stormwater runoff from lands that have been converted from native forest and wetlands to developed landscapes dominated by impervious surfaces.
- Streambed stability and spawning gravel quality have been degraded by high stormflow scour and fine sediment deposition. Major fine sediment sources include logging roads, construction sites, and agricultural fields.
- Stream channel morphological changes have resulted from direct alterations such as agricultural channelization or floodplain diking. In addition, streambank erosion has increased in frequency and extent due to higher stormflows, loss of natural vegetation cover, and subsequent streambank armoring.
- There is a general lack of adequate large woody debris (LWD) in streams, particularly large, stable coniferous “key” pieces that are critical to forming pools, providing cover for juvenile fish, retaining organic matter, and maintaining instream habitat complexity. In addition, there is a general lack of adequate, high-quality rearing habitat (pools) for juvenile salmonids and the lack of deep “holding” pools for adult salmon migration.
- There has been a significant degradation and loss of natural floodplain processes in our rivers and larger stream systems, including the loss of functional off-channel wetland habitat. This is mainly due to dredging, bank armoring, and stream channelization. Past and current agricultural land-use has had a significant impact on floodplain and riparian processes in a number of lowland watersheds. In addition, development has also continued this process of stream channel manipulation.



- Almost all local streams have experienced a loss of natural riparian function due to removal or alteration of natural riparian forest vegetation. This degrades water quality, increases streambank erosion, reduces shade needed for water temperature regulation, and impacts instream habitat conditions through the decline in LWD recruitment.
- Stream-riparian corridor fragmentation is a major problem in many watersheds. This fragmentation has impacted the structure and function of our stream-riparian ecosystems. In addition, there are a significant number of culverts, diversion dams, and other fish passage barriers throughout these same watersheds.
- Estuarine and nearshore processes have been significantly impacted by physical alteration of nearshore ecological structure and function. These impacts include extensive shoreline bulkhead construction, loss of shoreline forest and LWD recruitment, loss of shoreline riparian cover and shade, and degraded water quality. In addition, natural sediment transport and beach nourishment processes have been disrupted as nearshore drift-cells have been altered by shoreline armoring, dock construction, and other human activities. All of these modifications have impacted salmonid habitat in the nearshore environment to some extent.
- Other impacts (e.g. hatcheries and harvest) have also significantly affected salmonid populations, however those issues are beyond the scope of this report.

Using the refugia concept as a starting point, regional efforts to protect and restore Puget Sound salmon should first focus on protecting the last remaining high quality habitat. This report provides a prioritized listing of the highest value habitat throughout the study region. The identification and descriptions of these areas, as well as the scientific ranking for each potential refugia area will allow resource managers to prioritize conservation actions in the near term. Safeguarding or improving ecological conditions and salmon populations within these areas may not alone be sufficient to bring about salmon recovery, but it represents critical first step in a long-term process. However, no scientific analysis has shown that preservation of these designated refugia would be sufficient to protect salmonid populations from extinction, nor that it would necessarily prove adequate to sustain viable salmon populations in the long-term. The question of the net effect of future habitat damage or loss to salmon can only be addressed through specific analyses of local and regional population dynamics and detailed studies of ecosystem change, which is beyond the scope of this report, but is the focus of on-going research in the Puget Sound ESU. What we can say with some certainty is that the ecological consequences of degrading or losing habitat areas identified in this report will be significant for salmonid populations in the study region.

Conservation efforts will likely have the greatest near-term benefit for salmon by focusing in watersheds where large areas of intact habitat still remain, but conservation efforts will be necessary in each sub-watershed or riparian corridor to maintain the diversity of local salmon populations. This study provides a useful framework for establishing regional and watershed-wide priorities for conservation efforts intended to benefit salmon. While this study identifies most of the important refuge habitats for salmon, it does not mean that areas not designated as refugia are not worthy of some level of protection. This prioritization of salmonid habitat is a provisional attempt to identify areas of recognized high value to natural salmonid productivity and diversity. Areas may exist that have high biological value as salmon refugia but that remain unrecognized due to lack of data. While there is a high level of confidence that the areas identified in this report as salmon refugia represent the vast majority of existing refugia areas, it is strongly emphasized that areas that were not designated as refugia should not necessarily be considered to be unimportant. As was discussed



earlier in the report, salmonid refuge habitat consists of a shifting mosaic of habitats that are continuously changing in quality and salmonid utilization potential. There will be a need for update and revision of this report as new information becomes available or as analysis techniques are refined.

Ecologically, it is probably true that long-term conservation efforts are likely to be more effective in watersheds with extensive and high quality refugia than in those with limited and poor quality refugia. However, social and cultural priorities, as well as scientific considerations pertaining to local adaptation, ease of recolonization, and the need to geographically dispersed refugia to spread the risk against catastrophic local loss, argue for some level of protection and restoration of ecological function in almost every watershed in the PNW region. Based solely on this report, it is not appropriate to avoid conservation investments in “poor-quality” basins and focus it exclusively on “high-quality” watersheds. The majority of the most productive salmonid habitat, lowland rivers and streams, have been severely degraded by the cumulative impacts of multiple human activities. Salmon abundance and diversity are low in many of these important lowland areas where many salmonid populations spawn and rear and where salmon production was once greatest. In addition, many lowland systems, while not prime spawning or rearing habitat areas, do provide migration corridors for salmonid moving from and to Puget Sound.

Conservation and restoration efforts also need to be focused geographically and significantly expanded to ensure the long-term productivity of the high quality habitats in the region. The refugia approach assumes that areas with high-quality habitat, relatively intact and naturally functioning ecosystems, and supporting relatively strong salmon populations, constitute a high priority for protection and restoration efforts. This implies that conservation efforts will be most successful where healthy population-habitat-ecosystem relationships remain. This is an important consideration to ensure the success and value of conservation efforts as a whole. The number, size, and geographic distribution of these refugia areas will be a critical factor in the success of salmonid recovery efforts. The size of each designated habitat refuge must be large enough to encompass the migratory range and life-stage requirements of all species of concern. This is why watershed-scale refugia are preferred where possible. This is also why nearshore, marine refugia were designated in conjunction with freshwater habitat areas. In addition, this is also why some refugia areas of lower habitat quality will need to be protected and restored to provide refuge habitat in key geographic locations within the study region. These areas likely have lost some portion of their historic productivity for salmon, but they remain among the most important parts of the landscape for present and future salmon conservation. As was discussed earlier, meta-population dynamics in general and in the case of salmon in particular, implies that local sub-populations may go extinct for a variety of reasons (both natural and anthropogenic). This occurs on both a spatial and temporal scale. Therefore, simply protecting the habitat in which salmon are currently doing well (current high-quality refugia) is not enough. In addition, it is necessary to protect habitat where the fish may not be currently thriving or be present (historic habitat). Furthermore, degraded habitat that has the potential to support these species must also be restored so that these areas will be available as *potential or future refugia*. It is also critical to understand that protecting only one sub-population (the single preserve concept) is not enough to ensure the long-term survival of native salmonids. The overall survival and persistence of meta-populations requires sufficiently numerous sub-populations (the exact number of which we do not know as yet) located sufficiently close together to allow the establishment of new sub-populations through natural dispersal. The distribution and geographic arrangement of refugia must support the dispersal (recolonization and straying) of salmonids from one habitat patch to another. This was, in part, the basis for the selection of refugia in this study. The optimum distribution of habitat patches to support natural salmonid populations is not fully understood. Therefore, a conservative approach was taken in designating refugia for this project. Refugia size, distribution, and location also influence the vulnerability of each population to catastrophic disturbances and affect



their ability to recover from natural or human-induced disturbance. In that there were not sufficient high-quality refugia remaining in the region, the majority of the designated refugia will require long-term, active stewardship and restoration efforts. These efforts are already underway. Such efforts as the culvert replacement program are already showing positive results. The removal of fish blockages and the upgrading of passages is one of the single most important actions that can be taken because it opens additional habitat to salmon utilization and increases the refuge habitat available within each system.

Conservation of salmonid refugia areas will require substantial investment of resources in both protection and active restoration actions. Purchases of development rights or title to preclude disturbance and development of sensitive lands, active restoration of streamflow to depleted reaches, and hydrologic rehabilitation or obliteration of existing roads and railroad grades are among the common needs for these areas if the existing salmon habitat conditions are to be maintained into the future. For many of these refugia, effective conservation will not be as simple as maintaining existing patterns of land and water use and ownership. In general, restoration needs in these and similar areas should be the priority for investment of salmon restoration resources. In these areas, enough salmon production and diversity remains that populations can be expected to respond positively as habitat responds to restoration actions. In parts of the landscape that are more depleted of salmon populations, restoration of physical habitat conditions may not lead to the desired biological response because salmonid populations are constrained by small population size, inadequate distribution, lack of life history or behavioral diversity, the masking effects of other untreated mortality sources, or adverse interactions with other species that respond more favorably to habitat changes.

The identification, evaluation, and prioritization of salmonid refugia areas is not a static, one-time project. It should be an ongoing and improving process. Incorporation of adaptive management principles into the refugia process is essential for the long-term success of salmon recovery efforts as a whole. We must continually upgrade our knowledge of the ecosystems we share with salmon and be willing to adapt our behavior, as new information becomes available.

An excellent example of this is our nearshore areas. Little is known about the specific ecological characteristics of this critical habitat, however, the structural and functional attributes of these marine shorelines are believed to be very similar to their freshwater counterparts. This is the main reason why the nearshore-estuarine (NSE) refugia designated in this report should be considered as interim, to be updated as our level of knowledge and our assessment techniques improve.

The salmon landscape is composed of a complex and dynamic mosaic of habitat conditions that is maintained by several important natural processes. Salmon are adapted to local environmental conditions, including the associated temporal and spatial variability. Natural landscape factors and human land uses affect ecosystem functions and processes (e.g. hydrologic regime, riparian function, etc.) that shape the local habitat conditions on which native salmonids rely. Multi-scale comparisons between current and historic or reference (optimal) conditions can help assess the productivity, diversity, and overall health of salmon populations. Land use practices associated with habitat degradation or loss can also be correlated with biological integrity (or salmon population viability) and help identify potential causes of decline. Identification of the underlying, root cause of ecosystem degradation is important such that we treat the cause (usually a disruption of natural watershed-based processes) and not just the symptom of the problem(s).

Until we know more about these complex ecosystems, our best chance for recovery lies in protecting the remaining salmonid resources. The cornerstone of this conservation effort should be the refugia program. Based on the ecosystem approach to conservation, the ecological needs of species other than salmonids must also be considered. Salmon are considered “keystone” species,



and as such they are a critical component in their ecosystems, having close interrelationships with many other species. This should be the basis for management of both watershed and riparian corridor refugia. In addition to protecting salmonids and other wildlife, these refugia will benefit humans, providing recreational areas and other natural amenities.



REFUGIA MANAGEMENT RECOMMENDATIONS

- Continue to evaluate freshwater habitat conditions throughout watershed and correct identified salmonid habitat limiting factors.
- Develop salmonid habitat conservation programs that include protective purchases, conservation easements, and voluntary stewardship elements.
- Because salmonids are adapted to spatially and temporally varied local habitat conditions, it does not make sense to manage for the same conditions at all locations, or to expect conditions to remain constant at any one location. A “one-size-fits-all” solution is rarely appropriate in the case of salmonid habitat conservation and restoration.
- Evaluate all known and potential adult and juvenile salmonid migration barriers in the watershed. Prioritize and correct all migration barriers as necessary.
- Protect stable natural hydrology within the watershed. Conserve native forest cover throughout the watershed and minimize impervious surfaces in all developed areas.
- Restore floodplain function, natural channel configuration, and stream channel migration zone. This should include consideration of dike and levee removal, road and residential relocation, and restoration of off-channel and historic slough habitat.
- Develop and implement a forest road management plan to reduce erosion and other impacts from logging roads. Ensure timber harvest operations are conducting with long-term sustainability as a goal. The principles of ecosystem management should guide all logging activities.
- Protect and enhance natural estuarine structure and function. Maintain connectivity with the adjacent nearshore.
- Restore natural riparian integrity throughout the watershed; encourage conifer regeneration in deciduous stands that historically had a conifer component, particularly in disturbed areas. This effort should include planting conifers (cedar, hemlock, and spruce), reducing riparian corridor fragmentation, and the establishment of ecologically appropriate riparian buffer zones.
- Reconnect and restore historic riparian wetlands and other off-channel habitat, where possible.
- Develop and implement a short-term LWD strategy until full riparian function is restored.
- Reduce impacts of roads and road crossings, including increased stormwater runoff to surface waters, non-point source water quality impacts from stormwater runoff, and increased fine sediment delivery from road surfaces and associated ditch maintenance. Correct all fish passage barriers as soon as practicable.
- Reduce habitat impacts from hobby farms and agricultural lands, including development and implementation of farm plans that restore stream functions; identify and correct areas in the watershed that have unrestricted livestock access.



- Implement a long-term biological monitoring program for the creek using the macroinvertebrate-based benthic index of biotic integrity (B-IBI). Biological monitoring is an excellent tool for diagnosing and qualifying watershed health and is a good way to involve citizens in the assessment process.
- Implement an exotic vegetation management program in the watershed.
- Identify and correct sources of known water quality problems. Continue to monitor for water quality problems.

RECOMMENDATIONS FOR IMPROVEMENT OF THE REFUGIA PROCESS

- From a regional (Puget Sound) perspective, it is also important this refugia plan “fits” with other refugia plans. It is almost a certainty that protection and restoration of habitat throughout the Puget Sound will be necessary for the successful recovery of salmon stocks in the PNW region as a whole.
- Utilize higher resolution GIS data such as LIDAR to replace DEM-derived data, and DAIS multi-spectral data or digitized aerial photos to replace the 30 m LandSat LULC data.
- Obtain data on forest stand age or forest maturity and incorporate it into the GIS model.
- Conduct quantitative habitat assessment surveys on all streams that lack this data and incorporate this data into the GIS model.
- Better quantification of the level of uncertainty associated assessments and analyses can increase the effectiveness of modeling efforts.



"When you put your hand in a flowing stream, you touch the last of what has gone before and the first of what is yet to come..."

LEONARDO DI VINCI, 1518

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Zar, J.H. 1984. Bio-Statistical Analysis. Prentice-Hall, NJ.



OVERVIEW OF APPENDICES

Included with the paper copies of the 2003 Kitsap Salmonid Refugia Study is a CD containing several appendices. This section explains what the appendices contain.

APPENDIX A: WATERSHED DESCRIPTIONS

Appendix A contains 2- to 22-page descriptions of 34 Kitsap streams. The descriptions typically discuss salmonid utilization, a watershed description, several photographs of key features of the watershed, and a list of references.

APPENDIX B: SALMON DATA

Appendix B contains the following information about salmon:

- A 12-page paper discussing salmon distribution and abundance by species in Kitsap streams. It includes charts and graphs of fish populations.
- Excel spreadsheets with 2003 Kitsap Salmonid Refugia Report Fish Scores.
- Maps from the East Kitsap Limiting Factors Analysis depicting range of salmon species in East Kitsap streams.
- Maps of the West Coast showing the status of salmon populations.
- Spreadsheets with results of spawner surveys and escapement data.

APPENDIX C: HABITAT DATA

Appendix C contains the following information about habitat:

- An 84-page guideline on Habitat Assessment Field Protocols for Kitsap County by Chris May., June 2002.
- An 8-page document showing the criteria WCC uses in rating habitat conditions.
- Excel spreadsheets with 2003 Kitsap Salmonid Refugia Report Habitat Scores.
- Maps from the Chico Watershed Planning process.

APPENDIX D: WATER QUALITY AND B-IBI DATA

Appendix D contains the following information:

- A spreadsheet showing results of Kitsap “stream bug” monitoring
- A 176-page document showing the final 1998 Section 303d list for the Kitsap Peninsula.



APPENDIX E: RELATED SCIENTIFIC STUDIES

Appendix D contains several fact sheets, scholarly articles, major reports, and guidance documents that the author found particularly interesting and useful.

MAJOR REPORTS/GUIDANCE DOCUMENTS

1. A 74-page report by Chris May entitled "Stream-Riparian Ecosystems In the Puget Sound Lowland Eco-Region: A Review of Best Available Science."
2. A 180-page review by CH2M Hill of the scientific foundations of the Forests and Fish Plan for WA Forest Protection Association, April 2000.
3. The comprehensive 797-page Hood Canal Summer Chum Conservation Initiative completed by PNPTC and WDFW in April 2000.
4. The State's 59-page Guidance on Watershed Assessment for Salmon, published by the Joint Natural Resources Cabinet, May 2001.
5. A report by DNR's Jeff Cederholm describing the array of species which rely on salmon in our ecosystem. The 147-page report, "Pacific Salmon and Wildlife - Ecological Contexts, Relationships, and Implications for Management," was published in 2000.
6. Evaluation of Baseline Habitat Conditions, Tri-County Urban Issues ESA Study, R2 Resource Consultants, 46 pp.
7. A 183-page report by Oregon's IMST entitled "Recovery of Wild Salmonids in Western Oregon Lowlands." July 2002.

OTHER STUDIES/REPORTS

8. A 16-page paper by UW's Charles Simenstad entitled, "Estuarine Landscape Impacts on Hood Canal and Strait of Juan de Fuca Summer Chum Salmon and Recommended Actions." January 1998.
9. A 17-page paper by Carol Smith, Ph.D., Washington Conservation Commission, on the role of habitat for salmon populations.
10. East Kitsap Limiting Factors Analysis Baitfish Maps, 22 pp., 2000;
11. Independent Populations of Chinook Salmon in Puget Sound, NMFS TRT, April 2001. 61 pp.
12. The Functions of Riparian Buffers in Urban Watersheds, Masters Thesis, Jennifer Leavitt, 1998. 38 pp.
13. River Corridor Management Bibliography, Maryland Public Drainage Task Force, April 2000, 19 pp.

PEER-REVIEWED ARTICLES

14. A conceptual framework for the definition of the optimal width of riparian forests, Gerd Sparovek, Agriculture, Ecosystems and Environment, 2002. 7 pp.
15. Forest Buffer Strips, Theodore Endreny, Journal of Forestry, January 2002. 6 pp.
16. Landscape-Scale Spatial Population Dynamics in Human-Impacted Stream Systems, Winsor Lowe, Environmental Management, April 2002. 9 pp.
17. Pacific Salmon, Nutrients, and the Dynamics of Freshwater and Riparian Ecosystems, Robert J. Naiman, Robert E. Bilby, et al, Ecosystems, 2000. 19 pp.
18. Quantifying the mechanical and hydrologic effects of riparian vegetation on streambank stability, Andrew Simon, Earth Surface Processes and Landforms, 2002. 20 pp.



19. Riparian aquatic interaction simulator (RAIS): a model of riparian forest dynamics for the generation of large woody debris and shade, Jeffrey J. Welty, Timothy Beechie, Robert Bilby, George Pess, et al., Forest Ecology and Management, 2002. 20 pp.
20. Riparian ecology and management in the Pacific coastal rain forest, Robert Naiman, Robert Bilby and Peter Bisson, BioScience, November 2000. 16 pp.
21. Riparian Forest Restoration, Bernard Sweeney, Restoration Ecology, June 2002. 9 pp.
22. Role of Adaptive Management for Watershed Councils, Geoffrey Habron, 13 pp.
23. Toward Quantifying Water Pollution Abatement in Response to Installing Buffers on Crop Land, Michael Dosskey, Environmental Management, 2001. 22pp.

FACT SHEETS/PRIMERS

24. "Ecological Principles for Managing Land Use," Ecological Society of America, 12 pp.
25. A 2-page summary of research regarding riparian zones by the Washington Forest Protection Association, February 2002.
26. A 3-page overview of the importance of nearshore habitat by Chris May.
27. Monitoring urban streams: strategies and protocols, UW Center for Streamside Studies, Fact Sheet. 2 pp.
28. A 10-page primer on salmon ecology by Chris May.
29. A 5-page primer on watershed ecology by Chris May
30. A 7-page primer on benthic monitoring by Chris May.
31. A 9-page paper on freshwater salmon habitat by Chris May.
32. A series of 4 block diagrams showing impacts of urbanization and shoreline armoring.

APPENDIX F: NEARSHORE

Appendix F contains the following information related to nearshore areas:

- A 92-page draft white paper for WSDOT, Ecology and WDFW entitled "Development Guidelines for Aquatic Habitat Protection and Restoration: Marine and Estuarine Modification Issues." November 2000.
- Maps from the Bainbridge Island Nearshore Assessment

APPENDIX G: GIS DATA

Appendix G contains the following GIS data:

- Six spreadsheets containing the results of the refugia scoring effort. These spreadsheets also contain many of the graphs presented in the body of the report.
- 13 JPEG files showing maps of Kitsap/Jefferson sub-watersheds showing how each fared in the GIS analysis if imperviousness, forest cover, riparian fragmentation, etc.
- A folder containing ArcGIS layers
- A folder containing ArcView coverages of refugia and flood prone areas

