SALMON AND STEELHEAD HABITAT LIMITING FACTORS IN THE WESTERN STRAIT OF JUAN DE FUCA

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ABSTRACT

Through the Engrossed Substitute House Bill 2496 process, the habitat conditions of salmonid-producing watersheds within WRIA 19 were reviewed and summarized. Major and minor factors that limit salmonid production are summarized below by watershed, beginning with the larger watersheds that produce greater numbers and types of salmonids. Detailed discussions for each of these factors can be found within the body of the report. This first round report examines salmon and steelhead trout habitat conditions. Later versions will address the habitat issues for other salmonids.

The Hoko River is the largest watershed within WRIA 19. Excess sedimentation is a major limiting factor for this watershed, with sources from roads and clearcuts. The sedimentation has led to channel instability and a change in substrate to less suitable spawning gravels. Sediment transport and water velocity effects are worsened by a severe lack of large woody debris (LWD), which is another major limiting factor. Many riparian areas are dominated by hardwoods, and will not contribute to future LWD. Also, it is believed that the change in age and type of surrounding forests contributes to an increased frequency and severity of peak flows. Another major problem includes encroachments to the floodplain, such as riparian roads and an old railroad grade in the mainstem, as well as dikes and channelization in the Little Hoko River. These floodplain impacts constrain the channel, reduce side-channel habitat, and reduce riparian vegetation and associated LWD recruitment. In addition, riparian roads also contribute to excessive sedimentation. Another potentially large problem is low flows in the summer and early autumn. Low flows contribute to high water temperatures and limit the spawning distribution of fall chinook to less stable areas of the mainstem, possibly increasing the likelihood of scour during peak flow events. The naturally low flows are worsened by water withdrawals.

Minor limiting factors in the Hoko River include numerous culverts and changes in the estuarine area. Improving culverts would increase coho and steelhead habitat, but would not address the large problems in the mainstem that impact all salmonid species. The estuarine habitat has been altered by sediment deposition in recent history. The effects of the estuarine sediment deposition on salmon are unclear.

The Sekiu River has extensive sedimentation problems stemming primarily from high road densities and mass wasting sites. The sedimentation has led to debris flows that have incised the mainstem channel and removed LWD. The mainstem provides critical rearing habitat as well as spawning habitat for all salmon species in that watershed. The floodplain impacts to the mainstem such as the Mainline and other riparian roads have greatly impaired salmon production through an increase in channel instability (constrictions), increased sediment, loss of riparian vegetation, and loss of off-channel habitat. Other major problems include a lack of LWD and deep pools, extensive riparian areas that are dominated by hardwoods, and management activities that have significantly reduced the age of the surrounding forests. The alteration of riparian in the mainstem and South Fork has resulted in high summer water temperatures, while the forest management activities have contributed to increases in water turbidity. These water quality issues are

a major problem for salmon within the watershed. A minor limiting factor is passage problems, most impacting coho and steelhead.

One major limiting factor for the Pysht River is sedimentation from roads and mass wasting sites which leads to channel instability, especially in the mainstem. Another major problem is the lack of LWD, which results in increased channel instability and peak flow impacts as well as decreased the formation of pool habitat and spawning gravel storage. The conversion of a conifer riparian to open areas and hardwoods is also a significant limiting factor, leading to a lack of future LWD and high water temperatures. The Pysht River has severe floodplain impacts particularly from Highway 112, which contributes to sediment problems, reduces riparian vegetation, and increases channel instability. The removal of trees along riparian roads also reduces important riparian vegetation for salmon. It is believed that the change in age and type of surrounding forests contributes to an increased frequency and severity of peak flows.

Minor factors in the Pysht River include the channelization of the lower mile and a half of the mainstem, as well as excessive sediment delivery to the estuary. Members of the TAG believed that there may have been a loss of eelgrass habitat in the estuary, but historical data are not available to demonstrate this. Another minor habitat factor is human-caused blockages.

The Clallam River is impacted by excessive sedimentation combined with a lack of LWD and an open or hardwood riparian area. The altered riparian has contributed to high water temperatures in the summer. Significant floodplain impacts include gravel bar scalping and riparian road impacts. There has also been a loss of saltmarsh habitat in the estuary. It is believed that the change in age and type of surrounding forests contributes to an increased frequency and severity of peak flows. Some members of the TAG expressed concern about the intermittent blockage near the mouth caused by gravel, however the problem and potential solutions are not well-understood and need to be studied before restoration activities are planned for this issue. Blockages comprise a lessor impact on salmon production in the Clallam River, reducing coho and steelhead habitat.

Sedimentation is the major limiting factor for Deep Creek. Debris flows have resulted in extensive channel incision and instability. Large woody debris is lacking, and the conversion of riparian vegetation from old conifers to hardwood or open areas results in a future lack of LWD as well as high water temperatures. Channel incision has contributed to floodplain impacts such as a lack of off-channel habitat, and this lack of off-channel habitat has severely impacted all salmonid species in Deep Creek. The excessive sedimentation has also impacted the estuary, where the delta has increased in recent years. Another major problem is the conversion of surrounding forest vegetation to young conifers. The lack of older trees is thought to increase the frequency and severity of peak flow events. Channel incision and the lack of instream LWD worsens water velocities. Blockages comprise a lessor impact on salmon production in Deep Creek, and these are considered a lower priority restoration activity.

Not much is known about current habitat conditions in the Twin Rivers. It is believed that LWD is lacking in the lower reaches, and there is concern about sedimentation from

roads. Fish passage is an issue in the East Fork of the East Twin River, and estuarine impacts exist near the mouths of both Twin Rivers.

The Lyre River has been impacted with fine sediments from Boundary and Susie Creeks. The fines have degraded spawning habitat and increased water turbidity. Other major factors include an alder-dominated riparian in Nelson Creek, a lack of LWD in Nelson Creek, Susie Creek, and the lower mainstem, and a channelization in the lower mile of the mainstem. "Stream cleaning" or removal of LWD contributes to the lack of LWD in this river. Blockages comprise a lessor impact on salmon production in the Lyre River.

The greatest salmon habitat problem in Salt Creek is the lack of LWD, which has resulted in a loss of holding pools for salmon. Other issues include an increased demand for water, unauthorized water withdrawals, and excess sedimentation. These problems are likely the result of land conversion to accommodate development. Development in the floodplain has altered the riparian, and efforts to return the riparian to old conifers should be encouraged. Another significant impact is the loss of saltmarsh in the estuary due to roads. Blockages comprise a lessor impact on salmon production in Salt Creek, reducing coho and steelhead habitat. Another minor problem is the floodplain impact by riparian roads.

The small salmon-producing streams in the east end of WRIA 19 include Colville, Field, Whiskey, Murdock, Jim and Joe Creeks. Major problems in these creeks include a lack of LWD and a conversion of the riparian zone to alder or open areas. Excessive sedimentation is believed to be a problem in Whiskey, Field, Jim, and Joe Creeks. Blockages are known problems in Colville, Field, Jim, and Joe Creeks. Estuarine impacts have occurred near Whiskey and Jim Creeks.

For small streams in the west end of WRIA 19, major problems include a lack of LWD in Agency and Jansen Creeks, as well as in the Sail River. Another major problem is the conversion of riparian in Rasmussen, Bullman, and Jansen Creeks, and the Sail River. In Snow, Rasmussen, Bullman, and Jansen Creeks, excessive sedimentation from roads is another major habitat impact for salmon production, and in Jansen Creek, the resulting turbidity from roads is a significant problem. Blockages are known problems in Agency and Village Creek and the Sail River. High water temperatures have been documented in Agency and Rasmussen Creeks. In the nearshore environment, sediments from Highway 112 are impacting eelgrass habitat.

Many of the major limiting factors are similar throughout the WRIA, and several factors are often the result of a few causes. Because of this, the TAG recommends the following actions for the entire WRIA to help address some of these widespread, complex factors that stem from similar causes.

- Enforce current environmental regulations, such as the Hydraulic Code, Forest Practices Act, Shoreline regulations, Critical Area Ordinances, and Growth Management Act.
- Revise the Growth Management Act to protect salmon habitat.

- Protect the channel migration zone (floodplain) habitat. Floodplain development leads to a loss of riparian forest and loss of future LWD. It also increases sedimentation, channel instability, and water quality problems.
- Protect conifer riparian areas.
- Convert open and hardwood riparian areas to conifer.
- Increase off-channel habitat.
- Increase instream LWD, preferably with attached rootwads.
- Stop the removal of instream wood.
- Prevent the increase of water withdrawals. These can have a large impact on salmon because of the naturally low flow conditions in the summer and early autumn.
- Set up a State/Tribal/County committee to identify and purchase critical salmon habitat for conservation and to address problem areas.

A) INTRODUCTION

Habitat Limiting Factors Background

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

Engrossed Substitute House Bill (ESHB) 2496 in part:

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

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

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

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

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

It is important to note that the responsibilities given to the Conservation Commission in ESHB 2496 do not constitute a full limiting factors analysis. The hatchery, hydro and harvest segments of identifying limiting factors are being dealt with in other forums.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

In Washington, adult chum salmon (3-5 years old) have three major run types. Summer chum adults enter the rivers in August and September, and spawn in September and October. Fall chum adults enter the rivers in late October through November, and spawn in November and December. Winter chum adults enter from December through January and spawn from January through February. Chum salmon fry emerge from the nests in March and April, and quickly outmigrate to the estuary for rearing. In the estuary, juvenile chum follow prey availability. In Hood Canal, juveniles that arrive in the estuary in February and March migrate rapidly offshore. This migration rate decreases in

May and June as levels of zooplankton increase. Later as the food supply dwindles, chum move offshore and switch diets (Simenstad and Salo 1982). Both chum and pink salmon have similar habitat needs such as unimpeded access to spawning habitat, a stable incubation environment, favorable downstream migration conditions (adequate flows in the spring), and because they rely heavily on the estuary for growth, good estuary habitat is essential.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Introduction to Habitat Impacts

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

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

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

B) SALMON HABITAT IN THE WESTERN STRAIT OF JUAN DE FUCA

The western Strait of Juan de Fuca (WRIA 19) includes the area between Colville Creek on the east, to Cape Flattery on the west (Fig. B.1). The largest watersheds in this group are the Hoko, Sekiu, Pysht, Clallam, and Lyre Rivers. In addition, there are numerous small independent streams that flow northerly, draining the foothills of the Olympic Mountains into the Strait of Juan de Fuca. These are described in greater detail below, along with the salmon stocks they support. The data describing the salmon distributions came from several sources, including: the Salmon and Steelhead Stock Inventory (WDFW and WWTIT 1994), the Washington State Stream Catalog (Phinney and Bucknell 1975), existing watershed analyses, and the field observations of Technical Advisory Group (TAG) members. The salmon distributions are based on recent known distributions, and it is recognized that data are incomplete, resulting in the probable omission of some streams and especially tributaries that support salmon, but have not yet been documented with salmon presence. The salmon distribution data have been digitized by species, and is included in this report (Fig. B.2). Please refer to this map throughout the salmon distribution discussion below.

The region is characterized by a cool maritime climate with annual precipitation increasing as one moves either west or in an upward elevation (McHenry et al. 1996). Annual precipitation typically ranges from 80-130 inches in the headwaters of these streams.

Olympic Peninsula streams in the Twin River formation have high natural erosion rates due to a geology of sedimentary rocks, sandstones, and siltstones which quickly breakdown in the heavy rainfall climate (SCS 1984; Benda 1993). These streams include the Pysht River and all streams west of the Pysht. Streams to the east of the Pysht have a mixed geology, with less erodable basalt from the Crescent Formation in their headwaters, glacial out-wash in the lower plain, and siltstones of the Twin River Formation to the west (Tabor and Cady 1978). The stream channels in the region change quickly to variations in flow and sediment inputs.

The larger streams in the region such as the Hoko, Sekiu, Clallam, and Pysht Rivers have a tidal influence that extends upstream for several miles (Phinney and Bucknell 1975). Other streams have little estuary area.

Figure B.1. The location of Washington State WRIA 19.

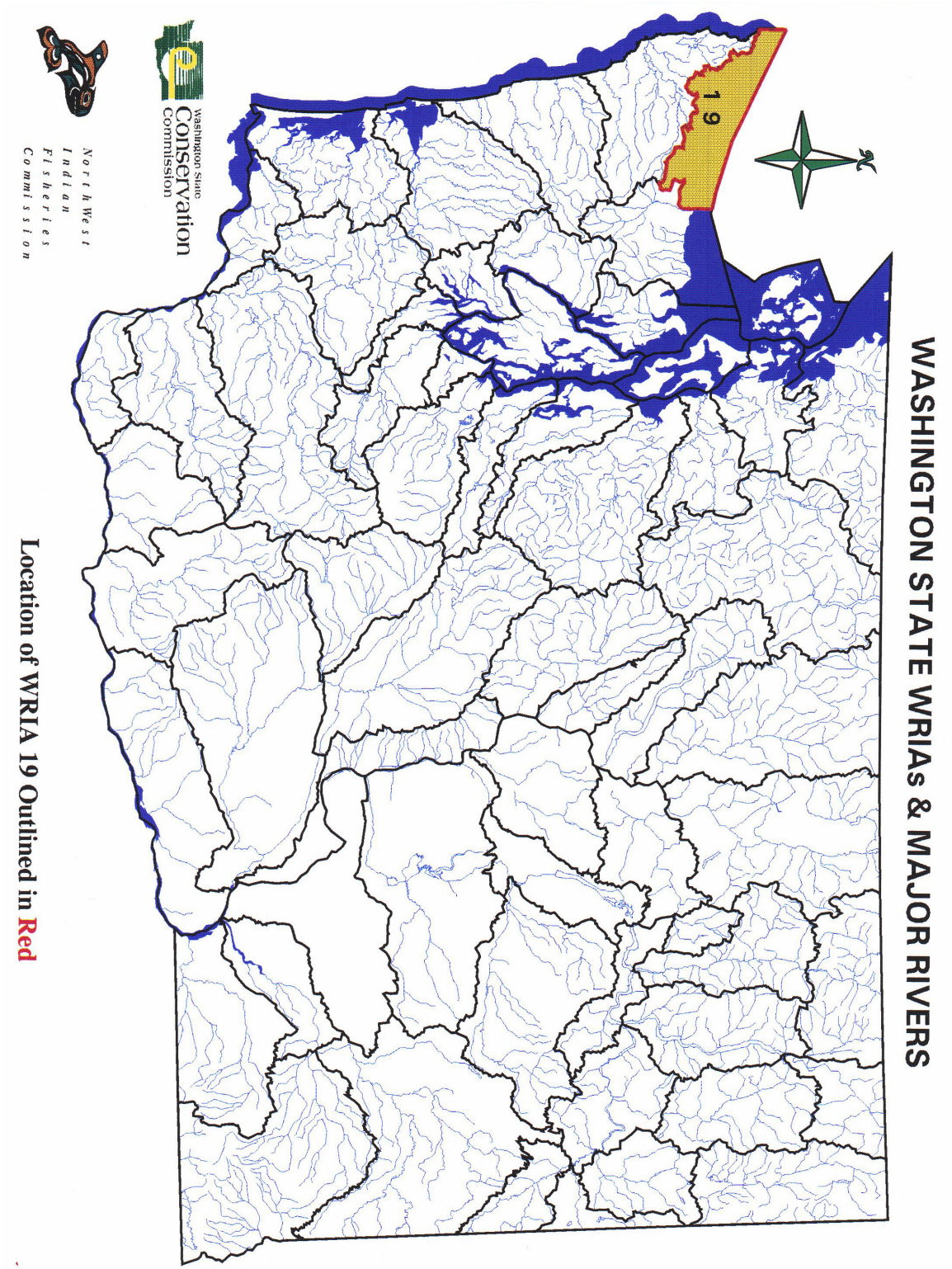
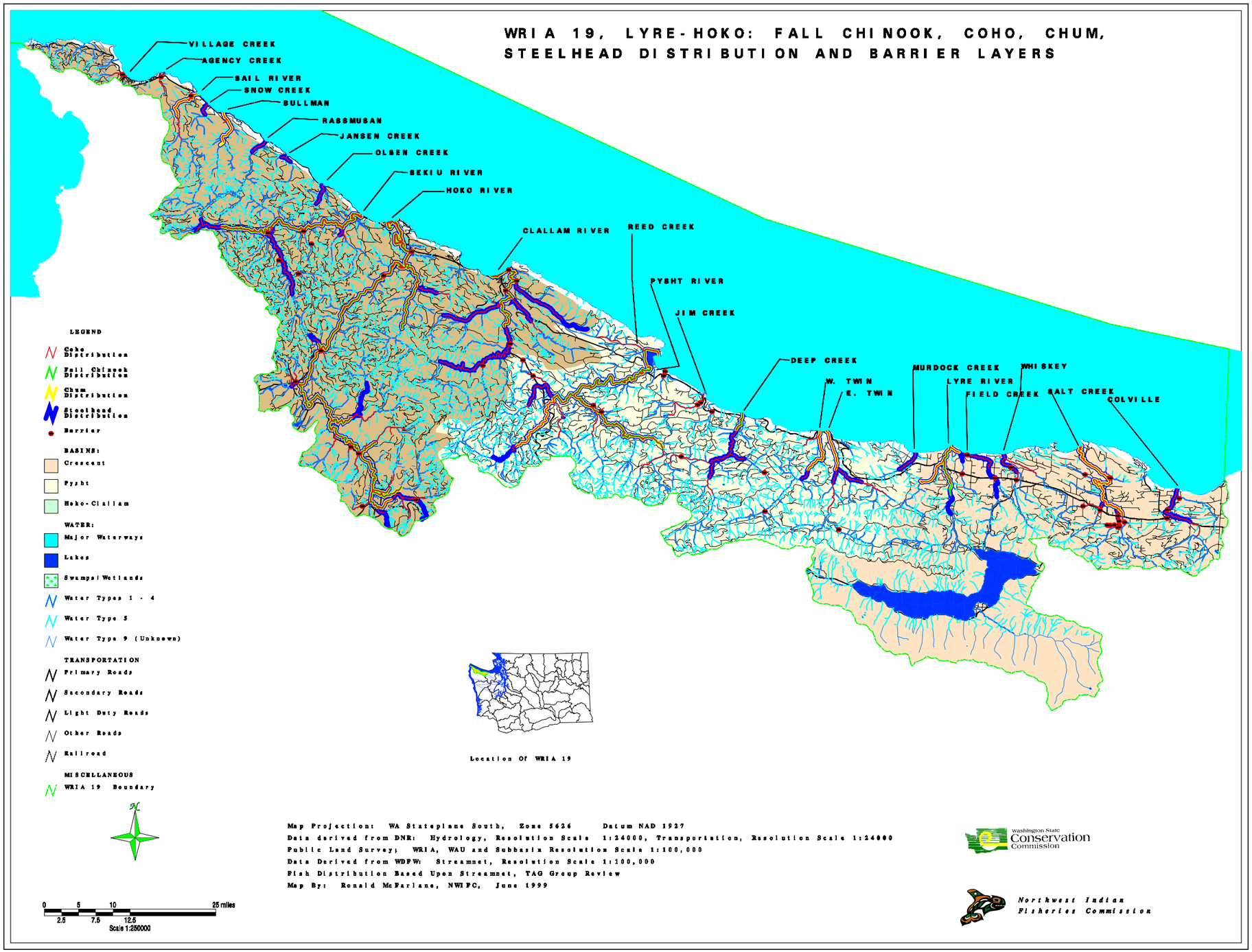


Figure B.2. Salmonid Distribution and human caused barriers in WRIA 19.



Colville, Whiskey, Field, And Murdock Creeks

These four small independent streams support limited steelhead and coho production, with the exception of Colville Creek, which has excellent coho production potential (Mike McHenry, Lower Elwha Tribe, personal communication). All have a naturally steep gradient in the lower reaches, limiting salmon access to a short reach (Phinney and Bucknell 1975). Spawning winter steelhead have been documented up to river mile (RM) 2.4 in Colville Creek (WDFW and WWTIT 1994), RM 1.0 in Whiskey Creek, RM 3.0 in Field Creek, and RM 1.0 in Murdock Creek (WDFW spawning ground survey database 1998). Coho (peak count of 46 adults in 1998) were documented in the lower 1.8 miles of Colville Creek, less than 10 adults in the lower mile of Whiskey Creek, and 1-2 adults in Field and Murdock Creeks (WDFW spawning ground survey database 1998). See Figure B.2 for stream location and salmon distribution information.

Salt Creek

Salt Creek and its tributaries provide important coho salmon spawning and rearing habitat throughout the mainstem and tributaries downstream of a passable dam at RM 6.5 (Fig. B.2). This same area used to support chum salmon, while chinook salmon were limited to the reaches downstream of river mile (RM) 3.5. Chum and chinook salmon have not been documented in Salt Creek in recent years (Phinney and Bucknell 1975).

Lyre River

The Lyre River is the only watershed in the region that is fed by a natural lake (Lake Crescent), resulting in a unique flow, temperature, and water chemistry regime. The surrounding land lies within the Olympic National Park, and a natural falls at RM 2.7 limits salmon access. The Lyre River produces predominantly chum, but also low numbers of coho and winter steelhead (Fig. B.2). Low numbers of chinook and pink salmon have been noted in the past, but the chinook salmon could have been returns from hatchery plants (Dick Goin, personal communication). Chum spawning extends all the way to the mainstem cascades. Coho spawn primarily in the tributaries, such as the lower 1.5 miles of Susie Creek and mainstem upstream of Highway 112, while the chinook and pink salmon historically spawned in the lower mainstem below the falls (Phinney and Bucknell 1975). Coho that spawn in the tributaries have a fall timing, but mainstem coho have a summer timing. Winter steelhead spawn in the lower mile of Nelson Creek and throughout the mainstem downstream of the falls (WDFW spawner survey database 1998). Winter steelhead also spawn in the lower mile of Murdock Creek, an independent stream west of the Lyre River (WDFW spawner survey database 1998). The Lyre steelhead population is heavily supplemented by Chambers Creek steelhead as well as summer steelhead.

Deep Creek, Jim Creek, Joe Creek, West and East Twin Rivers

Deep Creek, the West Twin River and the East Twin River share similar physical characteristics, and the mouths of each stream are in close proximity to each other (within three miles). The gradients are moderate to steep throughout and stream widths average between 3-9 yards (Phinney and Bucknell 1975). Jim and Joe Creeks also have moderate to steep gradients, but are smaller drainages, and both coho and winter steelhead have been documented up to RM 2 in Jim Creek (Fig. B.2). All of the streams are believed to produce coho and chum salmon (Phinney and Bucknell 1975) as well as winter steelhead (WDFW spawner survey database 1998), however no formal documentation of spawning was found in Joe Creek.

Deep Creek drains 11,048 acres, and the elevation ranges from zero to 3,400 feet (Young 1994). It historically supported significant levels of coho and chum production, with most of the chum salmon spawning in the lower three miles (WDFW and WWTIT 1994). Coho and winter steelhead spawners have been documented to RM 3.7 and 3.1 respectively (Fig. B.2) (WDFW spawner survey database 1998). Fall chinook used to spawn in Deep Creek but have been extirpated (McHenry et al. 1994). The West and East Twin Rivers have major spawning areas for coho downstream of RM 4.2 and 3.4 respectively (Phinney and Bucknell 1975), but these rivers have never produced large numbers of fall chum (Fig. B.2) (WDFW and WWTIT 1994).

Pysht River

The Pysht River is about 16.3 miles long, with eight tributaries that add another 35.6 miles of stream length (Phinney and Bucknell 1975). In the headwaters, the gradient is steep and the US Forest Service owns the surrounding land. Downstream, the low gradient runs through valleys for 11 miles. The Merrill and Ring Company owns a large portion of the surrounding land in this area, and it is managed as a tree farm. The South Fork Pysht joins at RM 7.2. Chinook have been documented in the mainstem as well as the lower 6 miles of the South Fork (Phinney and Bucknell 1975). Coho and winter steelhead spawn in all accessible areas in the mainstem Pysht (primarily between RM 3-12) and South Fork Pysht (Fig. B.2) (WDFW spawner survey database 1998). Most of the chum spawning is between RM 4-10 (Phinney and Bucknell 1975). Tributaries important for coho (and probably winter steelhead) spawners include Reed Creek to RM 3.1, Green Creek to RM 2.2, Gold Creek to RM 1, and Needham Creek to RM 1.8. A few unnamed tributaries support these two species as well (stream numbers 19.0116, 19.023, 19.0124).

Clallam River

The Clallam River is about 13.4 miles long, with steep gradients in the headwaters and low gradients downstream. Major tributaries include Charley, Last and Pearson Creeks. Nearby is the small independent stream of Falls Creek. Coho spawners have been documented between RM 3.6-11.4 in the mainstem, the lower 0.4 miles of Blowder Creek, and the lower 1.7 miles of Charley Creek (Fig. B.2). Winter steelhead have a similar distribution to coho with spawners documented from 2.8-11.4 in the mainstem, as

well as to RM 10 of Pearson Creek, RM 2 to Last Creek, and RM 3 of Charley Creek (WDFW spawner survey database 1998). Moderate numbers (500 or less) of chum have been observed in the lower mainstem. Chinook salmon haven't been observed in the Clallam River for many years. Previous sightings of chinook might have been the result of outplants of hatchery chinook salmon in the 1970s (Mike McHenry, Lower Elwha Tribe, personal communication).

Hoko River

The Hoko River is the largest stream in WRIA 19, providing about 25 miles of mainstem and about 80 additional linear miles of tributaries (Phinney and Bucknell 1975). It originates in the foothills of the Olympic Mountains at a lower elevation than the origin of the two other large watersheds in the Strait (the Elwha and Dungeness Rivers). Rainfall is abundant; a trait similar to the North Coast streams. Average annual rainfall is 90-120 inches (Pacific Northwest River Basins Commission 1970).

The lower 10 miles of the Hoko mainstem flows through a moderately sloped terrain, and has a low gradient and plentiful gravel. The estuary extends into the river for more than a mile. The mainstem supports chinook (up to RM 21.5), chum (up to RM 22), coho (up to RM 23.2), and winter steelhead (up to RM 23.4) (Fig. B.2) (WDFW spawner survey database 1998; Streamnet 1999). The Little Hoko River is the major tributary in the lower basin, and joins the Hoko at RM 6.8. The Little Hoko flows through moderately steep terrain and has moderate to steep gradients above RM 3.5. Downstream, the Little Hoko has a low gradient as it flows through a flat valley to its confluence with the Hoko River. Fall chinook salmon, coho salmon, winter steelhead, and chum salmon spawn in the Little Hoko River, with coho salmon and winter steelhead spawning up to RM 3.9 in the mainstem and the lower 1.5 miles of Leyh Creek. Chum and chinook salmon spawn up to RM 3 in the Little Hoko River (WDFW spawner survey database 1998). In high flow years, chinook salmon have also spawned in Herman Creek, Bear Creek, and Brownes Creek (McHenry et al. 1996). Two smaller tributaries, Ossert Creek and Brownes Creek, provide spawning (in the lower mile) and rearing habitat for coho salmon and winter steelhead production, and join the Hoko River at RM 4.4 and 10 respectively (Phinney and Bucknell 1975).

The upper Hoko River tributaries drain a precipitous, incised landscape. Several cascades exist, including Hoko Falls, which in low flow years impedes upstream passage of fall chinook. Four major tributaries enter the upper mainstem, and provide spawning and rearing habitat for coho salmon, winter steelhead, and occasionally for chinook salmon. These tributaries include: Johnson Creek (spawning from RM 0-1), Herman Creek (RM 0-2.8 for coho salmon and to RM 1.6 for steelhead), the North Branch Herman (RM 0-2.8 for coho salmon and to RM 1.6 for steelhead), Ellis Creek (spawning from RM 0-1.3), Cub Creek (RM 0-1.5 for coho and to RM 1.0 for steelhead), and Bear Creek (RM 0-1.5). Unnamed tributaries also support coho salmon and winter steelhead (stream numbers: 19.0174, 19.0176, 19.0188, 19.0189) (WDFW spawner survey database 1998).

Historically, the Hoko River basin was a coniferous forest of western hemlock, Sitka spruce, western red cedar, and Douglas fir with a few patches of red alder (Martin et al. 1995).

Sekiu River

The Sekiu River is 12.5 miles long (Phinney and Bucknell 1975), with an additional 36.7 miles of tributaries. At RM 5.3, the South Fork Sekiu River joins the North Fork Sekiu River. The North Fork has a falls at RM 8.8, which prevents upstream migration of adult salmon, but downstream of this area, the gradients are moderate to low and spawning coho salmon, winter steelhead, chinook salmon, and chum salmon have been documented throughout this reach (Fig. B.2) (WDFW spawner survey database 1998). At RM 8.5, Sonnybrook Creek joins the North Fork mainstem and supports coho and winter steelhead spawning and rearing (WDFW spawner survey database 1998). The tributaries to the North Fork have limited salmon access due to natural barriers. The South Fork Sekiu flows northerly through a narrow valley with moderate to steep gradients and coho and winter steelhead spawners have been documented to RM 3.1 (WDFW spawner survey database 1998). Coho salmon utilize all accessible areas in the watershed, while fall chinook salmon historically spawned in the mainstem Sekiu and North Fork Sekiu. Low numbers of chum spawn in the lower reaches of Carpenters Creek, which joins the mainstem at RM 1.3, and the South Fork Sekiu, but historically, chum also spawned in the North Fork Sekiu. Winter steelhead spawn in the mainstem Sekiu, Carpenters Creek, the South Fork Sekiu, and Sonnybrook Creek (McHenry et al. 1996). The lower 0.7 miles of Carpenters Creek has been documented spawning habitat for coho salmon and winter steelhead (WDFW spawner survey database 1998).

Olsen, Jansen, and Rasmussan Creeks are independent streams in this area. All are small with moderate to moderately-steep gradients. They are predominately winter steelhead streams, supporting limited coho salmon (Fig. B.2) (Mike Haggerty, personal communication). Phinney and Bucknell (1975) state that low numbers of chum also spawn in these creeks

Sail River, Bullman Creek, Snow Creek, Agency Creek, and Village Creek

The lower 2.5 miles of the Sail River supports winter steelhead, chum salmon, and coho salmon (Fig. B.2) (Mike Haggerty, personal communication). It is a moderate gradient river that flows through valleys within the Makah Indian Reservation. Bullman Creek supports coho salmon and to a lessor extent, chum salmon and winter steelhead to about RM 2 where the gradient steepens (Fig. B.2) (Mike Haggerty, personal communication). It used to produce chinook salmon as well. Snow Creek supports winter steelhead and limited coho salmon (Fig. B.2) (Mike Haggerty, personal communication). It is moderately confined with a 3-4% gradient. The tributaries are small and steep. Agency and Village Creeks are small streams that support limited winter steelhead and coho salmon (Fig. B.2).

Data Needs For Salmonid Distribution

- Improve fish distribution data, especially in the upper reaches of streams.

C) CONDITION OF NATURAL SPAWNING SALMONID POPULATIONS IN WRIA 19

Historic Salmonid Population Conditions

Historically, abundant runs of fall chinook originated from the Pysht, Sekiu and Hoko Rivers. Other chinook populations spawned in the Sail River, and perhaps in the Lyre and Clallam Rivers. All of these except the Hoko River fall chinook declined to near extinction in the 1960s and 1970s (McHenry et al. 1996). The decline in the Hoko River was probably avoided because of the chinook salmon supplementation program by the Makah Tribe.

Fall coho escapement levels are limited to index areas that were not standardized until 1984, and many spawning areas do not have historical data. In the areas supported by data, some streams have shown a sharp recent decline in coho escapement (Deep Creek, Green Creek, Little Hoko River, and Cub Creek), while other areas have variable escapement levels (South Fork Pysht, Hoko River, and Bear Creek) (McHenry et al. 1996). The decline in Deep Creek coho has been particularly sharp, and few spawners have been documented in Deep Creek in recent years (McHenry et al. 1996).

Fall chum escapement levels in the Pysht have also varied greatly, with a small increase in recent years (WDFW and WWTIT. 1994). Chum levels in the Hoko and Sekiu have not been well monitored in the past (McHenry et al. 1996), and recently, chum in Deep Creek have sharply declined (Mike McHenry, Lower Elwha Tribe, personal communication). Adult escapement of winter steelhead has only been monitored since 1984, so historical data are very limited. Catch levels of winter steelhead in Deep Creek indicate a decline in that population (McHenry et al. 1996).

Current Salmonid Population Conditions

SASSI defined one stock of chinook salmon in this area, Hoko fall chinook, which was defined as depressed (WDFW and WWTIT 1994). Very low numbers of chinook also spawn in the Sekiu, Lyre, Clallam, and Pysht Rivers, but it is not known whether these are remnants of a native run, or strays from the Hoko River or other stocks. Regardless, the status of chinook in the Sekiu, Lyre, Clallam, and Pysht is at best, critical and likely well below production potential. Fall chinook in Deep Creek have been extirpated (McHenry et al. 1995).

Four different fall chum stocks have been delineated by SASSI: Lyre, Deep/East and West Twin Creeks, Pysht, and Hoko/Clallam/Sekiu (WDFW and WWTIT 1994). Lyre and Hoko/Clallam/Sekiu chum were designated with an unknown status, while Deep/East and West Twin Creeks and Pysht chum were listed as healthy (WDFW and WWTIT 1994). However, from 1994-1998, chum salmon in Deep Creek have declined to less than 50 adults/year (Mike McHenry, Lower Elwha Tribe, personal communication). All chum stocks in this region are believed to be native.

Six different coho stocks have been identified in this region: Salt Creek, Lyre, Pysht/Twin/Deep, Clallam, Hoko, and Sekiu/Sail stocks (WDFW and WWTIT 1994). The stock separations were based upon geographic distance, and were described as "tentative" until genetic data are available. Compounding the uncertainty is the history of hatchery plants in most of the streams, using non-native stocks, which also resulted in a "mixed-origin" classification under SASSI. Salt and Hoko coho stocks were defined as "healthy", while Pysht/Twin/Deep and Sekiu/Sail River coho stocks have had severe short-term declines in escapement, warranting a depressed status. Lyre and Clallam coho were designated with an unknown status (WDFW and WWTIT 1994).

Seven different stocks of winter steelhead were listed in the SASSI report (WDFW and WWTIT 1994): Salt Creek/Independents, Lyre, Pysht/Independents, Clallam, Hoko, Sekiu, and Sail stocks. Stock separations were based upon geographic separation; no genetic information was available at that time. Three stocks were designated as unknown status and native origin: Sail, Sekiu, and Salt Creek winter steelhead (Salt Creek includes spawners in Whiskey, Colville, and Field Creeks). Lyre and Clallam are stocks with unknown status, unresolved origin. Pysht/Deep Creek/East and West Twin River winter steelhead is a single stock designated as healthy with an unresolved origin. Hoko winter steelhead are listed as native origin and healthy status, even though escapement levels fell from 913 adults in 1988 to 374 fish in 1992 (WDFW and WWTIT 1994.

Identification of Historic Patterns of Habitat Alterations

Hartman and Scrivener (1990) have described the common features of temperate rainforest watersheds of western Vancouver Island. These watersheds are similar to those in the western Strait of Juan de Fuca. The watersheds have abundant rainfall in the winter that could result in hydrologic stress, especially in a disturbed condition. The natural, pre-disturbed conditions have mild winter and summer stream temperatures. Coniferous forests surrounded the streams in the late seral stage. This resulted in abundant large woody debris and clean well-sorted gravels. Deep pools were numerous due to the abundant LWD, which also moderated gradient by forming step-pool profiles. The forests consisted primarily of large (200' tall) western hemlock, Sitka spruce, western red cedar, and Douglas fir. The canopy was relatively open due to low densities of the massive trees. Deciduous trees were much less numerous (ratio of deciduous to conifer 1:1000) and consisted mostly of red alder and bigleaf maple (Kuchler 1964).

Most of the stream areas in this region have been subjected to timber harvest (McHenry et al. 1994). Early logging techniques such as railroad logging, steam donkeys, and log floats, were very destructive, altering stream morphology, removing LWD, and increasing sediment delivery (Seddell and Luchessa 1982). In the 1940s, log trucks were used which resulted in road construction throughout the basins, even in steep slope areas. These early roads have caused large landslide and debris flows (Cederholm et al. 1981; Swanson et al. 1987).

Stream clearing also occurred for flood control reasons and for the misguided belief that salmon needed streams devoid of wood for spawning (McHenry et al. 1996). In addition to these general descriptions, some specific historic habitat conditions are detailed below.

Deep Creek

The Deep Creek drainage has been historically managed for forestry. The US Forest Service owns 50% of the acres (which is now in late successional reserve), ITT owns 29%, Merrill & Ring own 16%, the Department of Natural Resources owns 5%, and small private owners account for less than 5% of the land ownership in the basin. Timber harvest began in the 1920s, increasing in the 1940s. However, these early timber harvests occurred on level ground and took only the best timber. From the 1970s-1980s, very aggressive harvest occurred on U.S. Forest Service lands in the upper watershed, and private lands in the lower reaches. This resulted in numerous mid-slope roads using side-cast construction (prone to failures) in the headwaters area and clearcuts on steep slopes (McHenry et al. 1996). By 1990, about 60% of the basin was harvested.

Hoko River

Most of the basin is forested and managed for timber harvest. About 500 acres is non-forest and in agricultural use. This land is located along the lower mainstem Hoko River. The lower Little Hoko River is non-forested State Park. Timber harvest began in the late 1880s, and nearly all of the basin has been harvested at least once down to the streambanks (Martin et al. 1995). Currently, private timber companies dominate the land ownership. Crown Pacific owns 42% of the land in the basin, and Rayonier owns 28% (Martin et al. 1995). The Washington State Department of Natural Resources owns 25%, while other small private parties own 3%, and the Washington State Parks Department and the Olympic National Forest each own about 1% of the basin land. About 95% of the old growth has been converted into commercially managed tree farms (McHenry et al. 1996).

D) LOSS OF ACCESS TO SPAWNING AND REARING HABITATS

Introduction

Salmon are limited to spawning and rearing locations by natural features of the landscape. These features include channel gradient and the present of certain physical features of the landscape (e.g. logjams). Flow can affect the ability of some landscape features to function as barriers. For example, some falls may be impassable at low flows, but then become passable at higher flows. In some cases flows themselves can present a barrier such as when extreme low flows occur in some channels; at higher flows fish are not blocked.

Throughout Washington, barriers have been constructed that have restricted or prevented juvenile and adult fish from gaining access to formerly accessible habitat. The most obvious of these barriers are dams and diversions with no passage facilities that prevent adult salmon from accessing historically used spawning grounds. However, in recent years it has become increasingly clear that we have also constructed barriers that prevent juveniles from accessing rearing habitat. For example, in estuarine areas, dikes and levees have blocked off historically accessible estuarine areas such as tidal marshes, and poorly designed culverts in streams have impacted the ability of coho juveniles to move upstream into rearing areas.

Loss Of Access for Anadromous Salmonids In WRIA 19 and North WRIA 20

Data Sources

The Salmonid Screening, Habitat Enhancement and Restoration Division of WDFW maintains a database on fish passage problems and this was used as the primary data source (SSHEAR 1998). In addition, professional knowledge by the Technical Advisory Group (TAG) members included barriers that were not in the database. The TAG prioritized the obstructions based upon miles of blocked habitat, number and extent of salmonid stocks impacted (extent often refers to partial blocks versus complete blocks), quality of habitat upstream of the blockage, the presence or absence of similar habitat elsewhere for the impeded/blocked salmon stock (ie. how many other options does the impeded stock have), and presence/absence of additional blocks downstream. Additional downstream obstructions would decrease the priority of a particular block.

Most of these blockages are mapped in Figure B.2 (see Section B) along with the salmonid distribution data.

Blockages in Priority Order

1) A potential obstruction to anadromous salmonid access is the intermittent problem with a sandbar formation at the mouth of the Clallam River. Following the criteria outlined above, this intermittent blockage is listed as a high priority because of the miles of habitat impacted and the number of salmon stocks blocked. However, while about half of the TAG members agreed that this was a major problem, but another group expressed concern that insufficient data exists to characterize this problem as a human-

caused barrier. Randy Johnson,WDFW Puget Sound Technical Assistance, has conducted a thorough review of the topic and has contributed an addendum to this section, specifically discussing the Clallam River mouth blockage. Please see the last section within this chapter to read this addendum. The Clallam River mouth problem potentially blocks over 25 miles of chinook, chum, coho, steelhead, and cutthroat habitat (Randy Johnson, Tim Rymer). At this point in time, the TAG recommends a study to survey impacts to the tidal prism and their effect on the blockage. Restoration effects to specifically address this blockage should not occur without the additional studies to clarify the causes and solutions.

2) Roughly more than 10 acres of wetland and 0.3 miles of 1-2% gradient stream access is blocked to coho, steelhead, and cutthroat by a perched pipe at RM 1.01 in a right bank tributary (Bear Creek, 20.0007) to the Waatch River RM 1.05. (Mike Haggerty)

3) Roughly more than 10 acres of wetland access is blocked to coho and cutthroat by a perched pipe at the wetland outlet, in stream number X-20.0015 at RM 0.08. (Mike Haggerty)

4) Roughly more than four acres of wetland and 0.75 miles of stream access is blocked to coho, steelhead, and cutthroat by a culvert at RM 0.26 in Agency Creek (19.0238). The stream habitat includes 0.43 miles of 2-4% gradient, moderately confined stream and about 0.32 miles of 2-4% gradient confined stream. (Mike Haggerty)

5) Roughly more than four acres of wetland access is blocked to coho, steelhead, and cutthroat by a perched pipe at RM 0.2 in a left bank tributary to the Hoko River (19.0199a, Hoko RM 20.85). (Mike Haggerty)

6) A collapsed trestle in Colville Creek, RM 1.2, blocks about 4 miles of coho, steelhead, and cutthroat habitat. (Mike McHenry)

7) A logjam at RM 0.2 in Field Creek potentially blocks about 4 miles of coho, steelhead, and cutthroat habitat, and needs evaluation prior to any planned restoration activity. (Mike McHenry)

8) A SR 112 box culvert in Jim Creek (RM 0.5) blocks three miles of coho, steelhead, and cutthroat habitat. This partial barrier is slated for replacement by WDOT, and is not recommended for restoration funding at this time. (Randy Johnson, Tim Rymer)

9) A logjam at RM 0.6 in Jim Creek blocks about 3 miles of coho, steelhead, and cutthroat habitat. (Mike McHenry)

10) A perched pipe on the wetland outlet at RM 0.2 in Thirty Cent Creek (20.0027) blocks over three acres of wetland and a total of about 0.8 miles of stream habitat important for coho, steelhead, and cutthroat. The stream habitat includes about 0.5 miles of 2-4% gradient and 0.3 miles of unconfined 1-2% gradient stream. (Mike Haggerty)

11) A perched pipe on the wetland outlet at RM 0.22 in Thirty Cent Creek (20.0027) blocks over three acres of wetland and about 0.8 miles of stream habitat important for coho, steelhead, and cutthroat. The stream habitat includes about 0.5 miles of 2-4% gradient and 0.3 miles of unconfined 1-2% gradient stream. (Mike Haggerty)

12) A culvert at RM 0.03 to the unnamed stream X-19.0203 blocks about 2.5 acres of wetland habitat important for coho and cutthroat rearing. This is a right bank tributary to the Sekiu River at about Sekiu RM 3.7. (Mike Haggerty)

13) A culvert at about RM 2 in the Clallam River blocks about 2-4 acres of wetland habitat important for coho, steelhead, and cutthroat rearing. (Mike Haggerty)

14) Over 2.25 miles of coho, steelhead, and cutthroat spawning and rearing habitat are blocked by a small dam at RM 0.3 in Educket Creek (20.0010). The stream habitat includes about 1.5 miles of 2-4% gradient and 0.75 miles of 1-2% gradient stream. (Mike Haggerty)

15) Approximately 2 acres of wetland and over 0.2 miles of stream (1-2% gradient) habitat important for coho, steelhead, and cutthroat is blocked by a culvert at RM 0.15 in stream X-19.0148, which is a tributary to the lower Hoko wetland complex just west of Hoko Ozette/112 junction. (Mike Haggerty)

16) About 2 miles of steelhead and cutthroat habitat are blocked by a series of impassible jams in Whiskey Creek, near RM 0.7. (Mike McHenry)

17) A logjam near RM 0.2 in Stinky Creek (19.0141) blocks about 1.8 miles of coho, steelhead, and cutthroat habitat. (Mike McHenry)

18) Over 1.5 miles of coho, steelhead, chum, and cutthroat spawning and rearing habitat are blocked by a small dam at RM 0.45 in Waatch Creek (20.0004). (Mike Haggerty)

19) About 1.5 miles of coho, steelhead, and cutthroat habitat are blocked by an impassible culvert associated with 30 Road near RM 0.7 of the East Fork East Twin River. (Mike McHenry)

20) A logjam near RM 1.5 in West Fork Deep Creek blocks about 1.5 miles of coho, steelhead, and cutthroat habitat. (Mike McHenry)

21) Over 1 mile of sockeye, coho, steelhead, and cutthroat spawning habitat is blocked by culverts and channel avulsion at RM 0.4 in Solberg Creek (20.0061). (Mike Haggerty)

22) An undersized pipe (outlet blocked) at RM 0.4 in Shafter Creek (19.0033) blocks over 1.5 miles of spawning habitat important to coho, steelhead, and cutthroat. (Mike Haggerty)

23) Over 1 mile of spawning and rearing habitat important for coho, steelhead, and cutthroat is blocked by a culvert at RM 0.075, in a left bank tributary to Johnson Creek at Johnson Creek (19.0175) RM 0.2. (Mike Haggerty)

24) An impassible culvert/undefined channel, near RM 0.4 in Razz Creek (19.0113c) blocks about 1 mile of coho, steelhead, and cutthroat habitat. (Mike McHenry)

25) About 0.9 miles of coho, steelhead, and cutthroat habitat is blocked by a perched pipe at RM 23.3 in the mainstem Hoko River. (Mike Haggerty)

26) Slightly less than one acre of wetland and about 0.1 mile of 2-4% gradient stream habitat important for coho, steelhead, and cutthroat, is blocked by a culvert at RM 0.01 in a right bank tributary to Clallam River near RM 5. (Mike Haggerty)

27) A SR 112 box culvert in Bear Creek (RM 0.4) obstructs over one mile of coho, steelhead, and cutthroat habitat. WDOT is planning to replace this culvert, so this is not recommended for restoration funding at this time. (Randy Johnson, Tim Rymer)

28) In Whiskey Creek (RM 1.5), a 40% barrier at box culvert SR 112 MP 49.5 blocks 1.2 miles of coho steelhead, and cutthroat habitat. This documented blockage requires field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

29) Undersized perched pipes at RM 0.7 in Boe Creek (20.0064) partially blocks over 0.75 miles of spawning habitat important to sockeye, coho, steelhead, and cutthroat. (Mike Haggerty)

30) An old dam creates a partial barrier in Salt Creek (RM 6.5), blocking about 0.7 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

31) At the mouth of Pearson Creek (19.0130) is a partial barrier at an old fish screen foundation, blocking 1.4 miles of coho, steelhead, and cutthroat access. (Randy Johnson, Tim Rymer)

32) In Miller Creek (20.0026) near RM 0.4, a perched pipe on Sooes mainline blocks about 0.7 miles of coho, steelhead, and cutthroat habitat. This includes about 0.4 miles of 2-4% gradient, moderately confined stream and 0.3 miles of 1-4% gradient, moderate confined habitat. (Mike Haggerty)

33) In tributary 19.0009 to Salt Creek (RM 0.5), a corrugated metal pipe on 930 Road blocks about 0.5 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

34) In tributary 19.0011 to Salt Creek (RM 1.3), a culvert on Dempsy Road blocks about 0.7 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

35) At RM 0.1 in Rights Creek (19.0174), a partial barrier at a diversion dam obstructs about one mile of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

36) In Joe Creek at RM 0.5, a 60% passable box culvert on SR 112 MP 32.8 blocks about one mile of coho, steelhead, and cutthroat habitat, based upon database documentation. This culvert needs field verification of conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

37) At RM 2 in a tributary (19.0121) to Green Creek, an impassable culvert on SR 112 MP 32.8 blocks 0.5 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

38) In Field Creek (RM 2.1), there is a 40% passable corrugated metal pipe blocking about one mile of coho, steelhead, and cutthroat habitat. This is not recommended for restoration funds at this time because it is already scheduled for replacement. (Randy Johnson, Tim Rymer)

39) A 5' corrugated metal pipe at SR 112 MP 52.9, 30% partially blocks about 0.5 miles of coho, steelhead, and cutthroat habitat in tributary 19.0012 to Salt Creek (RM 0.2). (Randy Johnson, Tim Rymer)

40) In Nelson Creek at RM 1.6, a cement box culvert on SR 112 MP 47.1 blocks about 0.3 miles of coho, steelhead, and cutthroat habitat. This barrier needs field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

41) A culvert on Oxenford Road potentially blocks about 0.7 miles of coho, steelhead, and cutthroat habitat in tributary 19.0001A to Colville Creek at RM 0.2. This documented obstruction needs field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

42) In tributary 19.0007A (RM 0.1) to Salt Creek, a partial barrier by a corrugated metal pipe blocks about 0.5 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

43) An impassible culvert near RM 1.5 in East Fork Deep Creek blocks about 0.5 miles of steelhead and cutthroat habitat. (Mike McHenry)

44) A partial barrier associated with SR 112 near MP 12.3 blocks about 0.5 miles of coho, steelhead, and cutthroat habitat in tributary 19.0148A (RM 0.2) to the Hoko River. (Randy Johnson, Tim Rymer)

45) A 60% passable 3' culvert associated with SR 112 at MP 24.91 blocks about one mile of coho, steelhead, and cutthroat habitat in tributary 19.0113K (RM 0.0) to the Pysht River. (Randy Johnson, Tim Rymer)

The next four obstructions exist in the same tributary. For maximum benefits, they should be slated for restoration in the following priority order, beginning with the downstream-most blockage and working upstream. (Randy Johnson, Tim Rymer)

46) In tributary 19.0015 (RM .016) to Bear Creek, a 2' corrugated metal pipe barrier blocks about 0.41 miles of coho, steelhead, and cutthroat habitat.

47) In tributary 19.0015 (RM .25) to Bear Creek, a 2' corrugated metal pipe obstructs about 0.32 miles of coho, steelhead, and cutthroat habitat.

48) In tributary 19.0015 (RM .28) to Bear Creek, a blown-out dam outlet blocks about 0.29 miles of coho, steelhead, and cutthroat habitat.

49) In tributary 19.0015 (RM .32) to Bear Creek, a rock dam blocks about 0.25 miles of coho, steelhead, and cutthroat habitat.

50) A barrier at an 8' cement box on SR 112 MP 56.5 potentially blocks about 0.5 miles of coho, steelhead, and cutthroat habitat in tributary 19.0003 (RM 0.2) to Colville Creek. This needs field verification to assess fish passage conditions below and above the barrier prior to restoration planning. (Randy Johnson, Tim Rymer)

51) A barrier at the Pillar Point access road culvert blocks about 0.8 miles of coho, steelhead, and cutthroat habitat at the mouth of Butler Creek (19.0112). This requires field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

52) An 80% barrier at double 30" culvert on SR 112 MP 29.7 blocks about 0.5 miles of coho, steelhead, and cutthroat habitat in Butler Creek (19.0112 RM 0.3). This requires field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

53) An 18" culvert partially blocks about 0.44 miles of coho, steelhead, and cutthroat habitat in tributary 19.0014A (RM 0.13) to Bear Creek. (Randy Johnson, Tim Rymer)

54) In a left bank tributary to the Sail River near Sail RM 0.1, a culvert potentially blocks at least 0.4 (2-4% gradient) miles of coho, steelhead, and cutthroat habitat. This barrier needs field verification of fish passage conditions above and below the culvert prior to restoration planning. (Mike Haggerty)

55) In Grimes Creek (20.0025) near RM 0.3, a perched pipe on Sooes mainline blocks about 0.4 miles of coho, steelhead, and cutthroat habitat (2-4% gradient). (Mike Haggerty)

56) In stream 20.0056, a partially impassable fish-way at the road crossing near RM 0.12 blocks at least 0.35 miles of coho, steelhead, and cutthroat habitat (2-4% gradient). (Mike Haggerty)

57) In stream 19.0215 near RM 0.18, a highly perched pipe potentially blocks at least 0.3 miles of coho, steelhead, and cutthroat habitat (2-4% gradient, moderately confined). This needs to be field verified prior to restoration planning. (Mike Haggerty)

58) An impassible culvert near RM 0.3 in a tributary to Reed Creek (19.0014), blocks about 0.3 miles of coho, steelhead, and cutthroat habitat. (Mike McHenry)

59) A minor passage problem for coho, steelhead, and cutthroat exists with a 2' corrugated metal pipe in tributary 19.0014A to Bear Creek, RM 0.24, potentially impacting about 0.33 miles of habitat. (Randy Johnson, Tim Rymer)

60) In tributary 19.0014A (RM 0.27) to Bear Creek, a concrete slab blocks about 0.3 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

61) In tributary 19.0121A (RM 0.3) to Green Creek, a culvert on SR 112 blocks about 0.2 miles of coho, steelhead, and cutthroat habitat. This potential barrier requires field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

62) At the mouth of stream 19.0102X, a recently installed corrugated metal pipe associated with SR 112 near MP 34.8, blocks about 0.5 miles of coho, steelhead, and cutthroat habitat. This documented blockage needs field verification of fish passage conditions above and below the culvert prior to restoration planning. (Randy Johnson, Tim Rymer)

63) In stream 19.0214 at RM 0.08, a highly perched pipe is a possible blockage for 0.5 miles of coho, steelhead, and cutthroat habitat (4-8% gradient). This barrier needs field verification of fish passage conditions above and below the culvert prior to restoration planning. (Mike Haggerty)

64) In stream 19.0191 at RM 0.01, a culvert blocks access to about 0.48 miles of coho, steelhead, and cutthroat habitat (4-8% gradient, confined channel). This is a left bank tributary to the Hoko River near Hoko RM 18.2. (Mike Haggerty)

65) In a right bank tributary (19.0208X) to No Name Creek near No Name RM 0.6, a culvert blocks about 0.4 miles of coho, steelhead, and cutthroat habitat that is 4-8% gradient, moderately confined. (Mike Haggerty)

66) At RM 0.075 in a right bank tributary to the Hoko River near Hoko RM 5 (Hoko Gauge Creek), a culvert blocks at least 0.25 miles of coho, steelhead, and cutthroat habitat (2-8% gradient). (Mike Haggerty)

67) On Village Creek (19.0240) near RM 0.25, a 185' long perched culvert blocks 0.32 miles of coho, steelhead, and cutthroat habitat (0.23 miles of 2-4% gradient, moderately confined and 0.09 miles of 4-8% gradient, confined channel). (Mike Haggerty)

68) Near RM 0.38 in a left bank tributary to the Hoko River near Hoko RM 17.6, a perched pipe blocks at least 0.27 miles of coho, steelhead, and cutthroat habitat (0.23 miles of 4-8% gradient and 0.04 miles of 2-4% gradient). (Mike Haggerty)

69) On stream 20.0038 near RM 0.35, an undersized perched pipe blocks about 0.31 miles of coho, steelhead, and cutthroat habitat (0.21 miles of 2-8% gradient, moderately confined channel and 0.1 mile of 4-8% gradient, moderately confined channel). (Mike Haggerty)

70) In stream 20.0039 near RM 0.25, an undersized perched pipe blocks at least 0.15 miles of coho, steelhead, and cutthroat habitat (4-8% gradient). (Mike Haggerty)

71) In tributary 19.0014A (RM 0.44) to Bear Creek, an 18" corrugated metal pipe partially blocks about 0.13 miles of coho, steelhead, and cutthroat habitat. (Randy Johnson, Tim Rymer)

72) Near RM 0.06 in a right bank tributary to 19.0199 (RM 0.45), a culvert blocks about 0.1 miles of coho, steelhead, and cutthroat habitat. (Mike Haggerty)

73) Near RM 0.18 in a left bank tributary to 19.0218 (RM 0.44), a culvert blocks an unquantified amount of coho, steelhead and cutthroat habitat. This needs to be field verified prior to restoration planning. (Mike Haggerty)

Clallam River Mouth Obstruction (Randy Johnson, WDFW)

The Clallam River mouth is occasionally sealed-off by the approximately 3500-foot long sand and gravel spit that parallels the lower part of the river. Fish cannot enter or leave the Clallam River during times when this condition exists. Most often the mouth is blocked during the summer months when potential impacts to salmonid fish are probably at their least. Not uncommonly, however, the mouth is blocked during spring or fall months, thus impacting the migration of anadromous salmonids.

Many people view this phenomenon as being "natural", for other stream mouths are also periodically blocked by bars. The Clallam River mouth may or may not have been subject to blockage by natural processes in the years pre-dating human impacts to the watershed. But, I believe that in contemporary times, the frequency and duration of the river mouth's blockage is unnatural, to the detriment of anadromous salmonid production.

Physical Processes. The Clallam River mouth functions as a tidal inlet serving the Clallam River estuary. The term bypassing stability is used to describe the ability of a tidal inlet to bypass littoral drift from the up-drift shore to the down-drift shore without becoming blocked. The classic bypassing stability equation (Battjes 1967) states that a high degree of bypassing stability exists when $M/Qm < 10\text{-}20$. M = littoral drift in cubic units per year. Qm = maximum discharge through the inlet during an average spring tide in cubic units per second. In an estuary, Qm will be a function of (tidal prism) and Q (river discharge), and M will be a product of marine-derived sediments plus fluvial-derived sediments. Therefore, bypassing stability in a single-channel estuarine tidal inlet

will exist when: (marine sediment + fluvial sediment)/(tidal prism + river discharge) remains less than 10-20. At the Clallam River mouth, this condition persists most of the time and the mouth is open. But occasionally during periods of low stream flow, the product of + Q diminishes sufficiently to allow the mouth to become blocked. When this occurs, the entire river discharge infiltrates through the spit.

Human Impacts. Any human activity that either increases M (sediment) or decreases Qm (flushing power) will decrease bypassing stability, and the river mouth will become blocked more frequently and for longer durations. A brief examination of these variables is summarized below.

1. Forest practices have unquestionably increased the Clallam River's fluvial sediment load over pristine levels. In many areas, marine sediment supplies have diminished following coastal development, but I don't know whether or not that has occurred in the Clallam Bay drift cell. Therefore, M has most likely, but not necessarily, been increased by human impacts.

2. Water withdrawals in the Clallam River watershed reduce stream flows in the river, but the significance of this impact is unknown.

3. Human activities appear to have significantly reduced the tidal prism associated with the Clallam River estuary. These activities include the placement of tidal barriers or restrictors in at least three tributary streams, and the filling-in of portions of the tidal prism.

Conclusions and Recommendations. Evidence indicates that the frequency and duration of blockages at the Clallam River mouth have been increased by human impacts. Specifically implicated are 1) increased sediment caused by forest practice activities, 2) decreased river discharge due to surface water withdrawals in the basin, and 3) a decrease in the size of the tidal prism. Of these impacts, tidal prism restoration is likely the single-most effective measure to improve bypassing stability at the river mouth. Restoration of the tidal prism should be viewed as the primary tool for addressing this anthropogenic impact.

Major Recommendations For Barriers In WRIA 19

- To the extent feasible, improve the passage problems in their listed priority order.

Data Needs For Loss of Access In WRIA 19

- Surveys for barriers, including those in estuarine and freshwater habitats are needed throughout WRIA 19. These surveys should include information about the extent of the blockage and the quality of habitat blocked, quantity of habitat blocked, and species/life history stage blocked.
- Conduct studies on the blockage problem near the mouth of the Clallam River. Studies should address the causes and solutions for the blockage.

E) CONDITION OF FLOODPLAINS IN WRIA 19

Functions Of Floodplains

Floodplains are portions of a watershed that are periodically flooded by the lateral overflow of rivers and streams. In general, most floodplain areas are located in lowland areas of river basins and are associated with higher order streams. Floodplains are typically structurally complex, and are characterized by a great deal of lateral, aquatic connectivity by way of sloughs, backwaters, sidechannels, oxbows, and lakes. Often, floodplain channels can be highly braided (multiple parallel channels).

One of the functions of floodplains is aquatic habitat. Aquatic habitats in floodplain areas can be very important for some species and life stages such as coho salmon juveniles that often use the sloughs and backwaters of floodplains to overwinter since this provides a refuge from high flow events. Floodplains also help dissipate water energy during floods by allowing water to escape the channel and inundate the terrestrial landscape. This lessens the impacts of floods on incubating salmon eggs. Floodplains also provide coarse beds of alluvial sediments through which subsurface flow passes. This acts as a filter of nutrients and other chemicals and so maintains high water quality.

Impairment Of Floodplains By Human Activities

Large portions of the floodplains of many Washington rivers, especially those in the western part of the state, have been converted to urban and agricultural land uses. Much of the urban areas of the state are located in lowland floodplains, while land used for agricultural purposes is often located in floodplains because of the flat topography and rich soils deposited by the flooding rivers.

There are two major types of human impacts to floodplain functions. First, channels are disconnected from their floodplain. This occurs both laterally as a result of the construction of dikes and levees, which often occur simultaneously with the construction of roads, and longitudinally as a result of the construction of road crossings. Riparian forests are typically reduced or eliminated as levees and dikes are constructed.

The second major type of impact is loss of natural riparian and upland vegetation. The natural riparian and terrestrial vegetation in floodplain areas was historically coniferous forests. Conversion of these forested areas to impervious surfaces, deciduous forests, meadows, grasslands, and farmed fields has occurred as floodplains have been converted to urban and agricultural uses. Loss of connectivity and elimination of floodplain forests has: 1) eliminated off-channel habitats such as sloughs and side channels, 2) increased flow velocity during flood events due to the constriction of the channel, 3) reduced subsurface flows, and 4) simplified channels since LWD is lost and channels are often straightened when levees are constructed. This section of the report highlights the factors that impact connectivity. Riparian impacts are described in a separate chapter.

Elimination of off channel habitats can result in the loss of important rearing habitats for juvenile salmonids such as sloughs and backwaters that function as overwintering habitat for coho juveniles. The loss of LWD from channels reduces the amount of rearing habitat available for chinook juveniles. Disconnection of the stream channels from their floodplain due to levee and dike construction increases water velocity, which in turn increases scour of the streambed. Salmon that spawn in these areas can have reduced egg to fry survival due to the scour. Removal of riparian zones can increase stream temperatures in channels, which can stress both adult and juvenile salmon. Sufficiently high temperatures can increase mortality.

Floodplain Problems In The Western Strait Of Juan De Fuca

In general, typical floodplain impacts such as dikes are not a widespread problem in this WRIA. Most floodplain problems in this region are due to roads that border streams, and their impact varies with stream. These specific problems are described below and are mapped in Figure E.1.

Salt Creek

Camp Hayden Road is a riparian road constructed in the floodplain along the mainstem from RM 1-2 (Tim Rymer, WDFW, personal communication). The road prevents the lateral migration of Salt Creek and disconnects the Creek from potential wetlands and side channels. Impacts include a loss of juvenile coho, steelhead, and chinook rearing habitat, and less winter refuge areas to escape from peak flows.

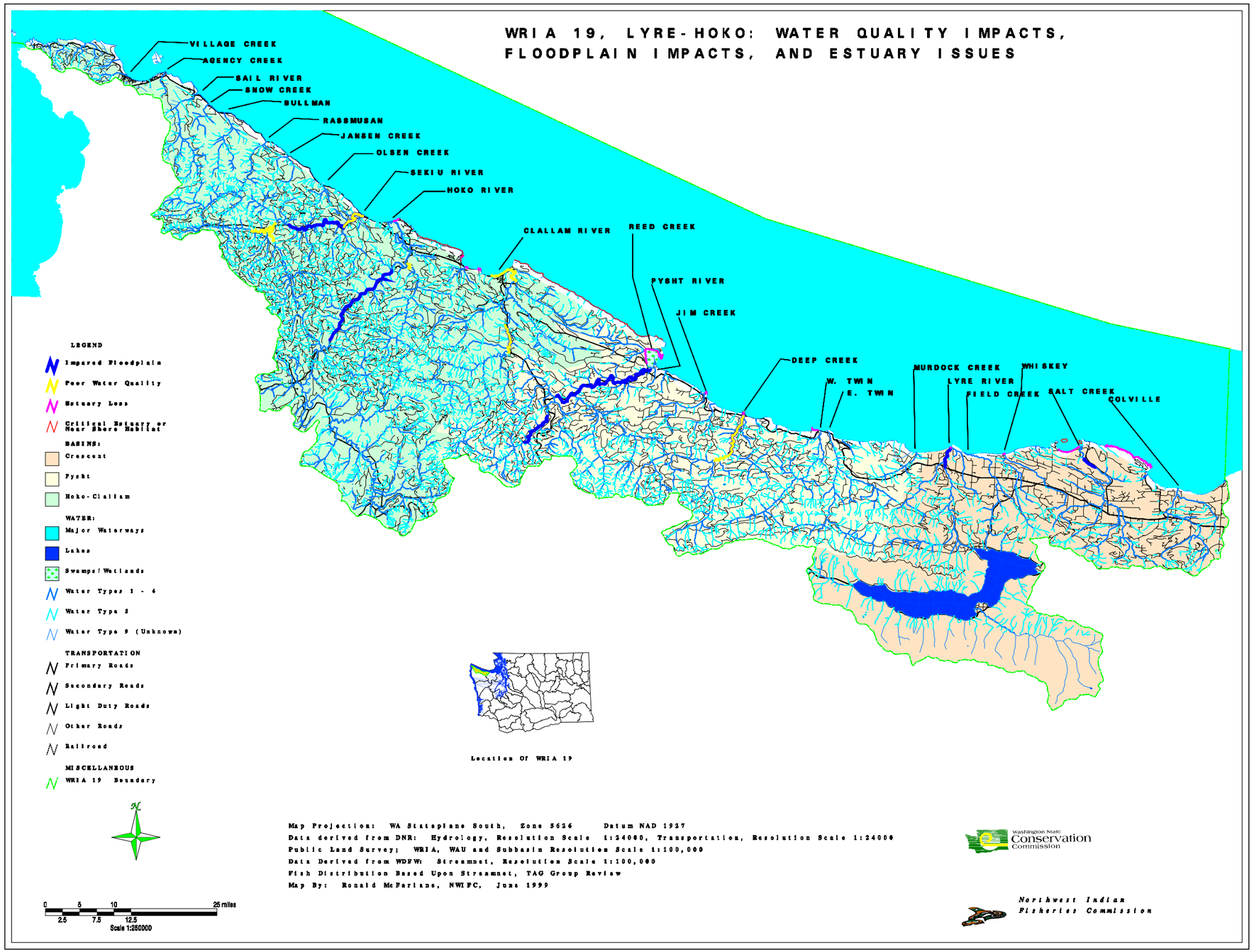
Lyre River

The lowest mile of the mainstem is channelized (Mike McHenry, Lower Elwha Tribe, personal communication). This area is also lacking in LWD, and is surrounded by a riparian that will not supply more LWD in the future. The LWD will be necessary to allow sediments to accumulate, raising the streambed to enable the floodplain to connect with the river.

Deep Creek

Almost no (only 112 m side channel habitat found) off-channel habitat areas were identified in the low gradient reaches of Deep Creek (McHenry et al. 1995). This is likely due to debris flows from high precipitation events in the early 1980s and in 1990 (see Streambed Chapter). The lack of off-channel habitat especially impacts fall coho and winter steelhead juvenile winter refuge rearing. It also impacts the early juvenile rearing needs of fall chinook, fall coho, and steelhead.

Figure E.1. Impaired floodplain areas in WRIA 19 are highlighted in dark blue.



Pysht River

The TAG members believe that the Pysht River has the greatest degree of floodplain impacts per stream mile in the WRIA. Most of the anadromous salmon mainstem habitat has an impaired floodplain, and the location of these impacts pose significant problems to all anadromous salmon production in the Pysht. The two greatest problems are Highway 112 and a railroad grade. Both act as dikes as well as contribute sediment. These two problems increase channel instability (increases salmon egg mortality) and reduces salmon juvenile rearing habitat. Highway 112 impacts begin near RM 2 on the rightbank (looking downstream), and continue upstream to RM 8.4. (The highway crosses the mainstem Pysht near RM 5.1 and impacts the left bank from the crossing to RM 8.4.) In the lower reaches, a railroad grade along the leftbank adds to the floodplain problems. Further upstream, a Crown Zellerbach road impacts the floodplain from RM 9.8 to RM 11.5 (Mike McHenry, Lower Elwha Tribe, personal communication).

Using the FEMA floodplain coverage plus a 50m buffer and the DNR transportation layer, the estimated quantity of floodplain roads in the Pysht is 3.6 mi/mi^2 (Ted Labbe, Point No Point Treaty Council, personal communication). Densities greater than 3 mi/mi^2 are considered "not properly functioning" by the NMFS (NMFS 1995). The estimate of 3.6 mi/mi^2 is conservative because the transportation layer does not include all roads, especially abandoned roads, which often impact streams to the greatest extent.

Clallam River

Highway 112 cuts through the Clallam River floodplain near RM 4.4-5.6, resulting in a loss of off-channel early juvenile rearing habitat that impacts fall chinook, fall coho, and winter steelhead (McHenry et al. 1996). It also reduces winter refuge habitat for fall coho and winter steelhead, and reduces incubation survival for all salmonid species.

Using the FEMA floodplain coverage plus a 50m buffer and the DNR transportation layer, the estimated quantity of floodplain roads in the Clallam Basin is 4.2 mi/mi^2 (Ted Labbe, Point No Point Treaty Council, personal communication). Densities greater than 3 mi/mi^2 are considered "not properly functioning" by the NMFS (NMFS 1995). The estimate of 4.2 mi/mi^2 is conservative because the transportation layer does not include all roads, especially abandoned roads, which often impact streams to the greatest extent.

Hoko River

The Hoko Drainage is greatly impacted by riparian roads. Using the FEMA floodplain coverage plus a 50m buffer and the DNR transportation layer, the estimated quantity of floodplain roads in the Hoko is 5.4 mi/mi^2 (Ted Labbe, Point No Point Treaty Council, personal communication). Densities greater than 3 mi/mi^2 are considered "not properly functioning" by the NMFS (NMFS 1995). The estimate of 5.4 mi/mi^2 is conservative because the transportation layer does not include all roads, especially abandoned roads, which often impact streams to the greatest extent.

Along the mainstem, a railroad grade extensively impacts the floodplain. From RM 4.5-9, the grade lies closely along the mainstem Hoko River floodplain, contributing sediment and in some areas, preventing lateral stream channel migration (Mike McHenry, Lower Elwha Tribe, personal

communication). The problems with the railroad grade continue upstream, but the problems are site-specific. Restoration sites need to be field verified before projects are planned. Sidecast roads are a big sediment contributor in the upper Hoko as well.

Channelization and diking has occurred in the lower two miles of the mainstem Little Hoko River (Bishop et al, 1996), which has contributed to the channel downcutting 4-5 feet into the floodplain (Martin et al. 1995). This not only further disconnects the stream from the floodplain, but also results in greater scour as the high water energy is less able to dissipate over the banks. The impacts are significant on incubation survival for fall chinook, fall coho, fall chum, and to a lessor extent, winter steelhead. There is also a loss of early juvenile rearing of fall chinook, fall coho, and winter steelhead, and a reduction in winter refuge for fall coho and winter steelhead.

Sekiu River

Channelization has occurred in the Sekiu basin (McHenry et al. 1996), but the Main Line logging road that parallels the mainstem is the greatest floodplain impact in the basin (Mike Haggerty, Makah Tribe, personal communication). This road constrains the lower 4.5 miles of the mainstem (McHenry et al. 1996), resulting in increased channel instability and a loss of off-channel early juvenile rearing habitat impacting fall chinook, fall coho, and winter steelhead. It also reduces winter refuge habitat for fall coho and winter steelhead, and reduces incubation survival for fall chinook, fall coho, fall chum, and to a lessor extent, winter steelhead. To remove all impacts (stream channel constraints and sedimentation), the road would need to be properly abandoned. If the road were sealed, the sedimentation impact would be reduced.

Using the FEMA floodplain coverage plus a 50m buffer and the DNR transportation layer, the estimated quantity of floodplain roads in the Sekiu Basin is 4.8 mi/mi^2 (Ted Labbe, Point No Point Treaty Council, personal communication). Densities greater than 3 mi/mi^2 are considered "not properly functioning" by the NMFS (NMFS 1995). The estimate of 4.8 mi/mi^2 is conservative because the transportation layer does not include all roads, especially abandoned roads, which often impact streams to the greatest extent.

Major Recommendations For Floodplains In WRIA 19

- Reduce riparian road impacts either by road abandonment or through better road surfacing.
- Increase off-channel habitat, particularly in areas vulnerable to scour.
- Increase LWD in areas of channel incision to allow sediments to accumulate for reconnection of the river to its floodplain. This is needed in the lower reaches of Lyre River, Deep Creek, Hoko River, and Sekiu River.

Data Needs For Floodplain Conditions In WRIA 19

- Develop maps comparing the current versus historic floodplains throughout WRIA 19, beginning with the largest watersheds.
- Regularly monitor floodplain alterations.
- Improve the transportation layer to show old, unused roads.

F) STREAMBED SEDIMENT CONDITIONS IN WRIA 19

Streambed Sediment Introduction

In an ecologically healthy stream channel, sediments are naturally dynamic, and are a function of a number of physical processes which input, store, and transport materials. Processes vary spatially and temporally and are dependent upon a number of features of the landscape such as stream order, gradient, stream size, basin size, geomorphic context, and hydrological regime. In forested mountain basins, sediment enters stream channels from mass wasting (e.g., landslides and debris flows), surface erosion, and soil creep. Inputs of sediment to a stream channel in these types of basins usually occurs periodically during extreme events such as floods (increasing erosion) and mass wasting which are the result of climatic events (e.g., rainstorms, rain on snow). In lowland (higher order) streams, erosion is the major sediment source. Inputs of sediment in these basins tend to be steadier in time.

Once sediment enters a stream channel it can either be stored or transported depending upon particle size, stream gradient, hydrological conditions, availability of storage sites, and channel form (e.g., amount of large woody debris). Finer sediments tend to be transported through the system as wash load or suspended load and have relatively little effect on channel morphology. Coarser sediments (>2 mm diameter) tend to travel as bedload, and can have larger effects on channel morphology as they move downstream through the channel network.

Some parts of the channel network are more effective at storing sediment, while other parts of the network more effectively transport material. There are also strong temporal components to sediment storage and transport, such as seasonally occurring floods, which tend to transport more material. One channel segment may function as a storage site during one time of year and lose sediments at other times. In general, the coarsest sediments are found in upper watersheds while the finest materials are found in the lower reaches of a watershed. Storage sites include various types of channel bars, floodplain areas, and behind large woody debris (LWD).

Effects Of Human Actions On Sediment Processes

Changes in the supply, transport, and storage of sediments can occur as the direct result of human activities. Human actions can result in increases or decreases in the supply of sediments to a stream. Increases in sediment result from the isolation of the channel from the floodplain by development of lowland areas; this eliminates important storage areas for sediment. In addition, actions that destablize the landscape in high slope areas such as logging or road construction increase the frequency and severity of mass wasting events. Finally, increases in the frequency and magnitude of flood flows increases erosion. Increases in the amount of coarse material tend to fill pools and aggrade the channel, resulting in reduced habitat complexity and reduced rearing capacity for some salmonids. Increases in total sediment supply to a channel increases the proportion of fine sediments in the bed which can reduce the survival of incubating eggs in the gravel and change benthic invertebrate production.

Sediment supply can decrease in some cases. This occurs primarily as a result of disconnecting the channel from the surrounding landscape. A dam can block the supply of sediment from upper watershed areas, while a levee can cut off upland sources of sediment. Reduction in sediment supply can alter the composition of streambeds, which can in some cases reduce the amount of material suitable for spawning.

In addition to affecting supply, human activities can also affect the storage and movement of sediment in a stream. An understanding of how sediment moves through a system is important for determining where sediment will have the greatest effect on salmonid habitat and for determining which areas will have the greatest likelihood of altering habitats. In general movement of sediment changes as a result of the isolation of the channel from its floodplain, and increases in the magnitude and frequency of flood flows. Larger and more frequent flood flows move larger and greater amounts of material more frequently. This can increase bed scour, bank erosions, and alter channel morphology, and ultimately degrade the quality of spawning and rearing habitat. Channels become unstable and very dynamic compared to conditions without development.

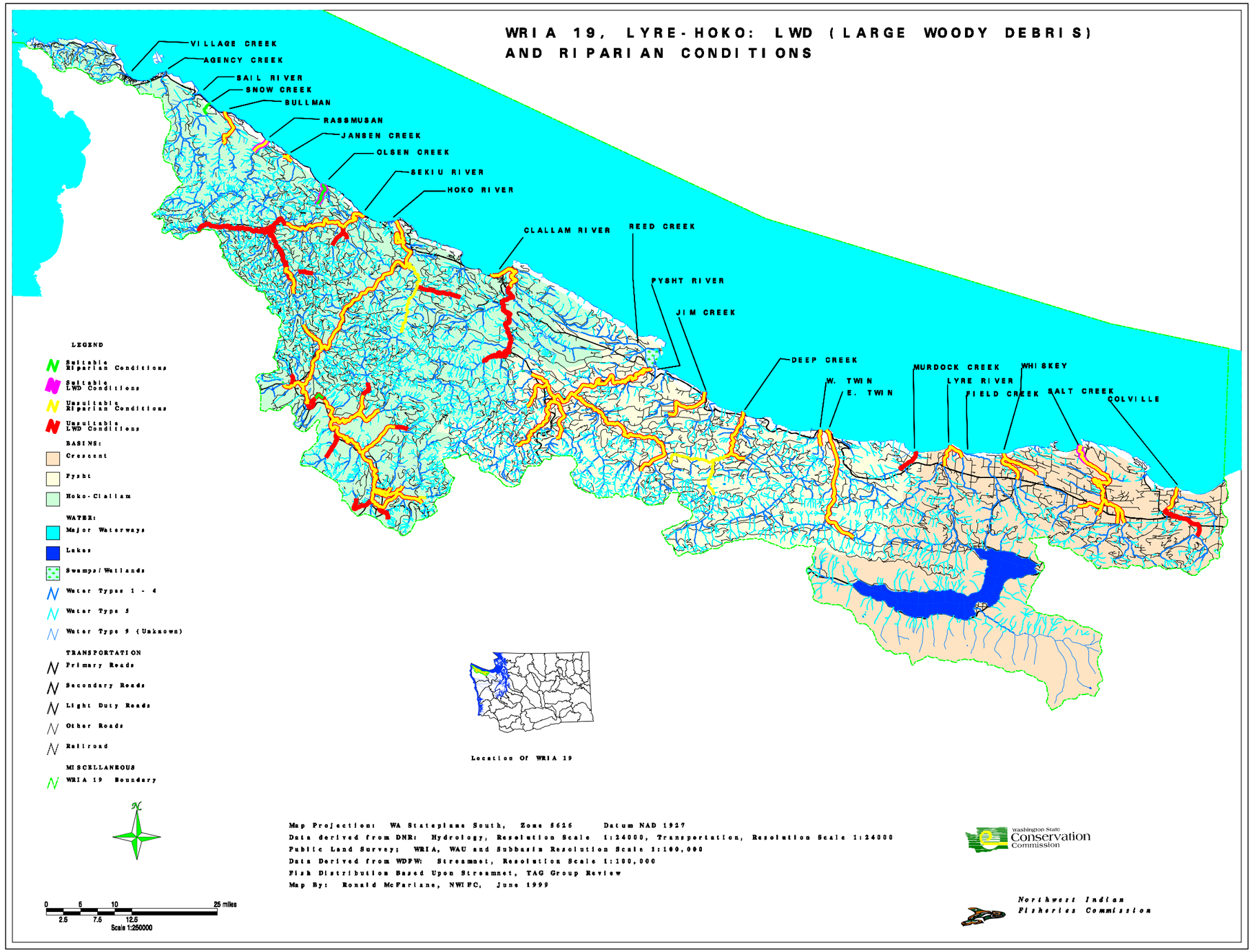
Human activities also change where sediments are stored. For example, increases in the magnitude and frequency of flood flows can more material through areas where it would have otherwise been stored.

Sediment Problems In The Western Strait Of Juan De Fuca

Problems with streambed and sediment are common in the salmon-producing streams draining into the western Strait of Juan de Fuca. In general, fine sediment levels in managed streams are roughly double the level found in streams managed in the Olympic National Park (McHenry et al. 1994). Scour has been documented in a few streams (see discussion below for specifics), and a lack of large woody debris (LWD) is a pervasive problem. The lack of LWD results in less storage of adequate spawning gravels, and more rapid transport of all types of sediment. The greater transport rate has lead to channel incision and scour in some cases. Figure F.1 shows the extent of LWD depletion in this WRIA. The mapped depletion is generalized, with the possibility that a specific site within a reach might have adequate LWD, while overall the reach is depleted. Unsuitable levels of LWD is defined as not meeting watershed analysis standards for either functional or key pieces of LWD, or that LWD is present but non-functional, such as along the stream margins. Please refer to Figure F.1 throughout the LWD discussion for the WRIA.

The assessment included a review of recovery plans and watershed analysis. However, these were only available for the larger streams. For conclusions regarding the smaller streams, we relied on the professional judgement of the Technical Advisory Group members.

Figure F.1. Riparian and LWD condition throughout WRIA 19. Areas that are not highlighted for LWD are either outside the known salmon distribution or are unknown for these values.



Colville Creek

Upstream of Highway 112, the Colville Creek channel is incised, while downstream of the highway, the streambed widens into a valley. Dredging has occurred in this valley, and possibly upstream of the Highway 112 crossing, resulting in an unstable, channelized stream that needs meanders (Tim Rymer, WDFW, personal communication). Livestock have stream access in this area, leading to water quality problems, including sediment inputs. Two blockages exist further downstream: one is fairly complete (see Loss of Access section). In the lowest reaches, the habitat is better. However, there is insufficient LWD in the lowest mile of the creek (Mike McHenry, Lower Elwha Tribe, personal communication).

Salt Creek

Sedimentation is a problem in Salt Creek, and is likely the result of heavy logging adjacent to west side tributaries in the 1980s (Theresa Powell and Dan Defoe, WDFW, personal communication). The lower reaches of Salt Creek have high LWD loadings, but the reaches upstream of Camp Hayden Bridge have low levels of LWD. This area is also channelized and incised (Mike McHenry, Lower Elwha Tribe, personal communication). There is an isolated problem with cattle along the banks near the county park, which could decrease water quality as well as increase erosion.

Whiskey Creek

Whiskey Creek appears to have a very high sediment load. Part of this is natural, due to the area geology, but part is also likely a result of extensive logging as well as inputs from the railroad grade (Mike McHenry, Lower Elwha Tribe, personal communication). Near Joyce, the streambed consists of unstable fines that do not provide habitat for spawning salmon. The lower reaches are in poor shape. There is a lack of LWD, and the channel has incised, creating inner slope failures that contribute to the sediment load. The fines have been such a severe problem, that chum could not be successfully incubated (remote site incubators) in Whiskey Creek water.

Field Creek

Streambed/sediment problems also exist in Field Creek. Sedimentation is likely the result of extensive logging due to land conversion as well as development activities in an area with a naturally high sediment load (Theresa Powell, WDFW, personal communication). Scour is another problem in the lower reaches as well, and salmon haven't been seen in Field Creek for about three years (Mike McHenry, Lower Elwha Tribe, personal communication). While the upper reaches have patchy amounts of LWD, the lower reaches have very few pieces of LWD (Theresa Powell, WDFW, personal communication).

Lyre River

Spawning habitat is in fairly good condition, but Boundary Creek is introducing fines into the Lyre (Mike McHenry, Lower Elwha Tribe, personal communication). In general, LWD levels are good, except in the lower reaches where the stream is channelized and "cleaned"

of LWD by local residents. Of the major tributaries, Susie Creek provides good salmon habitat, while Nelson Creek has low levels of LWD.

Murdock Creek

Although logging has occurred in this area, good practices were used, and the stream currently provides fairly good habitat, particularly for steelhead. One on-going problem has been the deposition of spoils (Department of Transportation) from roads placed along Highway 112 (Tim Rymer, WDFW, personal communication). These enter the stream and add to the sediment load. Development on the eastside is a concern as forestland is permanently converted to a use that may impact basin hydrology.

East and West Twin Rivers

Sedimentation has been a problem, mostly due to roads, particularly on Forest Service property (Mike McHenry, Lower Elwha Tribe, personal communication). Bank logging has occurred along the East Twin and West Twin. The lower reaches have been logged extensively by private individuals. This has probably contributed to the scour seen in the lower reaches of the East Twin River, which has impacted incubation survival. Another symptom of excessive sedimentation is channel widening noted in the East Twin. While the lower reaches of both Twin Rivers lack adequate LWD, the upper reaches (in Forest Service property) have good levels of LWD (Tim Rymer, WDFW, personal communication).

Deep Creek

Mass wasting is a major problem in Deep Creek. Shaw (1995) documented mass wasting sites by examining aerial photos from 1971-1992, and identified 134 mass wasting sites in the Deep Creek drainage. A large majority of the mass wasting sites were related to forest harvest (35%) and roads (34%). Only 5% were identified as natural sites, and 26% were indeterminate. Much forest harvest occurred prior to the aerial records, but without earlier photos, these indeterminate sites could not be directly linked to a particular activity.

Shaw (1995) noted that within the Deep Creek watershed, all regions had a moderate or high potential of surface erosion or mass wasting. While relatively low road densities and good maintenance has resulted in low surface erosion, there is a much greater problem with mass wasting, particularly with midslope roads using side-cast technology (McHenry et al. 1995). Just south of the USFS Road 30 in the upper watershed, there are 22 debris avalanches associated with roads and 7 failures associated with yarding. Most of these debris avalanches have entered the channels and started debris flows. Five of these have scoured the channel beds to bedrock between 1980-1992 (Shaw 1995).

One of these failures stemmed from the November, 1990 storm effects on 3 cubic yards of sidecast from a road deposited near a tributary. The debris flow traveled two miles, burying a road crossing and damming water flow in the upper mainstem of Deep Creek (Shaw 1995). This dam broke hours later, releasing a flood wave that scoured the mainstem to as much as 10 vertical feet from RM 12 to RM 2. It also removed logs from the channel and deposited a debris lobe downstream of the confluence with the East Fork. The changing

flow from the deposit triggered an earthflow with then released about 3000 cubic yards of fine sediments into Deep Creek (Shaw 1995).

Currently, the channel is severely degraded as a direct result of the mass wasting history (McHenry et al. 1995). The 1971 channel width increased 2-3 fold by 1992, which has contributed to high temperature problems in the mainstem and East Fork (see the Water Quality section). The lack of LWD has resulted in an increased gradient, decreased sediment storage, and decreased quantity and quality of pools. The decreased gravel storage capability has led to almost no available spawning gravel upstream of RM 3 due to scour events compounded with a lack of LWD (McHenry et al. 1995). This directly reduces wild salmon production to only the lower 3 miles and these reaches are severely degraded.

The percent fine sediment (<85mm) currently ranges from 18-23% in the mainstem Deep Creek (McHenry et al. 1994). This is higher than the western Washington target condition of less than 11% (Peterson et al. 1992) and in the "poor" range as defined by the Forest Practices Board. The levels of fines are high enough to include one segment of Deep Creek on the 1996 303(d) list for sediment and two additional segments on the 1998 Candidate 303(d) list (DOE 1999). Based upon literature results, values in this range decreased coho egg survival by more than 50% (Chapman 1988). The impact in this area would affect coho, fall chinook, chum, and winter steelhead.

Large woody debris is not only low in quantity, but also poorly distributed. Most (63%) is located in logjams and about 48% is categorized as unstable (McHenry et al. 1995). The lower reaches have abundant wood, but most is non-functional (McHenry and Shaw 1994). All other areas of the mainstem, East Fork, and West Fork have undersupplied levels of woody debris (McHenry and Shaw 1994). McHenry (unpublished) found that of the LWD quantified, only about 36% was coniferous, and the average diameter was small (50.3 cm for conifers, 29.5 cm for deciduous). Without adequate LWD, spawning gravels will not be stored, pools will not be formed and maintained, and water velocity will remain high. This will impact spawning adults, incubating eggs, and juvenile rearing of all four species of salmonids found in the watershed.

Jim Creek

Jim Creek has a high sediment load for several reasons: logging in the upper reaches, high road density, and spoils deposited by the Department of Transportation (Tim Rymer, WDFW, personal communication). Another major problem is a lack of LWD.

Joe Creek

Naturally high sediment loads coupled with a heavily roaded watershed, result in sedimentation problems in Joe Creek (Tim Rymer, WDFW, personal communication). A lack of LWD is another streambed problem.

Pysht River

From studies conducted from 1989-1991 (Steve Ralph, EPA, unpublished), there are large shifts in bed elevation and channel form in the Pysht River. He also noted significant channel aggradation at 15 out of 27 sites. This instability has a large impact on incubation survival for fall chum, fall coho, winter steelhead, and would have an impact on fall chinook if that species were still present in the watershed. Based upon egg basket results, coho eggs had very poor survival in the Pysht (0.02%) (McHenry et al. 1994). The South Fork Pysht had better survival to the eyed stage than elsewhere in the watershed (22% vs. 2.8%). Also in Green Creek, Benda (1993) noted highly unstable channel banks, frequent lateral channel migration and significant aggradation.

The cause of the channel instability problem is likely a combination of low levels of LWD throughout the watershed and high levels of sediment. The primary sources of sediment are roads and mass wasting (McHenry et al. 1994). Benda (1993) conducted a sediment budget for Green Creek, a tributary to the Pysht, and noted that 90% of the landslide-derived sediments inputted in the last four decades are still stored in the valley floor, ie. the input is much greater than the output.

Many of the mass wasting sites were from early logging techniques. Mass wasting has been identified around Green Creek, the mainstem Pysht, Middle Creek, and Salmonberry Creek, but not near Needham, Reed, and the South Fork Pysht (DOE 1993). Road density averaged 1.69 km/km2 in the Pysht (McHenry et al. 1994), about 2.2 km/km2 in the South Fork Pysht, 2.1 km/km2 near Needham Creek, and an exceptional high level (3.5 km/km2) surrounding Green Creek (DOE 1993).

In addition to the channel instability, fine sediments (<0.85mm) have a direct impact on the survival of incubating salmon eggs through suffocation and perhaps abrasion. In the lower mainstem (RM 3.5-5.2) fines averaged 20.3% (McHenry et al. 1994), while in the middle (RM 7.2-7.4) and upper (RM 9.7-14.5) mainstem the values were 16.9% and 15.4%, respectively (McHenry et al. 1994). All of the measured areas in the tributaries were also above the unmanaged watershed value of less than 11% (Peterson et al. 1992). Middle Creek averaged 19.6%, Salmonberry Creek averaged 19.9%, Reed Creek averaged 17%, Green Creek and the North Fork Green Creek averaged 14% and 17%, respectively, and Needham Creek averaged 19.1% (McHenry et al. 1994).

Clallam River

Roads and mass wasting sites are major contributors of the fines in the basin (WDNR 1994). Road density averaged 1.68 km/km2 (McHenry et al. 1994). The average percent fines (<0.85mm) was 21.5% in the lower mainstem (RM 2.8-4.5) and 11.5% in the upper mainstem (RM 5.4-9.5) (McHenry et al. 1994). All values in the tributaries were above the unmanaged watershed value of less than 11% (Peterson et al. 1992). Last Creek averaged 22% fines, Pearson averaged 32%, Upper Charlie Creek averaged 16.5%, and Lower Charlie Creek averaged 19.5%. The lower reaches lack LWD (Fig. F.1).

Hoko River

Channel instability is a major problem throughout the Hoko basin, and believed to be a result of increased sediment input coupled with a lack of LWD. In the basin, 330 landslides associated primarily with logging roads (40%) and clearcuts (55%) (5% natural) have been identified since 1995, and 141 occurred between 1981-1993 after the intense logging in the 1970s-1980s (Martin et al. 1995). About 70% of these landslides deposit directly into the stream channel, contributing to fines and channel widening (Martin et al. 1995). Areas particularly impacted by sediment input are the mainstem Hoko River, Little Hoko River, Leyh Creek, Johnson Creek, Bear Creek, and Cub Creek. Road density is high and averages 2.45 km/km2 (Fig. F.2) (McHenry et al. 1994).

Not only does the increased sediment contribute to channel instability, but a high level of fines directly impacts incubating salmon eggs. The average percent fines was 17.5% in the lower mainstem (RM 3.5-5.6), 11.8% in the middle mainstem (RM 9.8-15.6), and 20% in the upper mainstem (RM 21.3) (McHenry et al. 1994). The lower and upper mainstem values are well above the recommended 11% threshold (Peterson et al. 1992). Nearly all of the sampled tributaries also had high levels of fines. The Little Hoko averaged 13.3%, Brownes Creek averaged 15%, Rights Creek averaged 19.7%, Johnson Creek averaged 15.6%, Ellis averaged 14%, Herman averaged 11.5%, Cub Creek averaged 18.7%, Bear Creek averaged 16.6% and Leyh Creek averaged 12.7% fines (McHenry et al. 1994).

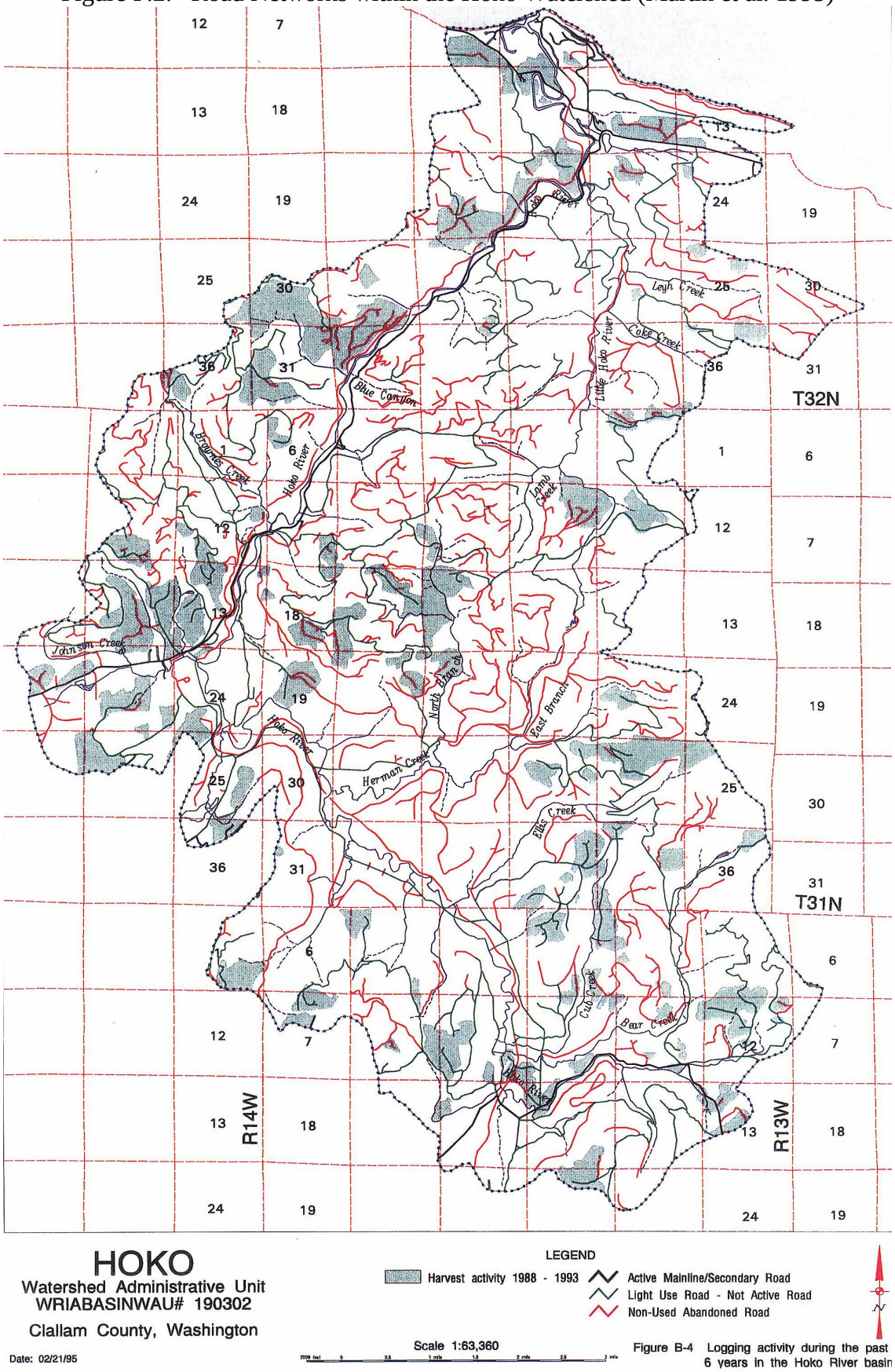
Coarse gravel for spawning needs was defined as “not limiting”; 47% of the sampled area had spawning gravel (Martin et al. 1995). However, concern was noted regarding the stability of the coarse gravel, which would impact incubation survival. McHenry et al (1994) documented large loses of coho eggs implanted at spawning sites. Increased peak flow due to timber harvest was determined to be insignificant, but hillslope erosion was believed to be a large factor in increasing sediment supply and decreasing channel stability (Martin et al, 1995).

The lack of stable LWD also contributes to channel instability. Increased scour has been associated with shifting LWD (Schuett-Hames et al. 1994), and LWD provides vertical and horizontal stability to the channel (Smith et al. 1993). Large woody debris levels are low and declining, and channel instability is not expected to improve in the near future. Nearly all sampled stream segments of the Hoko Basin were below natural reference levels in quantity of LWD (Martin et al. 1995). Piece counts averaged 0.67 per channel width compared to a target of 2-4 pieces per channel width (Martin et al. 1995). This impacts adult migration, incubation stability, and juvenile rearing for all species of salmon. In the Little Hoko River, LWD has been especially low, and is believed to be a major contributor to the recent decline in coho spawning levels in this stream (McHenry et al. 1994). However in the last few years, the Lower Elwha Tribe has done extensive restoration of LWD in the Little Hoko River. The mainstem Hoko River below RM 15.7 had only 0.17 pieces/channel width in the sampled area (Martin et al. 1995). This is where most of the chinook and chum (as well as some coho and winter steelhead) spawning occurs.

In 1993, LWD was re-measured at sites previously measured in 1982 in the mainstem Hoko, Bear Creek, Ellis Creek, and Cub Creek. There was an average loss of 39% of the

LWD volume in the 11 year period (McHenry et al. 1998). About 46% of the old growth was lost as well. In 1983, the LWD volumes in the Hoko were only 27% of the uncut reference site volumes for the Peninsula. In 1992, timber stand age classes were 15.8%<10 years old, 10% 10-20 years, 30.6% 21-40 years, 38.3% 41-80 years, and 5.3%>80 years (McHenry et al. 1994).

Figure F.2. Road Networks within the Hoko Watershed (Martin et al. 1995)



Sekiu River

Adequate levels of spawning gravels exist in the mainstem, Carpenters Creek below the East and West Forks, and North Fork Sekiu downstream of Sonnybrook Creek, but gravels are limiting salmon production in the lower South Fork, No Name Creek, and Ice Creek (Currence 1999). Gravels are also lacking in East Fork Carpenters Creek, in the North Fork Sekiu upstream of Sonnybrook, and in the remainder of the South Fork Sekiu, but the levels in these areas are not as severe as in the previously mentioned areas. Because the areas limited in spawning gravels are downstream of the highest mass wasting densities in the watershed, the lack of gravel is not due to a scarcity of source, but rather a lack of LWD to hold and sort gravels (Currence 1999). The gravel from the mass wasting sites is transported readily downstream, resulting in channel entrenchment and scour.

Large woody debris is especially low in the South Fork Sekiu, and is believed to be a major contributor to the recent decline in coho spawning levels in this stream (McHenry et al. 1994). In the South Fork, an average of 0 key pieces/channel width from the lower South Fork to above Canyon was measured, and two out of three segments also rated "poor" for functional pieces of LWD (Currence 1999). The mainstem Sekiu averaged 2.3 functional pieces/channel width, which is considered "good", but most of this was small, in the channel margins, and nonfunctional. In the same segment, no larger key pieces were observed (Currence 1999). The North Fork Sekiu was rated as "good" for functional LWD, except above the falls which was rated "fair", and these same areas rated as "poor" to "fair" for larger key pieces. Functional pieces in No Name and Ice Creeks both rated "fair", and Carpenters Creek rated "good" in the mainstem and "poor" in the East Fork (Currence 1999). One reach of No Name Creek rated "good" for LWD, but the wood was old and rapidly decomposing. All of these tributaries were rated "poor" for key pieces.

The Sekiu basin had high levels of fines (<85mm). The lower mainstem (RM 1.0-3.7) had 18.9% fines, while upstream (RM 5.2-8.3), the percent fines was 15.5% (McHenry et al, 1994). Three tributaries, Sonnybrook, the South Fork Sekiu, and the East Fork Carpenter Creek, had high values as well (21%, 15%, and 22.6% respectively). All of these values are higher than the unmanaged watershed value of less than 11% (Peterson et al, 1992). The West Fork Carpenter Creek was the only measured area with an acceptable level (10.3%) (McHenry et al. 1994).

Roads and mass wasting sites are major contributors of the fines (Benda 1993); Shaw 1993). Road density is very high, averaging 2.86 km/km2 (McHenry et al. 1994). Of the landslides identified in the 1999 watershed analysis, 76% deposited sediment directly into streams; 47% were associated with roads or landings, and 39% were associated with clearcuts (about half of the clear-cuts were new and half were 15-20 years old) (Parks and Sturhan, 1998).

Olsen Creek

Most of the tributaries associated with Olsen Creek do not provide good spawning habitat because they are confined with deep-seated landslides that introduce high levels of fine sediment (Mike Haggerty, Makah Tribe, personal communication). One right-bank tributary that meets the mainstem at about RM 0.27, has about ¼ mile of salmonid habitat. This is in addition to about 1 mile of habitat in the mainstem. Adequate levels of LWD are present.

Jansen Creek

Most of the steelhead, cutthroat and coho habitat is provided in the mainstem, which is impacted by a lack of LWD. The lower mainstem averaged only 0.6 pieces of functional LWD/channel width, a "poor" rating, and upstream averaged 2.5 pieces, but those pieces were old and rapidly decomposing or on the channel margins and nonfunctional (Currence 1999). The larger key pieces of LWD were almost non-existent (Currence 1999). The area is also heavily roaded which results in increased sedimentation. The tributaries have deep-seated landslides and shallow rapid landslides reducing habitat quality (Mike Haggerty, Makah Tribe, personal communication).

Rasmussen Creek

This stream is moderately confined with a 2-4% gradient, which limits the ability to retain LWD (Mike Haggerty, Makah Tribe, personal communication). Spawning gravel is limited and mostly located around existing LWD. Pieces of functional LWD averaged 4.2/channel width, a "good" rating, while key pieces were rated as "fair" (Currence 1999). While the creek has a naturally high sediment load, past forest harvest activities are believed to have increased the amount of material that moves through the creek. Roads are also contributing fines to the stream.

Bullman Creek

The lower mainstem has a moderate amount of LWD that could be increased to improve salmon habitat (Mike Haggerty, Makah Tribe, personal communication). The 1-2% gradient, unconfined channel used to support chinook in addition to the current production of chum, steelhead, coho, and cutthroat. In the upper reaches, the gradient steepens with tributaries that cut into the glacial Makah formation. This area is important for cutthroat habitat. The entire area is heavily roaded (4-4 ½ miles of roads/square mile) and subjected to a high level of logging. These activities have likely increased sedimentation. The percent of fine sediment is high, around 19% (Currence 1999).

Snow Creek

This creek is moderately confined with a 3-4% gradient, limiting salmonid production to steelhead, cutthroat, and occasional coho (Mike Haggerty, Makah Tribe, personal communication). The small steep tributaries have limited salmon access due to waterfalls. Sedimentation is a concern with high levels of natural sediment input in addition to a high sediment impact from roads. Logging is expected to increase, which may increase the impacts of sedimentation.

Sail River

The Sail River watershed has lower road densities than others in this WRIA (Mike Haggerty, Makah Tribe, personal communication).

Major Recommendations For Streambed/Sediment Issues In WRIA 19

- Reduce sediment inputs, particularly from roads, railroad grades, and mass wasting sites.
- Roads using side-cast technology should be properly abandoned.
- Cease deposition of spoils near streams (ex. Murdock and Jim Creeks).
- Increase LWD to aid in channel stability and gravel storage.
- Stop the removal of in-stream LWD.

Data Needs For Streambed/Sediment Issues In WRIA 19

- Conduct a complete inventory of side-cast roads and use to schedule road abandonment projects.
- Conduct studies to clarify how different types, locations, and usage patterns of roads impact salmon.
- Monitor scour throughout the WRIA.
- Conduct studies that lead to a better understanding of how changes in specific habitat factors effect salmon production.

G) RIPARIAN CONDITIONS IN WRIA 19

Riparian Zone Functions

Stream riparian zones are the area of living and dead vegetative material adjacent to a stream. They extend from the edge of the average high water mark of the wetted channel toward the uplands to a point where the zone ceases to have an influence on the stream channel. Riparian forest characteristics in ecologically healthy watersheds are strongly influenced by climate, channel geomorphology, and where the channel is located in the drainage network. For example, fires, severe windstorms, and debris flows can dramatically alter riparian characteristics. The width of the riparian zone and the extent of the riparian zone's influence on the stream are strongly related to stream size and drainage basin morphology. In a basin unimpacted by humans, the riparian zone would exist as a mosaic of stands of trees of different acreage, ages (e.g. sizes), and species.

Functions of riparian zones include providing hydraulic diversity, adding structural complexity, providing a refuge from predators and extreme environmental events, buffering the energy of runoff events and erosive forces, moderating temperatures, and providing a source of nutrients. They are especially important as the source of large woody debris (LWD) in streams which directly influences several habitat attributes important to anadromous species. In particular, LWD helps control the amount of pool habitat and can serve as a site for sediment storage. Pools provide a refuge from predators and high-flow events for juvenile salmon, especially coho, that rear for extended periods in streams while the gravels can provide sites for spawning and incubating.

Effects Of Human Activities On Riparian Zones

Riparian zones are impacted by all types of land use practices. In general, riparian forests can be removed to the stream bank, they can be broken longitudinally by stream crossings by roads, and their width can be reduced. Further, species composition can be dramatically altered when native, coniferous trees are replaced by exotic species, shrubs, and young deciduous species. Deciduous trees are typically of smaller diameter than coniferous forests, and decompose faster than coniferous species so they are vulnerable to washout from lower magnitude floods. Once impacted, the recovery of a riparian zone can take many decades as the forest cover regrows and coniferous species colonize.

Changes to riparian zones affect many attributes of stream ecosystems. For example, stream temperatures can increase due to the loss of shade, while streambanks can become more prone to erosion due to elimination of the trees and their associated roots. Perhaps the most important impact of changes to riparian zones is a decline in the frequency, volume and quantity of LWD due to altered recruitment from forested areas. Loss of LWD results in a significant reduction in the complexity of stream channels including a decline of pool habitat, which reduces the number of coho juveniles that can rear. Loss of LWD affects the amount of both overwintering and low flow rearing areas.

Riparian Conditions In The Western Strait Of Juan De Fuca

Figure F.1 in the Streambed/Sediment chapter illustrates extremes in riparian conditions throughout WRIA 19. Areas with dominant mid- to late seral stage conifer riparian were designated as suitable. A riparian that is open or hardwood dominated was mapped as unsuitable. While a hardwood riparian contributes towards shade and ecosystem value such as leaf litter, it was defined as unsuitable because of the inability to contribute to future LWD.

Colville, Whiskey, Field, Salt, Murdock, Jim, Joe Creeks, and Lyre River

Colville, Whiskey, Field, and Murdock Creeks have an altered riparian which has been converted from old-growth conifer to predominately alder (Mike McHenry, Lower Elwha Tribe, personal communication), with the exception of upper Field Creek which has a better riparian (Theresa Powell, WDFW, personal communication). Land conversion to accommodate development has contributed to the loss of riparian in the Joyce area. A current lack of LWD characterizes these streams as well. The lower reaches of Whiskey Creek are incised, and increased LWD might help raise the streambed to allow connectivity to its floodplain. The riparian of Salt Creek is particularly impacted with either predominately alder or barren riparian areas, and the upper reaches have low levels of LWD (Mike McHenry, Lower Elwha Tribe, personal communication).

The Lyre River has a better riparian condition due to a high percentage of maturing second growth conifer (Mike McHenry, Lower Elwha Tribe, personal communication). Pool development is good as a result of adequate levels of LWD. Susie Creek, a major Lyre River tributary, also has a good riparian, but Nelson Creek is surrounded by a riparian consisting primarily of hardwoods or open (Mike McHenry, Lower Elwha Tribe, personal communication).

Jim and Joe Creeks are surrounded by a primarily alder riparian with low levels of LWD (Mike McHenry, Lower Elwha Tribe, personal communication).

East and West Twin Rivers

The East Twin has areas of primarily alder riparian (Tim Rymer, WDFW, personal communication), and bank logging has occurred in the East Twin and East Fork East Twin (Mike McHenry, Lower Elwha Tribe, personal communication). The lower mainstems are in the worst shape. These areas have been extensively logged.

Deep Creek

In 1995, vegetation age classes were quantified for the Deep Creek drainage using DNR's State Methodology (Version 2.0). The total age distributions are 46% between 0-20 years, 13% between 20-40 years, 32% between 40-100 years, and 9% greater than 100 years (source). When based upon land ownership, most of the younger stands were on ITT land, which also had the greatest percentage of younger stands (70% less than 20 years).

Riparian zones in the lower (mouth to RM 2.5) mainstem Deep Creek and in the East Fork are primarily deciduous (Schuette-Hames and Malkin 1993). At RM 2.5 in the mainstem, only 21% of the reach was not impacted by erosion or blowdown, and at RM 0.25 and in the East Fork reach, only 36% of the reach was not impacted (Schuette-Hames and Malkin 1993). The LWD recruitment potential is

79% in the East Fork and only 27% in the mainstem, and this will not meet long-term needs. Most of the current LWD consists of alder. In many areas of the Deep Creek watershed, LWD levels are low in quantity and poorly distributed. Most (63%) is located in logjams and about 48% is categorized as unstable (McHenry et al. 1995). The lower reaches have abundant wood, but most is non-functional (McHenry and Shaw 1994). All other areas of the mainstem, East Fork, and West Fork have undersupplied levels of woody debris (McHenry and Shaw 1994). McHenry (unpublished) found that of the LWD quantified, only about 36% was coniferous and the average diameter was small (50.3 cm for conifers; 29.5 cm for deciduous). Without adequate LWD, spawning gravels will not be stored, pools will not be formed and maintained, and water velocity will remain high. This will impact spawning adults, incubating eggs, and juvenile rearing of all four species of salmonids found in the watershed.

The Lower Elwha Tribe and the US Forest Service (McHenry and Shaw 1994) quantified pool:riffle habitat. From the mouth to RM 2.2, there was an average of 48% pools with a maximum depth of 1.2 m, and very few pools were greater than 1m. The width/depth value was 41, indicating a severe problem with aggradation that contributes to temperature problems, a lack of protective habitat from predators, and a symptom of an unstable channel. The high temperatures and lack of depth would impact juvenile coho, winter steelhead, and to a lessor extent, fall chinook. The temperatures and lack of depth would also impact returning adult chinook (if chinook salmon are restored in Deep Creek, see Conditions of Salmon Populations section), while the lack of depth could potentially impact adult coho, chum, and winter steelhead. From RM 2.2-8.1, the percent pools averaged 26.6 with a width/depth value of 16.5. The East Fork had about 31.6% pools and a width/depth value of 14.1. In all areas, few deep (>1m) pools were observed. The lack of pools impact adult migration of fall chinook, coho, winter steelhead, and chum, as well as coho, winter steelhead, and to a lessor extent, fall chinook juvenile summer rearing habitat. High temperatures in these same reaches compound the impact. The West Fork had 54.4 % pools with a width/depth value of 11.2. These values for the West Fork combined with the cool summer temperatures recorded in that area indicate that the West Fork has the best current conditions for salmon production (McHenry and Shaw 1994).

Pysht River

The Pysht River riparian vegetation is dominated by red alder and bigleaf maple (McHenry and Murray 1996). The South Fork Pysht riparian zone has been converted from old conifers to red alder, which comprises about 95% of the riparian zone (McHenry et al. 1996), greatly reducing any near and long-term recruitment of LWD to critical levels. Red alder debris decays quickly and is not stable enough to contribute to salmon habitat functions. McHenry et al (1998) compared LWD volume and quantity from 1982 levels to 1993 levels and found that although the number of pieces did not decrease, the volume of old-growth derived LWD decreased significantly. Sampling occurred in a riparian area of Green Creek, last logged in 1930.

In another study, McHenry and Murray (1996), measured LWD in the Pysht River and its tributaries, and documented relatively low numbers of LWD, particularly in Salmonberry Creek (average 13 pieces/100m), the South Fork Pysht and Green Creek (16 pieces/100m), Middle Creek (17 pieces/100m), the North Fork Green and Pysht mainstem, and Needham Creek (23 pieces/100m). Five of the 10 tributary sampling sites had no LWD pieces with diameters greater than 35 cm (McHenry and Murray 1996). Overall, the average LWD volume in the Pysht basin is less than half the volume (McHenry and Murray 1996) found in old-growth Olympic Peninsula streams by Grette (1985), and of the total LWD sampled in the Pysht, less than half was derived from conifers and less than half contacts the ordinary low-flow channel (McHenry and Murray 1996).

The percent pool area in the Pysht River is highly variable, but pool depth is generally homogenous and shallow (<1.0 m, average 0.66m) (McHenry and Murray 1996). Pools were most numerous in the North Fork Green (86%) and Green Creek (57%), and least numerous in Middle Creek (18%) and Salmonberry Creek (25%). The South Fork Pysht and Needham Creek averaged 43% and 41% pool habitat respectively (McHenry and Murray 1996).

Clallam River

Hardwoods dominate the riparian area in the lower mainstem. McHenry et al (1998) compared LWD volume and quantity from 1982 levels to 1993 levels and found that although the number of pieces did not decrease, the volume of old-growth derived LWD decreased significantly. Sampling occurred in Charley Creek in a riparian area that was last logged in 1920.

Hoko River

The riparian zone is currently 91% red alder as compared to historic dominance of western hemlock, Sitka spruce, western red cedar, and Douglas fir with a few patches of red alder (Martin et al. 1995). This results in poor near-term and poor long-term LWD recruitment potential (Figs. G.1-G.2). McHenry et al (1998) compared LWD volume and quantity from 1982 levels to 1993 levels and found that although the number of pieces did not decrease, the volume of total and old-growth derived LWD decreased significantly. Sampling occurred in the upper mainstem Hoko (last logged in 1959), Ellis Creek (last logged in 1952), Bear Creek (last logged in 1945) and Cub Creek (last logged in 1945). Although there was an increase in second-growth derived LWD, that increase did not offset the decrease in old-growth derived LWD.

Large woody debris is low and declining, and is also the likely cause of low pool frequency (Martin et al. 1995). Pools comprised less than 37% of the measured habitat areas, compared to the target of 50% (Martin et al. 1995). The lack of pools was especially acute in the lower mainstem where two sites measured 9% and 14% pool area. Gravel aggradation has contributed to the lack of quality pools. This would impact all salmonid species (fall chinook, fall coho, chum, and winter steelhead) during adult migration. It would also decrease juvenile rearing habitat for coho salmon and winter steelhead, and to a lessor extent, fall chinook salmon.

Nearly all sampled stream segments of the Hoko Basin were below natural reference levels in quantity of LWD (Martin et al. 1995). Piece counts averaged 0.67 per channel width compared to a target of 2-4 pieces per channel width (Martin et al. 1995). This impacts adult migration, incubation stability, and juvenile rearing for all species of salmon. In the Little Hoko River, the Lower Elwha Tribe has recently restored LWD. The mainstem Hoko River below RM 15.7 had only 0.17 pieces/channel width in the sampled area (Martin et al. 1995). This is where most of the chinook and chum salmon (as well as some coho salmon and winter steelhead) spawning occurs.

In 1993, LWD was re-measured at sites previously measured in 1982 in the mainstem Hoko, Bear Creek, Ellis Creek, and Cub Creek. There was an average loss of 39% of the LWD volume in the 11year period (McHenry et al. 1998). About 46% of the old growth was lost as well. In 1983, the LWD volumes in the Hoko were only 27% of the uncut reference site volumes for the Peninsula.

The riparian area along the Hoko is also impaired due to the presence of roads (Martin et al. 1995).

Figure G.1. Near-Term LWD Recruitment in the Hoko Watershed (Martin et al. 1995).

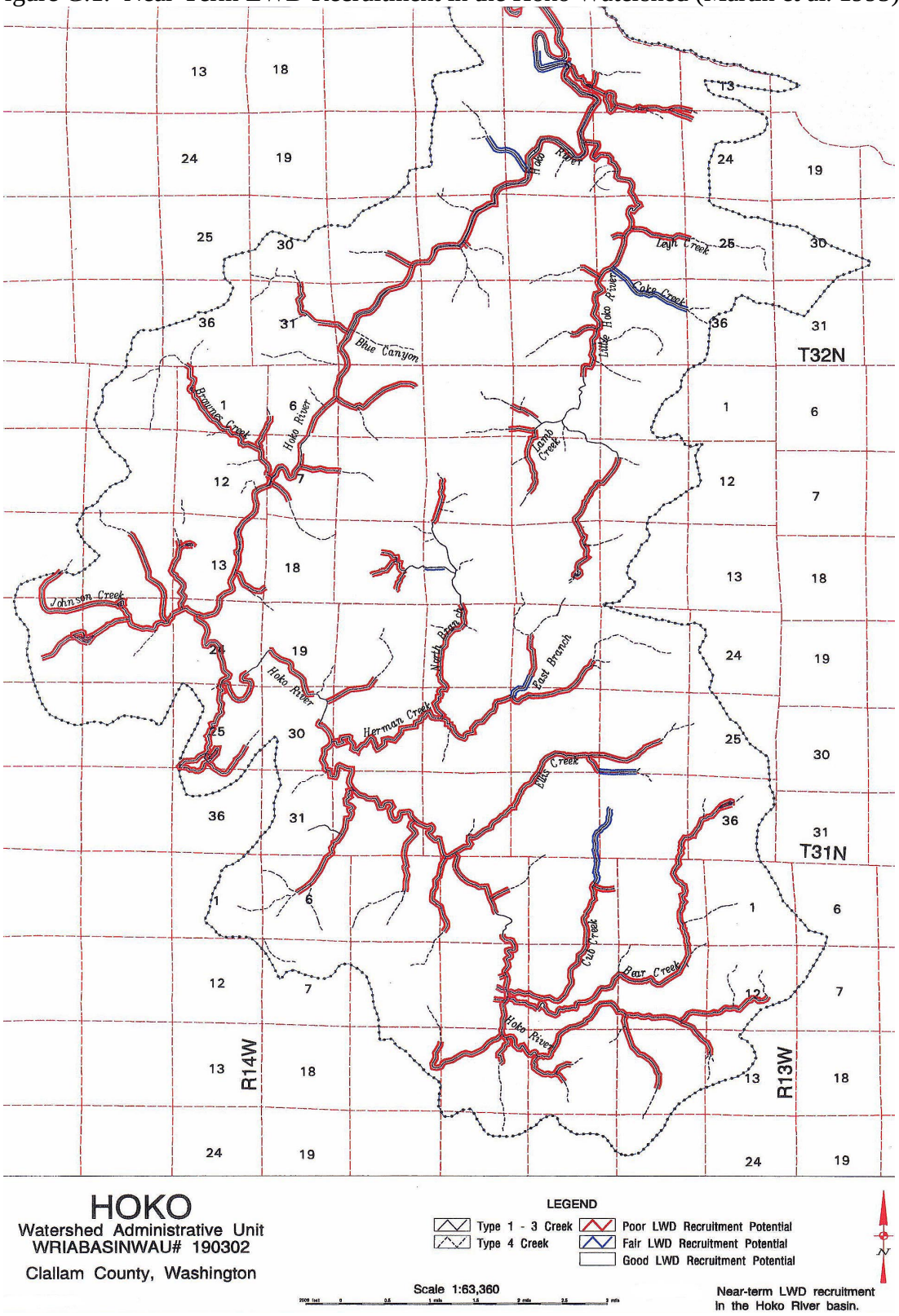
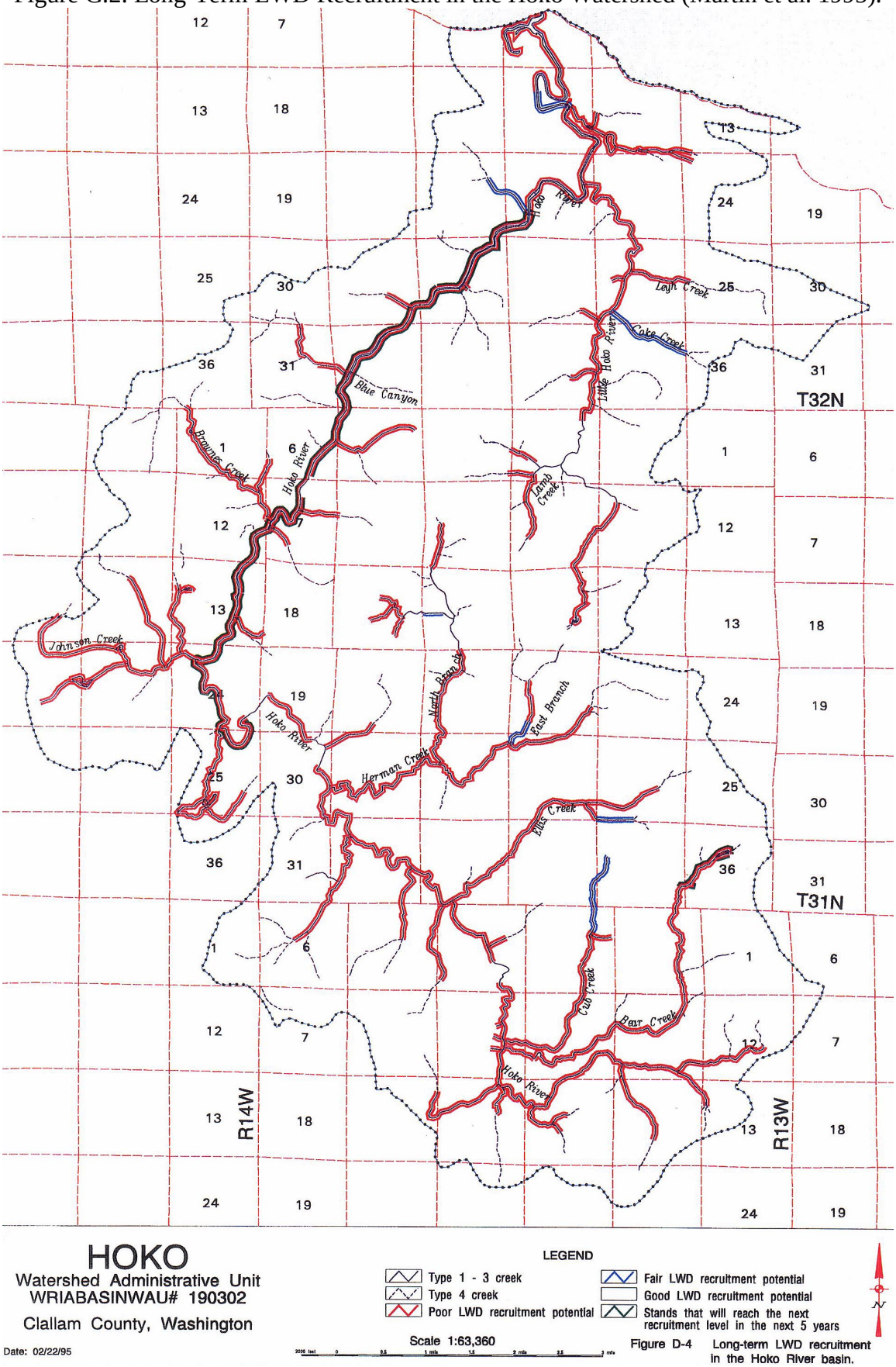


Figure G.2. Long-Term LWD Recruitment in the Hoko Watershed (Martin et al. 1995).



Sekiu River

The riparian has been altered throughout the Sekiu watershed, and after removal of conifers, streamside areas were generally not treated for hardwood or brush control (Monaghan et al. 1999). The mainstem Sekiu River and the upper South Fork Sekiu River are the two areas with the most impacted riparian. These are dominated by hardwood. The lower South Fork Sekiu has a riparian that contains the highest proportion of mature conifer in the basin (Monaghan et al. 1999).

In the mainstem, pools were numerous, but only one sampled pool was greater than 1 meter deep and few had woody cover (Currence 1999). Pool depth and woody cover was "poor" throughout the South Fork, due to a lack of LWD. Inadequate pool depth was also a problem in the North Fork Sekiu, although the percent of pool habitat was "fair" to "good" (Currence 1999). Lack of pool depth and lack of wood cover was also a severe problem for salmon in Carpenters Creek, No Name Creek, and Ice Creek.

Olsen, Jansen, Rasmussan Creeks

Jansen and Rasmussan Creeks have a riparian that consists of predominately alder (Mike Haggerty, Makah Tribe, personal communication). Jansen Creek is in-stream wood-depleted, particularly for key pieces. The riparian surrounding Olsen Creek is better than most small streams in the area. Remnant large conifers are found in this area.

Pool abundance was rated "good" for upper Jansen and Rasmussen and "fair" for lower Jansen, but none were deeper than 1 meter, and woody cover was inadequate (Currence 1999).

Bullman Creek, Snow Creek, and Sail River

The riparian surrounding Bullman Creek is alder dominated and in-stream levels of LWD are considered low to moderate (Mike Haggerty, Makah Tribe, personal communication). Snow Creek has a good riparian, but will soon be logged. The Sail River riparian consists of stretches of conifer and stretches of alder, with low levels of LWD.

Major Recommendations For Riparian Issues In WRIA 19

- Open riparian areas need to be vegetated with conifer.
- Hardwood riparian areas should be thinned to allow conifer introduction.
- Areas of mid to late-seral (and older) stage riparian should be conserved, with the higher priority given to the older stands.
- LWD should be increased to allow for pool habitat development.

Data Needs For Riparian Issues In WRIA 19

- Riparian data (vegetation type, age, size) does not exist for many of the smaller streams in WRIA 19, and should be updated in the other streams.

Comprehensive habitat surveys are needed throughout the WRIA. These should include assessment of LWD, pools, riparian, and gravels.

WATER QUALITY IN WRIA 19

The focus of this section is to highlight known water quality problems that affect salmon production in the freshwater habitats within WRIA 19. Types of salmon water quality issues include water temperature, dissolved oxygen, and toxins. Turbidity problems are discussed in this chapter, but the sources of sediment problems are discussed in the Streambed/Sediment section. Water quality problems in estuaries are discussed in the Estuary/Nearshore section.

Many of the streams in WRIA 19 are small independent streams that have little or no water quality data. This chapter discusses known water quality problems for streams that have data. Salmon-producing streams lacking data are not included in this discussion, and those are a research need for the future.

Lyre River

It is noteworthy that water turbidity is a current problem in the Lyre River. Local residents have stated that prior to the 1950s (prior to the loss of surrounding forest); the stream never had a turbidity problem (Dick Goin, personal communication). Turbidity decreases the feeding ability and growth rate of juvenile salmon (Everest et al. 1985). Turbidity also decreases primary productivity (Lloyd et al. 1987).

The Washington State Department of Ecology has conducted a stream bioassessment for the Lyre River near the DNR campground and rated it as “fair, slight impairment of biological condition” (DOE 1999a). Water temperature reached as high as 16.3^{o}C, above the State standard of 16° C. Related to the high water temperatures is a canopy cover of only 40% (DOE 1999b). Also, about ½ mile downstream of the lake outlet, water temperature reached 21 ^{o}C in 1998, likely a lake effect potentially contributing to impacts downstream (Mike McHenry, Lower Elwha Tribe, personal communication).

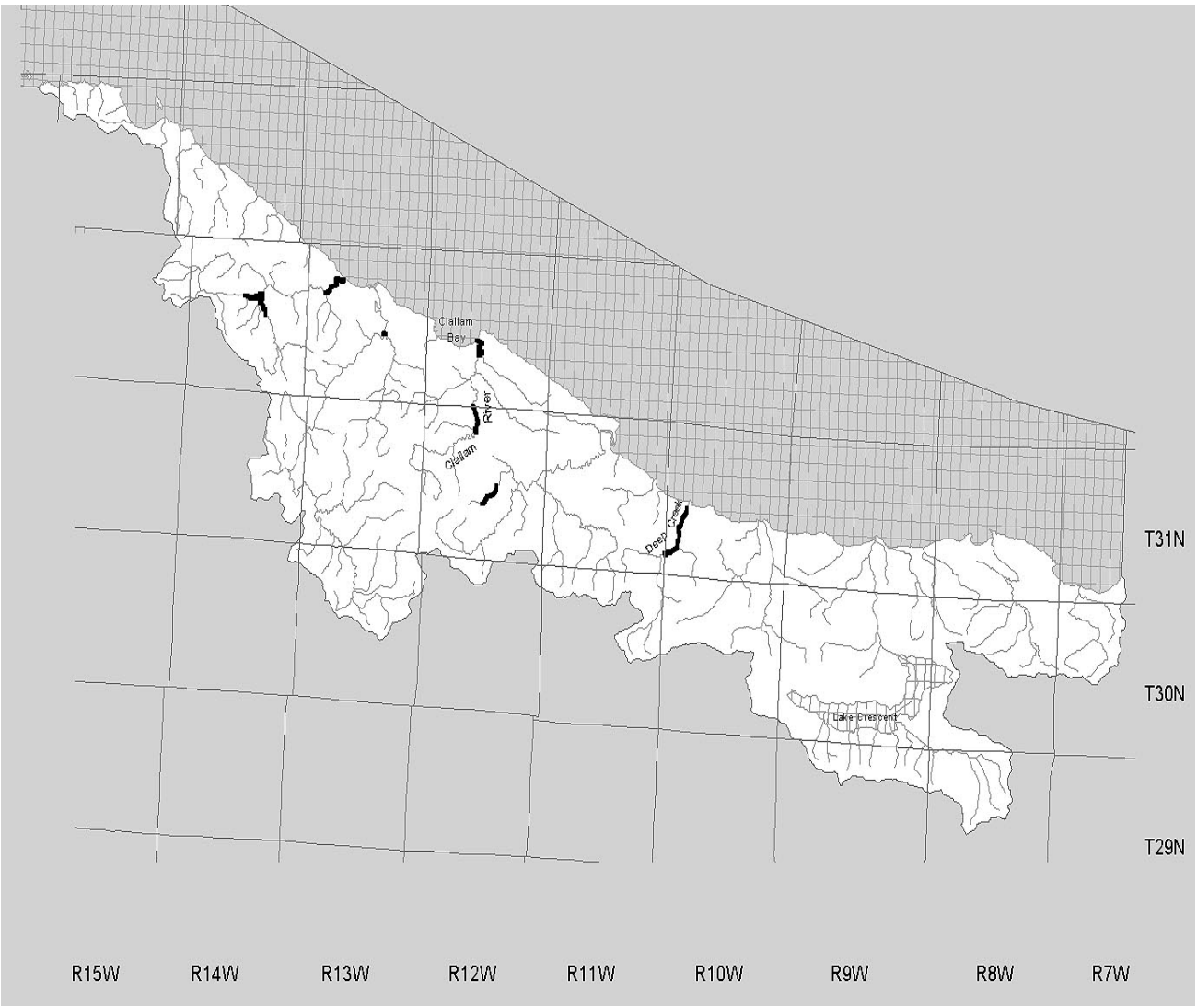
Deep Creek

Water temperature exceedances have been noted in the East Fork and mainstem Deep Creek; the West Fork was within the state water quality standards (McHenry et al. 1995). Deep Creek RM 0.25 exceeded that standard 77% of days measured, while Deep Creek RM 2.5 had 46% exceedances, and the East Fork Deep Creek was out of compliance with standards 54% of the time (Schuett-Hames and Malkin 1993). The high water temperatures have resulted the placement of Deep Creek on the 303(d) list. In 1996, two segments of the mainstem Deep Creek were listed on the 303(d) list for temperature, and an additional segment is on the 1998 Candidate 303(d) list (Fig. H.1) (DOE 1999b). Combined, these segments account for most of the mainstem downstream of the West Fork confluence (Fig. H.1).

The temperature problems are primarily related to stream channel widening/aggradation and secondarily to loss of shade (McHenry et al. 1996). Shade averaged 42% at Deep Creek RM 0.25, 59% at Deep Creek RM 2.5, and 58% on the East Fork (Schuette-Hames and Malkin 1993). For low elevation Class AA streams such as Deep Creek, the forest practices board manual (1992) specifies greater than 95% shade is needed for temperature protection.

The stream channel widening is mostly due to high sediment inputs from numerous mass wasting sites. The width to depth ratios were 37.5 for Deep Creek RM 0.25, 39 for Deep Creek RM 2.5, and 37.3 for the East Fork Deep Creek (Schuette-Hames and Malkin 1993).

Figure H.1. WRIA 19 river segments on the 303(d) list for high water temperatures and fine sediment (from DOE).



Pysht and Clallam Rivers

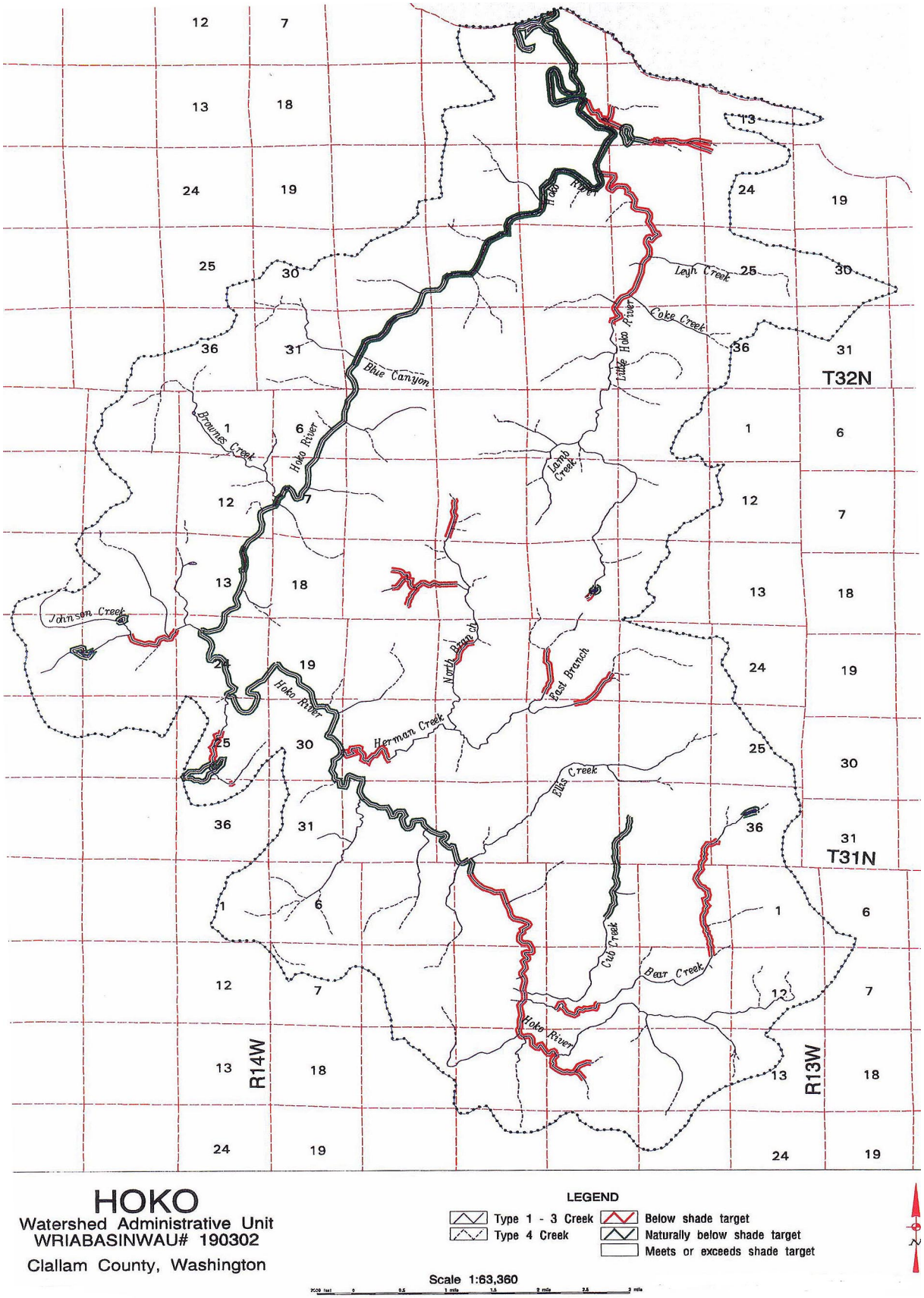
Maximum water temperatures were greater than the State water quality standard of 18°C (Class A streams) in the Pysht River and Green Creek, a major tributary to the Pysht River (McHenry et al. 1996), and Green Creek is on the 1998 Candidate 303(d) list for water temperature (DOE 1999b). The Clallam River also exceeded State water temperature standards, and two separate reaches are on the 1998 Candidate 303(d) list for temperature (Fig. H.1) (DOE 1999b). In 1992, there were 15 temperature exceedances between RM 3-4 (DOE 1999b).

Hoko River

The summer water temperatures at all monitoring stations in the mainstem and Little Hoko River exceeded the state standard of 16°C. At some stations, water temperatures reached 20-21°C (Martin et al. 1995), and the lower reach of the Little Hoko River is on the 1996 303(d) list because of high water temperatures (Fig. H.1) (DOE 1999). The temperature problems are at least partially related to

the below target shade levels in these same areas. The high temperatures reduce available rearing habitat for coho salmon and steelhead, and possibly chinook salmon (Fig. H.2). Elevated late winter and spring temperatures may increase juvenile development and subsequent mortality due to the a smaller juvenile size at smoltification, and a shifted out-migration timing that is out of phase with estuarine food supplies (Bishop et al. 1996).

Figure H.2. Shade Levels in the Hoko Watershed (Martin et al. 1995).



Sekiu River

The Sekiu River is a Class AA stream, and water quality standards for this type require maximum temperatures not to exceed 16°C. However, high summer water temperatures are a serious problem throughout most of the basin, with very few temperature refuges available to salmon. Segments of the mainstem, South Fork, and North Fork Sekiu are all on the 1996 303(d) list (Fig. H.1) (DOE 1999b). Summer water temperatures were especially poor for salmon in the mainstem and North Fork Sekiu, and the problem seems to originate upstream above the North Fork falls (RM 9.0) (Currence 1999). In 1985, the mainstem water temperatures were greater than 21°C for 16 consecutive days, which is high enough to cause direct mortality to salmon. In 1994 and 1996, the mainstem daily maximum temperatures exceeded 20° C on 5 and 4 days respectively, exceeded 18°C on 29 and 22 days, and exceeded 16°C on all but one of 44 and 45 consecutive days (Currence 1999). The South Fork was rated as "fair" with water temperatures between 16-18°C.

Sonnybrook Creek had excellent temperatures (<14° C) and may provide important thermal refuge habitat for coho salmon and steelhead juveniles (Currence 1999). No Name and Ice Creek are assumed to have cool temperatures for refuge as well.

Turbidity is another water quality problem in the Sekiu. Turbidity can decrease the ability of salmon juveniles to feed, therefore impairing growth. Turbidity can also decrease primary productivity too. Ice Creek is the greatest source of turbidity in the system. After timber harvest activity, Ice Creek discolored the South Fork and mainstem to the Strait of Juan de Fuca (Currence 1999).

Jansen, Rasmussen, Olsen, Snow, Agency, and Bullman Creeks

Turbidity has been a water quality problem in Jansen Creek. The turbidity is long-lasting, and occurs even in the absence of major storms (Currence 1999). Log transportation on poorly surfaced roads is believed to be the major cause.

High water temperatures are not a problem in Jansen, Bullman, Olsen, and Snow Creeks, but some samples exceeded 16°C in Rasmussen (Currence 1999).

Agency Creek has had at least 2 excursions where dissolved oxygen levels fell below the State standard in 1991. The data were submitted to DOE for inclusion on the Candidate 303(d) list, but it wasn't accepted for the list because the waterbody is on the tribal reservation and not under State jurisdiction. The low dissolved oxygen levels were found in 33N, 15W, 12 (DOE 1999).

Major Recommendations For Water Quality Issues In WRIA 19

- Reduce sediment inputs into Deep Creek, Pysht River, Clallam River, Hoko River, Little Hoko River, and Sekiu River to lessen channel widening and pool filling.
- Vegetate open riparian areas of all streams in WRIA 19 with conifer, and fund maintenance to promote healthy conifer stands (brush control etc). These actions will not supply shade for the short-term, but will contribute to both shade and the LWD needs in the long-term.
- Reduce sources of turbidity, such as the poorly surfaced roads.
- Increase LWD where needed (see Streambed/Sediment chapter). Large woody debris will help form pools that provide important thermal refuge for salmon.
- Sonnybrook Creek is an important thermal refuge in the Sekiu Basin, and this function should be maintained.

Data Needs For Water Quality Issues In WRIA 19

- Increase water quality monitoring to include all salmon-producing streams in WRIA 19.

I) WATER QUANTITY PROBLEMS IN WRIA 19

Introduction

The hydrologic regime of a drainage basin refers to how water is collected, moved and stored. The frequency and magnitude of floods in streams are especially important since floods are the primary source of disturbance in streams, and thus play a key role in how streams are structured and function. In ecologically healthy systems, the physical and biotic changes caused by natural disturbances are not usually sustained, and recovery is rapid to predisturbance levels. If the magnitude of change is sufficiently large, however, permanent impacts can occur.

Alterations in basin hydrology are caused by changes in soils, decreases in the amount of forest cover, increases in impervious surfaces, elimination of riparian and headwater wetlands, and changes in landscape context. Hydrologic impacts occur even at low levels of development (<2% impervious surfaces) and generally increase in severity as more of the landscape is converted to urban uses.

Water Quantity Problems In WRIA 19

The streams in WRIA 19 are low elevation watersheds, with flows dependent upon precipitation. They are naturally susceptible to low summer flows, as well as high peak flows in heavy storm events. Direct assessment of water quantity is hampered in this WRIA because of a lack of consistent water flow information. The most active gauging station is located on the Hoko River, but data from the late 1970s through the early 1990s was not collected. This assessment relied upon conclusions in watershed analysis and from the hydrologic maturity information when available.

Deep Creek

When comparing current to historic vegetative conditions, the average 2-10 year peak water discharge increased by about 10% in the watershed, and for unusual storm events, the peak water discharge increased by 15-20% (Young 1994). Immature (<20 years) and intermediate (20-100 years) cover classes account for 75-100% of the sub-basins within the Deep Creek Basin. The upper reaches are an exception with the largest proportion of mature cover (Young 1994). Further conversion to younger age classes will result in an increase of 1.5 times the current runoff (Young 1994). The Deep Creek sub-basins consist of about 65-100% lowland and rain dominated zones.

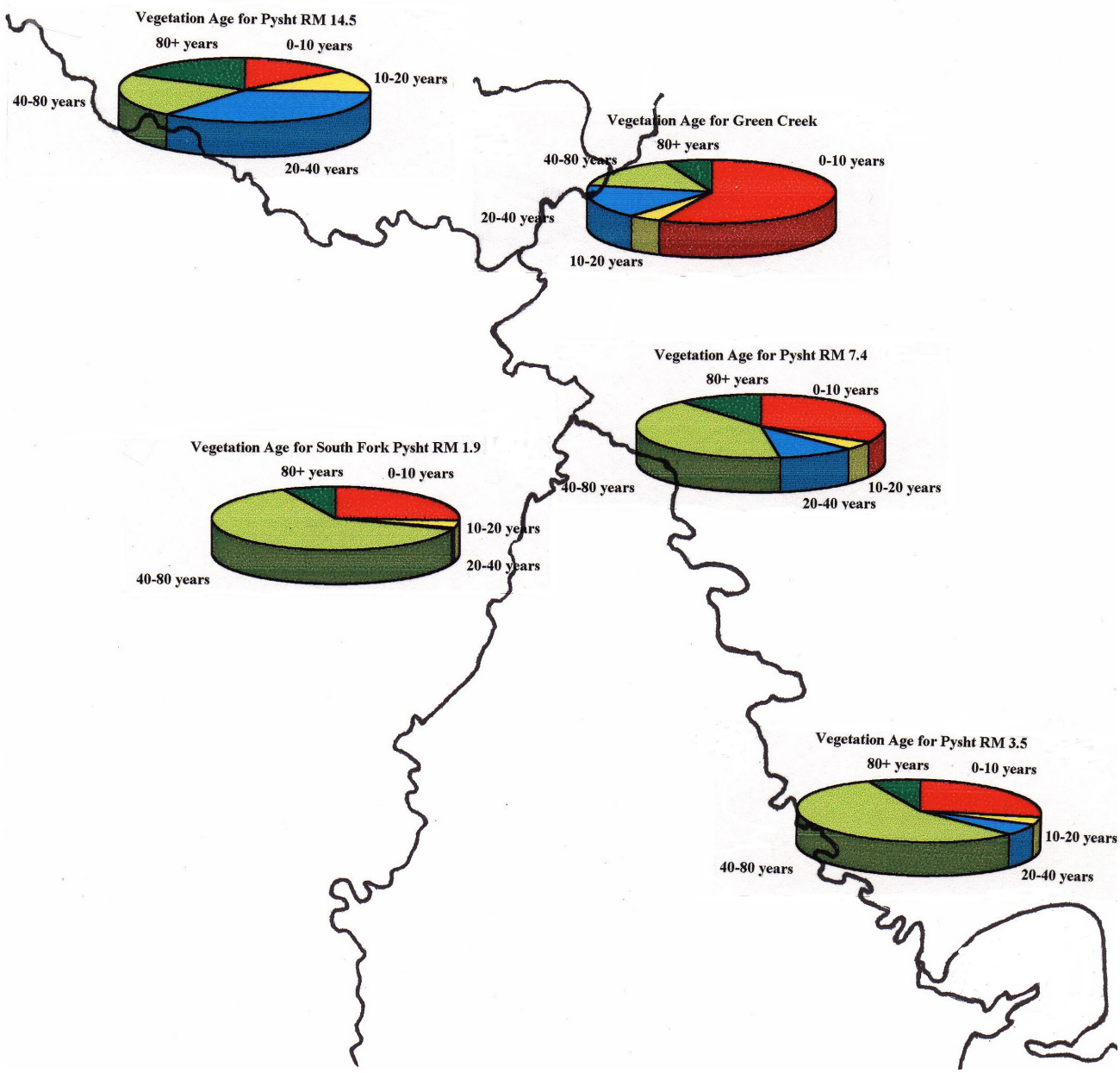
Pysht River

The latest data regarding the age of the surrounding forest is from the early 1990s. Since then, conditions are believed to have worsened. However based upon those data, most of the Pysht watershed consists primarily as intermediate cover and secondarily as immature cover. The dominant vegetation class in the lower mainstem Pysht River (to just upstream of the confluence with the South Fork) is 40-80 year old conifers, which averaged about 52% (Fig. I.1) (DOE 1993). However, the second greatest vegetation class is the 0-10 year old class (averaged about 29%). Further upstream, the dominant vegetation class changes to 0-10 year (34%) old in the region near the gravel pit at RM 9.7, with 40-80 year old cover accounting for about 31% of the land. Near the U.S. Forest Service 400 Road crossing (near RM 14.5), the dominant vegetation cover is 20-40 year old cover, which accounts for 35% of the region (Fig. I.1). This area also has 21% 40-80 year old cover and nearly 18% of over-80 year old cover (DOE 1993).

The South Fork Pysht is dominated by 40-80 year old vegetation (averaged 51%), with the 0-10 year cover the second largest class, averaging 23% (Fig. I.1) (DOE 1993). Green Creek has had the greatest conversion with 57% of its cover 0-10 years old (Fig. I.1). Needham, the North Fork Green, Reed, Salmonberry, and Middle Creeks are all dominated by 40-80 year old vegetation.

The direct impact of alterations in hydrological maturity on flows has not been linked in the Pysht River, but indirectly, there are several indicators that peak flows have impacted salmon production. Scour has been noted as a likely occurrence during peak flows (Rawson et al. 1997). The principal causes of instability are high sediment loads coupled with low levels of LWD. This is discussed in the Streambed section.

Figure I.1. Percent vegetative cover type in the Pysht Watershed (data from DOE 1993).



Clallam River

The mainstem Clallam River is mostly surrounded by an intermediate aged vegetation age. Trees that are 40-80 years old account for about 60% of the vegetation followed by 25% 20-40 year old trees (DOE 1993). All of the assessed tributaries (Charlie, Pearson, Last, and stream 19.0140) were dominated by 40-80 year old trees.

Hoko River

Low summer water flows are often a problem particularly for fall chinook salmon and sometimes for coho salmon (Currence 1999). When flows are very low, upstream adult migration is delayed and/or spawning is not as broadly distributed. This especially impacts the earlier spawning species such as chinook salmon. In low flow years, their spawning distribution is confined to the middle to lower mainstem, areas that are at high risk of scour during the peak flows in winter.

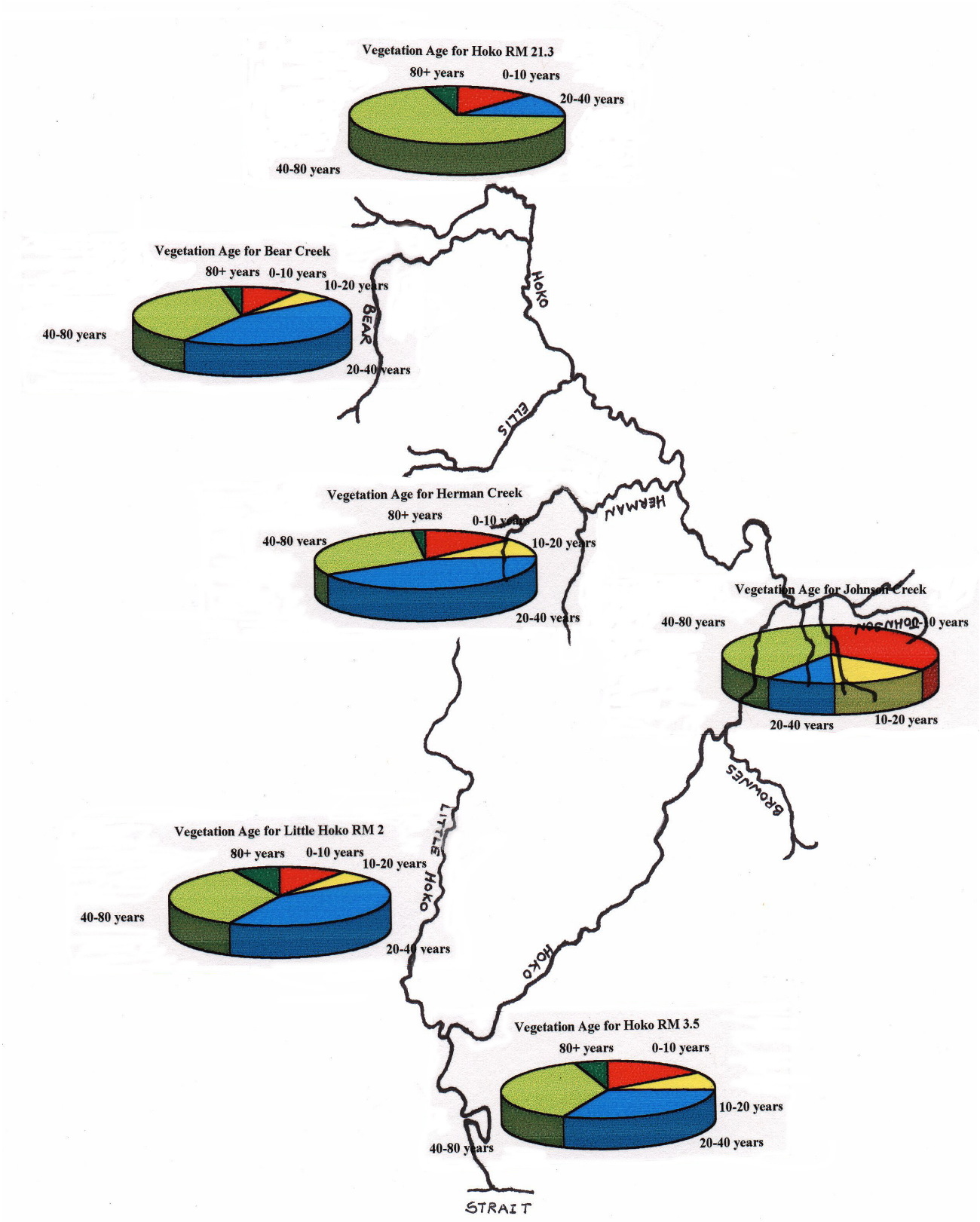
Although the basin is naturally susceptible to low water flows because of its low elevation and dependence on precipitation, human factors contribute to the problem. The infiltration gallery at RM 4 serves as the water supply for the towns of Clallam Bay, Sekiu, as well as the Clallam Bay Correction Center. The current pumping rate is 200-400 gallons per minute (4-8% of the lowest recorded flow) and this level is only 50% of the amount that has been approved for withdrawal (Bishop et al. 1996).

One flow problem occurs in the upper mainstem, near the Bear and Cub Creek confluences. In this area, summer rearing habitat becomes dewatered, but this is believed to be a natural condition (Martin et al. 1995).

The latest data regarding the age of the surrounding forest is from the early 1990s. Since then, conditions are believed to have worsened. However based upon those data, the Hoko watershed was covered with about 37% mature second growth, 3% intermediate maturity, and 40% immature vegetation (Pentec 1995). Within sub-areas, the dominant vegetation class along the mainstem Hoko is intermediate aged 40-80 year old, averaging 46% with lower percentages in the lower reaches (Fig. I.2) (DOE 1993). The second largest class was 20-40 year old trees, which averaged 26% of the land cover. The Little Hoko and Leyh Creek were surrounded primarily by 20-40 year old vegetation with the 40-80 year old class accounting for about 30% of the region (Fig. I.2). Most of the other tributaries to the Hoko were dominated by fairly young stands (20-40 year old). These tributaries include: Bear, Herman, Ellis, and Brownes Creeks. Rights, Johnson, and Cub Creeks were dominated by 40-80 year old vegetation classes (Fig. I.2) (DOE 1993).

The impact of the vegetation change influences peak flows. When peak flows are estimated and current conditions are compared to predicted undisturbed conditions, there have been increases in storm recurrence intervals (Pentec 1995). For a 2 year storm recurrence interval, the percent increase based upon current conditions are: 14% in the Johnson Creek sub-basin, 11% in the Ellis Creek sub-basin, 10% in the mainstem, 9% in the Herman Creek sub-basin, 8% in the Bear Creek sub-basin, 7% in the Brownes and Cub Creeks sub-basins as well as in the upper mainstem. The Little Hoko River 2 year storm recurrence interval has increased about 6%.

Figure I.2. Percent vegetative cover type in the Hoko Watershed (data from DOE 1993).



Sekiu River

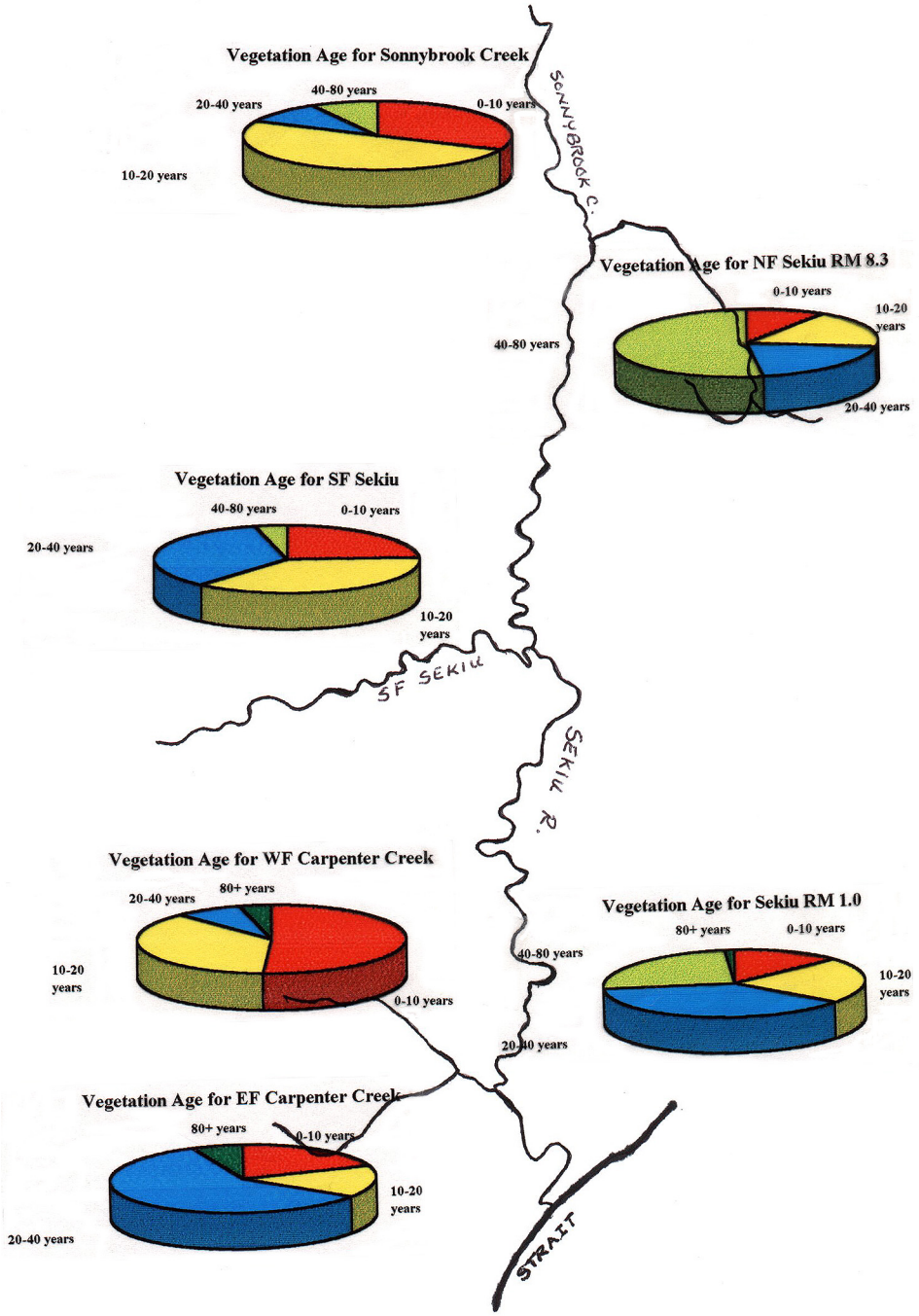
The greatest low flow problem in the basin occurs in the mainstem during the summer (Currence 1999). Shallow transverse bars can prevent adult chinook and even coho from migrating upstream. Because of this, the intertidal reaches are important thermal and flow refuges until freshets occur. However, the lack of deep pools and woody cover in the lower reaches degrade this refuge (Currence 1999).

Carpenters Creek goes subsurface in the summer, and sometimes strands juveniles due to a passage problem at a culvert (Currence 1999). Work has occurred on this culvert and further monitoring will be necessary to assure that the problem has improved.

Scour is a probable event in the mainstem and South Fork Sekiu due to the lack of LWD to slow water velocities and gravel transport (Currence 1999). The North Fork had better levels of functional LWD, but still poor levels of the larger key pieces. Because of this, scour is still a risk in the North Fork, although not as high as a risk as the mainstem and South Fork. Carpenters and No Name Creeks were considered to have a fairly high risk of scour (Currence 1999).

The latest data regarding the age of the surrounding forest is from the early 1990s. Since then, conditions are believed to have worsened. However based upon those data, most of the watershed has been converted to stands that are now in the intermediate age stage. The vegetation class surrounding the mainstem is dominated by 20-40 year old (averaged 33%, with the second largest class consisting of 40-80 year old trees (averaged 29%) (DOE 1993). The South Fork Sekiu is dominated by 10-20 year old vegetation (38%), followed by 20-40 year old trees (35%). The North Fork is in better condition with about 60% 40-80 year old trees. West Fork Carpenter Creek is dominated by 0-10 year class (51%), East Fork Carpenter by 20-40 year old class (59%), and Sonnybrook by 10-20 year old trees (50%).

Figure I.3. Percent vegetative cover type in the Sekiu Watershed (data from DOE 1993).



Olsen, Jansen, and Rasmussen Creeks

While there are no direct data available, the lack of gravels and LWD suggest that scour is a concern in Jansen and possibly even Rasmussen Creek (Currence 1999). Rasmussen rated better for LWD, but its channel is moderately confined which could increase scour risk.

Major Recommendations For Water Quantity Issues In WRIA 19

- Increase LWD where needed (see Streambed/Sediment chapter). Large woody debris slows water velocity and creates pools for thermal refuges important in low flow reaches.
- Reduce summer water withdrawals from the Hoko River, especially in years of anticipated low flows, and maintain current summer flows in other WRIA 19 streams.

Data Needs For Water Quantity Issues In WRIA 19

- Consistently fund flow-monitoring stations throughout WRIA 19.
- Study the location, cause, and extent of scour.
- Update the hydrological maturity data and create GIS layers.

Conduct studies on how changes in hydrological maturity alter in-stream flows (both peak and low flows) throughout WRIA 19 (high priority data need).

J) ESTUARINE AND NEAR SHORE HABITAT CONDITIONS IN WRIA 19

Types Of Habitat

Compared to Puget Sound, Grays Harbor and Willapa Bay, estuary habitat is naturally limiting in WRIA 19 (Dethier 1990). Saltmarsh habitat is located around the stream mouths and throughout the area of tidal influence in the lower stream reaches, serving as important salmon rearing habitat. The near shore environment of this WRIA is essential for rearing juvenile salmonids, offering a transportation corridor for both juvenile and adult salmonids as well as resting habitat for adult salmon transitioning to spawning streams (Anne Shaffer, personal communication). Areas of known use will be included in this discussion. Within the near shore environments, certain types of habitat are especially important for salmonid production. These include eelgrass and overstory and understory kelp beds. Nearshore kelp and eelgrass habitats, as well as sandy beaches are also critical for baitfish, which include herring, surf smelt, and sand lance, which are critical food fish for juvenile and adult salmon (Lemberg et al. 1997).

Eelgrass is found in sandy, protected areas (Phillips 1984) and provides important nursery habitat for juvenile salmonids. Juveniles use the eelgrass to hide from predators as well as feed on epibenthic and epiphytic zooplankton, including copepods and amphipods, that in turn feed on the bacteria from decaying eelgrass (Levings 1985; Webb 1991). Eelgrass also supports sand lance, surf smelt, and herring, all of which are important food items for salmon. Roughly 20% of the Straits coastline consists of eelgrass habitat (the Washington Department of Fisheries estimated 19.8% from studies conducted from 1975-1989, while the Washington Department of Wildlife estimated 23.3% in 1977) (Thom and Hallum 1990).

Kelp is preferred by adult salmon (Levings 1985; Webb 1991), particularly chinook and coho, and juvenile coho have also been observed in kelp beds (Dick Goin, personal communication). Kelp requires a rocky substrate (Phillips 1984). The Strait of Juan de Fuca consists of 16% of the Washington shoreline and 50% of the Washington kelp habitat (Shaffer 1998). Two dominant species of kelp comprise this habitat: bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis integrifolia*). While bull kelp is found throughout Puget Sound, giant kelp is confined from Freshwater Bay to the outer coast (Shaffer 1998). Lengths of Strait coastline occupied by kelp have been stable and perhaps have increased (Table J.1) (Thom and Hallum 1990). Understory kelp, made up of *Pterygophora californica*, is likely the dominant vegetated habitat of the Strait of Juan de Fuca. Unfortunately little information exists on understory kelp habitat use by salmonids (Anne Shaffer, personal communication). In addition to stable kelp, drift vegetation also provides food, refuge, and possibly transport from near shore to offshore. Juvenile chum, pink, and coho salmon have been observed in this drifting habitat (Shaffer et al. 1995).

Table J.1. Coastal lengths with kelp (meters) (Thom and Hallum 1990).

Original data sources	Rigg (1911-1912)	WDW (1978)	WA Coastal Kelp Resources maps (1989)
Cape Flattery to Port Angeles	69,600	84,000	76,750

Habitat Concerns

All along the WRIA 19 shoreline, landslides contribute sediment to the near shore environment. Of particular concern is Highway 112. Landslides have been shown to have short-term impacts on the species composition of kelp beds (Shaffer and Parks 1994). Given the importance of kelp habitat for salmon rearing in this area, near shore sediment problems should be recognized as a potential significant habitat problem.

Water quality issues are not thought to be a significant problem in the main basin Strait near shore environment. Contaminates carried to the Strait have a short residence time and are quickly transported to the ocean (Macdonald and Crecelius 1994). Water quality, including non-point pollution from residential and agricultural use, and sedimentation from upland and freshwater activities, is a concern for embayments along the Strait. Issues for specific embayments are listed below. The Department of Ecology monitors water quality throughout the State, but no water quality stations exist for the marine waters of the western Strait.

In general, shoreline armoring and dock construction is minimal within this WRIA (Broadhurst 1998). However, site-specific problems exist, and are documented below. Figure E.1 in the Floodplain chapter shows the location of estuarine problem areas, as well as known critical estuarine and near shore habitat for salmonids.

Colville Creek

Freshwater Bay is the site of a large kelp bed with considerable over- and understory structure. This is the most eastward extent of giant kelp, a perennial with diverse structure. Freshwater Bay also has eelgrass (Anne Shaffer, WDFW, personal communication). Together, the eelgrass and kelp resources are important for both juvenile and adult salmon. Adult chinook and coho, as well as juvenile coho, are attracted to the baitfish that habituate the kelp. Occasionally, blackmouth (juvenile) chinook salmon are found in the kelp (Dick Goin, personal communication).

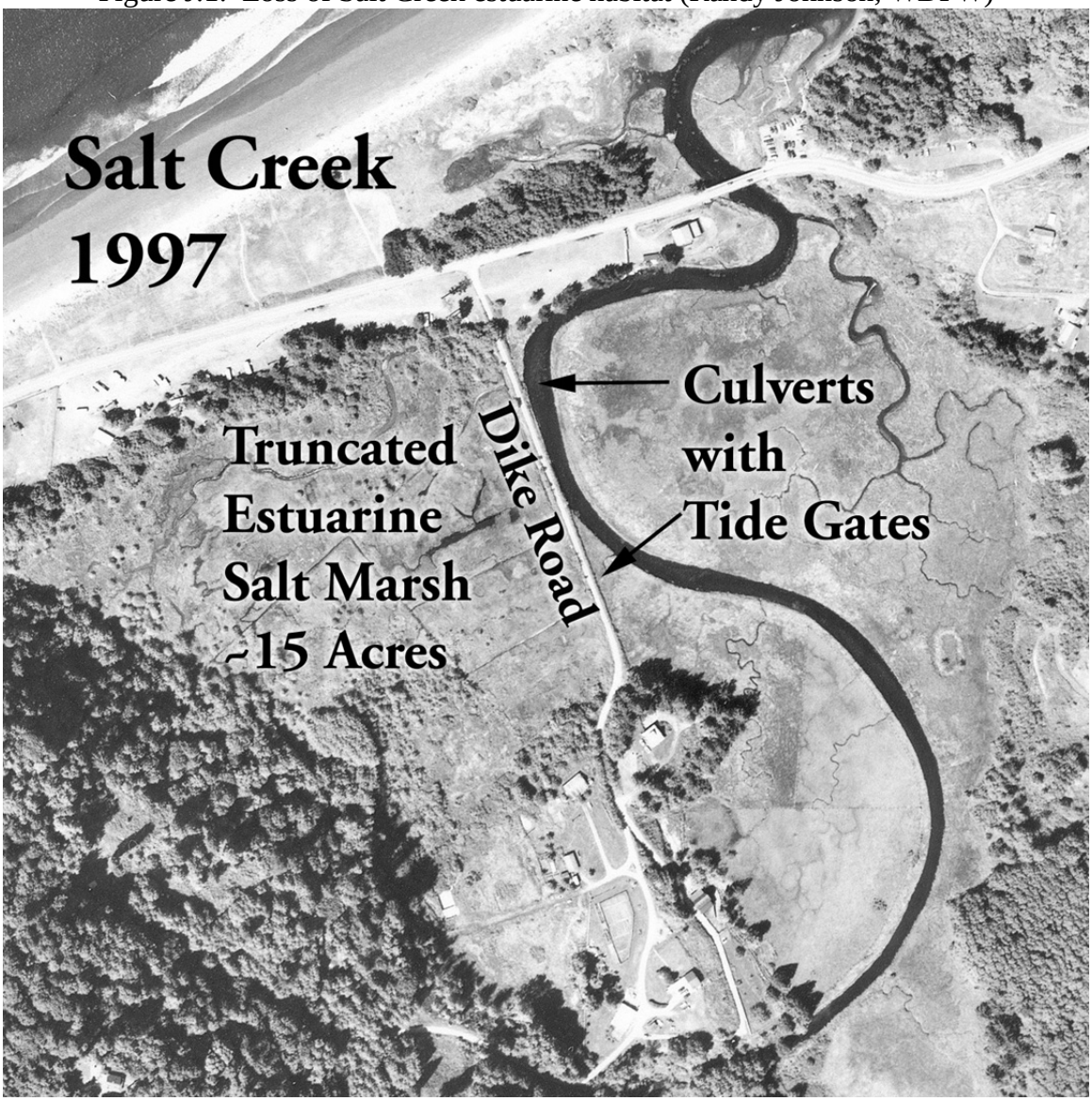
The shoreline between Freshwater and Crescent Bays contains kelp that is heavily used by salmon and is recommended for conservation. From 1995-1996, there has been a slight decrease (11%) in kelp canopy area, and this decrease is predominantly due to a decline in bull kelp (Van Wagenen 1996).

Salt Creek

In the Salt Creek estuary, about 15 acres of tidal marsh has been lost to a road that cuts across the estuary and disconnects the salt marsh from the tidal-influenced reaches of Salt Creek (Fig. J.1) (Randy Johnson and Tim Rymer, WDFW, personal communication). This impacts juvenile rearing of all salmonids produced from Salt Creek. Water quality issues for the Salt Creek/Crescent Bay area include residential run-off.

Crescent Bay is comprised of an extensive eelgrass bed within the main bay, and lush diverse overstory and understory kelp beds fringing Tongue Point and extending west to Agate Point. The shallow eelgrass area is important for sand lance and juvenile salmon. The kelp is also important salmon habitat, and two important sites are located off the tip of Agate Point and Tongue Point. All of these sites are recommended for conservation.

Figure J.1. Loss of Salt Creek estuarine habitat (Randy Johnson, WDFW)



Whiskey Creek

There have been bulkheads constructed near Whiskey Creek, as well as sedimentation from forestry-related activities. The sedimentation has likely affected the eelgrass quantities. East of the mouth of Whiskey Creek is a documented surf smelt spawning area (Dan Pentilla, WDFW, personal communication).

From Agate Point to Whiskey Creek, a run of blackmouth chinook salmon used to provide a significant fishery. These chinook were long and thin and fed on some especially large sand lance in the area (Dick Goin, personal communication). The blackmouth disappeared shortly after the sand lance disappeared. The cause of the sand lance loss is unknown.

Lyre River

The lower Lyre has been channelized and bulkheaded. At least in recent history, it never had much of an estuary, yet supports numerous chum salmon (which usually depend upon estuary rearing habitat). These chum have been noted as having a later return timing and a larger size (Dick Goin, personal communication). West of the mouth of the Lyre River is a documented surf smelt spawning area (Dan Pentilla, WDFW, personal communication).

Twin Rivers

Several impacts to the estuarine habitat occur near the East and West Twin Rivers. Increased sedimentation has occurred from both Twin Rivers, and gravel removal has removed beach between the two rivers. These activities have resulted in a loss of eelgrass habitat (Anne Shaffer, WDFW, and Dick Goin, personal communication), which is important for juvenile salmon. This section of beach is also a documented surf smelt spawning area (Dan Pentilla, WDFW, personal communication).

A mining operation located west of the West Twin River contributes fine sediments directly into the Strait. Nearby, dredging has occurred on a regular basis to allow for boat traffic. The dredging has removed kelp theorized important for adult and juvenile salmon (Anne Shaffer, WDFW, personal communication). A major landslide exists between the Twin Rivers and Deep Creek, and originates from Highway 112. This is located close to a smelt spawning area, and smelt are an important prey item for young salmon.

Deep Creek

Deep Creek has experienced major sedimentation problems, including debris flows. Lower Deep Creek has channelized itself, and the delta has changed in the last couple of decades. Figure J.2 shows two aerial photographs to compare the 1957 delta to the 1997 delta. Currently, the east side of the delta has elongated due to increased deposition (Fig. J.3). The sediment load is expected to remain high for many more years, and corresponding estuary changes will likely continue because of the sediment (see Streambed Chapter). Concern exists that the increased sedimentation will impact the smelt beds. Surf smelt spawning has been documented east of Deep Creek (Dan Pentilla, WDFW, personal communication).

Figure J.2. Aerial photographs (from DNR) comparing the Deep Creek delta from 1957 to 1997.

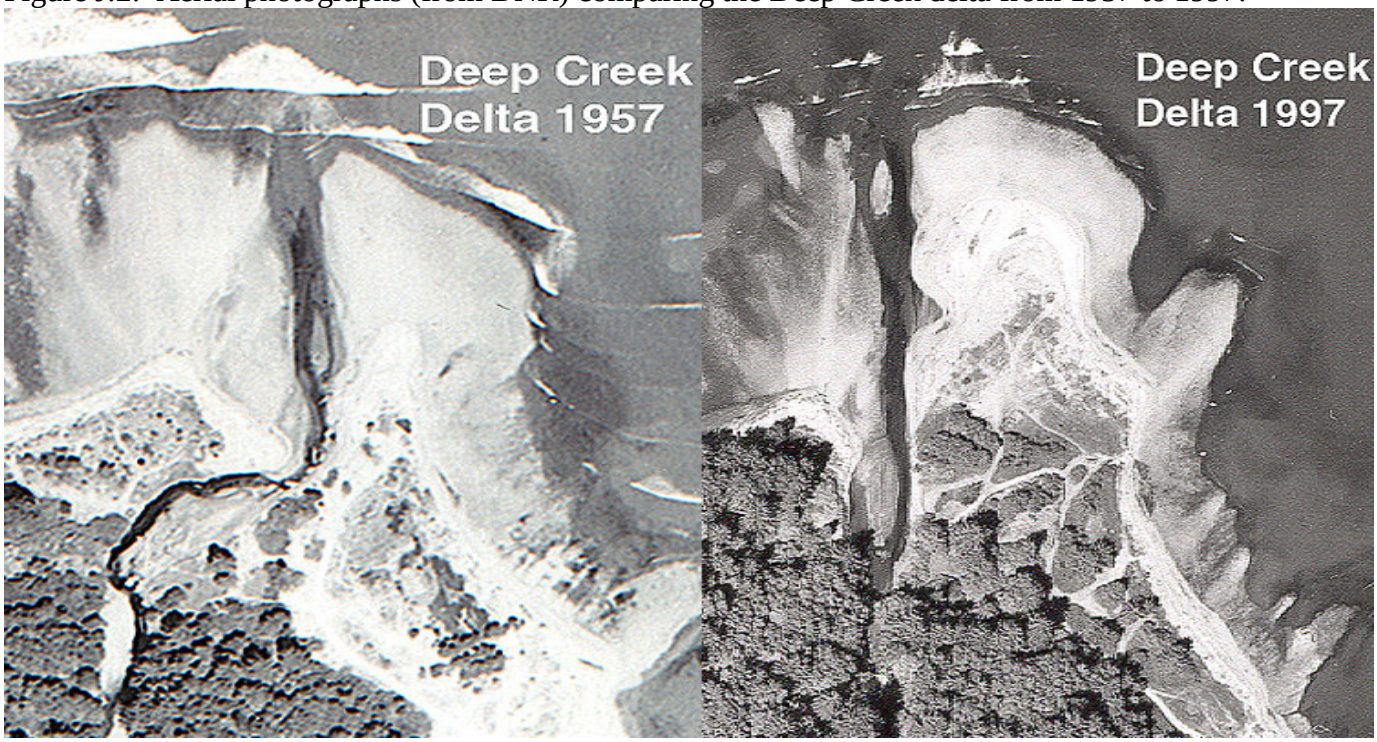
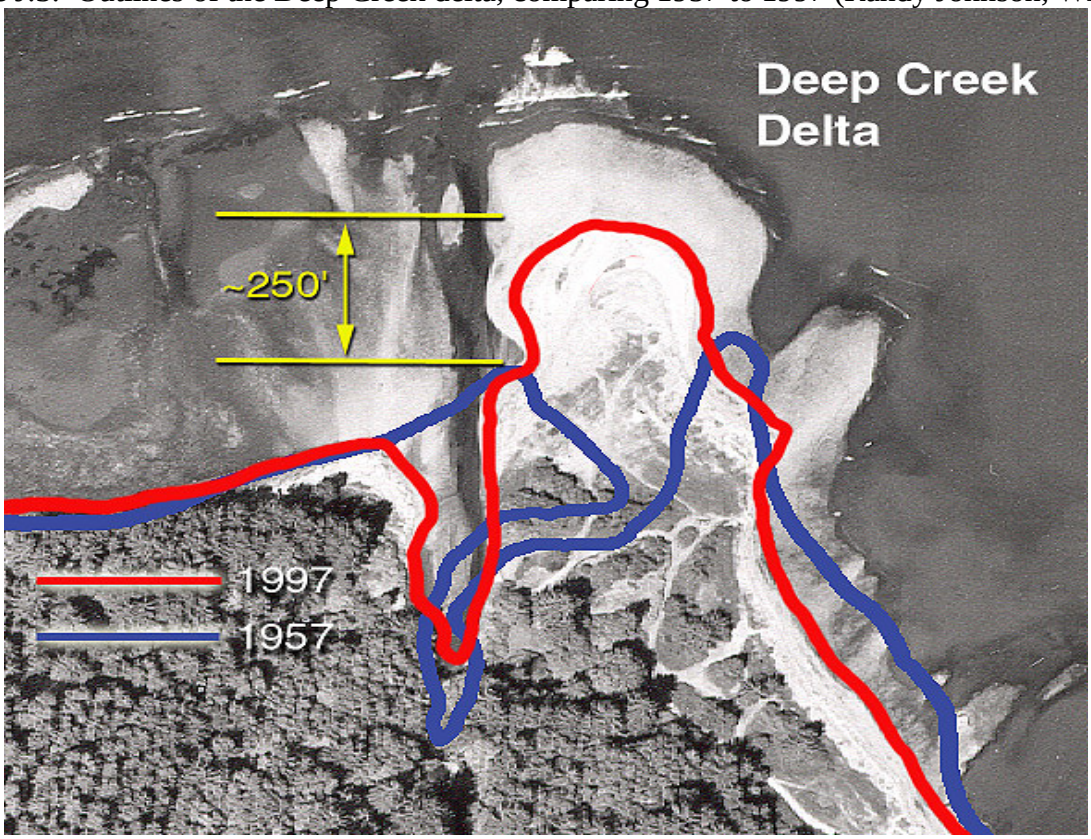


Figure J.3. Outlines of the Deep Creek delta, comparing 1957 to 1997 (Randy Johnson, WDFW)



Jim and Joe Creeks

A shale cliff near Joe Creek contributes sediment into the Strait. In addition, both watersheds have been extensively logged, which likely increased sediment transport to the estuary. A loss of estuary habitat has occurred due to the construction of two breakwaters coupled with dredging near the mouth of Jim Creek (Dick Goin, personal communication). The breakwaters will probably increase gravel deposition near the mouth of Jim Creek on the west beach.

Pysht River

The Pysht estuary is one of the largest in the WRIA, and is important salmon rearing habitat. In the past, the Pysht River estuary has been channelized and dredged to facilitate the transport of logs (Tim Rymer, WDFW, personal communication). Around the 1920s, pictures of the estuary illustrate the extent of log storage (Fig. J.4). Extensive upstream logging activity is believed to have increased sediment deposits in the estuary. Although it is thought that the estuary is recovering, local citizens have noticed a loss of eelgrass, and large quantities of bark from logs still cover areas of estuary substrate (Dick Goin, personal communication). Aerial photographs show that the left bank (looking towards the Strait) is filling in since dredging ceased, which may eventually increase habitat to support more eelgrass. Surf smelt spawning has been observed near the mouth of the Pysht River (Dan Pentilla, WDFW, personal communication).

Chinook and coho salmon heavily use a kelp bed located off the tip of Pillar Point. From 1995-1996, both bull kelp and giant kelp have increased in coverage area in this location (Van Wagenen 1996). Important kelp beds and eelgrass are located between Pillar Point and Clallam Bay (Dick Goin, personal communication), and these areas are recommended for conservation. However deep-seated landslides are common along this area, delivering sediment to the Strait (Anne Shaffer, WDFW, personal communication). Although this area has naturally high levels of sedimentation, it is thought to have worsened after the extensive logging in the 1940s (Dick Goin, personal communication).

Figure J.4. Pysht estuary photograph (circa 1920s) showing the extent of logging, log transport and storage, and bark deposition (photograph courtesy of Dick Goin).

Clallam River

The Clallam estuary is an excellent nursery area for salmonids (Mike McHenry, Lower Elwha Tribe, personal communication), with sightings of spawning surf smelt within the bay (Dan Pentilla, WDFW, personal communication). However, human disturbance has degraded this habitat. Problems with the tidal prism often result in delayed migration or blockage of spawning habitat to adult chinook (see Loss of Access Chapter). Several saltwater marsh areas have been filled, and tidal sloughs and wetlands have been cut-off (Randy Johnson, WDFW, personal communication). Other problems include rip-rap for local resorts, construction of a jetty, which filled estuarine habitat, bulkheading along Clallam Bay, and armoring associated with Highway 112.

Between Clallam Bay and the Hoko River is an extensive kelp bed comprised of large quantities of understory kelp *Pterygophora* and overstory kelps *Nereocystis* and *Macrocystis*. This area, which includes Kydaka point, supports sand lance and salmon (Miller et al. 1980; Anne Shaffer, WDFW, personal communication). From 1995-1996, the kelp coverage area in this region increased by 55% (Van Wagenen 1996).

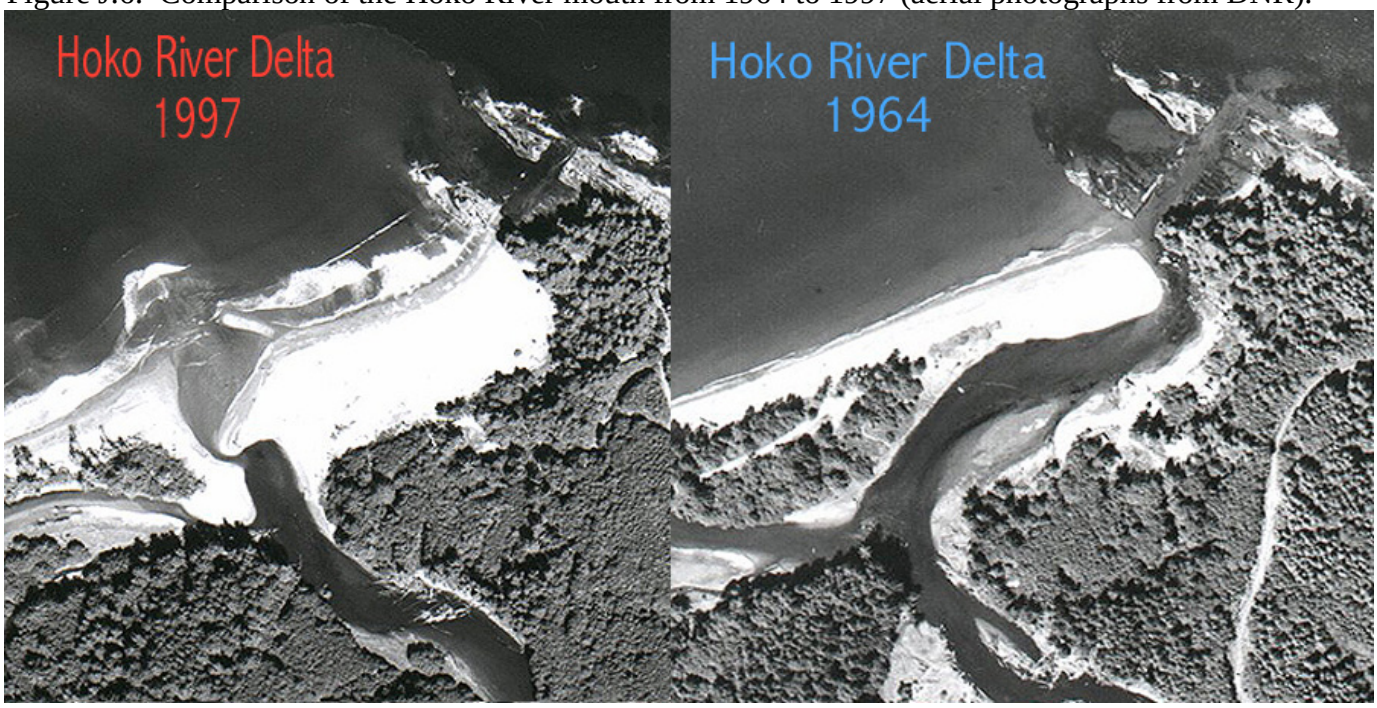
Hoko River

In the early part of the century, the Hoko River estuary was been used for log transport (Fig. J.5), and these activities have altered the estuary, although to a much lesser degree than the Pysht (Mike McHenry, Lower Elwha Tribe, personal communication). Eelgrass is present and provides habitat for sand lance and salmon (Dick Goin, personal communication).

Sedimentation from upstream forestry activities is probably the cause of recent changes at the mouth of the Hoko River. The river mouth has migrated westward, away from the cliff, as shown by aerial photographs comparing 1964 to 1997 (Fig. J.6) (Randy Johnson, WDFW, personal communication). Note that the photograph from the 1920s (Fig. J.5) shows the river mouth against the cliff, similar to its position in 1964 (Fig. J.6).

Figure J.5. Hoko estuary photograph (circa 1920s) showing the use of the estuary for log transport and storage (photograph courtesy of Dick Goin). Note the proximity of the cliff to the east side of the Hoko River mouth. The river has recently shifted away from this cliff.

Figure J.6. Comparison of the Hoko River mouth from 1964 to 1997 (aerial photographs from DNR).



Sekiu River To Neah Bay

The nearshore habitat in this area contains important kelp beds that have recently increased in coverage area (Van Wagenen 1996). Percent increases range from 21-90%. The Sail River estuary is regularly dredged, and the estuaries for Bullman and Rasmussen Creeks readily form sandbars near the river mouths (Mike Haggerty, Makah Tribe, personal communication.

Major Recommendations for WRIA 19 Estuaries and Nearshore Habitat

- Reduce sediment impacts to overstory and understory habitats in WRIA 19, monitor and reduce sediment inputs from Highway 112 to the nearshore environment.
- Reduce non-point impacts, particularly in Crescent Bay.
- Maintain eelgrass and kelp habitat throughout this WRIA.

Data Needs for WRIA 19 Estuaries and Nearshore Habitat

- Inventory understory kelp habitat in the Strait of Juan de Fuca.
- Define elements of differential salmon use of eelgrass, overstory and understory kelp habitat use in areas of known importance (Crescent Bay, Pillar Point, Hoko area).
- Conduct extensive baitfish use surveys in this WRIA.
- Conduct studies on the effect of estuarine sediment deposition on salmon production.

LITERATURE CITED

Battjes, J.A. 1967. Quantitative research on littoral drift and tidal inlets. *In* G.H. Lauff, editor. Estuary. American Association for the Advancement of Science Publication No. 83.

Benda, L. 1993. Geomorphic analysis of the South Fork of Green Creek. Hanson Natural Resources, Port Angeles, Washington.

Bishop, S. N. Currence, and M. McHenry. 1996. Hoko River basin-fall chinook. Pages 49-55 i*n* S. Bishop and A. Morgan, editors. Critical Habitat Issues by Basin for Natural Chinook Stocks in the Coastal and Puget Sound Areas of Washington State. Northwest Indian Fisheries Commission, Lacey, Washington.

Broadhurst, G. 1998. Puget Sound nearshore habitat regulatory perspective: a review of issues and obstacles. Puget Sound/Georgia Basin Environmental Report Series: Number 7. Puget Sound Water Quality Action Team, Olympia, Washington.

Burgner, R. L., J.T. Light, L. Margolis, T. Okazaki, A. Tautz, and S. Ito. 1992. Distributions and origins of steelhead trout (*Oncorhynchus mykiss*) in offshore waters of the North Pacific Ocean. International North Pacific Fish. Comm. Bulletin 51, 92 pp.

Busby, P.J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F. W. Waknitz, and I.V. Lagomarsino. 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-27, 261 pp.

Cederholm, C.J. and W.J.. Scarlett. 1981. Seasonal immigrations of juvenile salmonids into four small tributaries of the Clearwater River, Washington, 1977-1981. Pages 98-110 *in* E.L. Brannon and W.O. Salo, editors. Proceedings of the Salmon and Trout Migratory Behavior Symposium. School of Fisheries, University of Washington, Seattle, Washington.

Cederholm, C.J., L.M. Reid, and E.O. Salo. 1981. Cumulative effects of logging road sediment on salmonid populations in the Clearwater River, Jefferson County, Washington. Pages 38-74 *in* Proceedings from Salmon Spawning Gravel: A Renewable Resource in the Pacific Northwest? Report 39. State of Washington Water Research Center, Pullman, Washington.

Chapman, D.W. 1965. Net production of juvenile coho salmon in three Oregon streams. Transactions of the American Fisheries Society 94:40-52.

Chapman, D.W. 1988. A critical review of variables used to define effects of fines in redds of large salmonids. Transactions of the American Fisheries Society 117:1-21.

Currence, N. 1999. Sekiu coastal watershed analysis module F. Fish habitat assessment. Sekiu Coastal Watershed Analysis. Department of Natural Resources, Olympia, Washington.

Dethier, M. 1990. A marine and estuarine habitat classification system for Washington State. Washington Department of Natural Resources, Olympia, Washington. 56 pp.

Everest, F.H. and seven other authors. 1985. Salmonids. Pages 199-230 *in* E.R. Brown, editor. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington. USDA Forest Service Publication No. R6-F&WL-192-1985. Portland, Oregon.

Grette, G. 1985. The role of large organic debris in juvenile rearing habitat in small streams. Master's Thesis. College of Fisheries, University of Washington, Seattle, Washington.

Hartman, G. F. 1965. The role of behaviour in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of Fisheries Research Board Canada 22:1035-1081.

Hartman, G.F. and J.C. Scrivener. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223.

Hoar, W.S. 1958. The evolution of migratory behaviour among juvenile salmon of the genus Oncorhynchus. Journal of Fisheries Research Board Canada 15:391-428.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of Fisheries Research Board Canada 16:835-886.

Ivankov, V.N. and V.L. Andreyev. 1971. The South Kuril chum (*Oncorhynchus keta*) ecology, population structure and the modeling of the population. Journal of Ichthyology 11:511-524.

Kuchler, A.W. 1964. Potential natural vegetation of the coterminous United States. American Geographical Society, Special Publication Number 36, Washington DC.

Larkin, P.A. 1977. Pacific Salmon. Pages 156-186 *in* J.A. Gulland, editor. Fish Population Dynamics. J. Wiley & Sons, New York, New York.

Lemberg, N.A., M.F. O'Toole, D.E. Pentilla, and K.C. Stick. 1996. Forage fish stock status report. Washington Department of Fish and Wildlife, Olympia, Washington.

Levings, C.D. 1985. Juvenile salmonid use of habitats altered by a coal port in the Fraser River estuary, British Columbia. Marine Pollution Bulletin 17:248-254.

Lloyd, D.S., J.P. Koenings, and J.D. LaPerrier. 1987. Effects of turbidity in fresh waters of Alaska. North American Journal of Fisheries Management 7:18-33.

Macdonald, R.W. and E.A. Crecelius. 1994. Marine sediments in the Strait of Georgia, Juan de Fuca Strait, and Puget Sound: what they tell us about contamination? Symposium on the Marine Environment.

Marshall, A.R., C. Smith, R. Brix, W. Dammers, J. Hymer, and L. Lavoy. 1995. Genetic diversity units and major ancestral lineages for chinook salmon in Washington. *In* Genetic Diversity Units and Major Ancestral Lineages of Salmonid Fishes in Washington. Washington Department of Fish and Wildlife. Technical Report Number RAD 95-02.

Martin, D., L. Benda, C. Coho, S. Cooke, D. Vagt, D. Monaghan, N. Currence, and M. McHenry. Hoko River watershed analysis watershed administrative unit 1903023 resource assessment report and prescriptions. Prepared for: Cavenham Forest Industries and Rayonier Timberlands.

McHenry, M. 1992. Spawning gravel quantity report Deep Creek, Washington. Report for the Lower Elwha Tribe, Port Angeles, Washington.

McHenry, M. and J.F. Murray. 1996. Riparian and LWD demonstration projects in the Pysht River, Washington (1992-1996). A Final Report to the : Washington Department of Ecology and U.S. Environmental Protection Agency.

McHenry, M. and S. Shaw. 1994. Channel assessment report Deep Creek, a tributary of the Strait of Juan de Fuca. *In* Assessment of Physical and Biological Conditions within the Deep Creek Watershed, North Olympic Peninsula, Washington, and Recommendations for Watershed Restoration. Washington Department of Natural Resources, Forks, Washington.

McHenry M., N Jewitt, and C. Toal. 1994a. Fishery habitat conditions and trends in salmon populations in Deep Creek, Washington. *In* Assessment of Physical and Biological Conditions within the Deep Creek Watershed, North Olympic Peninsula, Washington, and Recommendations for Watershed Restoration. Washington Department of Natural Resources, Forks, Washington.

McHenry, M.L., D.C. Morrill, and E. Currence. 1994b. Spawning gravel quality, watershed characteristics and early life history survival of coho salmon and steelhead in five north Olympic Peninsula watershed. Unpublished report, Lower Elwha S'Klallam Tribe and Makah Tribe.

McHenry, M., S. Shaw, C. Toal, and J. Gorsline, 1995. Assessment of physical and biological conditions within the Deep Creek watershed, North Olympic Peninsula, Washington, and recommendations for watershed restoration. Report to Washington Department of Natural Resources, Olympic Region, Forks, Washington.

McHenry, M., J. Lichatowich, and R. Kowalski-Hagaman. 1996. Status of pacific salmon and their habitats on the Olympic Peninsula, Washington. Report to the Lower Elwha Klallam Tribe, Port Angeles, Washington.

McHenry, M., E. Shott, R. Conrad, and G. Grette. 1998. Changes in the quantity and characteristics of large woody debris in streams of the Olympic Peninsula, WA, U.S.A. (1982-1993). Canadian Journal of Fisheries and Aquatic Science Vol. 55, No. 6, pp. 1395-1407.

Meehan, W.R., F.J. Swanson, and J.R. Sedell. 1977. Influences of riparian vegetation on aquatic ecosystems with particular reference to salmonid fishes and their food supply. Pages 137-145 *in* R.R. Johnson and D. A. Jones, editors. Importance, Preservation and Management of Riparian Habitat: A Symposium held at Tucson, Arizona, July 9, 1977. U.S. Forest Service General Technical Report RM-43.

Miller, B., C.A. Simenstad, J. N. Cross, K.L. Fresh, and S.N. Steinfort. 1980. Nearshore fish and macroinvertebrate assemblages along the Strait of Juan de Fuca including food habits of the common nearshore fish: final report for MESA Puget Sound Project. University of Washington Fisheries Research Institute FRI-UW-8001.

Miller, R. R. 1965. Quaternary freshwater fishes of North America. Pages 569-581 *in* The Quaternary of the United States. Princeton University Press, Princeton, New Jersey.

Monaghan, D., D. Christiansen, and D.R. Berg. 1999. Riparian Function Assessment in the Sekiu Watershed. Sekiu Coastal Watershed Analysis. Department of Natural Resources, Olympia, Washington.

National Marine Fisheries Service (NMFS), 1995. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. Draft Non Federal Version November 2, 1995. The National Marine Fisheries Service Environmental and Technical Services Division Habitat Conservation Branch. 28 pp.

Neave, F. 1949. Game fish populations of the Cowichan River. Bulletin of the Fisheries Research Board Canada 84:1-32.

Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: community profile. U.S. Fish & Wildlife Service report FWS/OBS-84/24. 85pp.

Parks, D. and N. Sturhan. 1998. Appendix B: surface erosion assessment version 3.0, level II. Sekiu Coastal Watershed Analysis. Department of Natural Resources, Olympia, Washington.

Pentec, 1995. Appendix C- Hydrology assessment. *In* Hoko River Watershed Analysis. For The Department of Natural Resources, Olympia, Washington.

Peterson, N.P. 1980. The role of spring ponds in the winter ecology and natural production of coho salmon (*Oncorhynchus kisutch*) on the Olympic Peninsula, Washington. Master's Thesis. University of Washington, Seattle, Washington, 96 p.

Peterson, P., A Hendry, and T. Quinn. 1992. Assessment of cumulative effects on salmonid habitat: Some suggested parameters and target conditions. TFW Report, Center for Streamside Studies, University of Washington, Seattle, Washington.

Phinney, D. and Bucknell. 1975. A catalog of Washington streams and salmon utilization. Vol. 2 Coastal Region. Washington Department of Fisheries, Olympia, Washington.

Rawson, K. and eight other authors. 1997. Puget Sound salmon stock review group report 1997. An assessment of the status of Puget Sound chinook and Strait of Juan de Fuca coho stocks as required under the salmon fishery management plan. Pacific Fishery Management Council, Portland, Oregon.

Salmonid Screening, Habitat Enhancement and Restoration Division (SSHEAR). 1998. Fish passage database and barrier correction guidelines memo. August 31, 1998. Washington Department of Fish and Wildlife, Olympia, Washington.

Scarlett, W.J. and C.J. Cederholm. 1984. Juvenile coho salmon fall-winter utilization of two small tributaries of the Clearwater River, Jefferson County, Washington. Pages 227-242 *in* J.M. Walton and D. B. Houston, editors. Proceedings of the Olympic Wild Fish Conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, Washington.

Schuett-Hames, J. and D.R. Malkin. 1993. Deep Creek July to September 1992 reconnaissance temperature study. Report for the Department of Ecology, Southwest Regional Office, Lacey, Washington.

Schuett-Hames, D, N. Peterson, and T.P. Quinn. 1994. Incubation environment of chum salmon (*Oncorhynchus keta*) in Kennedy Creek, part C: patterns of scour and fill in the low-gradient alluvial channel. Pages 42-55 *in* T.P. Quinn and N.P. Peterson, editors. The Effect of Forest Practices on Fish Populations. University of Washington, Seattle, Washington.

Scrivener, J.C. and B.C. Andersen. 1982. Logging impacts and some mechanisms which determine the size of spring and summer populations of coho salmon fry in Carnation Creek. Pages 257-272 *in* G.F. Hartman, editor. Proceedings of the Carnation Creek Workshop: a Ten Year Review. Pacific Biological Station, Nanaimo, British Columbia.

Seddell, J.R., and K.J. Luchessa. 1982. Using the historical record as an aid to salmonid habitat enhancement. Pages 210-213 *in* N.B. Armantrout, editor, Acquisition and Utilization of Aquatic Habitat Inventory Data. American Fisheries Society, Western Division, Portland, Oregon.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout (*Salmo gairdneri gairdneri*) and silver salmon (*Onchorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish & Game Fish Bulletin 98, 375 p.

Shaw, S. 1995. Mass-wasting analysis Deep Creek watershed North Olympic Peninsula, Washington. *In* Assessment of Physical and Biological Conditions within the Deep Creek Watershed, North Olympic Peninsula, Washington, and Recommendations for Watershed Restoration. Washington Department of Natural Resources, Forks, Washington.

Shaffer, A. 1998. Kelp bed habitats of the inland waters of western Washington. Puget Sound Research Proceedings. Vol. 1. Puget Sound Water Quality Authority, Olympia, Washington.

Shaffer, A., D.C. Doty, R.M. Buckley, and J.E. West. 1995. Crustacean community composition and trophic use of the drift vegetation habitat by juvenile splitnose rockfish, *Sebastes diploproa*. Marine Ecology Progress Series. Vol. 123:13-21.

Shaffer, A. and D.S. Parks. 1994. Seasonal variations in and observations of landslide impacts on the algal composition of a Puget Sound nearshore kelp forest. Botanica Marina. Vol. 37: 315-323.

Simenstad, C.A. and E.O. Salo. 1982. Foraging success as a determinant of estuarine and near-shore carrying capacity of juvenile chum salmon (Oncorhynchus keta) in Hood Canal, Washington. Pages 21-37 *in* B.R. Meltreff and A. Neve, editors. Proceedings of the North Pacific Aquaculture Symposium. Alaska Sea Grant Rep. 82-2.

Smith, R.D., R.C. Sidle, P.E. Porter, and J.R. Noel. 1993. Effects of experimental removal of woody debris on the channel morphology of a forest, gravel-bed stream. Journal of Hydrology 152:153-178.

(SCS) Soil Conservation Service. 1984. Soil Survey of Clallam County.

Swanson, F.J., L.E. Benda, S.H. Duncan, G.E. Grant, W.F. Magahan, L.M. Reid, and R.R. Ziemer. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. Pages 9-38 *in* E.O. Salo and T.W. Cundy, editors. Streamside Management: Forestry and Fishery Interactions. Contribution 57. Institute of Forest Resources, University of Washington. Seattle, Washington.

Tabor, R.W. and W.M. Cady. 1978. Geologic map of the Olympic Peninsula. United States Geologic Survey, Miscellaneous Investigation Series, Map I-993, Denver, Colorado.

Thom, R.M. and L. Hallum. 1990. Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound. Final Report to Office of Puget Sound Region 10 U.S. Environmental Protection Agency. EPA 910/9-91-005.

Van Wagenen, R.F. 1996. Washington coastal kelp resources Port Townsend to the Columbia River Summer 1996. Final Report to Washington Department of Natural Resources, Olympia, Washington.

Washington Department of Ecology (DOE). 1993. Watershed characteristic worksheet. Centennial Clean Water Grant Study. Washington Department of Ecology, Lacey, Washington.

Washington Department of Ecology (DOE). 1999a. http://www.wa.gov/ecology/eils/wrias/fwb/data/lyre_r_at_dnr_campground.html. Washington Department of Ecology, Lacey, Washington.

Washington Department of Ecology (DOE). 1999b. Candidate 1998 Section 303(d) List-WRIA 19. Washington Department of Ecology, Lacey, Washington.

Washington Department of Fish and Wildlife. 1998. Salmonid Stock Inventory. Appendix Bull Trout and Dolly Varden. Olympia, Washington 437 p.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1993. 1992 Washington State salmon and steelhead stock inventory. Olympia, Washington 212 p.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Indian Tribes. 1994. 1992 Washington State Salmon and Steelhead Stock Inventory. Appendices. Olympia, Washington.

WDNR (Washington Department of Natural Resources. 1994. Landscape Management Plan. Olympia, Washington.

Webb, D.G. 1991. Effect of predation by juvenile Pacific salmon on marine harpacticoid copepods. I. Comparisons of patterns of copepod mortality with patterns of salmon consumption. Marine Ecology Progress Series 72: 25-36.

Wetherall, J.A. 1971. Estimation of survival rates for chinook salmon during their downstream migration in the Green River, Washington. Doctoral dissertation. College of Fisheries, University of Washington, Seattle, Washington, 170 p.

Withler, I.L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. Journal of the Fishery Research Board Canada 23 (3): 365-393.

Young, W., 1994. Deep Creek watershed analysis: hydrology module. *In* Assessment of Physical and Biological Conditions within the Deep Creek Watershed, North Olympic Peninsula, Washington, and Recommendations for Watershed Restoration. Washington Department of Natural Resources, Forks, Washington.