Critical Habitat Issues by Basin for Natural Chinook Stocks in the Coastal and Puget Sound Areas of Washington State

Hoh Tribe
Lower Elwha S'Klallam Tribe
Makah Tribe
Puyallup Tribe
Quinault Nation
Jamestown S'Klallam Tribe
Lummi Nation
Muckleshoot Tribe
Quileute Tribe
Skagit System Cooperative
Tulalip Tribes

Edited By

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Northwest Indian Fisheries Commission

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Introduction

The National Marine Fisheries Service is conducting a review on the status of natural stocks of chinook salmon (*Oncorhynchus tshawytscha*) originating on the United States West Coast as required for petitions submitted under the Endangered Species Act of 1973 (ESA). The purpose of this document is to identify the critical habitat issues affecting chinook stocks managed for natural production or those with a significant proportion of natural spawning and minimal hatchery influence (Figure 1). Captive broodstocking or native broodstocking programs associated with the stocks discussed below are not considered to provide hatchery influence.

The ESA clearly specifies in at least three instances that habitat should be considered when assessing risk to a petitioned species. First, when determining the current status of petitioned species and whether that species is at imminent risk of extinction (endangered) or "...likely to become an endangered species within the foreseeable future..." (threatened), (16 U.S.C. §§ 1531-1544), the reviewers must make assessments of all the major factors which might contribute to the petitioned stock meeting the criteria of endangered now or in the future. Second, under section 4(a)(1) of the ESA, a species may be listed as threatened or endangered when the following conditions exist or a significant risk exists that they will occur: 1) present or threatened destruction, modification, or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) inadequacy of existing regulatory mechanisms; or 5) other natural or manmade factors affecting its continued existence. In past status reviews, NMFS has carefully assessed risks of overexploitation, loss of genetic diversity, inappropriate hatchery practices and continued declines in abundance, in accordance with items 2,3,4 and 5 above. Like the other risk factors so carefully evaluated, habitat degradation has been documented to contribute significantly to juvenile and adult mortality, and as such should be considered in any risk assessment of chinook stocks petitioned under the ESA. Finally, Section 2(b) of the ESA defines the purposes of the act to be "...to provide a means where by the ecosystems upon which endangered species and threatened species depend may be conserved,...". If the goal of the Endangered Species Act is not only to halt the decline of a species into extinction and conserve the ecosystems on which it depends, NMFS is obligated to consider habitat in conducting its status review.

To assist NMFS in meeting this obligation, the following discussion will briefly address the role of freshwater habitat on life history stages of chinook salmon; present an overview of the watersheds supporting naturally spawning chinook stocks in Puget Sound and Coastal Washington rivers and then list and describe the primary critical habitat issues affecting chinook in each watershed. The Columbia River Tribes through the Columbia Intertribal Fish Commission (CRITFC), the Washington Department of Fisheries and the Oregon Department of Fish and Wildlife have previously provided information regarding habitat impacts on the Columbia River system and therefore they are not addressed in this document.

The assessment of stock status accompanying the descriptions of individual stocks are taken from the Washington State Salmon and Steelhead Stock Inventory (WDF et al. 1993) document compiled by the Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes in 1992:

Healthy - A stock of fish experiencing production levels consistent with its available habitat and natural variations in survival rates, but above the level where permanent damage to the stock is likely.

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

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

General Chinook Life History and Habitat Requirements
Chinook are thought to have evolved 50,000 to 1 million years ago from stream- or lake-dwelling *Salmo*-like fish (Neave 1958 (cited by Healey 1991)). Adults are distinguished from other salmonids by large size, the presence of spots on both caudal lobes, black pigment at the base of the teeth, a large number of pyloric caeca (McPhail and Lindsey 1970; Hart 1973), and flesh color ranging from white to red (Healey 1991). Juvenile characteristics are highly variable but generally they are distinguished by large parr marks extending well below the lateral line, an adipose fin edged in black, and an anal fin with a white leading edge where the leading rays do not reach past the posterior insertion of the fin when folded against the body (Healey 1991). Chinook are found from southern California to Unalakleet in the Bering Sea on the North American Coast, in the Canadian Arctic and on the Asian Coast (McPhail and Lindsey 1970; Hart 1973; Major et al. 1978 (cited by Healey 1991). Introductions have been made successfully in New Zealand (Hart 1973) and in southern Chile (Waugh 1980 (cited by Healey 1991)). In general, the size of individual chinook spawning populations is small compared to other salmonid species (Healey 1991).

Three basic life history types are generally recognized: ocean type or fall chinook, 90-day type of chinook, and stream type or spring chinook. These three life history types were reported by Carl and Healey (1984) to be genetically distinct in the Nanaimo River. According to Healey (1983), there is latitudinal variation in the distribution of chinook salmon populations showing these attributes, with stream type chinook salmon being more common at higher latitudes (Groot et al. 1995). Ocean-type chinook are characteristic of populations on the North American coast south of 56^0 N. They migrate to sea by the spring following emergence, spend most of their ocean migration in coastal waters and return to their natal river in the fall prior to spawning (Healey 1991). The 90-day and stream type juveniles spend anywhere from 90 days to one or more years in freshwater before migrating to sea, range extensively offshore during oceanic migration and return to their natal river in the spring or summer prior to spawning. The rearing strategy characteristic of a stock could be related to the optimal time of arrival in the ocean, similar to that suggested by Walters et al. (1978) for Fraser River chum and pink fry, or the optimal size to maximize survival during ocean migration. Stream-type chinook characteristically have longer freshwater migration distances and/or rear in colder climates than ocean-type chinook (Healey 1991).

Eggs and Alevins
Chinook salmon generally spawn in the mainstem and larger tributaries of river systems (Hart 1973), although they have been observed spawning under a wide range of conditions. Upon return, females establish territories within the spawning stream. Males patrol the spawning areas competing for access to females. Over several days, each female digs several shallow depressions in the gravel substrate of the river bottom, depositing and burying eggs in each. The total area of excavation is

called a *redd* (Healey 1991). Egg survival to hatching has been documented to be 80-90+ % when redds are undisturbed (Briggs 1953; Vronskiy 1972). However, perturbations caused by siltation, freezing, desiccation, disease, predation and most significantly flooding can decrease egg survival.

Adequate subgravel flow has been identified as the primary factor in the choice of redd site and subsequent survival to hatching (Chapman 1943 (cited by Healey 1991); Vronskiy 1972). In fact, Silver et al. (1963 (cited by Healey 1991)) observed the size at hatching was dependent on the water velocity during incubation. The depth of the redd is inversely related to the velocity of subgravel water flow (Healey 1991). Good subsurface flow is consistent with the probable incubation requirements of chinook relative to the other species. The smaller surface-to-volume ratios of the larger egg size (Hart 1973; Healey 1991) would require a greater rate of flow to ensure adequate oxygen exchange. Experiments conducted in artificial streams reported survival to hatching greater than 93% regardless of planting depth or substrate size when gravel percolation was at least 0.001 ft/s. Although emergence success was greatest at low percolation rates (0.001-0.03 ft/s) and shallow depth, it was less than 14% when gravel was small (<1 inch)(Shelton 1955).

Egg mortality due to temperature fluctuations is probably low since eggs are usually not subjected to lethal temperatures for periods of time sufficient to cause significant mortality (Healey 1991). Under constant incubation temperatures, 50% pre-hatch mortality occurred when temperatures were above 16^0 C or below 2.5^0-3^0 C. Egg survival was higher at low temperatures under conditions of fluctuating incubation temperatures, than under constant incubation at low temperatures (Alderdice and Velsen 1978 (cited by Healey 1991)).

Alevins appeared to be most affected by dewatering and the quality of spawning substrate (Shelton 1955; Becker et al. 1982, 1983 (cited by Healey 1991)). Dewatering of redds is most likely to occur in regulated rivers where discharge varies depending on domestic or industrial uses but could also occur in natural conditions where excess sedimentation or storm events create areas of high gravel aggradation.

At the time of emergence, there is an extensive downstream dispersal of fry (35-45 mm) either to appropriate nursery habitat within the natal stream or to a nearby estuary. Whether the primary rearing area is river or estuarine appears to have a genetic component (Carl and Healey 1984 (cited by Healey 1991); Taylor and Larkin 1986; Taylor 1988; Clarke et al. 1989 (cited by Healey 1991)). Both river flow and freshwater rearing area limitations have been hypothesized as determining the rate of downstream migration and dispersal (Lister and Walker 1966 (cited by Healey 1991); Reimers 1968 (cited by Healey 1991); Major and Mighell 1969 (cited by Healey 1991); Healey 1980 (cited by Healey 1991); Kjelson et al. 1981 (cited by Healey 1991)). During stream residence, fry appear to prefer lower flow velocities and shallower areas (<3 meters) of the river (Mains and Smith 1964 (cited by Healey 1991); Healey and Jordan 1982 (cited by Healey 1991); Healey 1991). Both ocean and stream-type fry move away from the river bank into higher velocity and larger substrate environs as body size increases (Chapman and Bjornn 1966 (cited by Healey 1991); Lister and Genoe 1970 (cited by Healey 1991); Everest and Chapman 1972 (cited by Healey 1991); Murphy et al. 1989 (cited by Healey 1991)).

Fry from ocean-type chinook populations migrate downstream to an estuary soon after emergence. Osmoregulatory capability develops quickly and fry are able to tolerate salinities of up to 20 ppm with no difficulties. However, studies of estuarine rearing in the Sacramento-San Joaquin River and Fraser River estuaries found that a majority of rearing took place in the freshwater habitats of the upper delta regions (Kjelson et al. 1981, 1982 (cited by Healey 1991); Levy and Northcote 1981, 1982). Fry were widely dispersed at the upper margins of the deltas at high tide, retreating to tidal channels and creeks at low tide. Young chinook appear to prefer larger tidal channels with low banks and subtidal refugia (Levy and Northcote 1981). At 70 mm or above, juveniles move out of estuarine areas into nearby marine areas (Healey 1991). Fry migration out of the estuary in late May and June appears to coincide with the arrival of fingerlings in the estuary. Several studies have shown residence in the rich feeding habitat of the estuary for fry and fingerlings to be a period of rapid growth (Rich 1920 (cited by Healey 1991); Reimers 1971 (cited by Healey 1991); Kjelson et al. 1982 (cited by Healey 1991)).

Juveniles

During stream residence some authors have reported territorial behavior (Edmundson et al. 1968 (cited by Healey 1991); Reimers 1968 (cited by Healey 1991); Don Chapman Consultants 1989 (cited by Healey 1991)). Initially, juvenile chinook prefer shallow, low velocity sites with small substrate (Chapman and Bjornn 1969 (cited by Healey 1991); Everest and Chapman 1972 (cited by Healey 1991)). As body size increases, chinook move into midstream sites with higher velocity, increased depth and coarser substrate (Chapman and Bjornn 1969 (cited by Healey 1991)). Juvenile chinook may also display diurnal behavior, occupying higher velocity sites during the day and moving inshore to lower velocity, finer substrate areas at night (Edmundson et al. 1968 (cited by Healey 1991); Don Chapman Consultants 1989 (cited by Healey 1991)).

Seaward migration begins in the spring of the first year, ending in the fall of the first or second year after spawning of the parental brood depending on rearing strategy. Fingerlings (50-150 mm) may migrate to sea any time of year, but typically, peak migration occurs in June (Lister and Walker 1966 (cited by Healey 1991); Lister et al. 1971 (cited by Healey 1991); Healey and Jordan 1982 (cited by Healey 1991); Healey 1991). Rate of downstream migration appears to be time- and size-dependent, influenced also by river flow and location of the juveniles when seaward migration begins. The later in the year, the faster the water velocity, and the larger the juvenile, the faster the rate of downstream migration (Cramer and Lichatowich 1978). Upon arrival in the estuary, fingerlings occupy deeper water areas and remain there for varying periods dependent on food availability and water temperatures (Kjelson et al. 1982 (cited by Healey 1991)). Estuaries along the coasts of Washington to California may also provide important sheltered habitat for young fall chinook during the summer and fall months prior to their migration to sea (Healy 1991). Washington chinook stocks from Puget Sound, the lower Columbia River and the coast are primarily ocean-type (J. Meyers, NMFS, Seattle, WA, pers. comm. October 1995).

Yearlings tend to move out of the tributaries and overwinter in deep pools or pockets in large bottom substrate of the mainstem (Reimers and Loeffel 1967 (cited by Healey 1991); Chapman and Bjornn 1969 (cited by Healey 1991); Bjornn 1971 (cited by Healey 1991); Carl and Healey 1984 (cited by Healey 1991); Don Chapman Consultants 1989 (cited by Healey 1991)). They typically migrate to sea in early spring, usually prior to the peak of fry and fingerling migration. Rate of downstream migration appears influenced by spring flood events and increasing water temperatures (Bell 1958; Raymond 1968 (cited by Healey 1991)). Yearling residence in the estuaries and coastal waters in general is brief (Healey 1980; Levy and Northcote 1981; Healey 1982, 1983 (cited by Healey 1991)) but may overlap somewhat with that of the fry. The two life history stages show spatial separation with the fry occupying the upland delta area and the yearlings further out in the delta front (Healey 1991) where their preferred diet of larval and juvenile fish is more available.

Adults

Ocean feeding migration proceeds northward along the coast, with some chinook documented as far as 1000 miles into the Pacific (Hart 1973). Chinook generally return to spawn in their natal stream in their fourth or fifth year but may return as early as the second (precocious males or females called jacks or jills) and as late as their eighth (Hart 1973; Bishop unpublished). Populations returning to the same river or stream are generally distinguished by differences in run timing (spring, summer and fall) and physical differences. Populations that spawn further upstream often appear more silver in coloration and more robust, reflective of the greater energy reserves necessary for longer migration. Earlier returning stocks, especially stream-type forms, may take advantage of the increased flows in the spring for migration to their natal spawning grounds in the upper watersheds. Return-timing generally gets progressively later as one moves south along the North American coast (Healey 1991). Spawning timing, however, may be similar among runs of different return-timing (Healey 1991; Hayman 1995). Generally, spawning occurs from August to November for Washington stocks. Adults begin to display gender specific secondary sexual characteristics. The silvery marine coloration of both sexes gives way to reddish dorsal to ventral bars. Males display hooked kypes and exaggerated dorsal humps.

Land Use Practices and Habitat Impacts

Temperature regimes, channel and hydrologic conditions provide habitat conditions needed for migration, spawning and rearing (Orsborn and Ralph 1994). Chinook, like other species of anadromous salmon and trout, have evolved physiological and behavioral adaptations to the habitat conditions and environmental characteristics of their natal stream. When those ecosystem parameters are significantly altered, the resident populations may no longer be adapted to successfully cope with the changed environment.

Throughout the Puget Sound region, continued degradation of these optimal conditions is occurring due to the cumulative effects of land use practices, industrial practices, and development. Many processes are inter-related and the effects rarely occur in isolation. Landslides in upper watersheds cause excessive sediment load in the stream which results in continuing bank erosion, removal of riparian canopy and channel instability as one moves downstream. Each subsequent event is exacerbated by the previous one as each event increases the sediment load in the stream. Siltation and aggradation of spawning gravel, filling of holding areas, increased channel width, decreased stream depth and increased temperatures impede upstream migration, degrade spawning and holding habitat and increase mortality at each life history stage.

It is important to understand the varying habitat requirements of chinook salmon at different life stages. These requirements define the parameters of the condition of the freshwater and estuarine habitat that must be met to ensure the species' survival.

Sedimentation

For almost all land use practices, as hillslope gradient increases, so does the potential for accelerating the entry of sediment into stream channels above the natural rate (Everest et al. 1987). Significant increases in sedimentation processes beyond the natural levels can result in aggradation of gravel which decreases the depth of the river, fills pools and widens the channel. These effects can cause the flow to become subterranean, causing eggs within the gravel to die due to desiccation, juvenile habitat dewatering and, impediments to both upstream and downstream migration of anadromous salmonids (Nawa et al. 1988). Loss of pools can increase mortalities as they are used by adults and juveniles as holding areas and as protection against predators. There is also evidence that gravel scour is common in stream reaches where aggradation is occurring (Nawa et al. 1988; Schuett-Hames et al. 1988). Scour lowers survival to emergence of salmonid eggs.

Siltation is the increased input of fine sediment (<0.8mm in diameter) into a stream. This input can originate from erosion of streambanks or from upstream storage areas and is transported as turbidity. The sediment can permeate redd gravels reducing the flow of water and oxygen, smothering or entombing the eggs and alevin (McNeil and Ahnell 1964; Koski 1966 (cited in Schuett-Hames 1988)). Bell (1990) reported an 85% egg mortality when 15%-20% of the interstitial spaces in stream bed substrate were filled with fine sediment. Fine sediment volume greater than 10% resulted in poor to variable survival of coho and steelhead smolts (Cederholm et al 1982). Siltation was shown to decrease survival to emergence for Pacific salmon eggs and alevin by 11% in the Carnation Creek study on forestry/fisheries interactions in British Columbia (Scrivener and Brownlee 1989).

Land use practices that increase erosion often result in increased stream sedimentation. Direct or indirect effects of forestry practices such as landslides (mass wasting) or landslide scars, surface erosion from roads, and clearcuts are notable sources of fine sediment. Continuing research on the Clearwater River on the Olympic Peninsula of Washington State has shown that logging road use is a significant cause of fine sediment input (Cederholm and Salo 1979). Other forestry practices that contribute to increased sedimentation are yarding logs across streams and removal of vegetation from the the riparian zone. These and other effects of forest practices appeared to increase the variation in abundance for Pacific salmon (Holtby and Scrivener 1988). Incorrect typing of streams in Washington State is a widespread problem, e.g., 60-70% on the Olympic Peninsula (Bahls and Ereth 1994), that may also result in increased sediment input. During stream evaluation, typing addresses the degree of salmon utilization in the stream. Underestimation of salmon use may result in land use activities in close proximity to the stream which contribute to increased sedimentation and which would otherwise not be allowed or be more tightly controlled (Bahls and Ereth 1994, M.Mobbs, QIN, Taholah, WA, pers. comm. 1995).

Agricultural use of lands adjacent to streams for grazing or crops also contributes to increased siltation. Domesticated animals often strip the riparian zone of stabilizing vegetation and increase bank erosion by walking on the unstable banks (Platts 1991).

Urbanization activities may also be a source of sedimentation. Erosion results from exposed soils during construction. Stabilizing vegetation is removed in the course of clearing land for development. Grading and paving activities change the natural drainage patterns, decreasing storage and holding capacity. The effect is to increase flows through more restricted channels. Structure or road building on unstable slopes may cause mass wasting, especially when those soils become water saturated.

Low Water Flows

When the river system has water removed or experiences excess sedimentation, the water depth is reduced. This lowered water depth exposes the redds to desiccation, siltation, low dissolved oxygen, and low flow velocities and these can result in egg mortality. Low water flows can result in increased water temperatures (Wickett 1958) and can limit the access to spawning habitat for adult salmon migrating upstream. Low water flows can be caused by: upstream land practices that increase sediment movement into the river system, impounding of water, irrigation withdrawal, lowering of the water table through well or city withdrawal of water, roading (especially when channels are constrained or passed through culverts), logging, and development activities (Everest et al. 1985).

Streambed Instability

The resulting increases in streamflow velocity due to excess sedimentation or channelization and, consequently, the shear stress on the bedload, causes the entrainment and movement of gravel known as *scour* (Ralph et al. 1994). Movement of the stream bed can lead to mortality caused by physical injury to the eggs from the moving gravel. Pacific salmon eggs are very susceptible to mortality from mechanical shock before they reach the eyed stage. Movement of the streambed gravel during this period can result in mass mortality and burial (Healey 1991).

Forest practices and other land use activities that lead to higher peak flows or greater sediment input increase the depth of scouring and thus the likelihood of egg mortality (Schuett-Hames et al. 1994). Land use practices that increase channel instability are: urbanization, channelization of the river, loss of off-channel or side channel areas, culvert use (or other flow restrictions), gravel mining, diking and other flood management methods (Meehan 1991). Loss of in-stream wood has also been linked with channel instability and bedload transport (Smith et al. 1993; Pentec 1995). In one study, scour increased, bed sediment was redistributed and flow paths were altered, changing the size and location of bars and pools as well as causing local bank erosion and channel widening, after instream wood removal (Smith et al. 1993).

High Water Temperatures

Stream temperatures and the surrounding air temperatures seek an equilibrium. The speed at which this happens is primarily determined by stream depth, i.e., deeper streams take longer to reach equilibrium with the air temperature and display low fluctuations in mean daily in-stream water temperatures. Temperatures in shallower streams respond to changes in air temperature more quickly and daily stream temperatures fluctuate more wildly (Schuett-Hames et al. 1988).

Salmonids prefer temperatures between 40-58° F. Poor survival has been documented at water temperatures above 70° F (Brett 1952; Lance 1971; Bell 1990). As water temperature increases, egg and alevin maturation accelerates, and consequently the time that alevin spend in the gravel decreases. This can cause earlier migration to saltwater and increased mortality (Godin 1980; Hartman et al. 1987). High water temperatures can also lower the dissolved oxygen content of the interstitial water, causing asphyxiation of the eggs. It effectively renders portions of the stream habitat unsuitable and may increase competition by crowding juvenile fish into limited habitats (Orborn and Ralph 1994). In adults, elevated temperatures may affect reproduction, vulnerability to disease and predation, spatial and temporal distribution and competition (Schuett-Hames and Schuett-Hames 1988). Growth is reduced at low temperatures due to reduced metabolism, and at high temperatures because most or all food must be used for maintenance (Bjornn and Reiser 1991). McCullough (1993 cited by Gregory et al. 1994) reported that adults ceased to migrate upstream at temperatures at or above 21° C. Increased water temperatures can be caused by removal of canopy cover (which in a small order, highly productive stream is nearly complete coverage), agriculture, urbanization, and forestry practices that remove the riparian vegetation (Everest et al. 1985).

Degradation of Estuarine and Nearshore Areas

Estuaries have been shown to provide valuable nursery habitat for juvenile chinook (Northcote 1976; Healey 1980, 1982; Levy and Northcote 1982). By comparing contribution to catch and escapement of chinook released at various sites along a river to estuary gradient in 1983 and 1984, data from the Campbell River estuary indicated that a lack of, or reduced time in an estuarine rearing environment could decrease survival as much as 68% (Macdonald et al 1988; Levings 1990). Levy and Northcote (1981) found more juvenile chinook in deeper channel areas than shallower habitats. Estuarine food webs supporting juvenile salmonids are dominated by invertebrates which are associated with the benthic and detritus microhabitats (Northcote, Johnston and Tsumura 1979 (cited in in Levings 1990); Stanhope and Levings 1985 (cited in Levings 1990)). In fact, length of residence in the estuary may be determined by availability and quality of food resources (Mason 1974; Macdonald et al. 1987).

Estuaries may also provide an important refuge from predators. Many of the non-salmonid species in the estuary are smaller than those in the adjacent river or marine zones (McCabe et al. 1983; Macdonald et al 1988).

Estuarine areas are becoming increasingly degraded. The degradation that is most harmful to juvenile salmonids is the loss of natural flow of energy and materials between the habitat areas of the shoreline and nearshore areas (Thom et al. 1994). Land use practices that negatively affect these areas are: stripping of the vegetation of riparian areas, decreased outflows of freshwater, dredging and filling, bulkheading or other bank protection methods, and increased sedimentation of the river system by forest practices or development (Gaumer et al. 1985). Bulkheading along Hood Canal has been shown to increase erosion, decrease vegetation, and increase point source pollution (Toal 1992). As growth continues along the shores of Puget Sound and the Washington coastline, these impacts all contribute to a cumulative degradation or loss of near shore and estuarine habitat.

Basin Specific Descriptions

We will present brief overviews of the basins of interest (Figure 1), the habitat issues for each basin and any restoration efforts aimed at those issues. Indepth studies for many of these river systems have been undertaken, including specific recommendations for necessary improvements to habitat and water (see References). We would encourage you to refer to those studies as well as the tribal and state agency staffs involved for more details.

Cedar River/Lake Washington Basin

Amy Morgan and Holly Coccoli

Basin Overview

The Cedar River originates in relatively high mountain country of the Cascade Range near Stampede Pass (Figure 2). It flows generally west-northwest for nearly 50 miles to its confluence with the southern end of Lake Washington at Renton. The upper ten miles of this stream cut through narrow valleyed , steep sloped, and heavily forested mountain terrain. Here it is typically a mountain-type stream containing numerous rapid and cascade areas and few pool-riffle sections. Below this, the next 9 miles contain two man-made [sic] storage reservoirs, Chester Morse and Cedar Lake, whose waters spread over the moderately broad valley floor. Below Cedar Lake, downstream to the Seattle City Water diversion dam at about river mile 21 near Landsburg (a distance of 14 miles), the Cedar courses through a relatively shallow and broad valley, densely forested with mixed conifer and deciduous growth. This section contains numerous gentle gradient stretches with many pool-riffle areas, and is considered highly suitable for fish spawning and rearing. Below the diversion dam, which presents a total barrier to upriver migration, the Cedar River flows some five miles to Maple Valley through a somewhat narrow, moderately steep sloped, densely forested valley interspersed with summer home developments. This stretch presents only intermittent areas having pool-riffle character, with numerous semi-rapid and large boulder sections. Below the town of Maple Valley, the lower thirteen miles of river meander over a shallow, relatively broad valley containing increasing urban development. The lower three miles of stream move through an intensely industrialized area. Below Maple Valley the Cedar maintains predominantly a pool-riffle character, providing excellent spawning and rearing conditions for both anadromous and resident fishes. Principal Cedar River tributaries contributing significant flow and accessibility for anadromous fish include Rock and Downs creeks, one unnamed creek, and possibly Peterson Creek. Total accessible stream area provided by this system is approximately 28 linear miles (Williams et al. 1975).

Stock Status

The SASSI report (WDF et al. 1993) lists the stock status as native stock origin with wild production and unknown status. The Muckleshoot Tribe believes that this stock is best characterized as "depressed". Close monitoring of this stock is underway as a short term decline may be occurring.

Fish Utilization

Chinook mostly spawn in the mainstem Cedar River with the heaviest use from RM 5.0 to RM 20.0. The Landsburg Dam is between RM 21.0 and 22.0 and serves as a barrier to further use by anadromous fish.

Critical Habitat Issues

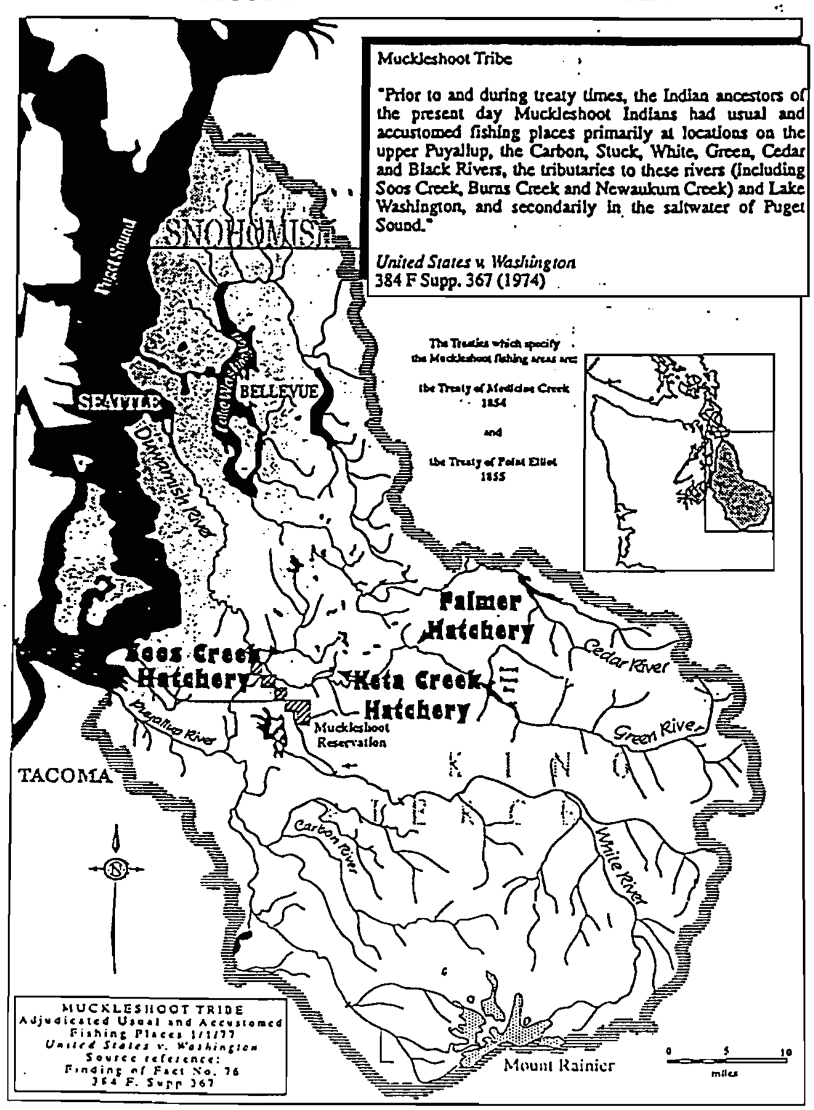
The habitat issues discussed below are summarized in Table 1.

Passage

Downstream passage at United States Army Corp of Engineers (COE) Chittendon Locks (Ballard

Figure 2. Location of the Muckleshoot Indian Tribe treaty area drainage

MUCKLESHOOT INDIAN TRIBE TREATY AREA DRAINAGE



Locks) is a problem for all of the anadromous fish in the basin. Passageways include dam spillway (radial gates), tunnels associated with small and large locks, saltwater drain, and fish ladder. In 1994 and 1995, COE, WDFW, Muckleshoot Tribe, USFWS, and NMFS documented significant injury and mortality associated with lockages and saltwater exchange operations during smolt outmigration. Bird predation at facility may or may not contribute. Passage situation may be worse in low runoff years. An 80 cfs surface spillway was installed by COE in spring 1995, and some operational changes were made resulting in some apparent improvement. Further study is needed to continue evaluating downstream passage success and potential operational and structural remedies.

Channelization and Lack of LWD

The area of Cedar River below Landsburg lacks rearing habitat due to channelization, rip-rap placement, and historic woody debris removal by flood control entities. Channelization causes an increase in streambed instability due to magnification of peak flows. Rip-rap, the placement of large rocks along a stream bank to harden it, has similar effects as channelization. While rip-rap does provide cover for juveniles, it can increase the mortality for the ingravel lifestage due to the increased streambed instability (Bell 1990). Loss of LWD leads to fewer pools, less cover, greater sediment movement, less diversity of habitat, and lower macroinvertebrate population levels (Bisson et al. 1987, Simpson et al. 1982).

Estuarine Loss

Due to extensive rerouting of the rivers draining into Lake Washington and urban development, there has been a complete loss of estuarine rearing habitat for naturally produced chinook (Figure 3). Migration through large lakes (Sammamish and Lake Wahsington) may limit native chinook production. For example, historically the Cedar River drained into the Black and Duwamish rivers. The Lake Washington nearshore and littoral environment is increasingly hostile to salmon juveniles due to exotic plants (milfoil) and fishes (smallmouth bass and other species), pier development,and herbicide application.

Hydrologic Issues

Extensive urbanization and water diversion have caused hydrologic changes such that low flows and peak flow events are magnified. This increases mortalities at all life stages for the chinook by dewatering and scouring redds, flushing fry and smolts prematurely downstream, and stranding adults during upriver migration.

<u>Existing Restoration Efforts</u>

Improvements to the fish passage problems at the Ballard Locks are noted above, for more information on these refinements contact the following people: Eric Warner, Muckleshoot Indian Tribe; Kurt Fresh/Dave Seiler, WDFW.

Figure 3. Changes in river routes between 1900 and 1994

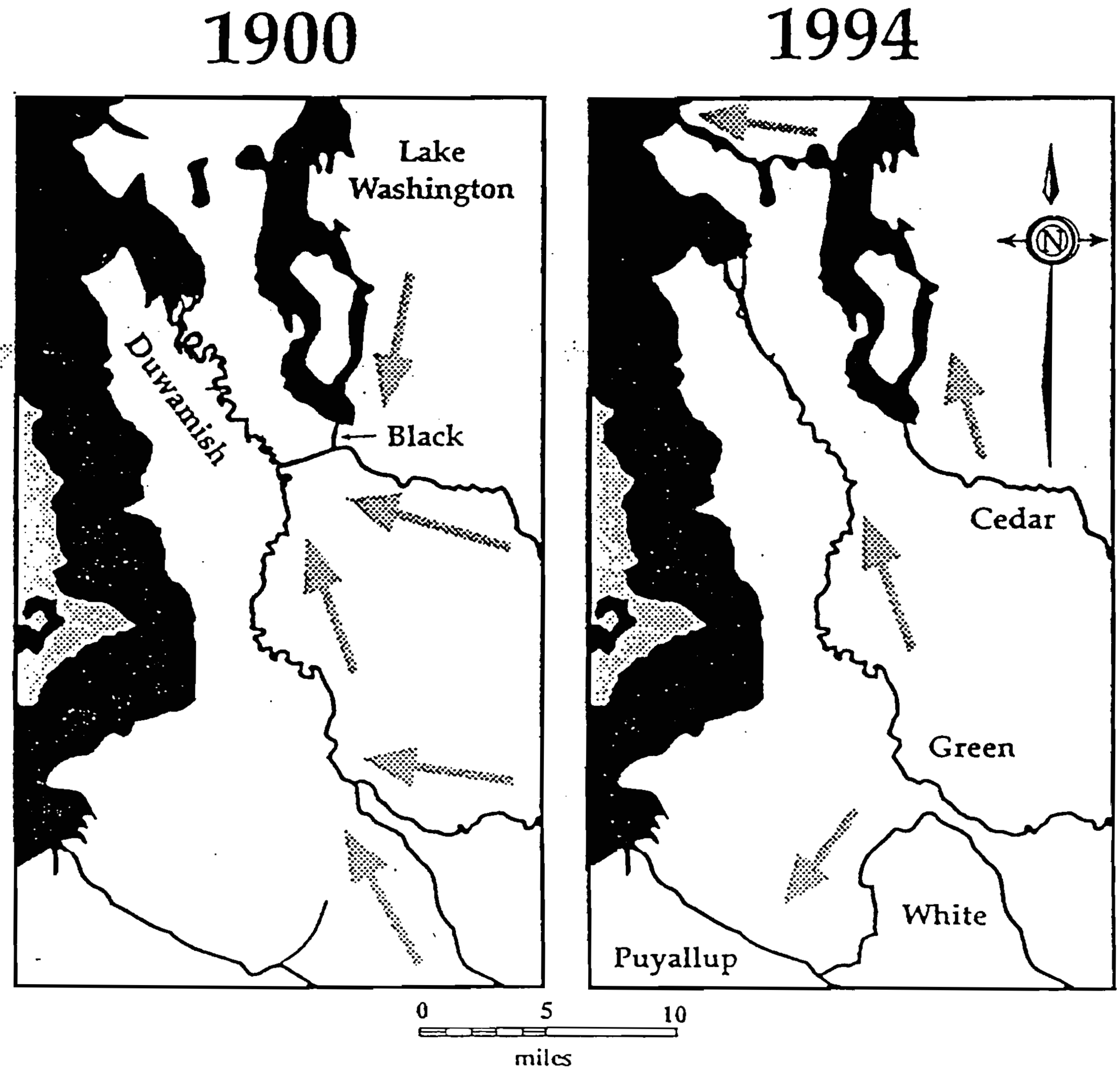


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Table 1. Limiting factors for the Cedar System by life history stage.

River/ Life History Stage	Flow Regime	Sedimentation	Passage	Streambed Instability	Estuarine loss
Cedar					
Ingravel	X	X		X	
Fry	X	X		X	
Smolts	X	X	X	X	X
Adults	X	X	X	X	
Activity	**Flow Regime**	**Sedimentation**	**Passage**	**Streambed Instability**	**Estuarine loss**
Urbanization	X	X	X	X	X
Water Diversion	X	X	X		
Flood Control	X	X		X	

Chehalis River Basin

Amy Morgan and Mike McGinnis

Basin Overview

The Chehalis basin is comprised largely of the Chehalis River watershed with two major and a number of minor, independent drainages (Figure 4). The Humptulips and Hoquiam rivers plus several smaller systems enter Grays Harbor from the north; the Chehalis River from the east; and the Johns and Elks river along with a number of smaller drainages enter from the south.
The Chehalis River forms on the higher slopes of south western Washington near the town of Pe Ell. The river flows generally northerly through a gradually broadening valley where a number of larger tributaries enter the river along its route. These include the South Fork Chehalis, Newaukum, Skookumchuck, Black, Satsop, Wynoochee, and Wishkah rivers. Of these, only the Wynoochee and Satsop river watersheds contain steep mountainous terrain in their headwaters. The lower reaches and most of the remainder of the Chehalis River watershed is composed of moderately sloped hills and broad valleys.

The Humptulips River is formed by its East and West forks which originate in the southeastern slopes of the Olympic Mountains. Its two major forks flow south through narrow valleys to their confluence from which the mainstem courses southerly through a gradually broadening valley to its entrance into Grays Harbor.

The Hoquiam River and its tributaries head in low, gentle hills north of Grays Harbor. Its stream courses are generally confined to moderately sloped valleys and the other tributaries to the north side of Grays Harbor and all the south side tributaries originate in low hills, meadering through broad valleys in their middle and lower reaches. There are 1,391 rivers and streams containing 3,353 linear stream miles within this basin.

Stock Status

The SASSI report (WDF et al. 1993) lists the stock status as several separate runs. We are presenting information on the runs within the purview of the Chehalis Tribe. Chehalis spring chinook are listed as native origin, wild production, and healthy status. The Chehalis fall run is listed as mixed origin, wild production, and healthy status.

Fish Utilization

Both spring and fall chinook are present in the Chehalis basin. Spring chinook enter the river in March through June destined for the upper reaches of the Skookumchuck, Newaukum, South Fork Chehalis, and Chehalis rivers and Stillman Creek. Fall chinook are found utilizing the Chehalis mainstem, Black River, Skookumchuck, Newaukum, South Fork Chehalis rivers and Stillman Creek (Table 2).

Figure 4. Location of the Chehalis River watershed

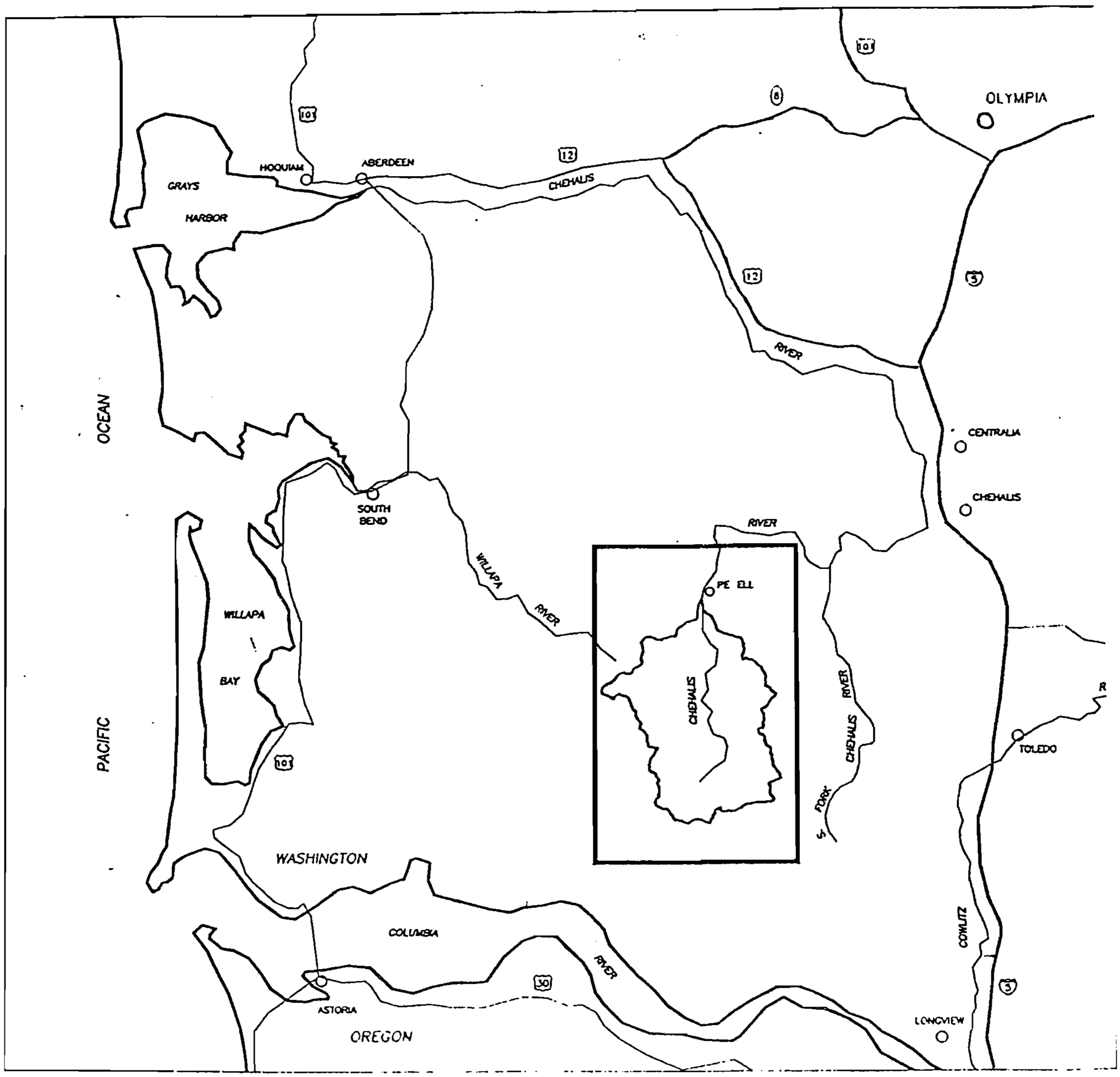


Table 2. Areas of Chinook Utilization

River	Spring Chinook Use	Fall Chinook Use
Chehalis mainstem	RM 97.0 to 106.25	RM 43.7 to 66.75 and 100.4 to 106.25
Black River	None	RM 0 to 9.25
Skookumchuck	RM 0 to 22.3	RM 0 to 11.0
N. Fork Newaukum	RM .5 to 10.75	None
Newaukum and S. Fork	RM 23.0 to 30.2	RM 7.0 to 11.0
S. Fork Chehalis	RM 0 to 5.75	RM 0 to 5.75
Stillman Creek	RM 0 to 4.4	RM 0 to 2.5

<u>Critical Habitat Issues</u>

The Chehalis system is very large but the impacts are similar to the point that a degradation study (Wampler et al. 1993) of the basin and sub-basins found there to be five main degradations in the areas listed in the table above. We list here the degradations and their causes as found in this study. We will also briefly touch on the life stage of the chinook that would be affected by the degradation (Table 3).

Riparian canopy reduced

The amount of coverage provided by the canopy of trees along the banks of the watercourses has been reduced in several areas by agriculture: Chehalis mainstem, Black River, and Skookumchuck River. And it has been reduced by logging on the Newaukum River. This canopy coverage helps to maintain a cool water temperature and provides an input of detritus. When it is reduced water temperatures can climb into a range that puts stress on the fish. A change in detrital inputs affects the stability of the reach (Vannote et al. 1980) and can also lead to the formation of inhospitable territory for fish. The life stages most affected by these changes are the stream-type juvenile and the up-river migrating adults.

Riparian vegetation loss

Streamside vegetation provides among other things: bank stabilization, detrital input, cover and shade. The Chehalis river system has several areas with riparian vegetation loss where the cause is not known: Chehalis mainstem, Newaukum River, South Fork Chehalis, and Stillman Creek. The life stages most affected by this change are the stream-type juvenile and up-river migrating adults.

When livestock have access to a stream they can cause the destruction of streamside vegetation and water quality problems such as increased turbidity and fecal coliform levels. The access provided to livestock has caused impacts all along the Chehalis River system. The mainstem, Black, Skookumchuck,and Newaukum rivers all show destruction of streamside vegetation and the Skookumchuck and Black show some evidence of water quality issues from this access.

Sedimentation

Excess sedimentation in rivers and streams can lead to many problems for salmonid fishes. As described in the earlier "Landuse Practices and Habitat Impacts" section, the problems range from a propensity toward scour to limiting the access to and range of spawnable areas. Excess sedimentation from an unknown cause is documented for the Skookumchuck River. It affects all of the life stages of chinook salmon.

Bank erosion impacts the rate of sediment input into a stream system. The Newaukum River is cited as having bank erosion as a prominent feature for most of its length. Bank erosion can be a leading cause of excess sedimentation. The causes for bank erosion can range from geology to loss of stabilizing vegetation. The cause is not cited in the degradation study but is probably due to streamside vegetation loss.

Existing Restoration Efforts

Several restoration projects are in process under the umbrella organization of the Chehalis Basin Fisheries Task Force. There are two that have direct bearing on the degraded habitat for the chinook runs. The South Fork Chehalis Habitat Conservation project is currently awaiting further informational contact from the USFWS Regional Archaeologist to the involved landowner. The Black River Salmon and Trout Enhancement-Phase I has done livestock fencing to address the degradations attributed to livestock. For information on all of the restoration projects currently active (many more than are noted here) please contact the Chehalis Basin Fisheries Task Force.

Table 3. Limiting factors for the Chehalis System by life history stage.

Stream or River/ Life History Stage	Sedimentation	Temperatures/ Riparian canopy loss	Estuarine loss
Chehalis			
Ingravel	X		
Fry	X	X	X
Juvenile	X	X	X
Adults	X	X	
Black			
Ingravel	X		
Fry	X	X	X
Juvenile	X	X	X
Adults	X	X	
Skookumchuck			
Ingravel	X		
Fry	X	X	X
Juvenile	X	X	X
Adults	X	X	
Newaukum			
Ingravel	X		
Fry	X	X	X
Juvenile	X	X	X
Adults	X	X	
Stillman			
Ingravel			
Fry		X	X
Juvenile		X	X
Adults		X	
Activity	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Estuarine loss**
Logging	X	X	X
Agriculture	X	X	
Urbanization			X

Dungeness River Basin - Spring/Summer Chinook

Mike Reed and Susan Bishop

Basin Overview

The Dungeness watershed drains 198 square miles in the northeastern part of the Olympic Peninsula. The mainstem extends 31.9 miles and its primary tributary, the Gray Wolf River, adds another 17.4 miles. In addition, there are another 256.2 miles of tributaries in the basin (Williams et al. 1975). The headwaters of the Dungeness and Gray Wolf rivers originate at about 4,000 feet in the Olympic Mountain Range. The river drops through steep gradients to the foot hills and finally opens on to an alluvial fan in the lower 10 miles of the river. The lowest five miles have a relatively flat gradient before entering the sea (Lichatowich 1992; Dungeness River Chinook Salmon Rebuilding Project Progress Report 1992-1993). The Dungeness watershed is located in a rainshadow and as such receives less than 20 inches in annual precipitation. Snow melt from the surrounding mountains contribute significantly to the annual water flow (WDF et al. 1993).

The glacial history of this region has shaped the types of soils in both the headwaters and the valley. Highly erosive glacial soils can be found throughout the upper portion of the watershed. The alluvial fan in the valley is comprised of these glacial sediments deposited by the river as it has slowly shifted its position from east to west over the past 10,000 years (Lichatowich 1993). Transport and deposition of these erosive glacial soils has been the main source of material for the aggradation in the lower river.

Stock Status

In 1992, Dungeness chinook were classified as "critical" based upon chronically depressed levels of spawning salmon (WDF et al. 1993). The vulnerable status of this stock led to the establishment of the Dungeness River Chinook Salmon Rebuilding Project - a captive broodstock program- with the goal to provide for a healthy, self-sustaining population that maintains the genetic characteristics of the existing chinook salmon stock. The program was designed with the recognition that habitat problems have contributed to the declines and that the long-term success of the rebuilding program is dependent upon *significant restoration of chinook salmon habitat in the Dungeness River* (Smith and Wampler 1995).

Fish Utilization

Spring/summer chinook in the Dungeness spawn from about river mile (RM) 3 to RM 18.9 in the mainstem and in the lower 5.1 miles in the Gray Wolf River (WDF et al. 1993; Orsborn and Ralph 1994; Smith and Wampler 1995). Peak spawning in the upper river occurs two weeks earlier than spawning in the lower river. Movement into the upper watershed may be triggered by the normal pattern of decreasing flows during August (WDF et al. 1993).

Critical Habitat Issues

Over the last several years the Jamestown S'Klallam Tribe has participated in a number of forums - The Dungeness-Quilcene Water Resources Pilot Project process, a federal watershed analysis and a cost-share agreement with the Forest Service to conduct a habitat inventory - in order to identify the critical issues in the Dungeness watershed. Water flows, particularly low flows, and gravel buildup (aggradation) in the lower river stand out as the critical factors contributing to the decline of chinook salmon in the watershed.

Low Flows

Insufficient flow regimes have resulted in a limited amount of spawning habitat with the requisite depth, velocity and substrate characteristics (Orsborn and Ralph 1994). Only during the month of June does total water allocation in the Dungeness River not exceed the average monthly flow in the river (Jamestown S'Klallam Tribe 1995).

In 1988 and 1989, the U.S. Fish and Wildlife Service (USFWS) carried out an Instream Flow Incremental Methodology (IFIM) study to establish a relationship between stream flow and usable habitat for different life stages of chinook, coho, pink and steelhead salmon, and dolly varden trout (Hiss and Lichatowich 1990). The IFIM study showed that only 45% of the weighted useable area (WUA) was achieved for adult chinook salmon holding and migration at the lowest flows measured at the sample sites. At the lowest recorded flows WUA for spawning was reduced by 90% (Hiss and Lichatowich 1990).

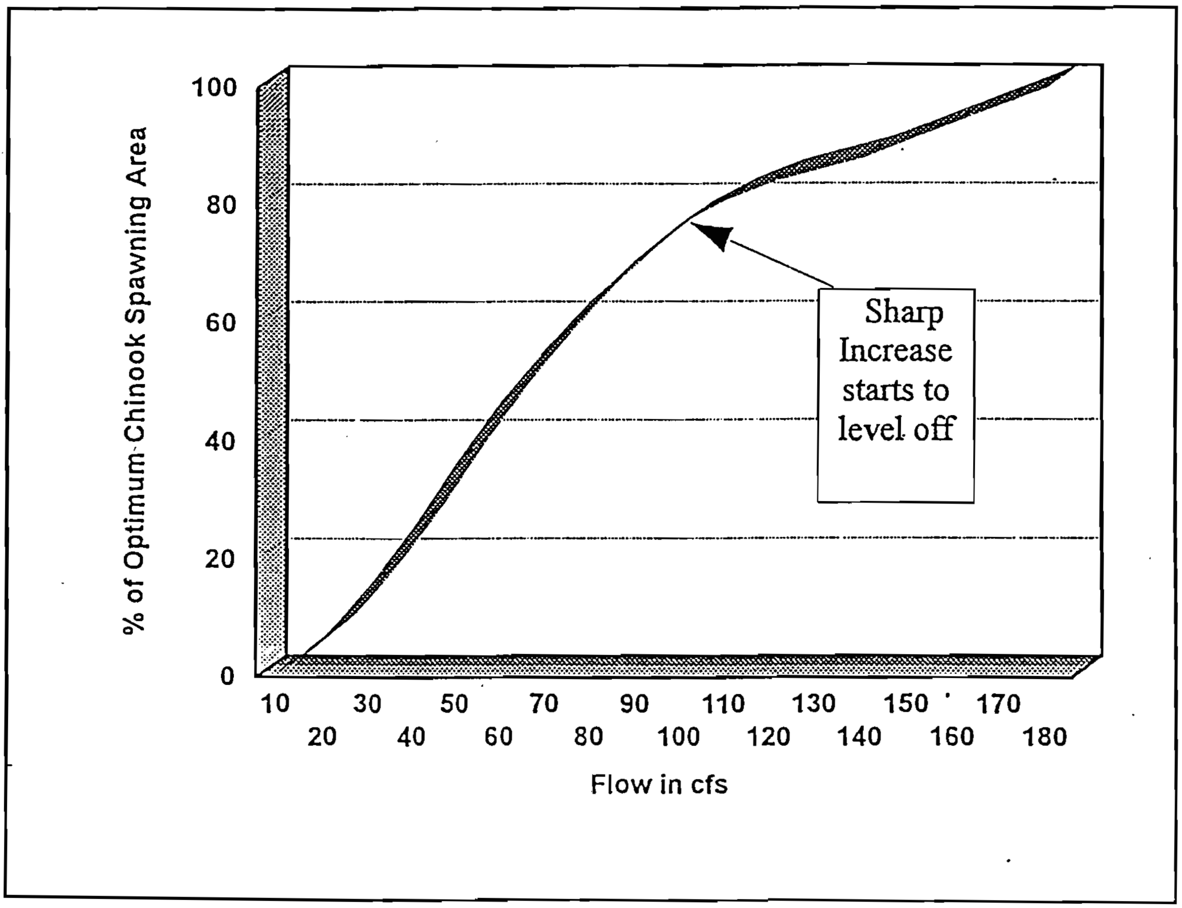
This loss of chinook salmon habitat was believed to be accounted for in part by normal low flows in August and September with the remaining loss consisting of irrigation withdrawals. At the time there was some speculation that gravel aggradation was playing a part but there was little documentation other than observations to support it (Lichatowich 1993). It was determined that it was "reasonable to assume that flows in the August - October period are the major limiting bottleneck for chinook production in the Dungeness River and adjustments in flows are necessary to increase fish production" (Hiss and Lichatowich 1990). This was the impetus for the Jamestown S'Klallam Tribe's involvement in the 1990 Chelan Agreement leading to the formation of the Dungeness-Quilcene Water Resources Pilot Project. One of the primary efforts was to address water allocations for fish.

The August-October period is of greatest current interest, for naturally diminishing instream flows available for irrigation coincide with salmon migration and spawning. Chinook habitat continues to increase over the entire range of flows leading up to the maximum habitat level, rather than reaching a maximum at some lower level (Figure 5). Optimum flows, for all species and life stages combined, is 180 cfs for the August-October period. For chinook, however, optimum flows are more difficult to achieve due to the aggradation.

Sedimentation and Streambed Instability

Scour and aggradation in the Dungeness have affected all stages of chinook life history. It is well documented that high levels of aggradation can destroy juvenile rearing habitat, create impediments to both upstream and downstream migration of anadromous salmonids, contribute to loss of pools, while unstable bedload kills incubating salmon eggs during high flows (Nawa et al. 1988; Lichatowich 1992). Peak flows (greater than 4,000 cfs) have been more numerous from 1976 to the present compared with the period of 1962-1975 (Lichatowich 1992). Besides redd destruction, stream resident juveniles may have difficulty maintaining position in the increased flows and become displaced downstream or be swept into the estuary. Increased juvenile competition or increased mortality from salinity intolerance may result. In 1994 the Jamestown S'Klallam Tribe and the U.S. Forest Service conducted a watershed inventory and channel stability analysis in order to determine

Figure 5. Increase in Chinook Spawning Area for Given Instream Flow[7]



the degree of streambed instability in the Dungeness. Twenty-nine scour monitors were installed at 16 locations throughout the lower 16 miles of river during the months of September - October (Orsborn and Ralph 1994). Site selection included; 11 active redd locations (suspected = 5 pink and 6 chinook), one at a former steelhead redd location, three within riffles where no redds were located, and one on a dry gravel bar three feet above the elevation of the low-flow channel (to show seasonal erosion of sediments stored in point bar features). As part of the chinook restoration project currently underway, each chinook redd was later "pumped" of its alevins in an attempt to transfer these fry to a captive brood facility. This procedure served as a check of the occurrence of scour and/or fill to which the redd was subjected, and a measure of egg and alevin survival (Orsborn and Ralph 1994).

Of the 12 redds where monitors were installed, five showed evidence of substantial scour (from 4-40 cm), while four were buried under fill material. Monitors could not be recovered at three locations because of extensive bank erosion that removed reference pins used to triangulate the monitor locations, or in one case, extensive deposition of fill. Subsequent information provided by the Washington Department of Fish and Wildlife confirmed that all but one chinook redd in the lower 10.8 miles of river failed to yield viable alevins or emergent juveniles (Carol Smith, WDFW, Olympia, WA pers. comm.). These results, when coupled with field observations, indicate that:

1) Both chinook and pink salmon redds in the lower 10.8 miles are largely unsuccessful because the locations chosen for redd construction appear to scour deeply at even moderate flow events (est. < 2 yr. recurrence interval storm event = < 2,000 cubic feet per second discharge);

2) Chinook and pink salmon appear to be choosing similar, limited areas to construct their redds;

3) Spawning habitat (especially "glides" associated with pool tailouts and heads of riffles) having the requisite depth, velocity and substrate characteristics for both chinook and pink, appear to be extremely limited (Wampler and Hiss 1991);

4) The lack of appropriate water depth and velocity is due to the combination of reduced flows (resulting from irrigation diversions) and an over-widened channel as a result of aggradation (Orsborn and Ralph 1994).

Loss of riparian vegetation
Removal of riparian vegetation has led to increased temperatures and decreased oxygen levels outside the range that salmon can survive. As discussed earlier, such conditions result in increased adult vulnerability to disease and other stress related factors, and increased egg mortality from asphyxiation.

Causes of habitat degradation

Major habitat impacts on chinook in the Dungeness system originate from human impacts, including removal of riparian vegetation for urban and agricultural development, forest practices in the upper watershed, flood control, water withdrawals for irrigation, pollution of the river and estuary by urban and agricultural run-off (Table 4) (WDF et al. 1993; Smith and Wampler 1995).

Flows

Water flows have been recorded in the Dungeness River by the USGS since 1923. Average mean monthly flows in the Dungeness River range from 175 cubic feet per second (cfs) of water in September to 706 cfs in June (Orsborn and Ralph 1994). A monthly total of 579 cfs of water from the Dungeness River has been allocated by the Washington Department of Ecology for agriculture and domestic use. Figure 6 shows graphically how these two scenarios combine to create a severe conflict in water use with fish production during critical low flow periods (August-October).

A complex irrigation system was constructed in the Dungeness River at the turn of the century to support developing agriculture. Over 400 miles of ditch - 100 miles of main line and 300 miles of laterals - carry Dungeness River water to irrigate farms in the lower watershed (Figure 7). The irrigation season runs from April 15 to September 1 each year, though smaller water withdrawals for livestock are made throughout the year. Initially, the irrigation system was not designed to minimize impacts to fish. After significant adverse impacts occurred, modifications were made in the 1960's to prevent diversion of juvenile and adult salmonids into the irrigation distribution channels. Five irrigation diversions between RM 6.8 and 11.0 (Figure 8) remove as much as 40% to 60% of the natural flow during critical low flow periods (Hiss 1987). These periods can correspond to the time of migration and spawning for adult chinook salmon returning to the Dungeness River, with significant withdrawals also occuring during emergence and smolt outmigration.

A Technical Committee within the Dungeness-Quilcene planning efforts found in making recommended monthly flow recommendations that ideal flows were *far more than the Dungeness River had ever had.* For example, in August the amount of habitat necessary for chinook rearing required 425 cfs but an average monthly flow for the month of August between the years 1923 - 1991 had been only 265 cfs (Smith and Wampler 1995). The Committee recognized that this exaggerated flow requirement resulted from gravel build-up over the past several decades (Hiss 1993). This intensified flow requirement suggests that irrigation diversion may now be a greater problem than it has ever been historically.

The following recommendations were made by the Technical Committee (Figure 7):

November through March	575 cfs
April through July	475 cfs
August through October	180 cfs

The recommendation of 180 cfs for chinook was based on the point above which incremental gains were less than at lower flows. The Committee made this recommendation with the understanding that until the streambed aggradation problem is solved, adequate flows required for maximum chinook habitat would have to be abnormally high (Hiss 1993). These recommendations were never adopted. Instead, it was decided to allow instream and out-of-stream needs to "share the pain of water-short years and the gain of abundant years" (Jamestown S'Klallam Tribe 1994).

An important note to make here is that this area is rapidly converting from a rural area dominated by farms and private timberlands to residential suburban sprawl. It is uncertain what this will mean for water allocation policies currently being constructed. In the meantime efforts are concentrated towards understanding how much flow the Dungeness River must have in order for salmonids to carry out their freshwater life history phase.

Figure 6. **Dungeness River Mean Monthly Flows and Recommended Instream Flows**

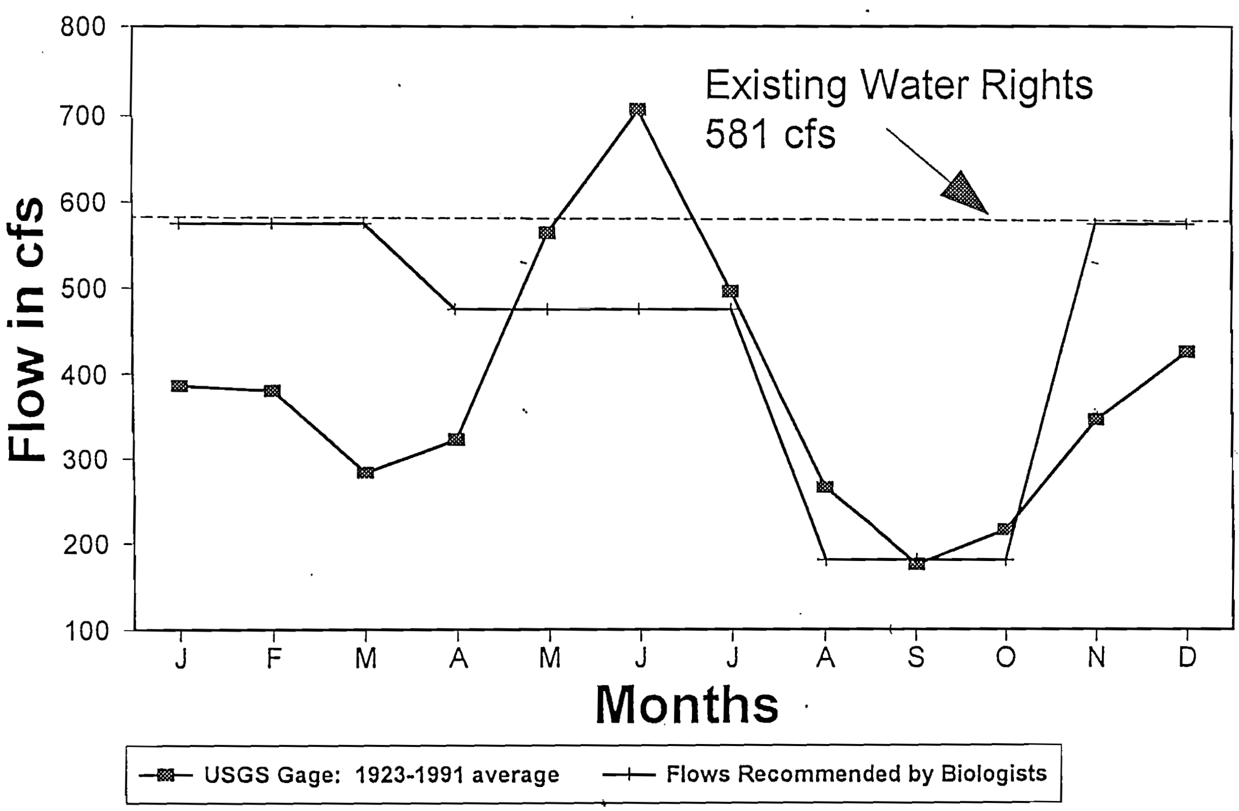


Figure 7·

Irrigation Ditches

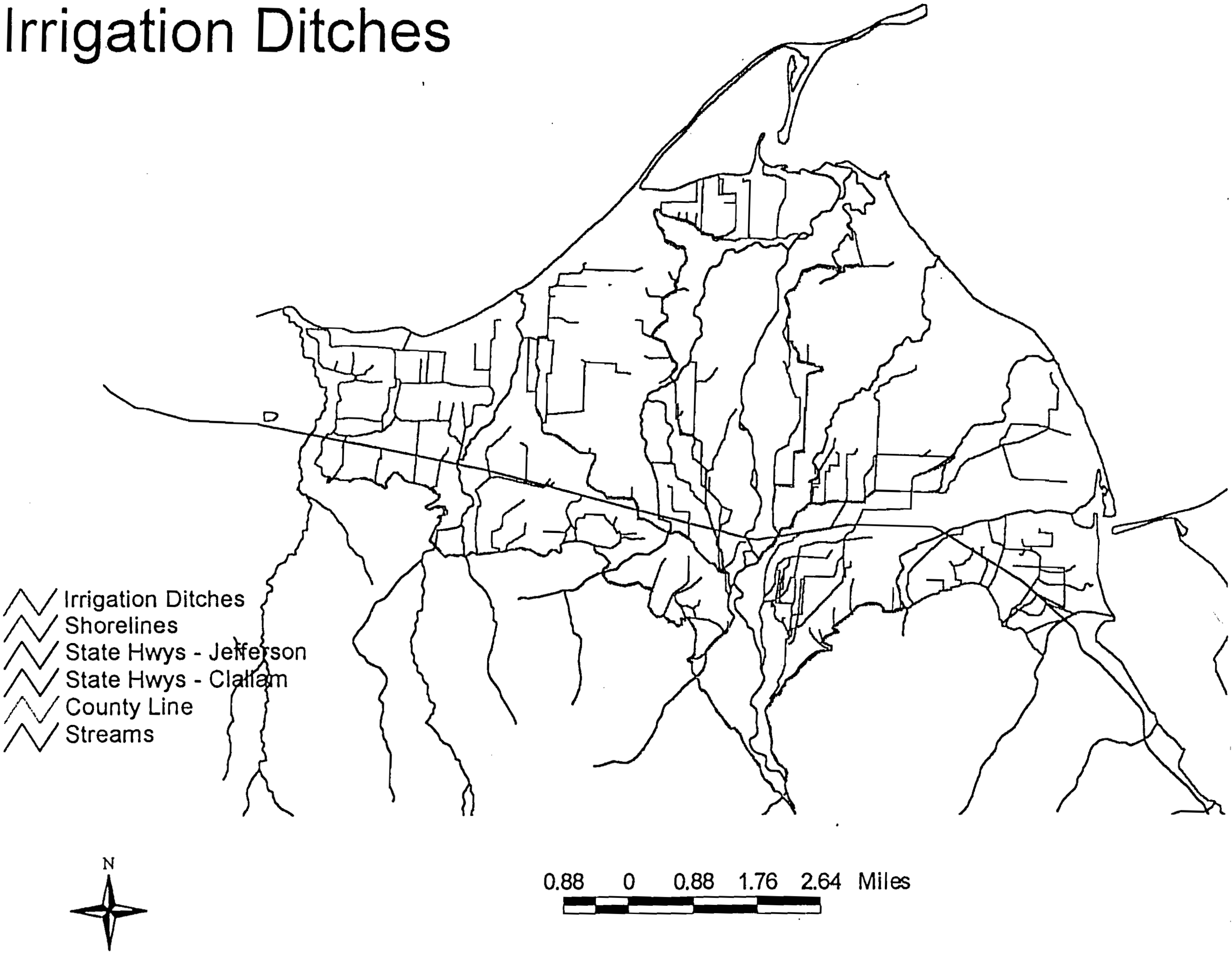


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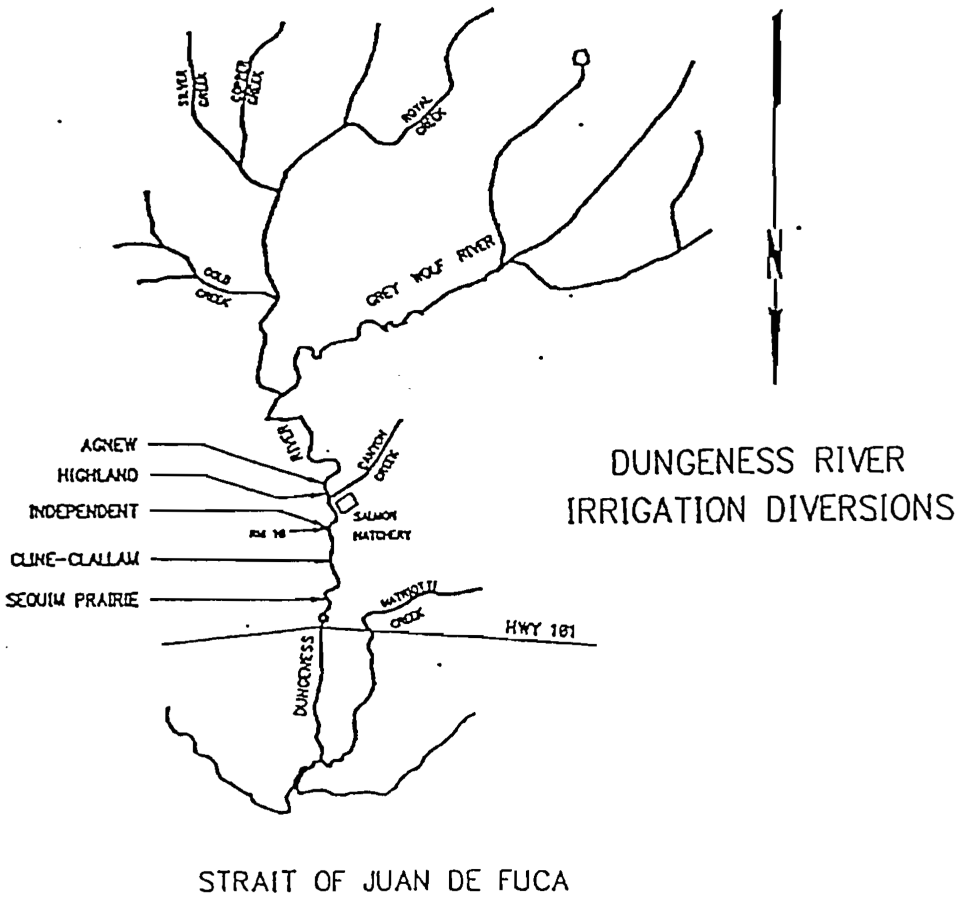
Figure 8. Map of the Dungeness Watershed showing Irrigation Diversions.



Sedimentation
Although sediment deposition is a natural process, when the amount of sediment deposited exceeds the stream's ability to transport it, the stream channel changes in ways that are detrimental to salmon habitat. Understanding how aggradation has occurred is an important step towards restoring some stability to the channel. Debate has focused on whether the deposition causing the aggradation was "natural" based on the erosive nature of the soils in the watershed or due to management activities in the upper watershed.

A number of studies examined the erosional processes in the Dungeness watershed (Henderson et. al. 1989; Koler et al. 1989; Golder 1993). All of the reports shared the perspective that (i) the Dungeness watershed is inherently sediment rich because of the dynamic and rapidly eroding geology and, (ii) large amounts of sediment have been delivered to the channel. However, either little attempt was made to quantify the input of sediment from road sources or slope failures or no historical summary of acres harvested or miles of road constructed in the upper watershed (Orsborn and Ralph 1992).

The Jamestown S'Klallam Tribe, supported by the Forest Service, attempted to provide a more comprehensive analysis approach to this debate. The analysis consisted of an aerial photo interpretation of historical channel changes in the lower river, an examination of old and recent maps to compile a roading history in the upper watershed, previous and current surveys, and use of the hydraulic record from measurements taken at USGS gaging stations since 1937 (Orsborn and Ralph 1994). Some conclusions regarding the possible causes of the channel aggradation are summarized below.

The Dungeness River has had a USGS gage on the river since 1923. Stream flows and cross-sectional channel measures are taken several times a year at the site. Since USGS gages are placed at contracting flow reaches (riffle or glide) where channel stability is fairly certain, any measurable changes in channel geometry at a USGS gage site would have to be caused by a significant disturbance or a higher than usual flood event (Orsborn and Ralph 1994). Operating under this assumption, calibration records at the USGS gage were analyzed in ten-year periods (1937-46, 1947-56, 1957-66, 1967-76, 1977-86 and 1987-93). The data showed significant changes in the channel geometry in the 1967-76 and 1977-86 periods. The data for the 1987-93 period showed a return to a similar uniform geometry as it had in the earlier periods (Note that this is an extreme simplification. For more details or for copies of all data and graphs used in this analyses please refer to Chapter 2 and Appendix VII of Orsborn and Ralph 1994).

Orsborn and Ralph (1994) concluded that some upstream activity had to have caused the size and shape of the low flow channel conditions to change significantly at the gage site. Known landslides and management activities during this period in the upper Dungeness watershed were investigated. These include (Figure 9):

> (1) The Gold Creek slides occurred in late 1968 and the spring of 1969. A significant slumping event during 1972 in Gold Creek, doubled the size of the 1969 failed area and created "extreme turbidity" (Golder et al. 1993). Further Gold Creek valley slope failures occurred in 1975, 1977, 1978, 1980, 1989, 1990 and 1991.

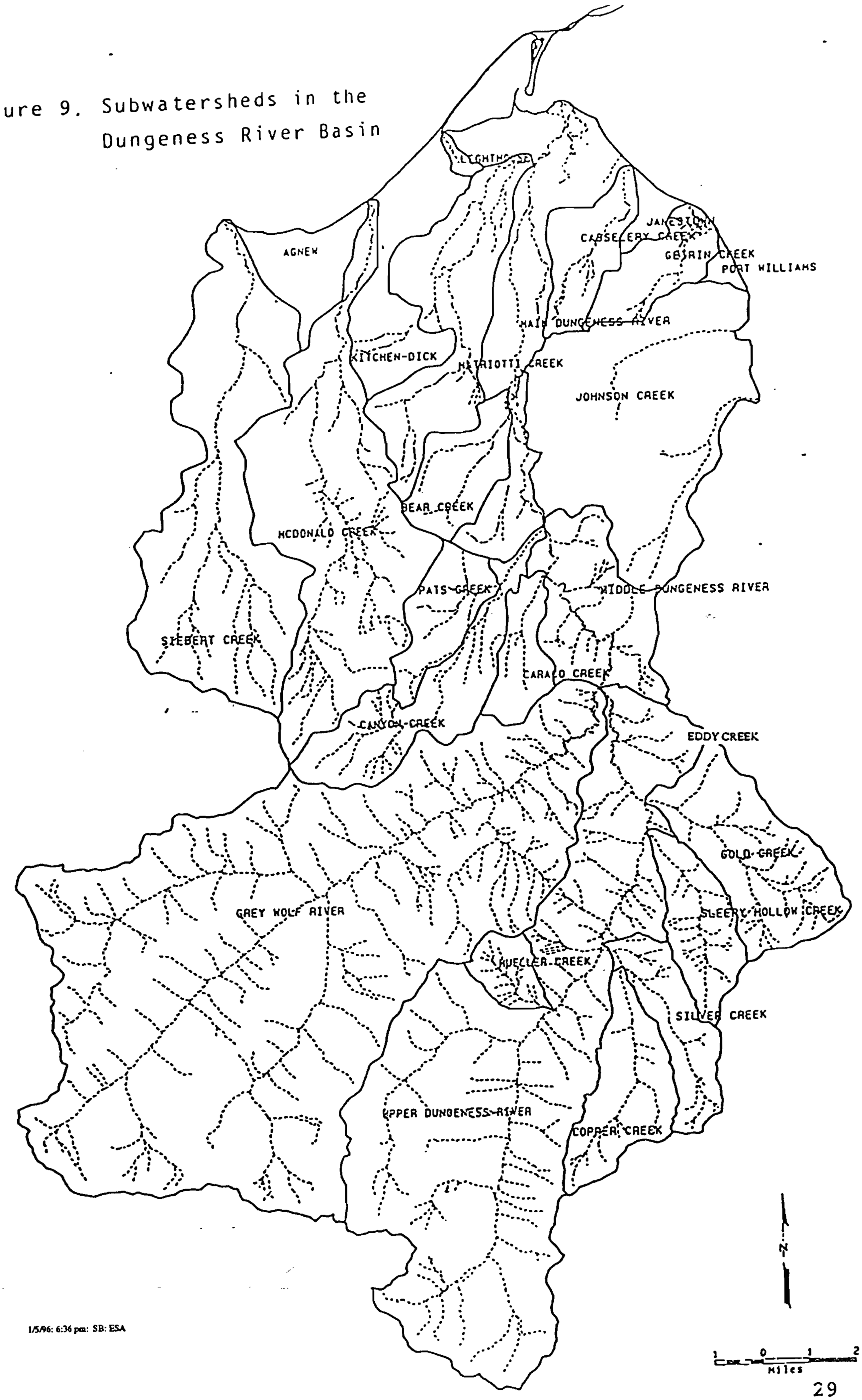


Figure 9. Subwatersheds in the Dungeness River Basin

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(2) Road construction in the upper watershed (USFS) almost doubled between 1965 and 1983 (Figure 10).

Years	Total Road (Miles)	Increase (Miles)
1949	8.3	8.3
1965	40.8	32.5
1983	76.9	36.1

Timber harvesting showed similar increase trends during this period. The Dungeness Watershed Analysis Team concluded that harvest activities with "relatively large areas of clearcut or thinning activities" were concentrated in several subwatersheds in the Dungeness Watershed. In addition, an analysis of soils in the upper watershed was conducted in order to determine which areas were more susceptible to erosion and mass wasting. Two subwatersheds were determined as most likely to have contributed significantly to the aggradation in the lower river.

The Gold Creek subwatershed was entered a total of 106 times between 1956 and 1991 with a harvest of over 2,003 acres. Of these, 30 entries were in the 1960s and 49 in the 1980s. The second subwatershed with significant harvest activity occurred north of the confluence of Gold Creek and the Dungeness River in the vicinity of Eddy Creek where 1,428 acres were clearcut in a total of 59 entries between the years 1945 and 1990. Twenty-seven entries occurred in the 1960s and 16 entries in the 1980s.

There are two things that are significant about this data for the purposes of understanding historic sources of bedload in the lower river. The first is that harvesting in both of these subwatersheds occurred most intensively in the 1960s and the 1980s - the period of record that showed the most significant channel changes at the USGS gage. The second is that watersheds underlain by glacio-lacustrine materials (Figure 11), such as these, are especially prone to deep seated failures and stream bank failures. These can occur very rapidly or in a slow creeping motion over a period of many years depending on various conditions (Dungeness Area Watershed Analysis Cooperative Team 1995).

Channelization

The series of natural events and management activities described earlier have combined to cause downstream impacts on the channel width and bed elevation. The result has been a severely aggraded river with an unstable bedload. The increasing frequency and magnitude of floods as a result of the raised riverbed have created many attempts at flood protection in the lower river, including diking and gravel excavation (Orsborn and Ralph 1994).

During the past several years between 40 - 60 gravel traps have been constructed in the river downstream of RM 10.8. There is currently much debate over the short- and long-term impacts on salmon. Bed scour and fill has been documented at and near sites of gravel mining activity in the lower 10 miles of river. Documented redd losses in 1993-94 near these mined locations suggest that hydraulic conditions at these sites attract spawners (WDF et al. 1993). In effect, gravel mining increases the amount of *marginal* habitat, i.e., unstable substrate, versus good spawning habitat and may increase the probability of low egg survival.

Existing Restoration Efforts

Restoration activities in the watershed are beginning to take a more holistic approach thanks to the years of working with the different user groups in the watershed. Due to the complexity of the

Quilcene District Roads

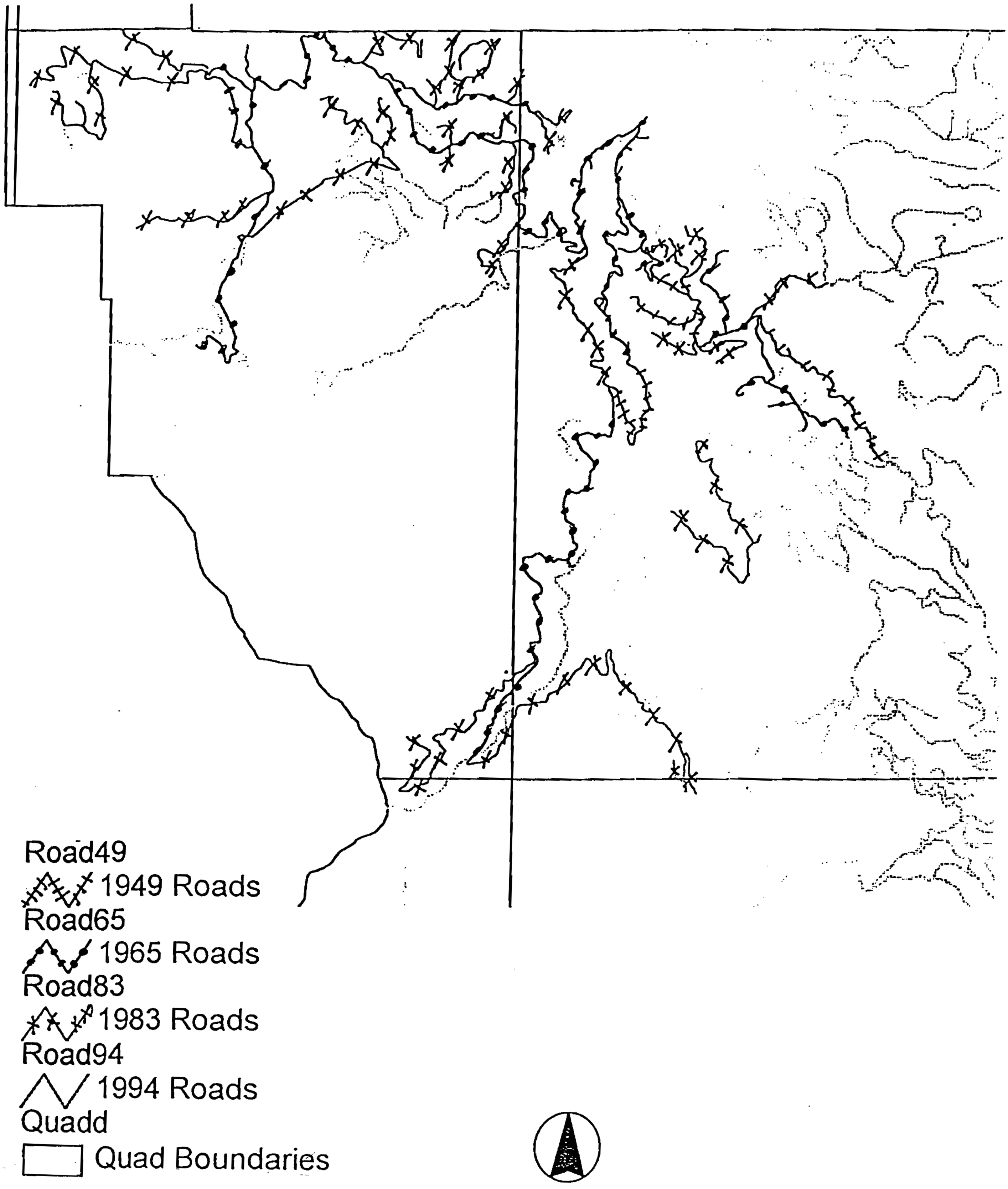


Figure 10.Description of the Quilcene road system

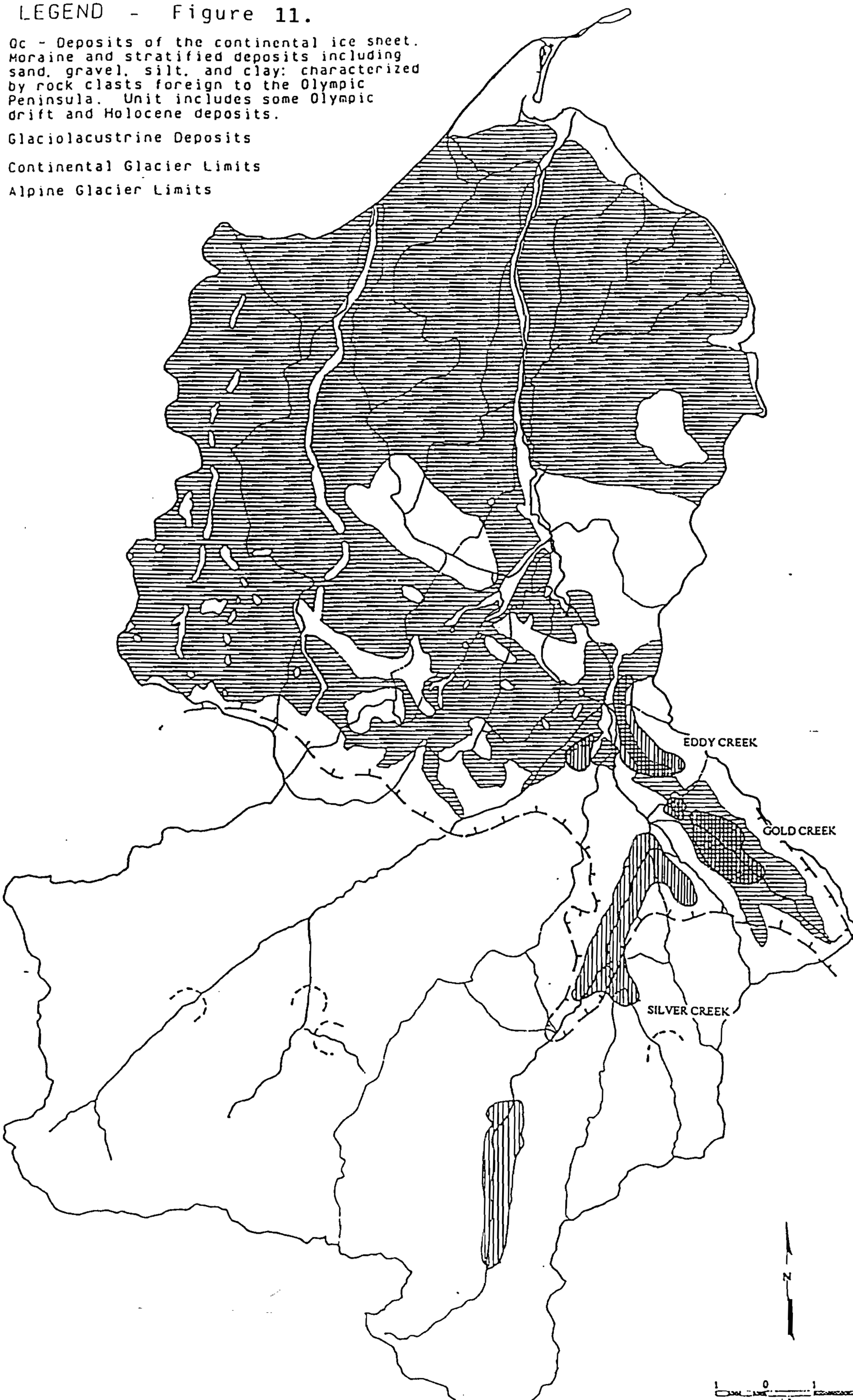
LEGEND - Figure 11.

Qc - Deposits of the continental ice sheet. Moraine and stratified deposits including sand, gravel, silt, and clay: characterized by rock clasts foreign to the Olympic Peninsula. Unit includes some Olympic drift and Holocene deposits.

Glaciolacustrine Deposits

Continental Glacier Limits

Alpine Glacier Limits



problems most restoration projects to date have been on the order of repairing irrigation intake structures or bioengineered dike structures.

For the last year a Dungeness Habitat Work Group consisting of biologists from federal, state, county and tribe have been working to complete a restoration plan. There are still many issues lacking complete agreement, i.e. gravel traps, but a strong component of all future restoration work will entail monitoring and research. This spring the first brood from the broodstock program will be released into the river. An aggressive approach to habitat restoration must be undertaken in order for that program to be successful.

The work of the Dungeness-Quilcene Water Resources Pilot Project has continued in two forums. One was the formation of the Dungeness Habitat Workgroup to develop a habitat restoration plan. The other was the formation of the Dungeness Watershed Management Committee, a cooperative effort involving local and state government officials, the Jamestown S'Klallam tribe, agricultural interests and private citizens. Its task it to balance community, and agricultural water use with maintenance of fish habitat (Smith and Wampler 1995).

Table 4. Limiting factors for the Dungeness System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine loss
Dungeness					
Ingravel	X	X	X		
Fry	X	X	X	X	X
Juvenile	X	X		X	X
Adults		X	X	X	
Gray Wolf					
Ingravel	X	X	X		
Fry	X	X	X	X	X
Juvenile	X	X		X	X
Adults		X	X	X	
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine loss**
Logging		X			
Agriculture	X	X	X		X
Urbanization	X	X	X	X	X
Water Withdrawal	X				
Flood Control				X	

Elwha River Basin - Summer/Fall Chinook

Susan Bishop and Pat Crain

Basin Overview

The Elwha River basin, located on the Olympic Peninsula in Northwest Washington, drains 321 square miles, 83% of which is located within the Olympic National Park (Figure 12). Much of the basin is therefore, essentially pristine habitat. The Elwha River is 45 miles long with over 100 miles of tributary streams. It is the fourth largest river by drainage area on the Olympic Peninsula. Precipitation in the drainage is strongly influenced by the rainshadow created by the Olympic Mountains. Annual precipitation in the upper watersheds averages 200+ inches while that of the lower drainage averages 56 inches (Dept. Interior et al. 1994).

Stock Status

Elwha summer/fall chinook is a native stock comprised of both hatchery and natural spawners which are indistinguishable from each other (WDF et al. 1993). With the exception of some out-of-basin plants from the Green River, Issaquah and Hoodsport Hatcheries were made in the late 1960's, all hatchery-reared chinook planted in the Elwha River have been of Elwha origin. At this time, the hatchery broodstock is of native origin and is augmented by continued collection from the naturally spawning populations.

Fish Utilization

Chinook spawn naturally below Elwha Dam, but returns are largely the result of production at the WDFW rearing channel and the Lower Elwha S'Klallam tribal hatchery (Dept. Interior et al. 1994). The stock is classified as healthy based on the combined escapement of natural and hatchery spawners which has met or exceeded the escapement goal each year since 1986 (WDF et al. 1993). However, in 1995, the escapement goal was not met and pre-spawning mortality of 40% further decreased the spawning population.

Critical Habitat Issues

The major habitat issues in the Elwha system are blockage of upstream migration of adults, reduction in the quality and quantity of spawning and rearing habitat, periods of lethal or sublethal water temperatures, low flows and reduction in the quality of estuarine rearing habitat (Table 5).

Dam Blockage

The Elwha and Glines Canyon dams were constructed in the early 1900's to provide power for local communities. Diashowa America's Pulp and Paper Mill in Port Angeles has been the only recipient of the power generated from the dams since the 1920's. Built without fish passage facilities, the dams effectively removed more than 70 miles of the Elwha River and its tributaries from use by salmonid species. Natural spawning is limited to the lower 4.9 miles of the river (WDF et al. 1993; Dept. Interior 1994).

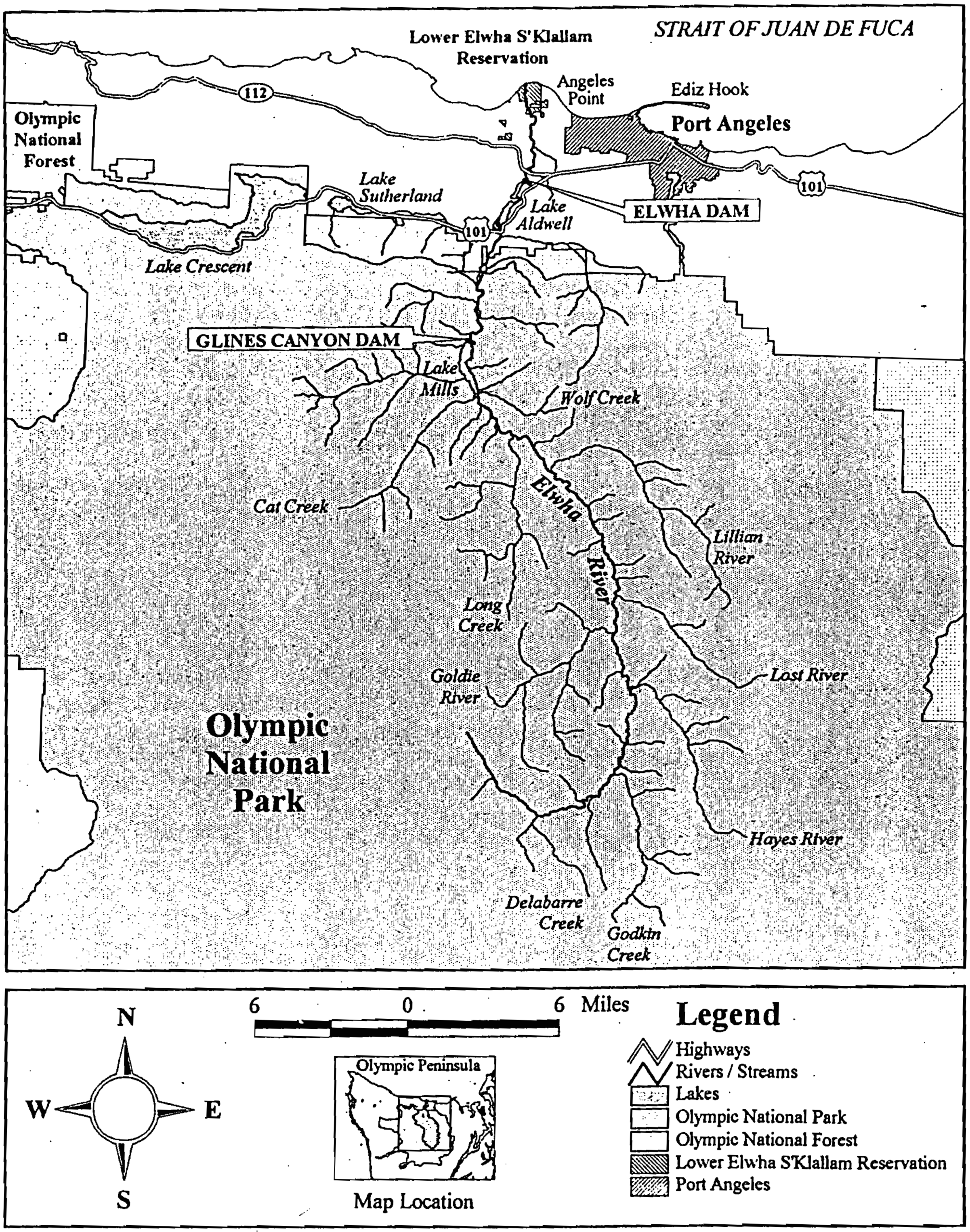
Figure 12. Map of the Elwha River system

Elwha River System

Olympic National Park

United States Department of the Interior • National Park Service

DSC • June 1995 • 149 • 20056A



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Loss of Substrate and In-stream Wood (LWD) Recruitment
The loss of recruitment of spawning and incubation substrate and woody debris has resulted in continued erosion of the stream bank, loss of riparian canopy, loss of pools and an increase in the coarseness of the spawning and rearing substrate. Females have difficulty digging redds of adequate depth in coarser substrate and tend to bury their eggs at shallower depth. Shallow redds can be more susceptable to scour and other disturbances. Loss of nutrients reduce the richness and diversity of the food available to the juveniles and fry. Loss of pools removes holding areas for adults used in migration and spawning and increases vulnerability to predators.

High Temperatures
Although impacts to water quality are considered minimal and the Department of Ecology has rated the water quality in the Elwha River as Class AA (a classification given to surface waters having "extraordinary" water quality) (Dept. Interior 1994), instream temperatures during drought years can exceed 70°F. Under excessive temperatures, the adults are more vulnerable to disease. In particular, pre-spawning mortality resulting from outbreaks of Dermocystidium has been as high as 70% of the returning adult chinook (WDF et al. 1993).

Low Flows
Current lower river flow patterns, including those in the available spawning habitat, can fluctuate depending on power needs and withdrawals for domestic and municipal use. During summer, low flows are exacerbated by water withdrawals for domestic and industrial use. Critically low flows impede upriver adult migration, reduce the amount of pool habitat, strand juveniles and dewater redds.

Although the Elwha Dam (the downstream facility) is operated at "run of the river", Lake Mills (behind the upstream dam) may be drawn down up to ten feet to meet power needs. The water storage capacity of Lake Mills is not great, but drawdown and refill periods alter the natural flow regime throughout the lower river. Historically, the dams were allowed to have even more control of the river. On more than one occasion, downstream flows were effectively reduced to zero for a period of time and it was a regular occurrence to rapidly alter flow to meet power needs. On these occasions, there are numerous reports of stranding of fry.

Estuarine Degradation
The nearshore and estuarine environment has been degraded due to loss of recruitment of sediment from the river. The shoreline has steepened and receded, landslides are more frequent and the intertidal and shallow sub-tidal zone bottom has become dominated by coarse substrate (Dept. Interior et al. 1994). The resulting loss of juvenile refugia, change in benthic communities and reduction of food resources may cause juvenile chinook to migrate to sea earlier, at smaller size and in poorer health than under healthy estuarine conditions. The loss of sheltered habitat may also increase vulnerability to predators.

<u>Causes of habitat degradation</u>
The two dams are the primary causes of habitat deterioration and decline of salmonid abundance in the Elwha basin (Dept. Interior et al. 1994)(Table 5). Besides the primary impact of blocking upstream migration, the major effects of the dams have been loss and reduction in the quality and quantity of spawning substrate below the dams, loss of nutrients and woody debris, now retained behind the dams, and elevated water temperatures (Dept. Interior et al. 1994).

High Temperatures
Increased water temperatures in the lower and middle reaches of the river in late summer and early fall result from thermal stratification in the reservoirs behind the dams, followed by spills from the warmer upper water layers (WDF et al. 1993). The heat storage effect of the dams are estimated to increase the temperature in the river below the dams by 2-4^0 C. Logging and agricultural activities conducted in the lower watershed outside the Park boundaries exacerbate the elevated water temperatures (Dept. Interior et al. 1994).

Low Flows
Water is withdrawn from the river for private, municipal, industrial and fish propagation purposes. During summer, some additional spill serves to dampen the effects of the low flow periods. However, the beneficial effects of dampening can be offset by water withdrawals for domestic and industrial uses. Up to 150 cfs are allocated for municipal use. In periods of extreme low summer flows, this could represent 75% of the flow (200cfs). Although the full allocation has never been taken, water withdrawals in some years may approach 50% of the flow.

Estuarine Degradation
The dams have been the primary source of estuarine degradation by preventing recruitment of substrate (Dept. Interior et al. 1994). It is estimated that 274,000 cubic yards of material is prevented from reaching the estuarine and nearshore marine environments each year (Nat. Park Service 1995).

Logging and agricultural activities in the lower watershed also contribute to non-point source pollution (primarily sediment input) and bank erosion (Dept. Interior et al. 1994). However, the geography of the river and regulation has restricted forestry and agricultural activities such that these impacts are minimized.

Existing Restoration Efforts
Restoration of the Elwha River is currently the subject of two EIS's being written by the Department of Interior. At issue is the evaluation of dam removal to restore access of salmon to the middle and upper reaches of the watershed. In addition, a detailed restoration plan has been developed by the Lower Elwha S'Klallam tribe, state and federal agencies (The Elwha Report). Implementation of the plan is contingent on appropriation of federal funding for dam removal. No significant recovery of the native chinook stock can be expected until this occurs and the stock will continue to rely on artificial production to maintain abundance.

Table 5. Limiting factors for Elwha River chinook habitat by life history stage

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures	Streambed Instability	Estuarine loss
Elwha R.					
Ingravel	X	X	X	X	
Fry	X	X	X	X	X
Juvenile	X		X		X
Adults	X		X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine loss**
Logging		X	X		
Agriculture		X	X		
Urbanization					
Water Withdrawals	X				
Dam Construction	X	X	X	X	X

Green/Duwamish Basin

Amy Morgan and Holly Coccoli

Basin Overview

The lower ten-mile segment of the Duwamish/Green River system from Tukwila to Elliot Bay is known as the Duwamish River (Figure 13). The rest of the river, upstream from Tukwila, is known as the Green River. The historic Duwamish River drained a 1,642 square miles watershed. The three main sub-basins, the Black, Green, and White Rivers were separated for navigation and flood control in the early 20th century (Blomberg et al. 1988). The White River was diverted by a high water event in 1906, possibly with human assistance. The Black River was drained permanently in 1916 with the construction of the Ballard Locks opening into Lake Washington. Currently the Duwamish drains only the Green River basin (483 square miles) (Figure 14). The upper drainage, heading at the crest of the Cascade Mountains near Stampede Pass, is fed by rain and snowmelt, while the lower drainage and two main tributaries, Big Soos Creek and Newaukum Creek, are fed by rain and groundwater (Grette and Salo 1986).

The present Green/Duwamish system is far from pristine. The Tacoma water diversion dam was built in 1913 between RM 60.0 and 61.0. The U.S. Army Corps of Engineers Howard Hanson Dam (HHD) was constructed at RM 64.0 in 1961. Neither dam was built with fish passage facilities, eliminating access to an estimated 107 miles of historic anadromous fish habitat. The lower floodplain, below RM 37.3, historically consisted of rapidly shifting meanders. This area is now almost completely contained within dikes, resulting in the lack of riparian cover, large woody debris, off-channel rearing areas, and reduced channel storage capacity. Flood control operations at HHD have encouraged further urban and commercial development in the floodplain. The present watershed of the Duwamish/Green represents a 93% reduction from historic levels in accessible area for anadromous fish (Blomberg et al. 1988). The lower 10 miles has been almost completely altered from its historic condition. Since 1854, the estuary has lost all of its original tidal swamp, most of its mudflats and tidal marsh for a 99% reduction in estuarine habitat. A navigation channel is maintained to provide ship access up to the Turning Basin (RM 6.2) creating deepwater habitat where none existed historically. Uplands have almost entirely been converted to industrial use. Most of the shoreline of the present estuary is vertical bulkheads, rip rap, and/or pilings (Warner and Fritz 1995).

Stock Status

(WDF et al. 1993)

The SASSI report (WDF et al. 1993) lists two summer/fall chinook stocks for this system: Duwamish/Green summer/fall chinook and Newaukum Creek summer/fall chinook. Chinook of largely Green River origin from the Green River Hatchery on Soos Creek have been widely distributed throughout Puget Sound. Hatchery origin chinook have been documented in the natural spawning populations in the Green River and Newaukum Creek. Genetic impacts from this straying are unknown. Because of straying and geographical proximity, it is possible that chinook spawning in Newaukum Creek are part of the same population as chinook spawning in the Green River. These two population are currently listed as separate stocks pending genetic analysis.

The Green/Duwamish summer/fall chinook origin is considered mixed with hatchery production at

Figure 13. Location of the Muckleshoot Indian Tribe treaty area drainage

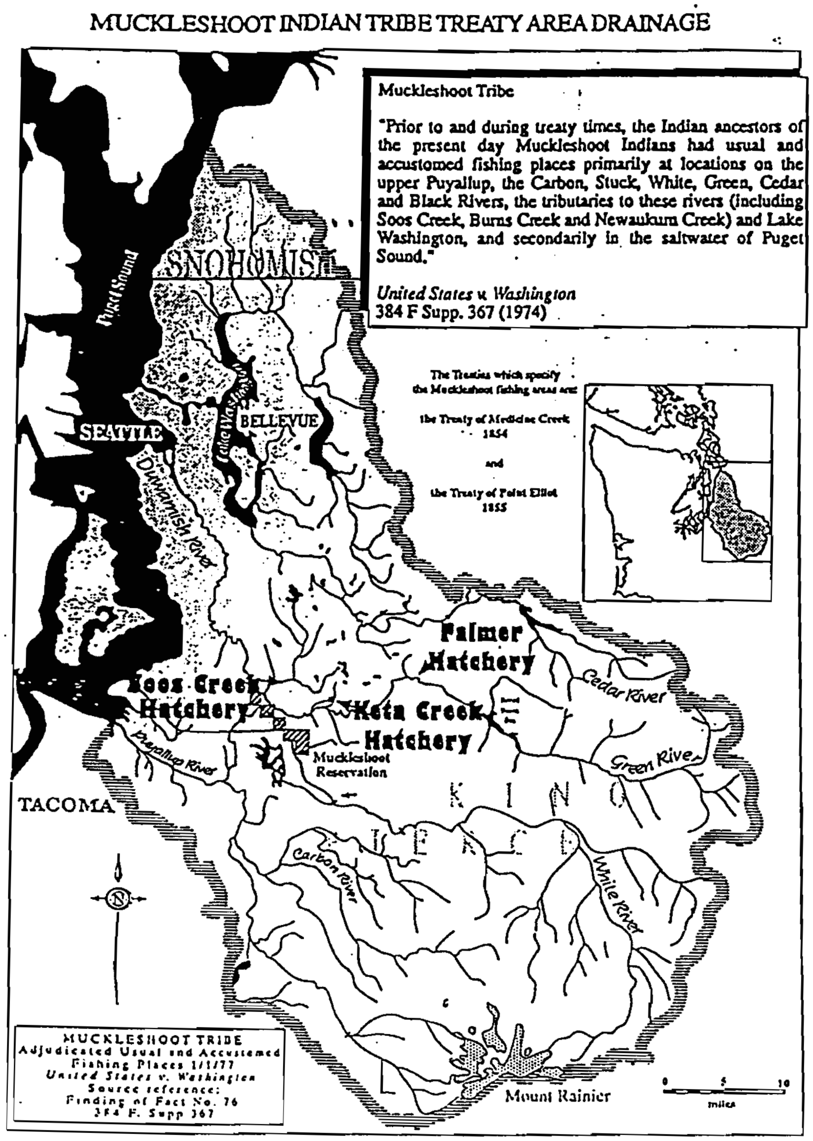

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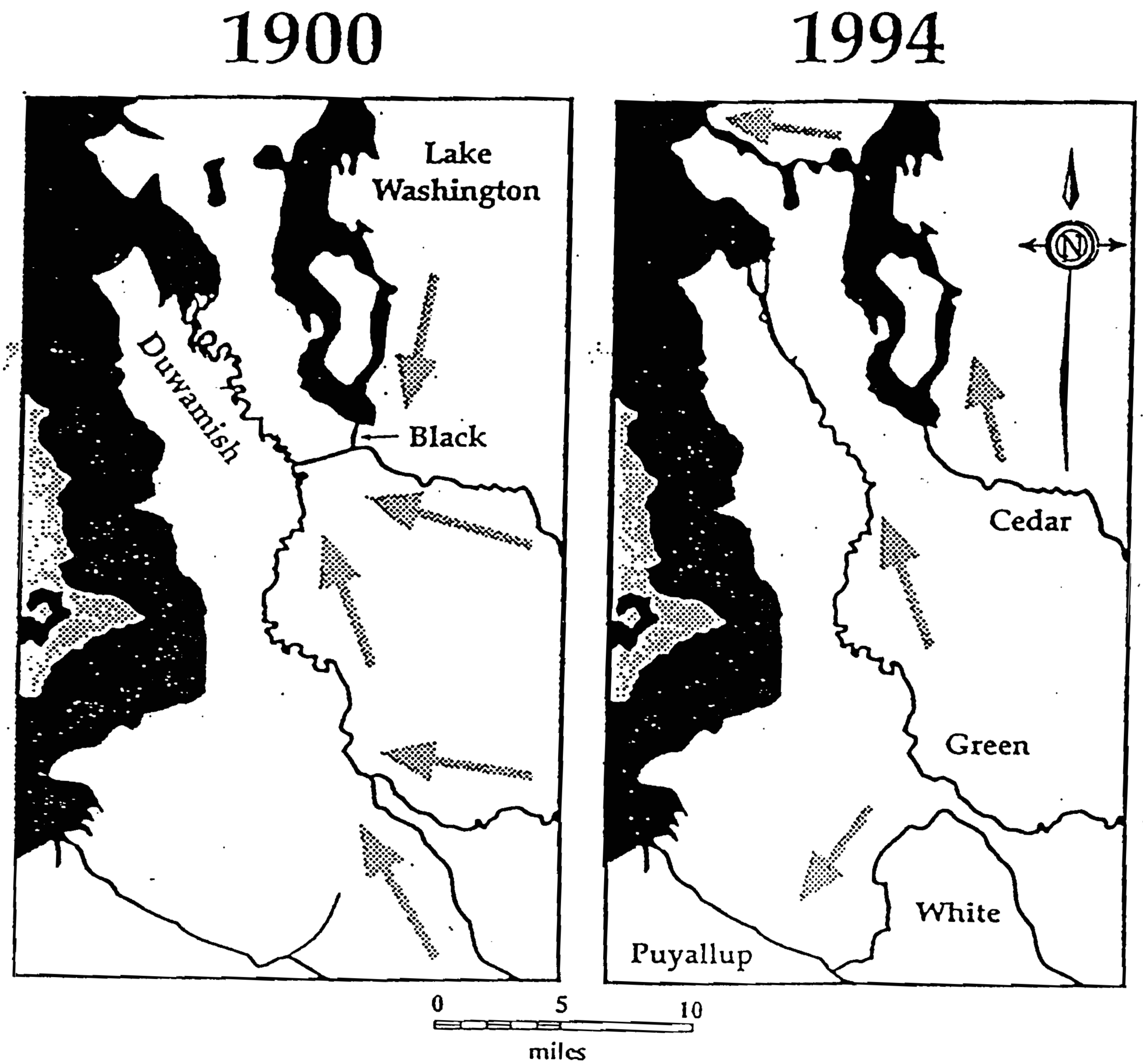
Figure 14. Change in river routes between 1910 and 1994



Soos Creek and natural spawning throughout the river. Stock status is healthy based on escapement levels. Escapement levels in the mainstem Green River range from 5,000 to 10,050 with an average of 7,600 (1987 through 1991). These counts are based upon redd counts in specified sections of the river and expanded by a factor to reflect the total spawning habitat of the river. The counts are good indicators for the surveyed areas but may not be accurate when expanded for the entire river. There has been an increasing trend in natural spawning escapement levels, but this increase may partially be due to hatchery contribution. Water temperatures and flows alter the ability of chinook to reach the hatchery rack at Soos Creek, and therefore influence the level of natural spawning below the hatchery.

The origin of Newaukum Creek summer/fall chinook is considered native with likely influence from hatchery strays whose origin is Green River Hatchery and Icy Creek. This is based on coded-wire tag recoveries in Newaukum Creek during spawning season. The status of this run is healthy based on escapement estimates. Escapement levels range from 300 to 3,000 with an average of 1,600 per year. Escapement estimates are based upon redd counts and considered very good measures of relative abundance from 1987 through 1991.

Fish Utilization

Chinook use the mainstem Green River, Big Soos Creek, and Newaukum Creek (Williams et al. 1975). They were also historically present above the City of Tacoma's diversion. Adult (fall) chinook spawn in the main river primarily between RM 24.0 and RM 61.0 (Williams et al. 1975). The two areas of heaviest spawning are RM 29.6 to 47.0 and RM 56.0 to 61.0 (Grette and Salo 1986). Spawn timing for Newaukum Creek summer/fall chinook peaks in October. Green/Duwamish summer/fall chinook spawn from mid-September through October.

Critical Habitat Issues

The habitat issues described below are summarized in Table 6.

Passage blocked

Passage for migrating adult chinook salmon above Tacoma Diversion Dam has been blocked since 1913. This accounts for a loss of 107 miles of historic anadromous habitat.

HHD affects outmigration of juvenile salmonids at RM 63.5. Direct mortality and injury occur at dam outlets. The in-reservoir delay during spring refill of reservoir increases mortality of outmigrating smolts. This currently affects only hatchery chinook, but would also affect restored wild runs.

Reduced flows

Reduced mainstem instream flows year round and during spring due to COE reservoir operations and water diversion from City of Tacoma can affect all life stages.

The basin has been affected by ground and surface water development with stream flow declines in tributaries and instream flows levels not being met in the mainstem (Green/Duwamish Basin Draft Watershed Assessment, DOE 1995).

Estuarine Loss
Nearly total loss of estuarine rearing habitat due to industrialization and urbanization at Elliot Bay.

High water temperatures
High temperatures in mainstem Green River, especially below RM 30 have been aggravated by urbanization changes in the riparian corridor.

Sediment
The high proportion of private timberlands in the upper watershed with very intense timber harvest and high road densities leads to especially poor habitat (e.g., a decrease in the number of pools in the upper areas) and water quality conditions due to forest practices. Washington DNR classifies less than 50% of the basin in large dense timber stands as of July 1993.

The lower river has been channelized and the banks hardened with rip-rap resulting in a loss of pools in the lower reaches, thus depriving the adults of holding areas in the lower river.

Riparian vegetation loss
Riparian habitat loss and degradation due to private landowners, urbanization, and flood control projects clearing riparian vegetation and limiting instream LWD.

Existing Restoration Efforts
About 20 acres of habitat has been or is being restored in the estuary under NRDA- Superfund or other programs.

An instream flow agreement has been reached between the Muckleshoot Tribe and the Tacoma Water Division resulting in restrictions on new water diversion and additional flow augmentation during late summer rearing and spawning, in conjunction with a planned water project. Tacoma has agreed to fund construction of a fish restoration facility to help reestablish anadromous fish to the upper watershed at the time of water project construction.

A major feasibility study is being conducted by the Corps of Engineers and Tacoma Water to significantly increase springtime reservoir storage and improve downstream fish passage at HHD, however, the fisheries benefit of this project are highly questionable due to the in-reservoir delay problems and downstream/estuarine effects of flow reductions during spring caused by the proposed increased storage.

Table 6. Limiting factors for the Green/Duwamish System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine Loss
Green					
Ingravel	X	X		X	
Fry	X	X	X	X	X
Juvenile	X	X			X
Adults	X	X	X		
Newaukum					
Ingravel	X	X		X	
Fry	X	X	X	X	X
Juvenile	X	X			X
Adults	X	X	X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine loss**
Logging		X		X	
Urbanization	X		X	X	X
Water Withdrawal	X				
Flood Control	X		X	X	

Hoh River Basin

Amy Morgan

Basin Overview

The Hoh River is formed by a number of small tributaries which head in the high slopes of the Bailey Range and the north slope of Mount Olympus (Figure 15). The source of the mainstem Hoh as well as a number of its upper tributaries are glaciers located in the high altitude portions of these mountains. Upper reaches are primarily confined in steep ravines and canyons. A number of braided channel areas are located in the broad gravel flood plain. Many reaches of the Hoh River are subject to continual streambed scouring and movement during the winter months. The mid-section consists of unstable channels meandering over a broad gravel floodplain. Lower mainstem Hoh evidences its channel instability by several areas where channel changes are common (Williams et al. 1975).

Land ownership in the basin ranges from the Olympic National Park (approximately 65% of the basin) for the headwaters and upper South Fork through the state owned timberlands along 5 miles of the South Fork. The mid-section has farm residences, a large public campground, and timber production lands. The lower mainstem runs through the Hoh Indian Reservation.

Stock Status

The SASSI report (WDF et al. 1993) lists one stock of spring/summer chinook for the Hoh River system. These fish are considered to be native origin, wild production, and healthy status. There is also one fall chinook stock listed for the Hoh system. They are listed as native origin, wild production, and healthy status. There is however, **considerable concern** about the future of the stock as a **result of significant recent habitat degradation.**

Fish Utilization

(WDF et al. 1993)

The spring/summer chinook begin entering the system in late April and continue through August. Spring/summer chinook spawning is believed to begin simultaneously in the upper reaches of the South Fork and mainstem in mid-August. Spawning activity starts progressively later as one moves downstream. Spawning at the convergence of the mainstem and South Fork begins approximately mid-September. Spawning in some larger or upper river spring-fed tributaries usually occurs only in conjunction with large and early freshets. Spawning overlap with fall chinook occurs from mainstem RM 15.0 through the first three miles above the confluence with the South Fork.

Fall chinook enter the river beginning in early September and continue through mid-November. Spawning begins after mid-October and continues through late December. They spawn in both the mainstem and larger tributary areas. Spawning occurs from RM 3.0 in the mainstem upstream to the lower three miles of the mainstem and south fork. As with spring/summer chinook spawning moves progressively down stream over time. Spawning overlaps with spring/summer chinook occur upstream of mainstem RM 15 (WDF et al. 1993).

Critical Habitat Issues

The Hoh system's primary issues related to chinook habitat degradation are all associated with the effects of forest practices in this steep sloped watershed. Increased sediment input has increased streambed instability, filled pools, increased fine sediment levels, and decreased the macroinvertebrate population (Table 7).

Sediment

Clearcutting and associated roading activities on steep slopes in the Huelsdonk Ridge area (RM 26.5 to 30 on the mainstem and RM 0.0 to 7.0 on South Fork) have led to an increase in landslides of 6 to 7 times the historical levels (Schlichte 1991). This greatly increased level of sediment input has caused several changes that have adversely influenced productivity of fish habitat (Logan et al. 1991).

The spawning gravels of landslide affected tributaries and side channels showed significantly higher levels of fine sediments (Hatten 1991).

Roading activities were shown to have contributed to 27% of the slope failures between 1981-1990 while 63% were in clearcut harvest units (Schlichte 1991).

In tributary streams of unaffected areas (within the Olympic National Park) macroinvertebrate populations were 75% greater than in the debris torrent affected streams (McHenry 1991).

Existing Restoration Efforts

Washington DNR has prepared alternative management practices through the Huelsdonk Ridge/Hoh River Slope Stability Task Force. Although these actions may prevent future increases in slope failures, it is not known how long the affected fish habitat will take to recover from the past decade's debris torrents.

Table 7. Limiting factors for the Hoh System by life history stage.

Stream or River/ Life History Stage	Sedimentation	Streambed Instability
Hoh		
Ingravel	X	X
Fry	X	X
Juvenile	X	
Adults	X	
Activity	**Sedimentation**	**Streambed Instability**
Logging	X	X

Hoko River Basin - Fall Chinook

Susan Bishop, Ned Currence and Mike McHenry

Basin Overview

The Hoko River watershed comprises 71.9 mi^2, and drains into the Strait of Juan de Fuca on the northwestern Olympic Peninsula (Figure 16). The mainstem to RM 22 and the lower portions of the chinook tributaries are low gradient and have abundant spawning gravels. Bankfull widths in the lower mainstem are 35-40 meters. The geology is composed of alluvium and glacial deposits, the Twin River formation (mudstones, siltstones and sandstones), and the Crescent formation (low grade basalts). Low flows commonly reach a low of 13-18 cfs in Sept. and Oct, and intense fall storms generate flows as high as 14,000 cfs (USGS data). The Little Hoko River is the largest tributary (11.5 mi^2) to the Hoko and contains approximately 20% of the available spawning habitat.

The basin is almost entirely managed for timber production (mostly private with some State ownership), and many areas are being harvested for the second time. Until recently no riparian trees were left. Timber stand age classes were as follows in 1992: 15.8% <10 yrs. old, 10.0% 10-20 yrs., 30.6% 21-40 yrs., 38.3% 41-80 yrs., and 5.3% >80 yrs (McHenry et al. 1994).

Stock Status

The Salmon and Steelhead Stock Inventory (SASSI) (WDF et al. 1993) classifies the Hoko stock as native with primarily native spawning. The stock is classified as depressed based on escapement estimates which are stable, but have failed to consistently meet the escapement goal since 1981 (WDF et al. 1993). Broodstocking efforts by the Makah Tribe since 1982 have resulted in hatchery supplementation of this stock and the overall numbers of returning adults appears to have increased in response to this program. Freshwater habitat degradation has been hypothesized as contributing to limitations on natural production.

Fish Utilization

Hoko chinook typically enter the river in late August and September. During low flow years spawning is concentrated in the mainstem between RM 1.5 to RM 10.2. Falls at RM 10.2 usually impede upstream passage. Brownes Creek enters at RM 10.1, and almost always has spawning activity. In high flow years spawning is more widespread and includes the mainstem from RM 10.2 RM 22 and the upper tributaries. In 1995 chinook spawned to RM 21.3, and in Herman and Bear creeks (9 and 7 redds respectively). Ellis Creek was not surveyed, but is also considered suitable. Only the lower 4 miles of the Little Hoko is generally accessible to salmonids due to falls which prevent upstream passage (Williams et al. 1975). Few chinook (< 10/year) were observed historically utilizing the tributary because of the shallow nature of the lower reaches. However, substantial spawning occurred in 1995 to RM 3.0 (48 redds), and one redd was also recorded in Leyh Creek.

Critical Habitat Issues

Habitat issues in the Hoko system include reduction in the quality and quantity of spawning and rearing habitat from sedimentation and loss of pools, and periods of lethal or sublethal water temperatures (Table 8).

Sedimentation and Stream Instability

The greatest habitat impacts have been from bedload instability due to mass wasting events, and removal of riparian canopy and large woody debris. Bedload scour and fill, and moderate to high levels of fine sediments (14.27% on average (McHenry et al. 1994) have been recorded in the early 1990's. Naiman et al. (1992) mapped the Hoko drainage within the most intense flood region zone for Western Washington. The timing of the intense annual peak flow events during the period of chinook incubation has maximized the effect of increased scour on egg mortality. For example, the 1995 major flooding occurred shortly after chinook spawning ended. In years when flows permit broader geographic redd deposition into tributaries and above the falls, later scour-related mortality may not be so severe.

McHenry et al. (1994) attempted to correlate coho and steelhead survival to emergence with fine sediment levels in the Hoko and Pysht drainages, placing fertilized eggs in egg baskets at a depth of 25-35 cm. Egg baskets in the Hoko were lost over a three year period to bedload movement, including those placed in several chinook spawning areas. The baskets placed in the mainstem in the pilot study at RM 15.7 (one of the least confined areas) experienced 100% loss. The authors then concluded that the mainstem was too unstable to expect to retrieve the baskets, so it was abandoned. Additionally 80% and 40% egg basket loss was experienced in the Little Hoko River (RM 1.4), 28% loss in lower Herman Creek, and 40% loss in lower Bear Creek.

Scour associated with channelization and woody debris removal has also increased channel downcutting, resulting in a loss of off-channel rearing habitat (Pentec 1995). Significant reductions in large woody debris have allowed sediment which otherwise might have been retained to scour. This has resulted in redd loss and burial with subsequent increases in egg and juvenile mortality.

There have been 330 distinct mass wasting events recorded from aerial photographs between 1953 and 1993 (Pentec, 1995). One hundred and forty-one of these mass wasting events occurred between 1981 and 1993. Seventy percent of the landslides deposited directly into channels enabling routing downstream. Increases in stored sediment (bar area), and channel widening were evident from aerial photograph interpretation on the mainstem and the Little Hoko in the 1960's and 1970's, but declines began in the 1970's and 1980's (Pentec 1995). Fine sediment levels (<0.85mm) are moderate to high in the Hoko basin (14.3% avg.), and in the mainstem below the falls, the three sites averaged 15.6% fine sediment (McHenry et al. 1994). Levels above 12% have been correlated with reduced egg to emergence survival for salmonids (Peterson et al. 1992). Rearing is also likely affected by high turbidity, including the ability to see to feed. The Hoko is now the last stream to clear along the Strait after moderate to intensive rain events. Altered channel conditions in the lower reaches of the Little Hoko has impeded upstream migration of adults.

Loss of Large Woody Debris

Instream LWD is very low in the Hoko, and also appears to be rapidly diminishing with recruitment from mature second growth failing to offset the loss of LWD associated with old growth. Amounts of LWD were below target conditions at 21 of 22 monitored sites (Pentec 1995). Piece counts averaged 0.67 per channel width for the basin (Pentec 1995), compared with a target of 2-4 pieces per channels width. The three sites in the mainstem below RM 15.7 where the majority of chinook spawn, are almost devoid of LWD (0.17 pieces/cw). In 1993, Peninsula Tribes re-measured LWD volume at 28 sites previously measured in 1982 on the Olympic Peninsula. The four Hoko sites were the mainstem Hoko, and Bear, Ellis, and Cub creeks. These sites lost an average of 39% of the LWD volume over this eleven year period, and 46% of the old growth derived volume (McHenry et al. in prep). By 1983 the Hoko site LWD volumes were only 27% of the uncut reference site volumes on the Peninsula.

Stump measurements from eight sites in the Hoko demonstrate that original riparian canopies were large to very large conifers (up to 10 ft DBH), but now 91% of the Hoko riparian areas are alder dominated (Pentec 1995). This conversion of large conifers to small alders has resulted in very poor future LWD recruitment potential, since alder is incapable of ever attaining the necessary size to function effectively in large channels including those where chinook spawn and rear. Alder is easily mobilized, brittle, and rapidly decomposes (Bisson et al. 1987; Murphy and Meehan 1991). Only large conifer pieces will remain over a period of years to function effectively in the larger chinook spawning and rearing channels of the Hoko (Pentec 1995). Pentec (1995) concluded that in the Hoko "LWD appears to be fundamentally important in reducing all forms of egg pocket scour and burial", because it provides channel stability and stores sediment.

Loss of Pool Habitat
Reduction in the amount of pool habitat available for holding and protection from predators has resulted primarily from an extreme shortage of instream woody debris. Pools have comprised less than 37 percent of the measured habitat areas. Gravel aggradation has contributed to the documented reduction of the quantity and quality of pool habitat.

Despite the low amount of instream wood, it still forms 65% of the pools in the Hoko, and live tree roots form another 26% of pools (Pentec 1995). However, both the quantity and quality of the pools is impaired by reduced depth and woody cover. The loss of pool area is particularly acute in the mainstem below the falls where the majority of chinook spawning and rearing occurs. The two sites below the falls had only 9% and 14% pool area, compared with the target of 50% pools (Pentec 1995).

High Temperatures
Sublethal to lethal instream temperatures (high 60's and low 70's °F) have been recorded in the mainstem and Little Hoko River in recent years (WDF et al. 1993). The younger, deciduous characteristics of many of the areas in the system, provide less cover than older growth, conifer dominated areas (Pentec 1995). Canopy cover in 74% of the monitored stream sites failed to provide enough shade to meet the State Water Quality Standards for Class AA drainages (instream temperature threshold of 16° C) (Pentec 1995). Elevated late winter and spring temperatures may result in increased egg and juvenile mortality by shifting egg emergence timing and smolt outmigration timing earlier. The former increases susceptibility of earlier emerging fry to loss during late winter freshets. The smaller size of these juveniles and reduced food sources earlier in the year may lead to reduced freshwater and marine survival (Hartman et al. 1987). Elevated summer temperatures may stress and impede upstream migration for adults which hold in the lower reaches of the river, but the data is inconclusive at this time.

Causes of habitat degradation

Impacts to the Hoko drainage have been due to historic patterns of land use such as historic logging practices, debris removal, conversion of riparian forests to pasture.

Sedimentation

Logging practices have had the greatest impact on the Hoko River drainage. Virtually the entire drainage was originally harvested to the streambank and much of the drainage is currently being harvested for the second time (WDF et al. 1993). Of the 330 mass-wasting events mentioned previously, 40% were associated with roads, 55% were associated with clearcuts and 5% with natural processes in old growth.

With regard to agriculture, the grazed area is small, but it is adjacent to the lower mainstem channel where adults hold in late summer, as well as along the lower Little Hoko. This area has recently been replanted and fenced by the Lower Elwha Tribe. The lower Little Hoko River valley was recently purchased by Washington Parks and Recreation Department.

Loss of LWD

Forestry, cedar salvaging, road building, agriculture, flood control cleanouts, fish passage improvements and other activities, have reduced or removed the riparian canopy and in-channel large woody debris. Logging activities have also reduced the large conifers which provide better shading and protects against elevated temperatures. From about 1917-1923 logs were transported down the mainstem during winter storms below roughly RM 6.5 (Pentec 1995). This required channel and estuary clearing of boulders and wood. The lower two miles of the Little Hoko River channel was cleared of wood and probably diked in 1937, and one channel response was downcutting 4-5 feet into its floodplain (Pentec 1995). Logjam removal and other instream wood removal was conducted throughout the drainage into the 1970's (Williams et al. 1975). Early railroad logging also occurred. Some of the old deep fill crossings of draws have failed. The basin road density is 2.5 mi/mi^2 (McHenry et al. 1994).

This has led to a shortage of in-channel wood throughout the Hoko drainage, most of which is either small alder which rapidly decomposes and is highly mobile, or decaying residual old growth wood (WDF et al. 1993; Pentec 1995). Associated lack of conifer reforestation and road building adjacent to streams have severely reduced recruitment of large woody debris in recent years (Pentec 1995) which is instrumental in maintaining pool habitat.

Flows and Temperature

The infiltration gallery on the mainstem at RM 4 serves as the water supply for the towns of Clallam Bay, Sekiu, and the Clallam Bay Correction Center. When pumping, the current rate is 200 or 400 gallons per minute depending on demand (4-8% of the lowest recorded flow). About 50% of the approved water withdrawal permit quantity is currently utilized. Periods of low flows can correspond with the peak chinook spawning period and withdrawals could be exacerbating the temperature problems in the mainstem, which commonly reach 60-70 degrees F. (Currence and McHenry unpublished data).

Current Habitat Restoration Efforts

For the past 18 months, the Lower Elwha Tribe has been conducting extensive restoration activities in the Little Hoko River to RM 2.7. In-stream channel improvements include woody debris and boulder placement to re-establish a low flow thalweg providing low flow migration routes, stabilize the bed, and increase pool area, depth and cover. Off-channel areas were excavated, primarily to develop overwintering habitat for coho. Cows have been fenced out of the riparian area, and revegetation with natural species was conducted. The improvements appear to be successful, and beneficial for chinook. In 1995, 48 chinook redds were observed in the Little Hoko, 10 times the density previously observed, and one was observed in Leyh Creek. These redds were well distributed throughout the system.

Table 8. Limiting factors for Hoko River chinook habitat by life history stage

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures	Streambed Instability	Estuarine loss/impacts
Hoko River					
Ingravel	X	X	X	X	
Fry	X	X	X	X	
Juvenile		X	X	X	X
Adults	X	X	X		X
Little Hoko					
Ingravel	X	X	X	X	
Fry	X	X	X	X	
Juvenile		X	X	X	
Adults	X	X	X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures /Riparian canopy loss**	**Streambed Instability**	**Estuarine loss/impacts**
Logging	X	X	X	X	X
Agriculture		X	X	X	X
Water Withdrawals	X		X		
Flood Control	X	X	X	X	

Nooksack River Basin - Native Chinook

Dan Neff, Richard Vanderhorst and Susan Bishop

Basin Overview

The Nooksack river basin is located in northwestern Washington state on the west side of the North Cascade mountain range and just south of the British Columbia border (Figure 17). In the U.S., the basin lies principally in Whatcom County with portions in Skagit County. The Nooksack River drains approximately 830 square miles. Its mouth, prior to 1860 was in Lummi Bay (Lummi Reservation) which likely provided very important estuarine habitat for chinook. Log jams diverted the mouth to Bellingham Bay from time to time and in 1860 a dam was built to block the exit through Lummi River (Deardorff 1992) thus making the Bellingham Bay mouth permanent. The river has three major forks: North, South and Middle. The confluence of the South Fork and mainstem occurs at RM 36.7 and the confluence of the North and Middle Forks occurs at RM 40. Besides Nooksack Falls, a diversion dam at RM 7.1 on the Middle Fork blocks anadromy (Williams et al. 1975), although from time to time there are anecdotal reports of adult salmon above the dam. On the South Fork, a falls-cascade partially blocks anadromy at RM 25 (Williams et al. 1975) and RM 30.4.

The headwaters of the North and Middle Forks arise in the glaciers on Mount Baker. Stream flow patterns in the North and Middle Fork are influenced by precipitation and mid-summer glacial and snow melt, characteristic of its higher elevation. Low flows, particularly in the summer, are maintained by the run-off from glaciers and snow-fields. Reduced visibility related to glacial origin, particularly in the North Fork, has greatly impeded the observation and quantification of chinook freshwater habitats and life history functions. The South Fork arises on Twin Mountain and is lower in elevation and gradient than the other two forks. Since the South Fork lacks the glaciers found in the watersheds of the North and Middle Forks, flow is precipitation driven. Peak flows primarily reflect winter storm events and spring snow melt (Schuett-Hames et al 1988) which typically occur from November through March.

Stream flow in both the North and South Forks is at its lowest by mid-summer, exacerbated by water withdrawals for agricultural, urban and industrial uses. These forks exhibit extensive stream braiding and channel instability. More than three-fourths of the streams were ranked unstable (WDF et al. 1993).

Stock Status

Two native Nooksack chinook stocks are identified in the Salmon and Steelhead Stock Inventory and are defined as critical based on assumed declines in escapement (WDF et al. 1993). The two stocks are distinguished based on spawn timing and location. Principal chinook spawning occurs above RM 45 and in larger tributaries of the North Fork, and below RM 30.4 in the South Fork (WDF et al. 1993). Nooksack Falls at RM 65 on the North Fork is a total block to anadromy (Williams et al. 1975). Early chinook observed spawning in the Middle Fork are presumed to be North Fork chinook although genetic samples from these fish have not been taken. North Fork chinook spawn two to three weeks earlier than South Fork chinook, and the native stocks return earlier than the hatchery fall stocks. Supplementation and egg banking have been used as attempts to recover both the North and

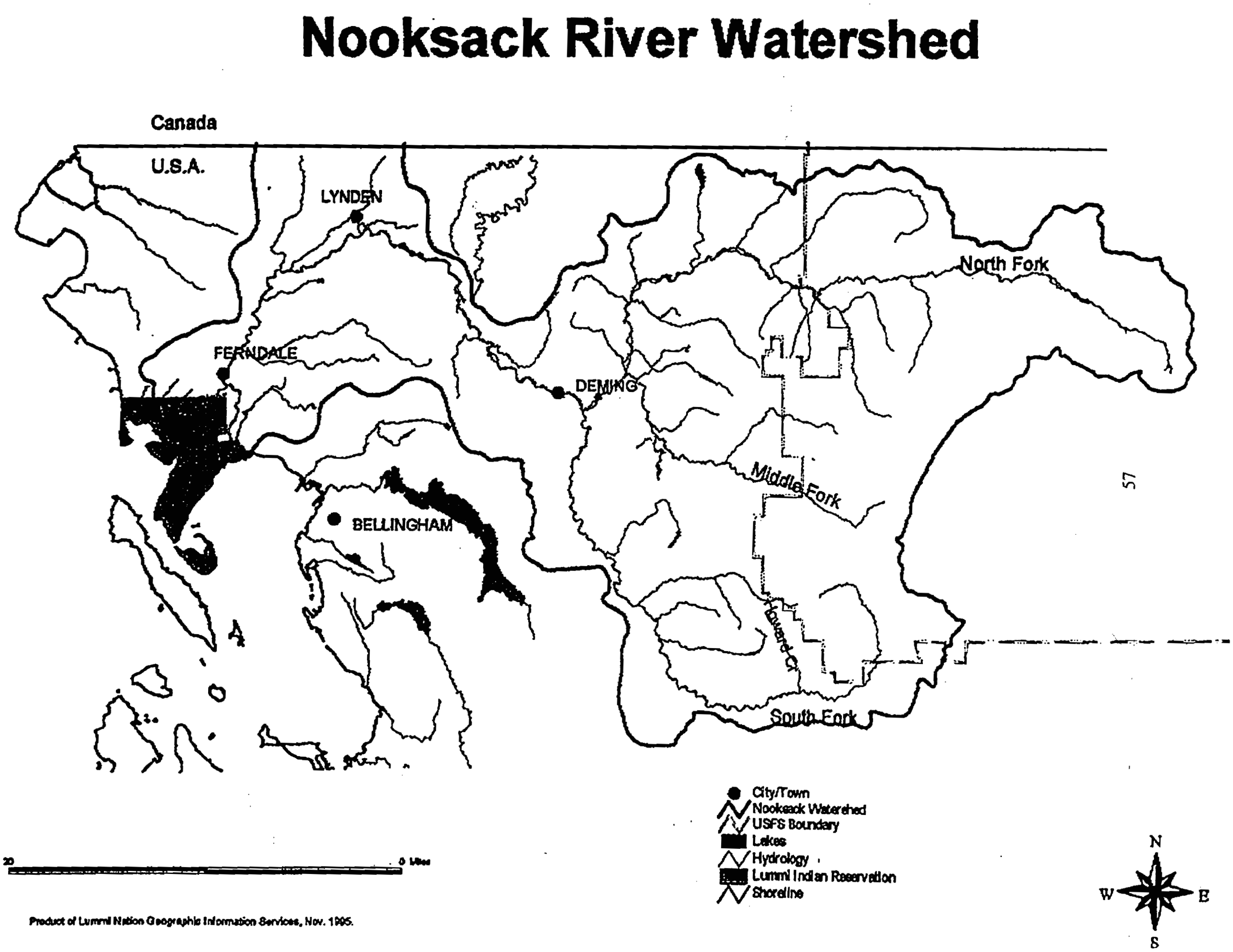


Figure 17. Location of the Nooksack River watershed

South Fork stocks since about 1980. Due to continued declines in the return of South Fork chinook supplementation, efforts were discontinued in 1992 in order to evaluate the practice. North Fork chinook brood stock seem to be responding favorably to supplementation and the use of acclimation ponds.

Comparison of mainstem spawning surveys from the North Fork done in the 1940's with those from the 1980's show that the location of the primary spawning areas is similar, However, of the six historically significant tributaries used by spring chinook, only one appeared to have habitat conditions conducive to chinook spawning and intergravel survival in 1986 (Schuett-Hames and Schuett-Hames 1987).

Critical Habitat Issues

Stream instability is widespread and is the most important factor affecting chinook productivity in the Nooksack (Schuett-Hames and Schuett-Hames 1984) and is recognized as the dominant habitat problem in current draft regional plan policy goals at Lummi Nation (1995) (Table 9). The most significant problems in the downstream areas are a lack of holding pools for upstream migrants, loss of side-channel rearing for fry, blockage of the Lummi River which prevents juveniles from rearing in Lummi Bay and sedimentation of the nearshore estuary in Bellingham Bay (WDF et al. 1993). Schuett-Hames et al. (1988) concluded that the quantity of holding and spawning habitat in the South Fork of the Nooksack River was not limiting for the small numbers of chinook observed at the time (1986), but that both holding and spawning habitat were of poor quality and would likely be limiting for recovering populations.

Channel Instability and Sedimentation

Channel instability results in scour and deposition of gravels, bedload movement and channel shifting, especially during high water events. Flood events in 1989, 1990 and 1995, all produced increased channel bifurcation and lateral migration. Channel movement and braiding mainly takes place during periods of spawning and incubation and therefore, is suspected to cause extensive destruction of redds and egg mortality (Nooksack Spring Chinook Technical Group, 1987; Schuett-Hames and Schuett-Hames 1987; Neff 1992). In one study to evaluate redd survival 37% of the redds studies were lost due to channel instability. Loss would be expected to be higher in years of increased number or intensity of storm events (Schuett-Hames et al. 1988). In the South Fork, problems associated with instability are concentrated in RM 19.0 to RM 30.4 which includes the area of greatest chinook spawning activity (WDF et al. 1993). In the North Fork, the most extensive stream braiding is from Glacier Creek to the confluence with the South Fork and in Canyon, Racehorse and Boulder Creeks.

Spawning gravel samples indicate sedimentation levels in the North Fork Nooksack basin sufficient to reduce egg and alevin survival due to lack of adequate oxygen exchange and entombment (Schuett-Hames 1984; Nooksack Spring Chinook Technical Group 1987; Schuett-Hames et al. 1988). A study of the Howard Creek watershed (PEAK Northwest 1986), a major tributary of the South Fork, concluded that many of the inner gorge landslides included high percentages of sand and silt. Schuett-Hames et al. (1988) indicated that many landslides transported high levels of fine sediments directly into the primary spawning areas.

Turbidity results from the excessive suspension of fine sediment. In the North and Middle Forks, it is primarily the result of the glacial origin of these waters. Turbidity samples taken in the South Fork indicate levels that are sufficient to cause avoidance behavior in adults and impede feeding behavior of juveniles, stunting growth and causing additional mortality (Schuett-Hames et al. 1988; Neff 1993a). Conversely, deposition of coarse sediment can also make spawning habitat unsuitable. Females are unable to bury eggs to sufficient depths because of the difficulty in excavating redds in such coarse substrate. Excessive deposition of coarse sediment has also reduced or eliminated holding pools for adults and generally reduced water flow to such an extent that upstream movement is impeded (Schuett-Hames and Schuett-Hames 1987).

Loss of Pool Habitat

A loss of both quantity and quality of adult holding pools is a potential limiting factor for spring chinook (Nooksack Spring Chinook Technical Group, 1987). Based on data collected in 1986, Schuett-Hames et al (1988) identified the loss of depth in pools used by adult salmon for holding prior to spawning to be a major problem, particularly in the South Fork. Loss of both the number and quality of holding pools was identified as a potential limiting factor in the South Fork (Nooksack Spring Chinook Technical Group 1987).

The filling of pools by excess sediment is further exacerbated by a reduction in the amount of available large woody debris (LWD) as old growth forests in the Nooksack Basin disappear. LWD is important for stabilizing pools, creating cover and increasing depth. Examination of scales on carcasses of South Fork chinook has prompted WDFW biologists to conclude that, in some years, a significant proportion of South Fork chinook are stream-type outmigrants, in contrast to other Puget Sound chinook stocks (WDFW 1995). If this is so, loss of holding pools and reduction in depth, as is the case for the South Fork, would also be especially detrimental to fry and fingerling production. A lack of functioning LWD for cover also affects adult chinook. Nooksack native chinook enter the river in May and June and hold in the river until they spawn in late August and early September. This long freshwater-holding period makes the adults vulnerable to poaching and predation where cover is lacking.

High Temperatures

For adult salmon the loss of pool depth translates to warmer summer temperatures making the shallower pools unsuitable for holding. In recent years, water temperatures at or above lethal levels (up to 75° (Neff 1993a,1993b)) have been recorded in the South Fork for salmonids during adult migration and spawning. The elevated pool temperatures are likely due to greater irradiation/unit volume of water, increased surface area/unit volume of water as channels have widened and shallowed and to a reduction in the input of ground water to the stream. However, none of these factors has been fully evaluated. Lack of riparian canopy and the generally shallower nature of the river channels, as well as the pools, are also believed to have contributed to conditions for elevated temperatures. Lack of riparian canopy cover in the South Fork has a greater impact than in the North Fork because the South Fork is not glacially fed, so water temperatures are inherently higher than in the North Fork.

Low Flows

Low summer stream flows in the South Fork Nooksack and North Fork tributaries magnify the impacts from high summer stream temperatures and lack of holding habitat. Diversion of large quantities of water from the Middle Fork by the city of Bellingham and from the mainstem for other municipalities and industrial users contributes to low flows and water quality problems in the mainstem (D. Schuett-Hames, NWIFC, Olympia, WA pers. comm. November 1995).

Blockages

Blockages in both the North and South Forks impede upstream migration of adults, limit the amount of available spawning area, and prevent smolt access to estuarine rearing habitat in Lummi Bay (Schuett-Hames and Schuett-Hames 1987; WDF et al. 1993). A diversion dam on the Middle Fork at RM 7.2 prevents access to important upstream habitat. The confluence with the Lummi River, which flows out of the Nooksack River at RM 4.5 has been blocked off so outmigrating smolts have no access to estuarine rearing habitat in Lummi Bay (WDF et al. 1993).

Causes of Habitat Degradation

The three principal land-use patterns in the Nooksack Basin are: 1) logging in the upper forested watersheds; 2) agriculture (principally dairy and berry) in the mid- and lower watersheds; and 3) municipal development (housing and industry) in the lower watersheds. A total of 23 of the 48 water body segments in the Nooksack basin were listed on the Washington Department of Ecology Water Quality Limited List (303(d)) for categories including siltation, fine sediment, turbidity, and fecal coliform.

Sedimentation

Sediment loads to the Nooksack relate to the interaction between the frequency and intensity of storm events, steepness of topography, geological composition, type and extent of forest practices, road-building and road maintenance (PEAK Northwest 1986; Schuett-Hames et al. 1988a, 1988b). Large glacial deposits of fine sediment and a wet climate make the upper watershed naturally prone to landslides. This natural instability has been further exacerbated by a century of logging, mining and road building on steep, unstable slopes. Between 1940 and 1983, the Howard Creek study showed that 70% of the landslide events were associated with logging or roadbuilding activities and contributed 77% of the total volume of sediment load (Schuett-Hames et al. 1988). These activities in the Howard Creek watershed were estimated to have increased sediment input 400% above the natural rate (Schuett-Hames et al. 1988). Most of the channel instability in the North Fork Nooksack results from major storm events that cause large amounts of sediments to wash downstream.

Steep upper watersheds of the Nooksack Basin are managed for timber production by the USFS, Washington State DNR, and by private landowners. The state of Washington, Treaty Tribes and private landowners have attempted to improve forest practices in the past several years through a joint Timber, Fish and Wildlife (TFW) program.

Agriculture

Whatcom County, in which the mid- and lower Nooksack watersheds fall, is the largest dairy county in Washington state and tenth largest in the nation. Much of the dairy production area is in drained wetlands now protected by levees.

Urbanization and Development

Whatcom County has been a rapid growth area in the state. Most recent commercial growth has been in retail. Major industries within the lower basin include two oil refineries, a plywood mill, an aluminum plant, an industrial incinerator, some mining and small hydropower development, and fisheries and vegetable processing plants. Since flooding is a major threat to the agricultural and industrial activities, flood control practices including diking and gravel removal are land-use patterns that also have had and continue to have a high potential for impacts on salmon or salmon habitat.

Channel modification and bank protection projects implemented to protect bridges and property from bank erosion and flooding have made previously utilized habitat unsuitable for spawning (Schuett-Hames and Schuett-Hames 1987).

Flows and Water Quality

Peak water flows relate to precipitation and snow melt. Rain-on-snow events and lack of adequate ground cover create a magnification of peak flow events during high fall and winter flows. Water withrawals or loss of wetlands contribute to low flow conditions. The City of Bellingham has a diversion dam on the Middle Fork (RM 7.1) and withdraws 50 mgd. The cities of Everson (RM 23.7), Lynden (RM 18.0) and Ferndale (RM 5.9) also withdraw significant quantities of water. Particularly, the Ferndale withdrawal (40 mgd) which supplies major industries in the Cherry Point region adversely affects flow in the lower mainstem. Vegetable processing plants in Lynden and Ferndale add substantial amounts of nutrients to the lower mainstem during the late summer when flow is low to moderate. Bellingham Frozen Foods has a tertiary treatment site in the flood plain of the lower mainstem, which creates the potential for heavy nutrient additions to the estuary during floods. Fields in the flood plain of the lower mainstem are routinely sprayed with dairy cattle wastes. Although management practicies preclude spraying of these wastes during times of high water and floods, there is a high potential for introduction of stored nutrients from this source. There is a commercial incinerator near the flood plain of the lower mainstem which has a high potential for addition of heavy metals to the ground water and which eventually enter the river through the Ferndale wastewater plant outfall.

Existing Restoration Efforts

Until sedimentation production and transportation rates are reduced so that channel stabilization and habitat recovery can occur, success of other recovery efforts, e.g., hatchery supplementation, on natural chinook stocks is expected to be low (Schuett-Hames and Schuett-Hames 1987). Some of this improvement is dependent on the frequency of major storms. Whatever recovery efforts are undertaken, both holding and spawning areas should be recovered simultaneously since chinook have been observed bypassing good spawning habitat in lower river reaches due to the lack of holding areas there (Schuett-Hames et al. 1988).

Projects to promote channel stability by reducing sediment production have been undertaken by the Washington State Department of Natural Resources, National Forest Service and fisheries agencies. These include reducing the number of roads used and implementing erosion control. The results of several projects have emphasized the importance of restoring the upper watershed before downstream projects can be expected to be successful (Schuett-Hames and Schuett-Hames 1987).

Table 9. Limiting factors for Nooksack River native chinook habitat

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures	Streambed Instability	Estuarine loss
North Fork					
Ingravel	X	X			
Fry		X			X
Juvenile		X			X
Adults		X			
South Fork					
Ingravel	X	X			
Fry		X			X
Juvenile	X	X			X
Adults	X	X	X	X	
Activity	**Flow Regime**	**Sedimentation**	**Temperatures /Riparian canopy loss**	**Streambed Instability**	**Estuarine loss**
Logging	X	X	X	X	
Agriculture	X	X	X	X	
Water Withdrawals	X		X		
Flood Control	X			X	X

Queets Basin - Spring/Summers and Falls

Scott Chitwood and Susan Bishop

Basin Overview

The entire length of the Queets River lies either within the Quinault Indian Reservation or the Olympic National Park on the central and western Olympic Peninsula (Figure 18). Peaks of the Olympic Mountain Range (Mt. Barnes, Mt. Queets and Mt. Olympus) form the upper end of the Queets River basin. The Queets River originates from the Jeffers, Humes and Queets glaciers while smaller streams head in the low foothills at the base of this range. The headwaters and upper tributaries are generally quite steep, but the middle and lower reaches contain many miles of moderate gradient stream channel with the lower mainstem meandering through a broad valley. Riparian cover provided by a mixture of coniferous and deciduous forests is adequate along the majority of the river. Stream flows are provided by the abundant rainfall in this area with snow-pack runoff becoming important in the spring and summer to those streams that flow from the Olympic Mountains (Williams et al. 1975).

Adult chinook returning to the Queets River systems predominantly utilize mainstem and large tributary spawning habitat. The Clearwater River is the largest Queets River tributary. Other large tributaries important to chinook spawning are Salmon River, Matheny Creek, Sams River and Tshletshy Creek.

The Queets River mainstem offers high quality chinook spawning habitat from the first riffle upstream of tidewater to the upstream limits of accessibility by salmon: large gravel and cobble material in relatively deep, fast moving water. On the Queets the upstream limit is a large hydrologic cascade feature named Killkelly rapids at RM 43.

Stock Overview

The Queets chinook run is comprised of spring, summer and fall components. The fall component is the most numerous. Spawning timing of spring and summer stocks overlap, but there is a distinct break between the fall run and the spring/summer aggregate. Fry emerge during March and April. The vast majority of Queets chinook migrate to sea as ocean-type fish. Large schools of chinook move seaward during May. Early migrants seem to move directly into the marine environment with only a short stay in the limited estuarine habitat. This migration pattern is a predominant feature in years of large parent spawning populations. Reduced estuarine residence may represent a density dependent response to increased levels of spatial and food competition as a consequence of large numbers of fry. The estuarine chinook populations peak in July or August, with some remaining in residence until the first fall freshets.

Spring/Summer

Queets naturally spawning chinook stocks have been classified as depressed based on a short-term severe decline in escapement in 1991 and 1992. The long-term abundance is stable (WDF et al. 1993).

Spring/summer chinook enter the river any time from February through August, sometimes holding

in the river for months before spawning in August to mid-October. The earliest adult migrants into the Queets River seem to represent the earliest spawners. Most of the "spring" chinook enter the river from April through June. These are thought to be the fish that spawn in the uppermost reaches of chinook accessibility from early August through early September. On the Queets River these early spawners use the Queets mainstem area from Killkelly rapids down to Paradise Creek. RM's 43-37. Infrequently, flow conditions may contribute to chinook accessing the area immediately upstream of the rapids. By late September, peak activity has moved to the reach from RM 37 to 17. The last of the spawning activity is usually over by mid-October. Summer chinook are the later, more numerous portion of the run and utilize the mainstem and, to a lesser extent, the lower reaches of the tributaries for spawning. Summer spawning includes the Clearwater from RM 0 to 23 and the lower 1-3 miles of the Tshletshy, Sams and Matheny tributaries.

Fall

Queets fall chinook stocks are classified as healthy based on increasing abundance (WDF et al. 1993). Fall chinook are separated from spring/summer chinook by river entry and spawning timing differences more than spawning location. Fall chinook begin river entry in September; spend little or no time holding in contrast to the spring/summers, and spawn from mid-October through December. Initiation of spawning is dependent on flows.

A significant portion of the accessible area is utilized for spawning by both spring/summer and fall chinook. In general, fall chinook do not migrate as far upstream as spring/summer chinook to spawn and are much more likely to utilize tributary spawning habitat. On the Queets mainstem, the upstream limit for fall chinook migration is about RM 37. In higher flow years, a greater portion of the spawning populations utilize tributary habitat for spawning. In particularly low flow years, fall chinook may not migrate as far upstream in either the mainstem or tributaries.

Critical habitat issues

Habitat is not considered a limiting factor for chinook productivity in the Queets system. Some reduction in habitat quality has occurred due to loss of estuarine rearing habitat, reduction in quality of spawning habitat and more frequent and intensive flood events due to road building and logging. The extent to which these activities have affected salmon production in the Queets system are largely unknown (Table 10).

The estuary plays a prominent role in Queets chinook life history and the primary impacts to the estuary are a result of diminished amounts of large woody debris in the lower river and the estuary. Potentially, it has limited the refuge areas available to juvenile chinook.

Sedimentation and increased bedload has resulted in some limited scouring and siltation. However, the amount is not believed to significantly impact chinook productivity most years.

Causes of habitat degradation

Forest management activities outside of the Olympic National Park boundaries have contributed to freshwater habitat degradation (WDF et al. 1993). The frequency and intensity of wasting events has increased in recent years as a result of logging and road building activity.

Bank erosion protection measures have contributed to the loss of large woody debris and reduction in the quality of spawning habitat.

Table 10. Limiting factors for Queets River chinook habitat by life history stage

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures	Streambed Instability	Estuarine Loss
Queets River					
Ingravel		X		X	
Fry		X		X	X
Juvenile					X
Adults					
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging	X	X	X	X	X
Urban Development					X

Quillayute Basin

Amy Morgan, Beth Naughton and Jeff Haymes

Basin Overview

The Quillayute river basin includes the Dickey, Sol Duc, Calawah, and Bogachiel rivers which conjoin to form the Quillayute 5.6 miles from the Pacific coast (Figure 19). The headwaters of this system are in the Olympic Mountain Range and are generally quite steep. Many miles of moderate gradient, lowland stream channels compose the lower reaches.

The Olympic National Park forms the core of the basin providing high water quality and undisturbed freshwater habitat in the North Fork Sol Duc and headwaters of the mainstem Sol Duc, a major portion of the South Fork Calawah, and the headwaters and upper mainstem of the Bogachiel River.

Annual precipitation in most of the Quillayute basin ranges from 90-120 inches. This precipitaion falls in the form of rain in the lowlands, and rain and snow at the higher elevations. The Quillayute system is rain dominated, with peak flows occurring in November, December and January. Snow pack melt has some influence on discharge in the upper Sol Duc in spring and early summer, but all three systems experience annual summer low flows from June into September. Major land managers in the Quillayute watershed are state, federal and private timber companies.

Stock Status

As listed in the SASSI report (WDF et al. 1993), the native stocks of chinook in the Quillayute system are all either summer or fall runs. Three stocks of summer chinook have been identified; Bogachiel/Quillayute, Calawah and Sol Duc. The Bogachiel/Quillayute summer chinook stock is listed as native origin, wild production, and of unknown status due to wide fluctuations in spawning activity from very low to moderate numbers during the period of 1980 to 1991. The Calawah run of summer chinook is listed as native origin, wild production, and of unknown status due to wide fluctuations in spawning activity from very low to moderate numbers during the period of 1980 to 1991. The Sol Duc run is listed as native origin, wild production, and healthy status.

Four stocks of native Quillayute basin fall chinook have been identified; Bogachiel/Quillayute, Calawah, Sol Duc, and Dickey. The Bogachiel/Quillayute fall chinook run is listed as native origin, wild production, and healthy status. The Calawah run is listed as native origin, wild production, and healthy status. Sol Duc fall chinook are listed as native origin, composite production, and healthy status. Dickey river fall chinook are listed as native origin, wild production, and healthy status.

Fish Utilization

The summer chinook are found approximately up to RM 50 in the mainstem Sol Duc River, RM 3 in Beaver Creek, RM 4 in Bear Creek, the mainstem of the Calawah River, up to RM 7 in the Sitkum River, RM 26 in the South Fork Calawah, and up to RM 32 in the Bogachiel mainstem. The fall chinook use approximately up to RM 8 in the Dickey River mainstem, RM 20 in the West Fork Dickey River and RM 13 in the East Fork. In the Sol Duc the fall run uses approximately up to RM 50 on the mainstem, RM 3 in Beaver Creek and RM 4 in Bear Creek. The whole Calawah mainstem is used by the fall chinook, as is the North Fork up to RM 13, the Sitkum River up to RM 7 and the South Fork up to RM 26. The Bogachiel mainstem is used by the fall chinook up to approximately RM 32.

Critical Habitat Issues
The primary issues for the Quillayute system are related to forest practices and associated roading activities. These effects are: summer low flows, sedimentation, water temperatures, and lack of LWD (Table 11). We will briefly catalog these effects by river basin.

SOL DUC RIVER- On average 87% of chinook spawning is concentrated between RM 13 and 40, downstream of the Olympic National Park (ONP) boundary. Potential hydrologic response to timber management in the form of increased peak flows is limited in the mid-upper mainstem Sol Duc River due to the large percentage of the drainage within the ONP. Flow records do show an increased frequency of 2 year (channel forming) storm events from the period 1977- 1992 due to unusual weather patterns (USDA 1995). Channel forming storm events cause bedload movement resulting in redd scour or entombment.

Aerial photo and channel analysis concluded that overall the mainstem Sol Duc has been relatively stable during the last 5 decades, though localized response reaches were identified. The upper mainstem is a confined bedrock- boulder controlled channel, efficient at transporting sediments and debris. The mid to lower reaches flow through less confined glacial deposits where the channel is more sensitive to increased peak flows, areas identified with high summer and fall chinook spawning activity.

Lands within the Olympic National Forest (ONF) comprise a significant portion of the upper drainage. The Sol Duc Watershed Analysis identified fine sediment inputs well over natural levels in all ONF drainages, due to extensive timber harvesting, road building, mass wasting and prescribed burning. Transport downstream of increased sediment loads has probably impacted response reaches in the mid to lower mainstem. Levels of fine sediment detrimental to salmonid egg development should be expected.

CALAWAH RIVER- Major spawning activity occurs in the South Fork Calawah between RM 11-15.3, below the confluence of the Sitkum River and South Fork Calawah, outside the ONP boundary. Information on changes in peak flow frequencies and magnitudes is undocumented, but have probably increased as a result of weather changes. This natural increase in peak flows may be exacerbated by extensive timber harvesting in the Sitkum River drainage. The Sitkum River has experienced significant mass wasting, particularly in the North Fork Sitkum. Since the mainstem is confined and lacks sinuosity, sediments are transported efficiently through the system, being deposited in the less confined, lower gradient reaches downstream. Levels of fine sediment detrimental to salmonid egg development should be expected as well as impacts associated with bedload movement.

BOGACHIEL RIVER- Spawning activity is scattered from RM 5-29 along the mainstem. The upper end of this reach is in the ONP. The Bogachiel River is the least confined tributary utilized by summer chinook in the Quillayute system. Aerial photo analysis has documented numerous unconfined segments where the mainstem is traveling across the valley floor. These unconfined reaches are very sensitive to channel forming peak flows causing redd scour or entombment. Based on flow records from the Sol Duc mainstem analyzed for the Sol Duc Watershed Analysis (USDA 1995), increased 2 year storm events would have resulted in increased channel shifting with subsequent redd loss. The upper mainstem and headwaters flow from the ONP and should provide high water quality, though the Bogachiel River has historically been known for its high degree of turbidity during winter storm events. While timber harvesting has been extensive downstream of the ONP boundary, contributions of fine sediment and related impacts are unknown.

DICKEY RIVER- The Dickey River has low to moderate levels of fall chinook production. Low to moderate spawning densities are observed in the mainstem Dickey (from RM 2-8), the East Fork Dickey (RM 0-13), and Coal Creek (RM 0-1). The West Fork Dickey has limited spawning activity due to a lack of adequate spawning gravels. The stream channel of the West Fork Dickey is low gradient, with few riffle areas. Both the East Fork and the West Fork drainages have gone through heavy timber management and increased road densities in the last twenty years, which has resulted in high levels of fines that are not flushed out due to the low gradient reaches.

Riparian / LWD

All riparian areas outside the ONP have been harvested in the last 100 years. The mid Sol Duc river has a history of recurrent wildfire. Contribution to the stream channel of LWD has decreased significantly. However, the Sol Duc and Calawah systems are confined, bedrock-boulder controlled channels, which efficiently transport materials through each system. Retention time for LWD is probably limited. The Bogachiel River with its wider, less confined reaches would be more sensitive to LWD input.

Table 11. Limiting factors for the Quillayute System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability
Sol Duc				
Ingravel	X	X		X
Fry	X	X	X	X
Juvenile	X	X		
Adults	X	X	X	
Dickey				
Ingravel		X		
Fry		X	X	
Juvenile		X		
Adults		X	X	
Calawah				
Ingravel	X	X		X
Fry	X	X	X	X
Juvenile	X	X		
Adults	X	X	X	
Bogachiel				
Ingravel	X	X		X
Fry	X	X	X	X
Juvenile	X	X		
Adults	X	X	X	
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**
Logging	X	X	X	X

Quinault Basin - Spring/Summers and Falls

Scott Chitwood and Susan Bishop

Basin Overview

Peaks of the Olympic Mountain Range (Mt. Anderson, Mt. LaCrosse and White Mountain) form the upper end of the Quinault River basin on the western Olympic Peninsula (Figure 20). The Quinault River originates from the Anderson glacier on the south side of Mt. Anderson. The headwaters and upper tributaries are generally quite steep, but the middle and lower reaches contain many miles of moderate gradient stream channel. Approximately 32 miles from the headwaters, the river enters a large lake, Lake Quinault, a feature not common to the larger Olympic Peninsula rivers. Most low elevation coastal lakes are shallow and eutrophic. Lake Quinault is unique in that it is oligotrophic with frequent turnover, 240 ft at its deepest point and large (3,729 acres). It is extensively used by several salmonid species as rearing habitat and for adult holding. The upper Quinault River between the forks and the lake is a low gradient meandering river with numerous side channels. Much of the river in this reach is on a broad gravel flood plain with little marginal vegetation on the stream bank. The Quinault River valley downstream from Lake Quinault broadens as the river flows southwest. Stream flows are provided by the abundant rainfall in this area with snow-pack runoff becoming important in the spring and summer to those streams that flow from the Olympic Mountains.

At approximately RM 46, the mainstem splits into two forks, the East Fork and the North Fork. The North Fork Quinault drains Mt. Noyes, Mt. Seattle, and Mt. Christie. The North Fork flows through a steep-sided valley for most of its length, becoming moderate in gradient and flowing through a narrow river valley to its confluence with the mainstem Quinault. Both the North Fork and its upper tributaries have steep gradients with numerous falls and cascades. Riparian cover provided by a mixture of coniferous and deciduous forests is adequate along the majority of the river.

As in the Queets system, adult chinook returning to the Quinault River system predominantly utilize mainstem and large tributary spawning habitat. The Quinault River mainstem offers high quality chinook spawning habitat from the first riffle upstream of tidewater to the upstream limits of accessibility by salmon: large gravel and cobble material in relatively deep, fast moving water. On the East Fork Quinault the upstream limit is the Graves Creek canyon. On the North Fork Quinault, a series of small cascades through a steep stretch of the river upstream of Rustler Creek appears to be the limit of salmon utilization. Juvenile chinook seem to thrive in the environment of Lake Quinault through the summer months much like those in the estuary.

Stock Overview

The Quinault chinook run is comprised of spring, summer and fall components. The fall component is the most numerous. Spawning timing of spring and summer stocks overlap but there is a distinct break between the fall run and the spring/summer aggregate. Fry emerge during March and April. The vast majority of Quinault chinook migrate to sea as ocean-type fish. Large schools of chinook move seaward during May. Early migrants seem to move directly into the marine environment with only a short stay in the limited estuarine habitat. This migration pattern is a predominant feature in years of large parent spawning. Reduced estuarine residence may represent a density dependent response to increased levels of spatial and food competition as a consequence of large numbers of

fry. The estuarine chinook populations peak in July or August, with some remaining in residence until the first fall freshets. Significant numbers of chinook also remain in the lake and lower river throughout the summer.

Spring/Summer

Quinault naturally spawning spring/summer chinook stocks have been classified as depressed based on a short-term severe decline in escapement in 1991 and 1992. The long-term abundance is stable (WDF et al. 1993).

Spring/summer chinook enter the river any time from February through August, sometimes holding in the river for months before spawning in August to mid-October. The earliest adult migrants into the Quinault River seem to represent the earliest spawners. Most of the "spring" chinook enter the river from April through June. These are thought to be the fish that spawn in the uppermost reaches of chinook accessibility from early August through early September.

The upper areas in the East Fork, RM 53 to 50, and North Fork Quinault, RM 8-5, are the areas most used by the early chinook for spawning. Beginning in mid-September, peaking in late September and ending in mid-October, the "summer" chinook utilize the East Fork from RM 53-46, the North Fork from 8-0, the upper mainstem from RM 46-36 (above the Lake) and the lower mainstem from 33 to about 16 for spawning. Spring/summer chinook spawning drops off sharply in early October.

Fall

Quinault fall chinook stocks are classified as healthy based on increasing abundance (WDF et al. 1993). Fall chinook are separated from spring/summer chinook by river entry and spawning timing differences more than spawning location. Fall chinook begin river entry in September; spend little or no time holding in contrast to the spring/summers, and spawn from mid-October through December. Initiation of spawning is dependent on flows.

A significant portion of the accessible area is utilized for spawning by both spring/summer and fall chinook. In general, fall chinook do not migrate as far upstream as spring/summer chinook to spawn and are much more likely to utilize tributary spawning habitat. On the Quinault, only a few miles separate fall chinook and spring and summer chinook spawning grounds.

<u>Critical habitat issues</u>

Habitat is not considered a limiting factor for chinook productivity in the Quinault system. Some reduction in habitat quality has occurred due to loss of estuarine rearing habitat, reduction in quality of spawning habitat and more frequent and intensive flood events (Table 12).

The estuary plays a prominent role in Quinault chinook life history and the primary impacts to the estuary are a result of diminished amounts of large woody debris in the lower river and estuary. Potentially, it has limited the refuge areas available to juvenile chinook.

Sedimentation and increased bedload has resulted in some limited scouring and siltation. However, the amount is not believed to significantly impact chinook productivity in most years.

Causes of habitat degradation

Forest management activities outside of the Olympic National Park boundaries have contributed to freshwater habitat degradation (WDF et al. 1993). The frequency and intensity of wasting events has increased in recent years as a result of logging activity and road building.

Bank erosion protection efforts in the upper mainstem river have contributed to the loss of large woody debris and decreased channel stability.

Table 12. Limiting factors for Quinault River chinook habitat by life history stage

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures	Streambed Instability	Estuarine Loss
Quinault R.					
Ingravel		X		X	
Fry		X		X	X
Juvenile					X
Adults					
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging	X	X	X	X	X
Urban Development					X

Skagit River Basin

Eric Beamer and Amy Morgan

Basin Overview

As described in Beechie et al. (1994), the Skagit River basin has an area of 8,270 square kilometers; the river drains the North Cascade Mountains of Washington and British Columbia (Figure 21). Elevations in the basin range from sea level to about 3,275 meters on Mt. Baker, with numerous peaks in the basin exceeding 2,500 meters in elevation. Average annual rainfall ranges from about 90 centimeters at Mt. Vernon on the lower flood plain to over 460 centimeters at higher elevations in the vicinity on Glacier Peak. Major watercourses are (north to south); Baker River, Skagit River, Cascade River, Sauk River, and Suiattle River. Land uses in this basin are predominantly agricultural and urban in the lower floodplain and delta areas, and upland areas generally support commercial forests. About 1,590 square kilometers (19%) of the basin are owned privately or by the State of Washington. Approximately 3,680 square kilometers (44%) of the basin lie within the federally owned North Cascades National Park, Mt. Baker and Ross Lake national recreation areas, and Glacier Peak wilderness area; the U.S. Forest Service controls an additional 1,960 square kilometers (24%) of the basin in the Mt. Baker-Snoqualmie National Forest. Approximately 1,040 square kilometers (13%) of the basin is in British Columbia.

Stock Status

The SASSI report (WDF 1993) lists three runs of spring chinook: upper Sauk, Suiattle, and upper Cascade. There are two summer runs: upper Skagit mainstem/tribs, and lower Sauk. And one fall run is listed for the Skagit system in the lower Skagit mainstem/tribs. Genetic analyses do not show a statistically significant difference between upper Skagit and upper Sauk chinook, or between upper Skagit summer and lower Skagit fall chinook.

Spring chinook in the upper Sauk are listed as native origin, wild production, and healthy status. Suiattle spring chinook are listed as native origin, wild production, and depressed status due to chronically low escapement estimates. Upper Cascade springs are listed as native origin, wild production,and unknown status due to a lack of consistent data.

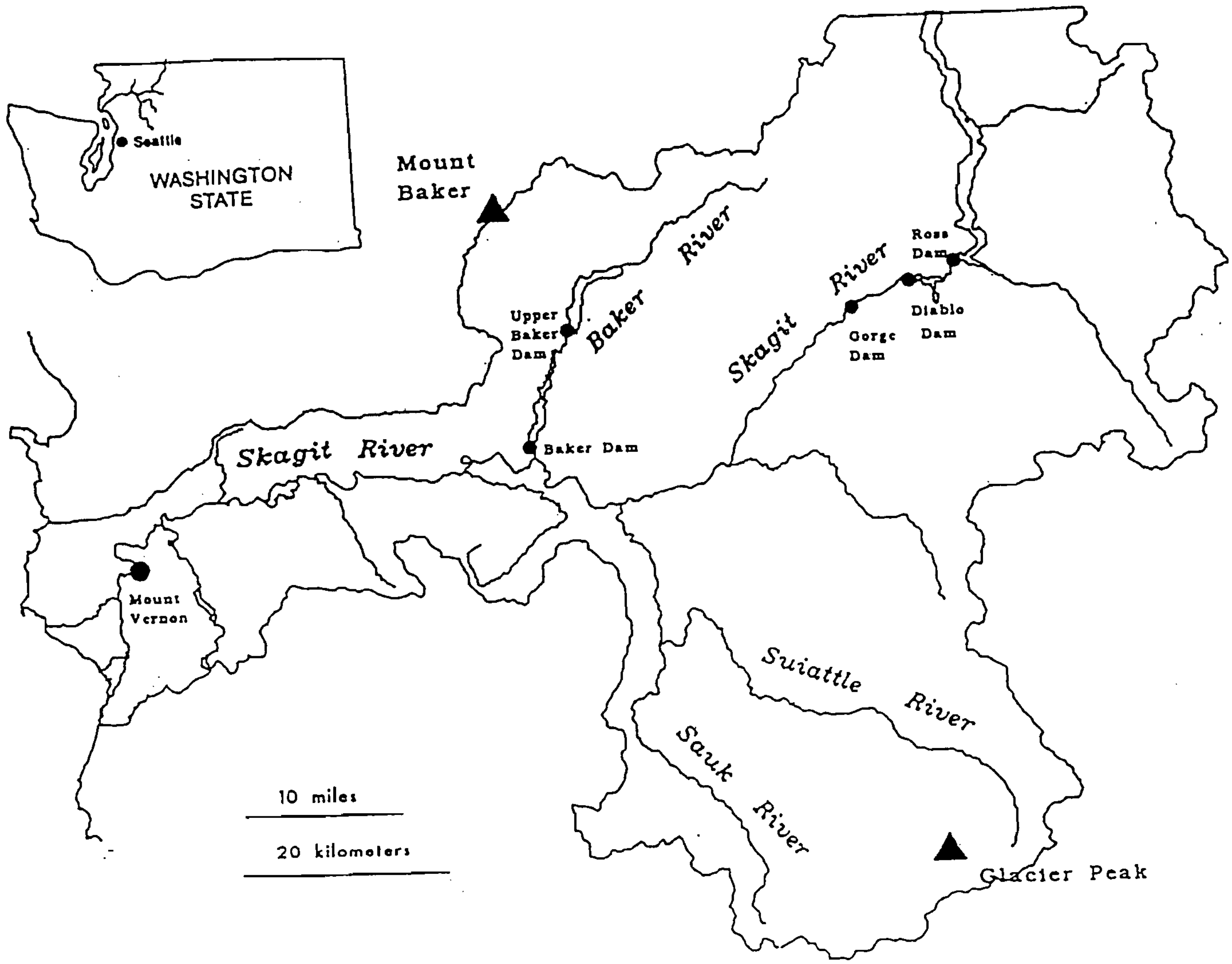
Summer chinook in the lower Sauk are listed as native origin, wild production, and depressed status due to chronically low escapement levels. Upper Skagit mainstem and tributaries summer chinook are listed as native origin, wild production, and healthy status.

Fall chinook in the lower Skagit mainstem and tributaries are listed as native origin, wild production, and depressed status due to a long-term negative trend and a short-term severe decline.

Fish Utilization

Access by anadromous fishes is generally confined to streams at elevations below 700 meters. The estimated upper limit of chinook usage of the Skagit mainstem is the Gorge Dam at RM 96.5, of the Sauk River it is RM 41.2 on the North Fork and RM 10 on the South Fork. Estimated upper limits on the Cascade River are RM 0.5 on the North Fork, RM 22.5 on the South Fork. On the Suiattle River, the limit is RM 28.6.

Figure 21. Location of the Skagit River watershed



Critical Habitat Issues

Both ocean-type and stream-type life history patterns are present in Skagit River wild chinook populations. Based on adult scale samples collected from spawning areas, the ocean-type life history pattern dominates the fall and summer chinook races, while the stream-type life history pattern is most common in spring chinook (WDFW, unpublished scale data).

As identified in the Skagit Chinook Restoration Study, the ocean-type chinook in the Skagit system show at least two different life history patterns. *Fry migrants* utilize habitats in the inner estuary (tidally influenced areas of the lower river and saltmarsh areas of the delta) for rearing and *fingerling migrants* rear in the riverine environment (possibly with a preference for off-channel areas) for several months following emergence and bypass the inner estuary for rearing. We can infer then, that any degradation or loss of these habitats would limit production. Beechie et al. (1994) examined off-channel habitat loss and degradation in the freshwater areas of the Skagit River basin, while Bortleson et al. (1980) documented the loss of estuarine habitats in the Skagit Delta. Most of the following results were drawn from their studies (Table 13).

Beechie et al. (1994) reported nearly 700,000 m^2 (54% loss) of Skagit River side-channel and distributary sloughs have been eliminated in the past century. Most of this loss has been in the lower Skagit River floodplain and delta areas. Bortleson et al. (1980) reported a total loss of 4200 acres of tidal marsh area in the Skagit River delta. This is a 59% loss of the delta's entire tidal marsh; 2965 acres were lost prior to 1889, while 1235 acres were lost after 1889. Diking associated with agricultural and urban lands accounted for the largest percentage of habitat lost in both studies.

Habitat loss in tributaries from the Beechie study were grouped into two categories: losses from habitats that have been degraded and losses from habitats that have been completely removed from production. For habitats completely removed from production, the Upper Baker and Lower Baker dams have inundated an estimated 43,400 m^2 of tributary habitat. Impacts associated with forestry practices are thought to significantly degrade tributary habitats important for chinook. The impacts are shown by the loss of pool area due to increased sediment, or removal of woody debris. Recent work completed by the Skagit Chinook Restoration Study suggests that tributary spawning chinook preferred the lower gradient channel types most susceptible to change by sediment influx or large woody debris loading; however, chinook did not prefer these low gradient channels if they lacked sufficient LWD. This implies that the loss of wood could reduce spawning habitat capacity at the stream reach level.

Only the direct loss of mainstem habitat through inundation by the Upper and Lower Baker dams was examined by Beechie et al. (1994). The loss was estimated at 46.8 km or a seven percent loss of all mainstem habitat. The impact of flow regulation on mainstem habitat from the Seattle City Light Skagit River Hydroelectric Project is thought to be significantly improved by a new license agreement adopted by the utility and fisheries intervenors in 1991. Minimum egg incubation and emergence flows are set at levels that account for the flows that occur during chinook spawning, which minimizes the possibility of redd dewatering. Ramping rates, based on Skagit specific studies, were also established to minimize the likelihood of fry stranding on bars following emergence.

The simplification and degradation of the quality of mainstem habitats has yet to be examined in the Skagit. It is assumed that current land use activities in the Skagit River basin are more likely to affect sloughs and tributaries before mainstem habitats, primarily as a result of the cumulative impacts of many small, unrelated, and poorly regulated actions. However, impacts on mainstem habitats do occur, largely as a result of flood control activities.

Existing Restoration Efforts

Information necessary for effective chinook restoration is currently being developed by Skagit System Cooperative through the Skagit Chinook Restoration Study and the Fir Island Watershed Analysis. The goal of the Skagit Chinook Restoration Study is to develop the analytical tools needed to evaluate actions to restore Skagit chinook. Study objectives include: (1) the identification of the life history patterns of ocean-type chinook, (2) estimating the respective percentages of the juvenile and adult populations of each life history type, and (3) estimating the capacity and survival rates of the habitats in which chinook rear. The Fir Island Watershed Analysis is an historical reconstruction of habitat loss and change in the Skagit River delta. The primary purpose of this analysis is to identify lower river and inner estuarine restoration options for the benefit of anadromous fish by identifying the potential areas and understanding the processes that influenced their history and function.

A restoration project effort that specifically targets habitat used by chinook is a dike breaching project located on the Skagit Wildlife Refuge. Up to 460 acres of tidally influenced wetlands and channels could be restored under this project. The project is currently in the feasibility stage and is cooperatively sponsored by the Washington Department of Fish and Wildlife, the Skagit System Cooperative, and the United States Fish and Wildlife Service.

Table 13. Limiting factors for the Skagit System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine Loss
Skagit					
Ingravel	X	X	X	X	
Fry	X	X	X	X	X
Juvenile	X	X			X
Adults	X	X	X		
Sauk					
Ingravel		X		X	
Fry		X	X		X
Juvenile		X	X	X	X
Adults		X	X		
Suiattle					
Ingravel		X		X	
Fry		X	X		X
Juvenile		X	X	X	X
Adults		X	X		
Cascade					
Ingravel		X		X	
Fry		X	X		X
Juvenile		X	X	X	X
Adults		X	X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging		X	X	X	
Agriculture		X	X		X
Urbanization	X	X	X	X	X
Flood Control	X			X	

Snohomish River Basin

George Pess and Amy Morgan

Basin Overview

The Snohomish River, with its multitude of tributary streams, represents the second largest drainage system within the Puget Sound region (Figure 22). Its overall watershed encompasses some 1,780 square miles. There are 1,730 rivers and streams identified in the Snohomish basin providing over 2,718 linear miles of drainage. The Snohomish River system consists of two principal rivers, the Skykomish draining approximately 844 square miles of watershed, and the Snoqualmie, draining approximately 693 square miles. These two large rivers have their confluence approximately five miles southwest of the town of Monroe, forming the mainstem Snohomish River which continues on to Puget Sound at the city of Everett (Williams et al. 1975).

The Skykomish River heads in the steep sloped, heavily forested, deep snow country of the high Cascade Mountains. Below the confluence of the North and South forks, the mainstem Skykomish River continues generally west for 30 miles to its junction with the Snoqualmie River. Moving through this stretch, the river leaves the high mountain country proceeding across an increasingly broader valley floor. Much of the lower river is bounded by cleared and semi-cleared farm land with intermittent sections of deciduous and coniferous forest and occasional small settlements and towns. Principal tributary streams entering the Skykomish along this lower course include the moderately large Wallace and Sultan rivers, plus Proctor, Elwell and Woods creeks.

The Snoqualmie River system also heads in the steep sloped, densely forested, heavy snow country of the high Cascade Range. From the Snoqualmie Pass area, the South Fork Snoqualmie flows generally northwest through mostly mountainous terrain for about 35 miles to Snoqualmie Falls. Approximately five miles above the falls the combined North Fork and Middle Fork Snoqualmie have their confluence with the South Fork. Below the 268 foot drop of Snoqualmie Falls, located near the town of Snoqualmie, the mainstem Snoqualmie River flows generally northwest and north 36 miles to its confluence with the Skykomish River. Here the river moves out of the high mountain country and meanders across a relatively broad flat valley floor. The accessible tributary streams contributing to the lower Snoqualmie's flow include the Tolt and Raging rivers, and Tokul, Griffin and Cherry creeks.

Below the confluence of the Skykomish and Snoqualmie Rivers, the mainstem Snohomish meanders 20.5 miles northwest to its meeting with Puget Sound at Everett. The major tributary of the Snohomish in this area is the Pilchuck River entering from the north at RM 13.4.

Stock Status

In the SASSI report (WDF et al.1993) Snohomish naturally spawning chinook are separated into four distinct stocks: Snohomish summer chinook, Snohomish fall chinook, Bridal Veil Creek fall chinook, and Wallace River summer/fall chinook. The Snohomish summer chinook are listed as native origin, wild production, and of depressed status due to chronically low escapement levels. The Snohomish fall chinook are listed as native origin, wild production, and of depressed status due to chronically low escapement levels. Bridal Veil Creek fall chinook are listed as native origin, wild production, and of unknown status due to a lack of data. Wallace River summer/fall chinook are listed as mixed origin, composite production, and of healthy status.

Fish Utilization

The SASSI report (WDF et al. 1993) shows chinook usage on the mainstems of the Skykomish, the Wallace River, the Pilchuck River, the North Fork and the South Fork of the Tolt River, the Raging River, and the Snoqualmie River.

Critical Habitat Issues

The habitat issues discussed below are summarized in Table 14.

Loss of natural shoreline, floodplains, and wetlands

Approximately 83% of the Snohomish estuary has been lost since 1884, due to diking, degrading, and port development (Bortleson et al. 1980). This does not include the loss of floodplains due to other reasons such as channelization and rip rap, which can lead to a simplification of habitat. Estuarine habitat is critical to chinook making the transition from fresh to saltwater, and such a loss in habitat leads to a long-term reduction in production potential.

Degradation of spawning and mainstem rearing habitat due to gravel mining

Gravel harvest in the Pilchuck River basin, a tributary to the mainstem Snohomish, has led to channel bed degradation, and a decline in chinook spawning use of the lower Pilchuck.

Low flows

Low flows occur naturally, but the effects have been exacerbated in the Snohomish River basin due to channel aggradation and channel widening. This can lead to high summer temperatures and affect chinook spawning and rearing survival rates, as well as alter potential capacity. Specific areas of concern in the basin with regards to low flow are the lower Pilchuck River and Elwell Creek, a tributary of the Skykomish River.

Pool filling due to channel aggradation

Pool filling over the past 20 years has been observed in the Skykomish River basin between RM 32 and RM 40. Pool filling can reduce the quality and quantity of pool area and limit adult holding and juvenile rearing habitat.

Lack of LWD/Habitat simplification

A lack of LWD due to clearing in agricultural and urban areas, as well as insufficient riparian buffers in forested areas has led to a lack of LWD recruitment. This results in a loss of pools due to a lack of obstructions, a reduction in in-stream cover for adult holding and juvenile rearing, and in an increase in the magnitude and frequency of potential channel movement due to a lack of large obstructions that create sediment reservoirs. This can result in an increase in disturbances that affect all life stages of chinook salmon.

Artificial barriers to fish passage

Four watersheds have been examined for fish blockage- the Tolt, Griffin, Tokul and Woods Creek. The study has found that 50 - 75% of the culverts are partial or full blockages to salmonids. The amount of habitat currently not available that historically was available to chinook and other salmonids is unknown at this point.

Existing Restoration Efforts

The largest restoration efforts to date in the basin have taken place through the Tolt River Habitat Restoration Group. An effort led by Washington Trout has replaced 10 to 12 culverts in the Tolt, and has resulted in the opening of approximately 8 to 10 miles of additional habitat. Contacts: Kurt Nelson (360) 651 - 4485 and Kurt Beardslee (206) 788 - 1167.

Table 14. Limiting factors for the Snohomish System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine loss
Skykomish					
Ingravel	X	X		X	
Fry	X	X	X		X
Juvenile	X	X	X	X	X
Adults	X	X	X		
Pilchuck					
Ingravel	X	X		X	
Fry	X	X	X		X
Juvenile	X	X	X	X	X
Adults	X	X	X		
Tolt					
Ingravel		X		X	
Fry		X	X		X
Juvenile		X	X	X	X
Adults		X	X		
Raging					
Ingravel		X		X	
Fry		X			X
Juvenile		X		X	X
Adults		X			
Snoqualmie					
Ingravel		X		X	
Fry		X	X		X
Juvenile		X	X	X	X
Adults		X	X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging		X	X		
Agriculture	X	X	X		
Urbanization	X	X	X	X	X
Flood Control	X			X	X

Stillaguamish River Basin

George Pess and Amy Morgan

Basin Overview

The Stillaguamish River system consists of two main streams; the North and South forks, each with numerous tributaries and a relatively long section of mainstem river flowing to Puget Sound (Figure 23). Both forks have their origins in heavily forested foothill slopes of the Cascade Range. This drainage basin contains over 975 linear miles of mainstem river and tributaries, plus independent streams. The North Fork heads in the Finney Peak area of the Mount Baker National Forest. Flowing south through some 12 miles of steep sloped, densely forested terrain, the upper stream reaches velocities that are quite rapid with numerous cascades and few pool and riffle areas. Emerging form a shallow canyon section about 2 miles northwest of Darrington, the North Fork turns west and flows some 35 miles over a broad, gently sloping floor to its confluence with the South Fork at Arlington (Williams et al. 1975).

Stock Status

In the SASSI report (WDF et al. 1993) the chinook in the Stillaguamish are divided into two different stocks: Stillaguamish summer chinook and Stillaguamish fall chinook. The summer chinook are listed as native origin, composite production, and depressed status. The fall chinook are listed as unknown origin, wild production, and depressed status.

Fish Utilization

(WDF et al. 1993)

The summer chinook are found along the mainstem North Fork Stillaguamish up to approximately RM 37 and along the mainstem Boulder River up to approximately RM 3. The winter chinook are found along the mainstem Pilchuck Creek up to approximately RM 6, the mainstem Stillaguamish, the South Fork up to approximately RM 43, and Jim Creek up to approximately RM 10.

Critical Habitat Issues

The loss of holding pools and increased incidence of low summer flows due to increases in sediment supply and peak flow events have a potentially negative effect on survival to emergence for summer chinook (Table 15).

The area of concern consists of the upper portion of the North Fork Stillaguamish. The drainage basin is approximately 420 km^2. The area stretches from RM 34 to 21 and is a 6th order reach. Approximately 75 to 80% of all summer chinook spawning occurs in this area.

Key freshwater environmental factors that affect egg to fry survival in the North Fork Stillaguamish include low summer flows, loss of deep pools (greater than 1 meter in depth), and high summer water temperatures. The loss of deep pools has been hypothesized to be linked to large scale changes in channel morphology and bed particle size due to several discrete pulses of coarse sediment, or sediment waves, that have moved through the mainstem North Fork Stillaguamish between 1978 and 1987 (Pess and Benda 1994).

Sediment waves have been documented using field and aerial photo techniques. Between 1978 and 1987 there was a six-fold increase in sediment supply due to an increase in the number of landslides

in the upper North Fork Stillaguamish. Approximately 92% of the landslides were due to timber harvest and road construction activities. This increase in sediment supply was coupled with ten of the fourteen largest peak flow events on record (guage installed in 1928) occurring over the last twenty years. This change in sediment supply and peak flows resulted in particular reaches of the North Fork Stillaguamish widening over 100% and channel bed aggradation and subsequent degradation of up to two meters in eleven years. Channel aggradation and widening can potentially increase spawning area, however, it can also reduce large holding pool quantity due to pool filling, as well as increase the duration of summer low flows and exacerbate the effects of high summer water temperatures. USGS cross-sections from 1970 to 1994 at the Arlington gauge confirm the filling of pools by showing that residual pool depth decreased by 50% between 1986 and 1991, and returned to its previous depth after sediment supply in that reach decreased.

It is hypothesized that sediment waves, in combination with low summer flows, have resulted in the downstream migration of where the peak chinook spawning distribution occurs. Between 1976 and 1991, peak chinook per mile has moved from RM 27 to RM 22 at a rate of 200 to 2300 meters per year. This movement relates to the loss of holding pool area, and can affect the survival to emergence of chinook.

The importance of holding pool habitat hypothesis was evaluated during the summer of 1995 and the results show that greater than 80% of the chinook redds surveyed in the North Fork occurred within 60 meters of a pool, even though pool spacing is one for every 207 meters. Over 80% of the spawning occurred in less than half of the spawnable area. The potential effect on survival to emergence is not as well understood, but USGS cross-section data suggests an increase of up to 100% in scour and fill depths between 1986 and 1992.

<u>Restoration Efforts</u>

For information on restoration projects, please contact Pat Stevenson at (360) 435 - 2275.

Table 15. Limiting factors for the Stillaguamish System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine Loss
North Fork					
Ingravel	X	X	X		
Fry	X	X	X	X	X
Juvenile	X	X		X	X
Adults		X	X	X	
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging		X			
Agriculture	X	X	X		X
Urbanization	X	X	X	X	X
Water Withdrawal	X				
Flood Control				X	

White River Basin

Amy Morgan, Russ Ladley and Blake Smith

Basin Overview

The White River drains a 494 square-mile basin which originates at the terminus of the Winthrop, Emmons and Fryingpan glaciers on Mt. Rainier (Figure 24). It flows approximately 68 miles from its origin to its confluence with the Puyallup River at Sumner. Runoff during summer months is characteristically turbid and is responsible for the river's namesake color. The combination of glacial action, high gradient and erosion through the course of a volcanic mudflow produces the tremendous volume of sediment transported within this system.

Stock Status

The spring chinook are listed in the SASSI report (WDF et al. 1993) as native stock origin, composite production, and critical status based on chronically depressed escapement levels. The original brood stock was collected from White River. The stock is considered to be a native stock reared in a hatchery setting located at Hupp Springs, a satellite of the Minter Creek hatchery, and the White River hatchery. A segment of the stock is kept in South Sound net pens to provide a captive brood stock. As the White River hatchery program increases, releases in the White River watershed will increase with the intention of re-populating the river. A small population of native, natural spawners still returns to the White River and is currently transported from the trap below the hydropower facility at Buckley and released into the upper river above the Mud Mountain flood control dam.

Fall/winter chinook are listed in the SASSI report (WDF et al. 1993) as being of unknown stock origin (although it is thought to be native), of wild production, and of unknown status. Early indication of genetic information concludes this run could be a late component of the spring run. Stock status is unknown due to poor mainstem visibility during spawning season.

Fish Utilization

Presently White River chinook are prevented from reaching their historic spawning grounds by two impassable dams on the White River, Puget Sound Power and Light Company's (Puget Power) diversion dam at RM 24.3 and the U.S. Army Corps of Engineers' (USACE) Mud Mountain Dam at RM 29.6. Returning adults are trapped near the Puget Power diversion dam near Buckley, WA and hauled by truck by the USACE to a point on the river above both dams and released. The fish swim to spawning sites from the release point. The spring chinook are listed as utilizing the mainstem White River below RM 24.3, the mainstems of Clearwater River, Greenwater River, and Huckleberry Creek in the SASSI report (WDF et al. 1993). The summer/fall run chinook salmon use approximately the same area excepting Huckleberry Creek.

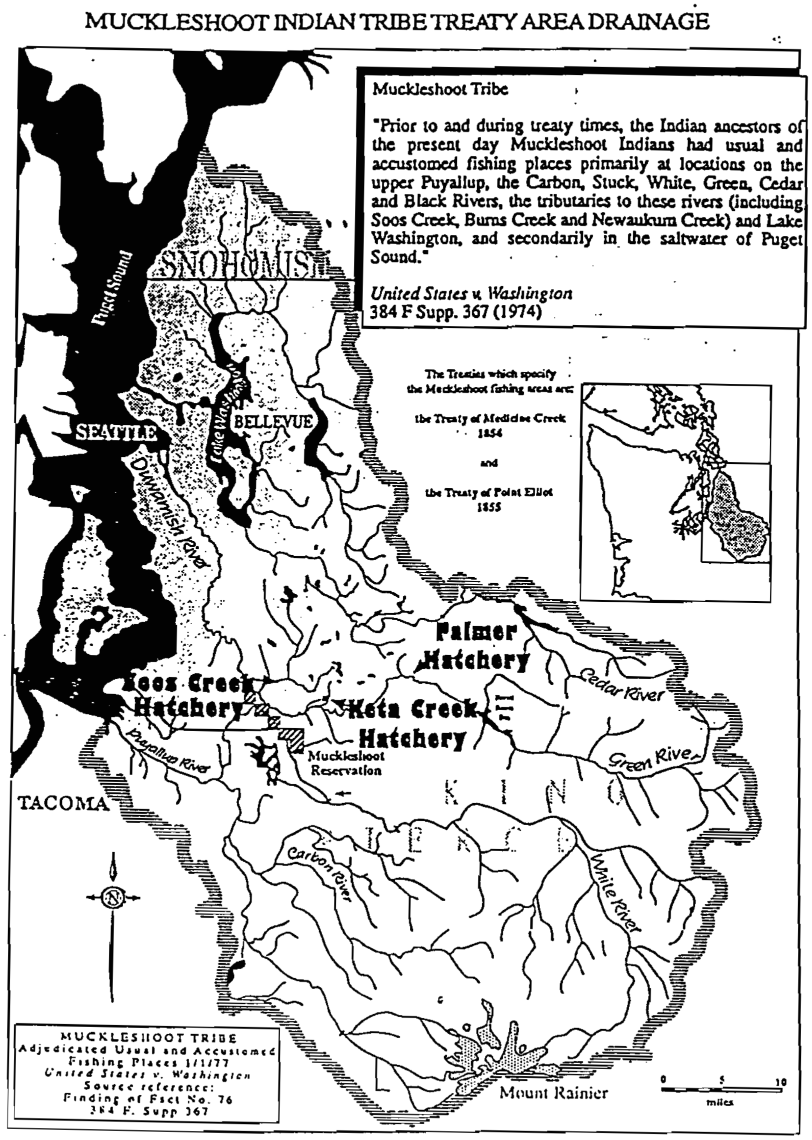
Critical Habitat Issues

(From Milward et al. 1995)(Table 16)

Sedimentation and Streambed Instability

Accumulating water behind Mud Mountain Dam reverses the natural sediment transport regime.

Figure 24. Location of the Muckleshoot Indian Tribe treaty area drainage



Instead of transporting high sediment loads during high flow events, sediment loads are now mobilized as the water level falls. This action is a result of the river cutting down through material deposited in the reservoir during flooding. Extreme storm events such as the flood of 1977 which deposited 2 million cubic yards of sediment in the reservoir and required four months to erode, may severely affect channel morphology, substrate composition and disrupt natural biological processes downstream.

Forestry practices in the upper watershed have contributed to increased input of sediment and streambed destabilization. Surface erosion associated with logging roads, mass wasting events on steep slopes due to loss of root strength, and bank erosion/shifting due to loss of large woody debris in the channel all lead to degradation of the fish habitat. Measurements indicate the main channel of the Greenwater River has aggraded 0.5 feet between 1986 and 1993 due to these impacts.

Channelization

Straightening is one of the most commonly used strategies in flood control. In the White and Puyallup rivers, meanders were cut off from the channel and filled. Dikes were built to maintain channel position and to allow farming and other land uses to take place in what was formerly floodplain or areas otherwise unsuitable for development. The construction of Mud Mountain Dam and the existing network of levees has promoted intense land use in the lower White and Puyallup River valleys. These structures have resulted in growth, development and conversion of the former floodplain and compounded the problems associated with inappropriate land use.

Lack of LWD

Collection and removal of large woody debris (LWD) from the channel has continued from the turn of the century to present day. These efforts are believed necessary to minimize the risk of log jam formation and subsequent channel changes during high flow events. Given the significance of woody debris within the stream environment, its ecological link with salmonids, and the depressed condition of many fish stocks, it is obvious that management changes are necessary. The Forest Service has recognized its past mistakes in clearing river channels of woody debris and, for the past 14 years, has actively pursued joint volunteer/tribal habitat improvement projects in the upper White River watershed. These projects typically involve the placement and pinning of logs and/or wood debris in the stream channel to restore the natural character, diversity and productivity of the stream. Such efforts have fostered a new relationship between the tribes and resource agencies which focuses on the shared responsibility of habitat restoration, enhancement and coordinated resource management.

Gravel Removal

Gravel excavation (scalping) from river bars is another controversial practice with deep roots in Puyallup River basin flood control history. Unfortunately, it is the fish resource agencies which must prove damage to fish from gravel extraction. Gravel removal operations performed by private parties are in fact, mining under the guise of flood control. Private operators sell the material as fill, yet market the practice as a flood protection tool. Surprisingly, there is no coordination or oversight by Pierce County River Improvement. Private operators should at least be required to monitor channel profile transects in proximity to the proposed operation. These data could then be used in models to enhance our understanding of gravel transport mechanics and more importantly, identify where gravel extraction would be most beneficial toward increasing conveyance capacity. The rate of gravel removal should equal the long term rate of deposition (Sikonia 1990).

Other Impacts related to Mud Mountain Dam and Puget Sound Power and Light White River Hydroelectric Project

Construction of Mud Mountain Dam has affected fish in the following ways: 1) the structure poses a complete block to upstream migration of anadromous fish, 2) it delays outmigrants when high pool conditions exist, 3) it inflicts high mortality upon outmigrants due to the 23 foot diameter tunnel outlet design, 4) it eliminates nearly three miles of river habitat between the dam and the upstream reservoir limit, 5) it discharges excessive levels of sediment for protracted periods out of phase with the natural regime, 6) it eliminates the recruitment of large woody debris to downstream reaches and 7) it creates the need to haul returning adult anadromous salmonids around the dam which stresses and kills some of them (Regenthal and Rees 1957).

The major impacts of the White River Project on fish include: 1) reduced instream flows; 2) ineffective fish screens on the diversion canal; 3) attraction and delay of returning adults at the tail race discharge; 4) ramping rate mortality and 5) sediment sluicing.

Estuarine Area

The Commencement Bay and Puyallup River estuary area has become heavily urbanized and industrialized in the past 50 years. Municipal and industrial activities and discharges have resulted in severe degradation and contamination of historically productive habitat. Because restoration is contingent upon not only cleaning up impacted sites but also in preventing additional contamination, it is essential that all sources of pollution are identified and controlled.

Under the Comprehensive Environmental Response Compensatory Liability Act of 1980 (CERCLA), trustees must approve a final natural resource restoration plan. However, before the trustees can approve the restoration plan and before project construction, federal and state laws require the trustees to prepare an environmental impact statement. The U.S. Army Corps of Engineers has recently issued a Scoping Notice for a Programmatic Environmental Impact Statement and Restoration Plan for Commencement Bay Natural Resource Damage Assessment Process. To date, activities completed under the Natural Resource Damage Assessment consist of setting up legal agreements between the trustees and responsible parties and development of the Commencement Bay Cumulative Impact study. Simpson Tacoma Kraft has completed a 17 acre restoration site along their shoreline and will begin a second shoreline restoration project in the Middle Waterway in 1995.

<u>Existing Restoration Efforts</u>

There are several entities involved in restoration efforts in the basin. The impacts above are noted with any restoration/mitigation efforts associated with them. For more information see the Recovery Plan for White River Spring Chinook Salmon put together by the South Sound Spring Chinook Technical Committee and edited by Milward, Appleby and Blakely. We referred to the draft version put out in August 1995.

Table 16. Limiting factors for the White System by life history stage.

Stream or River/ Life History Stage	Flow Regime	Sedimentation	Temperatures/ Riparian canopy loss	Streambed Instability	Estuarine Loss
White					
Ingravel	X	X		X	
Fry	X	X	X	X	X
Juvenile	X				X
Adults	X	X	X		
Activity	**Flow Regime**	**Sedimentation**	**Temperatures/ Riparian canopy loss**	**Streambed Instability**	**Estuarine Loss**
Logging		X		X	
Agriculture			X	X	
Urbanization	X		X	X	X
Water Withdrawal	X	X		X	
Flood Control	X	X		X	

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