WRIA 20

Technical Assessment Level I
Water Quality and Habitat

Presented to the WRIA 20 Planning Unit

by

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Part I. Overview of Watershed Planning Process

In 1998, the Washington State legislative session produced a number of bills aimed at salmon recovery and watershed health. The Watershed Management Act (initially known by its bill number as ESHB 2514 but later codified as RCW 90.82) was established to address the diminishing water quantity and quality, and the loss of critical habitat for fish and wildlife in the state. The statute aims to develop watershed planning and management that will support economic growth and promote water quantity and quality for the state. The statute also provides a framework to collaboratively solve water-related issues and allows local citizens and governments to join together with tribes and state agencies to develop watershed management plans for entire watersheds. To complete the goals outlined in RCW 90.82, a Watershed Assessment must to be completed for each Water Resource Inventory Area (WRIA) to evaluate water supply and use, and recommend strategies for satisfying water supply needs, meeting minimum instream flows and improving water quality.

This report aims to cover two sections of the Level 1 Assessment, water quality and stream habitat. Other sections, including groundwater and surface water quantities, water rights and use, and instream flows, will be covered in the Bureau of Reclamation report and the Level 2 Technical Assessment. The primary references for this document were the WRIA 20 Limiting Factors Report (1998) and Watershed Analyses completed for individual sub-basins within the WRIA. These sources contain synthesized data that stakeholders within the basin have sponsored and supported. These stakeholders include the Makah, Quileute, and Hoh Indian Tribes, state and federal agencies, Jefferson and Clallam Counties, the City of Forks, and private landowners. References that were synthesized by the above sources are listed with annotations in the appendix.

Part II. Assessment Criteria

Water Quality

Land use management and natural processes within watersheds can affect many components of water quality including temperature, turbidity (or suspended sediment), dissolved oxygen, pH, nutrients, and bacteria. Indirectly, alteration in the hydrologic flow regime and water quantity can also significantly alter these water quality components. The removal of riparian canopy and resulting loss of riparian shade can contribute to elevated stream temperatures that affect fish and other forms of aquatic life. Sediment transport from mass wasting events, road failures or clear cuts can change substrate composition and local channel morphology. Temperature and sediment changes can also directly affect pH and dissolved oxygen (DO), other important water quality parameters contributing directly to the level of stream quality.

Elevated stream temperatures affect salmonids at different life history stages. Effects can be either negative or positive. While increased temperatures may lead to higher invertebrate production and supply more food for fish, excessive temperatures lead to thermal stress, which affects salmonid mortality. Other negative effects of excessive temperatures include reduced growth and increased disease transmission and infection. Adverse levels of temperature can also affect behavior (i.e. migration and delays and timing) as well as a distribution of fewer more densely populated areas (Sullivan et al., 2001). In general, salmon prefer temperatures that range between 12- 14°C (Brett, 1952; Ferguson, 1958).

Table 2.1 Water Temperature (°C) Criteria for Fish in Western North America (Beschta et al., 1987) and Bull Trout Interim Conservation Guidance (USFWS, 1998)

Species	Upstream Migration	Spawning	Incubation	Juvenile Rearing		
				Preferred	Optimum	Upper Level
Chinook		5.6-13.9	5.0-14.4	7.3-14.6	12.2	25.2
Fall	10.6-19.4					
Summer	13.9-20.0					
Chum	8.3-15.6	7.2-12.8	4.4-13.3	11.2-14.6	13.5	25.8
Coho	7.2-15.6	4.4-9.4	4.4-13.3	11.8-14.6		25.8
Sockeye	7.2-15.6	10.6-12.2	4.4-13.3	11.2-14.6	15.0	24.6
Steelhead		3.9-9.4		7.3-14.6	10.0	
Cutthroat		6.1-17.2		9.5-12.9		24.1
						23.0
Bull Trout	10-12	8-10	2-4	4-10		

A recent study by Sullivan et al. in 2001 suggests that each site should undergo a specific risk assessment and that temperature requirements should vary based on seasonal use This will help to generate temperature criteria that is based on natural conditions, available food and metabolic growth rate by species rather than across the board temperatures derived from aquarium experiments.

Levels of dissolved oxygen in streams are directly linked to the survival and growth of eggs and alevins as well as invertebrates. DO is controlled by flow, temperature, stream gradient, sedimentation and organic matter inputs. The WA State water quality standard of 9.5 mg/L maintains adequate intragravel DO levels, the area of concern for juvenile salmonids and incubation. Increased sedimentation can result in reduced gravel permeability and lowered intragravel DO by reducing the rate of exchange between surface and intragravel water.

The period of maximum stream temperature also corresponds to periods of late summer low stream flow. Therefore, the number of fish (and/or eggs) a given volume or flow of water can support is reduced because of lower DO and temperature stress, while the reduced volume or flow further reduces fish capacity. This combination will most limit the salmonid populations during the summer. Conversely, during the over-wintering period populations, eggs or juveniles would be most limited by critical winter flow events (J. Jorgenson, pers. comm.).

Bacteria in surface water, as measured by fecal coliform or E. coli, is mostly a human health concern. Higher levels of bacteria indicate a higher risk of water-borne disease transmission via viruses and harmful bacteria. Bacteria can also be an indicator of increased nutrient loads. Increased nutrients can promote algae growth that depletes dissolved oxygen, called eutrophication.

State Water Quality Criteria

Water quality standards have been set for all surface waters in the State of Washington (WAC 173-201A). It should be noted that these are in the process of being revised. In fact, Department of Ecology has submitted new ones to the USEPA for approval. However, as of this writing, they are encountering legal challenges. Currently, the majority of streams within WRIA 20 are classified as class AA (extraordinary) waters and are expected to meet the criteria listed in Table 2.2 below.

Table 2.2.State Water Quality Criteria for Class AA Streams – Summary of Key Parameters (DOE, 1998)

Parameter	Criteria
Fecal Coliform	Shall not exceed a geometric mean of 50 colonies per 100ml and not have more than 10% of all samples used to calculate the geometric mean exceeding 100 colonies per 100ml
Dissolved Oxygen	Shall exceed 9.5 mg/L
Temperature	Shall not exceed 16° C due to human activities. When natural conditions exceed 16° C, no increases > 0.3° C are allowed. Incremental increases resulting from non point source activities shall be < 2.8° C.
pH	Between 6.5 and 8.5 +/- < 0.2 units.
Turbidity	Not > 5 nephelolometric turbidity units (NTU) over background when background is < 50 NTU, or have > 10% increases when background > 50 NTU.

303(d) Listings

On a biannual basis, the EPA creates a list of "impaired" waterways in the U.S. This list is referred to as "the 303(d) list" in reference to section 303(d) of the federal Clean Water Act which requires Washington State periodically to prepare a list of all surface waters in the state that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Waters placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs), a key tool in the work to clean up polluted waters. TMDLs identify the maximum amount of a pollutant to be allowed to be released into a waterbody so as not to impair uses of the water, and allocate that amount among various sources. In addition, even before a TMDL is completed, the inclusion of a waterway on the 303(d) list can reduce the amount of pollutants allowed to be released under permits issued by Ecology.

In both the 1996 and 1998 lists, the primary water quality problems in our state's waters were temperature and fecal coliform bacteria. Both are generally associated with nonpoint source pollution – that is, pollution that comes from many diffuse sources, rather than pipes or other discharges regulated by National Pollutant Discharge Elimination System (NPDES).

In the Salmon and Steelhead Habitat Liming Factors in the North Washington Coastal Streams of WRIA 20 (Smith, 2000), water quality is assigned ratings by the Washington Conservation Commission in order to easily identify the most significant limiting factors for salmonids in a WRIA and provide consistency across WRIAs for comparison. Ratings for water quality are summarized below:

Table 2.3 Rating Classifications for Water Quality from the Limiting Factors Report (2000)

Habitat Factor	Unit	Poor	Fair	Good
Temperature	Degrees Celsius	>15.6°C (spawning) >17.8°C (migration and rearing)	14-15.6°C (spawning) 14-17.8°C (migration and rearing)	10-14°C 10-14°C
Dissolved Oxygen	mg/L	<6 mg/L	6-8 mg/L	>8mg/L

Fish Distribution and Stocks

For the purpose of evaluating stock health across the WRIA 20 basin, the four sources used were:

- 1992 Washington state salmon and steelhead stock inventory (WDFW et al., 1993)
- Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington (Nehlson et al., 1991)
- Healthy native stocks of anadromous salmonids in the Pacific Northwest and California (Huntington et al., 1994)

- Status of pacific salmon and their habitats on the Olympic Peninsula, Washington (McHenry et al., 1996)

All of the above references use different definitions for “stock” or “health” and many have incomplete areas due to lack of consensus or information. Stock “health” was defined by Huntington et al. (1994) as a native stock at least ten percent as abundant as would be expected in the absence of human impacts, abundant relative to habitat capacity, not recently declining abundance and not previously identified as being at substantial risk of extinction. SASSI defines “healthy” stocks as fish experiencing production levels consistent with their available habitat and within natural variations in survival for the stock. SASSI uses essentially the same definitions with different screening measures as Nehlsen et al. (1991) who were attempting to identify stocks at risk of extinction. Nehlsen et al. (1991) did not list stocks that were considered to be healthy and instead used categories that included “high risk of extinction”, “moderate risk of extinction”, and “of special concern.” The latter category refers to stocks that are believed to be depleted and for which minor disturbances could be a threat (though specific information is missing). The information in McHenry et al. (1996) is the most current assessment of the area. It is important to note that the term “threatened” as used by SASSI and McHenry is not the same “threatened” as designated by federal listings in relation to the ESA.

The timing of salmon residence in the rivers and streams in WRIA 20 is shown in the following table. In the sub-basin descriptions later in this report, there is detailed information on specific stocks where it is available.

Table 2.4. Timing of Salmon and Bull Trout Fresh-Water Life Phases in WRIA 20 (Phinney and Bucknell, 1975) and Bull Trout Interim Conservation Guidance (USFWS, 1998)

Species	Fresh-water life phase	Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Spring Chinook	Upstream migration				■	■	■	■	▌				
	Spawning								▐	■	▌		
	Intragravel develop.	▌							▐	■	■	■	■
	Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juv. out migration			▐	■	■	■	▌					
Summer-Fall Chinook	Upstream migration								▐	■	■	■	
	Spawning									▐	■	■	▌
	Intragravel develop.	■	■	■						▐	■	■	■
	Juvenile rearing			■	■	■	■	■	▌				
	Juv. out migration			▐	■	■	■	■	▌				
Coho	Upstream migration	▌								▐	■	■	■
	Spawning	■									▐	■	■
	Intragravel develop.	■	■	■	■						▐	■	■
	Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juv. out migration		▐	■	■	■	▌						
Pink	Upstream migration							▐	■	▌			
	Spawning								▐	■	▌		
	Intragravel develop.	■	▌						▐	■	■	■	■
	Juvenile rearing	▐	■	■	■	▌							
	Juv. out migration		▐	■	■	▌							

Species	Fresh-water life phase	J	F	M	A	M	J	J	A	S	O	N	D
Chum	Upstream migration	◧									◨	■	■
	Spawning	◧										■	■
	Intragravel develop.	■	■	■								■	■
	Juvenile rearing	◨	■	■	■	■	◧						
	Juv. out migration	◨	■	■	■	■	◧						
Sockeye	Upstream migration			■	■	■	■	■	■	■	■	■	■
	Spawning	■									◨	■	■
	Intragravel develop.										◨	■	■
	Juvenile rearing	■	■	■	■	■	■	■	■	■	■	■	■
	Juv. out migration			■	■	■	■	◧					
Bull Trout	Upstream migration	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning									■	■	■	
	Intragravel develop.	■	■								■	■	■
	Juvenile rearing			■	■	■	■	■	■	■	■	■	■
	Juv. out migration	■	■	■	■	■	■	■	■	■	■	■	■

Habitat

Streamside management with the goal of protecting fish habitat concentrates on several separate issues including channel migration, the role of large woody debris (LWD), stream temperatures, hydrologic regime alterations, and the delivery and movement of sediment. It cannot be overlooked, however, that each of these components are inextricably linked to one another through physical and ecosystem processes. Channel morphology is driven by instream debris, LWD, and the transport of bedload material. LWD inputs are a result of riparian forest type and maturity, which also affects canopy shade levels. It has been suggested that long-term management should be expanded to a more holistic view of salmonid habitat and the condition of watershed processes as a whole rather than individually (Everest et al., 1987).

LWD

Large woody debris (LWD) creates fish habitat and enhances the quality of habitat in all sizes of stream (Bisson et al., 1987). Wood in streams serves both physical and biological functions. Physically, debris in streams influences channel hydraulics to form pools and other important rearing areas, stores sediment and organic matter, and influences water quality by providing thermal refugia. Biologically, LWD provides cover for fish from predators and refuge from high streamflow, in addition to offering organic processing sites for benthic communities (Bisson et al., 1987). The role of woody debris in streams changes from upper headwaters to lower mainstems. In headwaters, wood in streams serves to control the storage and release of sediment while in mainstem rivers, LWD tends to create complexity in habitat along the channel margins, and influences channel migration processes. In WRIA 20 where mass wasting is a dominant process, LWD is critical for buffering the effects of large inputs of sediments. LWD slows the rate of sediment movement through the stream and functions to retain gravel for spawning habitat (Bisson et al., 1987).

LWD is generally recruited through bank undercutting in the riparian zone, debris flows, or as channel meandering exposes buried or standing LWD. Fire and windthrow can also add debris to streams. Conifers provide the longest-lived LWD while deciduous species such as red alder have a significantly shorter residence time before decomposing.

Listed in Table 2.4 below are the parameters used for determining general categories for the condition of LWD in Western Washington streams.

Table 2.4 LWD Ratings According to Limiting Factors and Watershed Analysis Reports (Smith, 2000)

Source	Parameter/Unit	Channel Type	Poor	Fair	Good
Limiting Factors Report*	Pieces/m channel length	=4% gradient, <15 m wide	<0.2	0.2-0.4	>0.4
Watershed Analysis	Pieces/channel width	< 20 m wide	<1	1-2	2-4
Watershed Analysis	Key pieces/channel width	<10 m wide	<0.15	0.15-0.30	>0.30
Watershed Analysis	Key pieces/channel width	10-20 m wide	<0.20	0.20-0.50	>0.50

*Adopted from Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)

Shade

Although direct mortality to fish due to elevated temperatures is not a major concern in the Pacific Northwest, these conditions nonetheless can influence rates of egg development, rearing success, and species competition (Beschta et al., 1987). Stream temperatures can be affected by channel morphology, groundwater inputs, and seasonal flow cycles. Perhaps the most significant influence is the amount of solar radiation that reaches the stream. During winter, solar radiation levels at the stream surface level are generally low regardless of canopy cover due to short days, cloudy weather and low sun angles. During summer months, however, when stream discharges are low, the solar radiation levels are greatly increased. It is during these months that riparian canopy cover becomes critical. Exposure to solar radiation increases diurnal temperature fluctuations in streams. Watershed studies in the Cascade Mountains in Oregon have shown increases of 3 to 8°C following complete canopy removal (Beschta et al., 1987).

Table 2.5 Riparian Condition Ratings According to Limiting Factors Analysis and Watershed Analysis Reports (Smith, 2000)

Source	Parameter/Unit	Channel Type	Poor	Fair	Good
Limiting Factors Report*	-riparian buffer width (measured out from CMZ on each side of stream) -riparian composition	-Type 1-3 and untyped salmonid streams >5' wide	- <75' or <50% of SPT** height (whichever is greater) OR - Dominated by hardwoods, shrubs, or non-native species (<30%) unless these species were dominant historically.	- 75' – 150' or 50-100% SPT height (whichever is greater) AND - Dominated by conifers or a mix of conifers and hardwoods (=30% conifer) of any age unless hardwoods were historically dominant	- >150' or SPT height (whichever is greater) AND - Dominated by mature conifers (=70% conifer) unless hardwoods were historically dominant
Limiting Factors Report*	-buffer width -riparian composition	Type 4 and untyped perennial streams <5' wide	<50' with same composition as above	50' – 100' with same composition as above	>100; with same composition as above
Limiting Factors Report*	-buffer width -riparian composition	Type 5 and all other untyped streams	<25' with same composition as above	25'-50' with same composition as above	>50' with same composition as above

*Adopted from WDFW, Wild Salmon Policy (1997)
** Site potential tree (SPT) is defined as the estimated maximum height of dominant trees at 100 years

Sediment

In streams, there are two major forms of sediment transport mechanisms: suspended sediment transport (fines) and bedload transport (Everest et al., 1987). Suspended (fine) sediments are small particles usually transported in suspension (i.e., off the bed) that are transported downstream and deposited on floodplains or in the interstices or subsurface of the stream substrate. Bedload transport usually refers to the coarser particles transported via traction along the channel bed and is the major component in channel morphology and stream substrate.

Fine sediment can endanger the reproductive success of salmonids by reducing the permeability of gravels, interrupting intragravel flow, and reducing the amount of dissolved oxygen available for developing embryos (Everest et al., 1987). Along with threatening the salmonid life cycle, changes in the sediment equilibrium can also cause channel aggradation and instability.

Table 2.6 Sediment Ratings According to the Limiting Factors Analysis and Watershed Analysis Reports (Smith, 2000)

Source	Habitat Factor	Unit	Poor	Fair	Good
Limiting Factors Report*	Sediment Supply	$m^3/km^2/yr$	> 100 or exceeds natural rate	--	< 100 or does not exceed natural rate
Watershed Analysis	Mass Wasting		Significant increase over natural levels for events that deliver to streams		No increase in natural levels for events that deliver to streams
Limiting Factors Report**	Road Density	mi/mi^2	>3 with many valley bottom roads	2-3 with some valley bottom roads	<2 with no valley bottom roads
Limiting Factors Report***	Fine Sediment	Fines <0.85 mm in spawning gravel	>17%	11-17%	=11%

*Adopted from Skagit Watershed Council Habitat Protection and Restoration Strategy (1998)
**Adopted from NMFS Coastal Salmon Conservation: Working Guidelines (1996)
***Adopted from NMFS (1996)

Barriers

Barriers to fish passage can include, but are not limited to, beaver ponds, natural falls, non-functional culverts and cedar spalts. Barriers can often prevent access to large areas of watersheds available not just to spawning anadromous fish, but also to rearing juveniles.

Table 2.7 Barrier Ratings According to the Limiting Factors Analysis (Smith, 2000)

Source	Parameter	Poor	Fair	Good
Limiting Factors Report (WCC)	%known/potential habitat blocked	>20%	10-20%	<10%

Part III. WRIA 20 Introduction

The 735,000 acre watershed designated "WRIA 20" by the Washington Department of Ecology includes all rivers and streams that drain into the Pacific Ocean from Cape Flattery to Huelsdonk Ridge on the south side of the Hoh valley. The northern portion of the watershed lies within Clallam County, the slightly smaller southern portion within Jefferson County. This watershed generally is characterized by streams that have headwaters in the Olympic Mountains upwards of 6000' in elevation and drain into lowland valleys at sea level. The largest basin in the WRIA is the Quillayute with four major sub-basins: the Dickey, Calawah, Bogachiel and Sol Duc. Other basins in the WRIA include the Hoh, Ozette, Wa'atch and Sooes as well as several independent streams; these streams do not drain from the higher elevations of the Olympic Mountain core. Within the WRIA, there are 569 streams and 1,355 stream miles with three major lakes, Ozette Lake (Ozette sub-basin), Lake Dickey (Quillayute-Dickey sub-basin) and Lake Pleasant (Quillayute – Sol Duc sub-basin).

Annual rainfall in the basin is the highest in Washington State with an average of 80 inches near the coast to 240 inches in the Olympic Mountains. Streams flowing from much of the coastal lowlands are rain dominated while higher elevation streams are rain-on-snow dominated (i.e., mix of rain and snowfall). Several of the sub-basins on the eastern edge of the WRIA are glacially fed. The WRIA is often exposed to high winds and heavy rainstorms, which affect both vegetation and hydrology.

Undisturbed areas in WRIA 20 are naturally dominated by Sitka spruce (*Pincea sitchensis*) in the lowlands and western hemlock (*Tsuga heterophylla*) with silver fir (*Abies amabilis*) at higher elevations. Early successional species and riparian species often include hardwoods such as bigleaf maple (*Acer macrophyllum*) and red alder (*Alnus rubra*). Old growth stands are generally open canopied conifers and trees can reach up to 200' in height. As a result of logging and disturbance since the 1940s, much of the riparian diversity, size and abundance has been altered.

Geology

WRIA 20 is underlain by Tertiary marine turbidites, primarily thin to thick-bedded sandstone along with siltstone and shale (Tabor and Cady, 1978). Quaternary sediments, deposited by multiple advances and retreats of alpine glaciers from the Olympic Mountains, overlie the bedrock throughout much of the area. Sediments deposited by the Juan de Fuca lobe of the continental ice sheet cover much of the north end of WRIA 20. The Fraser glaciation lasted about 10,000 years and consisted of three stades. The last stade, known as the Vashon stade, retreated about 15,000 years ago in an eastern direction, leaving long u-shaped east-west valleys along the western side of the Olympic Mountains. As the Vashon stade retreated, a tremendous amount of glacial outwash was deposited on the valley bottoms. The valley bottoms today have several hundred feet of outwash above layers of glaciolacustrine silt deposits with ranging grainsize and stratigraphic characteristics.

The primary drainages in WRIA 20 are controlled by northeast trending high-angle strike-slip faults and have been modified by repeated glaciations. Northwest-trending thrust-fault systems and associated shear zones control many of the smaller streams and rivers. Active tectonic uplift of the core of the Olympic Mountains and the concurrent incision of the rivers have had a large influence on the landscape. The wet, moderate climate of the area, combined with the easily weathered bedrock and glacial deposits on steep slopes, have provided for rapid soil development across the area.

Land Use

Before white settlement, the Quileute, Hoh, Ozette and Makah tribes each with numerous villages inhabited many areas within WRIA 20 and used most of the land for hunting, fishing and gathering. The tribes today are on four separate reservations; however, the Ozette Reservation is under the treaty jurisdiction of the Makah Tribe and is currently managed as wilderness. All the tribes continue to use natural resources within their usual and accustomed places for sustenance, ceremonies, and economic development. Many of the rivers are sites of ceremonial and cultural importance.

White settlement began in the mid-1800s in the Ozette, Sol Duc, Calawah and Bogachiel watersheds. Much of the initial settlement was located on the Forks prairie where topography and a lack of trees were conducive to farming. Both natives and early settlers used fire to clear the way for homesteads, farming and primitive roads. With the arrival of the railroad in the 1920s, commercial timber harvesting swept across the area and billions of board feet were exported. Extensive road networks accompanied the logging efforts except in Olympic National Park (first protected in the late 1800s), which has remained relatively undisturbed. Logging continued through the 1980s but has slowed in scale and economic growth due to world timber markets, corporate agglomeration, and state and federal legislation. Limited riparian protection began in the 1970s and buffers of 50’ were required on Type 1 and 2 streams (i.e., large fish-bearing streams). By 1982, streamside buffers of 50’ were to be left on all non-federal fish bearing streams (i.e., Type 1 to 3). In 1990, national forests required a 200’ minimum disturbance buffer with no clearcutting within 100’ of Type I and II steams. In 1994, the Northwest Forest Plan was instituted in the Olympic National Forests, with additional riparian buffer requirements. This plan has dramatically slowed commercial harvests on federal land with the exception of occasional commercial thinning sales.

The Washington State Department of Natural Resources manages Trust Lands of the State and Clallam County under a Habitat Conservation Plan (HCP). The HCP, negotiated with the federal agencies, regulates their timber harvest and associated impacts for species that are or could conceivably come under ESA Protection. The Trust Lands are also subject to state regulation of timber harvest and other activities under the State Forest Practices Act and Shoreline Management Act. Private timberland is regulated under the State Forest Practices Act and Shoreline Management Act. The Forest Practices Act now includes provisions as a regulatory HCP, which were negotiated among federal, state, tribal and industry representatives. Provisions of this HCP have been designated as meeting requirements of the federal Clean Water Act.

With the slowdown of timber harvesting and an increase of urban centers in Washington State, the Olympic Peninsula communities have promoted the area as a destination for recreation in order to boost economic development. The undeveloped nature of the basins combine with abundant resources to make the area a natural for activities including hiking, sport fishing, biking, camping, and driving for pleasure. There has been little impact from these activities outside heavily used campsites, mainstem river access points, and occasional heavy sport fishing. As use increases, these impacts from recreating will most likely increase.

Dominant Processes

Winds off of the Pacific Ocean have a major effect on WRIA 20. The most famous historical event occurred in 1921 when more than 8 billion board feet were toppled in a single storm. Between 20 and 40% of the stands in the Dickey sub-basin alone were blown down. Patterns in most watersheds in WRIA 20 suggest that wind disturbance is frequent with return intervals averaging around 20 years. In the Hoh watershed, winds exceeding 100 mph disturb southern exposure slopes on the same return interval. Across the watershed, the largest canopied trees are often in protected draws as a result of the wind.

Fire is one of the dominant processes on the western portion of the Olympic Peninsula. Prehistorically, the fire regime was one of infrequent, very large, very intense events, which cleared entire stands (around 1 million acres) about every 200 years. The last major fire is thought to have occurred in 1708 and traveled from the east portion of the WRIA westward to the Pacific.

The historic fire regime includes most notably the Great Forks Fire of 1951. The fire began as a result of a clearing effort for the Port Angeles-Western railroad in the Sol Duc Watershed. Sometime later, driven by a strong east wind, the fire burned 33,000 acres through the North Fork Calawah Watershed, and the northwestern portion of the Sitkum and South Fork Calawah Watersheds according to the 1998 North Fork Calawah Watershed Analysis. Though the fire "damaged" a large area, subsequent management practices worsened conditions. Within five or six years, the entire burn area had been roaded and salvage logged, leading to a greater potential for mass wasting events and surface erosion.

Higher elevation steep slopes make mass wasting a common natural event in the mountainous portions of the WRIA. Forest roads and clearcutting have accelerated mass wasting rates within WRIA 20. Lack of road maintenance activity associated with the implementation of the USDA Northwest Forest Plan has contributed directly to mass wasting on federal lands (J. Dieu, pers. comm.).

Water Quality
Water quality information is limited in many areas of WRIA 20. There are currently 63 sites listed on the 1998 Department of Ecology's 303(d) list for temperature, dissolved oxygen and pH infractions. The majority of the sites are located within the Dickey, Sol Duc, Bogachiel and Hoh watersheds. Many of the temperature issues are related to barriers and low dissolved oxygen is often associated with excessive sedimentation. There are a few reaches that are naturally dewatered in summer months due to underlying geology. Other reaches have naturally open canopies which contribute to poor water quality ratings.

Much of the water quality data summarized in this report is out of date. Furthermore, the information is generally from studies that are limited to one field season of sampling. There are very few stations within WRIA 20 that have had long-term continuous sampling. Though the Department of Ecology is in the process of updating the 303(d) list, most of their ratings are from data before 1998. Recent data sets submitted to Ecology on water quality violations for the 2002 303(d) list have been referenced as available.

Habitat
Although run sizes are dramatically lower than historical numbers, the current health of salmonids within WRIA 20 is generally good compared to the rest of the Northwest. There are, however, several stocks listed as threatened (see stock health tables by sub-basin) and the Lake Ozette sockeye salmon is listed as threatened under the Endangered Species Act.

Listed by sub-basin in this report are the run and spawn times for each salmonid species. This information is intended to alert managers as to when flows are particularly critical for fish. The rearing times are not listed as multiple species rear for over one year in freshwater.

In the upper elevation watersheds within the boundaries of Olympic National Park, riparian habitat is excellent. The area has been undisturbed with the exception of natural events such as fire or wind and the development of visitor access and facilities. Natural riparian conditions provide shade and potential recruitment for LWD. Sedimentation levels are generally low as there is a low road density and little timber production. This generalization does not hold true for the portion of ONP surrounding Lake Ozette as there has been a greater history of anthropogenic disturbance within and outside of ONP.

In the mid and lower elevations of WRIA 20, the land has been more intensively managed for timber production and riparian stands are often hydrologically immature (i.e., forested stands in which root structure and canopy density have not reached the level of water use and influence created by mature stands, usually less than 30 years old). Though the maturation of the impacted stands will most likely eventually lead to recovery, the areas currently have a lack of instream LWD as a result of riparian logging, decreased recruitment, and historical stream clearing efforts. The immature stands have also led to a lack of riparian shade in WRIA 20 which in turn has affected stream temperatures. However, newer regulations that require modest buffer sizes will help slowly mitigate past disturbance.

Fish passage is a major concern in most of the sub-basins, particularly in the Bogachiel and Hoh where blockages occur on larger streams. Most of the blockages are a result of collapsed, perched or undersized culverts. In the Hoh sub-basin and several other streams, cedar spalts are common blockages and lead to decreased water quality and habitat.

Invasive plant species are becoming an alarming problem in WRIA 20. In the Quillayute sub-basin in particular, but also in the Ozette and Hoh basins, Japanese knotweed has spread on mainstems and tributaries. The 10 ft high plant grows on river banks and outcompetes native plants, leaving functionally unshaded river edges and choked channels. Cutting the plant helps to spread the species. Efforts are underway by counties and tribes to control the spread through the direct application of herbicides. Reed canary grass is also a widespread problem, particularly in Lake Ozette where the weed has overtaken the lake’s edge and encouraged sedimentation of spawning gravels.

Part IV. Sub-Basin Descriptions

Sooes/Wa'atch Sub-Basins

The Sooes River originates in the foothills of the northwest Olympic Mountains and flows through mostly private timberlands until it reaches the Makah reservation at RM 4.2. The mainstem is approximately 16 miles long with about 39 miles of tributaries. The Wa'atch River is located entirely within the Makah reservation and there is very little published information on the river.

Water Quality

The Department of Ecology reported high temperatures and low dissolved oxygen in the Sooes River in 1998. The Wa'atch River has exceeded state water quality standards for dissolved oxygen, pH and water temperature. Educket River, a main tributary to the Wa'atch River and a water supply source for the Makah tribe, had poor dissolved oxygen and pH samples.

Table 4.1. Water Quality Excursions on the 1998 303(d) List in the Class AA Sooes/Wa'atch (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Sooes River	Makah Tribe	Dissolved Oxygen	3	6/27/91, 7/24/91, 9/4/91
Sooes River	Makah Tribe	Temperature	1	7/24/91
Sooes River	Makah Tribe	Fecal Coliform	2	5/8/91, 6/14/91
Wa'atch River	Makah Tribe	Temperature	1	6/5/91
Wa'atch River	Makah Tribe	Dissolved Oxygen	1	7/5/91
Wa'atch River	Makah Tribe	pH	1	9/11/91
Educket River	Makah Tribe	pH	1	9/4/91
Educket River	Makah Tribe	Dissolved Oxygen	1	6/27/91

Fish Distribution

There is very little documented information about the distribution and conditions of salmonids in the Wa'atch and Sooes basins, although McHenry et al. (1996) listed fall chum as critical. WDFW reports that historically there was (is) an impassable natural barrier at on the Sooes River at RM 13.8 and, subsequently, salmonids only use about 14 miles of the tributaries. The US Fish and Wildlife Service currently operates a hatchery at RM 3 on the Sooes, which propagates and introduces coho, steelhead and Chinook to both the Sooes and Wa'atch rivers. The hatchery facility partially blocks anadromous fish access to at least 10 miles of mainstem river and at least 14 miles of tributary areas (Zajac, 2002). Listed below are the current stock statuses as reviewed in the WRIA 20 Limiting Factors Report (2000).

Table 4.2. Sooes/Wa'atch Salmon and Steelhead Stocks and Status

Stock	Nehlsen et al. (1991)	SASSI (1993)	McHenry et al. (1996)
Sooes fall Chinook		Unknown (hatchery produced)	
Sooes fall chum		Unknown	Critical
Sooes/Wa'atch coho		Unknown	Unknown
Sooes/Wa'atch winter steelhead		Unknown	

Table 4.3. Run and Spawn Times for Sooes Salmonids (SASSI 1992, A. Jensen, pers.comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chinook	■	■	■	■								
Fall Chum				■								
Coho			■	■	■	■						
Hatchery Steelhead				■	■	■	■					
Wild Steelhead								■	■	■		

Habitat

Sedimentation

Observations in 2000 show that the Sooes River can be characterized as having a dynamic, mobile bed with a coarse layer of gravel over a subsurface of coarse sand with little to no fine sand or silt (Zajac, 2002). This composition provides good spawning substrate but is easily mobilized (scoured) during high flows as there is little in-channel wood to dissipate hydraulic energy.

LWD

There is limited LWD data available within the Sooes and Wa'atch watersheds. Historically, wood jams were removed by the State of Washington and commercial landowners in misguided attempts to improve fish passage or reduce flooding in the Sooes and other streams, but documentation of this process is poor (Heckman, 1964) as compared to documentation in the Ozette (Kramer, 1953). Currently, few in-channel wood pieces or jams have been observed on the Sooes and immediate recruitment is considered poor due to past logging of riparian trees. Riparian stands are dominated by young alder with few conifers (Zajac, 2002). Due to lack of wood in these systems, high road density, which extends the drainage network, and the hydrologic immaturity of the upland stands coupled with the natural rain-dominated flow regime, these systems are thought to have an extremely "flashy" hydrologic pattern with brief, but frequent floods (Zajac, 2002).

Data Gaps
There are few data on habitat, the floodplain system, and logging history within these basins. Though there are known temperature and sedimentation issues, there have been no detailed studies of causes or impact locations. There is little documentation of known road and landslide issues. However, to address the water quality data gap, the Makah Tribe has periodically monitored several basic water quality parameters in these rivers for the past several years. Some channel and habitat data on the lower Sooes River have also been collected by the Makah Tribe, but has not yet been analyzed or summarized.

The Makah tribe has several upcoming projects (already funded), which include a Sooes Watershed Analysis, floodplain culvert barrier removals, and an Engineered Log Jam project on the mainstem of the Sooes River (J. Shellberg, pers. comm.)

Ozette Sub-basin
The Ozette Watershed is dominated by Lake Ozette, the third largest natural lake in the State of Washington. While the lake is large (11.4 sq. miles), the actual watershed is relatively small at 77 sq. mi. The total drainage area of the Ozette Watershed at the confluence with the Pacific Ocean is 88.4 sq. miles. Several large, low elevation, low gradient streams drain into Lake Ozette, which empties through the Ozette River into the Pacific Ocean. With the exception of some headwaters and tributaries, the watershed is generally characterized by gentle topography with a maximum elevation of 1900 ft.

Geology and Hydrology
The western portion of the Ozette Watershed is mainly underlain with glacial drift consisting of gravel, sand, silt and clay. The eastern portion of the basin is underlain with terrace deposits of fluvial and glaciofluvial sand and gravel (Bortleson and Dion, 1979).

Approximately 58% of the tributary flow into Lake Ozette is from the three main tributaries: Big River Umbrella Creek, and Crooked Creek respectively (Kidder and LaRiviere, 1991). Tributaries to the lake have a “flashy” hydrologic pattern due to the natural rain-dominated flow regime, which has been exacerbated by extensive road network development (A. Ritchie, pers. comm.), hydrologic immaturity of upland stands and indirect (i.e., riparian logging) and direct LWD removal.

Loss of wood has impacted the hydrology of Lake Ozette as well. Historically, wood jams are hypothesized to have acted as a porous dam at the outlet of Lake Ozette, naturally regulating lake levels, especially low lake and river levels. With the removal of this wood (Kramer, 1953), it has been hypothesized that the level regime of the lake has been significantly altered (Jeff Shellberg, pers. comm.).

To investigate the validity of these hypotheses, Abbe et al.(2003) modeled the current hydraulic conditions of the Ozette River as well as the roughness and backwater effects of 5 historic logjam locations derived from stream clearance reports from the 1950s (Kramer, 1953). The open channel flow model suggested that Lake Ozette low flow water surface levels could have been 1 meter higher and depths in the Ozette River up to 2 meters deeper than current conditions. The roughness and backwater effects were least pronounced during peak flood events and most pronounced at low flows. The influence of the logjams decreased as they were overtopped and drowned out during large flood events that inundated the floodplain of the Ozette River. Most importantly to sockeye salmon, spring/summer lake levels may have decreased by as much as 1 meter from historic conditions, thereby directly affecting sockeye spawning habitat availability and integrity along the lake edge. Lake level changes have potentially affected shoreline spawning physical habitat and water quality conditions through secondary effects such as vegetation encroachment and sedimentation.

The Makah Tribe is presently conducting further detailed analyses of both the hydraulic and hydrologic conditions of the lake system currently and historically, including a more detailed hydraulic model, a detailed hydrological water budget model of the lake, and a historic analysis of the change in shoreline conditions due to lake level changes. The National Park Service is conducting research on tributary sediment sources and sedimentation rates in Lake Ozette.

Land Use

In the Ozette Watershed, land was harvested in the 1880s to make clearings for settlements and small farms. Over time, commercial logging became more dominant. Commercial logging that began in the late 1930s and continued from the 1940s (railroad) to 1980s (trucked) has subsequently harvested 90% of the old growth in the watershed. There are many stream-adjacent roads and the average road density is about 6mi/mi^2 within the basin (J. Dieu, pers. comm.). While Olympic National Park surrounds Lake Ozette with a narrow swath of land, most of the tributary watersheds are within private timberlands. The strip of park-owned land with hydrologically mature stands is too narrow to buffer the lake from land-use activities within the drainage area (Meyer and Brenkman, 2001). Several miles of the Big River are owned by small landowners, and the riparian area in these reaches is primarily agricultural. The Ozette Indian Reservation borders the lower reaches of Ozette River and is currently managed by the Makah Tribe as a wilderness area.

Water Quality

The entire Lake Ozette system is rated Class AA (extraordinary waters) by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or permanent hatcheries located within these watersheds. For the Lake Ozette system, there are no water quality excursions on the 1998 303(d) list. However, Umbrella Creek, Crooked Creek, North Fork Crooked Creek and Big River are all on the proposed 2003/2004 303(d) list for elevated water temperatures (DOE, 2004). In summer 1994, Meyer and Brenkman (2001) found temperatures reached 20.3, 19.1, 18.4, and 17.4°C in Crooked, Umbrella, South and Siwash creeks respectively. Temperatures cool after October with fall rains affecting the surface waters. The warm summer lake surface temperatures affect upper Ozette River at the lake's outlet. Upper river temperatures have been recorded as high as 23.7°C in the summer, well above the preferred range of sockeye salmon or other salmonids (Meyer and Brenkman, 2001).

Lake Ozette also experiences elevated water temperatures. In 1994, temperatures exceeded 20°C on all sampled days from July to September from the lake surface to 6 m. (Meyer and Brenkman, 2001). Lake temperatures are probably naturally high, in part due to the color of the water (tannins absorb infared light very effectively) and to the low flows into the lake. The lake stratifies very strongly in the summer and suitable temperatures for salmonid holding and refugia are available deeper than 3 m (Crewson et al., 2004).

Summer dissolved oxygen levels range from poor to adequate in several tributaries, with levels ranging between 5.71 mg/L (Coal Creek) to 12.66 mg/L during 1994 (Meyer and Brenkman, 2001). Historically, low dissolved oxygen levels were also recorded during late summer (Bortleson and Dion, 1979).

Elevated turbidity levels are systematically a problem within the Ozette watershed. Turbidity is a surrogate measurement for suspended sediment. Tributaries to Ozette Lake, especially Big River and Umbrella Creek, deliver fine sediment under high flow conditions. The turbidity levels measured in Big River and Umbrella Creek were 161 and 185 NTU respectively during a storm event (Meyer and Brenkman, 2001). Without historical data, the State of Washington Class AA stream standards suggest levels should not exceed 5 NTU, which are consistently exceeded (Meyer and Brenkman, 2001). Tributary suspended sediment also causes visibility and turbidity problems in Lake Ozette. In December of 1999, storm conditions reduced visibility in the lake to less than one foot for 2 – 3 weeks (A. Ritchie, pers. comm.). Coal Creek also contributes sediment plumes to the lake via reverse flows in Ozette River and is considered to have poor water quality (A. Ritchie, pers. comm.).

Fish Distribution

The Ozette Watershed has one of the most diverse assemblages of freshwater fish species in the Pacific Northwest. Coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*Oncorhynchus nerka*) and winter steelhead trout (*Oncorhynchus mykiss*) are currently found in the Ozette watershed, as are kokanee salmon (*Oncorhynchus nerka)* and cutthroat trout *(Oncorhynchus clarkia)*. The area historically supported Chinook (*Oncorhynchus tshawytscha)* and chum salmon (*Oncorhynchus keta),* though their current status is not known and believed to be extremely low (chum) or even extinct (chinook) (Smith, 2000).

Of the salmonids in WRIA 20, only the Ozette sockeye has been listed as "threatened" under the Endangered Species Act. Comparing current numbers of fish with historical level estimates shows approximately a 75% drop in run size (Blum, 1988). The decline in the sockeye salmon is probably related to numerous factors including but not limited to over-fishing, marine productivity, predation by native and non-native fish and wildlife, and habitat degradation along the lake shoreline spawning habitat and in tributaries used for spawning (Meyer and Brenkman, 2001). Tributary spawning is currently limited to Big River, Umbrella Creek, and Crooked Creek and the spawning distribution along the lake shores has been significantly reduced.

Ozette fall Chinook and fall chum are virtually absent in the system with only the occasional Chinook stray recorded since 1995. Chum salmon fry are occasionally observed at the Ozette River smolt trap, and adult chum have been observed attempting to spawn with sockeye on lake beaches (A. Ritchie, pers. comm.). Downward trends in all species have encouraged more intense spawner surveys since 1997 along shorelines and on all Lake Ozette tributaries. However, spawner surveys are not regularly conducted along the Ozette River mainstem due to difficult surveying conditions.

Table 4.4. Ozette Salmon and Steelhead Stocks and Status

Stock	Nehlsen et al. (1991)	SASSI (1993)	McHenry et al. (1996)
Ozette fall Chinook	High risk of extinction	"Extinct"	Critical
Ozette fall chum	High risk of extinction	Unknown	Threatened
Ozette coho	Of special concern	Unknown	Threatened
Ozette sockeye	Moderate risk of extinction	Depressed	Critical
Ozette winter steelhead		Healthy	

Table 4.5. Run Times for Ozette Salmonids (SASSI, 1992)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chum												
Coho												
Sockeye												
Winter Steelhead												

Ozette sockeye hold in the lake before spawning. Run times are depicted by dotted cells. Spawning is depicted with cross-hatch.
No Chinook data was listed by SASSI, 1992

Habitat

Sedimentation

Though causes are undocumented, sedimentation is a major problem in Lake Ozette. Increased fine sediment in spawning gravels and native vegetation encroachment have severely degraded lakeshore spawning habitat. At some tributary mouths, and a few places along the shoreline, invasive species (reed canary grass, Japanese and giant knotweed) are exacerbating the problem. Degradation has occurred at Olson's Beach which is located near the mouths of Elk and Siwash creeks and along Swan and Ericson's bays (Meyer and Brenkman, 2001). Spawning gravels along the lower and middle reaches of the main tributaries average 18.7% fines by weight, well above the Western Washington target of 11% (McHenry et al., 1994).

Roads and poor surfacing material, along with mass wasting are some of the major causes for excess sediment in the watershed (Dlugokenski et al., 1981). Road density in the Umbrella Creek sub-basin was 4.4 miles/mi^2 in the early 1980s (Dlugokenski et al., 1981) and densities averaged 3.78 miles/mi^2 in the Big River sub-basin (as reviewed in Smith, 2000). Though these road densities are not considered extremely high, estimates are conservative as 10.1 miles of new road have been added in the last 5-6 years (as reviewed in Smith, 2000).

LWD

From the 1950s to 1980s, active removal of LWD occurred on Ozette and Big Rivers (Kramer, 1953). This practice removed many (26 large jams on the Ozette River in 1952 alone) of the functioning wood jams in the systems and presumably interrupted the riparian recruitment process, and the hydrologic and sediment regime. Loss of LWD in tributaries has undoubtedly destabilized channel morphology and potentially led to degraded water quality and spawning and rearing habitat (Haggerty, 2004 draft). Currently, levels of LWD are "poor" on the lower Big River, most of Siwash Creek and in parts of South Fork Crooked Creek. Quantities of LWD were rated as "good" in Crooked Creek, North Fork Crooked Creek, parts of South Fork Crooked Creek, lower Siwash Creek, middle South Creek and the middle reaches of Big River (Smith, 2000).

Data Gaps

As there is no recent watershed analysis for the Ozette Watershed, much of the above information is out of date or incomplete.

There is no continuous water quality data, particularly for turbidity and temperature, within the Ozette Watershed, though the Makah Tribe has begun basic ambient monitoring during the last few years. Though there has been speculation (Meyer and Brenkman, 2001) that temperature exceedances in Lake Ozette are part of the natural regime, this is unsubstantiated. The natural conditions of Lake Ozette and the Ozette River are unknown and local management effects cannot be teased out of the known water quality data.

The role of ONP in buffering the lake is also a data gap. It is not clear if the strip between timberlands and the lake is reducing sediment inputs and affecting water quality to any degree. The sediment dynamics within the lake system are currently unknown and it is unclear whether the turbidity in the lake is an artificial or natural condition. This data gap also extends to the levels of shoreline erosion and deposition.

The information on historical sockeye runs is a data gap as there are no data on historical tributary spawning locations and limited run size information. There is controversy as to whether tributary spawning ever existed. There is also controversy about the current population trends. The Ecologically Significant Unit (ESU) salmon recovery process recognizes this gap and is currently developing an appropriate recovery run size (include lake and tributary spawners) in lieu of determining actual historical run sizes.

Upcoming funded projects in the Ozette Watershed include:

- UW master's thesis study on sedimentation rates in Lake Ozette from tributary sources (Andy Ritchie)
- A National Park Service (via Herrera Consultants) sediment budget reconnaissance study
- Makah (Herrera Consultants) Phase 3 study on the Ozette Hydrological Changes (watershed water budget, improved Ozette River hydraulic model, effects of land use, and effects of wood removal on lake level regime)
- "Data Summary of Lake Ozette Tributary Habitat Conditions", currently in draft stage, to be released in 2004 by the Makah Tribe (Haggerty, 2004)

Quillayute Sub-Basins

The Quillayute drainage system consists of the 5.5-mile Quillayute mainstem, and the Bogachiel, Calawah, Sol Duc and Dickey rivers, which collectively become the Quillayute River at the confluence of the Sol Duc/Bogachiel rivers. The basin in total drains 628 sq. miles into the Pacific Ocean (Fretwell, 1984).

There is very little information on the Quillayute River mainstem. Water quality and tidal influence data was collected by USGS in the 1970s and the US Army Corps of Engineers examined the potential of the Quillayute River in 1981 for the purposes of navigation. The Corps also did an EIS of the area within the Quileute Reservation, in order to protect salmon stocks and other wildlife when meeting further dredging obligations under the River and Harbors Act. This EIS was updated in 2001 by the Corps with the assistance of contractors SAIC, and includes among other things, a habitat evaluation and study of water quality. The study, however, does not extend beyond the reservation. From 2001-2003, the Quileute Tribe performed water quality tests on the mainstem entirety, but as a training exercise, so the data should not be used for 303(d) purposes. The entire area between the reservation boundary and the confluence with the Sol Duc and Bogachiel can be considered a data gap for both fish habitat and water quality.

Dickey Sub-Basin

The Dickey River is a major tributary of the Quillayute River system. The Dickey mainstem is 22.8 miles long with a drainage basin of 108 sq. miles. The majority of the basin lies below 440 ft in elevation with the ridgetops ranging from 1,200 to 1,400 ft in elevation. Much of the area is within 10 miles of the Pacific Ocean. These conditions lead to high precipitation with little incident of snow or rain-on-snow events, as well as high winds, a factor that can adversely affect riparian buffers.

The Dickey basin contains three major tributaries (East, West and Middle Dickey), two major creeks (Skunk and Thunder) and a large lake (Dickey). The river sub-basins are very different in character.

Geology and Hydrology

The entire Dickey watershed lies at coastal lowland level. The watershed is underlain primarily by sandstone and siltstone assemblages, common components of the Eocene- and Miocene-aged sedimentary peripheral rock found surrounding the Olympic Mountains. The very northern edge of the watershed may be underlain by Eocene-aged metamorphic rock. Valley deposits are a mix of glacial outwash and till and glacio-lacustrine deposits. Stream channels have incised into the glacial materials leaving low-gradient channels and floodplains with sandy substrates. The continuing incision into deposits is a constant source for sediment in the watershed.

The majority of the West Dickey River is a long, low-gradient deep glide, with average gradients less than .5%. While the valley floor is broad, the actual channel is tightly confined as it is incised into glacial till and glacio-lacustrine deposits. Due to the low gradient and slow water velocity, there is a high volume of LWD. Banks are well vegetated and stable. The water temperatures are generally high and there is little gravel input as the headwaters of the river are Lake Dickey. Lake Dickey influences the West Dickey River strongly as it is a long shallow warm lake which traps sediment.

The Middle Dickey River is an unconfined channel bounded by broad terraces. The upper subwatershed is steeper with gravel substrate while the lower watershed has a very high sand content. The Middle Dickey River empties into the West Dickey River and provides almost all of the spawning habitat in the West Dickey system.

The East Dickey River is a dynamic channel dominated by pool-riffle habitat. The channel flows through both glacial deposits and bedrock sections. The glacial sections respond effectively to LWD by forming pools while the bedrock sections generally flush LWD out quickly and are dominated by large cobble.

Due to the low elevations and gentle gradients, mass wasting and coarse sediment inputs are not a concern in the Dickey watershed. Fine sediment from surface erosion events that delivered to channel networks have been observed and are a larger concern. These events generally are a result of historic logging practices (e.g., swing landing tracks). The only modern practices that significantly stand out are the vegetation removal or disturbance in southern-aspect inner gorges (LaManna et al., 1998). Since the morphology of the basin is predominantly low gradient, deliveries from activities in these inner gorges is a significant portion of the total sediment budget.

No hydrologic assessment currently exists for the Dickey Watershed. This may be due to several natural conditions occurring in the basin. First, low elevation precludes any rain-on-snow processes. Second, due to their incised nature, the channels are very stable and not easily impacted by increased stream flows. Finally, aerial photo analysis shows very few changes in the channel system in the last 50 years suggesting that management has little effect on high flows (Jackson, 1998). Therefore, not surprisingly, there are few flow data for the rivers in the Dickey system. Historically, the USGS had two gages in the watershed but there is no gage currently collecting data.

Flows in the Dickey are dominated by the highly seasonal rainfall. The basin follows the region's typical climatic regime with high winter precipitation and dry summers. The Dickey receives an average of 90 inches of rain annually. The 7-day low flow with a 50% probability of being exceeded in any year is 3.3 cfs in the West Dickey and 9.2 cfs in the East Dickey (Smith, 2000).

Land Use

The Dickey sub-basin lies within the Usual and Accustomed Fishing Grounds and Stations of the Quileute Tribe (treaty). The entire Dickey watershed can be characterized as a low-elevation, wet, maritime climate with dominant tree species consisting of western hemlock, Sitka spruce, red cedar and red alder. The major disturbance mechanism in the area is wind with fires occurring less frequently.

The main activity within the watershed historically was logging. The E/W Dickey was harvested progressively from the 1940s through the 1990s leaving variable aged timber today. There was little stream protection until 1982 when regulations required a 50% shade in the form of streamside buffers in the E. Dickey. However, for operational reasons, many trees were left along the West Dickey River during historical logging. Those trees contribute to current LWD levels. Currently, the main activity in the watershed is commercial forestry. There are also trails and access for fishing, hiking and other recreating. There are some private cabins in the watershed but no major human population centers.

Water Quality

The Dickey River and tributaries are rated as Class A by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds. Within the Dickey Watershed, parts of the West Fork, Middle Fork and East Fork Dickey are on the 303(d) list for high water temperatures. In 1997, the maximum temperature recorded just above the confluence with the East Fork was 22.4°C. The seven-day average temperature was continuously above 18°C for 27 consecutive days. Maximum temperatures in the East Fork just above the confluence were 21.3°C for the same period (Smith, 2000). The mainstems are thought to have elevated temperatures due to the loss of riparian shade and effects of wetlands.

Water quality data sources for the Dickey watershed include Quileute Natural Resources historical data going back to 1971 (grab samples) and recent Dickey Watershed water quality data. The recent data is a result of the E/W Dickey Watershed Analysis effort. Eleven water temperature stations were monitored with data loggers stratified across the watershed in 1997. Grab samples were also taken in 1997 from the upper Pond's Creek wetlands complex. Coal Creek, a tributary to the lower Dickey River, is also on the 303(d) list for elevated water temperatures (DOE, 1998). Other areas with high water temperatures include Dickey and Wentworth lakes, Skunk Creek, and Squaw Creek. These listings have resulted in temperature being the most outstanding problem in the Dickey Watershed (J. Dieu, pers. comm.).

Table 4.6. Water Quality Excursions on the 1998 303(d) List in the Class A Dickey Watershed (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Coal Creek T29N-R15W-S35	Quileute Tribe	Temperature	Numerous	6/23/92 – 9/28/92
Coal Creek T28N-R15W-S12	Quileute Tribe	Temperature	Numerous	6/23/92 – 9/28/92
E. Dickey T29N-R14W-S29	Quileute Tribe	Temperature	Numerous	7/19/90 – 9/20/90
E. Dickey T30N-R13W-S30	Quileute Tribe	Temperature	Numerous	7/19/90 – 9/20/90
Middle Dickey T30N-R14W-S23	Quileute Tribe	Temperature	2	7/24/91 – 7/30/91
Middle Dickey T29N-R15W-S35	Quileute Tribe	Temperature	2	7/24/91 – 7/30/91
W. Dickey T30N-R14W-S21	Quileute Tribe	Temperature	Numerous	7/19/90 – 10/14/91
W. Dickey T29N-R14W-S33	Quileute Tribe	Temperature	Numerous	7/19/90 – 10/14/91

There is one listing proposed for the 2003/2004 303(d) list for the mainstem Dickey River near La Push for elevated levels of fecal coliform. The excursions were sampled the DOE Ambient Monitoring Station in 1997.

High levels of sedimentation and organic materials occur naturally in the channel of the Dickey system. During 1997, the watershed analysis identified mainline roads as a critical source of sediment delivery as it related to water quality and turbidity. That concern was dealt with by a collaborative effort of DNR, Rayonier and the Quileute Tribe, and delivery was lowered by 50% as a result of the installation of a network of cross-drains and silt traps.

Sedimentation is a potential problem for Thunder Lake. The lake is fed by high gradient streams that drain from areas with an extensive network of logging roads. The lake's topography is shallow and flat which leads to a higher vulnerability for sediment inputs (LaManna et al., 1998).

Along with inputs from sandstone roads, clearcuts in the E/W Dickey Watershed have contributed to surface erosion events. Numerous field observations (LaManna et al., 1998) have shown that the inner gorges with southern aspects are particularly sensitive to any ground disturbance. While harvests on northern aspect slopes are able to revegetate quickly, southern aspect slopes are subject to winter raveling and cannot establish cover easily. The erosion from these inner gorges is directly contributing sediment to the channel networks and constitutes almost half of modern inventoried surface erosion events.

Fish Distribution

Nearly all of the perennial streams in the Dickey Watershed contain anadromous and resident salmonids. The Dickey Watershed produces an average of 19% of total fall coho, 2.6% of total fall Chinook and 4.1% of total steelhead productions for the entire Quillayute system. The Dickey is one of the most productive basins for coho in the entire state. This is likely due to low gradients and significant overwintering habitat. Steelhead and Chinook are found primarily in the East and Middle Dickey and Chinook are also located in the three tributaries in the lower East Dickey as well as the mainstem and its tributaries, such as Coal Creek. Chum occur sporadically in the system but there is little data on their existence.

Table 4.7. Dickey Salmon and Steelhead Stocks and Status

Stock	Huntington et al. (1996)	SASSI (1993)	McHenry et al. (1996)
Dickey fall Chinook	Healthy	Healthy	Threatened
Dickey fall coho	Healthy	Healthy	Stable
Dickey winter steelhead	Healthy	Healthy	Threatened

Winter steelhead do not appear to be currently in “threatened” condition. Dickey fall Chinook reported numbers are more likely to reflect survey problems than of actual low numbers (R. Lien, pers. comm.).

Table 4.8. Run and Spawn Times for Dickey Salmonids (SASSI, 1992; R. Lien, pers. comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Fall Chinook												
Fall Coho												
Fall Chum												
Winter Steelhead												

Habitat

Off Channel Habitat
Side channels and wetlands are particularly important as the basin provides many square miles of this habitat (especially in the West Fork) that is used for juvenile rearing, particularly coho. This report pre-dates the 2004 habitat study on the mainstem tributaries, but excellent wetlands and/or side channels may also be in those reaches (R. Lien, pers. comm.). As there were no buffers left on these areas during past logging practices (those that pre-date TFW), many of these areas are now completely unshaded and have high temperatures and sedimentation. Though some were naturally unshaded, high moisture content of the soil has led to slow regeneration (Bretherton et al., 1998).

LWD
Current in-channel LWD is adequate within the West Dickey Watershed where the low-gradient conditions tend to trap wood for long periods of time. Wood in this system is unlikely to be flushed out. LWD levels are also currently adequate on the Middle Dickey (Bretherton et al., 1998). This system, however, is more likely to lose wood in higher flows and therefore depends on continual recruitment. The East Dickey is extremely sensitive to jams and currently has a low count of LWD. The East Dickey has flows which regularly flush out jams and requires larger key pieces to secure wood. There are also local reports that fishermen may be clearing the channel of wood in order to float lower segments of the river. Most tributaries are in need of a continuous supply of coarse woody debris inputs and may be limited by the riparian channel overstories that are hardwood dominant.

Most stands with LWD recruitment potential in the E/W Dickey watershed are less than 50 years old and are generally mixed hardwood and conifer. Future recruitment may be poor until stands mature (Bretherton et al., 1998). In the Middle and East Dickey, active recruitment by bank undercutting has been observed in pool-riffle reaches. There is also evidence of windthrow and bank erosion actively adding wood to the East Dickey. The West Fork does not actively recruit wood on the majority of the river and depends primarily on tree mortality and windthrow. Though there are currently adequate LWD levels on the West Dickey, these levels will continue to decrease until the riparian stand matures (Bretherton et al., 1998).

Temperature
Most of the streams in the Dickey basin are vulnerable to high temperature as they have shallow water and an absence of riparian shading or microclimate controls. Only the West Fork glide habitat is not at potential risk as the river has deep cool areas and adequate LWD.

Currently, the average stand age in the Dickey Watershed does not provide adequate shading to streams with channel widths larger than 50 ft. The tributaries generally have sufficient shading as hardwoods regenerate quickly along the floodplains, thereby shading smaller channels. In tributary channels lacking proper shading, windthrow has usually destroyed buffers left from logging practices (Bretherton et al., 1998).

Approximately 10% of the streams in the Dickey Watershed received a high hazard shade rating in the 1997 E/W Dickey Watershed Analysis. This analysis was based on the color 1996 aerial photographs. The areas most degraded include the mainstems of both the East and West Dickey, Thunder Creek and Squaw Creek. There are also patches of high hazard shade areas on Middle Dickey and Ponds Creek.

Sediment
Natural loads of fine sediment are naturally high in the Dickey Watershed due to underlying geology, low gradients in the channel system and naturally low summer stream flows. Due to these factors combined with inner gorge deliveries and road erosion, fine sediments are one of the largest fish habitat concerns in the Dickey Watershed (LaManna et al., 1998). This concern relates only to areas in the Dickey Watershed that have gravel-bedded channels with high spawning probability. An increase of fines in these areas could significantly reduce the quality of the habitat.

Barriers
There are no natural barriers in the Dickey Watershed due to low gradients and gentle terrain. There are nearly 40 blocking culverts in the basin, however, resulting in a “poor” access rating in the 2000 Limiting Factors Report. Since the Dickey Watershed has the highest winter rearing habitat in WRIA 20 but low spawning habitat, these blockages are crucial. The majority of the blocking culverts are in the Ponds Creek area.

In addition to culvert blockages, the Dickey Watershed has several near riparian roads which act as dikes, blocking access to off channel habitat. The two most damaging roads are located in the Coal Creek and Colby Creek subwatersheds (Smith, 2000).

Data Gaps
The watershed analysis does not cover the mainstem of the Dickey in the Quillayute lowlands. This area has few data and can be considered a data gap. A fish habitat survey on this portion of the basin will take place in 2004 (BIA funding of Quileute Tribe).

The main data gap in the Dickey Watershed is the causes of elevated temperatures. The natural temperature regime is not known and it is difficult to link anthropogenic disturbance with temperature exceedances. The effects of harvesting forested wetlands on the temperature of shallow groundwater tables are also unknown.

Sol Duc Sub-Basin

The Sol Duc Watershed is located in the northeast corner of WRIA 20 and lies completely within Clallam County. The watershed is comprised of 20 subwatersheds and drains approximately 219 sq. miles. The upper portion of the Sol Duc is high country (elevations above 5,000 ft.) meadowland with many glacier lakes. These meadowlands drain into steeply incised headwater tributaries and form the rugged Upper and North Fork Sol Duc subwatersheds. The mainstem gradually broadens below Sol Duc falls and then adopts a lower gradient channel configuration typical of flat valley bottoms. Within the valley lowland reach, Camp, Lake, Bear and Beaver creeks are all major tributaries with Shuwah Creek to a lesser extent (R. Lien, pers. comm.). Lake Pleasant lies between Upper and Lower Lake Creek. Finally, 64.9 river miles from the headwaters, the Sol Duc and Bogachiel rivers meet to form the Quillayute River, a Pacific Ocean tributary.

Geology and Hydrology

The Sol Duc sub-basin follows the general trend in WRIA 20. During the last continental glaciation, major sediment deposition occurred on top of the underlying Miocene and Eocene sandstone, shale and conglomerates which underlie the area. These glacial depositions were outwashed by meltwater creating large broad valley floors. Since glacial retreat, the Sol Duc River has become entrenched in the valley fill.

Erosion and tectonic uplift are the major geologic processes which continue in the basin today. The rapid rate of uplift of the Olympic Mountains creates oversteepened slopes which when combined with a wet climate a vigorous vegetation lead to high natural rates of mass wasting (Sasich and Dieu, 1996). Human habitation and various land use practices have changed erosion patterns from infrequent large events to frequent smaller events. As forest practices slow, the landscape is recovering from elevated rates of mass wasting and erosion associated with clearcuts and heavily roaded areas. Currently, 68% of the watershed has had elevated sediment yields of over a 100% of the natural rate (Sasich and Dieu, 1996).

Most streamflow events in the Sol Duc Watershed are rain generated but there are rain-on-snow events are common in the eastern part of the watershed where snow persists December through April. The major floods of record occurred 1934 – 1956 but there have been numerous channel forming 2- to 10-year events in the past two decades (Jackson, 1996).

Because the upper Sol Duc is in the Olympic National Park and is not subject to timber harvesting, there has been no major changes in peak flow on the mainstem (Jackson, 1996). Some of the tributaries, however, including Kugel Creek, Camp Creek, Goodman

Creek and the S.F. Sol Duc contain immature forests and are less armored than the Upper Sol Duc and they are more sensitive to peak flow impacts (Jackson, 1996).

Within the lower watershed, with the exception of the South Fork of Bear Creek, nothing lies within the rain-on-snow zone. The South Fork of Bear Creek has experienced very little recent harvest and has a majority of mature forest. A greater concern in the lower watersheds is low flow problems due largely to local geology. Tributaries to the Sol Duc that must flow long distances over glacial outwash tend to dewater as the infiltration capacity of the streambed exceeds the flow. Currently, permitted water withdrawls equal 40% of the summer low flows and could potentially worsen the dewatering situation if the withdrawls were actually to be used all at once (Jackson, 1996).

Land Use

Of all the sub-basins in WRIA 20, the Sol Duc has some of the highest use and human activity. From RM 54.5 to the confluence, the river mainstem can be accessed by Highway 101, other State highways, and County, National Forest, Department of Natural Resources and private roads. The land ownership within the watershed is: 22.5% private (32,681 acres); 13.4% Washington State Land (19,480 acres); 31.9% Olympic National Park (46,353 acres); and 32.1% Olympic National Forest (46,607 acres). There are 26,404 acres of Late Successional Reserve and 20,144 acres of Adaptive Management Area within the National Forest. The Upper Sol Duc and North Fork have been kept pristine due to protection under the National Park.

The Sol Duc Watershed lies within the Quileute Tribe’s Usual and Accustomed Fishing Grounds and Stations (treaty). The tribe has long depended on the area for cultural and natural resources. White settlement began in the late 1800s with the nearby town of Forks established in 1877. Once the Spruce Railroad was completed in 1918, all accessible lands in the foothill and lowland areas of the Sol Duc were logged. At the peak of this extraction, logging companies were harvesting 500 million board feet a year. Around 1931, the Olympic Peninsula Loop Highway was completed, granting further access to the Sol Duc Watershed.

Most of the lowland (under 1,500 ft in elevation) is now held by private landowners and is managed for continuous timber rotation. The National Forest Lands in Camp Creek, Tom Creek, Goodman Creek, and South Fork Sol Duc subwatersheds were heavily harvested in the 1970s and 1980s. National Forest Lands in the Bear Creek and Kugel Creek areas are now managed as late seral reserves and almost all federal logging halted in 1994 as a result of the Northwest Forest Plan.

The Sol Duc is used heavily for both developed and undeveloped recreation. The pristine reaches of the upper Sol Duc within the Olympic National Park as well as the Sol Duc Thermal Hot Springs are major attractions for tourists and recreators. Salmon and steelhead resources combined with easy mainstem access provide incentive for sport fishermen, riparian boat launches and campgrounds.

Water Quality
All water quality data currently available is from Quileute Natural Resources (historical dating back to 1977) and the USFS Sol Duc Ranger District. The ranger district completely assessed water quality in 1994 as part of the 1995 Watershed Restoration Strategy contained in the Record of Decision for the Northwest Forest Plan (USDA and USDI, 1994). All water quality data currently published is in the Appendix of the 1996 Sol Duc Pilot Watershed Analysis and includes the following:

- Temperature data on 10 tributaries (USFS, 1994)
- Dissolved Oxygen and Temperature for Sol Duc RM 19.0 and 53.5 (QNR, 1992-1995)
- pH values for Sol Duc RM 6.5 (QNR, 1992-4), RM 23.4 and 44.9 (USGS, 1994), and RM 63.0 (ONP, 1993-4)
- pH values for Lower Lake Creek (QNR, 1992-4), Upper Lake Creek (QNR, 1992-4)
- Data for Lake Pleasant and Beaver Lake including temperature, secchi disk readings, fecal coliform, and dissolved oxygen (Fretwell, 1984)

Table 4.9. Water Quality Excursions on the 1998 303(d) list in the Class AA Sol Duc Watershed (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Beaver Creek	Quileute Tribe	Temperature	44	1994
Elk Creek RM 1.8	Horrock and Lombard	Temperature	10	1994
Lake Creek RM 2.75	Quileute Tribe	Temperature	16	1992 – 1995
Lake Creek RM 2.75	Quileute Tribe	Dissolved Oxygen	8	1992 – 1995
Lake Creek RM 2	Quileute Tribe	Temperature	5	1994 – 1995
Lake Creek RM 2	Quileute Tribe	Dissolved Oxygen	7	1994 – 1995
Sol Duc RM 44.9	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 23.75	Quileute Tribe	Temperature	2	1992 – 1995
Sol Duc RM 22.1	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 13	Quileute Tribe	Temperature	3	1992 – 1995
Sol Duc RM 19	Quileute Tribe	Temperature	2	1992 – 1995
Sol Duc RM 6.5	Quileute Tribe	Temperature	4	1992 – 1995
Sol Duc – WDFW hatchery	WDFW	Temperature	Numerous	NA
Sol Duc RM 44.9	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Sol Duc RM 22.1	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Sol Duc RM 19	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995

Temperatures regularly exceed 20° C in some locations in July and August while annual lows of approximately 5° C have recorded in heavy rains in November and March. According to state water quality standards, Beaver Creek and Bockman Creek, both tributaries to the Sol Duc, have exceeding temperatures, with Beaver Creek exceeding temperature requirements 44 times out of 80 sampled in 1994 (DOE, 1998).

There are few data on Sol Duc dissolved oxygen but most observations meet State water quality standards of 9.5 mg/L for class AA (extraordinary) waters. Instances where dissolved oxygen is low are usually due to high summer temperatures combined with low seasonal flows (Parks and Figlar-Barnes, 1996). The only area that exceeded state standards from 1992 – 1994 (measured by QNR) was RM 36 on the mainstem.

There is no continuous turbidity sampling currently done on the Sol Duc. However, instantaneous grab samples suggest that turbidity is extremely low (2 NTU) except for during elevated discharge during storm events. Data from tributaries seems to be more variable, ranging between 0.05 NTU and 87.8 NTU (Parks and Figlar-Barnes, 1996).

Water quality data for lakes in the Sol Duc sub-basin is limited to Beaver Lake and Lake Pleasant. Both lakes are thermally stratified. Data from QNR (1992) suggests that dissolved oxygen in Lake Pleasant is within state standards. Water temperatures in Beaver Lake (17.3° C) and Lake Pleasant (20-22° C) are well above state standards. As both lake outlets are discharges for streams, these elevated temperatures may have negative effects on the entire system (Parks and Figlar-Barnes, 1996). Lake Pleasant has low arsenic levels at the surface but sediment arsenic concentrations exceed the National Toxics Rule water criterion of 0.14 µg/L for the consumption of organisms (DOE, 2003).

Fish Distribution

The mainstem of the Sol Duc River is accessible to salmonids for almost 60 miles from the mouth of the river to Sol Duc Falls. Of all the streams in the watershed, 89 percent provide habitat for anadromous and resident fish species (Naughton and Parton, 1996). The 11 distinct salmonid stocks in the basin comprise the following percentages of total salmonids in the Quillayute Basin (Table 3.5)

Table 4.10. Contribution of Selected Sol Duc Watershed Salmonid Stocks to Total Natural Spawning Escapements in the Quillayute River Basin (Quileute Natural Resources data as reviewed by Naughton and Parton , 1996).

Stock	Range of Contribution to Quillayute Escapement
Fall Chinook	50.0% - 68.5%
Summer Chinook	42.8% - 66.3%
Fall (winter) coho	37.5% - 68.3%
Sockeye	100%
Summer coho	100%
Winter steelhead	40.6% - 57.5%

Two hatcheries are currently operating in the Sol Duc Watershed. WDFW operates the Sol Duc hatchery on the mainstem at RM 30 in cooperation with the Quileute Tribe. The hatchery produces and releases spring and fall Chinook, and summer and fall coho salmon. The spring Chinook stock is an introduced population; all other stocks are of local origin.

There is also a hatchery at the Snider Creek confluence at RM 44, operated by WDFW and the Olympic Peninsula Guides Association (OPGA). This facility captures wild winter steelhead with the help of sport fishermen volunteers. The steelhead are spawned and incubated at other hatchery facilities and then released as smolts from the Snider Creek facility.

The status of the Sol Duc salmonids is listed in the table below. In general, the Sol Duc stocks follow the same trend as other north coastal stocks and are mostly considered healthy.

Table 4.11. Status of Select Anadromous Fish Stocks in the Sol Duc Watershed by Referenced Source

		McHenry et al., (1996)	SASSI (WDFW et al., 1993)	Huntington et al., 1994
Stock	Production	Stock Status	Stock Status	Stock Health
Chinook:				
Fall	Natural/hatchery*	Healthy	Healthy	Present
Spring	Native/hatchery		Healthy	Healthy
Summer	Natural	Threatened	Healthy	Healthy
Coho:				
Fall	Natural/hatchery	Stable	Healthy	Present
Summer	Natural/hatchery	Threatened	Healthy	(not recognized)
Steelhead:				
Winter	Natural	Stable	Healthy	(not recognized)
Summer	Natural		Unknown	Not present
Sockeye:				
Fall	Natural		Unknown	Not present
Chum:				
Fall	Natural		Unknown	Not present
Cutthroat:				
Sea-run	Natural			

*Hatchery production of fall chinook are currently considered insignificant at < 10,000 smolts/yr (Naughton and Parton, 1996).

The status of spring Chinook is considered healthy, but there will be a DNA evaluation conducted of spring/summer Chinook to determine if there is intermingling. All spring Chinook have been introduced to the Sol Duc artificially. Spring Chinook are an introduced run from the Dungeness and the Umpqua River. The production of sockeye salmon is natural and of healthy status. The Quileute Tribe does not survey for cutthroat trout or chum (R. Lien, pers. comm.).

Table 4.12. Run Times for Sol Duc Salmonids (SASSI, 1992; R. Lien, pers. comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Spring Chinook	■	■										
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Summer Coho			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Lake Pleasant Sockeye				■	■	■						
Summer Steelhead							■	■	■			
Winter Steelhead							■	■	■	■	■	

Habitat

LWD

Throughout the Sol Duc channel network, LWD-jams in general were lacking and the condition of LWD in-stream was poor (Chesney, 1996). Areas that had adequate amounts of LWD included Goodman, Alckee, South Fork Sol Duc, Sol Duc (RM 52) and North Fork Sol Duc. Bear, Beaver, Lake, Shuwah and Bockman creeks were all lacking in-stream LWD. The character of LWD is different form historical records in the Sol Duc system. Key-pieces of LWD in poor condition often trap smaller more mobile rafts of alder. While these rafts provide structure, they are likely to have a short residence time (Chesney, 1996).

Overall, near-term LWD recruitment in the Sol Duc Watershed is good (60%). This is measured by the percentage of stream miles in which both sides of the channel can provide LWD (Christensen, 1996). Subwatersheds within ONP and the upper watershed, the Upper Sol Duc River, the North Fork Sol Duc, and Alckee Creek have upwards of 94% of area with good recruitment. Kugel Creek has the worst recruitment potential with 70% of the area rated as “poor” (Christensen, 1996). The areas with poor recruitment are likely due to intense timber harvesting and salvage operations following fire and wind disturbances. There is also a distinct lack of cedar as a result of stream cleaning and the continual planting of common species such as Douglas fire and Western hemlock (Christensen, 1996).

Sedimentation

A history of fire, wind, heavy precipitation and forest management activities has led to elevated sediment yields in parts of the Sol Duc drainage. Thirty two percent of the basin is unchanged from natural sediment yields and is located primarily in the headwaters of the basin. Twelve percent of the basin has elevated sediment levels recorded only in the past 20 years and will experience limited recovery in the near term. The rest of the basin (56%) has had elevated sediment yields for the last 40 years and is in recovery (Sasich and Dieu, 1996).

The basins that have limited recovery potential in the near term include the South Fork Sol Duc, Goodman, Upper Camp, Tom and Beaver creeks. The S.F. Sol Duc, Goodman and Tom sub-basins have the largest increases in sediment yield due to extensive clearcutting and harvesting (Sasich and Dieu, 1996). The road densities in these subwatersheds range from 3.05 – 3.73 miles/sq. mile. Two major debris flows in the Goodman and S.F. Sol Duc basins have contributed fine sediment to streams in the last 5 – 7 years (Sasich and Dieu, 1996). Beaver and Camp creeks have experienced elevated rates due primarily to wildfires and subsequent harvesting activities.

Shade

In general, the upper portions of the Sol Duc Watershed have good canopy cover with 77% of riparian areas providing adequate shade. Of the 23% of the area with low shade levels, 19% has natural low shade due to wide riparian corridors and only 4% is considered to have high impacts on water temperature as a result of lack of shade (Christensen, 1996).

Among areas that exceed state standards for temperature, the mainstem Sol Duc, N.F. Sol Duc, S.F. Sol Duc and Goodman Creek all have naturally low levels of riparian shade. Though these areas exceed 16°C, the duration of the exceedances is short term, lasting less than 7 days (Parks and Figlar-Barnes, 1996).

Tom Creek, Camp Creek, Upper Bear Creek, S.F. Bear Creek, Cold Creek, Shuwah Creek, Upper Lake Creek, Kugel Creek and Tassel Creek all have water temperatures well within current state standards even though the levels of riparian shade vary significantly. This suggests that shade is not the controlling factor for water temperature in these areas.

Lower Lake Creek and Beaver Creek have consistently high water temperatures and may be highly vulnerable to levels of riparian shade as they have naturally high levels of canopy cover. However, they are both fed by upper lakes which may compound high temperatures. Lower Bear Creek, Swanson Creek and Bockman Creek are all highly vulnerable to the removal of riparian canopy (Christensen, 1996).

Barriers

There were a few barriers present as a result of undersized or poorly engineered culverts primarily in Gunderson, Tassel and Bockman creeks. The barriers blocked about 5 miles of anadromous fish habitat. The Quileute Tribe has replaced defective culverts in Bockman, Tassel, and Fossil creeks since the watershed analysis was completed. Due to the low levels of LWD in the streams and reduced numbers of natural barriers, there actually may be more habitat available than historically. This, of course, does not take habitat quality into account. Barriers in the area have been recorded and maintenance efforts are currently underway (Naughton and Parton, 1996).

Data Gaps

The most outstanding data gap in the Sol Duc sub-basin is the lack of current data. The Sol Duc Pilot Watershed Analysis was the first to be performed in WRIA 20 and, in fact, was the pilot watershed analysis under the Northwest Forest Plan. The data as a result is 10-years old. The process may have also been less rigorous as there was little experience in watershed analysis in the area (J. Dieu, pers. comm.).

Currently, Streamkeepers is actively collecting data on several tributaries to the Sol Duc. The data, however, have not been synthesized.

There is also very little information on the historical condition of the mainstem of the Sol Duc. Since the channel is more tightly confined and there is less sediment transport than other large local systems like the Hoh, there isn’t a good model to relate the Sol Duc. The channel module of the 1996 watershed analysis did not include standardized wood counts. Until there is better information about the role of LWD in the mainstem, there can be little analysis done of the effects of LWD on the system. There is reason to think that low levels of LWD on the mainstem have had a deleterious effect as there is virtually no off-channel habitat (J. Dieu, pers. comm.).

Due to concerns of future over-allocation, there is a need for low flow studies on the Sol Duc. Degraded water quality has already been linked to low summer flows. If there are future needs which will further reduce these flows, they should be studied at length.

Calawah Sub-Basin

Because there is so little data on the Calawah mainstem, this report will cover the major tributaries of the Calawah that were subject to watershed analyses. The City of Forks is located within the lower Calawah Basin and is an important land use for the mainstem drainage. All of the mainstem Calawah Basin lies within the treaty area of the Quileute Tribe.

North Fork Calawah Tributary

The North Fork of the Calawah River lies south of the Sol Duc Watershed and north of the S.F. Calawah watershed and drains roughly 48 sq. miles. The tributary flows in a westerly direction for approximately 18 miles, eventually merging with the South Fork Calawah to form the Calawah mainstem. The Calawah River then flows together with the Bogachiel to form the Quillayute River which is a Pacific Ocean tributary.

Geology and Hydrology

This watershed straddles the peripheral rocks of the coastal portions of the Olympic Peninsula and the core rocks of the Olympic Mountains, a boundary known as the Calawah Fault. The northern side of the fault is dominated by volcano-lithic sandstone and siltstones while the area south of the fault is composed primarily of lithic sandstone.

Due to weak sandstones and extremely steep slopes, the N.F. Calawah Watershed is prone to high rates of landslides, particularly along the southern and eastern edges. In these areas, many of the hillslopes have gradients greater than 60% with knife-like ridgetops. A significant number of mass wasting events, however, do not actually deliver to the channel network because of substantial runout distances across glacial landforms and deposits (Dieu and Shelmerdine, 1996).

Like other subwatersheds in WRIA 20, the valley bottom of the North Fork Calawah is composed primary of advanced glacial outwash, several hundred feet of unconsolidated and highly permeable gravels and sands as a result of the Vashon glaciation. The highly permeable composition of the outwash in this watershed created a reservoir capable of conveying 30 – 60 cfs subsurface down the valley (Jackson, 1996). This has created one of the most unique hydrologic regimes in the state. Sections of the mainstem for 7 – 8 miles, annual averaging 135 cfs to 201 cfs, will go dry for several months of the year (Jackson, 1996). The drying regime is completely dependent on geology and is not affected by local management.

A large proportion of the watershed is dominated by rain-on-snow events, particularly in the eastern portion of the basin. Channels within these areas are sensitive to rain-on-snow events as the forests in the watershed are hydrologically immature. Tributaries which have high gradient, bedrock-controlled streams will have increased peak flows which in turn will deliver to a highly responsive glacial outwash filled valley floor (Jackson, 1996).

Land Use

The event defining current conditions in the North Fork Calawah Watershed was the Great Forks Fire in 1951. The fire originated from a slash and burn right-of-way effort in Camp Creek (Sol Duc Watershed) and burned over 30,000 acres southward and westward in 48 hours, covering much of the N.F. Calawah Watershed. After the burn, an extensive road network was built as part of the salvage effort. By the mid-1950s, the area was completely roaded and devoid of canopy cover.

Half a century later, the effects of the Forks Fire are still noticeable in the watershed. Channel conditions continue to be affected across the watershed as sedimentation has resulted from the many salvage-road-induced landslides. Hardwoods dominate on the valley floor and provide little opportunity for LWD recruitment. Finally, the fire and subsequent logging combined have created almost a complete absence of late successional vegetation, except in the far west and far east ends of the watershed.

Until the 1990s, the watershed continued to be managed primarily for timber production. Except for an area that is owned and farmed by a single family, almost the entire watershed is either owned by Rayonier Timberlands Operating Co. or the federal government. Though much of the land owned by Rayonier has been too young to harvest since the salvage logging following the Great Forks Fire, the USFS logged all remaining patches of timber through the 1980s. Since the Northwest Forest plan, federal management goals are being reevaluated and most timber operations have been limited to selective thinnings.

Water Quality

The Calawah River and tributaries are all rated Class AA (extraordinary) by the Department of Ecology. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds. The following is taken directly from the North Fork Calawah Watershed Analysis Fish Module (Martin et al., 1996). Data were a compilation of Quileute Natural Resources and Sol Duc Ranger District monitoring from 1993 to 1995. The QNR and Ranger District collected instantaneous temperature, DO and pH.

Mainstem

RM 0.0 – 9.0: Results along the mainstem downstream of the drying reach show a wide range of temperatures during the sampling period. Data suggest that there are several prominent areas of groundwater upwellings which result in localized cold spots. All sites upstream of Western Cool Creek and unaffected by groundwater inputs exceeded WA state water quality standards on 17 days in 1995. All sites were within state standards for pH and DO with the exception of one site that had minor exceedances.

RM 9.0 – 16.3: This reach of the river is dry from late spring to early fall.

RM 16.3 – 17.3: This section has the highest recorded temperatures during all the sample years. Temperatures exceeded state standards on 34 and 22 days in 1993 and 1995 respectively. Between RM 18 and RM 16.5, maximum stream temperatures increased by almost 4° C on the hottest days. This increase is probably due to the proximity of this reach to the downstream dewatered reach. This reach also had the highest number of DO exceedances (3) for the entire N.F. Calawah Watershed. All measurements for pH were within WA state standards.

RM 18, 20: Temperature regimes for these two reaches were similar with a slight increase recorded at the downstream site. Slight temperature exceedances were recorded at RM 18 and one exceedance for DO was recorded. All measurements for pH were within WA state standards.

In Eastern Cool Creek, Devils Creek and Fahnestock Creek: Water temperatures exceeded state standards with the highest number of exceedances in Fahnestock and Devils Creek and minor exceedances in Eastern Cool Creek. Though all three streams currently have adequate riparian cover, low summer flows and low elevation increase their susceptibility to increased temperatures.

Albion Creek: Although riparian cover is below target goals, low flow temperatures are within target levels.

Table 4.13. Water Quality Excursions on the 1998 303(d) List in the Class AA North Fork Calawah Watershed (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
NF Calawah RM 2	Quileute Tribe	Temperature (natural conditions)	12	1995
Devils Creek	Quileute Tribe	Temperature (natural conditions)	5	1995
Fahnestock Creek	Quileute Tribe	Temperature (natural conditions)	3	1995

Fish Distribution

The N.F. Calawah is home to substantial populations of Chinook, coho and steelhead. Stray sockeye (no lake for rearing) and chum are believed to be present though there is limited information on their locations. Resident cutthroat trout and mountain whitefish occur throughout the watershed as well as common sculpins and Pacific lampreys.

The N.F. Calawah Watershed has 220 miles of perennial streams. Anadromous fish occur in 44 miles of the streams: 17.3 miles of the mainstem and 26.7 miles of the tributaries. During the summer, rearing on the mainstem is reduced by up to 47% due to the drying reach. Several tributaries to the drying reach flow year round and provide critical summer and winter rearing habitat.

The populations occurring in the N.F. Calawah are the same populations found in the S.F. Calawah and Sitkum rivers. Currently, the Washington State SASSI report rates the following major salmonid stocks as healthy native stocks: fall Chinook, fall coho, and winter steelhead. The lack of information available on summer steelhead and Chinook has resulted in an unknown stock status determination. McHenry (1996), however, rates the summer Chinook and fall coho as threatened. Population trends over the last 20 years have been highly variable but there has been no consistent downward trend. The variability is though to be a result of ocean conditions and precipitation levels as opposed to habitat condition (Martin et al., 1996).

Table 4.14. Run Times for Calawah Salmonids (SASSI, 1992, R. Lien, pers. comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Summer Steelhead								■	■	■	■	
Winter Steelhead								■	■	■	■	

Habitat

LWD

The habitat quality ratings for total LWD in the system ranged from fair to good for all tributaries, but poor for all but the upper mainstem. For key pieces of LWD, only Western Cool, Eastern Cool, Fahnestock, and Pistol Creek were rated as good, suggesting that key pieces were a concern for all other creeks and mainstem segments. Due to lack of LWD on the mainstem, the channel has incised significantly resulting in a degraded floodplain condition (Martin et al., 1996).

Much of the LWD currently in the stream is composed of alder. Due to the rapid rate of decay, alders are not considered desirable LWD. The loss of large conifer LWD is considered the most important concern for the formation of fish habitat in the watershed.

The majority of LWD inventoried recently is assumed to have originated from landslides and debris flows that deposited directly into the mainstem and from dam-break floods and fluvial transport from major tributaries because the riparian zone is too young to have provided such wood (Benda, 1996). The current LWD-recruitment potential in the North Fork Calawah Watershed is improving as riparian stands decimated in the Great Forks fire are approaching maturity (Springer, 1996). There is concern about deciduous-dominated zones along the mainstem of the North Fork Calawah, though it appears that this may reflect natural conditions in the flood disturbance zones (Springer, 1996).

Shade

Although there are exceedances for water temperature in the basin, this is not the primary concern for fish habitat. Most of the riparian zone has adequate shade cover as the hardwood stands have reached maturity since the Forks Fire. Areas without adequate shade are usually a result of naturally open conditions (Springer, 1996). Groundwater inputs are an important component in stream temperatures in this system, Though the drying reach acts as a barrier, it provides cold groundwater to the mainstem downstream (Jackson, 1996).

Sedimentation
A majority of overall sediment contribution to the North Fork Calawah River is a result of landslides triggered by roads and timber harvest (Dieu and Shelmerdine, 1996). The steep upper tributaries and mainstem deliver most of the sediment to the river. The upper segments are therefore dominated by coarse sediment while the lower gentler segments have more fine sediment deposition. Though sediment delivery has slowed since logging practices stopped in the late 1980s, it is not expected to continue to decrease without additional road restoration efforts. The sedimentation has contributed to embeddedness in spawning habitat.

The N.F Calawah River, Pistol Creek and Albion Creek have all received poor channel stability ratings. In these areas, there have been significant debris jams resulting in channel aggradation. This in turn has led to a decrease in pool habitat and increase in fine sediment. The current lack of LWD in the mainstem increases the rate of sediment transport and worsens the fine sediment problem (Benda, 1996). Regardless of location, the average amount of fine sediments in low-gradient spawning gravel across the basin is 14%.

Barriers
The majority of barriers in the North Fork Calawah drainage are naturally formed. Since the area is prone to mass wasting events, there are debris flows that are not passable for anadromous fish. High gradients and waterfalls are also common in the upper portion of the watershed. Finally, the drying reach of the N.F. mainstem acts as a barrier in summer months.

There are few barriers on small unnamed tributaries that are a result of perched culverts. The highest priority culvert replacement is on a tributary to the drying reach. This tributary is crucial as it provides rearing habitat during summer months when the mainstem is not available (Smith, 2000).

Data Gaps
Though current water quality is a data gap, little has changed since the 1998 Watershed Analysis (J. Dieu, pers. comm.). The North Fork Calawah is known to have unique hydrology that leads to “losing reaches”, this relationship between poor water quality and this hydrology (natural conditions) should be examined.

South Fork Calawah and Sitkum Tributaries
The South Fork Calawah and Sitkum Rivers lie on the eastern edge of WRIA 20, abutting the Olympic Mountains and flow 21 miles and 12 miles long respectively. Both rivers flow in a westerly direction with a combined drainage area of about 72 square miles. Within the watershed, elevations range from about 100 to 3,750 ft, most high elevation ridgetops reaching over 3,000 ft. The Sitkum River flows into the South Fork Calawah

which in turn meets the North Fork to form the Calawah River. The Calawah River flows into the Bogachiel which eventually meets the Sol Duc to form the Quillayute River. The Quillayute drains westerly into the Pacific Ocean.

Geology and Hydrology

The South Fork Calawah and Sitkum watersheds are typical of the area with upthrust sedimentary rock ridges and broad glacial outwash till covered valleys. The northern part of the watersheds (Hyas Creek, Rainbow Creek and N.F. Sitkum River) show a different geomorphic character than the drainages on the south side of the Sitkum basin and the entire S.F. Calawah River Watershed. The drainage density is high and the pattern is northeasterly dendritic as opposed to the rectangular pattern found in the rest of the Sitkum and the S.F. Calawah. This is highly indicative of a northeastern trending fault system predominant in those drainages.

Though the area is predisposed to some mass wasting events, it is apparent that land use management in the area has had a significant effect. Of 759 mapped failures in both watersheds (identified between 1939 – 1997), 50% were related to road building and/or harvest activities (Lingley, 1998). Hyas Creek and Upper Sitkum subwatersheds had the most failures (78 and 65 respectively) and approximately 30% of these are the result of either road building activities and/or harvest operations (Lingley, 1998). The landslide density for these two subwatersheds, however, is close to the average of 4.2%

Streamflow patterns strongly correlate to precipitation patterns within the watersheds. July and August have low flows while peak flows occur in November and December. The two highest peak flows recorded have occurred since 1991 and over 60% of the events with a 2-year recurrence interval or greater have occurred since 1990 (Stoddard, 1998). Floods have increased in magnitude and timing.

Both watersheds are sensitive to rain-on-snow events as 58% of the area lies within rain-on-snow zones. The majority of the watersheds are hydrologically mature (69%) and immature areas are defined by harvested areas and road networks. The Upper Sitkum River (19%), the North Sitkum River (18%) and Rainbow Creek (11%) have the greatest amount of hydrologically immature area (Stoddard, 1998).

Land Use

The South Fork Calawah and Sitkum watersheds are divided among four main land stewards: Olympic National Forest, Olympic National Park, Washington State Department of Natural Resources, and private land owners.

Table 4.15. Watershed Administration Acres in S.F. Calawah and Sitkum Watersheds (ONP, 1998)

Watershed	Subwatershed	Private	State	ONP	ONF	Total
S.F. Calawah River	Mainstem S.F.	394.4	516.3	4.5	2,153.9	3,069.1
	Hyas Creek	1,248.7	159.9	0.0	3,547.3	4,055.9
	Lost Creek	0.0	0.0	1,586.7	1,998.9	3,585.5
	Lower S.F.	0.0	0.0	4,972.2	1.0	4,973.2
	Middle S.F.	0.0	0.0	5,660.4	0.0	5,660.4
	Upper S.F.	0.0	0.0	4,332.2	0.0	4,332,2
	Total	1,643.1	676.2	16,556.0	7,701.0	26,576.3
Sitkum River	Lower Sitkum	0.0	0.0	0.0	3,095.5	3,095.5
	Rainbow Creek	0.0	0.0	0.0	2,199.4	2,199.4
	N.F. Sitkum	0.0	0.0	0.0	3,183.9	3,183.9
	Middle Sitkum	0.0	0.0	0.0	3,429.8	3,429.8
	Upper Sitkum	0.0	0.0	0.0	7,875.4	7,875.4
	Total	0.0	0.0	0.0	19,784.0	19,784.0
Totals	Sitkum/S.F. Calawah River	1643.1	676.2	16,556.0	27,485.0	46,360.3

Within the Olympic National Forest, the land has been divided into two major management units under the Northwest Forest Plan: Adaptive Management Areas (AMAs) and Late Successional Reserves (LSRs). In the South Fork Watershed, these designations are about equal while in the Sitkum Watershed, there is a considerable larger portion of LSR.

Homesteading of the basins began in the late 1800s along the lower mainstem of the South Fork Calawah. Commercial logging followed in the 1940s and concentrated on salvage logging in the Hyas Creek area after the Great Forks fire of 1951. Through the end of the 1980s, logging took place primarily on federal lands but clearcut operations stopped completely in 1994 with the implementation of the Northwest Forest Plan. There is some harvesting that continues today on State and private lands.

One of the main uses of these watersheds today is recreation. Activities range from lowland forest and riparian use to high alpine use and include hiking, biking, hunting, fishing, boating and mountaineering. Though there is little data available on these recreational effects, anecdotal evidence points to minimal impacts except for in high use areas associated with the mainstems of the rivers.

Water Quality

All streams within the South Fork Calawah and Sitkum watersheds are classified as class AA (extraordinary) surface waters. The primary designated use requiring protection is anadromous fish production since there are no domestic water systems or hatcheries located within these watersheds.

Water quality data for the Sitkum covers sites along the mainstem and major tributaries. There is only one sampling site at the mouth of the South Fork Calawah. All water quality data summarized below were collected by the Sol Duc Ranger District, Olympic

National Forest, at selected sites in 1996 and 1997. Temperatures were recorded continuously from June to September at one hour intervals. Some sites were sampled throughout the year to detect seasonal variations in water temperature. DO measurements were only taken in 1996.

Table 4.16. Summary of Water Temperature Data in the S.F. Calawah and Sitkum Watersheds (DeCillis, 1998)

Stream Name	Site (RM) Seg #	Date	Max Temp/ Date (C)	Total # Days Exceeding 16 C	# Days 16 – 18 C	# Days 18 – 21 C
Rainbow Creek	1.0, F2	7/96 – 9/96 7/97 – 9/97	17.5 7/5 7/27 15.6 8/14	11 0	11 0	0 0
Hyas Creek	0.2, B1	7/96 – 9/96 7/97 – 9/97	18 7/27 16.8 8/14	12 11	12 11	0 0
Sitkum River	0.2, D1	7/96 – 9/96 7/97 – 9/97	21.6 7/14 21.4 7/28	45 52	N/A 27	N/A 25
S.F. Calawah	16.3, 12	7/96 – 9/96 7/97 – 9/97	21.2 7/14 7/27 19.3 8/13	43 24	N/A 11	N/A 13
N.F. Sitkum	1.2, E2	7/96 – 9/96	18 7/28	14	14	0
Trib. 0221	0.3, D77	7/96 – 9/96	18.1 7/27	14	13	1
Lost Creek	0.1, C1	7/96 – 9/96 7/97 – 9/97	16.2 7/27 16.3 15 8/13	1 0	1 0	0 0

Table 4.17. Summary of D/O Data for S.F. Calawah and Sitkum Watersheds (DeCillis, 1998)

Stream Name	Site Location (RM)	Date	D/O Average mg/L	# Days Below 9.5 mg/L	Range D/O (low/high)
Rainbow Creek	1.0	7/5 – 9/9/96	10.5	0	10.2-11.0
N.F. Sitkum	1.2	7/12 – 9/9/96	9.9	2	9.0-10.6
Trib. 0221	0.3	7/12 – 9/9/96	10.4	0	9.8-10.8
Lost Creek	0.1	7/9 – 9/6/96	10.6	0	10.3-10.9
Hyas Creek	0.2	7/6 – 9/9/96	10.5	0	9.9-10.8
Sitkum River	0.2	7/9 – 9/6/96	10.0	1	9.1-10.8
S.F. Calawah	16.3	7/9 – 9/6/96	10.3	0	9.7-10.7

All sites sampled from the summer of 1996 show increased water temperatures as a result of the warm, dry summer. All reaches exceeded WA state water quality standards with the exception of Lost Creek which only had one day of temperatures over 16°C. Temperatures from 1997 have a marked decrease of water temperature that reflects the cooler, wetter summer. Temperatures from 1997 show dramatic decreases in exceedances, particularly with samples from Rainbow Creek and the South Fork of the Calawah. The Sitkum River is the only site that has an increase in temperatures between 1996 and 1997. There were no sites listed on the state 303(d) list in 1998. There are, however, two listings proposed for the 2003/2004 303(d) list on the SF Calawah at RM 5.96 and on the Sitkum River at RM 0.1 and RM 2.8 for elevated temperatures. This data was collected by 1998, 2000, and 2002 by Olympic National Forest and conditions are most likely due to natural causes.

Fish Distribution

The S.F. Calawah and Sitkum watersheds are heavily used by substantial populations of Chinook salmon, coho salmon, and steelhead trout, along with stray populations of river-run sockeye salmon and chum salmon. Pacific lamprey and mountain whitefish are present in the lower mainstem of both watersheds but information on their location and populations is very limited. Resident and anadromous cutthroat trout and sculpins are also found throughout most of the watersheds.

The Sitkum and S.F. Calawah stock health and status are reviewed in the N.F. Calawah section.

Within the S.F. Calawah and Sitkum watersheds, there are 50.6 miles of fish bearing streams; 31.4 miles used by anadromous fish and 19.2 miles used by resident fish (DeCillis, 1998). Natural barriers such as high gradients and falls limit all anadromous fish use. There are currently no unnatural barriers listed within the watershed.

Habitat

LWD

Key pieces of LWD are currently rated "poor" throughout Hyas Creek, S.F. Calawah River, Sitkum River and Rainbow Creek. Total LWD was additionally rated as "poor" in Hyas Creek and sections of the N.F. Sitkum and Sitkum Rivers (DeCillis, 1998). The rating "poor" overall in Hyas Creek can be attributed to the Great Forks fire of 1951 and subsequent salvage operation in the subwatershed (DeCillis, 1998).

Within the S.F. Calawah Watershed, Lost Creek, and the lower/middle/upper S.F. Calawah had the highest near-term LWD recruitment potential. Hyas Creek had the worst potential with 99% of the area rated as low near-term potential. In the Sitkum Watershed, the lower Sitkum, middle Sitkum and upper Sitkum had the highest potential while Rainbow Creek and the N.F. Sitkum River had 69% and 61% of their areas rated as low near-term LWD potential recruitment. Overall, 57% of the entire Sitkum/S.F. Calawah watersheds could be rated as high potential recruitment (Lasorsa, 1998).

Shade

Water temperatures in the mainstems of the S.F. Calawah and the Sitkum rivers generally exceeded the upper limits recommended for migration. Due to run timing, fall Chinook, fall coho and winter steelhead should not be affected by elevated temperatures. Summer Chinook, however, are at risk due to their extended holding period during low flows in late summer.

Naturally low riparian cover may be to blame for some of the elevated temperatures found in these watersheds. The mainstem S.F. Calawah River, Lower S.F. Calawah River and Lower Sitkum River all have a majority of naturally low shade conditions. Though other subwatersheds, notably Lost Creek and Upper S.F. Calawah River, meet 100% shade targets, their management is of concern as they are upstream of areas with temperature concerns (Lasorsa, 1998).

Sedimentation
DO levels in the S.F. Calawah and Sitkum River watersheds appear to be within optimal range as defined by WA State. However, there are no data on intragravel DO levels which is the most important to certain salmonid life history stages. It is assumed that DO levels drop with increased stream temperatures as reflected by summer data.

Although current information is not available on fine sediment levels in gravels in these watersheds, there is concern that large mass wasting events in 1997 may have contributed to fines and, therefore, decreased intragravel DO. There is also aerial photo evidence that mass wasting in Hyas, Rainbow and N.F. Sitkum has increased in frequency following timber harvest and road building. Of the slides detected, 64% were a result of roads and harvests while 36% were due to natural causes (Dieu and Shelmerdine, 1998). There is a high connectivity between hillslope and channel and a large percentage of sediment from mass wasting events delivers into the stream system (Wilson, 1998). Excessive sedimentation has contributed to dewatered sections of Hyas Creek and Sitkum River.

Data Gaps
The mainstem of the Calawah was not part of any watershed analysis. As the water quality data is now outdated for its tributaries, current water quality conditions there are now a data gap, as well. Other data gaps include the role of mass wasting events and subsequent sedimentation on the “losing” hydrology within the basin.

Bogachiel Sub-basin

The Bogachiel River is formed by the North Fork and South Fork Bogachiel rivers that drain from the steep headwaters of the Olympic Mountains. Technically, the entire Calawah River is a tributary to the Bogachiel, but because of the size of the drainage, it is generally treated separately. The upper reaches of the Bogachiel River lie within the Olympic National Park while the middle and lower reaches are used primarily for timber production and farming. There is little information on the hydrology of the Bogachiel Watershed.

Land Use
There is little human activity in the upper Bogachiel and therefore few data. The lower Bogachiel (floodplain) has agriculture and also supports the southern edge of the City of Forks (pop. 3120). There is also a state fish hatchery near Forks (for summer and winter steelhead), at the confluence of the Bogachiel and Calawah rivers.

Water Quality
The Bogachiel is rated as Class AA by the Department of Ecology. There are several 303(d) listings on the mainstem Bogachiel River for high water temperatures. Those sites listed for just high temperatures include RMs 8.7, 9, 9.8, 12.6 and 15.7 and were submitted to the DOE by Quileute Natural Resources in 1996. Two segments (RM 0 and RM 20) have been listed by DOE for both temperature exceedances and low dissolved oxygen. The exceedances on the mainstem of the Bogachiel cover the longest stream segments in WRIA 20. Maxfield Creek has also been listed for high temperatures (DOE, 1998). There are tributaries within the upper watershed that have sites that exceed State water temperatures but since they are located in old growth, it is assumed that the conditions are natural (Smith, 2000). Below is a summary of the Bogachiel's condition on the 1998 303(d) list.

Table 4.18. Water Quality Excursions on the 1998 303(d) List in the Class AA Bogachiel Watershed (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Bogachiel RM 15.7	Quileute Tribe	Temperature	5	1992 – 1995
Bogachiel RM 20	Quileute Tribe	Dissolved Oxygen	2	1992 – 1995
Bogachiel RM 8.7	Quileute Tribe	Temperature	2	1992 – 1995
Bogachiel RM 9	Quileute Tribe	Temperature	6	1992 – 1995
Bogachiel RM 12.6	Quileute Tribe	Temperature	2	1994 – 1995
Bogachiel RM 0	Quileute Tribe	Temperature	6	1994 – 1995
Bogachiel RM 9.8	Quileute Tribe	Temperature	4	1992 – 1995
Maxfield Creek	Quileute Tribe	Temperature	Numerous	1992

Turbidity is a problem on the Bogachiel mainstem and has resulted in a "poor" water quality rating in the Limiting Factors Report from RM 16 downstream to the mouth. This turbidity is a direct result of channel incision which has exposed unstable clay layers and contributed fines to the river (Smith, 2000).

Fish Distribution
The Bogachiel River and many of the major tributaries provide spawning and rearing habitat for summer and fall Chinook, coho and chum salmon and summer and winter steelhead. Small numbers of sockeye salmon have been reported in lower reaches of the Bogachiel River though these may be strays from other populations. Small numbers of pink and spring salmon have been noted on the mainstem.

Table 4.19. Bogachiel Salmon and Steelhead Stocks and Status

Stock	SASSI (1993)	McHenry et al. (1996)
Summer Chinook	Unknown	Threatened
Fall Chinook	Healthy	Healthy
Fall coho	Healthy	Threatened
Summer steelhead	Unknown	Unknown
Winter steelhead	Healthy	Healthy

Summer Chinook primarily use the Sol Duc; only a small component use the Bogachiel. This influences the appearance of the stock status (R. Lien, pers. comm.).

Table 4.20. Run and Spawn Times for Quillayute/Bogachiel Salmonids (SASSI, 1992; R. Lien, pers. comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Summer Chinook	■	■	■									
Fall Chinook			■	■	■							
Summer Coho			■	■	■							
Fall Coho				■	■	■						
Fall Chum			■	■	■							
Summer Steelhead							■	■	■			
Winter Steelhead								■	■	■	■	

Habitat

Sedimentation and LWD
There was very little information on in-channel habitat on the Bogachiel and its tributaries until 2000 (see below) when the Quileute Tribe began a three year in-channel evaluation for the mainstem and the upper, middle and lower tributaries. This study was designed to re-assign stream types to the Bogachiel system. Though there was not detailed survey data, members of the 2000 Limiting Factors Analysis Technical Assessment Group noted that there are sedimentation issues in the mainstem. As in many of the other rivers in WRIA 20, problems with excessive sedimentation and low levels of LWD occur below mostly below Olympic National Park.

Levels of LWD on the mainstem are poor for the area from below the Highway 101 bridge to just below the confluence with Hemp Hill Creek. Levels of LWD in

Maxfield, South Maxfield and Bear Creek range from fair to good. Riparian levels tend to mimic LWD levels within the Bogachiel Watershed, ranging from poor on the mainstem to good within Olympic National Park (Smith, 2000). Data, however, is limited.

The lack of LWD on the mainstem has led to increased water velocity and sediment transport on the mainstem of the Bogachiel. This in turn has increased channel incision and exposed unstable clay layers. This incision has released sediment into the river and has resulted in a level of fines greater than 17% (Smith, 2000). Collapsing banks have been a problem from the Hemp Hill confluence to Highway 101 and have required localized road relocation.

Barriers
In the year 2000, the Quileute Tribe surveyed the Bogachiel mainstem for fish habitat and fish passage blockages. In the basin, they found 37 blocked culverts but all cross drains were functioning. In 2001, the tribe surveyed the lower tributaries: Weeden, Maxfield and Murphy Creeks and found 123 impassable culverts and retyped several segments of the tributaries. Of the retyped streams, over 23 new river miles of fish habitat was discovered (Type 3 and 4). The most disturbing observation during these surveys was the blocked/perched culverts of the 3000 Goodman mainline over the South Fork of Maxfield Creek. This blockage blocked the most access in the entire Quileute Tribe's usual and accustomed places. In 2002-2003, Rayonier and the Quileute Tribe cooperated in replacing these culvers with a bridge. In 2002, the tribe found 83 non-passable culverts in the middle tributaries: Mill, Grader, May, Dry and Bear Creeks. In these creeks, 30.4 miles of stream was reclassified from fish-bearing to non fish-bearing. In 2003, tribal surveys covered the upper tributaries, Dowans, Hemphill, Morganroth, and Kahkwa Creeks and discovered 18 impassable culverts. In these creeks, 23.76 miles of stream were upgraded. In Dowan Creeks, cedar spalts were recorded which block habitat and degrade water quality (QNR, 2003).

Data Gaps
The Bogachiel Watershed contains the largest number of data gaps compared to watersheds of the Quillayute in which watershed analyses have been completed. However, some of these were filled by the above-described Quileute surveys. No study exists on sedimentation, hydrology, mass wasting, or vegetation as with the watershed analyses. Though there are currently water quality exceedances, there is no historical information for the mainstem of the Bogachiel. Since the lower Bogachiel is very open, the higher temperatures may be a natural state. There are no water quality data for the tributaries to the lower Bogachiel which help answer whether the temperatures were natural or not. Furthermore, if the hydrology of the Bogachiel resembles the larger area, the lower Bogachiel may be a "losing reach" which also might help explain water quality.

Though there is abundant data on fish presence, based on Quileute annual redd surveys, the area within Olympic National Park has fewer data because flyovers and access are limited. The Quileute Tribe conducted redd surveys for summer and fall Chinook in the upper tributaries, but not coho. The Quileute stream typing efforts conducted during 2000-2003 did survey for fish presence in the upper reaches (R. Lien, pers. comm.).

Hoh Sub-basin

The Hoh Watershed lies along the most southern edge of WRIA 20. The river system is fed by several glaciers on Mt Olympus and flows westward for approximately 60 miles to the Pacific Ocean, draining 299 sq. miles along the way.

Geology and Hydrology

The Hoh watershed is bounded to the south by Huelsdonk Ridge, the drainage divide for the southwestern portion of WRIA 20. The ridge extends west from the Olympic Mountains to Owl Mountain (near Hoh River Mile 27) and is composed of highly deformed and faulted siltstones, sandstones and conglomerates of the Western Olympic Lithic Assemblage. At the top of the ridge, colluvial soils are on top of bedrock and local patches of till. The midslopes are commonly till and colluvium and the lower glacial/fluvial terraces are composed of sand, gravel and silt. North flowing tributaries have cut deeply into Huelsdonk Ridge leaving extremely steep canyon walls. The middle reaches of the Hoh have the classic U-shaped valleys associated with those that were glacially carved. There are several relic terraces within the middle reaches that strongly affect the character of the tributary streams (Hatten, 1991).

The mainstem and the South Fork of the Hoh are glacially fed. Although the highest peak flow occur in winter months, the highest average flows are in June as a result of glacier melt. Like other watersheds in WRIA 20, low flows are generally in August and September. The glacial nature of the watershed leads to a marked diurnal difference in flows due to glacial melt. This in turn affects peak flows and a dynamic channel pattern. The glacial influence dropped significantly on the South Fork Hoh between 1992 and 1993 resulting in lower flows.

The middle Hoh (RM 15.2 to RM 30) as well as the lower Hoh (below RM 15.2) have had the greatest amount of management and as a result have the highest percentage of hydrologic immaturity and road density. Both conditions lead to increased peak flows. Loss of vegetation also contributes to the negative effects of midslope roads. Subwatersheds with hydrologic immaturity greater than 60% include Braden, Anderson, and Nolan Creeks within the middle Hoh and Elk Creek within the lower Hoh (Smith, 2000).

Land Use

The entire Hoh Watershed lies within the Usual and Accustomed Fishing Grounds of the Hoh Tribe (treaty). The upper Hoh lies entirely within the Olympic National Park. The middle Hoh is dominated by Department of Natural Resources timberlands which extend from the lower South Fork along the main Hoh valley floor and up to the Huelsdonk Ridge to the south and Willoughby Ridge to the north. Other owners in the middle Hoh include private timberlands and a 400 acre US Forest Service parcel. There are a limited number of agriculture lands with residences located on the main Hoh, primarily on the north bank. The lower Hoh is dominated on the upper terraces by DNR and private timberlands. Low density residences (minimum 5 acres) and agricultural lands dominate the floodplain and area around Highway 101. The Hoh Indian Reservation (443 acres) lies on the south side of the river mouth. There is a strip of ONP less that one mile wide that follows the coast from the north and surrounds the Hoh Reservation. The areas outside Olympic National Park have a history of intense timber harvesting and therefore present many associated water quality and habitat issues.

Water Quality

The Hoh River is rated as Class AA by the Department of Ecology. There are several sites within the Hoh basin on the 1998 303(d) list for temperature exceedances. Most of the sites are located on the middle Hoh between Highway 101 and the confluence of the South Fork of the Hoh. The tributaries with slightly high temperatures include Fisher, Willoughby, Rock, Elk, Canyon, Anderson (lower Hoh), Alder, Line, Maple, Nolan (lower Hoh), Owl, Split, and Tower Creeks (DOE, 1998).

Table 4.21. Water Quality Excursions on the 1998 303(d) List in the Class AA Hoh Watershed (DOE, 1998)

River	Listing Agency	Type of Exceedance	Number of Exceedances	Date
Alder Creek	Hoh Tribe	Temperature	31	7/1/92 – 8/31/92
Anderson Creek	Hoh Tribe	Temperature	11	7/1/92 – 8/31/92
Canyon Creek	Hoh Tribe	Temperature	2	7/1/92 – 8/31/92
Fisher Creek	Hoh Tribe	Temperature	47	7/1/92 – 8/31/92
Line Creek	Hoh Tribe	Temperature	20	7/1/92 – 8/31/92
Maple Creek	Hoh Tribe	Temperature	9	7/1/92 – 8/31/92
Nolan Creek	Hoh Tribe	Temperature	49	7/1/92 – 8/31/92
Owl Creek	Hoh Tribe	Temperature	34	7/1/92 – 8/31/92
Rock Creek	Hoh Tribe	Temperature	30	7/1/92 – 8/31/92
Split Creek	Hoh Tribe	Temperature	54	7/1/92 – 8/31/92
Tower Creek	Hoh Tribe	Temperature	2	7/1/92 – 8/31/92
Willoughby Creek	Hoh Tribe	Temperature	16	7/1/92 – 8/31/92
Winfield Creek	Hoh Tribe	Temperature	44	7/1/92 – 8/31/92

In August 1999, temperatures in Winfield Creek were so elevated that extensive salmonid mortality occurred. This temperature spike and subsequent mortality was a result of a pile of road spoils collapsing into the creek. The channel was completely blocked and fines persisted for at least a season, contributing to extremely poor water quality overall and a complete change in channel structure (J. Dieu, pers. comm.).

From September to October 2002, DO measurements were taken for Alder, Anderson, Lost, Maple, Mosquito, Nolan, Owl, Rock, Tower, West Twin, Willoughby and Winfield creeks. None of the sites were in compliance with state water quality standards for class AA waters (10,000 Years Institute, 2003).

One of the major contributors to poor water quality in the Hoh Watershed is cedar spalts, leftover waste wood from cedar shake and shingle-wood salvage operations. The majority of the spalts are found in regime channels where gradients are low, water velocities are low and streams may be susceptible to stream heating (McHenry, 2000). The presence of these spalts may lead to lower dissolved oxygen, higher acidity and higher water temperatures than natural conditions. Dissolved oxygen in these areas falls considerably below the standard 9.5 mg/L with ranges between 3.5 mg/L to 6 mg/L. Water temperatures reportedly are 4 to 5°C warmer above spalt dams than in free flowing reaches. Currently impacted streams include Winfield, Braden, Clear, Nolan, Red, Lost, Pins, Snell, Anderson and Willoughby creeks in the Hoh basin (Smith, 2000).

Logging activity within the basin has also raised temperatures. When compared to unlogged areas, Hatten (1991) found that mean daily stream temperatures in logged areas (>65%) vs. unlogged areas (<10%) were 10.9% higher. The affected creeks (Willoughby, Owl and Split) in Hatten's 1991 study all *marginally* exceeded state water quality standards while the unaffected streams (Matson, Jackson and Rock) were cooler than critical levels. Logging activities were also to be blamed for major sediment pulses into tributaries. In 1989-1990, Logan et al. (1991) estimated that 243,000 yd^3 was mobilized off of the Huelsdonk tributary basins and more that 90% of the failures originated in clearcut areas. Roads and landings are also primary contributor to these tributaries and the Hoh River. Midslope failures commonly occur in affected areas where soils are less than 5 feet thick (75%) and gradients range from 26 to 46 degrees (Logan et al., 1991).

Murray et al. (2000) suggest that partial harvesting (7-33%) had little influence over temperature, chemistry and turbidity 11-15 years post-harvest. Though stream temperatures were increased by about 3°C, neither of the creeks measured (Rock and Tower) exceeded state water quality standards. Elevated nitrate levels were recorded and thought to be a result of the alder-dominant riparian zones.

Though there have been no studies, there is suspicion that alterations to alluvial aquifers in the Hoh Watershed may be contributing to water quality problems. The Hoh Watershed is highly dependent on groundwater upwellings to maintain baseflows and cool temperatures in the summer (Smith, 2000). Removal of upland vegetation prevents the infiltration of groundwater on hillslopes. Excessive sedimentation may also disturb the cool, nutrient-rich upwellings.

Fish Distribution

There are five native species of salmonids and three species of trout within the Hoh River Basin. Of the eight species of salmonids, the three that are most intensely managed are coho, Chinook and steelhead. The Chinook population consists of a spring/summer run, one of five remaining native spring Chinook stocks considered healthy in the Pacific Northwest. This run has typically used spawning grounds on the South Fork Hoh in the vicinity of Big Flat, the North Fork Hoh and Mt. Tom Creek. Owl Creek historically supported the run but habitat conditions have degraded to a level where few species are using the tributary at all (Smith, 2000). Recent observations by WDFW and tribal staffs indicate that Chinook and steelhead utilization has fallen off considerably, partly because gravel substrate has become larger in the lower half of the anadromous reach and partly because the number of stable LWD, jams and overall channel stability has also decreased substantially (J. Jorgenson, pers. comm.).

Coho are the most abundant salmon population in the Hoh Watershed but there have been population declines since 1992 due to freshwater habitat decline. More severe declines were observed with the 1993, 1994, and 1997 returns, with ocean conditions being the largest factor affecting those years' runs. A recent set of more favorable ocean conditions and reduced Canadian fisheries led to large returns of coho in 2001 and 2002 and temporarily counteracted effects of any decline in freshwater production (J. Jorgenson, 2004, pers. comm.). Fall chum have never been numerous due to limited estuary area and have shown a long-term population decline (McHenry et al., 1996).

The Hoh Watershed supports winter and summer steelhead. Quinault River steelhead are planted in the Hoh annually but have different run return timing and high exploitation rates resulting in limited interaction with wild fish. Though there has been a generally declining trend since the 1980s due to poor marine survival, winter steelhead stocks are described as stable. Less is known about the summer steelhead stock which has a smaller population and spawns in upper reaches.

Table 4.22. Hoh Salmon and Steelhead Stocks and Status

Stock	SASSI (1993)	McHenry et al. (1996)
Spring/summer chinook	Healthy	Stable
Fall Chinook	Healthy	Healthy
Fall chum	Long term decline	
Fall coho	Healthy	Healthy
Summer steelhead	Unknown	
Winter steelhead	Healthy	Stable

Table 4.23. Run and Spawn Times for Hoh Salmonids (SASSI, 1992, J. Jorgenson, pers. comm.)

Species	A	S	O	N	D	J	F	M	A	M	J	J
Spring/Summer Chinook	■								■	■	■	■
	▐	▒	▌									
Fall Chinook		■	■	▌								
			▐	▒	▌							
Coho		■	■	■	■	▌						
				▒	▒	▒						
Winter Steelhead				▐	■	■	■	■	▌			
									▐	▒	▌	

Run times are solid. Spawn times are cross-hatched.

Bull trout are present in the Hoh River Basin and have been listed as threatened by the US Fish and Wildlife Service. They are thought to use the Hoh River as a migratory corridor and they possibly spawn and rear in side channels of the mainstem (Erickson, 2001). The majority of the redds have been identified within the ONP boundary.

Habitat

LWD

The upper watershed mainstems and tributaries found within Olympic National Park generally have good ratings for LWD as there has been little management and old growth riparian areas still exist. In the rest of the watershed, LWD levels were generally poor. Some of these areas (Owl Creek) had many pieces of LWD outside the ordinary bankfull width, due to dam break floods, that were considered to be not functioning (McHenry, 2000). In Anderson, Elk, Braden, Lost, Nolan, Pins and Winfield creeks, LWD ratings were low due to lack of large key pieces. The large wood loads of Winfield, Canyon and Dry creeks are dominated by red alder which are unable to provide habitat and durability like conifers (McHenry, 2000). Streams with recent history of channelized landslides such as Spruce and Willoughby had almost no instream wood. The loss of wood in steeper streams results in the loss of step morphology and promotes incision (Kennard, 2000).

Near-term LWD recruitment reflects current instream conditions in most cases. In the middle Hoh, 72% of the subwatersheds have poor recruitment (Smith, 2000). This is due primarily to past logging efforts which often cleared land to the stream banks. Cedar spalts have worsened riparian conditions as areas with spalts on the bank cannot establish any vegetation.

The ability to physically recruit wood within the Hoh Watershed differs from sub-basin to sub-basin. In many areas, wood is delivered to streams either through mass wasting events or blow down. In Alder and Winfield creeks, wood is captured from within the channel migration zone when channels meander. This process is extremely successful when riparian growth is fully mature. On the S.F. Hoh and N.F. Hoh below ONP, the majority of wood is located on top of gravel bars and is hydraulically not functioning (McHenry, 2000). This shows the tremendous need for sufficiently large key pieces within the bankfull width to trap the smaller wood during elevated flows. Another problem with recruitment on the mainstem is shallow reaches. On the S.F. of the Hoh (RM 6.2), the channel topography is so shallow and flat that the transport of wood is impossible (McHenry, 2000)

LWD levels have also been affected by mass wasting, namely dam-break floods and channelized landslides. Channelized landslides will remove all functional wood and reduce roughness and sinuosity, and increase bank and terrace erosion. Dam break events often happen on streams that were previously forced pool-riffle and often have fewer pools and larger substrate after events (Kennard, 2000).

Sedimentation

The quality of spawning gravels has been significantly reduced by excess sedimentation from mass wasting events and road erosion. High levels of fines have been measured in Iron Maiden Creek (57%) and Canyon Springs Creek (45%) following mass wasting events (Smith, 2000). There were also high levels of fines in Spruce, Bradenberry and Lost creeks. Levels of fines between 11% and 17% were recorded in Alder, Elk, Split, Anderson and Braden creeks (Smith, 2000). Cedar spalts often float up and down with flow and carve out banks and contribute to the delivery of fines. Channel incision in Owl and Nolan creeks has exposed unstable clay layers and delivers fine sediments. In the upper watershed (within ONP) there are few sedimentation problems and coho production has been 2-3 times higher than anywhere else in the watershed.

There has been discussion over the effects of sedimentation on the mainstem Hoh River. Because the river is heavily influenced by glaciers that release a tremendous amount of sediment (glacial flour), many argue that sediment produced by management activities is inconsequential. Lum & Nelson (1986) found that 60% of the mean fluvial sediments in the Hoh River originated upstream of the Olympic National Park Boundary. Kennard (2000) supports this finding by recording fine levels of 60% at Big Flats, an unmanaged mainstem segment. Though these levels exist naturally on the mainstem, they are a concern in steeper gradient tributaries (Kennard, 2000).

The greatest anthropogenic contributor to sediment in the Hoh basin is roads. Generally in the basin, roads were designed to high levels and are well surfaced. The major problem is the interconnection of the standard road ditch system with the channel system (Powell, 2000). The sub-basins with the largest percentage of sediment over background levels are S. Fork Hoh (156%), Owl Creek (286%) and Winfield Creek (210%). The majority of the sediment in the S.F. Hoh and Owl Creek sub-basins is coming from the H-1000 mainline road while in the Winfield sub-basin, the majority of the sediment is delivered from the MLC-1000 road (Powell, 2000).

Sedimentation affects everything from temperature to off channel habitat. Excessive sedimentation is blamed for interfering with hydraulic connectivity within the floodplain. Since the Hoh is a basin largely dependent on in-channel springs, sediment will block the upwellings and deprive the channel of cooling water and nutrient rich, productive areas for salmonids. Major segments of complex off-channel habitat normally dominated by clean water inputs such as side channels plugged with LWD, spring-fed wall-based channels, or floodplain refugias often become degraded from increased sediment inputs due to activities along the adjacent terraces during flood events.

Off-Channel Habitat

The Hoh River terrace is a complex system of springs, side channels, ponds and wetlands which provides critical habitat and refugia to fish and wildlife. Compared to the system within ONP, the downstream floodplains have been extensively degraded through several processes (McHenry, 2000). Lack of wood and influence from riparian roads has changed sediment processes and been particularly damaging for the floodplain. The access road for ONP, upper Hoh Road has been a problem and washed out continually resulting in a highly armored bank (Rot, 1996). Forest management practices have had an impact on the floodplain as the channel migration zone has not historically been recognized (McHenry, 2000). The floodplain at RM 19 and Elk Creek is exceptionally important as they support high levels of smolt production and a safe site for over-wintering salmon (Rot, 1996).

Another important component of the channel migration zones are forested islands that form when LWD stabilizes gravel bars and allows for vegetation to establish. These bars encourage multiple channels and eventually serve as LWD banks (Rot, 1996). Lack of LWD combined with large coarse sediment loads prohibit the formation of forested islands thereby decreasing current and future floodplain complexity (Kennard, 2000).

In September 2000, the Hoh River was surveyed with FLIR (Forward Looking Infared) to evaluated stream temperatures in the Hoh Watershed and develop longitudinal temperature profiles. Stream temperature patterns and the location of and range of cool water sources provided a better understanding of floodplain hydrology. This survey observed that many of the side channels started within the floodplain and were formed by cool subsurface flows. Since 79% of the surface inflows to the mainstem Hoh were found to be warmer than the Hoh River, it is believed that these subsurface floodplain inputs are an important part of the river's thermoregulation (Watershed Sciences, 2001).

Barriers

Barriers are one of the largest concerns in the Hoh as they have not only blocked streams for anadromous fish but also are often the cause of degraded habitat and water quality. Cedar spalts, leftover waste wood from cedar shake and shingle-wood salvage operations, are blamed for increased temperatures and sedimentation as well as a loss of access to more than 1,000 ft of stream in 18 sites (Smith, 2000, McHenry, 2000). In the Fullerton Tributary alone, more than 6,000 ft of stream are impacted. The streams with the highest cedar spalt impact include the Fullerton Tributary, and Nolan, Cedar, and Sand creeks (Smith, 2000).

There are also over 40 blocked culverts in the Hoh Watershed which are blocking coho, steelhead and cutthroat habitat (Smith, 2000). This number has decreased from estimates of 60 impassable culverts in 1997 (McHenry, 2000). In some cases these faulty culverts block up to 10,000 ft of free flowing stream while others block critical wetlands used for off-channel rearing.

Data Gaps

The Hoh sub-basin has been extensively studied and there are few large data gaps. Recently the Hoh Tribe has become concerned with increased exposure of clay deposits and the influence of fine clay particles on habitat and fish. Road maintenance and replacement projects, the use of shallow gravel pits for the deposit of unstable fill material and the increased frequency of flood events have exacerbated this concern (J. Jorgenson, pers. comm.).

Further study needs to be done on the connectivity of the floodplain. The Hoh has an active channel migration zone but little is known about the groundwater dynamics within the floodplain.

Other Drainages

This report will not deal specifically with small drainages that flow directly into the Pacific Ocean, such as Mosquito Creek or Goodman Creek.

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