DUCKABUSH WATERSHED ANALYSIS

MAY 1998

HOOD CANAL RANGER DISTRICT

Duckabush
May 1998

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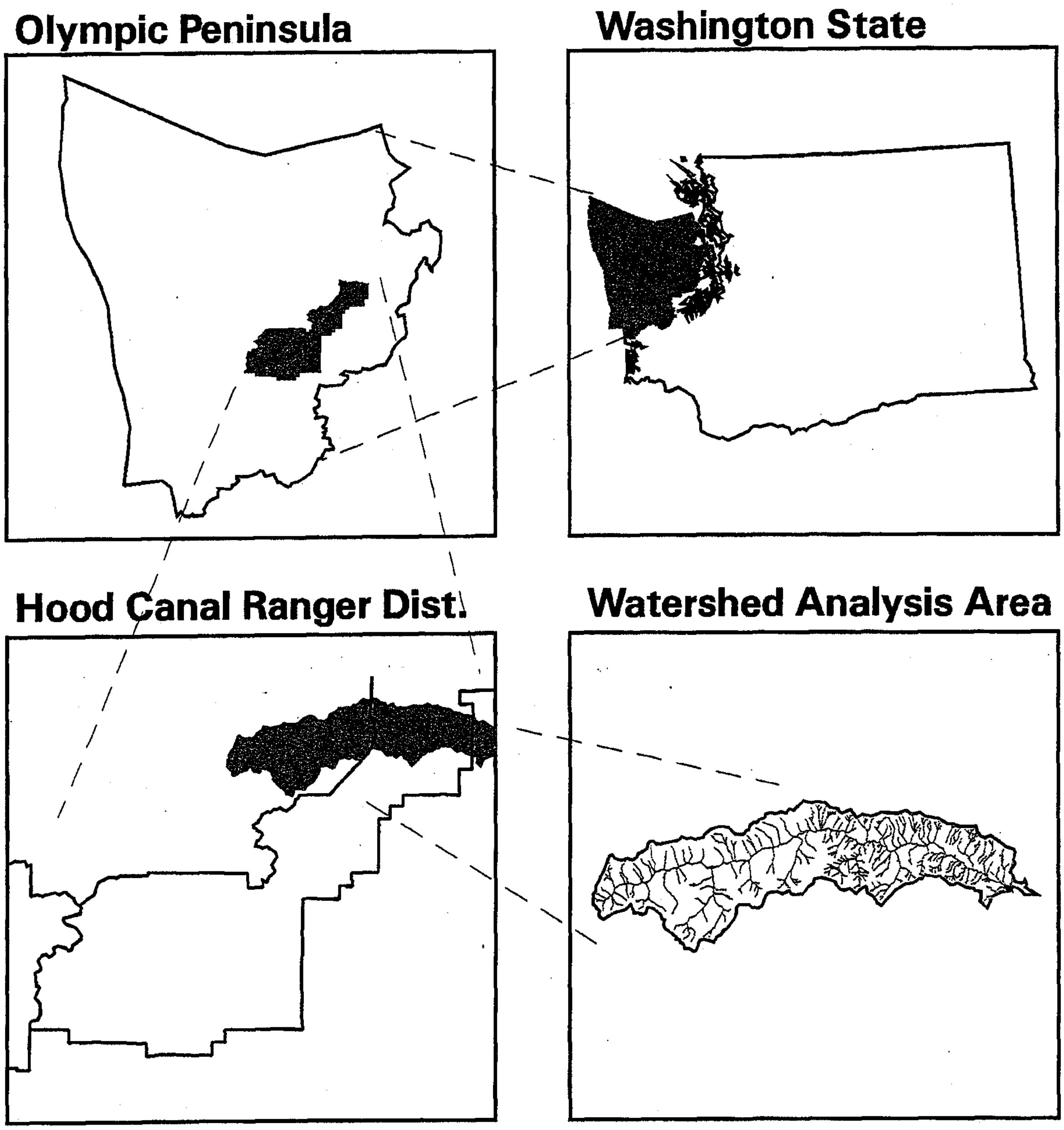

Geographic Locator
Duckabush
Watershed Analysis Area

Duckabush Watershed Analysis Map List

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Section 1

Introduction

This watershed analysis frequently refers to, and takes guidance from, the larger assessments and watershed analysis documents covering adjacent drainages (Hamma Hamma River and Big Quilcene River). It is important to maintain the context of each watershed analysis to adjacent watersheds as well as to the larger Provincial scale.

LOCATION AND SIZE

The Duckabush watershed lies on the eastern side of the Olympic Peninsula. It is located approximately 33 miles north of Shelton, and approximately 52 miles south of Port Angeles. The watershed is bounded by Hood Canal (elevation -sea level) on the East and Mt. Duckabush (approximate elevation 5996') on the West, the Hamma Hamma River to the South, and the Dosewallips River to the North. The watershed is approximately 49,933 acres in size.

Ownership and Land Allocations

Eighty nine percent of the watershed is under federal ownership. Fifty eight percent of that federal land is managed by the USDI - Olympic National Park and thirty one percent by the USDA - Olympic National Forest. The remaining eleven percent is split with two percent managed by the State of Washington - DNR and the other nine percent under private ownership in the form of private industrial forest use and residential use (see Table 1A).

The Northwest Forest Plan allocations are as follows: Congressionally Reserved Areas (Olympic National Park) 28,860 acres, Wilderness (Olympic National Forest) - 8,057 acres; Late - Successional Reserves 7,328 acres, the objective of this land use allocation is to protect and enhance conditions for late-successional and old-growth related species; Adaptive Management Area - 163 acres, the objective of this land use allocation is for developing and testing new management approaches to integrate and achieve ecological and economic health and other social objectives; Riparian Reserves are provided along all streams, wetlands, ponds, lakes and unstable and potentially unstable areas where riparian-dependent resources receive primary emphasis. Administratively Withdrawn Areas (Collins Campground and Interrorem Guard Station), where planned or scheduled timber harvest is excluded through current plans. See map 2.2B for a graphical display of this information.

Table 1A Land Ownership and Land Use Allocation

Ownership	Reserved	Wilderness	Late - Successional Reserve	Adaptive Management	Riparian Reserve	Acres
ONP	28,859					28,859
USFS		8,057	7,328	163		15,549
PRIVATE (forest land)						4,443
PRIVATE (other)						
STATE						1,082
TOTALS	28,859	8,057	7,328	163		49,933

The watershed analysis area was delineated into one fifth field watershed subdivided into six subwatersheds (Map 1.0A, Table 2.3A in Appendix 2.3). Team members delineated these hydrologic boundaries using USGS quadrangle maps (1:24,000 scale), following direction given in the National Instruction No. 170-304: Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit (HU) Boundaries (USDA Natural Resources Conservation Service, 1996). Information based on aerial photo interpretation and field reconnaissance was also used to determine watershed boundaries for areas that were not easily discernible on quadrangle maps. Subwatershed coverage is stored electronically in the Olympic National Forest Geographic Information System (ONF GIS) database.

1.1 RELATION TO OTHER PLANS

Relation to the Record of Decision and the Olympic Forest Plan

On April 13, 1994, the Record of Decision(ROD) for the President's Forest Plan[1] was signed. This decision, and its accompanying Standards and Guidelines, has dramatically changed the management of the National Forests of the Pacific Northwest, within the range of the northern spotted owl. The standards and guidelines contained in this plan amend those of the existing Olympic National Forest Plan (USDA, 1990). A key principle of the plan is the adoption of the Aquatic Conservation Strategy, developed to restore and maintain the ecological health of watersheds and aquatic ecosystems contained within them on public lands. Watershed analysis forms one of the four components of this strategy, along with riparian reserves, establishment of key watersheds, and watershed restoration.

Watershed Analysis

The purpose of watershed analysis is to develop and document a scientifically-based understanding of the ecological structures, functions, processes, and interactions occurring within the watershed, and to identify desired trends, conditions, and restoration opportunities. Watershed analysis is the mechanism to support broad ecosystem management objectives at watershed scale, as described in the President's Forest Plan. This analysis examines terrestrial, aquatic, and social aspects of the Duckabush River Watershed.

Watershed analysis is one of four elements of the Aquatic Conservation Strategy, as described in the President's Forest Plan. These four elements are designed to operate together to maintain and restore the productivity and resiliency of riparian and aquatic ecosystems.

The Module Approach

This analysis is divided into sections, or modules, each representing major physical, biological and social processes occurring in the watershed. An inventory and detailed evaluation of the resources of each module was conducted, with objectives of: (1) understanding past and present watershed conditions, along with a comprehensive view of cumulative effects of land management practices, and (2) identifying specific areas of sensitivity; those areas vulnerable to erosion, hydrologic change, and other watershed functions. A key outcome of these "resource assessments" is to characterize conditions in the watershed that will help address key questions and issues developed through inter-agency and public participation. These resource assessments are presented in Section 2. It was not the intent to gather new data for each module, but rather to use existing information such as aerial photos, surveys and maps. The following modules are presented in Section 2.

- Cultural Resource Assessment
- Public Works

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[1]Officially titled "Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl" (USDA and USDI, 1994).

- Erosion
- Wildlife
- Fisheries
- Riparian Assessment
- Vegetation and Landscape Patterns

Synthesis and Resource Integration

Once a complete inventory of the resources was completed it was necessary to understand the interrelationships of all watershed functions and how they influenced specific areas of concern. "Linkages" were established between existing or potential hazards, and existing and potential cumulative effects of land management practices. The Watershed Analysis Team developed these linkages through a series of meetings and group discussions, collectively called "synthesis". A main product of synthesis is mapping of sensitive sites, and affects of land management on these areas over time. To determine whether an activity in the sensitive area would cause a significant change to the stream, the Watershed Analysis Team compared the likelihood of adverse change and deliverability to the resource vulnerability. Factors that contribute an adverse effect or response were also identified.

1.2 RELATION TO THE SITE LEVEL

The ultimate goal of the analysis is to produce guidance for project level planning and design. *It is not the intent of this analysis to be a decision-making process.* The results of the analysis will be used to identify watershed processes and ecosystem concerns that will need to be addressed at a project planning scale. Generally this project-level planning will be done through the NEPA process and involve an interdisciplinary team. Recommendations are not intended to be site-level specific, but will be on the scale of stratification defined in resource assessments.

REFERENCES

Mason County 1995, West Shore Hood Canal Watersheds Report. Puget Sound Cooperative River Basin Team, Shelton, Washington.

Thomas, J.W.; Raphael, M.G., (and others). 1993 Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. Portland, Oregon: U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Bureau of Land Management, Fish and Wildlife Service, National Park Service, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service; U.S. Environmental Protection Agency.

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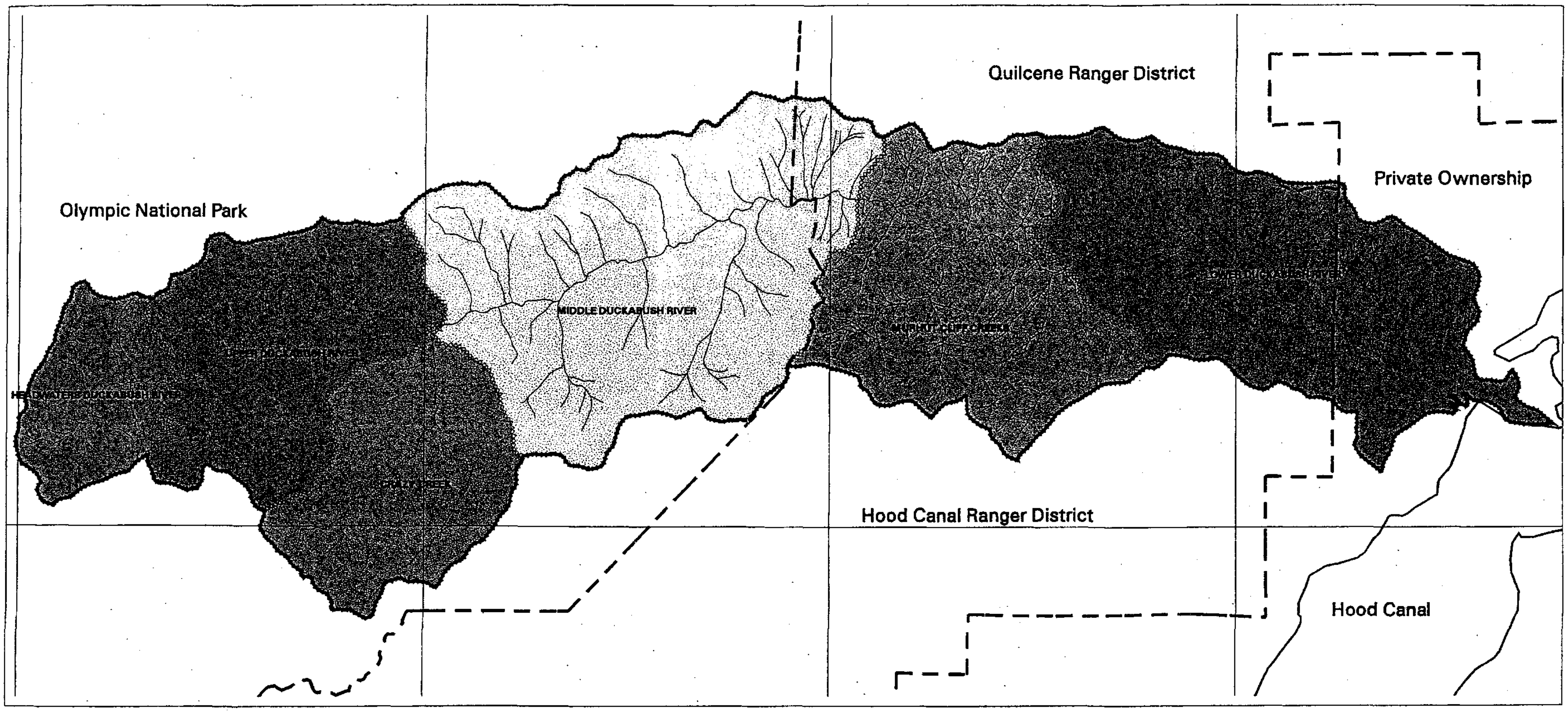

The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

LEGEND

- Watershed Analysis Area
- Subwatersheds
- Quad Lines
- Hydronet
- Forest Boundary

Subwatersheds

Map# 1.0A

The Duckabush Watershed Analysis Team

l_wasswa April 15, 1998

SECTION 2

CONDITION ASSESSMENTS

ISSUES AND KEY QUESTIONS

This section identifies the Issues the interdisciplinary team focused their analysis on and provides a brief description of each. The key questions, listed by resource module, are questions the team will attempt to answer as they relate to the watershed scale Issues. Resource modules will also list unanswered key questions and the rationale as to why they could not be answered at this time.

ISSUES

- Water Quality as it relates to fish and aquatic habitats
- Simplification and conversion of vegetative structure as it relates to habitat
- Human Uses - the variety of uses associated to this watershed.

KEY QUESTIONS BY RESOURCE MODULE

2.1 Cultural/Human Uses

- What is the cultural history of the area and are there cultural resources within the watershed?
- What are the processes that affect these resources?
- What kind of recreational uses are in the watershed?
- How does recreational use affect the resources within the watershed?

2.2 Public Works

- What are the public works and facilities in the watershed?
- How have the public works sites been affected by the processes in the watershed?

2.3 Channel Assessment

- What is the spatial distribution of channel response types (DNR#1); and what are the basic morphological characteristics of stream valleys or segments, and what are the general sediment transport and deposition processes in the watershed?
- What are the current conditions and trends of stream channel types and sediment transport and deposition processes prevalent in the watershed?
- What are the natural and human causes of change between historical and current conditions?

2.4 Erosion

- What erosion processes are dominant within the watershed and where have they occurred or are likely to occur?
- What are the current conditions and trends of the dominant erosion processes prevalent within the watershed?
- What are the natural and human causes of changes between historical and current erosion processes in the watershed? What are the influences and relationships between erosion processes and other ecosystem processes?

2.5 Wildlife

- What is the occurrence and distribution of species of concern that are important in the watershed? The recommended species for the Duckabush Watershed Analysis are as follows (prioritized):

  1. Northern Spotted Owl
  2. Marbled Murrelet
  3. Peregrine Falcon
  4. Roosevelt Elk
  5. Other late seral forest spp.
  6. Riparian spp.
  7. Cavity sensitive spp. including Survey & Manage, State listed, etc. not included above.
  8. Bald Eagle

- What is the distribution and character of their key habitats?
- What are the current habitat conditions and trends for the species of concern and their habitats as identified in above questions?
- What was the historical occurrence and distribution of species of concern and the condition and distribution of their habitats in the watershed?
- What are the natural and human causes of change between historical and current species distribution and habitat quality for species of concern in the watershed?
- What are the influences and relationships of species and their habitats with other ecosystem processes in the watershed?
- What are the present and future management objectives for the wildlife species of concern?
- What are the opportunities within the watershed for restoration, maintenance, protection, alteration, etc. to achieve management objectives for the wildlife resources?
- What are the data gaps, monitoring and research needs applicable to the wildlife resources within or dependent upon the watershed?

2.6 Fisheries

- What is the distribution and stock status of fish in the analysis area?
- What are the current conditions and trends of aquatic habitats?
  - How has complexity of instream habitat changed from historical conditions?
  - What are the processes that deliver wood and where do they occur?
  - What changes have occurred in input and routing of large woody debris?
  - What migration barriers exist for fish?
- What processes, physical and biological, are affecting fish populations?
- Where and what types of restoration actions might maintain or improve aquatic habitat conditions?
- What role does the watershed play in providing for conservation or recovery of the fish species of concern?
- Where and what types of monitoring efforts are needed in the analysis area?

2.7 Riparian Reserves

- What was the riparian area's forest composition historically?
- What is the riparian area's forest composition currently?
- What is the condition of the riparian area relative to its ability to supply large woody debris to the stream in the near-term? In the long-term?
- What processes, physical and biological, are affecting the riparian system
- Where and what types of restoration actions might maintain or improve riparian processes and functions?

2.8 Vegetation and Landscape Patterns

- What are the historic and existing patterns of plant communities?
- How do current plant communities compare with historic plant communities?
- What are/were the major disturbance regimes and how do they affect the kinks and patterns of plant communities?
- What restoration actions enhance important vegetative processes and structures compromised over historic levels as determined by the watershed analysis?

2.9 Hydrology

- What are the dominant hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and other notable hydrologic features and processes in the watershed (e.g., cold water seeps, ground-water recharge areas)?

- What are the historic hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and features (e.g., cold water seeps, ground-water recharge areas) in the watershed?

- What are the current conditions and trends of the dominant hydrologic characteristics and features prevalent in the watershed?

- What are the natural and human causes of change between historic and current hydrologic conditions?

- What are the influences and relationships between hydrologic processes and other ecosystem processes (e.g., sediment delivery, fish migration)?

- What are the influences and relationships between water quality and other ecosystem processes in the watershed (e.g., mass wasting, fish habitat, stream reach vulnerability)?

2.1 CULTURAL RESOURCES

Purpose

The intention of this module is to inform land managers of historical and archaeological uses of the watershed under federal jurisdiction, to identify areas of cultural significance, and allow land managers to effectively manage resource activities.

Key Questions:

1. What is the cultural history of the area and what cultural resources are present in the watershed?
2. What are the processes that affect these resources?

Introduction

Cultural resources identified in this report include those significant to the Skokomish Tribe in the past, present and future, and historic sites, such as settlements, cabins, logging and mining camps, and USFS and NPS administrative sites and facilities from the depression era.

The work of noted anthropologist, William W. Elmendorf (1960) was referred to extensively for the Twana/Skokomish historical information, supplemented by the work of Karen James, anthropologist and Nile Thompson, linguist, on behalf of the Skokomish Tribe. Elizabeth Righter (1978a,b), who wrote a two volume cultural resource overview for Olympic National Forest was referenced for other historical information. Gail Throop's (1996) historic context for USFS recreation facilities was used along with other sources to outline the administrative history and significance statement. Righter's work is supplemented by excerpts from a cultural resource survey of the Duckabush, Calawah and West Fork of the Humptulips River (Daugherty, et al 1983) which is included in Appendix A. Records from the Washington State Office of Archaeology and Preservation were also examined. Descriptions of significant sites noted by Righter (1978 a,b), a National Register Nomination Form of Historical Places (1976), and identified in SHPO files which can be found at the Olympic National Forest headquarters office in Olympia, Washington.

The authors of this report are Jack Janda, Cultural Resources Module Leader, Olympic National Forest; Jacilee Wray, anthropologist, Olympic National Park; with contributions by Karen James, anthropologist, Skokomish Tribe, and Nile Thompson, linguist, Skokomish Tribe.

Cultural History

The Twana

William Elmendorf identifies the Twana as the people occupying the entire Hood Canal drainage before and at the time of European contact. On Hood Canal, this initial contact was in 1792 by Captain George Vancouver. The Indian people of the canal called themselves collectively tuwa'duxq, commonly anglicized as Twana, who spoke a Salishan language unintelligible to neighboring Indian groups (Elmendorf 1960:255).

Elmendorf identifies nine Twana winter village communities existing before and during 1850. He describes village communities as populations which annually took up winter residence in plank houses at single locations. "The personnel of each of these winter village communities was definite and constant. Each person had permanent membership in a particular village community" (Elmendorf 1960:306). The village communities of the Twana were Dabop (Dabob), Quilcene, Dosewallips and Duckabush in the northern part of Hood Canal; Hoodsport, Skokomish and Vance Creek in the vicinity of Hood Canal's Great Bend and the Skokomish River Basin; and Tahuya and Duhlelap in the southeastern area of Hood Canal (Elmendorf 1960:258).

Throughout Western Washington anthropologists have identified two main culture types, one oriented toward the inland environment and the other toward saltwater. Elmendorf found the majority of the Twana communities were of the saltwater type with winter villages located on the shore of Hood Canal, usually at the mouth of salmon streams. Resource acquisition was concentrated on saltwater food supplies, however, river fishing and inland hunting were also common procurement activities. Seasonal summer encampments were often located upriver or in the mountains. Some communities, like the Vance Creek people, lived entirely inland and were largely hunters and river fishers (Elmendorf 1960:256). Elmendorf found that the Twana language reflected the grouping of Skokomish with "salt water peoples" while Vance Creek people, like their non-Twana neighbors the Satsop, were termed "people of the interior" (Elmendorf 1960:256).

Food resources utilized by the Twana, "in approximate order of importance, were fish, sea mammals, mollusks, waterfowl, land game, and vegetable products" (Elmendorf 1960). Important fish included four species of Pacific salmon (chinook, coho, chum, and pink) and steelhead trout. Most salmon catches occurred in the river using weirs and associated dip nets and harpoons (Elmendorf 1960). Saltwater trolling and netting yielded salmon, skate, sole, flounder, rock cod, and, in the northern canal, halibut. Herring were trapped in tidal shore enclosures and the roe was collected on brushwood entrapments located offshore (Elmendorf 1960).

Salmon were such an important component of Twana culture that certain rituals had to be followed while fishing in the river (Elmendorf 1960). The river had to be kept clean before the salmon started running. No rubbish or food scraps could be thrown into the river, nor could canoes be baled out in the river. Each season the tribe celebrated the catch of the first salmon. The salmon was specially cared for prior to cooking and all members of the community ate from this salmon. The bones were then returned to the river following certain rituals. Salmon was dried or smoked and stored for the winter, during which it was the main staple. Other less common fish, such as skate and halibut, were cooked and eaten immediately. Important mollusks included clams (littleneck or rock clam; butter clam; horse clam) cockles, geoduck, oysters, and mussels. Octopi, crabs and barnacles were also obtained (Elmendorf 1960). Archeological sites along the canal containing shell middens provide insight as to the importance of these resources to the Twana.

Land animals were also a very important food source for Twana groups. Common game animals included elk, deer, black bear, mountain beaver, beaver, and muskrat. Elk in particular were culturally significant. Each year the Twana groups had communal elk drives in the Olympic mountains. The first elk killed was ritually cooked and eaten by all participants in the hunt. The bow and arrow was the most common tool used for hunting. Clubs, spears, nets, pitfalls, loop snares, and dead falls were also used. Dogs were used to trail or drive deer during hunts. Plant products were important for subsistence. In addition, they were highly important for utensils, clothing, tools, lodging, and canoes. Dave Peter of the Olympic National Forest summarized ethnobotanical references by Gunther (1974) and Turner (1975; 1979) concerning the native use of plants within the Hood Canal area. This summary is available at the Olympic National Forest and includes specific uses for plants, such as food, materials, etc. and the groups (Twana) likely to use them. This list was examined and verified by Karen James and Bruce Miller. Karen James is a cultural anthropologist who has worked with the Skokomish Tribe. Bruce Miller is a Skokomish Tribal member and is knowledgeable with regard to Native American customs and uses of natural resources.
Righter (1978a) suggests that some controlled burning took place in order to maintain open areas to induce berries and camas to grow and to attract deer and elk for hunting. Native burning practices should be researched more thoroughly as this is important information for understanding existing conditions in the watershed analysis process.

THE TWANA ON THE DUCKABUSH

The general use of the term Twana to identify the people along Hood Canal is used when referring to activities prior to the treaty of Point No Point (1855). After the treaty was signed and the Skokomish Reservation was established, most of the Twana were consolidated onto the Skokomish Reservation and are Skokomish tribal members today. The Duckabush watershed is within the traditional territory of the Skokomish Tribe. The Skokomish Tribe recognizes a relationship to the Duckabush watershed that dates back hundreds, if not thousands of years—from time immemorial. The good health of the Duckabush River and its watershed as a habitat for anadromous and other

fish is very important to the Skokomish, now and in the future. The tribe is also concerned that the watershed continue to provide productive habitat for elk and other land animals as well as other traditional resources that are found in the area.
In earlier times, the Twana had a winter village near the mouth of the Duckabush, called duxwyabu's in the Twana language, which means "place of the crooked-jawed salmon" (ya'bu's, "crooked-jawed salmon"). The crooked-nose salmon is the chief of fish and brings all the other salmon with him when he returns to the river.

The people at this village would have considered the Duckabush River and its watershed as their home territory. This is the area where they practiced their home fisheries, hunting activities and gathering practices, and all other aspects of their daily and spiritual lives. Based on Elmendorf's information about the Twana, these activities would have taken the Duckabush Twana into the highcounrtry of the Olympic Mountains, into the foothills, along the river valley and the shoreline and beaches and marine waters of Hood Canal.

This drainage is part of the Skokomish Tribes' usual and accustomed fishing grounds and stations adjudicated in U.S. v. Washington (384 F. Supp. 312 (1974):377). The Point No Point Treaty of 1855, ceded Skokomish, Klallam and Chemakum territory to the United States. The Duckabush watershed is solely within the ceded territory of the Skokomish Tribe. Historically the mouth of the river was resorted to by other Twana. It has been documented that Klallam friends and relatives fished as guests of the Twana at the mouth of the Duckabush. The village headman in the early nineteenth century was a warrior named hwahw'kwseb. (Elmendorf 1960:42).

When the Skokomish Reservation was created under the terms of the treaty, most of the people from the various Twana village groups were moved to the reservation. A few families remained at their former homesites. This was the case at the mouth of the Duckabush, where a Twana community was recorded in an 1880 census. Some of the family members are described as employees of the sawmill (presumably Seabeck or Port Gamble); two of the family heads were listed on this census. Docewaillopsh Bill was listed as a farmer and fisherman and Old Pulsifer was listed as a fisherman (United States Census 1880). In the excerpts from the research conducted by Daugherty and others included in Appendix 2.2, the authors have noted that Charley Brinnon was "an Indian who owned land at the mouth of the Duckabush." Clearly, Twana people lived here past treaty times and continued to utilize this area as a traditional fishery, as they do to this day.

To the south of the Duckabush River mouth is a series of large rock ledges in a tide flat. The Skokomish name of this place means "elks." According to Elmendorf, the name has probable myth reference. Communal elk drives were held in the Olympic mountains and the Duckabush drainage provides easy access between known hunting camps on the upper reaches of the Dosewallips and Quinault Rivers.

Guardian spirits were the center of spiritual life for the Twana and often were obtained in the mountains. There is an interesting account of a shaman power which occupied this drainage discussed in the following section on place names. During the spirit quest the person would go inland for a specific length of time and generally to a specific location. Some of these inland sites may have also been used as ceremonial sites (Elmendorf 1960). Written information regarding ceremonies and locations is practically nonexistent because of the sacred nature of these activities. However, before assuming that there are no known sites, consultation with the tribe and further research must be done to insure that sacred sites are protected. Geographic features such as the Big Hump are the type of physical places that may be of importance in Twana spiritual practices.

Archaeology

The prehistory of the Olympic Peninsula can be divided into four major time periods: early prehistoric (12,000-6000 B.P.), middle prehistoric (6000-3000 B.P.), late prehistoric (3000-200 B.P.), and historic (Post A.D. 1775) (Bergland 1988). Archaeological deposits throughout this region are tied to the Fraser River sequence of cultural development (Borden 1970, cited in Righter 1978a). Little is known about the early prehistoric period, due to changes in the coastline following glacial recession (Righter 1978a). All known sites in Washington State from this time period are located at considerable distances form modern shorelines. Common artifacts from this time period are shaped projectile points and knives, and pebble and heavy spall tools. Faunal remains and bone tools are rarely found from early prehistoric sites because of poor organic preservation, however, indications are that both terrestrial and littoral resources were utilized. Terrestrial species represented include deer, elk, bison, mastodon, and mammoth. As the glaciers receded, people moved into the high country where new vegetation attracted game and provided hunting and gathering opportunities. Archeological surveys in the Olympic mountains by the National Park Service have documented lithic scatters and hearth sites believed to date between 8000 and 4000 B.P. near high mountain lakes, meadows and along ridge lines. It was here that people made tools for hunting and plant processing.

The only documented prehistoric archeological sites within the Duckabush watershed are two isolated finds. One at Marmot Lakes, which is a leaf point projectile, made of dacite. Another isolated projectile point was found at Home Sweet Home. This is a notched stem point, also of dacite. Both areas probably date to the middle prehistoric period and have high potential for further archaeological research.

Coastal archeological sites of the middle prehistoric period south of the Strait of Georgia are rare. Mainland and island archeological sites north of Puget Sound are characterized by ground-stone implements as well as earlier types of artifacts, such as projectile points, knives, adzes, and celts (Righter 1978a). Bone, antler, and ground shell implements are also present. The presence of toggling harpoons indicates that marine resources such as sea mammals were exploited in coastal areas during this time period (Righter 1978a).

Cultural developments for the late prehistoric time period have been studied intensively (Righter 1978a). Numerous, but relatively minor, local and regional differences are found in artifacts from this period. These differences are probably the result of resource availability across the region as well as local cultural histories (Righter 1978a). Artifacts from this time period represent a maritime-oriented culture, which is also supported by ethnographic records (Righter 1978a).

The historic time period is poorly documented in archaeological records (Righter 1978a). Refer to Appendix 2.2 for excerpts from the cultural resource survey covering portions of the Duckabush by Western Heritage Inc. (Daugherty, et al 1983).

To date there has not been a representative amount of archeological survey on the Olympic Peninsula. Less than 1% of the acreage of the Olympic Peninsula has been surveyed for archeological sites, and of those sites that have been recorded, relatively few have been tested, excavated, or published (Righter, 1978a). However, the lack of archaeological sites does not indicate a lack of early use in this area, only a lack of archeological surveys. As few records exist and little research has been done specifically on the post-contact history of Native American groups within the study area, this aspect of the region's history remains poorly understood. Further research including archeology and oral history is needed to fill out these important gaps in the cultural record.

LOGGING ON THE DUCKABUSH

Historic use has been divided into three primary themes following Richter's' (1978a) designations. These include settlement, logging and mining. Small temporary homestead settlements were established in the eighteenth and early nineteenth centuries. Although the first settlers arrived as early as the 1860s, the first major influx of settlers occurred between 1890 and 1895 (Righter, 1978a). Settlers took up homesteads (160 acres) in anticipation of making a livelihood at farming. As such, these homesteads were located in the lowlands. Most of the early homesteads were abandoned due to difficulty in getting food to market and having the resources to purchase necessary supplies. A second wave of settlers arrived between 1900 and 1910. These settlers were interested in timber and mining claims. The farthest upriver homestead was probably at "the falls on the Duckabush on National Forest Land, where the concrete bridge is now" (Daugherty, et al 1983).

Most logging in the late 1800s was conducted by teams of men utilizing oxen and skid roads. Loggers worked near the shores of tidewater rivers or inlets so that logs could be floated to market. Chutes and flumes directed logs downhill to tidewater wherever the terrain was suitable (Righter 1978a).

Logging railroads started at the river mouths, where the teams initially had unloaded their logs, and worked their way upslope into the more remote forest stands. Transportation of equipment to the upland areas was difficult; thus light engines or converted street railway engines were used. In the early days of railroad logging, engines were floated up shallow rivers aboard barges; then dismantled and loaded onto wagons which carried them over primitive trails to the mountains. Sometimes the engines were pulled into the hills on sleds which made their own trails as they passed. As newer equipment became available, the old obsolete donkey engines typically were rebuilt and converted to home-made locomotives. Integral to logging operations was the construction of railroad trestles and inclines. Wood trestles, constructed using pile drivers, often were built over marshy areas and rivers. As logging operations moved up the mountainsides, trestles and bridges were built over steep canyons (Righter 1978a). All logging operations on the Duckabush were carried out by the Webb logging company between approximately 1912 and 1929. Maps of logging transportation routes are on file at the Hood Canal Ranger District office. Culturally significant logging remains, such as railroad trestles, railroad grades, logging camps, and dump sites within the Duckabush should be fully documented and managed. For further reading on logging operations in the Duckabush see Appendix 2.1.2.

Cultural Resources and Historical Recreational Development on Federal Lands within the Duckabush Watershed
The first forest reserves were created by presidential proclamation under the General Land Law revision or Forest Reserve Act of March 3, 1891. Olympic Forest Reserve was proclaimed by President Cleveland on February 22, 1897 and on March 3, 1905 the Bureau of Forestry became the U.S. Forest Service. Forest Reserves were renamed National Forests in 1907. By 1910 preservationists began pushing for a National Park bureau in addition to the USFS and the National Park Service was established in 1916.

National Monuments are proclaimed under the Antiquities Act of 1906. This act extended the principle of the Forest Reserve Act of 1891 to antiquities and objects of scientific interest on the public domain. It authorized the president to "declare by public proclamation historic landmarks, historic and prehistoric structures, and other objects of scientific interests" (P.L. 59-209, 34 Stat. 335).

On March 2, 1909 President Theodore Roosevelt established Mount Olympus National Monument within the center of the Olympic National Forest in order to protect the endangered elk population. The forest service administered both the monument and forest and began to develop recreation plans for Lake Quinault, Lake Crescent, and the Olympic Hot Springs as early as 1910 (U.S. Forest Service Correspondence/Boundary file 3/4/37).

In 1915, the boundaries of the National Monument were reduced by half because of timber and mining interests. Between 1915 and 1933, management of the national forest was designated for multiple use, however, the 1916 ONF management plan stressed that management furnish a "continuous supply of timber" (NPS 1990:44).

In 1923 the forest service landscape architect wrote of the need to address human service as well as timber harvest in planning, which resulted in a multiple use plan written by F.W. Cleator in 1927. Cleator, a forest service engineer and recreation examiner, divided the forest and monument into resource units within the national monument.

The Cleator Plan called for maximum recreational development of the Snow Peaks Recreation Area within the center of the Olympics: "Summer homes, hotels, and resorts...permitted under a carefully worked out recreation plan" (Cleator 1927). An Olympic Primitive Area was created on December 22, 1930 south and east of Snow Peaks to preserve the "rugged wilderness." Two areas along the Duckabush became primitive areas at this time. The primitive areas were to contain only those modifications necessary for fire protection and administration, such as, trails, telephone lines, look-outs, and shelters. The primitive area was to be managed as rugged wilderness with only horse and foot travel accessibility.

On June 10, 1933, Franklin Delano Roosevelt signed Executive Order 6166, assigning responsibility for the management of all National Monuments to the NPS. The NPS took over management of Mount Olympus National Monument in 1934.

Roosevelt supported the establishment of a National Park on the Olympic Peninsula and came to Port Angeles on September 30, 1937, calling for a large park to include all of the national monument. The park was established June 29, 1938. On January 2, 1940, Lake Crescent, the Port Angeles administrative area, Deer Park, Hurricane Ridge, Obstruction Point, the Elwha, Bogachiel, and Quinault River valleys were added to the park—as well as an area along the Duckabush from Lena Lake to the Brothers (some of which was part of the forest service primitive area). In 1984 The Brothers Wilderness was established from the Dosewallips to Lena Lake (see GIS maps attached to appendix).

National Forest Recreation Development

Management of the Olympic National Forest in 1912 included issues of land claims, grazing, trail improvement, land status, trespass, special use permits, reconnaissance, timber sales, fire protection and prevention. Year-round ranger stations were established at Storm King, Interrorem, and elsewhere. Trail construction began in 1909, and by 1910 the reserve had 73 miles of trail, 12 miles of road, 9 miles of telephone line, 3 bridges and 6 cabins. The Duckabush trail from Interrorem to Cliff Creek was constructed prior to 1918. Early trails in the National Forest were for official use in land management and resource protection. Trail-side shelters began to appear in the 1910s and 1920s. Trail shelters were necessary for management and fire protection, but they were also viewed as a necessity for the hiker, because of the extreme weather conditions in the Olympics. After the 1930 lightning bust, many fire lookouts were constructed, as "Olympic was no longer regarded as one-half asbestos" (Adams 1946:12). The Mount Jupiter lookout was built in 1933 and removed in 1967.

The forest reserve superintendent suggested a fire protection plan which outlined the construction of an extensive trail system and roads that paralleled phone lines. He also proposed patrol boxes every five miles and shelters for travelers, fire fighters, and fire fighting tools.

The period from 1919 to 1932 saw little development of recreation facilities on the National Forests. It wasn't until 1923 that there were even funds available to cover the cost of installing toilets, fireplaces, and other simple facilities required by recreationists. Most forest service shelters were constructed in locations where they could be used not only by trail maintenance crews, but also as overnight stops for hikers. Sites near meadows were selected to take advantage of available forage and at trail junctions which allowed crews to access more miles of trail and phone lines from a single location (Throop 1996).

Development of backcountry access specifically for recreation was not undertaken until the 1920s. Planning and design for trails proceeded under the guidance of Fred Cleator in the Regional Office, and numerous trails were constructed. Cleator's design differed from administrative trails in that a recreation experience was the objective. Scenic views, terrain and vegetation to interact with natural features was incorporated into trail routes. Recreation trails were engineered, sometimes in difficult terrain (Throop 1996). According to one trail worker, trails were four feet wide and graded like a sidewalk so burros could pack supplies to forest fires.

In 1932 the forest service developed the Meinecke plan for campground development which called for extensive rehabilitation of existing campgrounds and the construction of new ones. This campground development program was timely. In November of 1932, FDR approached the USFS and instructed Chief Forester Stuart to develop plans for the employment of 25,000 men in the nations forests. The Emergency Conservation Work was formally enacted on March 9, 1933.

By the 1930s, recreation planning was a priority for forest service land use. The governing factors in planning were to meet the needs of the traveler; to provide for sanitary conditions; and to protect the forests from fire. The USFS devised operating plans and work schedules based on recently completed forest work surveys (Throop 1996). The NPS also drew up schedules for conservation work, including state parks. Plans for Camp Collins, designed by Ward Ellis in 1936, was probably constructed by the CCC.

Civilian Conservation Corps Camps

Each CCC Company was assigned a number by the war department. Fort Worden organized administration of the first four CCC camps on the Olympic Peninsula: Elwha, Co. 936; Quilcene, Co. 946; Lake Cushman, Co. 947; and Humptulips, Co. 982.

The Forest Service, National Park Service and other agencies supervised CCC work and administered the camps. The operating agency usually had a name for a camp as well as a letter to designate the type of land ownership. For example the Forest Service had the following camps on the peninsula in May of 1933: F-16 Snider; F-17 Elwha; F-18 Slab Camp; F-19 Quilcene; F-20 Lake Cushman; F-21 West Fork Humptulips; F-46 Bogachiel/Hoh.

The Lake Cushman camp managed side camps at Hamma Hamma and Interrorem. Because work projects required that the enrollees be located near the site, when the project was too far away from the main camp, a side camp was established. Usually the side camps consisted of 10 to 20 men living in tents, with a foreman in charge of the camp. The CCC boys often preferred these side camps, as the routine was quite informal and less stringent schedules were enforced. Under an agreement between CCC director Fechner and Washington State Governor Martin, the type of work projects initially undertaken by the camps was confined to roads chiefly of value for forest fire protection, insect disease control, and sheet erosion involving forest lands.

After nine years and three months the CCC ceased active operation and the decision to liquidate was made on June 30, 1942 and completed by June 30, 1943. In excess of one thousand Depression-era sites and structures survive in the PNW region of the USFS (Throop 1996). Relatively few remain within Olympic National Park and Olympic National Forest

The CCC advanced forest and park development by many years. Protective facilities, greatly needed fire trails and other forest fire-prevention facilities such as lookout towers, ranger cabins and telephone lines connecting them were constructed which resulted in the best fire protection in history.

A major outcome of the CCC was the growth of the recreation movement, and a resultant appreciation of the meaning of conservation. Recreation became as important as the conservation of human wealth because it provided relief from the pressures of modern life.

NPS Recreation Development

One of the chief responsibilities of the NPS in its administration of the national park and monument system is to bring about a proper compromise between preservation and protection of the landscape, and developments for making park areas accessible and useful to the public.

At the time of acquisition, the total trail mileage in the national monument was approximately 115 miles. Many of the trails were impassable because of washouts, land slides and fallen timber. By 1935, all trails had deteriorated to such an extent that they needed to be practically reconstructed, widened and relocated so they would be reasonably safe and free of excessive grades. A survey was completed to determine the amount of development to be undertaken and the proposed trail work. One of the trail proposals included reconstruction of 15 miles of the east fork Quinault/Duckabush River Trail and subsidiary trails in the southeast section of the monument. In December of 1934 the NPS submitted a list of projects covering improvements at Mt. Olympus National Monument for consideration with Public Works Programs that might be authorized. The list included guard and patrol cabins, barns and corrals, water and sanitary facilities for patrol cabins, campgrounds, 4 ranger stations, and 12 stone, log and shake trail shelters.

The NPS submitted a request for PWA funds to build trails; included on the list was a trail to Lake LaCrosse. The trail work was needed because the area was in an electrical storm belt and an adequate trail system would make the forests accessible for fire patrol and fire fighting. Patrol and shelter cabins were also requested for the protection of personnel, and camp sites and shelters for visitors.

One of the requested patrol cabins was at Home Sweet Home. The cabin was to house a ranger to protect the many hikers who passed through the area and to supervise maintenance and other protection needs. Out of the five patrol cabins, Home Sweet Home is the only extant structure.

At the time Olympic National Park was proposed, all CCC work that might be constructed in what was to become the national park was carefully considered by the forest service. In 1936, Forester W.H. Horning wrote a report on the proposed enlargement of Mount Olympus National Monument and its probable effects upon the National Forest. In this report he outlined suitable projects for using CCC labor in possible park development. Horning felt that the principal development work in the park would probably be restricted to a few new trails required to complete the existing trail system, additional trailside shelters considered essential to public use of the Olympic wilderness, and several additional guard stations at strategic locations. On September 15, 1938, forest supervisor Bruckert stated that no further action in the way of road or trail building would be conducted in the proposed park area until the ultimate boundaries were fixed.

After the park was established, a January 1939 park service document said that guard and ranger stations would be built and a few trail shelters for hikers and riders for whom the park was particularly designed. There would be no highways through the park, however, 300 miles of trail existed at the time, which required improvement. The NPS planned construction of not more than 30 or 40 miles of new trail to be built by the same CCC boys who had carried out forest service projects when the area was under forest administration (NPS Correspondence 1/12/39).

In 1939, ONP requested construction of 10 miles of revision on previously constructed trails and reconstruction of 25 miles of trail because of erosion and washouts. Many miles of poorly located and maintained trails came under the jurisdiction of NPS and it was important to the future administration of the park that the trail system be rehabilitated. Since no regular road and trail funds were available for the park, the only trail work accomplished would be by the CCC. Trail building in the Olympics required hand drilling holes in bedrock and blasting. In the PNW the CCC built or improved 85,000 miles of truck trails and over 42,000 miles of foot trails.

Cultural Properties and Potential Affects

Historic

Interrorem Ranger Cabin
Home Sweet Home Patrol Cabin
Lake LaCrosse Trail
Duckabush Trail
Gauging Station - 1938
Camp Collins

Archeological

Home Sweet Home
Marmot Lakes
CCC Side Camp - Interrorem
Webb Logging Trestles and Archeology
Webb Lookout Site
Mt. Jupiter Lookout Site

Potential Affects

Erosion
Fire
Vandalism
Flooding
Recreation and other human impacts
Road and trail maintenance

Recommendations and Conclusions

Topographical features likely to contain prehistoric remains can be projected from ethnographic data and recorded sites located in the Hood Canal region and elsewhere in Washington State (Righter 1978a). Based on the ethnographic data, coastlines should be considered archaeologically the most sensitive. Other areas that may be sensitive include riverbanks, (especially where two streams join) bogs, marshy areas, meadows, prairies, cedar groves, and lake shores.

The known cultural properties located on federal lands within the watershed are associated with prehistory, early settlement, late 18th or 19th century logging practices and Forest Service/National Park Service history. Cultural sites and their significance are recorded and on file at the Skokomish Tribal Center, the Olympic National Forest Headquarters, Olympic National Park and the Washington State Historic Preservation Office. Cultural resource reports are required to be approved by the State Historic Preservation Officer before management activities can proceed.

Further archeological analysis is necessary before ground disturbance on federal lands, especially in sensitive areas or areas of high archeological potential.

Within the Duckabush drainage there are few structures standing that are associated with early forest service administration and the CCC. Because there are so few their evaluation and protection is critical for proper management.

Logging is what originally brought the second wave of settlers to this region. This industry has been a major employer and life style for residents of this area since that time. Thus, the cultural significance of this life style is also extremely important. Culturally significant areas such as railroad trestles, railroad grades, old ranger stations and guard stations, logging camps, trails and shelters are deserving of protection. Many of the resources listed above are sensitive to upland management activities and should be considered in management decisions.

Although there is a lack of documented evidence readily accessible for locations of specific Skokomish places of traditional and cultural importance, there is the potential for archeological evidence and traditional use within the Duckabush watershed. There is high potential for archeological evidence at the mouth of the Duckabush River, though not on federal land, the affects from upriver need to be considered. The existence of traditionally used Skokomish places in this watershed is also likely. Consultation with the tribe is necessary before land management prescriptions or undertakings occur.

The answer to key question #1 is addressed above. Locations of cultural resources are not delineated in this report due to the potential of vandalism and theft. Some information may be available through the respective repositories listed above on a case by case basis.

The answer to question #2 on the processes that affect these resources may include, but are not limited to, logging, road building, campground construction, flooding, erosion, vandalism, fire, and human impacts. The current condition of the cultural resources in the Duckabush Watershed within Olympic National Forest and Olympic National Park are largely documented, controlled, and protected. Protection of these resources is ongoing and by law all activities must stay within agency regulations, laws and mandates.

Recreation

Duckabush Watershed Analysis

Purpose

The purpose of this section is to provide the land manager with a description of the recreation activities occurring on federal lands within the watershed and the impacts this use causes or may cause in the Duckabush watershed. Recreation activities outside of the study area will be addressed by other agencies responsible for their respective jurisdictions. This module will also identify existing recreation facilities within the watershed and the Forest Service and Park Service's desired future projects There are two key questions identified in the scoping process:

1. What kind of recreation uses are in the watershed?
2. How do recreation uses affect the resources?

Background

The watershed plays an important role in providing developed and undeveloped recreational opportunities. Five million people live within a hour and a half driving time of the Duckabush area. Recreational values are diverse within this watershed, ranging from coastal and marine values to alpine forest as well as non-forest values. Uses identified within the watershed (estuary to headwaters) are: camping, picnicking, fresh water fishing, saltwater fishing, shellfishing, birding, mycology, berry picking, hunting, backpacking, hiking, mountain biking, mountain climbing, wilderness use, photography, boating, viewing scenery, and auto touring. Access to the Duckabush Recreation Area, the Olympic National Park, The Brothers Wilderness, Collins Campground, Interrorem Nature Trail and Picnic Area are only a few examples. The scenic value of the watershed is high. The watershed provides a range of scenic quality, from recently harvested and planted trees, to large old-growth stands. A full range of vegetative age classes, from immature trees to large old-growth stands, and alpine vistas above tree line. The higher elevations offer opportunities to view the interior Olympic Mountains, Olympic National Park, Puget Sound basin and Mt. Rainier.

The general pattern of recreation in the Duckabush watershed is based upon landscape characteristics and management direction. Fundamental factors include proximity to Seattle-Tacoma metropolitan area and surrounding communities, low elevation, topography, management direction in the Forest Plan, and road access. This key watershed is centrally located on the east side of the Olympics between Hoodsport and Quilcene, Washington and is approximately 25 miles north of Hoodsport just off of State Highway 101. The pattern of dispersed camping within the watershed is a reflection of the high use found on the east side of the Olympics because of the close proximity to Puget Sound population areas and transportation corridors. This watershed is characterized by steep to rolling terrain with easy access near the valley bottom. Heaviest use occurs March through October, with the prime time being the summer months where temperature relief and summer recreation can be found.

There are three developed recreation sites within the watershed. Interrorem Ranger Cabin is a historic log cabin built in 1907 that is now operated under the cabin rental program and available for public use. Collins Campground is a 16 unit campground that accommodates overnight campers and recreation vehicles. Interrorem Day Use and Picnic Area has three picnic sites adjacent to the old ranger cabin.

There is also one semi-developed rustic camp called the Duckabush Horse Camp located adjacent to the lower Duckabush trailhead. In addition to the developed sites within the watershed there are approximately 75 dispersed campsites which include backcountry wilderness. While some changes in the distribution of dispersed sites have occurred over the last 25 years, the number and pattern of sites is relatively consistent. The total number of acres impacted by dispersed camping is unknown.

Trails within the watershed are often located adjacent to streams or rivers and in some cases in unstable areas where mass wasting can occur. This erosion is not a significant occurrence on trail systems, but when it does occur it can affect the aquatic systems to an unmeasureable degree. Future trail construction projects require an environmental assessment and biological evaluation before work can proceed. Compaction of soils and vegetation, sensitive plant specie disturbance, and degraded (and potentially harmful) contamination from human feces are of concern and will likely continue until proper sanitation, and environmental education and interpretation occurs within the watershed.

During the fall hunting season, the pattern of use disperses more broadly throughout the forest service land of the wathershed to upland sites along roads and timber sale landings. There are many special places to which generations of hunters come back to use their favorite sites. Desired settings for fall hunting camps does not appear to be contingent upon a wooded or scenic setting, but is dependent upon flat areas, water and road access. Deer and ruffed grouse populations have increased over the last four decades. This can be attributed to young succulent vegetation that sprouts immediately after timber harvest and broadcast burning. Recreational hunting pressure is long-standing and consistent in the watershed, but minor in relationship to other parts of the subbasin. Elk populations appear to be drastically low and hunting pressure has subsequently fallen in the last decade. Cougar and black bear populations are relatively high and receive notable harvest pressure by hunters. Fishing is a popular activity with use primarily concentrated on the Duckabush River.

Trends

The demand for outdoor recreation on publicly owned lands is likely to continue to rise as urban areas continue to grow. The capacity for increased recreation use was exceeded a decade ago on the Hood Canal Ranger District. Puget Sound populations will increase by another million people in the next five years and the capacity will far exceed the opportunity for an outdoor recreational experience. People are visiting the national forest and national park more and more for the love of the outdoors. The annual visitation is likely to exceed the 1970s. This imposes a challenge for managing wilderness and recreation resources.

In a study on outdoor recreation, Clawson proposes that "the analyst who extends past trends in recreation use on public areas should do so with considerable sophistication. Specifically, if a formula is devised or a statistical regression coefficient is calculated, the analyst would be well advised to include a retarding variable, probably one which would grow in strength as time marched on, in whatever projections of future demands were made" (Clawson 1985).

A 1994 Roper Survey for the Recreation Roundtable, include some of the following statements:

"Active outdoor recreators are more completely satisfied with the quality of their lives than is the general public. Similarly, those who grew up in families in which outdoor recreation played an important role are among the most satisfied Americans."

"40% of all Americans report that they have driven for pleasure in the last twelve months. Other leading activities are swimming (35%), picnicking (33%), fishing and camping (both 25%), bicycling (21%), running or jogging (19%), boating and hiking and wildlife viewing (18%), and photography (15%). On average, each American has participated in nearly four outdoor recreation activities!"

"Outdoor recreation also is perceived to be widely available—not just a luxury for the affluent."

"The top motivations of the public for participating in outdoor recreation are fun, relaxation, health and exercise, family togetherness, stress reduction, to experience nature and to be with friends."

"Two-thirds of all Americans participate in outdoor recreation every year and half do so at least monthly."

"A vacation spot at an ocean, lake, reservoir or river is the top choice for Americans, followed by federal and state parks.", which support key findings from the Clawson study, "Outdoor Recreation in America".

"While obtaining information on places to go is not a major problem to most Americans, the public is relatively unsatisfied with the amount of instructional, interpretive and environmental information available during the outdoor recreation experience itself."

Tighter budgets at every level of government are a fact of life for the future. The competition for public funds for recreational activities will be very keen and the public opposition to higher taxes will be enormous. The recreation community may have to look to alternative sources of funds as well as to the general taxes. There will almost surely be increased debate over how much of the cost should be borne by the recreation user. The realistic alternatives may be larger user fees or some degree of neglect of the public recreation areas, if the opposition to larger use of general tax revenues should increase. Olympic National Forest is one of the forests in the northwest that is participating in the Trail Park Pass which requires a fee to park at identified forest trailheads. Olympic National Park has recently begun its Wilderness Use Fee program.

Inventory of Recreation Resources

There are 49,933 acres within the study area referred to here as the Duckabush Recreation Area which includes private, state and federal lands. The recreation use in this area is considered moderate except for the Duckabush trail which is considered heavy. There are few facilities available in the river drainage. The heaviest concentration of recreation use is along the Duckabush River. Public lands receive moderate use in the front country, backcountry, and roadside recreation. In comparison to other park areas the Duckabush is one of the least used drainages. 1.3% of total park use is in the Duckabush drainage. Hamma Hamma is much higher. 1320 visitor use nights Duckabush in 1995. Busiest Duckabush park locations—in order—Marmot Lake, Home Sweet Home, 10 Mile Camp, Upper Duckabush Camp, Hart Lake—for overnight wilderness use. The Brothers Wilderness does receive heavy use via the Duckabush Trail. This wilderness area is heavily used by increasing numbers of people from the Puget Sound area and many of the users are entering the Olympic National Park and destinations such as LaCrosse Pass, Honeymoon Meadows, O'Neil Pass and Marmot Lakes. This area does not meet the needs of existing use and recreation facilities do not meet present or future trends. Table 3 is a summary of existing facilities within the recreation area and Olympic National Forest's and Olympic National Park's desired future condition to meet existing demand.

Existing recreation facilities:

Facility	Description
Collins Campground	Overnight camp, 16 units, hand pump well, vault toilets, fee site.
Interrorem Day Use/Picnic	Day Use, No overnight camping, 3 sites, vault toilet
Interrorem Ranger Cabin	Historic log cabin built in 1907 available for rent through Hood Canal R.D.
Duckabush Horse Camp	Rustic camp accommodating horse groups up to 10 parties. Semi-primitive setting next to trailhead.
Upper Duckabush Trailhead	Parking for 20 vehicles, 1 toilet, primary parking for Duckabush Trail
Lower Duckabush Trailhead	Parking for 20 vehicles with horse trailers. Equestrian use only, horse unloading area, horse stalls and hitching rails
Murhut Falls Trailhead	Parking for 5 vehicles, no facilities
Murhut Falls Trail	1 mile of trail leading to beautiful falls, considered a more difficult trail to hike
Mt. Jupiter Trailhead	Parking for 8 vehicles, no facilities
Mt. Jupiter Trail	7.1 miles of trail along Jupiter ridge which includes 2 miles of Wilderness trail
Ranger Hole Trail	1.0 mile of trail accessing popular fishing area along the Duckabush River
Interrorem Nature Trail	0.3 mile of interpretive trail located behind Interrorem Cabin.
Duckabush Trail (ONF)	6.7 miles of trail accessing the Brothers Wilderness and the Oly Nat'l Park
Duckabush River Trail (ONP)	10.9 miles of Olympic Nat'l Park trail accessing O'Neil Pass and Home Sweet Home trails
LaCrosse Pass Trail (ONP)	3.3 miles of Olympic Nat'l Park trail leading to the Dosewallips
O'Neil Pass Trail (ONP)	4.6 miles of trail accessing Hart Lake, Marmot Lakes and O'Neil Pass and leading to the East Fork Quinault and Dosewallips
Home Sweet Home Trail (ONP)	2.8 miles of trail accessing Home Sweet Home.
10 Mile Camp	Wilderness Camp consisting of 3 campsites
Home Sweet Home Camp (ONP)	Wilderness Camp consisting of 1 shelter and privy
Upper Duckabush Camp	Wilderness camp, 6 campsites, 1 privy.
Marmot Lake	Wilderness Camp consisting of 5 campsites and 1 toilet.

The following proposals are identified as desired projects within the Duckabush Watershed:

Facility	Description
Collins Campground Expansion	Expansion of site by adding 20 units to accommodate future use. Site location adjacent to existing campground.
Interrorem Cabin	Development of new water system to replace abandoned well, and construction of new vault toilet to replace existing toilet.
Duckabush Fisherman Trail	2 miles of fisherman trail that ties into existing Duckabush trail.
Mt. Jupiter Trailhead Relocation	Relocate trailhead from present location to gravel pit across from Collins Campground. Present access causes problems for users that have to cross private lands/roads.
Mt. Jupiter Trail Construction	Abandon road access and Mt. Jupiter trailhead for new public access to Mt. Jupiter Trail via new trailhead and 2 miles of new trail. Partnership with forest land owners in area.
Webb Lookout Trail	Road to trail project for old Webb road #2510-090 consisting of 1 mile of trail.
Webb Lookout Trailhead	Establishes new trailhead for access to Webb Lookout trail.
Murhut Loop Trail	Road to trail project for logging spur roads #2510-032 and 2530-016, consisting of 4.0 miles of trail. Sections of trail would be identified for interpretation for railroad logging history.
10 mile camp (ONP)	Construction of a stock camp with a fixed highline.
Interrorem Nature Trail	Pave 0.3 tenths mile of trail to meet barrier free needs. Interpretative signs will be installed in FY 98.
Ranger Hole Trail	Minor reconstruction of segments of trail where erosion or safety is a problem.

Recreational Opportunities

Recreation Use: The primary factors determining pattern of recreation use in the area are:

- The proximity of the watershed to the Seattle-Tacoma metropolitan area, Puget Sound residents, and its geographic location as it relates to the eastern Olympic Peninsula.
- The topography of the watershed (large area with sub-watersheds), relatively flat near the river corridor at lower elevations to very steep mountainous terrain at the higher elevations.
- Year around access ranging from winter sport activities such as cross country skiing, tubing and general snow play to traditional seasonal use such as fishing, hiking, climbing, camping, driving for pleasure, viewing scenery and general day use.

Some watershed specific factors are:

- Road access, there are 50 miles of forest roads within the analysis area.
- The presence of wildlife offers opportunities for hunters and wildlife viewing.
- Traditional and generational use.
- Limited development of recreation facilities encourages users to create their own opportunities.
- Mountain lakes, rivers and streams offer opportunities for scenic viewing and fishing.

The Duckabush is within close proximity to the residents of Puget Sound and provides easy access to the area's recreational opportunities. Open roads within the watershed are available for people to drive for pleasure. In addition, there are 50.2 miles of trails (16.2 miles are ONF and 34 miles are ONP) within the watershed ranging from the high elevation trail, to trails that access viewing areas, lakes and ponds. Dispersed recreation opportunities are numerous in the analysis area with many areas being accessible for rustic camping and privacy.

The largest developed recreation facility that is accessed by motorized use within the drainage is Collins Campground.

Findings

Capacity for existing recreation use has been exceeded. Demand for recreation opportunities will continue as population centers continue to grow. The demand will be centered on a population that wants to center their activities around water.
Resource impacts are occurring within the watershed due to heavy volumes of use, lack of defined areas for users to recreate, lack of sanitation facilities and lack of personnel to administer the area.

- A need for additional facilities and trails within the area.
- Concerns for the safety of the public has increased with increased use.

Summary

All recreational activity occurring in the watershed such as hiking, overnight camping, general day camping, driving for pleasure, scenic viewing, mountain biking, horse back riding, fishing, hunting and backcountry use will continue to increase in the future and will cause impacts to the resources. For the most part these impacts are minimal except for high use areas such as Collins Campground, and the Duckabush Trail. Resource problems are occurring in other areas within the watershed but not to the degree that high use area's are impacted. Law Enforcement reports, observations by forest personnel and physical evidence on the ground indicate that the most significant impacts are: excessive littering, improper sanitation, abandoned campfires, fireworks, vegetation damage, and soil erosion. There is not adequate information available to determine the indirect or cumulative effects on the physical components of the environment to determine significance. However, impacts can be reduced by improving information and education programs, closing access to sensitive sites, by developing adequate facilities to accommodate recreation use, personnel to administer this use and incorporating regulations and enforcing these regulations through law enforcement efforts.

Recreation use appears to be affected very little in regards to other uses in the watershed. As a matter of fact, it is commonly believed that the high recreation use is directly related to the benefits that timber harvesting has provided by opening the timber canopy and allowing sufficient sunlight for users of the area to enjoy. This is evidenced by large numbers of people enjoying themselves along river corridors and sun bathing in open areas. Other activities such as the gathering of forest products has indicated little to no adverse affects on recreation use. Access and travel management planning (ATM) is a focus that the user groups expect from Forest Service managers for the future.

Recommendations

- Pursue the desired future conditions and incorporate into the Forest Plan by amendment.
- Pursue monitoring of watershed for resource impacts and gathering additional data on resource damage.
- Work with other resource disciplines in developing an access and travel management plan where roads can be converted to trails. Look for opportunities to utilize railroad grades as interpretive trails.
- Continue with emphasis on public safety and visitor protection by increased signing of hazardous areas and public information.

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2.2 PUBLIC WORKS

Purpose
This module is used to inform the land manager of the Public Works Facilities within the watershed, so as to determine how these facilities are affected by management activities and natural processes within the watershed.

INTRODUCTION
A variety of transportation systems exist within the watershed. Roads, trails, railroads and waterways have historically been utilized for transportation. Today there is approximately 50 miles of roads within the Duckabush watershed and 36 miles of developed trails. Watershed ownership by subwatershed group is displayed in Table 2.2A. Transportation systems within the watershed is graphically displayed in Map 2.2A and Table 2.2B displays the amount of road by ownership and the amount within riparian designated areas.

Key Questions:

1. What are the public works and facilities in the watershed?
2. How have the public works sites been affected by the processes within the watershed?

Methods and Data
A variety of methods for analyzing the public works was utilized. A review of Forest Service roads data base (TRANSMAN) was made to compile Forest Service road information. Recreational information from Olympic National Park and Olympic National Forest was utilized for trail information. Reports and extract were made from corporate GIS technology. Chronological road construction information was obtained from aerial photo interpretation and data base review. Off Forest Public Works information was acquired through review of " WEST SHORE HOOD CANAL WATERSHEDS, MASON/JEFFERSON COUNTIES, WASHINGTON, September 1995" document and through synthesis with other module leaders.

TABLE 2.2A Acreage by Ownership

Ownership	Sub-Watershed Group	Acres	Totals
Olympic National Forest	Lower Duckabush	5,635	
	Middle Duckabush	1,253	
	Murhut/Cliff	8,660	
Sub-totals			15,548
Olympic National Park	Crazy Creek	5,671	
	Headwaters Duckabush	3,049	
	Middle Duckabush	12,933	
	Upper Duckabush	7,204	
	Murhut/Cliff	1	
Sub-totals			28,860
Private	Lower Duckabush	4,443	
Sub-totals			4,443
State	Lower Duckabush	1,082	
Sub-total			1,082
Totals			49,933

Table 2.2B Amount of road by sub-watershed group in miles

Subwatershed Group	Ownership	riparian miles	non-riparian miles	Total Miles
Lower Duckabush	Private	7	17	
	Olympic N. F.	4	11	
Sub-total				**39**
Murhut	Olympic N. F.	6	5	
Sub-total		6		**11**
TOTALS		**17**	**33**	**50**

The Public works facilities will be listed by subwatersheds starting from the western most end and proceeding eastward.

SUBWATERSHEDS

Headwaters Duckabush River

- No roads
- Approximately 4 miles of Duckabush Trail (Olympic National Park)
- 3049 acres of Olympic National Park lands

Upper Duckabush River

- No roads
- Approximately 10 miles of Duckabush Trail (Olympic National Park)
- 7204 acres of Olympic National Park lands

Crazy Creek

- No roads
- No trails
- 5671 acres of Olympic National Park lands

Middle Duckabush River

- No roads
- Approximately 5.5 miles of Duckabush Trail (Olympic National Park)
- Approximately 1 mile of Duckabush Trail (# 803 Olympic National Forest)
- 12933 acres of Olympic National Park lands
- 1253 acres of Olympic National Forest lands
- 1253 acres of the Brothers Wilderness Area

Murhut Cliff Creeks

- 11.0 miles of national forest roads (primarily all 11.0 miles are within Murhut Creek)
- Access and travel management plan will decommission 1.85 miles of road in this subwatershed
- Road density 0.8 miles per square mile for the combined watershed but Murhut has 10.8 miles of road within 1819 acres(approximately 3.8 miles/sq. mile)
- Approximately 4.7 miles of Duckabush Trail (# 803, Olympic National Forest)
- 1.3 acres of Olympic National Park lands
- 8660 acres of Olympic National Forest lands
- 6279 acres of the Brothers Wilderness Area
- Seismic monitoring station, special use permit to U.S.G.S. (Formerly to the University of Washington) T25N, R03W, Section 22

Lower Duckabush River

- 15 miles of national forest roads
- Access and travel management plan will decommission 3.7 miles of road in this subwatershed
- 24 miles of State, Jefferson County and private roads
- Road density 2.2 miles per square mile, all ownership's
- Road density 0.86 miles per square mile national forest roads only
- Approximately 1 mile of Duckabush Trail (# 803, Olympic National Forest)
- 5,635 acres of Olympic National Forest lands
- 525 acres of the Brothers Wilderness Area
- 4,443 acres of private lands
- 1,082 acres of state lands
- 1,747 acres of private and state lands within National Forest boundaries
- Gauging station (installed 1938), special use permit to U.S.G.S., T25N, R03W, Section 1
- Buried telephone line(s), special use permit to Sprint United Telephone, T25N, R03W, Section 1
- PUD No. 1 buried transmission line, special use permit to PUD No. 1, Hoodsport WA, T25N, R03W, Section 1
- Private road to single family residence, .17 miles long, 14 feet wide, special use permit, T25N, R03W, Section 1
- Murhut Falls Trail Head, parking for 5 vehicles, T25N, R03W, Section 10
- Murhut Falls Trail, 1.0 miles, T25N, R03W, Section 10
- Lower Duckabush Trail Head, parking for 20 vehicles with horse trailers, horse unloading area, horse stalls and hitching rails, equestrian use only, T25N, R03W, Section 3, road # 2510065
- Duckabush Horse Camp, adjacent to Lower Duckabush Trail Head, T25N, R03W, Section 3
- Upper Duckabush Trail Head, parking for 20 vehicles, 1 toilet, T25N, R03W, Section 3, road # 2520060
- Collins Campground, 16 unit overnight campground, 1 hand pump well, 4 vault toilets, fee site, T25N, R03W, Section 2, road # 2510070
- Interrorem Ranger Cabin, log cabin built in 1907, available for rent through cabin rental program, due south of road junction 2510 and Jefferson County road 2274, T25N, R03W, Section 1
- Interrorem day use picnic area, 3 sites, vault toilet, adjacent to Interrorem Ranger Cabin
- Interrorem Nature Trail, 0.3 miles of interpretive trail behind Interrorem Ranger Cabin, (#804, Olympic National Forest)
- Ranger Hole Trail, 1.0 miles to Duckabush River (Ranger Falls), trail head adjacent to Interrorem Ranger Cabin, (#804, Olympic National Forest)
- Mount Jupiter Trail Head, parking for 8 vehicles, access through private and state timberlands, private gate denies access from October to April, poor and incomplete right of way (needs upgraded), road # 2610011, trail head on private property, T25N, R02W, Section 5
- Mount Jupiter Trail, 7.1 miles to Mount Jupiter, first 1.0 miles on private property, approximately 2.0 miles within the Brothers Wilderness Area (#809, Olympic National Forest)
- Mount Jupiter Lookout, constructed in 1933, decommissioned and removed in 1967, T25N, R03W, Section 33
- Rock quarry, closed, road # 2510075, T25N, R03W, Section 2
- Proposed rock quarry (mid 1980's), road # 2510000, T25N, R03W, Section 11
- Road # 2510000, milepost 19.1, bridge over the Duckabush River
- Road # 2510000, milepost 18.2, bridge over unnamed stream

SUMMARY OF FINDINGS

The high road density within Murhut Creek (3.8 miles/sq. mile) in conjunction with the mass wasting sites associated in steep inner gorges indicates decommissioning of 6.95 miles of road. This would result in reduced road densities, sediment reduction in the long term (primarily beneficial to aquatic habitats) and reduced miles of road within riparian areas (refer to Erosion Module 2.4 and Wildlife Module 2.5).

Roads currently being utilized by dispersed recreationists, which are classified as non-system and are unmanaged, are currently delivering sediment to anadromous fish habitat and require restoration and rehabilitation. Two roads adjacent to the mainstem are the highest priority restoration projects within the watershed. The first road is located near milepost 18.3 on FS road 2510 on the south side of the Duckabush River. The second is near milepost 20.1 on FS road 2510 on the north side of the Duckabush River (refer to Erosion Module 2.4 and Fish Module 2.6).

Improving surface drainage and reducing sediment being delivered to fish bearing streams but especially associated with anadromous reaches within the Lower and Middle Duckabush subwatersheds.

Hazard trees associated with developed recreational facilities, roads and power transmission lines should be assessed annually and removed if potential exists to jeopardize public safety.

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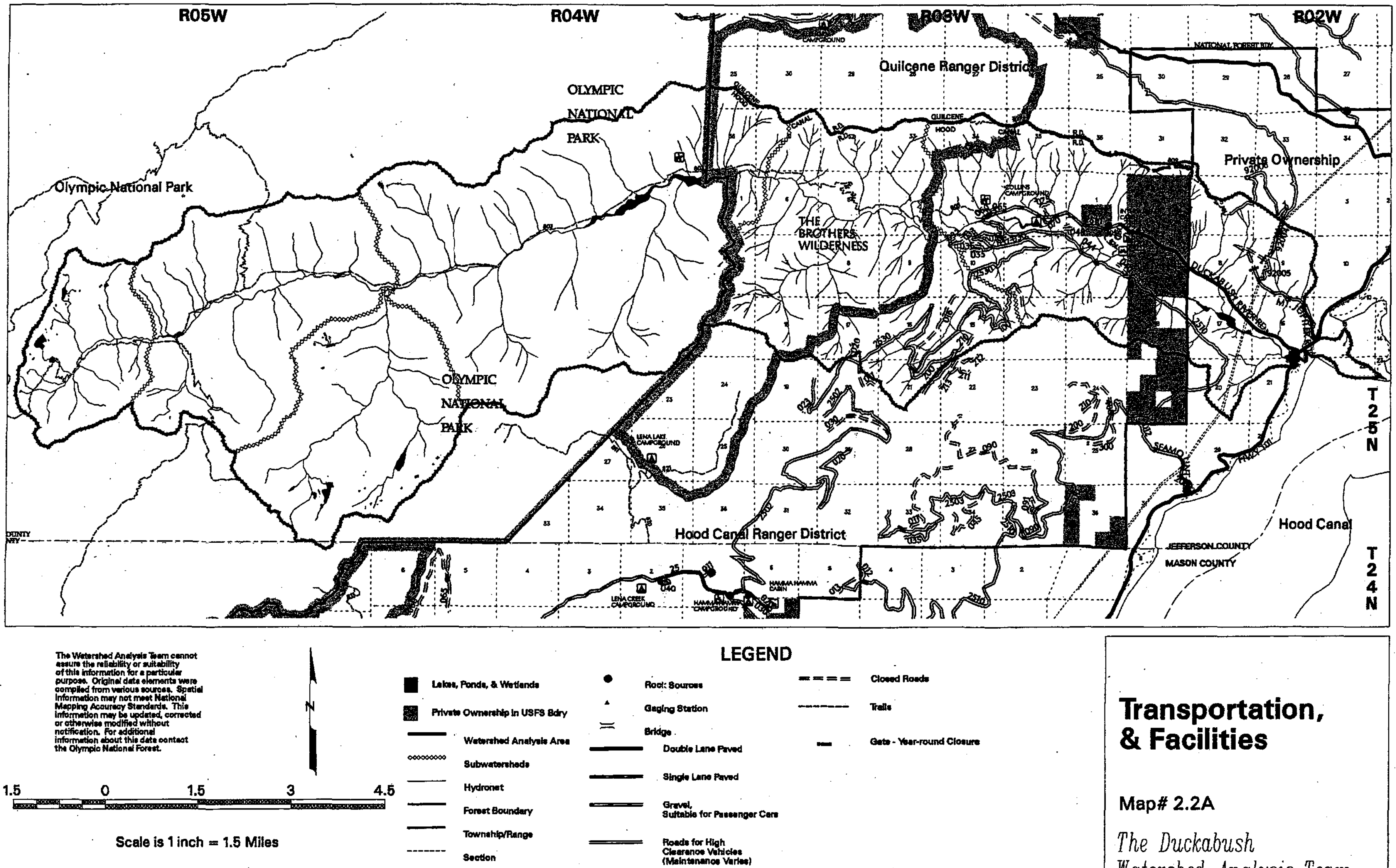
Hamma Hamma Watershed Analysis, 1997



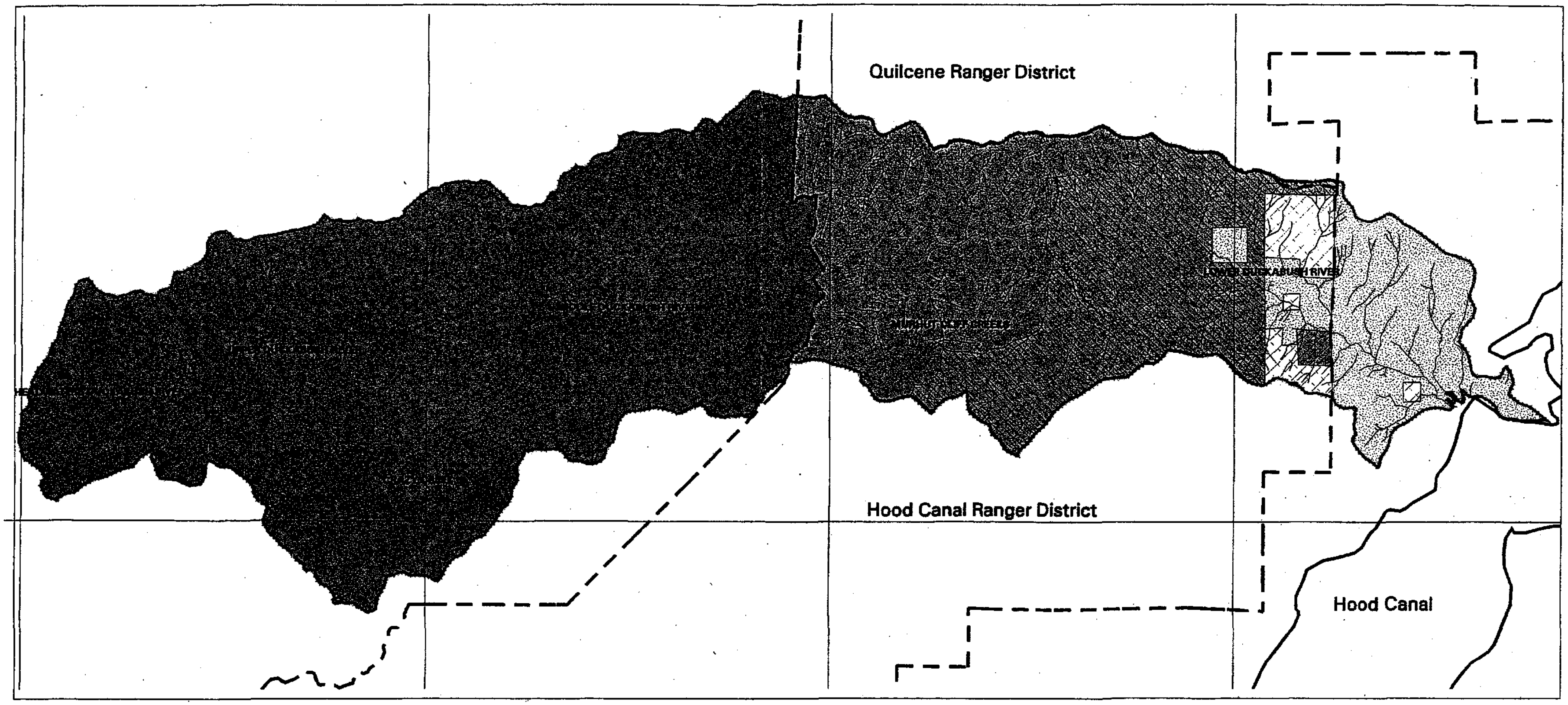
The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

Transportation, & Facilities

Map# 2.2A

The Duckabush Watershed Analysis Team

l_trans April 15, 1998



The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

l_admin May 26, 1998

LEGEND

- Forest Boundary
- Hydronet
- Subwatersheds
- Quad Lines
- Watershed Analysis Area
- U.S. Forest Service
- WA. Dept. of Natural Resources
- Private Ownership
- Olympic National Park
- Late Successional Reserve
- Adaptive Management Areas

Ownerships and Land Allocations

Map# 2.2B

The Duckabush Watershed Analysis Team

2.3 CHANNEL MORPHOLOGY

I Key Questions:

The following questions are from the Federal Guide for Watershed Analysis, stream channel assessment.

1) What is the spatial distribution of channel response types (DNR Q#1); and what are the basic morphological characteristics of stream valleys or segments, and what are the general sediment transport and deposition processes in the watershed?

- The channel network has been stratified by gradient and confinement using the Standard Methodology for Watershed Analysis (WA DNR, Version 3.0, 1995). These segments are shown on Map 2.3A.
- Table 2.3A; Stream Channel Attributes; displays gradient, confinement, geomorphology, and response type for each channel segment.
- The distribution of source, transport, and response reaches as defined by the Washington DNR Watershed Analysis Process are displayed on Map 2.3A
- Basic morphologic characteristics are displayed in Table 2.3A. A description of each geomorphic type includes characteristics, typical channel form, important processes, functions and controls and is given under geomorphic unit descriptions.

2) What are the current conditions and trends of stream channel types and sediment transport and deposition processes prevalent in the watershed?

- Tables 2.3A; Stream Channel Attributes, display attributes and forms based on current conditions (recent air photo record) for the channel network.
- Processes, sensitivity and significant associations (sediment and LWD) are included with channel geomorphic unit descriptions.
- Trend analysis is included in Section IV.

3) What are the natural and human causes of change between historical channel and current conditions?

- Refer to the trend analysis in Section IV.
- Trend of channel width changes are shown in Figure 2.3.1. This data is based on a time series aerial photograph evaluation of 8 mainstem channel segments. Figure 2.3.1 appears to indicate two trend patterns, differing between the lower watershed and mid to upper watershed. Widening is believed to be related to increases in coarse sediment storage in channel and bar areas.

  The lower watershed shows a channel width peak in the earliest photo year, the timing of which is consistent with the disturbance following the intense pre-1939 fires (and possibly associated timber harvest). Narrowest widths are consistent in the 60's and 70's with a trend towards increasing width in the 80's and 90's. This latter trend is similar to trends seen in the upper segments, upstream of roading, development or timber harvest (wilderness and national park). Therefore, the current trend towards widening in the lower watershed may be the result of natural variability. Considering the mass wasting history (Erosion Module, 2.4), particularly in Murhut Creek, an alternate explanation could be related to cumulative effects and lagged 20 to 30 years. At any rate the peak width is in the earliest photo years and temporally associated with peak losses in vegetation, particularly riparian vegetation).

The segments evaluated in the mid watershed sections are upstream or the fire effects noted in the lower watershed areas. Changes here are much more variable, and do note show the same peak widths in the earliest photo years, supporting the idea that peak widths downstream are related to vegetative conditions following extensive fire (and timber harvest?). Width increases and the frequency of groups of small peak flows (partial peaks) show a similar timing pattern, however there is little relation to peak flow occurrence.

Note that the questions from the WA DNR watershed analysis channel module are also addressed or partially addressed by the above questions:

- DNR Q1) What is the spatial distribution of channel response types? (#1 above)
- DNR Q2) Is there evidence of channel change from historic conditions? (#2 above)
- DNR Q3) What do existing channel conditions indicate about past and present geomorphic processes? (#' 3)
- DNR Q4) What are the likely responses of channel reaches to potential changes in input factors? (not covered per se, but inferred through channel classification, identification of response reaches, description of geomorphic types and documented channel disturbance (Table 2.3.4))
- DNR Q5) What are the dominant habitat forming processes in different parts of the channel network? (partially covered under #1)

II Methods

The channel network was divided into segments using the criteria established in DNR Standard Methodology for Watershed Analysis, Version 3.0. Segments are classified using combinations of gradient and confinement.

The primary sediment processing function; source, transport, or response can be evaluated from gradient (Montgomery and Buffington 1993; Washington Forest Practices Board, Standard Methodology for Conducting Watershed Analysis, Ver 3.0). This information is compiled in Table 2.3A, stream channel attributes, and is displayed on Map 2.3A, Source, Transport and Response Reaches.

Channel segments are lumped into geomorphic units, which indicate significant conditions, processes, character, and response or sensitivity. These units are defined later in this report, and are shown on Map 2.3B; Channel Geomorphic Units.

Channel disturbance was evaluated in 5 areas *(identified in sub-basin discussions)* using aerial photographs. Photo years ranged from 1939 to *1993*. Channel segments were selected based on size (good visibility on aerial photographs), expected sensitivity to disturbance (response reaches), location within the watershed with respect to management history, or obvious indicators of disturbance (I.E. debris flow impacts). Five areas were selected: 1) the lower mainstem (segments 3-6a), 2) mainstem below Road 2510, 3) the mainstem between Murhut and Cliff Creeks (segment 16), the mainstem just above the national park boundary (segments 22 and 23), and 5) a short response reach in Murhut Creek (segment B4).

This analysis was conducted from the office using maps and aerial photographs. One field day was scheduled following synthesis in order to validate some assumptions and view some areas where questions were generated during synthesis. Sites visited included Murhut Creek, channel segments B1a, B10 and B11, and areas adjacent to Mainstem segments 10 through the bottom of segment 14. These sites were selected in order to visit areas where roads and/or adjacent hillslope processes were believed to be affecting stream channel conditions, as well as to validate geomorphic unit and or active process assumptions.

III. Watershed - Area Characterization

A. Current Conditions

Stream Channel Attributes

Table 2.3A displays channel attributes for each stream segment. Because of it's length, Table 2.3A is located within Appendix 2.3A. 317 channel segments were defined and are include in Table 2.3A and Map 2.3 Each attribute is defined in the narrative that follows.

Segments: Gradient Class and Confinement

Segments are defined primarily on the basis gradient and confinement as well as at locations of significant tributary inflows. This is constant with the methodology defined in the Washington DNR watershed analysis process. Channel segments are shown on Map 2.3A. The gradient is specified by gradient classes 1 through 6. The gradient class uses the following slope ranges: 1 = 0 to 1%, 2 = 1 to 2%, 3 = 2 to 4%, 4 = 4 to 8%, 5 = 8 to 20%, and 6 = 20% +.

Confinement is defined as follows:

- C = Confined, valley width (vw) < 2 times the channel width (cw)
- MC = Moderately confined, vw = 2 to 4 times the cw
- U = Unconfined, vw > 4 times cw

Geologic Formation (Geol)

The symbols given in Table 2.3A are from the Geologic Map of the Olympic Peninsula, Washington (Tabor and Cady, 1978). In most instances these units relate directly to the geomorphic units (geomorph) defined below. Differences occur where the majority of the surrounding terrain is one geologic unit, but the area directly adjacent to the channel is another. Examples include alluvial deposits or narrow floodplains developed within glacial deposits (Segments 22 and 23), channels that have downcut through glacial deposits to the underlying bedrock (Segment 10), and channels adjacent to deposits of limited extent such as fans, landslides, etc, (Segments 24, F11, etc.).

Source, Transport, and Response Reaches (Response Type)

Source, transport, and response reaches are listed under response type in Table 2.3A. They represent one way of looking at how a stream or stream channel processes inputs, for example sediment. Typically each stream segment performs all of these functions (source, transport and response), however, one process or function may/ will dominate. Which function is dominant is controlled primarily by gradient, but confinement also limits or controls the type and amount of response or adjustment that occurs.

Source reaches (> 20% gradient) are often the source areas and local pathways for mass wasting inputs and often provide the clearest links to hillslope processes (I.E. erosion and mass wasting). These channels also serve to store colluvial materials that can be entrained with mass wasting inputs from upstream and therefore can greatly influence the magnitude of impact from such processes. These are typically at the head of channel networks. They do not include the steep (>20%) reaches at the lower end of some of the larger tributaries which are expected to function more like transport reaches. Transport reaches (3-20% gradient) are steep enough that they readily transport disturbances or inputs through the routing network. It will be assumed here that in a general sense disturbances tend to be short lived and these reaches tend to be rather resilient (especially steep transport reaches). Response reaches (<3% gradient) typically perform storage functions. Their form and attributes are typically or commonly controlled by coarse sediment storage, riparian condition, and stream flow (energy) characteristics. These are often alluvial geomorphic types.

Map 2.3A shows the relative distribution of Source, Transport, and Response Reaches for the analysis area. These can be significant elements for prioritizing or determining restoration opportunities. Sensitivity to change or response to changes in input variables (sediment, wood, and water/energy),and degree of connection to source or activity (direct, indirect, cumulative, etc.) can be inferred from such a characterization.

Channel Geomorphology (Geomorph)

Channel segments are lumped into geomorphic types in an attempt to provide a framework for characterizing similar functions, processes, and sensitivities. These are briefly described under the accompanying geomorphic unit descriptions. Table 2.3A lists all segments and indicates the geomorphic designation for each. Table 2.3B provides a brief description for each one, a more detailed description of each geomorphic units is included in Appendix 2.3B. Note that the geomorphic types in Table 2.3B are organized by larger groups: alluvial, glacial, etc. The distribution of these larger groups are shown on Map 2.3B, Channel Geomorphic Units.

Table 2.3.2B

Alluvial Channel Types

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
A1	Alluvial	Qa, Qo	M, T	R (response)	As for all alluvial types below: morphology determined by stored coarse sediment. Moble and deformable bed and banks. Valley width and developed floodplain or terrace limits connection to hillslopes
A2	Shifting Alluvial	Qa, Qo	M, T	R	Lateral channel shifts noted in the photo record
A3	Constrained or Entrenched Alluvial	Qo	M, T	R	Lateral constraint by terrace, floodplain, etc limits lateral channel shifts
A4	Trib on Mainstem Alluvial	Qo	T	R	Tributary stream on mainstem (or trunk) floodplain or terrace. Mainstem conditions exert strong influence.

Glacial Channel Types

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
G1	Glacial U-Shaped Tributaries	Qo,Qc , Tcb etc	T	T (transport)	Channels in u shaped valleys. Concave profile limits connection to hillslopes. Extent of glacial deposits variable, as is sediment production from valley floor deposits
G5	Channels in Glacial Deposits, Undifferentiated	Qc, Qo	M/T	R/T	Channels often incised into glacial deposits. Generally confined and directly connected to hillslopes, hillslope length is limited to lower valley slopes. Sediment production from channel adjacent glacial deposits can be significant. Shallow debris slides and raw banks can be common.

Bedrock Controlled Channels

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
Crescent Formation Basalts and Breccias					
C1	Incised Canyons	Tcb, Tcbb	M	T, R	Steep walled canyons of low to moderate gradient. Bed and banks non deformable. Sediment production is expected to be low, mainly rockfall blocks and boulders from durable bedrock walls
C2	Fluvial Mountain Channel (V-Shaped)	Tcb, Tcbb	M, T	T	Bedrock exerts strong influence on bed and banks. Steep narrow valleys provide direct connection to hillslopes. Hillslope channels (H2) are an important source of mass wasting to these channel types. Bedrock material strength is generally high and clasts have high durability
C2b	Steep Fluvial Mountain Channel	Tcb, Tcbb	T	T, S	Steep channels (generally > 20%), similar to C2 above. Differs from H2 in well defined valley, and larger, perennial streams. Often represent hanging valley segments. Typically 3rd order.
C5	Bedrock Controlled, Undifferentiated	Tcb, Tcbb	T	T, S	Specific type not differentiated. Most are expected to be like C2 designated channels.

Sedimentary Bedrock Controlled Channels

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
Un-differentiated Sedimentary Rocks (several geologic formations lumped together)					
S2	Bedrock Controlled, Fluvial Mountain Channel (V-Shaped)	Tcs	T	T	Bedrock believed to exert strong influence on bed and banks. Steep narrow valleys provide direct connection to hillslopes.. Bedrock quality and clast durability unknown
S2b	Bedrock Controlled, Un-differentiated	Tcs	T	T	Steep channels (generally > 20%), similar to S2 above. Differs from H2 in well defined valley, and larger, perennial streams. Often represent hanging valley segments. Typically 3rd order.
S5	Bedrock Controlled, Un-differentiated	Tcs	T	T	Not differentiated to specific type, see notes for S2 above.

Headwater and Hillslope Channels

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
H1	Headwater Channels	Tcb, Tcbb, Tnm, Tlct	T	S (source)	Generally steep and small 1st and 2nd order channels with converging networks. Join downstream channels at low intersection angles.
H2	Hillslope Channels	Tcb, Tcbb, Tnm, Tlct	T	S	Steep 1st and 2nd order source channels, generally colluvial storage, mass wasting source channels. Join trunk stream at high intersection angles favoring debris flow deposition & temporary blockages.
H3	Cirque Channels	Tcb, Tcbb, Tnm, Tlct	T, M	S,T	Variable profile, often stairstep including cirque headwall, cirque basin and hanging valley sections. This profile may exert strong influence on sediment routing

Toe Slope Deposits - Active Slopes and Valley Bottom Deposition

Unit*	Description	Geologic Formation	Mainstem/ Tributary	Primary Sediment Function	Notable Characteristics
F1	Constrained by Fans		M, T	T (R)	Restricts lateral position of channel. Provides sediment source for bank or channel edge erosion. Fans appear to be connected to hillslope mass wasting, but currently may buffer channels (mainstem) from additional hillslope inputs
LS1	Constrained by Landslides	Qls, Qc, Tcbb	T	T (S)	lateral channel position may be controlled by deep seated landslide movements. Slope movements may control channel complexity (force pools, falls, etc.) Slope movement rate may be very slope and periodic. May behave more like source channels, sediment production expected high.
TS1	Constrained by Toe Slope Deposits - undifferentiated	Tcb, Tcbb	T	T (S)	Deposition of material at toe of slope and channel edge provides controls on channel position and instream structure as well as sediment source. Material source is undifferentiated and may be glacial, colluvial, or mass wasting etc.
Other - Active slopes					
UIG	Inner Gorge; Un-differentiated	Qc, Tcbb	T	T (S)	Expected to be significant sources of mass wasting inputs (sediment, wood, etc). Connection to adjacent hillslopes is high. Lateral channel erosion may initiate or reactivate slope instability. Hillslope materials may be weathered bedrock, slide debris or glacial.

*In all cases the number 5 in the unit name indicates an undifferentiated type within a specified geology

Mainstem Vs Tributary Units

Many tributary geomorphic units have a comparable mainstem geomorphic unit. They differ primarily in basin area (discharge). This in turn affects valley size, (especially affects of and extent of glaciation), channel size, and sediment discharge. Valley size and shape greatly influence the connection between the channel and hillslope processes, and therefore primary sediment sources. Channel size influences the degree to which certain habitat forming elements are effective (for example large wood (LWD) as a stabilizing element or pool forming element).

Primary sediment function is the same as the source (s), transport (t) and response (r) reaches displayed on Map 2.3A, and discussed in the text under stream channel attributes.

IV Trends

Channel disturbance and Trends

Trends and disturbance were evaluated using air photo examination of specific (response) reaches. Reaches were selected using basically three considerations: 1) response reaches, those low gradient reaches expected to exhibit visible change, 2) channel size, those reaches large enough (wide enough or exposed enough) so that features are visible on aerial photography, 3) Location in the watershed, representative of certain conditions or locations. Photography (and scale) used included 1939 (1:30,000), 1962 (1:12,000), 1968/69 (1:15,840), 1973 (1:15,840), 1982 (1:12,000), and 1993 (1:12,000). In addition 1951 (1:15,840) photos were used for upper watershed areas (channel segments 22-24), and 1996 (1:12,000) were examined for channel segment 11. In addition tracings were made of these segments and plotted to a common scale using an Auto-Cad drafting program. These tracings could then be overlain in order to examine width (exposed bar area) and position (lateral shifting and sinuosity) changes. This method was used to reduce apparent changes due to change of photo scale, as well as to allow for quantifiable measurements of channel parameters (width, length, bar size, and position shifts).

Channel segments examined for trends and disturbance are shown in Table 2.3C.

Table 2.3C

Location	Subwatershed Area	Area and Conditions Represented
Segments 3-6	Lower Duckabush - Bottom	- Lower mainstem, cumulative changes for watershed throughout multiple land ownerships and land management conditions - Alluvial within relatively wide glacial deposits buffers mainstem from hillslopes
Segments 11-12	Lower Duckabush - Upper	- First mainstem response reach below Murhut Creek. USFS forest management adjacent and upstream, 90% of watershed upstream is wilderness and National Park. - Similar morphology or conditions as Segments 3-6. Just upstream valley bottom deposits narrow and hillslopes are more directly connected to mainstem
Segment 16	Mainstem, Murhut to Cliff Creeks	- First response reach upstream of Murhut Creek. Currently w/in Brothers wilderness. Timber harvest (railroad) through riparian and valley bottom at this locations prior to 1939, no timber management since. Furthest upstream managed reach, no roads. Wilderness and National Park only upstream. - Last section of wide valley bottom (alluvial and glacial), comparatively narrow upstream.
Segments 22-24	Mid Duckabush, Mainstem	- Wilderness and National Park adjacent and upstream, no timber harvest or roading ever here or upstream. Represents natural range and reference conditions. - Above the area of recent large fires. - Geomorphology or character different than downstream. Relatively narrow valley (channel well connected to hillslopes) Alpine and glacial character, debris avalanche paths reaching mainstem are common. Natural sediment production may be higher than downstream.

It should be noted that none of the tributary channels were large enough to get a good view of channel conditions using this methodology.

Factors potentially influencing channel changes

- Fire History
  1929 Interrorem Fire (see 2.8 Vegetation Module)
- Flood history:
  Duckabush gage records, Peak discharge approx. Q20 and greater (from figure 2.3E)
  1950 (Q40), 1980 (Q20)
  Skokomish and Westside (Queets) gages include extreme flows in 1934 and/or 1935 (Predate Duckadush records)
  Partial peak discharge (multiple floods/year > Qx) - grouped. (from figure 2.3H)
  1940-1942 (12 flows > Q1+), 1967-1968 (9 flows >Q1+), 1980-1984 (27 flows >Q1+)
- Land use
  Railroad logging: pre 1939 photos
  Timber management: Pre 1939 much of the lower Duckabush sub-basin is harvested or burnt.
  Early 1960's entry into Murhut Creek (only significant area of mid Duckabush entered)
  No timber management or roads upstream of the confluence of Murhut Creek and the mainstem Duckabush River.
  Powerline Road: Just predates 1962 photos
  Lower valley land use

Table 2.3d shows apparent change in width for all response reaches and photo years examined.

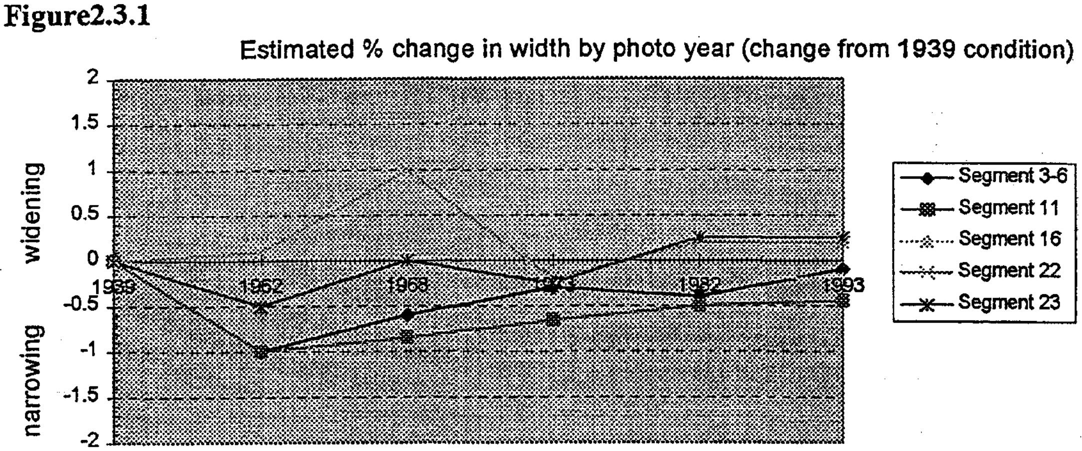
Table 2.3d Apparent Change in Channel Width by Photo Year

	Estimated % change in channel width as compared to 1939 channel width				
Photo Year	**Segment 3-6**	**Segment 11**	**Segment 16**	**Segment 22**	**Segment 23**
1939	0	0	0	0	0
1951				0.1	-0.5
1962	-1.0	-1.0	-0.2		
1968			-0.2	1.0	0
1973	-0.3	-0.7	-0.2	-0.2	-0.25
1982	-0.4	-0.5	-0.2	0.2	0.25
1993	-0.1	-0.4	-0.2	0.2	0.25
1996		-0.4			

* a value of 1.0=100% change, or a 2 fold increase (+) or decrease (-) in channel width compared to 1939

The information from Table 2.3d is displayed in Figure 2.3.1 below.

Figure2.3.1



Several trends are evident on Figure 2.3.1 and are discussed briefly below:

- Channel segments in Wilderness and Olympic National Park (Segments 22 and 23, upstream of recent large fires, roading, or timber management) seem to show the most variable pattern of width changes, with increases and decreases over 1939 conditions. These are also the segments with the narrowest valley width (highest connection to hillslope), most active hillslopes (highest number of debris avalanche deposits reaching the channel), and <u>largest areas of hydrologic immaturity</u>; all potentially significant elements in producing sediment and wood.
- 3 of the 5 segments (all below the Park/ wilderness boundary) are widest in 1939. All are within the area affected by the large fire(s). All are also within areas of relatively wide valley bottom width and varying land use (most notably timber management).
- 4 of the 5 Segments are at their narrowest in 1962.
- If wide channel conditions of 1939 are excluded, 4 of the 5 areas examined are currently at their widest.
- The largest increases in channel widths are in all cases associated with recent and relatively large shifts (meander cut-offs, avulsions). Examples are recent shifts evident in 1939 in Segments 5/6 and 11, and in 1968 in Segments 22 and 23

Note that 1939 photography clearly shows the conditions following one or more large fires and railroad logging. Much of the valley bottom and riparian area around channel segment 8, 11, 12, and 16 had few trees remaining at that time. This corresponds well with periods of peak channel widths evident in the lower watershed.

Some additional more detailed discussion will take place under sub-basin heading that follow.

Lower Duckabush **(Mainstem channel segments 1-14, tributary segments A1-A75)**

Disturbance - Trends

Channel trends and disturbance evaluated at Segments 3-6a, and 11. These segments showed the greatest width changes in managed portion of the watershed (below wilderness and National Park boundary)

Segments 3-6 (lower):

- Disturbance indicators include changes in width, changes in sinuosity (straightening), and lateral shifts (meander cutoffs, avulsion)
- Dramatic channel straightening occurred around, just prior to 1939 in Segments 3-6. The high width and straight channel conditions shown in the 1939 photos are considered the peak disturbance conditions for the period of (record). These types of large scale changes are often attributed to flood disturbance mechanisms
- Trend of increasing width from 1962-1993 parallels point bar development and building of sinuosity. Though increases in width are expected to reflect increases in coarse sediment storage and are often considered a negative trends for aquatic habitat, the resulting increase in sinuosity may not be indicative of deteriorating in-stream habitat.

Segment 11 (upper)

- Downstream migration of meander bends in Segment 11 (200-300 feet through photo record) indicate very active channel, possible lateral instability.
- Meander bend migration and dramatic gullying of terrace from road drainage may be contributing to instability (widening and shifting) in Segment 11. Shallow, riffle forms were noted on outside of bend where dramatic gullying was noted in the field (a location where one would expect pool development).

Land Use

Most rural development along the river is downstream of this area. Channel controls such as straightening and bank hardening are not in evidence above Segment 2.

Primary Sediment Sources

(pertains primarily to coarse sediment responsible for morphologic changes notable in air photos)

- Throughflow of sediment from upstream and redistribution of alluvial sediment.
- Undercutting and erosion of high banks of glacial deposits. In particular where the channel (often outside meander bends) are flowing at the edge of the alluvial flats (flood plains and/or low terrace)
- Small tributary streams flowing over glacial terrace edge are subject to gully erosion and shallow (debris slide) mass wasting. Otherwise wide glacial terrace in many places buffers upper hillslopes from the mainstem channel.

Interpretation/ Synthesis

- Note relationship between upper watershed reference condition (segments 22-24) and current condition. I.E. Nearing historic peak.
- Note width increase with development of sinuosity and resulting point bar development.
- High widths and evidence of lateral instability (shifting) throughout the lower watershed in 1939 coincide with the affects of the 1929 Interrorem fire, fire salvage and or railroad logging, and the generally poor riparian conditions in evidence in the 1939 air photos.

Range of Variability *(1939-1993)*

- Difficult to determine a natural range as all photos are post railroad logging. In 1939 photos riparian and/or valley bottom vegetation cover seems to be at a historic minimum. How much of this is natural, how much is human caused fire, and how much is railroad or salvaged logged is undetermined. This period does represent the historic high in channel width and may reflect the channel conditions following major fire events.

- Historic channel width changes have shown about a 2 fold change, with maximums around 1939 (see comments above), and minimums around 1962. 1962 conditions correlate fairly well with a period lacking significant extreme stream flow (refer to both annual and partial peak flow data from table 2.3E and table 2.3H.
- Sinuosity patterns in the lower part of this subwatershed have varied from fairly straight (S<1.1) around 1939 to a maximum of about 1.2 in 1993. The 1993 condition (assume current condition) is expected to be about at a maximum because sinuosity is limited by the relatively narrow alluvial plain entrenched within the glacial terrace occupying much of the valley bottom.

Murhut and Cliff Creeks (Mainstem channel segments 15-21, tributary segments B1-B13, C1-C30, D1-D20)

Channel trends and disturbance evaluated at Segment 16. Trends or disturbance noted in segment 11 (upper portion of lower sub-basin) may be related to changes in this sub-basin.

Disturbance - Trends

- Channel width in 1939 photos is the widest in the photo record, though change is small. This is the only time in which point bar development is really noticeable.
- Width has decreased by 1962, or rather point bars (stored sediment) are smaller or absent. No significant change was noticed in subsequent photo years (1969, 1973, 1982, 1993)
- No changes in lateral channel location, pattern, or sinuosity were noted throughout the photo record.
- Debris accumulations noted in Murhut Creek, Channel Segment B1b in 1982 from road fill/ inner gorge failures (Erosion Module)

Land use

- 1939 photos show the entire valley bottom area and portions of the adjacent hillslopes lacking any significant forest cover, right to the channel edge. The 1929 Interrorem fire (D.Peters, personal communication; Vegetation module) and railroad logging (fire salvage ?) prior to 1939 are clearly evident.
- Following 1939 no further timber harvest has occurred in the area. Other than the railroad , no vehicle transportation corridors (roads) have been established. No timber harvest or roading has ever occurred in the watershed upstream of this area.

Sensitivity

- Not particularly sensitive to disturbance, at least at the scale of air photo examination. Reaches examined upstream and downstream show much more variability both with respect to width and position changes. Much of this (perceived insensitivity) may be the result of the channel's inability to adjust laterally due to confinement (which limits sediment storage, bar formations).

Primary Sediment Sources

- Mainstem: Terrace edge erosion and gullying (from skid roads and small terrace tributaries) in alluvial and/or glacial-alluvial (outwash) terrace deposits adjacent to channel segment 16. Through flow from upstream sources, primarily debris avalanche deposits from valley walls, and streambank erosion and undercutting of debris avalanche and fan deposits on mainstem valley floor.
- Tributaries: Debris flows and slides (shallow rapid mass wasting) from heads of steep first order tributaries; debris slides from inner gorge slopes (see Map 2.3B)

Interpretation/ Synthesis

- Lack of any change in channel width, position, or form is probably more an indicator of confining mechanisms than the lack of conditions that might cause these changes in more typical (unconfined) alluvial reaches.
- The effects of the 1929 Interrorem fire and subsequent railroad logging had the greatest effect on channel conditions during the period of photo record.

- The loss or removal of valley bottom and riparian vegetation during the period prior to 1939 probably had the greatest effect on channel condition in recent time. Estimated effects are high bank erosion rates and a lack of in channel LWD. Current condition is unknown, but expectation is lower sediment production and continued low LWD occurrence.
- There is no good correlation between flood history and disturbance in the mainstem (Segment 16)
- Channel disturbance in tributaries, particularly Murhut Creek associated with mass wasting from road fill and landing failures. Trend is recovering.

Range of Variability *(1939-1993)*

- Variability is low. Though Segment 16 is a response reach by gradient, lateral constraint may limit the amount of disturbance visible on aerial photography. This reach has an A3, Constrained alluvial, geomorphology.
- Alternatively, lack of significant disturbance mechanisms through most of the photo record, i.e. No roading or timber management, no large fires, and only one flood approaching Q20 or greater (1980) in all photo years after 1939.
- Assume 1939 conditions represent peak disturbance conditions for recent history. Entire valley bottom burned and Railroad logged along with much of the adjacent hillslopes. Disturbance = good correlation between fire/ timber management and channel disturbance. Poor correlation to flood history.

Mid Duckabush **(Mainstem channel segments 22-32, tributary segments E1-37, F1-F21)**

Channel trends and disturbance evaluated at Segments 22 through lower 24

Disturbance - Trends

- Some large width changes (up to an estimated 1.8x) have occurred within this reach, most notably between 1951-1968, and 1973-1982.
- The largest width change was associated with significant lateral position changes of the channel between 1951 and 1968
- Significant lateral shifts or channel adjustments are evident in 1968 and 1993 photography
- The trend in width through the photo record seems to be towards overall widening, with significant variability (particularly true for upper reaches, 23 and 24, trend less clear for the short segment 22). Refer to Figure 2.3.1

Land Use

- Managed as wilderness and National Park throughout. No history of timber harvest or roading. Should represent reference condition for similar geomorphology and drainage size.

Sensitivity

- Sensitivity is believed high. Channel widths in this area exhibit more variability than any other areas that were examined.
- Significant lateral shifts have taken place over the period of photo record
- Streambank instability noted (raw banks) where channels flow against valley bottom (debris avalanche? Fan deposits)
- Pattern shift from pool-riffle to braided has occurred associated with channel widening. Possibly associated with changes in large woody debris accumulations

Primary Sediment Sources

- Throughflow of sediment from upstream
- Low terrace edge through segment 16
- Mass wasting in steep first and second order channels adjacent to mainstem (along segment 16 these are buffered by wide terrace)
- Mass wasting in steep first and second order channels in Murhut and Cliff Creeks. The effect of these sources is difficult to determine because they flow into the mainstem at relatively steep, confined bedrock transport reaches.

Interpretation/ Synthesis

- The pattern and timing channel widths is somewhat consistent with the timing of concentrations of partial peak flows
- The pattern and timing of channel width and position changes cannot be explained by the pattern of peak flows at the Duckabush gaging station.
- Variability or frequency of channel changes might be related to the combination of narrow valley bottom (hillslopes directly connected to mainstem channel) and the large number of mass wasting features (debris avalanches/ debris avalanche deposits) that reach the channel at this location and upstream. (Indicating a high natural supply of sediment from hillslopes and streambank locations)
- Note relationship between high channel width, braiding, lateral shifting and LWD accumulations

Range of Variability *(1939-1993)*

- High variability of channel width and position throughout these response reaches. Photo record shows 2 fold increases (

Crazy Creek (Segments G1-G21)

Channel trends and disturbance not evaluated

- No information gathered
- photo coverage for 1939 (1:30,000) only on Forest
- Reference conditions for similar geomorphology and size (5671 acres, 3rd order drainage)
- Entirely within National Park Boundary
- Geomorphology and geology includes Sedimentary bedrock, glaciated terrane and alpine conditions
- 2 response reaches (G2b and G2d)

Upper Duckabush (mainstem channel segments 33-42, tributary segments H1-H27)
Duckabush Headwaters (mainstem channel segments 42-50, tributaries J1-J11)

Channel trends and disturbance not evaluated

- Conditions as for Crazy Creek
- 4th order channel at mouth downstream end of Upper Duckabush sub-basin (7204 ac)
- 3rd order channel at the lower end of Duckabush Headwaters sub-basin (3049 ac)

2.4 Erosion Module

I Introduction

This module focused efforts on identifying and characterizing mass wasting and mass wasting processes. Surface erosion is expected to account for a much smaller amount of the overall sediment production, *or at least in the change in sediment production (Reference: Cited mass wasting vs surface erosion contributions)*, and was given a much lower emphasis. *(Landform associations, vegetative conditions and road density were used as indicators of surface erosion potential/hazard/sensitivity/)*

The inventory data collected for this assessment was completed only for the lower half of the watershed. This amounts to essentially to the lower 2 of 4 USGS 7.5 minute Quad maps. The watershed above this point is within the Olympic National Park boundary and has never been subject to timber management or road construction. While the Olympic National Forest has limited Air photo coverage, the Olympic National Park has coverage of this area.

II Key Questions

The key or core questions used in this analysis are taken directly from the document Ecosystem Analysis at the Watershed Scale, Federal Guide for Watershed Analysis, Version 2.2. These are listed below.

1. What erosion processes are dominant within the watershed? Where have they occurred or are they likely to occur?

- Shallow rapid mass wasting from steep (>70%) first and 2nd order drainages and drainage headwaters accounts for the greatest number of mass wasting features inventoried. A slope morphology map, Map 2.4A (a computer generated slope and slope shape model) reflects high hazard areas for this condition. This model was used to create the portion of the riparian reserve map based on unstable or potentially unstable slopes. See Map 2.7A, Proposed Riparian Reserves.
- Inner gorge areas accounted for a high percentage of mass wasting and erosion features (probably the highest concentration when considering the relatively small area involved). These areas have been included with the areas identified as high hazard for mass wasting. Shallow rapid, deep seated, and surface erosion are common. These landforms are concentrated in the lower part of the watershed particularly associated with areas of glacial deposits.
- Steep (>65%) glacial terrace edges, especially where adjacent to mainstem channel (flowing at base of slope), or where tributary streams flow over the terrace edge. Shallow slides (debris slides), stream under-cutting and gullying are typical processes. Severe gullying (catastrophic incision) was noted where water form road runoff was concentrated. Road drainage is a concern in these areas and should be further evaluated.
- In the upper watershed (upper 4 sub-basins), outside of the area of mass wasting inventory, stream undercutting of fan deposits is believed to be an important source of sediment.

2. What are the current conditions and trends of the dominant erosion processes prevalent within the watershed?

- Map 2.4B, WIN Inventory displays the current condition of inventoried erosion features for the area from the Olympic National Forest boundary to the Olympic National Park boundary.
- The mass wasting inventory data sheets are included in Appendix 2.4A, the photo year for active features is included in the table. A map displaying these features has been drafted but was not finalized and included in this document. These overlays exist at the Olympic National Forest Headquarters in Olympia.

Trends for the bulk of the managed portion of the watershed show the largest number of inventoried mass wasting features in 1939. This is consistent with frequent high intensity fires prior to 1939. Differentiating between early timber harvest, fires, slash burns, and salvage operations was not possible. However, conditions which resulted in loss of vegetation and presumably root strength are associated. Murhut Creek has a somewhat different trend. This area did not have the extensive pre-1939 fire history of the lower watershed and mainstem to Cliff Creek. The trend in inventoried mass wasting generally followings the pattern of entry (roading) and timber harvest in the basin. Peak activity occurred there in the 1960's and 70's and currently seems to be on declining trend. This too follows a declining trend in timber harvest and road construction.

3. What are the natural and human causes of changes between historical and current erosion processes in the watershed? What are the influences and relationships between erosion processes and other ecosystem processes?

- As pointed out in the trend discussion above, both natural and human causes that result vegetation and subsequently root-strength loss are a key factors associated with changes in mass wasting occurrence. Fire history (with or without timber harvest) is associated with the mass wasting frequency in early photo years. Since 1939 little evidence of fire related mass wasting was noted. More recently timber management in the form of road construction, clear-cut harvest and landing construction on steep (>70%) slopes are associated with increases in mass wasting occurrence. This is primarily true for the Murhut Creek area. Here root strength loss on inner gorge slopes and road drainage and fill/ sidecast construction on inner gorge and dissected midslope areas are primary causal mechanisms.
- Concentrated drainage (known occurrences involve road drainage) has resulted in dramatic gullying where water flows on slopes composed of granular, unconsolidated glacial deposits. Current examples include the powerline road (steep graded road on main valley slopes), and a local logging road downstream of the 2510 road bridge over the Duckabush (road drainage flowing over glacial terrace edge). In the latter case a seemingly small concentration of water draining from a small overgrown road on gentle slopes near the terrace edge has created a rather dramatic gully (estimated at 30 feet deep and 90 feet long in February 1998). This site provides an example of the potential for change and the sensitivity of this landform (glacial terrace edge).

III Methods

Mass Wasting

A mass wasting inventory was conducted as the primary method for evaluating erosion processes in the watershed. This inventory consisted of an air photo inventory conducted using the following photo series (and scale): 1939 (1:30,000), 1962 (1:12,000), 1973 (1:15,840), 1982 (1:12,000), and 1993 (1:12,000). In some cases 1968 photos (1:15,840) were used where gaps existed in 1962 photo availability. The air photo inventory used is essentially the same as the mass wasting assessment process in the Standard Methodology for Conducting Watershed Analysis, Version 3.0; Washington State Forest Practices Board (1995). The definitions used are consistent with that document. A systematic field reconnaissance of selected mass wasting features or terrains was not attempted.

Surface Erosion

Assessment of surface erosion primarily relies on observations made while conducting the mass wasting inventory described above. Such observations provide a framework to link the various erosion processes to certain landforms or geomorphic types. Review of low elevation aerial video of the channel was conducted using large format video taken of the channel in 1993 and available at the Forest Headquarters office of the Olympic National Forest.

A field and air photo based Watershed Improvements Needs Inventory (WIN) was conduced in the area. The location map of WIN sites (erosion and mass wasting features) is included, Map 2.4B. In addition road density for the Murhut Creek sub-basin is included as an indicator of potential surface erosion related to roads. This information was not available for the lower watershed (the upper watershed is unroaded).

IV Overview - Summary -

Mass Wasting Summary- Watershed.

A summary of the inventory data for the watershed is complied here. The Inventory data sheets are included in Appendix 2.4A. In the next section this information will be compiled by sub-basin and interpreted there. 191 features were identified on air photographs from 1939 to 1993. This information pertains only to the lower two subwatersheds. ***Large scale, natural mass wasting features are common in the sub-basins upstream and are briefly discussed under watershed geomorphology.***

The degree of certainty of inventory information is as follows: 81% are of definite, 15% are probable, and 5% are of questionable occurrence. The questionable features are concentrated in the category of deep seated slope movements.

Erosion features inventoried fall into the following process categories:

Table 2.4A

Erosion Process	Number of features Inventoried	Percent of Total
Shallow rapid mass wasting	158	83%
Deep seated slides and/or slumps	20	10%
Debris Torrent	*	*
Surface erosion	13	7%
Total	191	100%

* Debris torrent features are lumped with shallow rapid mass wasting. Many features initiated in steep first order tributaries moved through and scored these channels, but were not inventoried separately as debris torrents.

Of the above features, 78% were estimated to deliver to stream channels and therefore affect aquatic habitat to some degree. The rest deliver to valley floor or hillslope locations but are not connected to the mainstem channel network.

Land use associations are compiled in Table 2.4B. It should be noted that the occurrence of a number of wildfires prior to 1939 (the earliest air photos) clouds the picture somewhat. These fires over lapped in extent and occur at a time where extensive early logging, in particular railroad logging, was taking place (see Vegetation Module 2.8 for more details). Because of this complex mosaic it was beyond the scope of this assessment to determine whether many of these erosion features (1939 only) are associated with natural wildfire, man-caused fires, post-fire salvage logging, post logging slash burns, or clear-cut harvest within the fire area. These have been categorized as simply fire associated erosion features.

Table 2.4B

Land use association	Number of features Inventoried	Percent of Total
Natural*	59	31%
Fire* (natural or man caused)	67	35%
Clearcut*	9	5%
Logging Landings	4	2%
Roads	52	27%

* As noted in the previous paragraph, there may be considerable overlap in fire area associated erosion features. Relating these to natural conditions or timber harvest was not possible during this analysis. Unfortunately the large number of features involved limits the usefulness of comparing natural versus timber harvest associated erosion.

Geomorphology

Erosion processes vary through the watershed in a fairly systematic way that is characterized here in terms of landform or geomorphology, refer to Table 2.4C below.

Table 2.4C

Landform	Number of features Inventoried	% delivered to streams	Location in watershed
Highly dissected mountain slopes	115	75%	Upper 1/2 of lower sub-basin to headwaters
Inner gorges	39	85%	Concentrated in lower sub-basin and Murhut Creek
Convergent headwater drainage areas (1st and 2nd order)	15	100%	Lower two sub-basins, concentrated north side
Glacial depositional areas*	7	50%	Concentrated in lower, patchy in mid and upper
Low dissected mountain slopes*	10	20%	Lower sub-basin
Cirque headwalls	3	66%	Larger tributaries throughout mid and upper sub-basins
Fan deposits	1	(100%)	Along mainstem and larger tribs upstream of Cliff Cr.
Existing landslides	1		Mapped mainly in lower

Slopes with low frequency and depth of dissections are at least in some cases associated with glacial depositional terrains. There may be overlap between these two types.

Hazard

The information presented in Table 2.4C indicates where on the landscape much of the mass wasting is taking place (again this information pertains only to the lower two subwatersheds). However, It does only a fair job of providing a hazard assessment. Since the entire area was not mapped by geomorphic units, there is no way to integrate frequency or density of failures on a special scale. A somewhat qualitative assessment of hazard follows. Landforms are listed in order of highest expected hazard:

- **Inner Gorges:** High hazard, relatively small area involved, expect a significant number of features missed (most found only when vegetation is sparse or absent as in 1939 photos). Process: Debris slides, and deep seated (slides and slumps), bank erosion.
- **Convergent headwater drainages**: High hazard, relatively small area involved, 100% deliver to streams, usually scour long sections of 1st or 2nd order channel. Process: Debris slides, flows and torrents.
- **Highly dissected hillslopes:** Moderate hazard overall, high within individual dissections. Most failures occur at the head or edges of steep (> 70%) 1st and 2nd order drainages. Evaluating the mountain slopes overall results in a moderate call due to the large amount of area involved (many of the areas out side of dissections contain few mass wasting features). For this landform a terrain module integrating steep slopes and converging topography is used to provide a better picture of high hazard areas, Map 2.4 A. Process: Debris slides, flows and torrents.
- **Fans:** Moderate hazard overall, high along channel edges, low at toe slopes and on terraces away from channel. Generally this unit is under reported, concentrated in upper 1/2 of watershed where detailed inventory was not conducted. Process: Bank erosion and channel edge debris slides.
- **Existing landslides:** Site specific, low to high hazard. Refers to slides (usually shallow rapid) within larger slides and/or slumps. Assumed to be significantly under-reported, most common occurrence expected to be along the toe or headwall of larger features (where they are difficult to see on air photos). Expected high hazard on toe slopes adjacent to streams. Process: Debris slides, bank erosion/ under-cutting.
- **Glacial depositional areas:** Generally low hazard. The exception in steep (>65%) terrace edges where channel is at base of slope, and banks of tributary streams flowing over terrace edge which is high hazard. This latter condition is difficult to see in photo's (under reported) but evident in field and low elevation aerial videos of channel. Process: Debris slides, bank erosion/ under-cutting, gullying (catastrophic incision observed in places, along channel segment 11). Note: Drainage concentration near steep terrace edge is a potentially high hazard condition.

- **Low dissected mountain slopes:** Low to moderated hazard. May be primarily glacial depositional areas on slopes, related to unit above. Most areas are upslope of glacial terraces and do not deliver to channel network connected to mainstem. Process: Gullying, debris slides, bank erosion/ under-cutting, and. Note: Drainage concentration on slopes provides good examples of gullying along powerline road (lower sub-basin).

V Summary by Sub-Basin

Mass wasting inventory data is presented here by sub-basin for the lower two sub-basins only. For the purposes of this assessment sub-basin 2, Murhut-Cliff Creeks, is divided into 2 areas, Mainstem Duckabush, and Murhut Creek (2b) This was done primarily to facilitate interpretation of data especially for managed (timber harvest and roading) vs natural conditions.

Lower Duckabush Sub-Basin (11,160 acres)

95 features were inventoried in this sub-basin.

- **Year of first occurrence:** 59% of failures inventoried in 1939 photos, 30% in 1962, 8% in 1973, 2% in 1982 and 1 % in 1993.
  Interpretation: High numbers of features recorded in 1939 are 4-fold: 1) Most of the naturally occurring failures are recorded in the first photo year examined, 2) young timber stand age and lack of vegetation offers good view of underlying land surface, 3) fire disturbance combined with timber removal are most prevalent during this photo year, and 4) much of the transportation is in place. 1962 represents the first photo year of relatively low elevation, again these numbers may reflect somewhat the ability to see features well. Low numbers in later years are expected to reflect increasing tree growth, especially along riparian areas, terrace edges, and inner gorges.
- **Associated Land Use:** See Table 2.4 D below:

Table 2.4D Land use associations

Land use association	Number of features Inventoried	Percent of Total
Natural*	7	7%
Fire* (natural or man caused)	52	55%
Clearcut*	3	3%
Logging Landings	2	2%
Roads	31	27%

Interpretation: It is unclear whether features recorded here as fire related should really be viewed as timber harvest related or natural. However, it seems that reduction of root strength associated with vegetation loss is a key factor. Failures associated with roads at least in part are probably related to early road construction methods.

Murhut Cliff Creeks Sub-basin (8661.5 acres)

This sub-basin is divided into two areas in order to better reflect difference between natural and managed (timber management) conditions.

Murhut Creek (approx. 1819 acres)

38 features were inventoried in this sub-basin.

- **Year of first occurrence:** 3% of failures (1) inventoried in 1939 photos, 53% in 1962, 24% in 1973, 8% in 1982 and 3% (1) in 1993.
  Interpretation: The timing of mass wasting in the sub-basin reflects the pattern of entry (roading) and timber harvest. In particular roading and clear-cut harvest in the Inner gorge areas, concentrated in 1962. The next most common association is roading and clear-cut harvest of steep midslope areas reflected in 1973 data.
- **Associated Land Use:** See Table 2.4 E below:

Table 2.4E Land use associations

Land use association	Number of features Inventoried	Percent of Total
Natural*	8	21%
Fire* (natural or man caused)	1	3%
Clearcut*	6	16%
Logging Landings	2	5%
Roads	21	55%

Interpretation: The pattern represented in the table above is quite different than the one shown in the lower sub-basin (Table 2.4D). This pattern appears associated with timber management. Taken collectively timber management activities (harvest, roads and landings) account for 76% of the failures inventoried. The road associated pattern is clearly displayed on Map 2.4B (WIN inventory). Over 90% of the features inventoried deliver to stream channels. Care must be taken in relating management vs. natural sediment production however. A recent Oregon Department of Forestry report (Draft) on storm related landslide damage indicated that air photo based landslide inventories significantly under-report landslides in all timber stand ages, and is most severe in mature stands (Dent et.al. 1998). The discrepancy in that study was well in excess of 50% (more than 1/2 of the slides found in field surveys were not located using aerial photos). Nevertheless, it appears that a distinct increase in sediment production is associated with timber management in the basin, but any estimate of the relative increase compared to natural is beyond the scope of this analysis. Mass wasting is concentrated in inner gorge and steep dissected hillslopes.

Surface Erosion

In addition to mass wasting data provided above, this is the only area of the watershed where road density information was available. This information is often used as an indicator of potential for surface erosion, and is primarily associated with fine sediment production. Road density was compiled by decade for the 1960-1990 (see public works module) and is shown in Table 2.4F below.

Table 2.4F Road Density

Decade	Road Density, miles/square mile
1960-1970	2.4
1970-1980	3.7
1980-1990	4.4

A value of 2.4 miles/sq. mile was used by the Olympic National Forest Value Team Analysis (1993) as a threshold value to indicate potential for road related sediment effects. The trend indicated in Table 2.4F shows that the potential for cumulative effects of a chronic nature in this sub-basin.

Mainstem and Cliff Creeks (approx. 6843 acres)

58 features were inventoried in this sub-basin.

- **Year of first occurrence:** 67% of failures inventoried in 1939 photos, 36% in 1962, 8% in 1973, 2% in 1982 and 1 % in 1993.

  Interpretation: The timing pattern reflected above is similar to the pattern found in the lower sub-basin. See interpretation under that sub-basin.

- **Associated Land Use:** See Table 2.4 G below:

  Table 2.4G Land use associations

Land use association	Number of features Inventoried	Percent of Total
Natural*	44	76%
Fire* (natural)	14	24%
Clearcut*	0	NA
Logging Landings	0	NA
Roads	0	NA

Interpretation:. All failures are of natural occurrence and may provide a framework for evaluating frequency and occurrence, i.e. Reference conditions for similar parts of the watersheds. No recent roading or timber management has occurred in the area. Timber harvest and railroad access pre-dates 1939 on the lower slopes and valley bottom up to about the confluence of Cliff Creek. No mass wasting was inventoried associated with these activities, but they occur on generally low mass wasting hazard landforms.

VI Recommendations and Conclusions

Riparian Reserve:

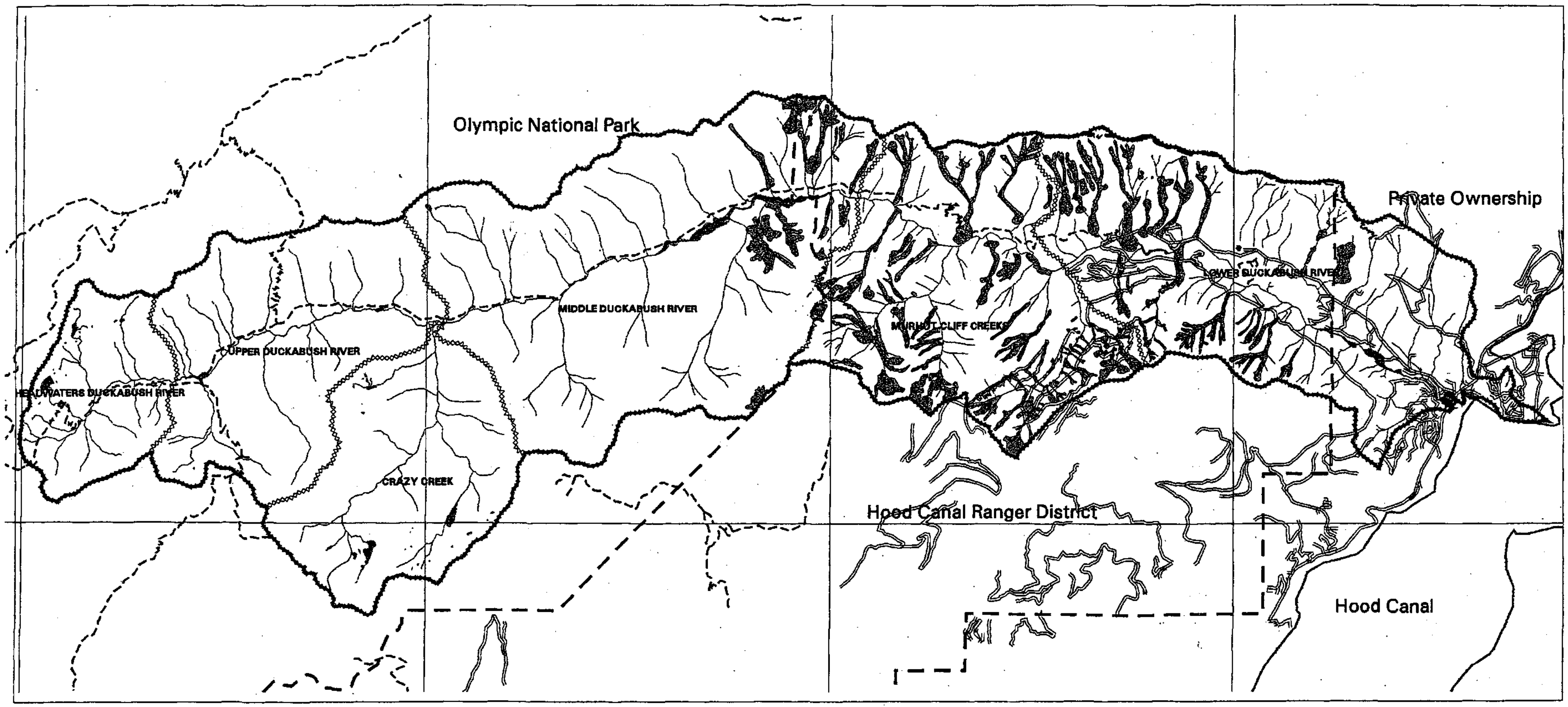
- Include high hazard mass wasting areas defined under geomorphology. This includes Inner gorge areas; steep (>65%) glacial terrace edges; steep converging topography on highly dissected mountain slopes (1st and 2nd order channel edges channel heads, and convergent headwaters). This latter condition is reflected in slope morphology model, Map 2.4A)

Restoration:

- Drainage concentration areas from roads on glacial terrace edge locations, or other areas of glacial deposits.
- Inner gorge road locations especially along Murhut Creek.

Future Work

- Complete mass wasting mapping for watershed
- Map geomorphic units on base map
- Field evaluation of features to develop critical slope, drainage or other key associations.



The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

LEGEND

- Watershed Analysis Area
- Subwatersheds
- Quad Lines
- Hydronet
- Forest Boundary
- Roads
- Trails
- Lakes, Ponds, & Wetlands
- WIN Inventory Sites

Watershed Improvement Needs & Inventory

Map# 2.4B

The Duckabush Watershed Analysis Team

t_win May 21, 1998

2.5 WILDLIFE

INTRODUCTION

Purpose

This module presents an assessment of the wildlife and wildlife habitat found within the analysis area. The analysis area for the wildlife module includes the Duckabush River, and is referred to in the following section as the watershed or analysis area. The objective of the Wildlife Module of watershed analysis is to provide resource managers with specific information necessary to make decisions on how best to manage the resource according to the President's Forest Plan and the Record of Decision (Feb., 1994). Due to limited budget and time constraints, as well as limited data, there are gaps to be filled in by subsequent iterations of this analysis. The following Key Questions have been identified for wildlife in the watershed:

KEY QUESTIONS:

- What are the occurrence and distribution of species of concern that are important in the watershed? The recommended species for the Duckabush Watershed Analysis are as follows (prioritized):

  1. Northern Spotted Owl
  2. Marbled Murrelet
  3. Peregrine Falcon
  4. Roosevelt Elk
  5. Other late seral forest species
  6. Riparian species
  7. Cavity sensitive species including Survey & Manage, State listed, etc. not included above.
  8. Bald Eagle

- What are the distribution and character of their key habitats?
- What are the current habitat conditions and trends for the species of concern and their habitats as identified in above questions?
- What were the historical occurrence and distribution of species of concern and the condition and distribution of their habitats in the watershed?
- What are the natural and human causes of change between historical and current species distribution and habitat quality for species of concern in the watershed?
- What are the influences and relationships of species and their habitats with other ecosystem processes in the watershed?
- What are the present and future management objectives for the wildlife species of concern?
- What are the opportunities within the watershed for restoration, maintenance, protection, alteration, etc. to achieve management objectives for the wildlife resources?
- What are the data gaps, monitoring and research needs applicable to the wildlife resources within or dependent upon the watershed?

Note: The wildlife module analysis proposes to address Core Questions within each identified species of concern listing and not question by question. Also considered were questions in the FY1994-96 Watershed Analysis Guidelines (July 1994) document relating to the Endangered Species Act and other species considerations. These guidelines developed by the Interagency Watershed Analysis Coordination Team include questions on the following species, or group of species: northern spotted owl, bald eagle, amphibians, peregrine falcon, and marbled murrelet.

Background

An ecosystems approach was used to analyze the wildlife habitat values of the watershed. The primary goal of the analysis is to address the conservation of biodiversity and ecological processes within an ecosystems management framework. Of particular concern are those species listed and proposed for listing under the Endangered Species Act, and those on the Record of Decision Survey and Manage list (ROD, Table C-3). The northern spotted owl, marbled murrelet, peregrine falcon, and bald eagle are federally listed as threatened or endangered and will be discussed independently. The gray wolf, an endangered species, historically occurred on the Olympic Peninsula, but has been extirpated. A list of species of concern for listing under the Endangered Species Act, which occur on the Olympic Peninsula, has been provided. Candidate and species of concern fish species will be discussed in the fisheries section. The Record of Decision (ROD) Survey and Manage list includes three species of bats, and ten species of mollusks that may occur in the watershed, which will also be discussed. Amphibians will be addressed as a group. The Roosevelt elk is of high cultural or social concern and will also receive independent discussion. Other wildlife species found in the analysis area will be treated in relation to their habitat orientations.

Recommendations are made for restoration, future data needs, long-term monitoring, interagency coordination and site-level analysis. Target areas for potential wildlife habitat restoration and monitoring activities included issues on forest fragmentation, road-related impacts, coniferous forest stand diversity, deciduous shrub and tree species diversity, within-stand habitat features and selected special habitats.

THREATENED AND ENDANGERED SPECIES

Northern Spotted Owl

General

The northern spotted owl (spotted owl) (*Strix occidentalis caurina*) was federally listed as threatened on June 23, 1990, under the Endangered Species Act, and state listed as threatened, due to declining populations as a result of habitat loss. (USDI, 1990) Critical habitat for the northern spotted owl was designated on January 15, 1992, and included 6.9 million acres within the range of the owl. (USDI, 1992) There has been an estimated 76% loss of suitable habitat on the Olympic Peninsula from historic levels (USDI, 1992b). The draft recovery plan for the spotted owl rated the following threats as severe for the Olympic Peninsula population: low population, isolation, and risk of natural disturbances. The following threats were rated as moderate: declining population, limited habitat, declining habitat, distribution, and predation (USDI, 1992b). The following discussion will look at some of these potential threats at a more local scale. Two important criteria for spotted owl population viability are maintenance of suitable nesting habitat and retention of adequate habitat conditions for dispersal.

On the Olympic Peninsula, surveys from 1992 - 1994 confirmed a minimum of 155 pairs, which has been extrapolated to an estimate of between 282 and 321 pairs on the peninsula (of which 173 pairs are estimated in the Olympic National Park). The nests within the eastern subprovince range in elevation from 375 to 3900 feet, with 95% of 154 nests below 3500 feet. Juvenile survival through their first year is currently estimated at 0.4 for the Olympic Peninsula (range of estimates from 0.24 to 0.61). (Holthausen et al., 1994)

Methods

The following analysis utilized spotted owl survey data, GIS map layers including suitable spotted owl nesting, roosting, and foraging (NRF) habitat, critical habitat designated for the northern spotted owl, ROD land allocations, land ownership, and activity centers. A new suitable habitat layer was recently developed by the forest ecologist in conjunction with the wildlife biologists and was used for this analysis. This new suitable habitat layer combined potential natural vegetation with age classes. The wildlife biologists worked with silviculturists to determine at what age they felt the different potential natural vegetation groups would become suitable habitat, and the forest ecologist developed the resulting suitable habitat layer. The dispersal habitat layer was also generated using potential natural vegetation groups and age class when stands would develop an average diameter at breast height (dbh) >= 11" with a minimum 40 % canopy closure and would provide dispersal habitat. The January 1998 Washington State Department of Fish and Wildlife (WDFW) spotted owl activity center layer was utilized for this analysis.

Population Data

Information specific to the condition of spotted owl populations within the Duckabush Watershed was nearly non-existent prior to the early 1980's. The majority of the survey work has been done since 1987, and has covered most of the large contiguous blocks of habitat within the analysis area on National Forest lands. Surveys were conducted in Spotted Owl Habitat Areas (SOHA's) (USDA, 1988) within and adjacent to the analysis area in 1988-1990 following the regional spotted owl survey protocol. These SOHA's were 2800-3200 acres in size and covered most of the large contiguous blocks of habitat within, and adjacent to, the analysis area. In 1991 SOHA's were replaced by Habitat Conservation Areas (Thomas et al., 1990) which included most of the large contiguous blocks of habitat within and adjacent to the analysis area. A portion of these areas was surveyed by district crews in 1991. About 70% of the suitable habitat within the analysis area is within the Olympic National Park where only minimal surveys have been conducted due to funding and logistic constraints.

The Pacific Northwest Forestry Sciences Laboratory (PNW) has been conducting the majority of surveys for spotted owls on the Hood Canal Ranger District since 1991 as part of a forest wide demographic study. Since 1991 the Hood Canal Ranger District has conducted surveys for owls primarily only in situations where potential projects might impact unsurveyed habitat. Most of the non PNW surveys in the watershed that were conducted to protocol are no longer valid because the survey results are only good for 2-3 years (USFS, 1991). The following table (Duckabush Watershed Spotted Owl Reproductive History) displays the results of survey efforts within home range radius (2.7 miles) of the analysis area. The first year with data indicates when the territory was located.

Table 2.5A - Duckabush Watershed Spotted Owl Reproductive History. From District and PNW surveys. PNW has primarily conducted the surveys since 1991

OWL SITE	WDFW owl #	Highest Status	Pre '87	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Group A														
Big Hump	20	T	S				T							
Upper Duck	130	S		S										
Murhut	273	P		P										
Lower Duck	438	R				R	S	R	P		R	P	R	R
Group B														
Cabin Cr	10	R	P		P	R	P	R	R	P	R	T	R	R
Gamm Cr	24	P			T			S				P	S	A
Lena Lake	40	R		P	R	R	R	P	R	P	R			R
Waketickeh	97	S												
Brothers	274	R			S	R	P	R		S				
Watson Cr	276	R	P			P	R	P	P	P	S	T		P
Bull Elk	301	P					P				S			
Dose Wfk U	444	S				S								
Ignar Cr	1072	P								P				

Owl Site = Owl Activity Site name
WDFW # = Washington Department of Fish and Wildlife spotted owl database activity center number
Highest status = Highest status recorded for each activity center
Group A = activity centers within the analysis area
Group B = activity centers within spotted owl home range radius (2.7 miles) of the analysis area
R = pair with reproduction confirmed
P = pair, no reproduction confirmed
T = territorial single owl
S = single bird, non territorial
A = surveys were conducted to protocol and no owls were detected
Blank years indicate no surveys were conducted or no owls were detected

The Duckabush watershed supports four known spotted owl territories within the watershed, and nine known territories that are influenced by the watershed as of August 1997. (See table 2.5A) Spotted owl territories influenced by the watershed are those whose activity centers fall within home range radius (2.7 miles) of the analysis area and are listed as Group B in Table 2.5A. Of the four territories within the watershed, two are pair sites, one of which has had reproduction confirmed. Of the nine territories influenced by the watershed seven are pair sites, four of which have had reproduction confirmed. The territories have been mapped using a standard circle radius of 2.7 miles (14,582 acres), which approximates the median annual home range size for Olympic Peninsula northern spotted owls (14,271 acres) (Holthausen et al., 1994). Site locations of spotted owls are sensitive information and are only available to cooperating state and federal agencies (Map 2.5XINSO "Spotted owl activity centers").

Habitat Conditions

For this iteration habitat analysis was done only for those owl territories centered within the analysis area. None of the northern spotted owl territories in the analysis area are fully contained within Late Successional Reserves (LSR), although 3 of the 4 territories analyzed are over 95% within LSR, national park, or wilderness lands. Two of the 4 territories analyzed have a portion of the 2.7 mile home range radius within the Adaptive Management Area (AMA), with the percent of habitat ranging from 0.01% to 0.02% of the total habitat available for the activity site. The average home range for the 4 owl territories analyzed had 5033 acres of suitable NRF habitat available, or 35% of the home range (habitat acres ranged from 2732 acres, 19%, to 7355 acres, 50%). Table 2.5B, "Suitable Northern Spotted Owl Habitat by Owl within 2.7 Miles of Activity Center," displays each owl's estimated home range by Critical Habitat Unit (CHU) acres, LSR acres, AMA acres, Other areas (e.g. wilderness), Olympic National Park (ONP) acres and Non-Federal acres. Three of these 2.7 mile radius circles overlap.

Table 2.5B - SUITABLE NORTHERN SPOTTED OWL NESTING, ROOSTING, AND FORAGING HABITAT BY OWL WITHIN 2.7 MILES OF ACTIVITY CENTER. Suitable nesting, roosting & foraging habitat retrieved from Hood Canal Ranger District GIS database, based upon TRI cell data, ONP data, and district biologist input, broken out by land allocation and ownership. Total acres within 2.7 mile radius circle = 14,582 ac.

Owl No.	Total Acres	CHU Acres	% Hab in CHU	LSR Acres	% Hab in LSR	AMA Acres	% Hab in AMA	Other Acres	% Hab in Other	ONP Acres	% Hab in ONP	Non-Fed Acres	% Hab in Non-Fed
20	7335	469	25	559	26	0	0	6000	53	776	64	0	0
130	4550	0	0	0	0	0	0	4550	31	0	0	0	0
273	5515	2636	35	3128	37	68	5	2319	50	0	0	0	0
438	2732	1511	24	2046	24	44	3	612	35	0	0	29	1
average	5033	1154	21	1433	22	28	2	3370	42	194	16	7	0.25

Owl number = Olympic National Forest northern spotted owl (owl) number from STRIX (spotted owl) database
Total Acres = total suitable (nesting, roosting, foraging) owl habitat acres within 2.7 mile radius owl activity center
CHU = Northern spotted owl Critical Habitat acres(CHU), designated 1/15/92; overlaps with other National Forest land allocations (LSR, AMA)
LSR = Suitable owl habitat acres in Late Successional Reserves (LSR) on National Forest land, designated by the Record of Decision
AMA = Suitable owl habitat acres the in Adaptive Management Area (AMA) on National Forest land, designated by the Record of Decision
Other = Suitable acres in other land allocations: Congressionally Reserved Areas and Administratively Withdrawn Areas (e.g., wilderness)
ONP = Suitable owl habitat acres in Olympic National Park (ONP)
Non-federal = Suitable owl habitat acres on non-federal lands, which include Department of Natural Resources and private ownership
% = % of land allocation or ownership within 2.7 miles of activity center that is suitable habitat

A 0.7 mile radius circle is used rangewide for analyzing the core area available for an activity center. The average core area for the 4 activity sites analyzed had 467 acres of suitable NRF habitat available (48%), ranging from 397 acres (41%) to 598 acres (61%). Table 2.5C, "Suitable Northern Spotted Owl Habitat by Owl within 0.7 Miles of Activity Center," addresses the available habitat acres within a 0.7 mile core area by land allocation or ownership: LSR, AMA, Other areas (e.g. wilderness), Olympic National Park (ONP) and Non-Federal.

Table 2.5C - SUITABLE NORTHERN SPOTTED OWL NESTING, ROOSTING, AND FORAGING HABITAT BY OWL WITHIN 0.7 MILES OF ACTIVITY CENTER. Suitable nesting, roosting & foraging habitat retrieved from Hood Canal Ranger District GIS database, based upon Forest TRI cell database and district biologist input, broken out by land allocation and ownership. Total acres within a 0.7 mile radius circle = 980 ac.

Owl No	Total Acres	LSR Acres	% Hab in LSR	AMA Acres	% Hab in AMA	Other Acres	% Hab in Other	ONP Acres	% Hab in ONP	Non-Fed Acres	% Hab in Non-Fed
20	397	0	0	0	0	397	41	0	0	0	0
130	598	0	0	0	0	0	0	598	61	0	0
273	462	273	39	0	0	189	69	0	0	0	0
438	411	411	42	0	0	0	0	0	0	0	0
average	467	171	20	0	0	147	28	150	15	0	0

Owl number = Olympic National Forest northern spotted owl (owl) number from STRIX (spotted owl) database
Total Acres = total suitable (nesting, roosting, foraging) owl habitat acres within 2.7 mile radius owl activity center
CHU = Northern spotted owl Critical Habitat acres(CHU), designated 1/15/92; overlaps with other National Forest land allocations (LSR, AMA)
LSR = Suitable owl habitat acres in Late Successional Reserves (LSR) on National Forest land, designated by the Record of Decision
AMA = Suitable owl habitat acres the in Adaptive Management Area (AMA) on National Forest land, designated by the Record of Decision
Other = Suitable acres in other land allocations: Congressionally Reserved Areas and Administratively Withdrawn Areas (e.g., wilderness)
ONP = Suitable owl habitat acres in Olympic National Park (ONP)
Non-federal = Suitable owl habitat acres on non-federal lands, which include Department of Natural Resources and private ownership
% = % of land allocation or ownership within 2.7 miles of activity center that is suitable habitat

All of the activity centers on the district are in LSR so there is no need to designate 100 acre core areas. The "take threshold" is defined as the level below which there may not be sufficient habitat to support a territorial northern spotted owl or pair of owls. There are two take criteria, the first requires at least 40% suitable habitat within the home range radius (5708 acres) (USFWS). One of the territories within the analysis area is above this first take threshold, however, the other three northern spotted owl territories (#130, 273, 438) within the analysis area are below the take threshold. The second take criteria requires 500 acres of currently suitable habitat within a 0.7 mile radius of the activity center. Three spotted owl territories (#20, 273, 438) within the analysis area are currently below this take threshold.

Currently non suitable stands located within the home range radius of spotted owl territories with lower levels of currently suitable habitat available to them (especially those listed above) should be higher priority for stand manipulation designed to create suitable habitat characteristics. For the quickest results stand manipulation to create suitable habitat characteristics should take place in the older nonsuitable stands first, utilizing prescriptions with demonstrated beneficial effects.

Suitable Habitat

Based on current maps of suitable habitat there are 18,595 acres of suitable NRF habitat within the watershed (37%). See map 2.5A "Spotted Owl and Marbled Murrelet Suitable Habitat". Within the watershed there are 1799 acres of NRF habitat in LSR and 1.2 acres of NRF habitat in AMA. The LSRs make up 15% of the watershed of which 25% is currently suitable. Even though only 37% of the analysis area is currently suitable, 77% is capable of being suitable. Capable of being suitable for this analysis includes all acres capable of being forested (excluding rock, wetlands, and water). However, this may generate an unrealistically high number because not all of the areas which can become forested may be capable of developing a stand with the structure needed to become owl habitat. See table 2.5D for a breakdown of the above acreage's by subwatershed.

Historically fire has been the dominant shaper of landscape habitat patterns within the Duckabush watershed. The fire history for the analysis area has been moderately intense; on the Olympic Peninsula only the Big Quilcene, Dungeness, and Elwha have burned more frequently and intensely. These fires were normally stand replacing and started during dry climate periods with strong east or northeast winds, and burned across the northern peninsula and down the east side. These large fires occurred within the analysis area approximately every 200 years; the last three of which encompassed most of the analysis area were in 1701, 1508, and 1308. However, wetter areas often survived these fires and occasionally ridgetop areas as well. The 1508 and 1701 fires were concentrated mostly in the lower drainage. This fire history resulted in a fairly homogenous landscape with older stands in the wetter areas and the upper watershed, with stands over time varying in age from 0 - 200 years in age. Current land management practices have resulted in a more fragmented landscape. Opportunities exist to accelerate the development of habitat within the analysis area.

Table 2.5D - SUITABLE NORTHERN SPOTTED OWL HABITAT BY SUB-WATERSHED. Suitable nesting, roosting & foraging habitat generated from potential natural vegetation groups and age class, broken out by land allocation and ownership.

Sub-Watershed	Total Suitable Habitat	Percent SWS Suitable	Future Potential Acres	Crit. Habitat Acres	LSR Habitat Acres	AMA Habitat Acres	Other Habitat Acres	ONP Habitat Acres	Non-Fed Habitat Acres
Crazy Creek	2358	42	4073	0	0	0	0	2358	0
Headwaters	711	23	767	0	0	0	0	711	0
Lower Duck	837	8	10314	797	800	1	12	0	24
Middle Duck	7571	53	11112	0	0	0	978	6592	0
Murhut/Cliff	3924	45	7437	976	999	0	2925	0	0
Upper Duck	3195	44	4803	0	0	0	0	3195	0
TOTAL	18,596	37	38,506	1,773	1,799	1	3,915	12,856	24

Future Potential Acres = Acres which have the potential to become suitable owl habitat (includes currently suitable)
Northern spotted owl Critical Habitat = Defined in Federal Register 1/15/92; overlaps with other National Forest land allocations, (e.g. LSR, AMA)
LSR = Suitable owl habitat acres in Late Successional Reserves (LSR) on National Forest land, designated by the Record of Decision
AMA = Suitable owl habitat acres in the Adaptive Management Area (AMA) on National Forest land, designated by the Record of Decision
Other = Suitable acres in other land allocations: Congressionally Reserved Areas and Administratively Withdrawn Areas (e.g., wilderness)
ONP = Suitable owl habitat acres in Olympic National Park (ONP)
Non-federal = Suitable owl habitat acres on non-federal lands, which include Department of Natural Resources, tribal, and private ownership

Critical Habitat

There are 6,246 acres of critical habitat designated for the northern spotted owl within the watershed, of which 28% is currently suitable NRF habitat and 6,209 acres overlap with LSR. There are 34 acres of critical habitat which are not in LSR (0.5% of critical habitat within the watershed). There are no known spotted owl activity centers within this non-overlap area. Within this non overlap area 21% is suitable NRF habitat.

Dispersal Habitat

For this analysis, dispersal habitat in the watershed has been defined by the 11-40 standard: stands with an average of coniferous trees greater than or equal to 11 inches in diameter at breast height (dbh) with no less than 40% canopy cover. Currently suitable NRF habitat is also included within dispersal habitat. Table 2.5E displays dispersal habitat acres by subwatershed by ROD land allocation and by land manager. The ROD allocations include Interim Riparian Reserves (RR), LSR, AMA; other land managers include the Olympic National Park, and Non-Federal. The dispersal habitat layer was generated using potential natural vegetation groups and age class. Mortality of spotted owls after dispersal might be caused by predation, starvation, or accident (USDI, 1992b). Mortality is likely increased by the increase in habitat fragmentation. Dispersal habitat on non-federal land may be important to spotted owls dispersing off of the Peninsula, and also as maintenance habitat which can provide minimal habitat needs for 'floaters', spotted owls which are waiting for currently occupied territories to become available. See map 2.5A "Spotted Owl & Marbled Murrelet Habitat".

Table 2.5E - NORTHERN SPOTTED OWL DISPERSAL HABITAT BY LAND ALLOCATION & OWNERSHIP WITHIN SUB-WATERSHEDS. Suitable dispersal habitat generated from potential natural vegetation groups and age class data.

Sub-Watershed	Total Acres	% Disp. Hab.	Interim RR Acres	LSR Acres	AMA Acres	ONP Acres	Non-Fed Acres
Crazy Creek	3678	62	890	0	0	3678	0
Headwaters	711	23	198	0	0	711	0
Lower Duck	7108	64	2608	4206	152	0	2596
Middle Duck	9504	67	2778	0	0	8513	0
Murhut/Cliff	5143	59	2710	1234	0	0	0
Upper Duck	4365	61	845	0	0	4365	0
TOTAL	30,509	61	10,029	5,440	152	17,267	2,596

Total Acres = Total acres of suitable northern spotted owl (owl) dispersal habitat in the sub-watershed
Percent disp hab = Percent of subwatershed that is dispersal habitat
Interim RR Acres = Acres of suitable owl dispersal habitat which occur in Interim Riparian Reserves as stated in the Record of Decision (ROD) B 12-14 & C 30-31.
LSR Acres = Acres of suitable owl dispersal habitat in the sub-watershed in Late Successional Reserve (LSR), designated by the ROD
AMA Acres = Acres of suitable owl dispersal habitat in the sub-watershed in the Adaptive Management Area (AMA), designated by the ROD
ONP Acres = Acres of suitable owl dispersal habitat in the Olympic National Park (ONP)
Non-Fed Acres = Acres of suitable owl dispersal habitat on non-federal lands

Habitat Restoration

The primary opportunity to restore spotted owl habitat on National Forest lands is in stands less than 80 years. The objective of attempting to manage these younger stands is to promote habitat development though the promotion of important structural components of suitable NRF habitat such as: multi-storied, multi-specied, forest habitats with variable spacing, small openings, large trees, large snags and down material. (USDI, 1992b; USDA/USDI, 1994) Similar opportunities exist on state and private lands in the watershed, but it is assumed that on those ownerships there will be more emphasis on mitigation of activities for existing owls, than on restoration of currently unsuitable habitat. Areas with the greatest difference between currently suitable habitat and future potential habitat provide the most opportunity for restoration (e.g. subwatersheds Lower Duck and Murhut/Cliff, from Table 2.5D).

Marbled Murrelet

General

The marbled murrelet (*Brachyramphus marmoratus marmoratus*) was federally listed as threatened in September 1992 under the Endangered Species Act, and state listed as threatened, due to declining populations caused by a decrease in nesting habitat, and to a lesser degree, threats from gillnet and oil spill mortality. (USDI, 1992a) Marbled murrelets are sea birds that nest in forest habitats and feed at sea. The nesting season in Washington is from April to mid-September. Marbled murrelets generally spend the remainder of the year at sea in coastal areas. Murrelets generally nest in low-elevation old-growth forest habitats, on trees (generally larger than 32 inches in diameter) which have large limbs or mistletoe growth, providing a five inch or greater nesting platform. Typical nest stands are multi-storied with moderate to high canopy closure. Murrelets tend to nest in the oldest trees in the stand (USDI, 1992a). The principal limiting factor for marbled murrelets in the Duckabush watershed is suitable nesting habitat. Also, because of the fragmentation of the existing habitat, especially in the lower watershed, the potential for predation is greatly increased. (Nelson, 1995)

The estimated marbled murrelet population is approximately 5,000 in the state of Washington (PSG, 1993). Historical numbers were thought to be higher. Removal of nesting habitat by timber harvest is considered to be a primary factor in population decline (PSG, 1993; USDI, 1992a). Other limiting factors which may contribute to population decline include predation, oil spills, and entanglement in gill nets. Since marbled murrelet reproductive rates are low, laying one egg per year, and juvenile survival rates are low, they recover slowly from population declines (PSG, 1993). Recent counts have found very low percentages of juveniles on the water (range 1-5%, highest in Alaska) indicating that recruitment rates are lower than reproduction rates (PSG, 1993).

Nest success information was recently compiled for the known tree nests in North America (Nelson, 1995). Of these nests (n=32, 23 of which have known outcomes) 67% hatched young, and 45% fledged young. This compares with other alcids whose fledging rates range from 66% to 100%. Also, since there have been multiple discoveries of grounded chicks (46 since 1940) actual nest success may be lower than that based on fledging rates. It was found that successful nests were further from a nesting habitat edge (mean 166 meters, minimum 57 meters) than were the failed nests (mean 27 meters, maximum 64 meters). Another critical component was nest concealment. Both of these characteristics relate to predation, the more exposed the nest is, the more likely it is to be predated.

Methods

The following analysis utilized marbled murrelet survey data, GIS map layers including suitable murrelet nesting habitat, ROD land allocations, and land ownership. For the murrelet suitable habitat layer the spotted owl suitable NRF habitat layer as described in the previous section was utilized. Most type 1 marbled murrelet habitat (mature and old growth coniferous forest) is covered by the suitable owl habitat layer. Type 2 murrelet habitat (younger stands with either remnant old growth trees, or defect which creates suitable nest platforms) does not show up when using this layer. Mapping of type 2 habitat within the National Forest lands in the analysis area has occurred adjacent to proposed project areas which had the potential to affect marbled murrelets. Mapping the type 2 habitat is time consuming and provides a level of detail that was not deemed necessary for this iteration of watershed analysis. However, this mapping should be completed for the next iteration.

The district survey records and the Washington State Department of Fish and Wildlife (WDFW) marbled murrelet database were searched for murrelet detections within the watershed. There were two 1992 detections listed in the WDFW database, but neither were of occupied behavior. Therefore an occupied site layer was not generated for this iteration.

Current Conditions

Forested Habitat Use

Limited information exists regarding marbled murrelet nesting and habitat relationships. Habitat variables that affect murrelets are not well understood. Marbled murrelet nesting surveys have been conducted on the Hood Canal Ranger District since 1990, and have only covered a small portion of the suitable habitat within the watershed. Interagency protocols for surveys (Pacific Seabird Group, 1991-1996) have been followed for district surveys.

As of the end of the 1997 survey season, no known marbled murrelet occupied sites have been identified within the analysis area. The district is not conducting any surveys within the analysis area during the 1998 survey season. The PNW lab has been conducting a radar study of marbled murrelets in 1996 and 1997. The Duckabush was sampled both years in July as a third site to look at annual variability. The primary sample areas are further north. The radar site in the Duckabush was located at a small community park about 1.5 km upstream from the river mouth. The site was surveyed once in 1996 with 44 landward targets and 27 seaward targets identified as murrelets. The site was surveyed 3 times in 1997 with 32, 44, and 52 landward targets, and 17, 14, and 22 seaward targets identified as murrelets. More information is needed regarding murrelet life history and habitat use in the watershed.

Within the watershed there are 18,596 acres of suitable marbled murrelet nesting habitat (note suitable owl NRF habitat was used for this iteration). There are 19,910 acres of recruitment habitat within the analysis area, which are areas that are not currently suitable, but have the potential for becoming suitable murrelet nesting habitat. Recruitment habitat for this analysis was generated using all stands not currently suitable which are capable of being forested (excluding rock, wetlands, and water). However, this may generate an unrealistically high number because not all of the areas that can become forested may be capable of developing a stand with the structure needed to become murrelet nesting habitat. See map 2.5A "Spotted Owl & Marbled Murrelet Habitat".

Peregrine Falcon

Past Conditions

The peregrine falcon (*Falco peregrinus*) was federally listed in 1970 under the Endangered Species Act, as well as state listed as endangered. Across the country peregrine populations were apparently stable until well into the 1940's. Dichlorodiphenyltrichloroethane (DDT) was mass produced and stockpiled during WWII and was later made available in large quantities for civilian use in 1946 (Ratcliffe, 1980). High levels of eggshell breakage were documented first in 1958 (Ratcliffe, 1958). The tie between DDE (DDT metabolizes into DDE) and eggshell thinning was made in 1968 (Hickey and Anderson, 1968). By 1970 there were only two known pairs of peregrines in California (Herman, 1971), and none in Oregon or Washington (Pagel and Jarman, 1991). DDT was banned in the United States in 1972. Even though many species are recovering after the ban, the peregrine is still affected by eggshell thinning (Pagel and Jarman, 1991). DDT and similar organo-chlorine chemicals are still being heavily used in Latin America which is the migratory destination of peregrine falcons and a large portion of their prey base, neotropical migratory passerines (Goldberg, 1975; Henny et al., 1982; Peakall and Kiff, 1988; Poole, 1989). However, many of the peregrines which nest at higher elevations do not migrate to the neotropics and they are also still experiencing eggshell thinning, which may indicate that local levels of these organo-chlorides are still high (Joel Pagel, pers. comm. 1995). This may have an unknown effect on the future outcome of any management efforts to improve the peregrine population.

Current Conditions

The analysis area has some of the best potential peregrine habitat on the forest. In the past it was felt that there was very limited potential for suitable peregrine habitat within the analysis area, however, the habitat definitions have recently changed, and it has been discovered that peregrines can utilize much smaller cliffs than previously believed (Pagel, 1992). As part of a 1996 partnership with Hawkwatch International, cliffs within the analysis area were rated for peregrine falcon potential. Two rock faces were rated as having a high potential for peregrine use (St. Peter's Dome and Mt. Jupiter); and two were rated as having medium potential for peregrine use (Cliff Creek, and unnamed cliffs northwest of Murhut Creek). Nesting status within the analysis area is unknown. Monitoring of the cliffs with a high or medium rating should be conducted. There were three peregrine sightings in 1989 within the analysis area in the Mt. Jupiter area; and one possible sighting in both 1990 and 1995.

Bald Eagle

General

In 1978, the Bald Eagle (*Haliaeetus leucocephalus*) was federally listed as threatened in Washington state under the Endangered Species Act, and listed as threatened by the State. Bald eagles are also protected under the Migratory Bird Treaty Act (1918), The Eagle Protection Act (1940), and the Lacey Act (1901). Bald eagles have been the nation's symbol since 1872. Bald eagles occupy most of their historical range in the Pacific Northwest, but until recently the population had been declining. A recovery plan for the pacific bald eagle was developed in 1986 that divided the Pacific Recovery Area into recovery zones. The analysis area falls within two of these zones. The upper analysis area is within Zone 2, the Olympic Peninsula; the lower analysis area is within Zone 4, Puget Sound. Although the rest of the zones in Washington have been doing relatively well in moving toward meeting their recovery goals, both Zones 2 and 4 have not been doing as well. Threats identified in the recovery plan for these two zones included: Zone 2, logging and increased recreation use; Zone 4, logging, shooting, and harassment; loss of habitat; contaminants in ecosystem; lead poisoning. (USFWS, 1986)

General - Ecological Requirements

Bald eagles typically nest in one of the tallest trees in a forest stand thereby securing support for a heavy nest, providing an open flight path, and a view of potential prey. Anthony and Isaacs (1989) found that bald eagle nests in

Oregon are associated with aquatic foraging areas. Most (84% of 201 nests) were located within 1.6 km of water, all were within 2.7 km of permanent water. Most of the nests located in the Douglas Fir forest type were located in douglas fir trees which were dominant or codominant in the stand, and were larger in height and diameter than other trees in the surrounding stands. (Anthony and Isaacs, 1989) Grub (1976) found that in western Washington 70% of 218 nests were located in douglas fir trees. Nest tree diameters at breast height (dbh) were found to be 115% to 150% greater than the average dbh for the surrounding forest stand (Stalmaster et al., 1985).

Bald eagles show extremely strong fidelity to a nest site, and often to particular nests. They maintain alternate nests and perch sites within their territory. Grub (1980) found that 38% of nesting territories in Washington had one to two alternate nests. Bald eagles are most susceptible to disturbance during the egg laying and incubation period. Vegetation screening can substantially reduce disturbance to eagles because they will flush much sooner from a disturbance activity that is seen than from one that is heard only. (Stalmaster et al., 1985)

Perch sites tend to be near water, whereas roost sites may not be. Roost sites are similar in characteristics to nest sites, with protection from wind being one of the most important factors. (Stalmaster et al., 1985) Winter perch and roost sites are typically in mature or old-growth habitat, usually associated with water, and may be communal. Availability of prey resources is a determining factor of wintering patterns. Key characteristics of winter roosts in northwest Washington are: 1) clear line of sight, 2) favorable microclimate, 3) strong perches high above the ground, and 4) freedom from human activity (Hansen et al., 1980).

Current Conditions

Nesting

There are no known bald eagle nesting territories within the analysis area. The Duckabush territory is just south of the estuary but not within the analysis area (territory was discussed in the Hamma Hamma/Hood Canal Tribs watershed analysis).

Anthony and Isaacs (1989) found that nest sites which had older and more contiguous forests available with low human disturbance had higher productivity rates than other nest sites with less favorable conditions. Also, maintaining higher tree densities and canopy closure is important for both visual buffers to disturbance activities and protection from blowdown of nests and nest trees. There are opportunities adjacent to the Duckabush nesting territory to improve the habitat through stand manipulation to grow larger trees in the riparian areas; improve the prey base by improving fish habitat and fish runs; and reduce the disturbance potential by reducing road densities within and adjacent to the territory and creating visual buffers.

Winter Use

Midwinter survey results for the analysis area conducted along specific routes by the Hood Canal Ranger District, and others, for the bald eagle are as follows (these sightings were all in survey quad 473-1225):

Table 2.5H - Midwinter Bald Eagle survey results for Duckabush

Year of survey	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1997	1998
Date of survey	1/11	1/10	1/11	1/9	1/13	1/14	1/11	1/21	1/14	1/16	1/19	1/20	1/31
# Adults	1	2	1	0	2	2	0	0	4	10	4	3	4
# Immatures	1	1	2	2	5	9	0	4	6	21	8	3	3
# Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0
Total # Eagles	2	3	3	2	7	11	0	4	10	31	12	6	7

Source: WDW Midwinter survey results for 1985-1988, District records for 1989 - 1998.

The number of eagles sited in the Duckabush during midwinter surveys averaged 8 per year. Because winter use is dependent on prey availability the number of eagles observed in the analysis area, as represented by the midwinter counts above, is dependent on the winter fish runs. Bald eagles will move fair distances in winter to the best food sources. The numbers in the table above do not necessarily reflect any change in the number of bald eagles wintering in the general area, but they do demonstrate the value of the area for wintering bald eagles.

Significant Habitat

The most significant bald eagle habitat within the analysis area which is being currently utilized by eagles is that within the territory of the Duckabush nest just south of the estuary and the winter use area(s). The recovery plan identified tasks needed for recovery, those tasks which are particularly applicable to the analysis area include:

1.3 Manage Breeding and Nonbreeding habitat

- **1.31 Maintain and improve quantity, quality, and availability of food supplies.**
  - 1.311 Manage inland and anadromous fish populations and habitats to maintain and enhance adequate food for eagles
    - 1.3111 Manage water levels to maintain and enhance eagle food sources
    - 1.3117 Protect and enhance natural spawning populations and spawning grounds of salmon and other important fish spawners to increase availability to eagles
    - 1.3118 Maintain and improve habitat for fish by reducing siltation from logging, roads, and overgrazing
- **1.32 Maintain and improve forested habitat in both the breeding and wintering range**
  - 1.321 Maintain forested habitat that is presently used by eagles
  - 1.322 Maintain and develop nesting and roosting habitat for future use by eagles
    - 1.3221 Manage young tree stands to meet desired physical characteristics
    - 1.3222 Plant new trees in potential bald eagle use areas devoid of tree reproduction
    - 1.3223 Provide artificial perches and nest structures where natural sites are not available
    - 1.3224 Create snags where suitable perch trees are not available
- **1.33 Restrict human disturbance at eagle use areas**
  - 1.331 Establish buffer zones around nest sites
  - 1.332 Exclude logging, construction, habitat improvement, and other activities during critical periods of eagle use
  - 1.333 Prohibit building construction near key bald eagle nesting and wintering habitats
  - 1.334 Prohibit vehicle traffic at sensitive key areas during periods of eagle use

For a complete list of tasks needed for recovery of the pacific bald eagle, and a more in-depth discussion for each objective please see the Recovery Plan for the Pacific Bald Eagle (U.S. Fish and Wildlife Service, 1986).

Northwest Timber Wolf (Grey Wolf)

Past and Current Conditions

The gray wolf (*Canis lupus*) was federally listed as endangered in 1967 under the Endangered Species Preservation Act and is state listed as endangered. Wolves are native to the Olympic Peninsula, but were extirpated in the late 1920's or early 1930's due to shooting, poisoning, and reduction in their prey base. Potential for reintroduction may exist. (Lowrie, 1994) Booth, while preparing his "Systematic Review of the Land Mammals of Washington", examined two specimens collected from the Olympic Peninsula: one from Clallam County, 22 miles south of Port Angeles; and the second from Jefferson County, in the Hoh River Valley. He confirmed both as *Canis lupus fuscus*, the Northwestern timber wolf. Two other specimens have been collected from the peninsula but were not examined by Booth (1947).

Reintroduction of the gray wolf to the Olympic Peninsula was proposed by the group Defenders of Wildlife in early 1997 and is supported by Washington State Representative Norm Dicks. The first step will be to conduct a biological feasibility study to determine if the wolf could survive on the peninsula. If the results are positive than an Environmental Impact Statement would be prepared. If reintroduction is found to be feasible, the reintroduced wolves will most likely be considered an experimental population. The status provides more flexibility in dealing with any "problem wolves".

SPECIES OF CONCERN - UNDER ESA

The following are Species of Concern for listing under the Endangered Species Act and documented as occurring in the Olympic National Forest:

California wolverine	*Gulo gulo lutens*
Cascades frog	*Rana cascadae*
Long-eared myotis	*Myotis evotis*
Long-legged myotis	*Myotis volans*
Northern goshawk	*Accipiter gentilis*
Olive sided flycatcher	*Contopus borealis*
Pacific fisher	*Martes pennanti pacifica*
Pacific western big eared bat	*Plecotus townsendii pallescens*
Tailed frog	*Ascaphus truei*

The northwestern pond turtle (*Clemmys marmorata marmorata)* is the only Species of Concern that is suspected, but not documented, of occurring on the Olympic National Forest. There was insufficient time to discuss these species this iteration, they should be discussed in more depth in the next iteration.

SURVEY & MANAGE SPECIES

Bats

Three species of bats suspected of occurring in the watershed are listed on the Record of Decision Survey and Manage List: Long-eared myotis, long-legged myotis, and silver-haired bat, of which the first two are species of concern under the ESA.

Long-eared myotis (*Myotis evotis*) occurs in forested habitat up to 9,000 feet. It feeds on moths and beetles at the edges of mature forest, especially riparian zones. The long-eared myotis roosts in crevices in caves, mines, snags, trees, and buildings, and generally hibernates in caves and mines, or buildings, although few have been found hibernating in Washington or Oregon. Small water sources, such as ponds in forest clearings, appear to be important for this species. Timber harvesting activities that involve removal of large snags and decadent trees has reduced bat roosting habitat. (Christy and West, 1993; Perkins, 1988)

Long-legged myotis (*Myotis volans*) occurs in coniferous forest habitat, is associated with old growth (Perkins, 1988). This bat is an aerial forager that pursues insects high over the forest canopy, feeding almost exclusively on moths. The long-legged myotis also forages in drainages of tributary and intermittent streams. Day and maternity roosts occur in trees, snags, and rock crevices and in buildings. Hibernacula and night roosts are in caves, mines and large rock crevices. Timber harvesting activities that involve removal of large snags and decadent trees have reduced bat roosting habitat. (Christy and West, 1993; Perkins, 1988)

Silver-haired bats (*Lasionycteris noctivagans*) are a migratory species that occurs in forests throughout northern spotted owl range during summer. This species is strongly associated with old-growth forests for both roosting and foraging. All known day and maternity roosts are in crevices in large snags and decadent trees; it rarely enters caves. Maternity colonies are small aggregations of 8-10 females, and most give birth to twins. Silver-haired bats forage by pursing prey over dense, mature forests near streams and ponds, feeding on a wide variety of arthropods. They are known to follow stream corridors when traveling from roosts to foraging sites. Harvesting of old-growth forests has reduced roosting and foraging habitat. (Christy and West, 1993)

Only one survey for bats has been conducted on the Hood Canal Ranger District (Perkins, 1988). A total of 37 ponds or structures were surveyed at 24 sites. Bats were found at five sites, four of which were bridges. No survey and manage bat species have been located within the analysis area. Much is currently unknown about the population size or population trends of the above species. Habitat loss is believed to have contributed to the decline of these and other species. Maintenance of undisturbed old-forest and riparian habitat in the Olympic National Park and Late-Successional Reserves and Riparian Reserves on the Olympic National Forest, along with retention of snags and green tree patches in other land allocations, is important for providing the habitat conditions necessary for long-term viability of these species. Protection of roost sites and hibernacula is also important. (USDA/USDI, 1994)

Disturbance

Disturbance to caves, mines, and bridges; and removal of surrounding vegetation may also negatively impact bat roost and hibernation sites. Cumulative effects on these species' populations may result from disturbance of caves, lack of protection of riparian habitat, loss and fragmentation of forested habitat, and accumulation of pesticides on adjacent non-federal lands (USDA/USDI, 1994). Pesticide accumulation in insect populations may affect all bat populations. Many bats are sensitive to human disturbance and loud noises, especially during hibernation. Timber-harvesting and road building or maintenance activities near caves, mines, and bridges may result in the abandonment of these hibernacula.

MOLLUSKS

General

Mollusks are associated with aquatic and riparian habitats and are therefore strongly tied to water quality, water temperature, and availability (Lowrie, 1994).

Ten species of mollusks included on the Record of Decision Survey and Manage List have historic range and are suspected to currently exist on the Olympic Peninsula. Their existence in the Duckabush Watershed is unknown. Mollusk species include (Burke, 1994):

Land Snails		Slugs	
+Megomphix hemphilli	Oregon Megomphix	*Hemphillia burringtoni*	Keeled Jumping-slug
Cryptomastix devia	Puget Oregonian	*Hemphillia glandulosa*	Warty Jumping-slug
**Vertigo n. sp.*	Hoko Vertigo (suggested)	*+Hemphillia malonei*	Malone Jumping-slug
		+Hemphillia pantherina	Panther Jumping-slug
		Prophysaon coeruleum	Blue-gray Taildropper
		Prophysaon dubium	Papillose Taildropper
		Deroceras hesperium	Evening Fieldslug

*surveys not required outside of Clallam County. +species may occur, but not expected, surveys not required

Much is currently unknown about the range and habitat associations of the above species. Habitat loss is believed to have contributed to the decline of these and other species. Undisturbed old-forest and riparian habitat in the Olympic National Park and Late-Successional Reserves and Riparian Reserves on the Olympic National Forest might provide the habitat conditions necessary for long-term viability of these species. Most of these species are highly endemic and therefore are more susceptible to affects from habitat modification where they occur.

Land Snails

Oregon megomphix (*Megomphix hemphilli*) is associated with old-growth and riparian habitats, and is generally found in moist, lower elevation, relatively undisturbed forests. It has been extirpated from most historic sites and is rare on remaining sites (Frest and Johannes, 1993; USDA/USDI SEIS J2, 1994).

Puget Oregonian (*Cryptomastix devia*): "Ecology: low to middle elevation; old growth and riparian associate; habitat includes leaf litter along streams, under logs, among brush, and in talus (Roth, 1993)." in (Frest and Johannes, 1993)

Hoko vertigo (*Vertigo n. sp.*) has been found in leaf litter at the base of a wooded slope near a stream at moderate elevation. It is associated with old-growth and riparian habitats, and is a local endemic. It is a newly discovered species (hence n. sp.) whose range is very poorly understood (Frest and Johannes, 1993; SEIS J2, 1994). This species is most likely a highly endemic species so surveys to meet the survey and manage requirement will only be conducted within Clallam County, and will not be required within the analysis area.

Slugs

Keeled jumping-slug (*Hemphillia burringtoni*) is associated with riparian and old-growth habitats, and is locally endemic. It is found in rainforests from 500 - 3500 feet in elevation (Branson, 1980). Its current status is unknown, but historically may have been common on the Olympic Peninsula (Frest and Johannes, 1993; SEIS J2 1994).

Warty jumping-slug (*Hemphillia glandulosa*) is associated with relatively moist and undisturbed old growth coniferous forest, generally at low to middle elevations, and is locally endemic (Frest and Johannes, 1993). Timber harvest and urbanization has extirpated the warty jumping-slug in known historic locations and its current range is unknown (Frest and Johannes, 1993; SEIS J2, 1994).

Malone jumping-slug (*Hemphillia maloneii*) is associated with riparian and old-growth habitats, and is locally endemic. It is found generally in open but uncut forests at low to high elevation (Frest and Johannes, 1993).

Panther Jumping-slug (*Hemphillia pantherina*) has been located in deep forest litter either in or near riparian areas (Burke, 1994). This species has not been located on the Olympic Peninsula, the closest known location is on the Gifford Pinchot National Forest, but it is felt that there is potential for it to occur here (Burke, 1994).

Blue-gray Taildropper (*Prophysaon coeruleum*) is associated with relatively undisturbed, moist old growth and riparian areas, from low to middle elevations, and has been extirpated from historic sites due to urbanization so its current range is unknown (Frest and Johannes, 1993). Solitary individuals were located in dark coniferous stands under damp logs (Burke, 1994).

Papillose Taildropper (*Prophysaon dubium*) is an old growth and riparian associate found in low to middle elevations (Frest and Johannes, 1993). This species has been found in riparian meadows (Burke, 1994).

Evening fieldslug (*Deroceras hesperium*) is associated with intact old-forest stands characterized by high vegetative diversity. It has been found in mixed salmonberry, hemlock, spruce, and black cottonwood forest (Frest and Johannes, 1993). The evening fieldslug does not have a strong riparian association (SEIS J2, 1994).

OTHER SPECIES OF CONCERN

Amphibians

Amphibians occurring on the Olympic Peninsula, and which may also occur within the analysis area, include: Northern red-legged frog, Cascade frog, tailed frog, Van Dyke's salamander, pacific treefrog, western toad, roughskin newt, northwestern salamander, long-toed salamander, Cope's giant salamander, Olympic torrent salamander, ensatina, western red-back salamander, and the bullfrog. The first three species are candidates for federal listing. The Van Dyke's salamander is a Survey and Manage species (ROD, table C-3), but only for the Cascade population. It was felt that the Olympic's LSR and riparian reserve network would provide sufficient protection for the Olympic population without additional mitigation measures. (USDA/USDI, 1994a)

Surveys have been conducted within the Fulton subwatershed of the Hood Canal Tribs watershed, which is located adjacent to the lower Duckabush analysis area. It is assumed that similar species would occur between the watersheds, particularly in the southern portion of the Duckabush analysis area where the two watersheds are directly adjacent to one another. Species documented in Fulton, and which are also likely to occur within the Duckabush, include roughskin newt, northwestern salamander, ensatina, western red-back salamander, tailed frog, Pacific treefrog, and Northern red-legged frog. (Schaeffer, 1997):

Roosevelt Elk

General

The annual home range for elk on the Olympic Peninsula is 11 sq. km (4 sq. mi.), which is the smallest home range in Washington (Jenkins and Starkey, 1980). Taber and Raedeke (1980) found that the most important mortality factors for the herds found within the Quilcene and old Hoodsport R.D. (hereafter known as zone 3 which is bounded by the Olympic National Park to the west; and by private lands to the north, east and south) are winter mortality and legal harvest. Smith, et al. (1993) recently found that poaching is the second largest mortality factor in Washington state. The low elk densities in Zone 3 are probably a result of the drier climate within this zone than the rest of the peninsula (Taber and Raedeke, 1980).

Population

Taber and Raedeke (1980) found that the herds in Zone 3 have been declining at a rate of approximately 20 elk per year since the mid 1960's. This zone has the lowest population density on the peninsula at 0.4/square mile. The pattern of decline within this zone is that of a population unable to recover after episodes of unusually high mortality. During the extreme winter of 1968-1969 there was a 30% loss to winter mortality. There was also high winter mortality during the winter of 1971-1972, although not as extreme as the 68-69 episode, and in 1978 nearly 37% of the population was harvested through legal hunting. After each of these episodes of high mortality the population stabilized at a level below that which existed before the episode. (Taber and Raedeke, 1980)

Game management unit (GMU) 621 includes the analysis area plus the Hamma Hamma watershed analysis area and the Quilcene Ranger District, and has 6 elk herds. From 1965-1968 the Washington State Game Department estimated the population within GMU 621 at 500 elk. By 1978 the elk population in GMU 621 had declined to a minimum of 150 elk (Schirato, 1995), less than 30% of that reported in the 1960's. The eastern Olympic elk herds declined due to state and tribal overharvest and did not respond to cow closures in the Point No Point Tribal and State seasons (Schirato, 1995). Consequently, in 1993 a conservation closure was implemented within GMU 621. To monitor population levels two elk in each herd were fitted with radio collars (Smith, et al., 1993). In 1994 winter mortality equaled calf production; while in 1995 calf production and winter survival both went up resulting in a population increase and numbers higher than preclosure. However, the elk herds still do not appear to be expanding to the size that the habitat could accommodate (Schirato, 1995).

One of the six elk herds within GMU 621 utilizes the analysis area. In the 1930's the Roosevelt elk herd population within the Duckabush drainage was reported to be approximately 75-100 animals (Schwartz, 1938; Springer, 1939). In the 1980's the herd size still fell within the 1930 estimates, but by spring of 1993 had dropped to 35 animals, less than 45% of that reported in the 1980's. Since implementation of the conservation closure the Duckabush herd has recovered to almost the same number of animals as reported in the 1980's. However, the Duckabush herd is increasing at a rate of 0.12 which is below the maximum rate of increase for elk, >0.20 (Schirato & Murphie, 1997). Schirato and Murphie (1997) estimated the 1996 winter population of the Duckabush herd with 95% Confidence Intervals at between 72-180 animals.

Table 2.5I - Estimated Elk Population: Duckabush Herd

Year / Area	1938	1939	1953	Fall 1980	1984	Fall 1985	Fall 1991	Fall 1992	Spr. 1993	Fall 1993	Fall 1994	Spr. 1995	Fall 1995	Spr. 1996	Fall 1996	Spr. 1996
Duckabush	100	75	100	80	80		55	44	35	42	47	49	70+	73	78	66
Duckabush & Dosewallips	250	155	150		123	127		64								
Source	1	2	3	3	4	3	3	3	3	3	3	3	3	3	3	3

Source: 1 Schwartz, 2 Springer, 3 Schirato 1997, 4 Shroer 1986

Summer Range

According to Taber and Raedeke (1980) summer range is not a limiting factor for the herds found in zone 3. Almost all of the summer range within this zone is within the Olympic National Park which has been only minimally altered and continues to provide good summer range. The Duckabush herd summers in the Mt. Hopper area and overlaps with elk from the Skokomish and Quinault drainages, however since 1995 the herd has not migrated (Schirato & Murphie, 1997).

Winter Range

Winter range within zone 3 on the Olympic Peninsula was found to be most areas below 1500 ft in elevation. Taber and Raedeke found that the limiting factor for herds within zone 3 was the continual reduction in amount and quality of winter range. Urbanization in the lowlands, and the amount of second growth (which is poor winter habitat) within winter range on national forest lands is contributing to a reduction in the carrying capacity of the winter range. Some of the elk bands that winter within the analysis area may winter within the saltwater marshes along the canal (Schwartz, 1939). The key forage species used on winter range on the Olympic Peninsula is vine maple, and western hemlock is the principal conifer species utilized for browse (Schwartz and Mitchell, 1945). The Duckabush currently has an abundance of forage available at lower elevations due to recent clearcutting on private lands, which probably explains why the herd has not migrated for the past two years. However, as the replacement stands develop forage may become a limiting factor.

Roads

Use of roads can be disturbing to elk. Roads also provide access for hunting, both legal and illegal. It has been found that elk will avoid areas within 400 feet of primary roads and 200 feet of secondary roads (Lyon, 1979; Pederson et al. 1980). Road density has also been positively associated with legal and illegal harvest of elk (Leege, 1976; Smith et al. 1993). Those roads which have been closed to traffic no longer result in a significant disturbance to elk (Witmer et al. 1985). The Washington State Department of Fish and Wildlife recommends that road densities be kept below 1.5 miles per square mile in summer range and below 1.0 miles per square mile in winter range (Rodrick and Milner, 1991). The following table displays current road densities within the analysis area and miles of road which would need to be closed in order to meet recommended road densities. The table does not include roads that have been closed to traffic; see Table 2.9E in the Hydrology Appendix 2.9 for all roads.

Table 2.5J - Road Densities

SWS	LOW ELEVATION (<1500')				HIGH ELEVATION (>1500')				TOTAL	TOTAL	TOTAL
	SQ. MILES	RD MILES	RD DENS	ROADS +	SQ. MILES	RD MILES	RD DENS	ROADS +	SQ. MILES	RD MILES	RD DENS
Lower Duc	11.47	37	3.23	25.58	5.97	2	0.34		17.44	39	2.24
Murhut	1.85	0	0		11.68	11	0.94		13.53	11	0.81
Middle Duc	1.42	0	0		20.75	0	0		22.17	0	0
Headwaters	0	0	0		11.26	0	0		11.26	0	0
Upper Duc	0	0	0		8.86	0	0		8.86	0	0
Crazy	0	0	0		4.76	0	0		4.76	0	0
Totals	14.71	37	0.22		63.28	13	0.21		78.02	50	0.64

SWS = Subwatershed
ROADS + = miles of road in each subwatershed which are above the state recommended road densities
SQ. MILES = area in square miles within each subwatershed (below 1500', above 1500', and total)
RD MILES = miles of road within each subwatershed (below 1500', above 1500', and total), open roads only
RD DENS = road density, miles of road/ square mile for each subwatershed (below 1500', above 1500', and total)
TOTAL = Totals for the entire analysis area (bottom row)

Based on Table 2.5J priorities for road closures in winter range would be in the subwatershed Lower Duckabush. Overall, to meet the WDFW recommended road densities would require closing over 25 miles of road within the analysis area (50% of the existing roads); all in winter range. The above table looks only at road densities and does not take into consideration benefits of gate closures.

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2.6 FISHERIES

INTRODUCTION

The analysis area covers Duckabush watershed. These streams range from the un-named tributaries with little to no fish habitat to the main stem Duckabush providing over 88 miles of habitat utilized by anadromous and resident fishes (Williams et al 1975). A variety of sources have been used to summarize and update the available information, including agencies, tribes and local residents

Fish distribution and stock status on the Duckabush River are addressed in the key question of the fisheries module. Fish distribution is important in the drainage as it relates to land management and riparian reserve designation. A map is provided showing the verified anadromous habitat as well as the estimated resident trout habitat. Stock status is an important component in order to determine potential effects of activities on habitat of recently proposed threatened fish under the Endangered Species Act.

Chinook and summer chum are currently proposed as threatened by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA), see table 2.6D. Conditions and ecological processes have changed from historical conditions. Channel reconstruction and alignment, changes in input and routing of sediment, large woody debris (LWD), and fish management action have all contributed to the changes in productive capacity of the drainages.

Methods & Data Sources

This module was completed by compiling data regarding the historic and present condition of the analysis area. Estimates of resident fish distribution were made using existing publications, local knowledge and likely gradient breaks in the streams. Data were gathered from county, state and federal agencies, the Point No Point Treaty Council, journal articles and local authors and residents. Key issues were clarified with local experts familiar with the streams. Historic conditions of riverine habitat and species assemblage were estimated from historic records, historic trends of nearby habitat, and anecdotal information. Limited field time was spent to familiarize the authors with river reaches of key concern and to verify main issues.

There were many contributors to this analysis module. Organizations and individuals consulted include Brian Winter of the Olympic National Park, Marty Ereth of the Skokomish Tribe; Charles Toal of the Washington State Department of Ecology; Byron Rot of Point No Point Treaty Council; Thom Johnson, and Paul Mongillo of the Washington State Department of Fish and Wildlife.

Information used from the various sources include recent basin analyses, government and tribal publications, stocking information, spawning survey data, local professional knowledge and limited field verification.

Hood Canal Salmon Management

In 1935 state initiative 77 closed the Hood Canal to commercial fishing, thereby creating a "salmon sanctuary." In 1973 state legislation allowed the director of the state Department of Fisheries to open previously closed waters to commercial fishing (Simmons 1997). In 1974 *US vs* Washington (Conen et al. 1986) affirmed indian rights by requiring all harvestable salmon be allotted equally between indian and non-indian fishers (Simmons 1997). After the court ruling, the Hood Canal Salmon Management Plan (HCSMP) was eventually developed and then approved by the courts in 1981.

A new HCSMP was court approved in 1986 and now forms the backbone of the cooperative state and tribal management. This document fits under the larger Puget Sound Salmon Management Plan dealing with production and harvest issues (Simmons 1997). Under the new plan, the Hood Canal is essentially managed as a "hatchery management zone." It directs managers to manage by aggregate escapement, that is looking at return numbers as a whole rather than on an individual stream basis (Simmons 1997). This hatchery management zone does not benefit escapement for wild fish for the Hood Canal (B.Winter, personal communication).

Hatchery practices have dominated the Hood Canal for many years. Hatcheries in the Hood Canal include George Adams, McKernan, Shelton, Eel Springs and Hood Canal (state facilities); Enetai and Little Boston tribal facilities; the Wild Salmon Restoration Facility (AKA Lilliwaup Hatchery, administered by Long Live the Kings); and the Quilcene National Fish Hatchery (USFWS). Net pen facilities include the state Sund Rock site; the cooperatively managed Glen Ayr, Hood Canal Marina, Hoodsport Marina, and Pleasant Harbor Marina; and the Point No Point Treaty Council facility in Quilcene Bay. Remote Site incubators are at six locations around the Hood Canal and are intended to help rebuild runs with minimal hatchery influence.

The Washington Department of Fish and Wildlife has used the Hood Canal hatchery complex (includes Hoodsport, George Adams, McKernan, and Eel Springs) as a major tool in fishery management of the lower Hood Canal. A memorandum of understanding with the local treaty tribes obligates the state to salmon production of a certain number and species composition. Up until recently the emphasis has been primarily on chum release. The hatchery complex emphasis is evolving now to a greater fall Chinook release (2.2 to 4.3 million 0 age) and a decrease in chum production. The evolution of the hatchery role in fish management is due in part to tribal agreements and a three year quarantine due to IHN infection at Hoodsport (which prohibits exporting any fish to freshwater). The Endangered Species Act listings will have the greatest effect on Hood Canal salmon management. Recent and forthcoming documents, including the Wild Salmonid Policy, stock status reports and species management plans will further shape the hatchery complex role in fish management of the Hood Canal.

General Reference Conditions

Habitat

Information on historic channel conditions is scarce. The general character of the drainage was that of a post-glacial valley dominated by western red cedar, Douglas-fir, western hemlock and hardwoods. The instream habitat in the steeper upper watersheds was likely made up of a complex combination of step pools and riffles created and stabilized by abundant Large Woody Debris (LWD), and most likely has not changed from historical conditions. The lower valley habitat of the Duckabush drainage flowed through glacial outwash and likely was characterized by abundant LWD, creating deep pools and off channel overwintering habitat. The LWD was a major habitat forming factor in the streams, providing for a stable streambed, energy dissipation, sediment retention and habitat diversity to meet species life stage requirements. The concentration of LWD may have been greater in some time periods more so than others given the relatively frequent natural and human-caused disturbances. There was likely frequent interaction between the streams and their flood plains, thereby minimizing flood damage in the riparian zone. The instream wood and intact riparian zone throughout the watersheds provided some hydraulic control for stream bed stability.

Species

Except for brook trout (*Salvelinus fontinalis*), it is likely that the fishes currently utilizing the aquatic habitat were also present prior to European colonization. Eastern brook trout exist in the main stem (Marty Ereth, personal communication) and headwater lakes. See map 2.6A for distribution of species within the analysis area.

Table 2.6A Fishes likely inhabiting the analysis area prior to European settlement. (Johnson, WDFW, personal communication).

Family	Genus - species	Common Name	Race	Comment
Cottidae	*Cottus aleuticus*	coastrange sculpin		
	Cottus asper	prickly sculpin		
Salmonidae	*Oncorhynchus keta*	chum	summer	wild populations
			late fall	wild populations
	Oncorhynchus kisutch	coho		
	Oncorhynchus mykiss	steelhead	winter	wild populations
			summer	wild populations
		rainbow trout	resident	
	Oncorhynchus gorbuscha	Pink		wild populations
	Oncorhynchus tschawytscha	Chinook	fall/sum	
	Oncorhynchus clarkii clarkii			
		cutthroat trout	searun	Little known/wild
			resident	

Fish Community

The fish diversity (see table 2.6A) in the analysis area prior to European settlement could be traced back to geologically-recent glacial events; events that have resulted in a relatively low diversity of ichthiofauna.. The most important aspect of the Pleistocene history of western Washington on fish distribution was the glaciation of the Puget Sound region (MacPhail 1967). The area under analysis was covered by the glacial ice up to a mile thick (USDA Forest Service Dungeness Watershed Analysis, 1995).

In ancient Lake Russell of the southern Olympics (MacPhail, 1967), freshwater lakes formed at the ice margins, providing refuge for freshwater species. With glacial retreat to present day Everett, a marine route for invasion by saltwater and estuarine species was opened. The actual route and origin of marine fishes in the immediate post-glacial period is secondary to the issue of stock distinction. This is of prime consideration in characterizing the uniqueness and thus genetic "value" of a population and the habitat that supports it. Ricker defines stock as "... fish spawning in a particular lake or stream (or portion thereof) at a particular season, which to a substantial degree do not interbreed with any group spawning in a different place or in the same place at a different season..."(Ricker, 1970).

Anadromous distribution prior to European settlement was likely similar to that of today. Stream gradient changes pose the main barriers. Resident fish range was also likely limited in the steeper gradients and reduced stream flows at the headwaters.

Fish Species Inhabiting the Area

Chinook

Chinook salmon are proposed as a threatened species under the Endangered Species Act, with a final listing decision due in February 1999. Total escapement for Hood Canal Chinook has generally been on the decline since 1968 with a notable peak in 1985. The total Hood Canal escapement in 1991 was 1823 fish (WDFW 1994).

Chinook are largest of the salmon species. They are found in the mainstem Duckabush River up to RM 13.2. A mature spawner can range from four to five years old (Groot and Margolis 1991). Redds are often 3.6 meters long and 30 cm deep with a female laying between 2,000 and 14,000 eggs. Eggs laid in the fall hatch in the early spring (Groot and Margolis 1991). In fresh water the juveniles are opportunistic drift feeders; adults feed primarily on fish in the marine environment (Moyle 1976). As the juveniles grow, they gradually move out into swifter water, to enter the marine environment after several months.

Chum Summer and Late Fall

Summer chum are currently proposed as threatened under the Endangered Species Act, with a final listing decision expected in January of 1999. Genetic studies show that the Hood Canal and Juan de Fuca summer chum salmon are distinguishable from other Northwest chum salmon stocks (WDFW 1995). Summer chum are in the Hood Canal/Strait Evolutionally Significant Unit (ESU) while the late fall chum are considered part of the Puget Sound ESU.

Hood Canal summer chum spawn from early September to late October and late fall chum spawn from mid-November to mid-January (WDFW and WWITT 1994). Juvenile chum salmon spend little time in fresh water, from a matter of days to weeks, before migrating to salt water. They usually occupy the lower most sections of anadromous habitat, not extending beyond barriers that are easily passed by other salmon. Chum in the Duckabush emerge from the gravel from late December to early March and outmigration starts in March and goes through April (Telles personal communication 1998). They leave the gravel when they reach 30-35 mm. Some populations of juvenile chum spend several months in the estuaries (Groot and Margolis 1991). The chum spend close to four years at sea before returning to their natal stream to spawn, die and regenerate the cycle

Coho

According to the NMFS, coho are not currently listed under the ESA but are part of a vulnerable Evolutionally Significant Unit and may be a future candidate for listing. Although stock-specific information is not available, wild coho salmon in the Duckabush are managed secondary to Hood Canal hatchery stocks, that only those fish that survive hatchery harvest rates escape to spawn. Overall, harvest rates are a limiting factor for this coho stock (WDFW and WWITT 1994). Coho escapement for the Duckabush River has declined since 1981 (1,682 fish) with a the lowest escapement in 1989 (97 fish). The most recent data in the SASSI inventory shows 566 fish returning in 1991 (WDFW 1994).

Coho females lay 1,000 to 5,000 eggs, depending on their size. The eggs hatch in eight to twelve weeks and the fry emerge from the gravel four to ten weeks later, depending on the water temperatures (Groot and Margolis 1991). The fry school in the shallow stream margins, feeding on a wide variety of small invertebrates. As the fish grow, individuals will establish territories. This territory is characteristically quiet backwater or off channel areas in winter and main stem pools during summer. Young coho are voracious feeders, ingesting any organism that moves or drifts through its territory. A major part of their diet is aquatic insect larvae and terrestrial insects; small fishes are taken when available (Groot and Margolis 1991). After the first year in fresh water, the amount of suitable habitat for the growing fish becomes limited, and the parr start to smolt in preparation to go to sea. At sea, coho are pelagic and prey mostly on other fishes (Groot and Margolis 1991), returning usually in two years to their native stream to spawn, die and start the cycle again (Winter, personal communication 1998).

Pink

Pink Salmon are not currently listed under the Endangered Species Act. The Duckabush Pink escapement increased slightly from 1967 (70,000 fish) to 1991 (72,000 fish) with significant declines in the 1970's and early 1980's (lowest return of 2,300 in 1981) (WDFW 1994).

Pink salmon spawn in the secondary and side channels of large rivers, as well as moderately sized rivers (Winter personal communication 1998). The male has the distinctive hump on its back, giving the nickname "Humpies" to the species. The stocks in the analysis area, as in nearly all Puget Sound rivers, spawn only in odd numbered years, thus defining their life history to two years. The female spawns in gravel of a moderately sized stream and the eggs hatch in four to six months. Most of the life cycle is in salt water as the fry head straight out to the marine environment after absorbing the yolk sack and subsequently emerging from the gravel (Moyle 1976). The fry school in estuaries for several months before finally going out to sea (Moyle 1976).

Steelhead Summer and Winter

There is no escapement data for summer steelhead escapement. Winter Steelhead escapement data in the Duckabush reflects 5 years' data showing a range of 10 to 42 fish with 22 returning in 1992 (WDFW 1994). Cooper and Johnson (1992) examined trends in steelhead abundance in Washington and found an overall decline. They used sport harvest data to provide the best indication of long-term abundance trends, finding an overall recent decline beginning in 1985, with the 1990-91 harvest being the lowest on record since 1962. Cooper and Johnson (1992) provides a comprehensive review and discussion of factors likely responsible for declines in abundance of steelhead. An assessment of genetic conservation management units for Washington steelhead is presented by Leider et al. (1994) and Leider et al. (1995).

Steelhead are the anadromous form of rainbow trout. Aside from their sea going habit and large size at spawning, there is little to distinguish them from the resident rainbow. Winter steelhead utilize the analysis area for juvenile rearing and adult spawning. Like other salmonids, the steelhead female digs the redd in a riffle. The number of days from egg deposition to first emergence of winter steelhead fry from the gravel in Snow Creek averaged 62 days with 50 percent of emergence occurring by 71 days; it is likely similar in the Duckabush system. Emergent winter steelhead fry are an average 30 mm in length and 0.21 g in weight. The fry initially live in waters close to shore. Unlike the salmon, the steelhead can spawn more than once in a lifetime, and it is not unusual for a fish to skip a year between spawning. About 5-25% of the steelhead in the Hood Canal are repeat spawners, mostly females (T.Johnson, personal communication).

Freshwater habitat in many of the drainages has been impacted by forest management (WDFW and WWTIT 1994), often resulting in decreased spawning habitat quality, as well as increased runoff, flood frequency and downstream erosion.

Resident Rainbow

Resident rainbow trout often have the reddish band along the side from which their name is derived. They are easily distinguished from salmon by the presence of spots on the dorsal fin and fewer than 13 anal fin rays. Unlike their anadromous form, steelhead, they reside in freshwater their entire lives. They are distinct from cutthroat in that they lack the yellow or red slash mark under the jaw.

Rainbow prefer highly oxygenated water less than 70 degrees F (Wydoski et. al 1979). They normally spawn in the spring, with most maturing at 3 years of age (Wydoski et al 1979). Much like other salmonids, the female rainbow digs a redd, producing at least 200 eggs (Wydoski et al 1979). Food items are associated primarily with bottom dwelling organisms, including aquatic insects, amphipods, aquatic worms, and fish eggs. An occasional small fish is consumed (Wydoski et al 1979).
The upper extent of resident fish distribution in the Duckabush River is estimated for this watershed analysis. Stream slopes less than 20% are considered to provide fish habitat until such time as a survey can refine our knowledge of the drainage.

Cutthroat

Little is known about the status of cutthroat in Hood Canal. Naturally small sea-run cutthroat populations are present in most small creeks along with coho. A proposed ruling for the species on the west coast is expected December 1998.

Studies by Michael (1983) suggested that resident and anadromous cutthroat populations in Salmon Creek are reproductively separate. Anadromous cutthroat trout in Snow and Salmon Creeks are late-entry, entering freshwater in winter or spring. This timing in Puget Sound is usually associated with small, independent drainages (Michael 1989). Michael also suggests that regulation can maintain the carrying capacity for cutthroat smolt production by allowing the population to spawn once prior to harvest. Resident salmonids sympatric with the anadromous cutthroat may displace or replace anadromous stocks if the searun stock declines (Michael, 1989). Resident cutthroat trout spawning behavior is similar to other trout species. Each female, depending on her size, lays 400 to 4,000 eggs. Each fish may spawn up to five times in its lifetime (Moyle 1982). The eggs hatch in six to eight weeks, and the fry begin feeding about two weeks after hatching. Sea-run cutthroat rear in Snow and Salmon Creeks for one, two, or three years before smolting and migrating to salt water; the pattern may be similar in the Duckabush.

Coastrange Sculpin

Typically, coastrange sculpins are found in swift gravel riffles in the lower reaches of the larger coastal streams but they can also inhabit the brackish quiet water of stream mouths, on bottoms ranging from mud to sand to coarse gravel (Moyle 1976). Coastrange sculpin are most active at night and, except during breeding season, usually exhibit little social behavior (Moyle 1976). Coastrange sculpin feed primarily on aquatic insect larvae and other benthic invertebrates. They also feed on salmon eggs and fry when readily available, however, it is doubtful that this predation has much effect on salmon populations (Moyle 1976). Coastrange sculpin mature during their second or third year and usually spawn in early spring (Wydoski and Whitney 1979). Some females may have two separate spawning periods (Moyle 1976). The usual spawning site is the underside of a flat rock in swift water, to which clusters of orange eggs are attached. Immediately after hatching, sculpin larvae are carried by current into estuaries, lakes, or large pools where they live on and among the plankton for three to five weeks; once they assume a bottom existence they gradually move upstream (Moyle 1976). The potential range of the coastrange sculpin extends up the western coast of the Hood Canal, and are found up to the elevation of 700 ft in the Duckabush (Mongillo, personal communication).

Prickly sculpin

Few fishes occupy the wide range of bottom habitats occupied by prickly sculpin populations. They live in waters ranging from fresh to salt, in streams ranging from small, cold and clear to large, warm, and turbid (Moyle 1976). Prior to spawning, prickly sculpin move into areas, in either a freshwater or intertidal zone, that contain large flat rocks and a moderate current (Moyle 1976). Males frequently spawn with more than one female, so as many as 25,000 to 30,000 eggs have been found in one nest (Moyle 1976). The young of the prickly sculpin are pelagic for 30 to 35 days (Wydoski and Whitney 1979). Prickly sculpin primarily feed on benthic organisms such as crustaceans and immature aquatic insects (Wydoski and Whitney 1979). Within the analysis area, the prickly sculpin has a similar distribution to that of the coastrange sculpin, however the prickly sculpin do not extend as far up the drainages as does the coastrange species (Mongillo, personal communication).

KEY QUESTIONS

1) What is the distribution and stock status of fish in the analysis area? What migration barriers exist for fish?

Fish Distribution

- Twelve fish species are present in the analysis area, see Table 2.6C and 2.6D
    - Six anadromous fish species are present
- Most of the fish distribution is likely the same as in historical times, defined by geologic barriers for anadromous species and steep headwater reaches for resident species (T.Johnson, personal communication.).
- There is a total of 13.2 miles of anadromous habitat and 61 miles of resident habitat within the analysis area. See table 2.6B for stream miles utilized by anadromous and resident fish.
- Except for brook trout, it is likely that the fishes currently utilizing the aquatic habitat were also present prior to European colonization.
- See map 2.6A for distribution of species within the analysis area.
- Non-native salmonids including brook trout have been planted in high elevation lakes.
    - Historically, lakes were not fish-bearing.

Table 2.6B Miles of utilized habitat. Length of stream utilized by anadromous and resident fishes in the Duckabush river. One or more life stages of resident fishes assumed to be present through anadromous stream reaches.

Subwatershed	Anadromous Fish Use (miles)	Exclusive Resident Fish Use (miles)
Lower Duckabush	10.2	0
Murhut/Cliff	3.0	25.2
Middle Duckabush	0	23.8
Crazy Creek	0	12.4
Upper Duckabush	0	27.6
Headwater Duckabush	0	12.4

Table 2.6C Fish Distribution

Species	Lower Duckabush	Murhut/Cliff Creek	Middle Duckabush	Crazy Creek	Upper Duckabush	Headwaters Duckabush	Lakes
*coho	●						
chum late fall	●						
*chum summer	●						
*Chinook fall/ summer	●						
pink	●						
steelhead winter	●						
steelhead summer	●						
resident rainbow	●	O	O	O	O	O	
*searun cutthroat	●						
resident cutthroat		O	O	O	O	O	
coastrange sculpin	●						
prickly sculpin	●						
eastern brook							O

*** = On USFS Regional Forester's Sensitive Species List**
● Documented habitat utilization
O Suspected habitat utilization

Stock Status

- The status of anadromous fish stocks in the analysis area varies relative to the defining publication and delineation of the population characteristics. The following stock evaluations are considered:
    - *Washington State Salmon and Steelhead Stock Inventory* (WDFW and WWITT 1994), referred to as SASSI.
    - *Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho and Washington* (Nehlsen, et al. 1991).
        - Fall Chinook are considered to be at a high risk of extinction
        - Hood Canal early timed(summer) chum are considered to be at a moderate rate of extinction
        - Hood Canal Sea-run cutthroat trout are of special concern
- National Marine Fisheries Service proposed designation of Puget Sound Spring Chinook and Hood Canal Summer Chum as endangered under the Endangered Species Act (February 1998).
- The stock status of populations in the analysis area is summarized in table 2.6D. The status under the Endangered Species Act listing procedure is also presented within this table.
- The US Forest Service Region 6 sensitive species list was updated in August 1997 to include several anadromous fish stocks within the analysis area (see table 2.6D). This status requires that all Forest Service activities within the watersheds occupied by these fish (table 2.6C) must be reviewed to determine if the activity would likely result in a trend toward federal listing or loss of viability of these stocks. The review and determination will be recorded in National Environmental Protection Act (NEPA) documentation and/or Biological Evaluation (BE). The activity need not be within the habitat range of the species. The National Marine Fisheries Service (NMFS) matrix (see appendix 1) is the best tool for making this determination.

- Hood Canal summer chum are considered to be at the greatest risk of extinction. The US Fish & Wildlife Service, Washington Department of Fish & Wildlife, and Western Washington Indian Treaty Tribes since 1992 have been involved with a recovery brood stock program for summer chum (Telles and Wong personnel communication).
- Anadromous fish passage has not changed from historical conditions.
- Due to time constraints field verification of potential resident fish blockages was not possible.

Table 2.6D STATUS OF ANADROMOUS FISHES IN THE ANALYSIS AREA SUMMARIZED FROM PUBLISHED REPORTS

	WDFW and WWITT 1994 (SASSI)			USFS Region 6 SSL		
Stock/Race	**Stock Origin**	**Production Type**	**Stock Status**	**Species Classification**	**Evolutionary Significant Unit (ESU)**	**ESA Listing Status ***
Chinook, Summer/Fall -Hood Canal	Mixed	Composite	Healthy	Sensitive	Puget Sound	Proposed rule threatened
Chum, Summer -Hood Canal	Native	Wild	Critical	Sensitive	Hood Canal	Proposed rule threatened
Chum, Late Fall Duckabush	Native	Wild	Healthy	NM	Puget Sound	Presently petitioned
Coho Duckabush	Mixed	Wild	Depressed	Sensitive	Puget Sound/ Str. Georgia	Candidate
Pink Duckabush	Native	Wild	Healthy	NM	Puget Sound	Presently not warranted
Steelhead, Winter Duckabush	Unresolved	Unresolved	Depressed	NM	Puget Sound	Presently not warranted
Steelhead Summer Duckabush	Unresolved	Unresolved	Unknown	NM	Puget Sound	Presently not warranted
Cutthroat, searun	NM	NM	NM	Sensitive		Proposal due Jan., 1999

SASSI definitions

Stock Origin:

Native - An indigenous stock of fish that has not been substantially impacted by genetic interactions with non-native stocks, or by other factors, and is still present in all or part of its original range. in limited cases, a native stock may also exist outside of its original habitat (e.g. captive brood stock programs).

Mixed - A stock whose individuals originated from commingled native and non-native -a stock that has become established outside of its original range-parents, and by mating between native and non-native fish (hybridization); or a previously native stock that has undergoes substantial genetic alteration.

Unresolved - There is insufficient information to identify stock origin with confidence.

Production Type:

Wild - A stock that is sustained by natural spawning and rearing in the natural habitat, regardless of parentage (includes native).

Composite - A stock sustained by both wild and artificial production

Unresolved - There is insufficient information to identify production type with confidence

Stock Status:

Healthy - A stock of fish experiencing production levels consistent with its available habitat and within the natural variations in survival for the stock.

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

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

Unknown - There is insufficient information to identify stock status with confidence.

SSL= Sensitive Species List

Sensitive - Status given by the Regional Forester to species for which population and habitat are currently and predicted to have a downward trend (FS Handbook 2670-2671, p. 11).

NM - Not Mentioned In Text.

* Subject to change

Current Conditions

Habitat

- In general, the middle and lower watershed is affected by forest management activities and the associated roading while the lower reaches near the canal are developed with sporadic houses and small communities. Most of the fish distribution is likely the same as in historical times, defined by geologic barriers for anadromous species and steep headwater reaches for resident species.
- Forest practices and associated roading often contribute to limiting upstream passage and a change in flow regime. Culverts may create a fish passage barrier for resident fish migrating upstream to spawn. Because of the cursory level of analysis, resident fish blockage due to culverts was not investigated.
- While extreme flows are not considered to be a problem on the Duckabush (R.Stoddard, 1998), a change in flow regime is typified by greater extremes in summer and winter that reduces the productive capacity. Extreme low flows in summer result in stressful temperature increases and stranding of fish. Extreme high flows in winter can flush out juveniles and produce an environment that reduces suitable holding areas for returning adult spawners. Increased sediment can suffocate eggs in the gravel and increased aggredation associated with high energy flows can scour redds, killing the eggs (Table 2.6E).
- It is not possible to determine the relative contribution of boulder created fish habitat in the pre-settlement era since no stream data is available from that time period. Lack of large woody debris in some stream reaches today has resulted from intense logging efforts and related fires since the 1850's as well as the Washington Department of Fisheries Stream Improvement Division stream cleaning efforts from 1951 thru 1971 (Amato 1996).
- The concentration of LWD may have been sporadic over the centuries given the relatively frequent natural and human-caused disturbances. There was likely frequent interaction between the streams and their flood plains, thereby minimizing flood damage in the riparian zone. The instream wood and intact riparian zone throughout the watersheds provided some hydraulic control for stream bed stability, thereby withstanding high flow events with less damage than we see today in the areas prone to mass wasting.

- The elimination of the largest of trees within the riparian area can deprive a river system of the stabilizing mechanism needed to produce alluvial channels; habitat which is hospitable to aquatic life. The elimination of such structure, or its future recruitment will convert these alluvial channels into bedrock reaches (Montgomery, et al 1996). This may be the case for the rock dominated reaches in the analysis area.
- A review of the gradient profile (see Channel module) locates the transportational and response reaches. This analysis helps determine the primary function of the channel as it relates to sediment and, in a much more general way, large in-channel wood. It ties together the flow of energy and materials from the headwaters to the anadromous lowlands. This analysis helps evaluate the vulnerability valuable habitat by locating beneficial or degraded habitat connected by transport reaches.
- Response reaches within the Duckabush include the anadromous habitat within the first 13.2 miles and three other sections within the resident habitat. The remaining reaches within the watershed are either source or transport reaches.
- Analysis of the riparian condition within and between transport reaches allows the connectivity to be ascertained. The connectivity is dependent upon the location of unstable slopes and large woody debris relative to these reaches. Streams that, by nature, have intermediate low gradient or response reaches have less tendency to transport material all the way downstream as opposed to streams whose response reach is limited to the lowest most reach.
- The significance of locating transport and deposition reaches is more pertinent to sediment as opposed to LWD due to the character of the headwater valleys. The many branches of the drainage that make up the headwaters are narrow, often narrower than the length of wood within the stream or in the riparian zones. The net result is that wood from the headwaters, despite being in a transport reach, does not travel far from its recruitment site and therefore contributes little to downstream LWD concentrations.
- Determining whether unstable slope areas and, to some extent, LWD recruitment sites are in transport or depostional areas can help us establish the degree of potential positive or negative impact to downstream habitat. This information can also prioritize and locate restoration efforts as well as avoid potential future degradation.
- The extent of habitat connectivity within a watershed is mirrored by the degree of downstream consequences from a ground disturbing upstream activity. For example, intensive logging and road construction likely has contributed to increased runoff, sedimentation, and bedload instability in the lower watersheds.
- For anadromous salmonids both habitat conditions and reduced spawning populations (escapement) are interacting in complex ways to limit production.
- In subwatersheds with management histories, there appears to be some simplification of habitats through inputs of coarse and fine sediment, coupled with reduced inputs and decay of key pieces of LWD.
- Spawning populations of Chinook, chum, coho, pink salmon and steelhead trout are controlled by complex interactions of smolt production, ocean conditions, management of in river populations, artificial production programs, and ocean fisheries.

Table 2.6E. Watershed processes affecting salmonids and their stream habitats.

Watershed Process	Affected Species and Life Stage
Simplification of habitats through reduction of LWD recruitment and removal of instream LWD.	All species and freshwater life stages are affected by the lack of LWD. Primary loss is lack of deep pools, hiding and rearing habitat, and spawning ground creation.
Routing and in-channel storage of course and fine sediments from mass-wasting and surface erosion. Result is decreased pool volume and increased pool spacing. In some subwatersheds secondary mass-wasting and/or bank erosion from channel adjustments is observed. Effect is exacerbated by reductions in LWD.	Impacts include detrimental affects on incubating eggs with decreased survival to emergence. Decreased pool volume and increased spacing impairs habitat capability for summer rearing juveniles (coho and steelhead) and resident fish. Conversely, increased riffle habitat may favor the surviving young-of-year steelhead and cutthroat.
Alteration of stream saltwater interface	In the case of blocked or diverted streams, habitat is lost for all species and life stages.

Table 2.6F. Locally significant habitat

Sub-watershed	River Reach	Length (miles)	Conditions
Lower Duckabush	Anadromous habitat	up to RM 13.2	Supports greatest diversity of anadromous fishes

Site-Specific Recommendations

The specific recommendations suggested in this module are not based on results of the key question, but rather issues brought up during synthesis. There are some opportunities to decommission roads that either currently contribute sediment to the aquatic ecosystem or have the potential to do so.

- Unofficial roads on National Fores Lands that remain open by use but receive no maintenance are informally referred to as "ghost roads." The closure of two of these roads off FS Road 2510 (T25N, R03W, Sec 2 & 3) would benefit water quality within anadromous habitat. These roads are a direct sediment source into the anadromous reach of the Duckabush.
- Water quality in Murhut Creek would benefit from the decommissioning of FS Road 2530 and its 016 spur.

Unanswered Key Questions

Due to lack of stream survey data, the level of resolution desired for the fish module was not achieved. Most of the analysis was based on existing data with little to no field verification. Key questions that were not addressed in this iteration, but are important in the authors' viewpoint include:

- What are current trends of aquatic habitats?
  - How has complexity of instream habitat changed from historical conditions?
  - What and where are the features that provide instream structure and what processes deliver them?
  - What changes have occurred in input and routing of these structures?
- What biological processes are affecting fish populations?
  - What role does the watershed play in providing for conservation or recovery of the fish species of concern?

Monitoring Recommendation

Conduct stream surveys within the Duckabush River watershed. The priority should be to survey the anadromous reachs first, followed by the non-anadromous reaches for all streams within the watershed.

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2.7 RIPARIAN

INTRODUCTION

Riparian areas are portions of land with vegetation directly influenced by aquatic systems such as rivers, streams, wetlands, or floodplains. Riparian vegetation in turn, directly influences its associated aquatic system both biologically and physically. Commonly, riparian areas form linear corridors along or around their associated aquatic systems, and riparian vegetation may occur in wetlands or on uplands. Typically, riparian areas cannot be clearly delineated, but grade gradually between terrestrial and aquatic systems.

Riparian areas function to:

- regulate nutrient exchange between terrestrial and aquatic systems;
- recruit large woody debris (LWD) to stream channels;
- moderate light and temperature effects to streams and streamside corridors;
- stabilize streamside banks and soils;
- attenuate stormwater flows;
- maintain water quality; and
- contribute organic materials to the food web base.

In addition, riparian areas provide habitat for various plant and animal species, particularly riparian dependent fauna such as certain species of arthropods, amphibians, birds, and mammals. See Appendix 2.7, table B-6 for a listing of species.

Large woody debris is a focal point of riparian functions and processes and therefore the potential for its recruitment is a key element of analysis for the riparian module, when applying watershed analysis methods. Large woody debris is integral to developing certain channel features and complexity such as pools, steps, roughness, and diversity of velocity. These features are fundamental to the formation of aquatic species habitat, sediment and biomass storage, and ultimately channel stability.

Reduction in the distribution, quantity, and size of coniferous large woody debris (which endures as LWD appreciably longer than deciduous LWD), results in:

- channel simplification with attendant loss or degradation of instream habitats;
- loss or degradation of storage potential for water (in pools), for sediment (in wedges),
- and for biomass (behind LWD); and
- loss or degradation of riparian vegetation which contributes to bank stability from root strength,
- materials for use in customary Tribal uses, food web support by the input of insect and detrital matter,
- primary and secondary fish and wildlife habitat, and thermal regulation at both the stream
- temperature scale as well as at a microclimatic level.

Other functions, processes, and resources yet unrecognized may also be affected.

Federal land management directives provide for special protection of riparian areas, as increasingly do local governments through sensitive area ordinances. Analysis of past and present riparian area conditions, in combination with other watershed elements, is necessary to guide riparian area management, restoration, and monitoring in the context of ecosystem management. Therefore, this riparian module integrates a number of watershed elements including vegetation, wildlife, fish, channel morphology, mass wasting, water temperature, hydrology, public works, and cultural uses. All of these watershed elements influence, or are influenced by, riparian area function. Information from this riparian module should thus be utilized in determining riparian area regulation and management.

METHODS

Application of Federal Riparian Reserves

Riparian Reserves are a network of corridors closely coupled with streams, rivers, and lakes including intermittent channels, wetlands and unstable areas, where riparian-dependent resources receive primary emphasis. The ROD's Standards and Guidelines (C30 - C38) prohibit and regulate activities in Riparian Reserves that may prevent or retard attainment of the Aquatic Conservation Strategy (ACS) objectives (B11) as referenced in the ROD (C31).

Riparian Reserves are one of several strategies to maintain and restore riparian structure and function, confer benefits to riparian-dependent and associated species other than fish, enhance habitat conservation for organisms that are dependent on the transition zone between upslope and riparian areas, improve travel and dispersal corridors for many terrestrial animals and plants, and provide for greater connectivity of the watershed. (ROD B13).

Interim widths were identified in the ROD. Table 2.7A describes criteria to determine such interim widths. No proposed changes to these criteria are recommended by the Duckabush Watershed Analysis. To meet the Aquatic Conservation Strategy and objectives for all riparian dependent species it was felt that maximum widths were necessary to protect aquatic resources including intermittent channels. At this time, there is so little known about some of these species that the determination to minimize widths or to delete a portion of the reserve network is not supported by the knowledge base.

Table 2.7A Criteria for defining interim Riparian Reserves[1].

CATEGORIES	WIDTHS
Fish-bearing streams	Consists of the stream and the area on each side of the stream extending: • from the edges of the active stream channel to the top of the inner gorge; or • to the outer edges of the 100 year floodplain; or • to the outer edges of riparian vegetation; or • distance equal to the height of two site potential trees; or • 300 feet slope distance (600 feet total); whichever is greatest.
Permanently flowing, non-fish bearing streams	Consists of the stream and the area on each side of the stream extending: • from and includes the active stream channel to the top of the inner gorge; or • to the outer edges of the 100 year floodplain; or • to the outer edges of riparian vegetation; or • to a distance equal to the height of one site potential tree; or • 150 feet slope distance (300 feet total); whichever is greatest.
Constructed ponds, reservoirs, and wetlands >1 acre	Consists of the body of water or wetland, and: • the outer edges of riparian vegetation; or • the extent of seasonally saturated soil; or • the extent of unstable area and potentially unstable areas; or • to a distance equal to the height of one site potential tree; or • 150 feet slope distance from the edge of the wetland greater than 1 acre or the maximum pool elevation of constructed ponds and reservoirs; whichever is greatest.
Lakes and natural ponds	Consists of the body of water and: • the area to the outer edges of riparian vegetation; or • to the extent of seasonally saturated soil; or • to the extent of unstable and potentially unstable areas; or • to a distance equal to the height of two site potential trees; or • 300 feet slope distance; whichever is greatest.
Seasonally flowing or intermittent streams, wetlands less than 1 acre, and unstable and potentially unstable areas	Consists of areas which include: • the extent of unstable and potentially unstable areas including earthflows; or • the stream channel, extending to the top of the inner gorge; or • the outer edges of riparian vegetation; or • the distance equivalent to one site potential tree; or • 100 feet slope distance; whichever is greatest.

The following methodologies for site potential—tree height, slope distance, and slope stability—were established for consistent application of width criteria within this watershed.

[1] No changes to these criteria are proposed by this analysis.

Site Potential Tree Height

The use of site potential tree heights as a unit of measure for determining the width of the riparian reserve is suggested by FEMAT and the ROD. FEMAT provides discussion and rationale for using multiples of tree heights (FEMAT, V-26 - V-30). Interim guidelines (Table 2.7A) were applied using the following methodology:

The height growth potential for a site was determined by constructing growth curves for Plant Association Groups. Plot data from the Ecology Program was used to construct these curves. Plant Association Groups were delineated using the Potential Natural Vegetation (PNV) model which produces a pixel based map based on site characteristics expected to produce conditions for a particular group of plant associations (see Map 2.7B). This map was converted to PAG polygons. For the purposes of this analysis, all polygons of a given PAG were treated as having the same height growth potential.

Height growth curves for each PAG were constructed by Jan Henderson, Area Ecologist. Curves were carried out to 600 years where they are flat. The height corresponding to 95% of the 600 year potential was selected from each curve as the site potential to be used in constructing the Riparian Reserve boundaries. Table 2.7B contains the heights and the age that height is attained for each PAG in the Duckabush watershed.

Table 2.7B Height and Age Relationship to PAG.

PLANT ASSOCIATION GROUP	95% OF 600 YR HEIGHT	AGE AT 95% OF 600 YR HEIGHT	Range of Site Index (base 100)
WESTERN HEMLOCK SERIES			
1902 PACIFIC RHODODENDRON	115	243	82-108
1903 DRY SALAL	142	211	86-139
1906 MESIC SALAL-OREGON GRAPE	173	178	95-165
1907 MOIST SWORDFERN	201	223	166
1910 DEVILS CLUB	141	248	151-188
SILVER FIR SERIES			
2201 PACIFIC RHODODENDRON	141	258	113-128
2202 SALAL-OREGON GRAPE	162	258	113-143
2203 ALASKA HUCKLEBERRY DRY	147	239	94-145
2204 BIG HUCKLEBERRY-BEARGRASS	135	421	79-85
2209 DEVILS CLUB	147	197	121-123
MOUNTAIN HEMLOCK SERIES			
2304 BIG HUCKLEBERRY MESIC	102	407	<90
2305 ALASKA HUCKLEBERRY	111	354	<90

Slope Distance Measurement

The ROD specifies distances measured in slope distance for interim widths. For this analysis, measurements were made in horizontal distance. Horizontal distance more closely meets the criteria for including the top of the inner gorge within the Riparian Reserve boundary.

Unstable or Potentially Unstable Slopes

Geomorphic Terrains were delineated based on similar landform processes. Each Terrain has been observed to have unique properties in transporting or collecting water, sediment and wood debris. A chronological sequence of aerial photography was examined over 40 years of forest management to determine response to management activities. Terrains with observed natural instability and those responding to management contrary to meeting the objectives of the Aquatic Conservation Strategy (ACS) are included in the proposed Riparian Reserves.

To assure meeting the ACS, the appropriate team of experts (e.g. hydrologist, geologist, geotechnical specialists, soil scientist) is needed to provide site specific interpretations for what and where activities can take place.

Issues to examine include: vegetative-hydrologic recovery, acceleration of surface runoff, decrease of root strength and other slope instability factors, subsurface hydrology, soil erosion and deliverability, sediment routing, potential for LWD recruitment, and proximity to locally significant aquatic habitats.

Geomorphic Terrains are identified on Map 2.3B Channel Geomorphic Units. Table 2.7C displays those terrains included in Riparian Reserves. Some Terrains have only a small percentage of land area included, usually limited to steep (>70% slopes), concave areas and stream channels while in other Terrains, hydrologic response and slope stability are interconnected requiring the entire Terrain to be included in the reserve. Site level analysis for project development will need to consider not only the area within the zone of sensitivity but also the adjacent area's contribution to this sensitivity. A Mass Wasting Hazard Map, (Map 2.4A) represents the areas limited to slope instability for further clarification.

Table 2.7C Geomorphic Terrains included in Riparian Reserves.

Geomorphic Units	LandTypes	Geomorphic Mapping Units
64	Alluvial Valley Bottom	64
71	Deep-seated Landslides/Slumps	71
72	Existing landslides/slumps	72
77	Convergent Headwalls	77
78	Debris Tracks	78
91	Inner Gorges	91

Similar to protection of interior microclimates of riparian with adequate width, treatment of the boundaries of unstable and potentially unstable areas are as important as within the unstable area. Traditionally, boundaries have been drawn along slope breaks. For example, sharp edges in many cases may not adequately protect from windfall of stabilizing vegetation or be adequate to address changes in slope hydrology. These site specific determinations should be made in the field using the Geomorphic Terrain concepts of inherent physical processes as a guide (e.g. convergent drainage's with flashy surface runoff, compacted sub-layers producing springs at slope breaks, presence of bedrock hollows, stream action undercutting toeslopes, etc.).

Identification of Riparian Reserve Boundaries in the Field

Map 2.7A displays the proposed riparian reserves for the Duckabush watershed. This map was produced at 1:24,000 scale. Map delineation's only approximate the riparian reserve and this map should only be used for display purposes.

Boundaries are to be identified in the field during site-level analysis. The following list is not inclusive but should serve to highlight some of the steps in field identification of final Riparian Reserve boundaries.

- Determine site-potential tree height, using either of the following methods:
    1. Use tree height from surrounding or adjacent old growth stands, or
    2. Use heights as established for the appropriate PAG.

- Locate boundaries of Geomorphic Terrain Map Units using the map unit descriptions and basic concepts of sediment and hydrologic flow identified by these units.

- Use slope breaks as a starting point for boundaries and further refine with local observations on slope instability or potential for instability and wind-throw risk.

- Locate all perennial, intermittent and ephemeral streams. Use local knowledge, stream survey data, and "fish-bearing" guidelines to riparian reserve widths, see map 2.6A. Intermittent and ephemeral streams may or may not be flowing water at the time of field work. Look for a defined channel, riparian vegetation, signs of vegetation that are laid downslope from water flow, deposition of sediment and intermittently exposed soil pipes as indicators of these seasonal or infrequently flowing streams.

- Locate wetlands, ponds, reservoirs and seeps. Identify hydrologic network between wetlands when they are in close proximity.

- Apply the widest width according to this priority:
  1st Priority -- slope stability
  2nd Priority -- site tree potential measured by slope distance.

There are a total of 16,594 riparian acres within the Duckabush watershed analysis area as displayed in table 2.7D. Riparian areas by ownership and by subwatershed group totals are displayed in table 2.7E. There are a total of 50 miles of road, as displayed in table 2.7F, within the designated riparian area. For the purpose of this analysis all ownership riparian calculations were based on riparian criteria specific to the ownership.

Table 2.7D Riparian acreage by Subwatershed Group

NUMBER	SUBWATERSHED GROUP NAME	ACREAGE
01	Lower Duckabush River	3,877
02	Murhut & Cliff Creeks	4,303
03	Middle Duckabush River	4,087
04	Crazy Creek	1,696
05	Upper Duckabush River	1,606
06	Headwaters Duckabush River	1,025
	TOTALS	16,594

TABLE 2.7E Riparian acreage by Ownership

Ownership	Sub-Watershed Group	Acres	Totals
Olympic National Forest	Lower Duckabush	2,147	2,147
	Middle Duckabush	503	2,650
	Murhut/Cliff	4,303	6,953
Sub-totals		6,953	
Olympic National Park	Crazy Creek	1,696	1,696
	Headwaters Duckabush	1,025	2,721
	Middle Duckabush	3,583	6,304
	Upper Duckabush	1,606	7,910
Sub-totals		7,910	
Private	Lower Duckabush	1,305	1,305
Sub-totals		1,305	
State	Lower Duckabush	424	424
Sub-total		424	
Totals		16,592	16,592

Table 2.7F amount of road within riparian by sub-watershed group in miles

Subwatershed Group	Ownership	Miles
Lower Duckabush	Private	7
	State	0
	Olympic N. F.	4
Sub-total		11
Murhut	Olympic N. F.	6
Sub-total		6
TOTALS		17

KEY QUESTIONS

What was the riparian area's forest composition historically?

Historically, the riparian area's forest composition had a greater abundance of tree species diversity and late succession vegetation. In particular, a greater array and abundance of conifers were present in riparian areas, in association with Sitka Spruce Series and Western Hemlock Series PNVs. Fire and wind events were minor determinants of landscape level vegetation patterns, homesteading and timber harvesting were the major determinants of late succession riparian vegetation. Remote areas in the upper portion of the watershed remain unchanged due to human activity and serve as riparian refugia for both plant and animal species.
For a more complete discussion see Vegetation module 2.8.

What is the riparian area's forest composition currently?

In response to Federal needs, the current riparian area forest composition is identified ecologically and best represented by Map 2.7A and Table 2.7H, Proposed Riparian Reserves, which identifies approximately those areas which will comprise the Federal Riparian Reserve system within the Duckabush watershed. These approximate boundaries include both riparian forest and associated areas which affect riparian area processes and functions. ROD criteria used in determining Riparian Reserve interim widths are displayed in Table 2.7A.

In general, the riparian area forest's species diversity, abundance, and size is reduced compared to conditions which existed prior to Euro-American settlement. That is, the number and distribution of tree species within the Sitka Spruce Series and the Western Hemlock Series have become dominated largely by red alder, western hemlock, and Douglas fir. Sitka spruce and western red cedar are greatly reduced in number, distribution, and size, in riparian area forests.

Currently and historically riparian hardwoods tend to be in the watershed lowlands, particularly along river terraces, toeslopes, and floodplains of the mainstem river and its major tributaries, although an abundance is currently located along old road systems and landings from previous ground disturbance activities. Current hardwood conditions, however, reveal a greater predominance of red alder, particularly in moist soil PNVs, rather than being interspersed with conifers typically found within those PNVs.

Currently there is less late successional lower elevation forest than there has been as a result of timber harvest and conversion to both agricultural and urban uses.

What is the condition of the riparian area relative to its ability to supply large woody debris to the stream in the near-term? In the long-term?

Past timber harvest, streamcleaning, salvage logging, and selective removal of cedar from riparian areas and stream channels are physical activities that have occurred and continue to have both physical and biological effects on riparian area functioning. Channel configuration and peak flow events also displace LWD within the stream. Typically, there is a relatively continuous generation and supply of tree species suitable for LWD recruitment from riparian areas to the stream channel. LWD is supplied to the channel by both episodic, deliverable mass wasting events, as well as by or in conjunction with fire, wind, and flood events. LWD recruitment is also achieved by tree mortality and bank erosion.

See Table 2.7G for a quantitative assessment of the riparian area's ability to supply LWD to the stream in the near-term.

Table 2.7G Near-term Large Woody Debris Recruitment by Subwatershed Group.

Subwatershed	Total Miles			Near-Term LWD Recruitment			
		Poor	%	Fair	%	Good	%
Crazy Creek	18						
Headwaters Duckabush	14						
Lower Duckabush	69	26.5		8.3		39.6	
Middle Duckabush	49	.61	1.24	3.09	6.31		
Murhut & Cliff Creeks	54	16	29.67	7.8	14.41	32.6	60.46
Upper Duckabush	24						
Total	228	43.11	34.03	19.19	15.15	72.2	56.9
Percent	100%						

The figures in Table 2.7G can be used to compare tree distribution and size in managed and unmanaged riparian stands, and to identify and rank restoration opportunities. Those areas with a "high" impact call have the "poorest" ability to provide LWD in the near-term and should be targeted for restoration treatments. Those areas with "low" impact calls have "good" capabilities for providing near-term LWD. Only those sub-watersheds where restoration opportunities were identified have been classified. Those riparian areas within the Wilderness and Park that are primarily undisturbed were not classified to reduce the workload during this iteration.

Table 2.7H Current Riparian Timber Condition and Associated Impact Call for Near-term LWD summary[1]

Stand Type[2]	Total Riparian Acres	Percent of Total Riparian Area	Total Stream Miles[3]	Percent of Total Stream Miles	Impact Call[4]
CYS	500.7	5.5	9.00	6.7	high
CYD	348.4	3.8	6.34	4.7	med
CMS	303.0	3.3	6.58	4.9	med
CMD	2,480.4	27.2	51.68	38.3	low
COS	239.8	2.6	1.64	1.2	low
COD	2,538.6	27.8	21.15	15.7	low
DYS	237.3	2.6	4.39	3.3	high
DYD	784.3	8.6	.66	.5	high
DMS	14.4	.2	.34	.3	med
DMD	136.3	1.5	2.57	1.9	med
DOS					
DOD					
MYS	324.5	3.6	6.65	4.9	high
MYD	111.4	1.2	2.45	1.8	high
MMS	105.5	1.2	2.37	1.8	high
MMD	892.8	9.8	17.67	13.1	high
MOS	65.8	.7	.45	.3	m,ed
MOD	49.6	.5	.74	.6	med
non-for					
TOTAL	9,132.8	100	134.68	100	

Table Legend:

CYS= conifer, young, sparse
CYD= conifer, young, dense
CMS= conifer, mature, sparse
CMD= conifer, mature, dense
COS= conifer, old, sparse
COD= conifer, old, dense

DYS= deciduous, young, sparse
DYD= deciduous, young, dense
DMS= deciduous, young, sparse
DMD= deciduous, young, dense
DOS= deciduous, old, sparse
DOD= deciduous, old, dense

MYS= mixed, young, sparse
MYD= mixed, young, dense
MMS= mixed, mature, sparse
MMD= mixed, mature, dense
MOS= mixed, mature, sparse
MOD= mixed, mature, dense

Notes:

[1] Table developed using State methods (WFPB manual) for riparian function assessment
[2] Riparian acreage developed using site-potential tree height criteria for appropriate PNV, measured in feet from ordinary high water mark.
[3] Stream mile calculation counts both sides of fish-bearing waters.
[4] Impact call indicates level of concern for LWD recruitment (i.e., high impact call is due to poor recruitment potential, medium impact call is due to fair recruitment potential and low impact call is due to good recruitment potential).

What processes, physical and biological, are affecting the riparian system?

A multitude of processes, both physical and biological, are affecting the riparian system. These processes are naturally occurring as well as human-induced. The present riparian system is a manifestation of watershed conditions, past and on-going natural events, and Tribal and non-Tribal activities.

Prior to the activities of Euro-American settlers in the watershed, fire, wind, floods, and associated mass wasting, were the primary factors in natural disturbance regimes affecting riparian areas given its geology, hydrology, topography, and climate. The Tribal effects in riparian areas were relatively insignificant and localized.

The abundance and composition of wildlife have interacted with and on riparian vegetation in many ways such as by limiting its growth (herbivore), affecting its distribution (seed dispersal), and inducing mortality (trampling, scrapes). Plant species composition and plant successional paths have also affected riparian area composition (i.e., amounts of hardwood, conifer, brush, herbs). Fish have also affected and been affected by the riparian system. Their use of channels and wetlands within riparian areas draws a multitude of predators and scavengers to riparian areas (food web contribution) and their carcasses decompose in both aquatic and terrestrial areas (nutrient recycling).

Once human settlement began in the mid-1800s, human impacts to riparian areas increased steadily as a result of homesteading, clearing, agriculture, and logging. Timber harvest was the most widespread activity and likely caused the most adverse impacts to riparian areas due to its extent throughout the watershed. Splash damming was not a technique utilized in the Duckabush watershed. However, other methods employed to move timber likely resulted in soil compaction, bank erosion, and riparian area denudation. These impacts became more widespread as timber harvest quickened with technological progression from animals, to steam donkeys, to railroads, and then to gasoline-powered trucks and machinery. Timber harvest and associated roading has, and is likely to continue to have, the largest human-induced effect on the riparian system and the watershed as a whole.

Past timber harvest, streamcleaning, salvage logging, selective removal of cedar from stream channels and riparian areas, and continued planting of common commercial tree species (i.e., Douglas fir and western hemlock) have resulted in a decrease of durable large woody debris in, and available for recruitment to, the stream channel. Past removal of this valuable and integral channel-forming element, continues to have a large impact on the riparian system, its processes and functions.

As an overlay to major natural and anthropogenic processes, dispersed recreation, public works, agricultural development, landownership patterns, and forest practice regulations have and are affecting the riparian system and will continue to do so.

Wind, fire, floods, mass wasting, and timber harvest have interrupted vegetative succession, redistributed and removed riparian biomass, and affected riparian vegetation patterns and utilization by riparian associated fish and wildlife species. Naturally-occurring disturbance events recurred within the watershed at particular intervals; Euro-American land management has altered the frequency, rate, and magnitude of these events.

These natural and anthropogenic processes are affecting the riparian system as they have:
- reduced stream channel complexity, roughness, and stability;
- decreased quality and availability of both aquatic and terrestrial habitats;
- increased habitat fragmentation and decreased habitat connectivity;
- accelerated mass wasting and surface erosion;
- altered microclimatic conditions and decreased thermal refuge;
- increased colonization by non-native plant species;
- altered peak flows;
- decreased soil productivity; and
- impaired customary Tribal uses.

These effects have occurred through most of the watershed, with human effects being prevalent in the middle and western portions of the watershed. For further discussion of disturbances such as fire, wind, and mass wasting in the watershed overa and within riparian areas, see Vegetation, section 2.8 .

Where and what types of restoration actions might maintain or improve riparian processes and functions?

Restoration actions could be taken throughout the watershed to maintain or improve riparian processes and functions. However, given limited funds to implement restoration, it is wise to rank those areas of highest priority for restoration. There are various ways to rank areas for restoration; several are presented for consideration.

See Table 2.7G above for rankings of subwatersheds which have (1) the largest percentage, and (2) the highest number, of stream miles of riparian timber in poor condition for LWD recruitment. This table thus indicates, in descending order, which subwatersheds hold the greatest number of potential riparian area restoration opportunities. These rankings, while useful, provide a perspective limited to timber stand condition and do not have other resource conditions integrated into the ranking.

Reading this same table in reverse would indicate which subwatersheds would require the least amount of restoration to be implemented in order to secure the subwatershed's functions and processes. This ranking is useful if prioritizing restoration funds on those areas with the least amount of degradation, so that upon effective restoration these areas function fully as watershed refugia.

There are a variety of types of restoration actions that might maintain or improve riparian processes and functions. These types of restoration actions could include the following (since riparian areas are influenced by conditions both internal and external to them, other module reports in this document should be reviewed for additional information as indicated in parentheses):

- increase the size, amount, and durability of LWD to the stream channel (Channel Morphology);
- increase the size and amount of coarse woody debris in riparian areas (Wildlife);
- improve the quality, amount, and continuity of riparian corridors (Wildlife, Vegetation);
- improve the distribution and quantity of, and the access to, riparian vegetation for customary Tribal uses, (Vegetation);
- reduce and prevent non-native plant species distribution (Vegetation);
- increase stream channel complexity (Channel Morphology, Fish);
- minimize and prevent mass wasting and surface erosion to reduce sedimentation to background levels (Sedimentation, Channel Morphology, Water Quality);
- minimize hydrologic immaturity in the subwatershed (Vegetation); and
- increase unimpeded streamflow (Fish, Channel Morphology, Public Works, Water Quality).
- relocate facilities to restore floodplain or riparian function (Public Works).

Restoration of riparian processes and functions for this module's purposes focuses mainly on increasing the relative size, amount, and distribution of coniferous trees in riparian areas. To accomplish this conifer component increase, a variety of riparian silvicultural manipulations such as thinning, planting, releasing, and reforesting could be undertaken, as described in the ROD (B-31) and FEMAT (V-J). In addition, brush control, fertilization, herbivory control, use of nurse logs for seedling establishment, and importing wood to specific sites could be accompaniments to these techniques.

Measures should be taken to determine where conifers exist under hardwood-dominated canopies and to evaluate the feasibility of their release for improved growth. This could be done most accurately by field site inspections, and most expediently with high quality, low level aerial photography conducted during months when leaves are not present on hardwood trees.

Riparian restoration techniques are a mix of both established and experimental techniques, as well as variations of established techniques based on forestry and silvicultural practices. Long-term monitoring would help assess the effectiveness of various treatments and facilitate adaptive management of riparian areas.

Consideration of riparian restoration by hardwood conversion should take into account the needs of wildlife dependent on or associated with riparian hardwoods and the patchiness therein. As a general recommendation, no more than 50% of the current hardwood-dominated areas within a subwatershed should be treated for conversion to conifers, in order to maintain riparian diversity and benefit riparian fauna (also see Wildlife section 2.5).

Other riparian restoration techniques involve the placement of wood in the stream channel to address the lack of channel wood in the near-term. While this is a quick-fix that immediately addresses a missing riparian component, isolated channel wood placement should not be undertaken. Rather, such measures should be part of a larger project to restore riparian area units where both in-stream and upslope conditions are restored for long-term, sustainable benefits. Isolated channel wood placement could be appropriate in select situations but in addition to an analysis of channel form and function, evaluation of the amount of benefit derived relative to the extent of the problem and the condition of the subwatershed, should also be undertaken.

Furthermore, placement of wood pieces in the active stream channel requires an in-depth understanding of site specific conditions in relation to overall channel form and function. Specifically, such restoration actions need to very carefully consider placement plans that intentionally or unintentionally deflect the thalweg of the stream at critical attack angles toward the toes of oversteepened inner gorge slopes that are highly susceptible to failure from such triggering actions. Otherwise, additional unwanted problems could result from such well-meaning efforts.

Restoration actions in riparian areas need to consider that current riparian conditions largely represent conditions that have resulted from human activities and influences within that riparian area, rather than unmanaged conditions which are deficient relative to a reference condition in a more productive area. Consideration of biomass and structure that has been lost from the riparian area as a result of timber harvest of live trees, salvage after fire or blowdown (both on land and in the stream channel), streamcleaning, and selective wood removal (particularly of cedar which has high in-channel value due to its long-lasting qualities), should be used to formulate holistic restoration packages at site level or subwatershed level planning.

MONITORING

Monitoring of the Riparian Reserve is of the highest importance. The first priority would be to conduct "implementation monitoring" to evaluate the restoration treatments occurring within the riparian areas. Some parameters to track may be: (1) amount of change in land allocation, (2) type and amount of ground disturbing activities within Riparian Reserves, and (3) forest canopy reduction within Riparian Reserves. Second priority would be to conduct "effectiveness monitoring" to track the extent of change.

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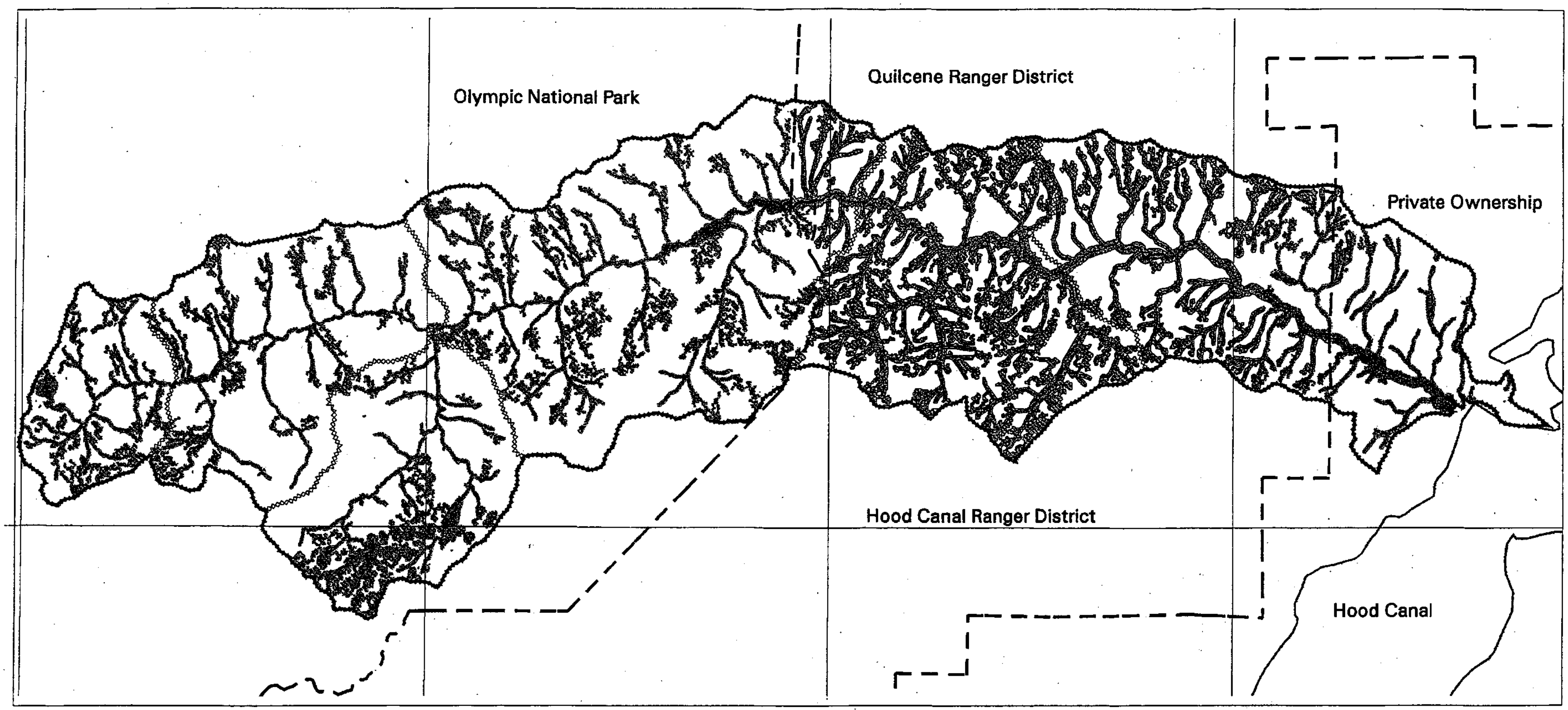


The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

LEGEND

- Watershed Analysis Area
- Subwatersheds
- Forest Boundary
- Hydronet
- Quad Lines
- Proposed Riparian Reserve (USFS)
- Potential Riparian Reserve (OTHER)
- Lakes, Ponds and Wetlands
- High Probability of Slope Failure within Proposed and Potential Riparian Reserve

Proposed Riparian Reserves

Map# 2.7A

The Duckabush Watershed Analysis Team

l_ripreserve May 18, 1998

2.8 VEGETATION

INTRODUCTION

The purpose of this chapter is to describe the vegetation of the Duckabush Watershed and the processes that create vegetation patterns on the landscape. Understanding the processes allows land managers to evaluate proposed plans or stand treatments in the context ecosystem function.

This report focuses on the watershed and subwatershed scale. A provincial view is also needed. Many of the processes operating on vegetation in the Duckabush Watershed also operate over much wider areas. Most species in the Duckabush Watershed are distributed over much wider areas and in many cases are more abundant elsewhere. It is not possible to maximize or optimize management for all species in the watershed. The optimum management strategy will draw on an understanding of vegetation at a wider scale. The information presented in this report when combined with similar information province wide will facilitate planning and management.

Four key questions were posed to focus the report. The text of the report follows the key questions. The key questions are interrelated which necessitates mixing discussions to a certain degree.

Key Questions:

1) What are the historic and existing landscape patterns of plant communities?
2) How do current plant communities compare with historic plant communities?
3) What are/were the major disturbance regimes and how do they affect the kinds and patterns of plant communities?
4) What restoration actions enhance important vegetative processes and structures compromised over historic levels as determined by the watershed analysis?

Response to the Key Questions

1) What are the historic and existing landscape patterns of plant communities?

Historically much of the watershed fluctuated widely between late and early successional communities due to large wildfires about every 200 years. Each fire was followed by a successional sequence culminating in late successional vegetation on better sites and well developed mid successional vegetation on poorer sites which was then converted back to an early successional state by another fire (see Appendix 2.8.1 for definitions of successional stages). Most of the area has been in an early or mid successional state most of the time. Old-growth, except in a few important refugia has been an important but ephemeral plant community.

Patterns of potential vegetation have been more stable than successional patterns but have shifted with climatic changes. Prior to seven hundred years ago the climate was warm enough for Douglas-fir to establish in the Silver Fir Zone and portions of the Mountain Hemlock Zone. During the Little Ice Age (1300-1850) the climate was cool enough to allow the Silver Fir Zone to descend into areas that are now in the upper Western Hemlock Zone. With climate warming potential vegetation patterns are shifting up in elevation again.

Currently vegetation patterns in the upper 4 subwatersheds continue to reflect mostly natural processes. Vegetation in the lower 2 subwatersheds has been largely modified by a combination of clearcut harvesting, human caused wildfire and land conversion to agricultural and urban uses. The effect has been fragmentation of remaining old-growth stands, conversion of large areas to structurally simple early and mid successional forests and removal of forest lands for other human uses.

Potential Vegetation Patterns:

Potential vegetation is the vegetation that would develop under the current environment given a long period without disturbance. Potential vegetation defines a kind of habitat. Potential vegetation also defines the endpoint and helps define the direction and rate of succession. Potential vegetation is classified into units called plant associations that can be aggregated upward into plant association groups and series (see Appendix 2.8.2 Descriptions of Plant Association Groups). Plant associations are named for a climax dominant tree species and one or more climax understory species which best characterize that environment. A climax species is one that would be present in a very old stand. When vegetation is undisturbed for very long periods of time it tends to stabilize with a predictable species composition. The stable stage is called the climax stage. All stages of development leading to the climax stage are seral stages or successional stages.

The five dominant vegetation zones from low to high elevation are the Western Hemlock Zone, Silver Fir Zone, Mountain Hemlock Zone, Subalpine Zone and Alpine Zone. There are also small amounts of Douglas-fir Zone, Subalpine Fir Zone and wet and dry non-forest openings. Plant association groups in each vegetation zone are described in Appendix 2.8.2. Plant associations in each plant association group are listed in Appendix 2.8.2 Tables 3-7. Plant associations and the vegetation zones are described in detail in Henderson et al. (1989).

Wetter Western Hemlock Zone plant associations (Appendix 2.8.2 Table 4) occupy toeslopes and bottoms and are usually dominated in the understory by swordfern, Oregongrape, Alaska huckleberry, vine maple, vanilla leaf, Devil's club and skunk cabbage. The overstory is dominated by western hemlock and western redcedar in very old stands and by Douglas-fir with western hemlock and western redcedar in young to mature stands. Young to mature stands may also be dominated or codominated by red alder, big leaf maple or black cottonwood. Most non-forest openings are wetlands that include salt marshes near the mouth of the river and shrub dominated wetlands along the Duckabush River.

The dry Western Hemlock Zone plant associations (Appendix 2.8.2 Table 4) are found mostly on mid to upper slopes or very well drained benches such as the one between Collins Campground and the Duckabush Trailhead. The overstory is always dominated by conifers including Douglas-fir, western hemlock and western redcedar except in very young stands when herbs and shrubs are dominant. The understory is dominated by salal and Pacific rhododendron. Oceanspray and Oregongrape are also common. Non-forest openings are mostly dry, rocky balds dominated by mosses, lichens, herbs and grasses including Idaho fescue. These are common on south slopes. In some cases rocky balds may be fringed by a narrow band of Douglas-fir Zone.

The Western Hemlock Zone extends from sea level to 4892 feet but averages 1715 feet (Table 1). The upper boundary of the Western Hemlock Zone is on the average about 600-700 feet higher on south slopes than north slopes in the Duckabush Watershed.

Table 1. Vegetation Zone elevations in the Duckabush Watershed.

Vegetation Zone	Mean Elevation	High	Low
Douglas-fir	4388	4600	4265
Western Hemlock moist	1039	4308	7
Western Hemlock dry	1905	4865	13
Western Hemlock	1715	4892	7
Silver Fir moist	2834	4262	1421
Silver Fir dry	3359	5499	1467
Silver Fir	3436	5600	1421
Mountain Hemlock	4505	5738	2671
Mountain Hemlock parkland	5436	6683	4557

The Silver Fir Zone is on the slopes above but may extend into the Western Hemlock Zone where soil moisture is high and cold air accumulates.

The Western Hemlock Zone extends up the Duckabush River into the Upper Duckabush Subwatershed where it is entirely restricted to dry south facing slopes (Map 2.8A). It is the dominant potential vegetation zone in the Lower Duckabush Subwatershed and is important in the Murhut/Cliff Cr. Subwatershed and the Middle Duckabush Subwatershed (Table 2).

Table 2. Acres of each Vegetation Zone by subwatershed.

Zone	Zone ID	Lower Duckabush	Murhut/C liff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Duckabush Watershed
Western Hemlock	19	10701	5198	5114	199	20		21231
Silver Fir	22	427	2751	4498	2856	1206	335	12073
Mountain Hemlock	23	32	612	3625	3146	3309	1719	12444
Mountain Hemlock Parkland	32		101	947	1003	1136	995	4181
Alpine	33			3	2	1		6
Subwatershed acreage		11160	8662	14187	7204	5672	3049	49934

Wetter Silver Fir Zone plant associations (Appendix 2.8.2 Table 5) occupying toeslopes, bottoms and moist north facing slopes are usually dominated in the understory by Alaska huckleberry, queenscup, foamflower, avalanche lily, swordfern, Devil's club and skunk cabbage. The overstory is dominated by silver fir, western hemlock and western redcedar and includes Douglas-fir in young to mature stands. Very young to mature stands may also include red alder in the wetter plant associations especially at lower elevations. Most non-forest openings are wetlands that include herb and shrub dominated wetlands along the Duckabush River or wet openings around ponds, seeps and springs.

The dry Silver Fir Zone plant associations (Appendix 2.8.2 Table 5) are found mostly on mid to upper slopes or very well drained benches. The overstory is always dominated by conifers including western hemlock, western redcedar and often Douglas-fir. The understory is dominated by Pacific rhododendron, Alaska huckleberry, Oregongrape, twinflower, and white rhododendron. Non-forest openings are mostly dry, rocky balds dominated by mosses, lichens, herbs and grasses. These are mostly found on south slopes.

The Silver Fir Zone extends from about 1421 feet to 5499 feet but averages 3436 feet (Table 1). The upper boundary of the Silver Fir Zone is about 400-500 feet higher on south facing than north facing slopes in the Duckabush Watershed. The Mountain Hemlock Zone is on slopes above but extends into the Silver Fir Zone where soil moisture is high and cold air accumulates.

The Silver Fir Zone extends up the Duckabush River midway into the Headwaters Subwatershed where it is more common on south slopes (Map 2.8A). It is the dominant potential vegetation zone in the Upper Duckabush Subwatershed and is important in the Middle Duckabush, Crazy Cr. and Murhut/Cliff Cr. Subwatersheds. It is found in small quantities in the Lower Duckabush and Headwaters Subwatersheds (Table 2).

Wetter Mountain Hemlock Zone plant associations (Appendix 2.8.2 Table 6) occupying toeslopes, bottoms and moist north facing slopes are usually dominated in the understory by Alaska huckleberry, avalanche lily, marsh marigold and Devil's club. The overstory is dominated by mountain hemlock, silver fir, with some Alaska yellowcedar and western redcedar. Most non-forest openings are wetlands which include herb and shrub dominated wetlands along the Duckabush River or wet openings around ponds, seeps and springs. Near the upper elevation boundary, plant associations typical of the Subalpine Zone frequently appear in areas where very deep snow accumulates.

The dry Mountain Hemlock Zone plant associations (Appendix 2.8.2 Table 6) are found mostly on mid to upper slopes or very well drained benches. The overstory is dominated by mountain hemlock and silver fir. The understory is dominated by big huckleberry, white rhododendron and beargrass. Non-forest openings are mostly dry, rocky balds dominated by mosses and lichens and are mostly found on south slopes. Some warm, dry sites may support Subalpine Fir Zone vegetation but this is a minor zone in the Duckabush Watershed.

The Mountain Hemlock Zone extends from about 2671 feet to 5738 feet but averages 4505 feet (Table 1). The upper boundary is about 300 feet higher on south facing than north facing slopes. The Subalpine Zone is above it but may extend into the Mountain Hemlock Zone where snow accumulation is high and cold air accumulates.

The Mountain Hemlock Zone is the dominant potential vegetation zone in the Headwaters Subwatershed and is important in Crazy Cr. and on the north facing slopes of the Middle Duckabush Subwatersheds (Table 2).

The Subalpine Zone (also referred to as Parkland Zone) is a transitional zone between the Alpine Zone and the Mountain Hemlock Zone. Mountain Hemlock Parkland is the dominant vegetation in this zone in the Duckabush Watershed. Mountain Hemlock Parkland is an interdigitating mix of closed Mountain Hemlock Forest with meadows dominated by heather, blue-leaf huckleberry, valerian, lupine and other herbs. The forest tends to be more continuous at lower elevations and the meadows more continuous at higher elevations. There is currently an upslope invasion of Mountain Hemlock Zone trees into the lower meadows as a result of post Little Ice Age climate warming.

The Subalpine Zone lies mostly between the elevations of 4557 and 6683 feet in the Duckabush Watershed (Table 1). It is important in the Headwaters, Upper Duckabush and Crazy Cr. Subwatersheds. It extends into the Middle Duckabush and Murhut/Cliff Cr. Subwatersheds on ridgetops and upper slopes (Table 2).

The Alpine Zone lies above the tree line. Trees may be found growing as wind and ice battered shrubs known as krummholtz. No other trees are found in the alpine. There is frequently much barren rock or rock covered with mosses or lichens. Wetlands are typically dominated by sedges such as black headed and showy sedge. Drier areas are dominated by heather, blue-leaf huckleberry, lupine, valerian and many other herbs, sedges and grasses.

The Alpine Zone lies above the Subalpine Zone and is a minor zone in the Duckabush Watershed.

Historic Potential Vegetation Patterns

Potential vegetation is strongly linked to climate which constantly changes. Evidence of climatic shifts can be seen in the vegetation of the Duckabush and elsewhere on the Olympic Peninsula. It is not possible at this point in time to know how far or how fast this shift in vegetation zones will go.

Large old Douglas-fir trees dating to 1308 are occasionally seen at higher elevations than Douglas-fir can currently grow. These trees show that the climate was warmer at the time of their establishment. During the Medieval Optimum which ended around 1308 the vegetation zones of the Olympic Peninsula shifted higher in elevation.

Following the Medieval Optimum was the Little Ice Age which ended about 1850. During the Little Ice Age vegetation zones shifted down relative to modern levels. Since the end of the Little Ice Age the climate has been warming driving the vegetation zones back up.

The tree line as viewed from a distance is lower than the present potential tree line. The subalpine and alpine are currently shrinking due to upward expansion of the Mountain Hemlock Zone. Also visible are many bare areas exposed as Little Ice Age glaciers and snowfields melted. These areas are currently growing into subalpine and alpine plant communities.

Silver fir trees near the lower boundary of the Silver Fir Zone are frequently dead or dying and infested with barkbeetles. Stress due to the warming climate is probably responsible. This is a natural process that will result in expansion of the Western Hemlock Zone into the former lower portion of the Silver Fir Zone.

Current Seral Vegetation Patterns:

Current vegetation is determined by current environmental patterns on the landscape, relict vegetation from past environments and disturbance. The kind and size of disturbance defines the starting point for succession. Succession proceeds along one of several pathways which is determined by the site potential and the nature of the disturbance which initiated the succession.

The upper 4 subwatersheds and most of Cliff Creek exhibit patterns of vegetation relating to prehistoric fires, snow avalanching, post Little Ice Age climate warming and different growth potentials. Human influences are minimal. The last large wildfire to disturb this area was in 1701. Some of the area, especially in the vicinity of Cliff Creek and in the Headwaters Subwatersheds have been undisturbed since 1308. The lower 2 subwatersheds exhibit mostly patterns related to human caused wildfire, timber harvesting and land conversion to agricultural or urban uses (Table 3). Map 2.8B shows age classes of vegetation which are summarized in tabular form in Table 4.

Table 3. Acres by structural condition in each subwatershed.

	Lower Duckabush	Murhut/Cliff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Duckabush Watershed
Agricultural/Urban	543						543
Early	1023	33					1056
Early Mid/Conifer	561	470	46	38			1114
Early Mid/Hardwood	106	0					106
Late Mid/Conifer	1734	1057	4963	2874	2100		12728
Late Mid/Hardwood	306						306
Late Multistoried	35	1773	829	594	1374	711	5315
Late Singlestoried	861	1516	3712	897	204		7189
Middle Mid/Conifer	4901	1360	6	12			6279
Middle Mid/Hardwood	269						269
Aquatic	20		37	1	5		63
NB Terrestrial (non-forest)	226	1225	2948	2394	1591	2282	10664
Non-forest (PAG forecast)	519	1228	1556	389	395	57	4145
Wetland	33		90	6	3		132
Wetland with hardwoods	24						24
Total Subwatershed	11160	8661	14187	7204	5671	3049	49933

Table 4. Acres by subwatershed and age class.

Age range	Lower Duckabush	Murhut/Cliff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Duckabush Watershed
0-10	1096						1096
11-20	600	243					842
21-30	113	181					294
31-40	78	441					519
41-50	204	182					386
51-70	3817	55					3872
71-95	3359	1611	96	70			5136
96-145	62						62
297	960	2469	10151	3785	2456		19820
490	37	867	267	262			1433
690		1392	597	687	1617	767	5060
agricultural/ urban	543						543
nonforest	214	1221	2930	2386	1536	2242	10529
water	77	0	145	14	63	41	339
Acres of subwatershed	11160	8662	14187	7204	5671	3049	49933

From Cliff Creek to the headwaters of the Duckabush the seral patterns represent mostly differences in growth potential in forest stands at least 300 years old. Areas burned in 1701 with low growth potential such as Mountain Hemlock Zone and slower growing portions of the Silver Fir Zone are mostly in a late middle state of succession and are only just beginning to express old-growth conditions. Areas with higher growth potential such as in the Western Hemlock Zone, more productive portions of the Silver Fir Zone and areas last burned in 1508 or 1308 are in a late stage of succession with old-growth characteristics clearly expressed (Map 2.8C).

Climatic warming since the end of the Little Ice Age (about 1850) has converted meadows and non-forested areas near the early 1800's tree line to Mountain Hemlock Zone forest potential. These areas are now in an early state of forest succession but on Map 2.8H are included in the non-burnable terrestrial mapping unit. Many areas that were snowfields during the Little Ice Age are now undergoing succession into non-forest plant communities such as heather meadows.

Snow avalanching produces a pattern of long narrow shrub and herb communities along small stream courses in areas with forest potential. These communities are especially common on south facing slopes. Vine maple and sitka alder are common dominants in these communities when avalanches are frequent. These areas are constantly undergoing succession toward coniferous forest communities. Forest expression is a function of avalanche frequency in avalanche chutes. Early successional herb communities to mid successional forest communities are commonly associated with these chutes. Map 2.8C includes early successional, mostly non-forest communities in the non-burn terrestrial mapping unit.

Overall the portion of the Duckabush Watershed above and including Cliff Cr. has the largest contiguous areas of late successional vegetation in the watershed. Near the forest/non-forest ecotone at higher elevations there is a considerable degree of natural fragmentation due to rock outcrops, patterns of snow accumulation, snow avalanche and small lightning fires. Snow avalanche also fragments forest stands on mid and lower slopes especially on south facing slopes. The largest contiguous blocks of old-growth are on north slopes and in the valley bottom. Old-growth on south and north facing slopes differs in degree of fragmentation, site potential and species composition (Maps 2.8C and 2.8A).

Seral vegetation patterns in the Lower Duckabush Subwatershed and the Murhut/Cliff Cr. Subwatershed exclusive of Cliff Creek are strongly influenced by human activity. The largest change has been conversion of late successional vegetation to early and mid successional vegetation through human caused wildfire but conversion of late successional vegetation to early and mid successional vegetation by clearcut timber harvest is also important. Conversion of native vegetation to agricultural and urban uses is important in the lowest part of the Lower Duckabush Subwatershed.

There are about 765 acres of hardwood dominated stands in the lower Duckabush Subwatershed in stream bottoms, toe slopes and moist benches. On Map 2.8C they are denoted by EARLYMID_H, MIDDLEMID_H and LATEMID_H. These areas are mostly dominated by red alder, bigleaf maple and some black cottonwood. Bigleaf maple is especially prominent in the lowest portion of the Lower Duckabush Subwatershed on private lands. Throughout the watershed the area with potential for hardwoods is equivalent to the wetter Western Hemlock Zone plant association groups (Map 2.8A).

Most of the hardwood stands are older than 50 years. Red alder usually starts declining around 70-80 years and somewhat later for bigleaf maple. Some small younger stands have been created on some of the private lands.

There are important differences between north and south facing slopes of the Duckabush in the lower subwatershed. Historically the north facing slopes had more late successional vegetation both because of a lower fire frequency and because of faster rates of succession due to higher site potential.

Currently there is still more late successional vegetation on the north facing slopes but timber harvest and human caused wildfire has eliminated much of it in the lower two subwatersheds. Most of the late successional vegetation left south of the Duckabush River in the Lower Duckabush Subwatershed has been affected to some extent by wildfires in 1922 and 1929 (Map 2.8D). Fire appears to have passed through most of this area thinning the old-growth dominant trees and causing fragmentation. Sufficient old-growth trees remain for some old-growth functions to continue. These stands should be viewed as two aged stands with an old-growth component.

Important multistoried late successional refugia exist between Murhut Cr. and Cliff Cr. and one small patch east of Murhut Cr. There was formerly more late multistoried forest in Murhut Cr. but most has been removed by clearcut timber harvest. The Murhut/Cliff Cr. area is relatively fire resistant allowing the development of older stands than elsewhere in the lower Duckabush.

The largest amount of high contrast fragmentation due to timber harvest activity in the watershed occurs in the Murhut Cr. since the original matrix was mostly late successional forest. Roads and clearcuts in this area create high contrast edges which compromises the value of the remaining stands of old-growth.

State and private lands in the lower portion of the Lower Duckabush Subwatershed exhibit a high degree of fragmentation. Edge contrast is lower due to conversion of the matrix to mid-seral conditions through wildfire and clearcut timber harvesting. There is virtually no old-growth remaining on these lands. Conversion of land to agricultural and urban uses has also contributed to the fragmentation in this area.

North of the Duckabush River nearly all land has been converted to mid-seral conditions by wildfire (Map2.8D). Railroad logging removed much of the timber in the valley bottoms and lower slopes. Wildfires from 1906 to 1929 subsequently burned much of the cutover land as well as upslope into timber returning from the 1701 wildfire. Nearly all the forest east of Big Hump has been cut or burned north of the Duckabush River. Occasional isolated trees or small riparian patches are all that remain but the largest of these patches was cut in the 1940's.

Historical Seral Vegetation Patterns

Larger patch size in the Lower and Murhut/Cliff Cr. Subwatersheds in the past is the most apparent difference between past and present vegetation patterns. Large wildfires of the past created much larger patches than timber harvesting. Patterns in the upper four subwatersheds are the natural extension of past conditions.

Large shifts from late to early successional conditions resulted from fires in the past. At times in the past much more of the watershed was in an early or mid seral condition than at the present (Map2.8E). The principal fires were around 1308, 1508 and 1701 (Map 2.8F). Another large fire in 1668 burned into the Duckabush but its extent is not known due to the effects of the 1701 fire. Between fires large areas grew into late successional vegetation but most of the landscape was in early or middle successional conditions most of the time. Under current management succession on state and private lands is truncated at a mid seral condition.

Map 2.8G shows the successional conditions prior to the large 1701 fire and Map 2.8E shows the conditions after the fire. Similar shifts in conditions occurred after the even larger 1308 and 1508 fires. Late successional refugia high in the watershed, in Murhut/Cliff Cr. and in some river bottom or north slope riparian locations can be seen on Maps 2.8E and 2.8C.

2) How do current plant communities compare with historic plant communities?

Current and historic plant communities in the upper 4 subwatersheds differ little. Climatic shifts in the past probably caused some differences in species composition of plant communities. Climatic shifts did shift the positions of communities on the landscape (discussed in the previous section on Historical Seral Vegetation Patterns). Large wildfires also converted much of the landscape to early seral communities at several points in time (also discussed previously in Historical Seral Vegetation Patterns). Coarse wood in the form of snags and logs was abundant in early and midseral stands originating from wildfire. These structural elements are nearly absent from modern early and mid seral communities originating from clear cutting and will become less common with successive rotations unless efforts are made to include them. Conversion of land from forest to agricultural or urban uses and introduction of exotic species are two more important differences between current and historic plant communities.

The biggest change in plant communities has occurred in the lower portion of the Lower Duckabush Subwatershed where 543 acres have been converted to agricultural or urban uses. Vegetation in these areas consists mostly of early to middle successional stands with a large proportion of exotic and ornamental species including trees, shrubs and herbs. Much land in this area has been converted to roads and structures. It is likely that this area will grow in size and be a source of new introductions of exotic species, some of which may become troublesome weeds.

Early seral plant communities elsewhere in the lower 2 subwatersheds also include many aggressive exotic species, some of which are listed as noxious weeds by the State of Washington. Surveys along the 2510 road on U.S. Forest Service land in 1997 show tansy ragwort, bull thistle, St. Johnswort, Canada thistle, oxeye daisy, catsear, foxglove and reed canary grass are common. Evergreen blackberry and scotch broom are also present. A small population of brown knapweed is the first for the Olympic National Forest. There is also an unconfirmed report of spotted knapweed that would also be one of the first sightings on the Olympic National Forest. Many other exotics can be found in campgrounds, clearcuts, road cuts, fills and other disturbed areas. There are currently no known exotics capable of invading late successional forest in the Duckabush Watershed.

Spotted knapweed, brown knapweed and tansy ragwort are State of Washington Class B weeds. Bull thistle, Canada thistle, St. Johnswort, and reed canary grass are State of Washington Class C weeds.

St. Johnswort has antidepressant properties making it a potential special forest product.

Currently there are no known survey and manage species in the Duckabush Watershed. Claytonia lanceolata var. pacifica is a state of Washington sensitive species known from one location in the Headwaters Subwatershed. Surveys are currently inadequate to know if other rare plants or survey and manage species are present in Duckabush Watershed plant communities. This is a potentially serious data gap.

3) What are/were the major disturbance regimes and how do they affect the kinds and patterns of plant communities?

The major disturbance regimes are fire, wind, snow avalanche and human activity especially timber harvest. Historically fire, wind and snow avalanche were the major disturbances. In the riparian zone flood has been and continues to be an important disturbance. Mass wasting generally affects only a small proportion of the watershed at any point in time but creates sites that are very slow to recover and highly vulnerable to exotic plant invasion. Fire is the natural disturbance regime that has affected the most area.

Most of the Duckabush Watershed with exception of some moist or cool stands burned on about a 200 year interval in the past. Fire frequency is greater as a result of modern human activity in the Lower Duckabush Subwatershed and south facing slopes in the Murhut/Cliff Cr. Subwatershed. Fire was and still is infrequent in the upper 3 subwatersheds and in Murhut and Cliff Creeks.

Windstorms have had minor impacts as a stand replacement disturbance but acts across all the landscape to topple weak trees and snags.

Snow avalanche has produced a pattern of vertical stripes of herbaceous or shrubby vegetation on the south facing slopes in all the subwatersheds.

Only the lower two subwatersheds have been affected by timber harvest and fragmentation. Conversion of land to agricultural and urban uses is one of the most important disturbances in the Lower Duckabush Subwatershed. Disturbance associated with building and maintenance of roads, campgrounds and trails continuously provides exotic plant habitat.

Fire

The most significant change in effects from fires in recent times has been increased frequency in some areas and the use of post fire salvage. Salvage and frequent fires can produce early and mid-successional stands with much less structure than would otherwise occur.

Fires in the Duckabush Watershed are usually stand replacement fires. The interval between fires is usually long enough to allow considerable accumulation of ground and ladder fuels resulting in hot crown fires that kill all or most trees. The natural pattern has been for large fires to burn at about 200 year intervals. The large fires were probably fast moving fires burning under high east or northeast winds. Smaller fires may have burned portions of the landscape more frequently but evidence of them has been destroyed by the larger fires. During the first half of the 1900's recreation, settlement or logging related fires sometimes burned at intervals of a few years.

Large stand replacing fires occurred in 1308, 1508 and 1701 (Map 2.8F). The 1308 fire probably burned most of the vegetation in the watershed. The 1308 fire burned at the end of the Medieval Optimum under a different climatic regime that was warmer and drier. Fire was probably much more common at that time and the vegetation zones were shifted higher in elevation relative to the present. There is evidence of another large fire in about 1250 which may also have affected the Duckabush Watershed. Stands dating to this event can be found north and south of the Duckabush but so far not in the Duckabush Watershed.

The fire of 1508 appears to have missed most of the north facing slopes from Cliff Creek to the headwaters but burned all of the lower watershed and the south slopes as far up as the Upper Duckabush Subwatershed.

The fire of 1701 though smaller than the fire of 1508 apparently burned more of the Duckabush Watershed than the 1508 fire. Many of the north slopes missed by the 1508 fire were burned by the 1701 fire. Areas missed by the 1701 fire became important old-growth refugia for plants and wildlife.

Another fire in 1668 burned into the Duckabush Watershed but its extent is not known. It may have been quite extensive but the 1701 fire burned most of the evidence. Map 2.8G displays the extent, as understood at the present, as a large patch of earlymid successional stage in the southeast part of the map.

The large fires all produced a pattern consisting of mostly large patch sizes. The dominant matrix after each fire was early successional. Small patches of older trees survived in cool moist locations scattered throughout the area but most of the surviving patches were large areas such as around Murhut and Cliff Creeks after 1701 (Map 2.8F).

Early and early mid-successional stands inherited abundant snags and down logs from the burned forest which gradually decompose with time. Spies et al. (1988) measured a gradual decline in coarse woody debris in Western Oregon and Washington Douglas-fir forests for 80-100 years after disturbance. Large Douglas-fir and western redcedar logs can be very persistent. Decomposition may take several centuries (Franklin and Spies 1991). Most of the snags had probably fallen by 100 years. There may have been relatively few large snags outside of the surviving remnant stands for the next 100 years.

For several decades following the fires coarse sediment and large woody debris may have been supplied to the streams in the drainage in large quantity. As reforestation occurred and dead trees fell over and rotted the supply of sediment and large woody debris probably declined. Eighty to 120 years after the fire new large woody debris and coarse sediment recruitment probably slowed considerably. Recruitment of large woody debris would gradually increase as the forest grew in size and older trees began to die but by the time the forest was 200 years old another large fire usually occurred. In this kind of regime large wood and sediment are recruited episodically and synchronously. This allows for efficient storage of wood and sediment in smaller tributaries.

Lower parts of the mainstem Duckabush move coarse wood and sediment rapidly downstream to Hood Canal. It is not clear whether the mainstem Duckabush River has ever retained much coarse woody debris in the lower two subwatersheds. Only extremely large pieces could be retained in such a large, confined stream. A narrow strip of land bordering the river throughout most of its length is highly productive. Some trees 4-6 ft. in diameter and up to 200 feet in height were probably present.

The current climate is warm but fairly moist and conditions suitable for large fires have not reoccurred. Most of the fires in the Duckabush during this century have been man caused (Table 5).

Table 5.

cause	Number of Fires	Duckabush Acres	Total Acres
Miscellaneous*	3	2	2
campfire	11	4576.029	4850.2
incendiary	2	0.305	0.305
lightning	13	327.5807	327.5807
logging related**	4	37.61796	37.61796
smoking	9	3846.442	10143.01
unknown	16	427.0302	427.0302
Prehistoric***	5	103320.4	1402972

*debris burning, burning on right of way
**cables,loaders,railroads,slash burning
***probably lightning, sum of 3 fires

Fires this century have been smaller but have come at more frequent intervals than in the past (Map 2.8D). The fire mosaic which was created (without the effects of timber harvest) is shown in Map 2.8H and is summarized in Table 6. Note that even though the 1308 and 1508 fires burned the Lower Duckabush Subwatershed very little if any of these age classes remain due to the effects of later fires.

Table 6. Acres by the most recent fire year.

	Lower Duckabush	Murhut/Cliff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Duckabush Watershed
1308		1392	601	688	1622	767	5070
1508	38	1092	307	262			1699
1701	1399	3119	10235	3790	2458		21000
1906	67						67
1910	2228						2228
1914	15						15
1918	1777	1324	5				3106
1920	692						692
1922	1204	335					1539
1924			91	70			161
1929	1897	138					2035
1935	1619						1619
1971		37					37
nonforest	226	1225	2948	2394	1591	2282	10664
Acreage of subwatershed	10934	7437	11239	4811	4081	767	39268

Wildfires this century have been caused by lightning and human activity but fires caused by human activity have burned much more acreage (Appendix 2.8.2 Table 11). The addition of human sources of wildfire has reduced the fire return interval from 171 to 168 years in the Lower Duckabush Subwatershed (Table 7) when calculated over the entire period of record (1308-1998). When calculated just for this century the Lower Duckabush Subwatershed has a fire return interval of 149 years. If the modern fire return interval remains unchanged late successional vegetation will not develop in the Lower Duckabush Subwatershed even where timber harvesting does not take place. Previously structure associated with late successional vegetation developed on higher site lands but was not a long lasting feature on the landscape except in unburned refugia.

Structure associated with late successional vegetation did develop in most of the rest of the watershed under the previous fire regime and was a long lasting feature of most of the higher site lands as well as many of the cool, moist northern exposures.

Table 7. Acres and fire return interval of Duckabush Watershed fires by subwatershed.

Year	Lower Duckabush	Murhut/Cliff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Total acres burned in Duckabush Watershed	Total acres burned in all areas	GIS ID
1308	10935	7437	11239	4811	4081	767	39268	1638848	F297
1508	10935	5933	5296	1745			23909	1244856	F298
1668	5843	1140					6983	179901	F447
1701	10897	4938	10331	3861	2458		32484	1146276	F299
1906	325						325	325	F92
1914	169						169	169	F111
1918	3480	1324	5				4809	5415	F274
1922	1204	335					1539	1550	F96
1924			91	70			161	392	F307
1929	2167	138					2306	13541	F95
1971		37					37	37	F336
1910*	2496						2496	2496	F453
1920*	692						692	692	F452
1935*	1619						1619	1619	F459
Fire return interval for period 1308-1900	171	264	313	409	513	2354	288		
Fire return interval for period 1308-1998	168	281	363	474	598	2743	308		

*Areas which were cut and/or burned prior to the given date. Cause of deforestation not determined. These areas were not included in the calculation of fire return interval. Inclusion of all or part of these lands would further reduce the fire return interval.

Land Conversion

Currently the dominant disturbance regimes are timber harvest and land conversion to agricultural and urban uses. In the past human disturbances were small and limited to a native American village site near the mouth of the Duckabush River. Native Americans probably only intensively affected a few acres in and around the village site. Currently 543 acres have been converted to modern cultural uses of an agricultural or urban nature. The degree of conversion on this acreage varies a great deal. Much of this acreage still retains many elements of native vegetation while other areas have been converted to roads and structures. The constant high degree of disturbance creates conditions for introductions and spread of opportunistic exotic plants and noxious weeds. Much of this land continues to have wildlife value for some species due to native and non-native plant communities but constantly changing land use makes it impossible to count on this habitat in the future.

Timber Harvest

Timber harvest is a more extensive but less intensive disturbance regime than land conversion. Timber harvest has affected most of the Lower Duckabush Subwatershed and much of Murhut Cr. Railroad logging earlier in the century affected the valley bottom and lower slopes as far upstream as the flats between Big and Little Hump.

Many areas in the lowlands have already been harvested twice. Clearcutting began late in the 1800's and early 1900's but most land was cut from about 1930 to 1990 for the first time. The combined effects of wildfires and clearcutting converted much of the valley bottoms and lower slopes to younger forests severely deficient in snags and coarse woody debris. Cutting and burning was often complete to the edge of stream courses and timber was often yarded through streams

Fire has been used traditionally to dispose of logging slash and prepare the site for planting Douglas-fir. Following planting most stands receive a precommercial thinning and later some may be commercially thinned.

Commercial thinning removes only a portion of the trees with the objective of accelerating growth of the remaining trees while extracting commercially valuable timber. It has been assumed a final harvest clearcut would be made at some point in the future to remove the remaining trees after they have grown larger. Commercial thinning mimics to some degree the kind of attrition that occurs naturally in a stand as it ages and self thins. A major difference is that large wood that would remain in the forest as snags or logs is removed. Commercial thinning is usually only done once before the harvest clearcut. If repeated it would favor the conversion of the forest to climax species such as western hemlock and western redcedar. Seral species such as Douglas-fir could rarely reproduce in these circumstances.

Most timber harvest has been accomplished by clearcutting stands of trees. Clearcutting and burning creates site conditions suitable for regenerating Douglas-fir. This mimics to some degree the natural conditions under which Douglas-fir regenerates.

Regenerating forests by clearcutting and burning differs in several important ways from wildfire. Clearcutting traditionally left no snags but wildfire leaves nearly all the trees standing as snags. Clearcutting results in stands that have no recruitment potential for large logs to the forest floor during the early and mid-successional stages. Clearcutting was often practiced in areas where fire rarely burned which eliminated the most stable component of vegetation in the landscape. Clearcutting creates a patchwork of ages in formerly large even-aged forests. Clearcutting creates smaller chronic disturbances as opposed to single large disturbances. Slash fires associated with clearcutting have escaped and burned considerable acreage.

Timber harvest does not replace wildfire functionally or physically. Timber harvest should be viewed as an additional disturbance regime to the landscape. The older disturbance regime of large wildfires will continue to play an important role despite suppression efforts.

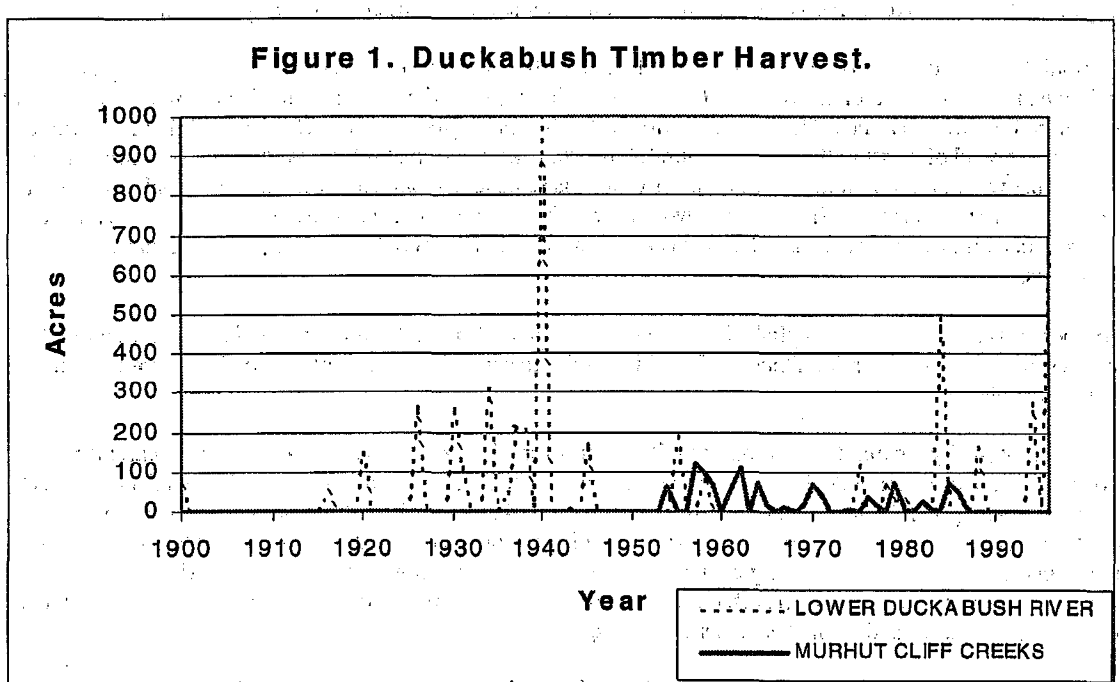
Clearcutting in the mid-elevation forests tended to remove stands with the largest trees. These were the fastest growing stands or the older stands that had survived multiple large fires in the past. The result was the selective reduction or elimination of stands with the greatest structural diversity. In even aged areas dating to large fires clearcutting has created greater age diversity by fragmenting even aged forests but where much clearcutting has been done there is a reversal of matrix from old to young and an overall reduction in structural diversity.

Wildfires left all the trees on the site first as snags and later as logs. This provided important habitat diversity not present in the current situation. Pre-settlement fires also left patches of trees in riparian or other cool-moist situations. In the recent past these patches have been highly sought after for timber.

The major consequences of the new fire and cutting regime is not the killing of trees or the conversion of large tracts of forest from old to young. This has occurred repeatedly in the past at larger scales than is currently taking place. Most major consequences relate to road building, the removal of logs from the site, the more rapid rotation rate of forests, the selective elimination of stands with the greatest structural diversity and the permanent occupation and conversion of important lowland forests, and winter range by people.

Low elevation forests once provided much needed wintering grounds for many species of wildlife and unique high quality year around habitat for many other species. These species are now excluded, forced to compete with people, or with animals people have introduced. Many species of native vegetation have been partially displaced by non-native species. Roads, chronic harvest entry and rapid rotation is creating sedimentation problems for aquatic species.

Logging in the Duckabush started about the turn of the century and reached a peak in the 1930's and 1940's (Figure 1). Most of this logging consisted of railroad logging on public and private lands in the Lower Duckabush Subwatershed. Forest Service logging records appear to be incomplete for railroad logging in the Murhut/Cliff Creek Subwatershed. It appears that as many as 200-300 additional acres may have been harvested from the Duckabush valley bottom and toeslopes in the Murhut/Cliff Cr. Subwatershed than what shows in Figure 1.



Snow Avalanche

Snow avalanche has been and remains an important disturbance agent on south facing slopes. When wildfire burns the upper slopes avalanche activity increases. As the forest grows back at higher elevation more snow is held in place and less avalanching occurs. Snow avalanche activity is probably lower now than at most times in the past with the possible exception of the lowest two subwatersheds where wildfires have affected the upper slopes during this century.

Avalanching snow frequently sweeps paths free of large woody vegetation on steep, high mountain slopes. Snow avalanches can carry both woody debris and sediment into streams. Snow avalanching is especially pronounced when fires remove forest vegetation that would otherwise hold snow from sliding. Following the 1701 fire avalanche chutes were probably more common and longer. Regrowth of forests have increasingly stabilize the snow on the slopes reducing the number, size and frequency of avalanches. Avalanches create open brushfields of supple stemmed plants such as vine maple, sitka alder and many herbs. These openings are important for wildlife.

Wind Disturbance

Ultimately most trees and snags probably fall under the influence of wind. Most fall only after having been severely weakened by root rots, stem rots, butt rots or insect excavation. Windstorms also break out live tree tops reducing growth, deforming stems and allowing entry of pathogens. Across the entire landscape the cumulative effect of wind is very large. Clearcutting creates unstable high contrast forest edges vulnerable to blowdown. Blowdown is more common in this environment than under natural conditions.

Mass Wasting

Mass wasting is one of the few disturbances capable of altering the vegetation potential of the land. Deep seated mass wasting events remove soil, create new surface shapes and alter moisture relationships. Plant communities that return to these sites may be different from those that grew there before the event. Cumulatively over long periods of time mass wasting is a dominant force shaping the vegetation on the landscape. In the short term the concern is more for aquatic systems and for lost forest productivity at the site of the event. Scars from mass wasting take a very long time to heal and productive forest soils may take centuries to form.

Mass wasting events are often related to other disturbances in the landscape. Large fires which temporarily alter hydrologic characteristics of the land and reduce root strength by killing soil holding trees and plants may set up conditions conducive to mass wasting. Windstorms which sway or blowdown trees on saturated soils may trigger mass wasting. Clearcutting and road building are also important in setting in motion events that could lead to mass wasting. Large earthquakes have caused very large rock avalanches in the past creating boulder fields and damming drainages to create lakes (Schuster et al. 1992, Buckman et al. 1992).

Some of these events may have occurred in the Duckabush and affected vegetation by altering drainage patterns and creating unique soils. Drainage appears to be shunted under or around a glacial bench above Collins Campground by one slide creating conditions for a dryer than expect plant association. Fine soils across the river that may have accumulated in a slide impoundment of the river support a moister than expected plant association on similar flats. Whether these soils are the result of a landslide is conjectural but evidence of a large slide is present.

Insect and Disease

There are no disease or insect infestations that are known to have achieved epidemic proportions. Fungi, insects and parasites cumulatively have large impacts on the forests. These species usually affect trees in a scattered or diffuse manner over long periods of time and often pass unnoticed.

Hemlock dwarf mistletoe (*Arceuthobium tsugensis*) is a common stem and branch parasite of old-growth stands of western hemlock, mountain hemlock and occasionally on silver fir and subalpine fir (Henderson et al. 1989). Hemlock Dwarf mistletoe infects younger trees in the vicinity of older infected trees. It is also common in young-stands of western hemlock which have been released by wind or harvest overstory removal of an older stand. It causes swelling and profuse branching thereby diverting resources of the tree into creating more habitat for itself. While this activity degrades lumber quality and slows growth of the tree it also creates dense "brooms" used by birds for roosting and nesting. Similar brooms caused by Chrysomyxa rust on spruce trees are used by flying squirrels for nesting sites in interior Alaska (Mowrey and Zasada 1984).

There are three common root diseases, laminated root rot, Armillaria root disease and annosus root disease (Henderson et al. 1989). Root diseases reduce the vigor and growth of the infected tree and occasionally kill the tree. Often root strength is reduced allowing the tree to blow over in wind storms. Root diseases normally spread out from tree to tree through root contacts creating expanding centers of infection. Not all trees succumb to the infection and some species are less susceptible than others.

Root rots sometimes decrease the harvestable volume of timber substantially. They are also responsible for a steady recruitment of green trees into snags and down logs useful to wildlife as the forest ages and important to nutrient cycling. Root diseases help thin young stands unevenly creating a diversity of stand conditions earlier than would otherwise be the case.

Heart and butt rots are normally decay organisms of dead wood. In this role they are important to nutrient cycling and soften the wood so other organisms can excavate cavities in which to live. Occasionally some of them attack live trees through wounds such as might be caused by wind breakage or thinning damage. In this case they degrade lumber quality and leave trees vulnerable to stem breakage and windthrow. When heart or butt rots infect live trees they create new habitats such as hollow centers which are used by many species of wildlife. Important heart and butt rots include brown cubicle butt rot, annosus root rot, red ring rot, brown trunk rot, rusty-red stringy rot, armillaria root rot, crumbly brown rot and long pocket rot (Henderson et al. 1989).

There are five potential insect pests of conifers in the Duckabush Watershed. They are the Douglas-fir beetle, silver fir beetle, western blackheaded budworm, hemlock looper and balsam wooly aphid (Henderson et al. 1989). None of these species have been observed causing significant mortality in recent years. The main ecosystem role of these species is their contribution toward weakening trees for creation of snags useful to other species.

Herbivory

Herbivory by mammals has a substantial but not always highly visible effect on vegetation. Some the most visible effects are produced by black bear consumption of inner tree bark that can result in tree mortality. Black bear damage is generally not a significant problem in the Duckabush Watershed. Occasionally hungry bears will strip bark from trees in the spring severely damaging or killing them.

Bear usually strip young trees with thin easily strippable bark. For this reason they are more likely to cause observable damage in regenerating clearcuts or other young stands. The effect is usually a beneficial uneven thinning which creates habitat diversity in very even young stands. Occasionally enough trees are killed to create a significant impact on timber productivity of the stand.

Bear damage is typically heaviest on 5-15" diameter trees but much larger trees are sometimes used. The greatest damage has been reported to Douglas-fir trees but significant amounts have been observed on western hemlock, western redcedar and silver fir. Most other conifers and hardwoods have only occasionally been observed with damage (Poelker and Hartwell 1973).

Large herbivores such as elk and deer consume a variety of plants but without the benefit of exclosure studies the effects are often not apparent. Extreme effects of herbivory are sometimes visible in areas where elk or deer populations are adjusting to new conditions. Examples of this can be seen when disturbance creates large openings with small residual islands of older vegetation. Vegetation in the islands is commonly heavily utilized.

Introduced mountain goats have been shown to significantly impact alpine and subalpine vegetation both through herbivory and trampling (Houston et al. 1994). Most evidence indicates that there were no mountain goats present in the Olympics prior to introductions in the 1920s. Mountain goats have been present in the Duckabush Watershed since at least 1946. The Duckabush is not considered to be one of the more densely populated areas for mountain goats. Some rare plants including Claytonia lanceolata var. pacifica which is found in the Headwaters Subwatershed are grazed by mountain goats. There appears to be legitimate concern that subalpine and alpine communities in general and some rare plants in particular are being adversely impacted by mountain goat herbivory.

4) What restoration actions enhance important vegetative processes and structures compromised over historic levels as determined by the watershed analysis?

Restoration should focus on restoring historically stable landscape components, reducing fragmentation of late successional vegetation, maintaining connectivity between late successional stands and incorporation of some late successional structure into managed stands. Introduction and early spread of exotic species should be prevented or controlled. Prevention and control of human caused fires is integral to achieving restoration activities. In many cases planning and time are the only means of restoration.

The following section states first a problem and then discusses restoration actions.

1) Wildfires resulting in:

a) more mid-successional vegetation in the lower two subwatersheds than would have occurred naturally and

b) reduced fire return interval reducing the chances of growing late successional vegetation in the future.

Fire suppression to prevent small fires from becoming large remains important. Without effective fire suppression it is unlikely that late successional vegetation can be grown in the Lower Duckabush Subwatershed and portions of the Murhut/Cliff Creek Subwatershed. Public education to make known the consequences of a reduced fire return interval in terms of economics and ecology is needed.

Stand treatments to create additional structure could be undertaken in mid seral stands assuming the investment would not be lost to wildfire. These treatments would show the quickest results and have the highest probability of surviving on moister, higher site lands (most of which have also been subjected to timber harvest). Lower site lands and dry south facing slopes where fire is more likely might be left to recover naturally. Treatments could include variable thinning and snag creation however it should be noted that the efficacy of these treatments is not yet proven for this use.

2) Land conversion from forest to agricultural and urban uses mostly in the Lower Duckabush Subwatershed.

Effects of land conversion from forest to agricultural and urban uses must be addressed at the local level since willing participation by the property owners would be needed. In general actions resulting in more coherent riparian corridors, more native forest cover, less ground disturbance, fewer exotic plant introductions and control of existing noxious weed infestations would be desirable.

3) Fragmentation from timber harvest of late successional vegetation in the lower two subwatersheds.

Fragmentation is mainly an issue on Forest Service lands in the Murhut Cr. drainage where timber harvest has created a patch pattern in formerly old-growth forest. The early and mid seral stands growing back from clearcutting are simpler in structure than the late successional stands they replace or early and mid successional stands which might have resulted from fire. The inclusion of this area in Late Successional Reserve will allow this area to grow old forests again which will have complex structure and will eliminate edge effects in adjacent stands. Stand treatments to create additional structure could be undertaken. These treatments would show the quickest results on moister, higher site lands. Treatments could include variable thinning and snag creation however it should be noted that the efficacy of these treatments is not yet proven for this use.

Fragmentation in the Lower Duckabush Subwatershed is not an issue at the current time because the forest matrix is mid successional. Under these conditions fragmentation may add needed diversity. Younger patches provide game browse and open habitat. Old patches would provide at least some refuge for old-growth dependent plants and animals if places could be found to grow them. The U.S. Forest Service quarter section in section 18 should be considered for this use. It is currently an Adaptive Management Area which would allow stand treatments deemed beneficial or neutral for this objective now or in the future.

4) Conversion of the forest matrix from late to mid successional in the Lower Duckabush Subwatershed.

This has been addressed on Forest Service lands by inclusion of most of the ownership in Late Successional Reserve. Stand treatments to create additional structure could be undertaken. These treatments would show the quickest results and have the highest probability of surviving on moister, higher site lands. Treatments could include variable thinning and snag creation however it should be noted that the efficacy of these treatments is not yet proven for this use. Lower site lands and dry south facing slopes where fire is most likely might be left to recover naturally.

5) Introduction of noxious weeds and other exotic species into the early successional flora and disturbed sites.

Exotic species introduced to date benefit from open sites and ground disturbance. In most cases it is not practical to eradicate existing exotic plants. Eradication efforts should focus on small new populations. Prevention of new infestations is the most effective way to deal with exotic plants. Prevention aims to eliminate dispersal and create habitat not suitable for establishment.

Exotic plant seeds hitch rides on vehicles, machinery, people, wildlife, and domestic stock. Washing of vehicles and machinery has been effective in some instances, especially prior to entry into areas with newly disturbed ground. Educational efforts can be made to encourage people to avoid walking through infested areas into uninfested areas. Domestic stock can be quarantined on a weed free diet and cleaned prior to entry into uninfested areas.

Habitat can be made less suitable for weeds by maintaining or creating shade. Areas of newly disturbed ground should be rapidly revegetatated with native plants, sterile hybrids or non-native plants that can be shown to give way to natives over time. Rapid establishment of forest cover should be the main goal. Every effort should be made to establish a diverse community on the disturbed site to preempt habitat from exotics. Monocultures of erosion control species are still vulnerable to weed invasion. A diverse community preempts more niches that would otherwise be available to weed species.

6) Overgrazing by non-native mountain goats.

Active restoration is probably not needed in most cases, however strict controls on mountain goat populations needs to be maintained. Subalpine and alpine vegetation and rare plants known to be used by mountain goats should be closely monitored.

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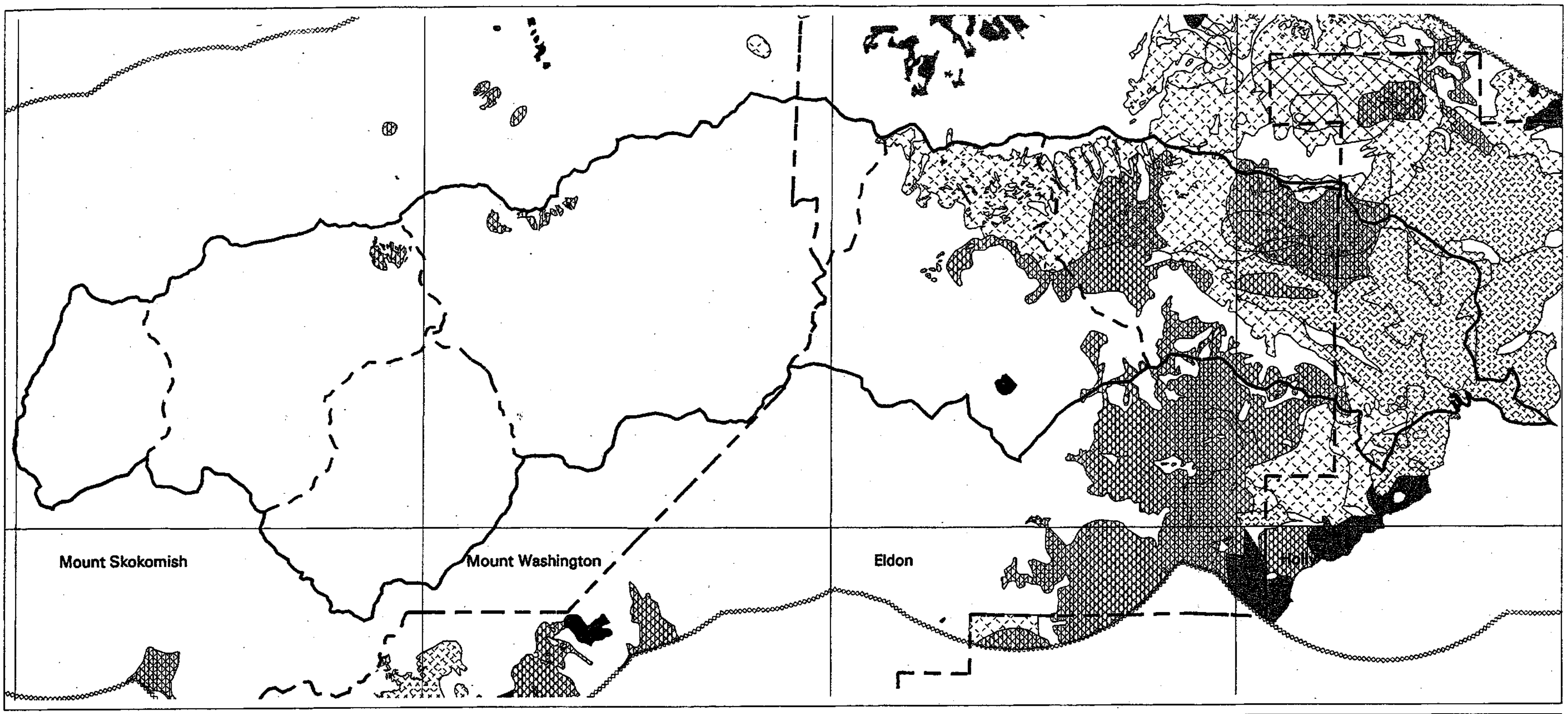


The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial Information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

LEGEND

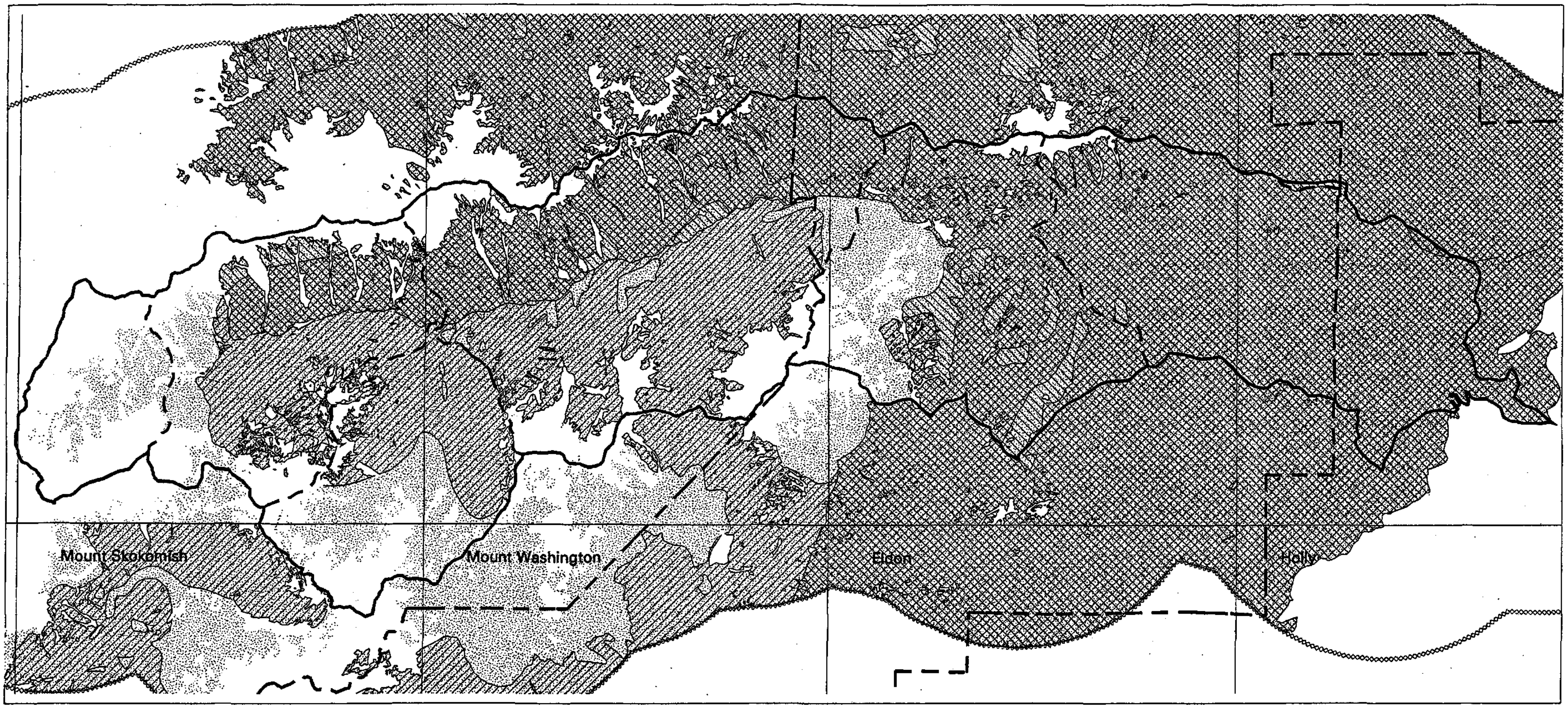
- Fire Years 1867 & 1895
- Fire Years 1900 - 1910
- Fire Years 1911 - 1920
- Fire Years 1921 - 1930
- Fire Years 1931 - 1940
- Fire Years 1941 - 1950
- Fire Years 1951 - 1960
- Fire Years 1961 - 1970
- Fire Years 1971 - 1980
- Fire Years 1981 - Present
- Prairies
- Quad Boundaries
- Watershed Analysis Area
- Subwatersheds
- Forest Boundary
- WAA Buffered 2.7 miles

Fire History- Historic Fire Groups

Map# 2.8D

The Duckabush Watershed Analysis Team

l_histfires April 15, 1998



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N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

l_oldfires April 14, 1998

LEGEND

No Known Fires
Fire Year 1308
Fire Year 1508
Fire Year 1701
Quad Boundaries
Watershed Analysis Area
Subwatersheds
Forest Boundary
WAA Buffered 2.7 miles

**Fire History-
Prehistoric Fire
Groups**

Map# 2.8F

*The Duckabush
Watershed Analysis Team*

2.9 Hydrology

Introduction

Purpose

This module presents a hydrologic assessment of the Duckabush River watershed analysis area. The purpose of conducting this assessment is to describe the hydrologic functions of the watershed and to examine the probable influence of land management on hydrologic processes. The following questions will be addressed:

1. **What are the dominant hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and other notable hydrologic features and processes in the watershed (e.g., cold water seeps, ground-water recharge areas)?**

2. **What are the historic hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and features (e.g., cold water seeps, ground-water recharge areas) in the watershed?**

3. **What are the current conditions and trends of the dominant hydrologic characteristics and features prevalent in the watershed?**

4. **What are the natural and human causes of change between historic and current hydrologic conditions?**

5. **What are the influences and relationships between hydrologic processes and other ecosystem processes (e.g., sediment delivery, fish migration)?**

6. **What are the influences and relationships between water quality and other ecosystem processes in the watershed (e.g., mass wasting, fish habitat, stream reach vulnerability)?**

Methods

The team used the Ecosystem Analysis at the Watershed Scale, Version 2.2, Revised Federal Guide for Watershed Analysis (USDA, 1995). Water quantity and quality characteristics were determined using United States Geological Survey (USGS) gauging station data, various studies, and very limited field reconnaissance. Precipitation, vegetative condition (hydrologic maturity), drainage density, road density, and anecdotal information were used to analyze the study area.

Team members delineated the watershed analysis area into one fifth field watershed subdivided into six subwatersheds (Map 2.9A, Table 2.9A in Appendix 2.9). Team members delineated these hydrologic boundaries using USGS quadrangle maps (1:24,000 scale), following direction given in the National Instruction No. 170-304: Mapping and Digitizing Watershed and Subwatershed Hydrologic Unit (HU) Boundaries (USDA Natural Resources Conservation Service, 1996). Information based on aerial photo interpretation and field reconnaissance was also used to determine watershed boundaries for areas that were not easily discernible on quadrangle maps. Subwatershed coverage is stored electronically in the Olympic National Forest Geographic Information System (ONF GIS) database.

The team stratified the watershed analysis area into five different precipitation zones based on elevation according to the Washington State Department of Natural Resources (WDNR): 1) lowland (less than 800 feet elevation), 2) rain-dominant (800 to 1600 feet elevation), 3) rain-on-snow (1600 to 2900 feet elevation), 4) snow-dominant (2900 to 4400 feet elevation), and 5) highland (greater than 4400 feet elevation) (Washington Forest Practices Board (WFPB), 1995) (Map 2.9C, Table 2.9B in Appendix 2.9). In addition, historic and current climatological data derived from data files and reports of various organizations was used.

The entire watershed area was characterized with respect to hydrologic maturity. Land use and vegetative cover types were categorized in accordance with the State Watershed Analysis Manual (WFPB, 1995) for this purpose. Hydrologic maturity is based on the percent total crown closure and the percent crown cover in hardwoods or shrubs, and is grouped into the following categories: hydrologically immature, intermediate hydrologic maturity, and hydrologically mature. Hydrologically mature areas include those in which crown closure is at least 70 percent. These areas include old-growth and mature second growth stands. Intermediate hydrologic maturity have crown closure ranges from 10 to 70 percent. Second growth stands are predominant in these areas. Hydrologically immature areas are those with less than 10 percent crown closure. Clearcut harvest and young stands characterize these areas. Four non-forest land use types also included in the hydrologically immature category include: agricultural, urban, open water and other (Map 2.9B, Tables 2.9B and 2.9C in Appendix 2.9).

The team determined hydrologic maturity conditions based on a combination of methods that best fit the vegetative cover and land use data available at the time of analysis. Hydrologic maturity for National Forest System (NFS) lands was based on information taken directly from managed stand data within the vegetative data base, air photo interpretation of unmanaged stands and satellite imagery interpretation. Vegetative information for Olympic National Park (ONP) was derived from satellite imagery and air photo interpretation. Hydrologic maturity for non-NFS lands was assigned upon determination of the relationship between age thresholds and crown closure by series and sub-series utilizing air photos and satellite imagery obtained from Washington State Department of Natural Resources. This relationship was established in consultation with the Olympic National Forest's Area Ecologist and Vegetation Module Leader, a person who is familiar with the landbase being studied. Series and sub-series information was obtained from the Olympic National Forest Plant Association Group (PAG) Model (See Vegetation Module) (Table 2.9D, in Appendix 2.9).

Streams, lakes, ponds, and wetlands were mapped for the entire analysis area (Map 2.9D). The stream layer was derived by combining Forest Service Geometronics Service Center (GRC) hydrology layer and the WDNR hydrology layer data. The GRC and WDNR layers were both digitized at the 1:24,000 scale from USGS 7.5 minute quadrangles, and included photogrammetric interpretations and information from various other internal sources within their respective agencies. In addition to the GRC and WDNR data, the lakes, ponds and wetlands layers also include National Wetlands Inventory layer data. This inventory was conducted at a 1:100,000 scale. Refer to Exhibit 2.9A in Appendix 2.9 for a more detailed description of the wetland layer development methodology.

Stream and road densities were determined using stream and road length (linear miles) and subwatershed area (square miles) data generated from the ONF GIS system data base (Table 2.9E in Appendix 2.9).

1. What are the dominant hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and other notable hydrologic features and processes in the watershed (e.g., cold water seeps, ground-water recharge areas)?

Spatial and temporal variations in precipitation drives the hydrology of the watersheds. The influence of maritime air masses from the Pacific Ocean results in high precipitation to the south of the watershed, while the northern portion of the watershed analysis area is more shielded from intense Pacific winter storms. Precipitation occurs predominantly as rain within the low-lying areas, with concentrations of snow in the higher elevation areas. Average annual precipitation ranges from 81 inches in the Lower Duckabush subwatershed to over 155 inches in the Headwaters Duckabush subwatershed. Mean annual precipitation for the entire watershed estimated about 113 inches. Seasonal variation is well defined, with about 95 percent of the precipitation occurring September through May within the lower watershed (based on measurements taken at Hoodsport).

Surface water runoff patterns relate directly to the amount, intensity, and of precipitation. Runoff response within the Duckabush watershed shows a moderate to rapid response in precipitation events. Runoff response to precipitation events within the lower elevation rain-dominant areas is moderate to rapid. The seasonal variation in runoff follows the precipitation pattern, and is characterized by high winter flows and moderately low summer flows. However, the seasonal runoff pattern within this watershed reflects the influence of snowmelt. High winter flows are followed by a series of high flows that occur during spring snowmelt. Snowmelt in the headwater areas attenuates summertime low flows.

Topographic conditions vary within the roughly 78 square mile analysis that is about 24 miles long and ranges in width from 2.6 to 5.6 miles. The watershed is oriented in a west-east direction, with drainage from the headwaters flowing in a general easterly direction to Hood Canal. Elevation in the analysis area ranges from sea level to over 5,000 feet. Shoreline character transitions from relatively flat within the estuary and mouth area to gently sloping or steep, nearly vertical bluffs. Headwater areas of many of the stream systems extend into the steep-sloped Olympic Mountains. Within the study area, the highest point is The Brothers (6,866 feet).

Topography does effect the timing of surface water runoff as the result of high drainage density that occupies the watershed. Delivery of water from steep first and second order channels is generally rapid. Aspect of the slopes also influences surface runoff patterns. North-facing slopes in the higher elevation zones maintain snowpack for longer periods in comparison with south-facing slopes, due to the influence of solar radiation. The character of vegetation on the differing slope aspects (See Vegetation Module) also effects runoff.

Lakes are concentrated within the upper areas of the watershed. Within the Headwaters Duckabush River subwatershed the largest lakes include Buck, LaCrosse, and Marmot Lakes. Crazy Creek subwatershed includes Hagen and Scout Lakes. The largest wetlands are associated with the mainstem Duckabush River and lie predominantly within the Middle and Lower Duckabush River subwatersheds (Map 2.9D).

2. What are the historic hydrologic characteristics (e.g., total discharge, peak flows, minimum flows) and features (e.g., cold water seeps, ground-water recharge areas) in the watershed?
3. What are the current conditions and trends of the dominant hydrologic characteristics an features prevalent in the watershed?

Climate

The present climate of the Olympic Peninsula is relatively wet and warmer in comparison to the past 50,000 years. On a global scale, current climate conditions are characterized as cool, temperate, and maritime. On a broad scale, the climate patterns we see today have probably occurred since the end of the last ice age, about 10,000 years ago. Westerly flow from the Pacific picks up moisture from near the Hawaiian Islands and deposits extremely high precipitation as it rises over the mountainous terrain of the Olympics.

Limited historic evidence indicates large fluctuations in climate on the Olympic Peninsula. Conditions during the Pliocene and Miocene periods (13 to 25 million years ago) was quite different from recent climate conditions. Climate during the Miocene was warm, wet and temperate. The Hypsithermal Period from 4,000 to 10,000 years ago was considered the driest and warmest in the last 50,000 years. The Neoglacial period that began about 4,000 years ago was slightly cooler, but much wetter and more maritime. Two or three glaciations occurred from about 1,000 to 4,000 years ago. The period of the Medieval Optimum from about 1000 to 1300 AD was warm and dry (Henderson et. al., 1989).

Variations of general climate pattern have also occurred in recent centuries. Past climate was relatively cooler and drier compared to present conditions. The fourteenth century through about 1850 is the period called the "Little Ice Age", which marked approximately 600 years of cold winters in northern latitudes. The coldest periods were probably between 1400-1510 and 1645-1715. Higher proportion of the precipitation likely fell as snow because of the colder conditions. Towards the end of the Little Ice Age, from about 1750 to 1830, the climate in the Pacific Northwest was probably cool and wet. Glacial records and tree rings that indicate poor tree growth show this trend (Henderson et. al., 1989).

Within the overall wetter conditions since the Little Ice Age, drier periods occurred in the mid 1930's and 1940's, followed by a wetter period up to 1973 (Haushild et. al., 1978). Average annual precipitation during the late 1970's to the present time has been somewhat drier than pre-1973. Precipitation data collected at Port Angeles since 1878 indicate that the late 1800's was wetter than previous conditions, and drier periods occurred in the 1920's and 1940's (Brubaker, not dated). Rainfall data collected in Olympia, Washington indicate very low summer (June, July, and August) precipitation levels, often measuring less than 2 inches, in the 1910 and 1920 decades. In comparison, for the period 1953 through 1983 showed only two years with less than 2 inches of rainfall (Henderson, et. al., 1989).

Spatial distribution of precipitation within the analysis area due partly to orographic controls, and results in annual precipitation ranging from around 81 inches in the Lower Duckabush subwatershed to over 155 inches in the Headwaters Duckabush subwatershed. Total annual precipitation was calculated for each of the subwatersheds based on data generated from GIS as follows: Headwaters Duckabush River (156 inches); Upper Duckabush River (139 inches); Crazy Creek (137 inches); Middle Duckabush River (113 inches); Murhut and Cliff Creeks (101 inches); and, Lower Duckabush River (81 inches). Average annual precipitation for the entire watershed is estimated to be around 113 inches. Data used to calculate average annual precipitation values is stored in project files at the Olympic National Forest.

Precipitation data collected in the community of Hoodsport (south of the Duckabush watershed) was used to show general precipitation trends for the area. Measurements taken at the Hood Canal Ranger Station (located in Hoodsport), indicate the variation in annual precipitation rates and a wide range in monthly averages. Total annual precipitation for the period January 1959 to December 1996 ranged from a low of about 53 inches in 1985 to a high of about 117 inches in 1983, averaging roughly 89 inches (Figure 2.9A, Table 2.9F in Appendix 2.9). Mean monthly precipitation ranges from about 1 inch in July to around 16 inches in December (Figure 2.9B, Table 2.9F in Appendix 2.9). About 95 percent of the precipitation occurs September through May (USDA Forest Service, 1996, unpublished).

Figure 2.9A Hood Canal Ranger Station Annual Precipitation 1959-1996

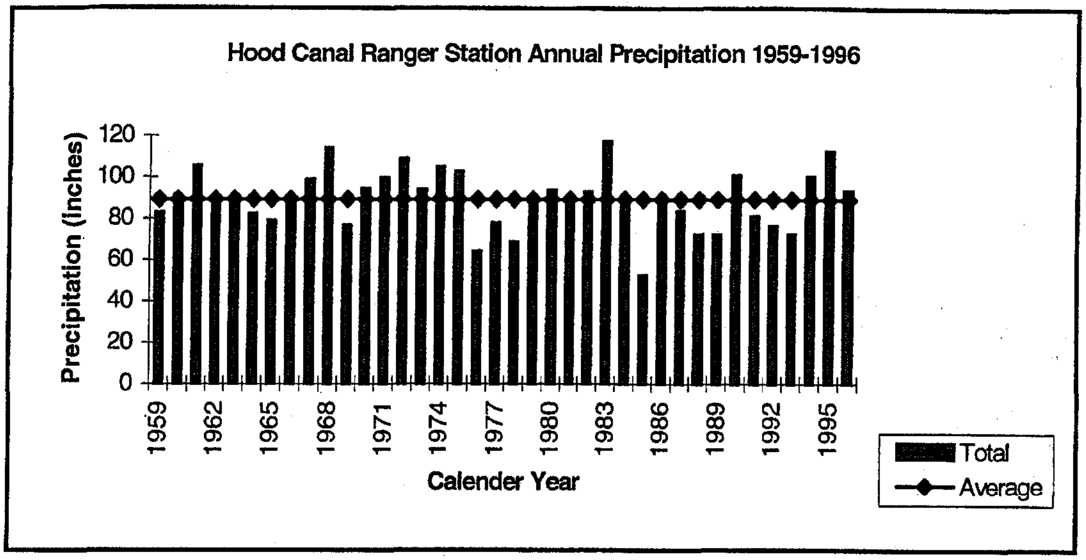
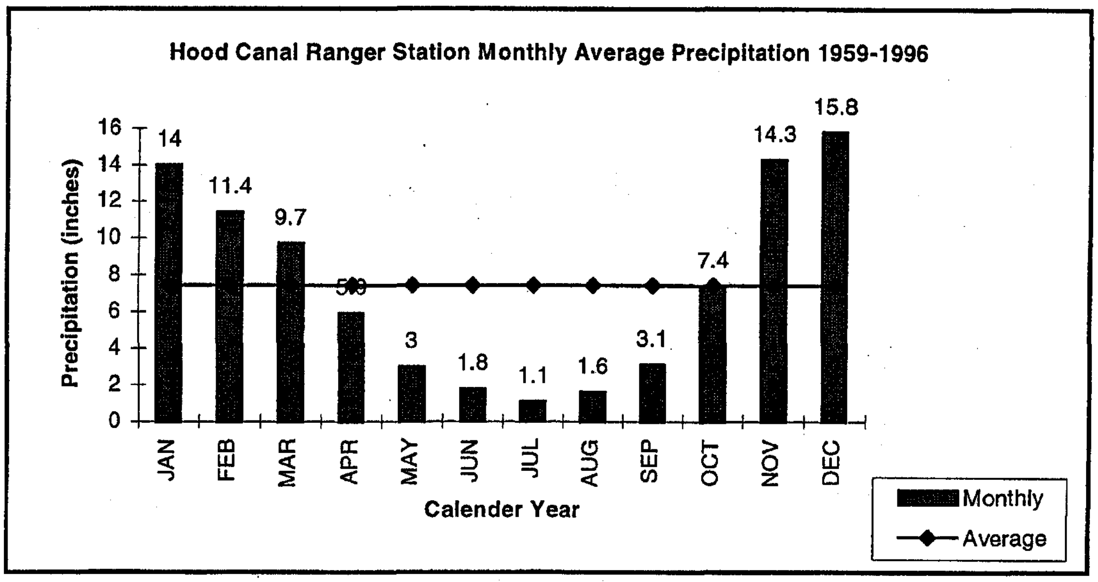


Figure 2.9B Hood Canal Ranger Station Monthly Average Precipitation 1959-1996



Hydrologic Setting
On a broad scale, hydrologic conditions have probably been about the same throughout the Holocene, the period from about 10,000 years ago, to the present time. However, variations in ground water and surface water occurred throughout this period, given the changes to climate, vegetative cover, and development of soils.
The climate during the Holocene varied slightly about the generally wet, moderate conditions. Slightly drier or wetter periods resulted in somewhat higher or lower amounts of water being available for ground-water recharge. The landscape presumably changed markedly with the retreat of the most recent glaciers. The earliest post-glacial surfaces of till, outwash, and alluvial fans would not have supported plant growth. Soils slowly formed from these surficial deposits (Henderson, et. al., 1989).

The evolving vegetative cover changed the proportion of the incident precipitation available to recharge groundwater or surface runoff. Generally, the plants used more of the precipitation for evapotranspiration, which translated to a loss from the amount available for recharge or runoff. The forest cover limited surface-water runoff amounts. The large crowns intercepted precipitation falling on the forest and allowed much to evaporate. The trees also transpired much of the water that either fell to the forest floor directly or dripped from the canopy. However, the forest cover also retained some of the storm water that had previously run off by capturing it in the forest canopy or in forest litter. This capture typically represented a gain for the amount available for recharge.

More recent historical streamflow records indicate distinct variations within the streamflow regime. Runoff distribution similar to precipitation distribution characterizes the watershed analysis area. In general, retention time in the watershed is relatively short, and stream levels rise and fall rapidly. Peak flows occur during the rainy season, predominantly in December and January. Peak flows also occur in May and June as the result of runoff due to snowmelt within the higher elevation areas of the Duckabush.

Streamflow data collected at USGS gauging stations (see Table 2.9G, in Appendix 2.9) characterize runoff distribution within the analysis area. The USGS has measured daily streamflow on the Duckabush River at gauging station 12054000 continuously from June 1938 to the present. High average daily and average monthly streamflow occurs in the winter months (November, December and January), and again in the Spring (May, June), as is illustrated in the graph in Figure 2.9C. This graph depicts daily flow for Water Years 1979 through 1985, a period selected simply to show streamflow patterns that occur in the watershed.). Streamflow records for the Duckabush River indicates that slightly higher average monthly flows occur in December (585 cfs) as compared to the Spring months May (556 cfs) and June 571 (cfs) (Figure 2.9D, Table 2.9H in Appendix 2.9)). Precipitation in the form of rain influences runoff the winter and spring months. However, snowmelt contributes greatly to flow conditions in the months of May and June. Snowmelt within the Duckabush headwaters attenuates summer flows in general. Daily streamflow values are stored in electronic form in the project files. On annual basis, average daily discharge at the Duckabush gage is 411 cfs.

Figure 2.9C Average Daily Streamflow for Duckabush River Water Years 1979-1885

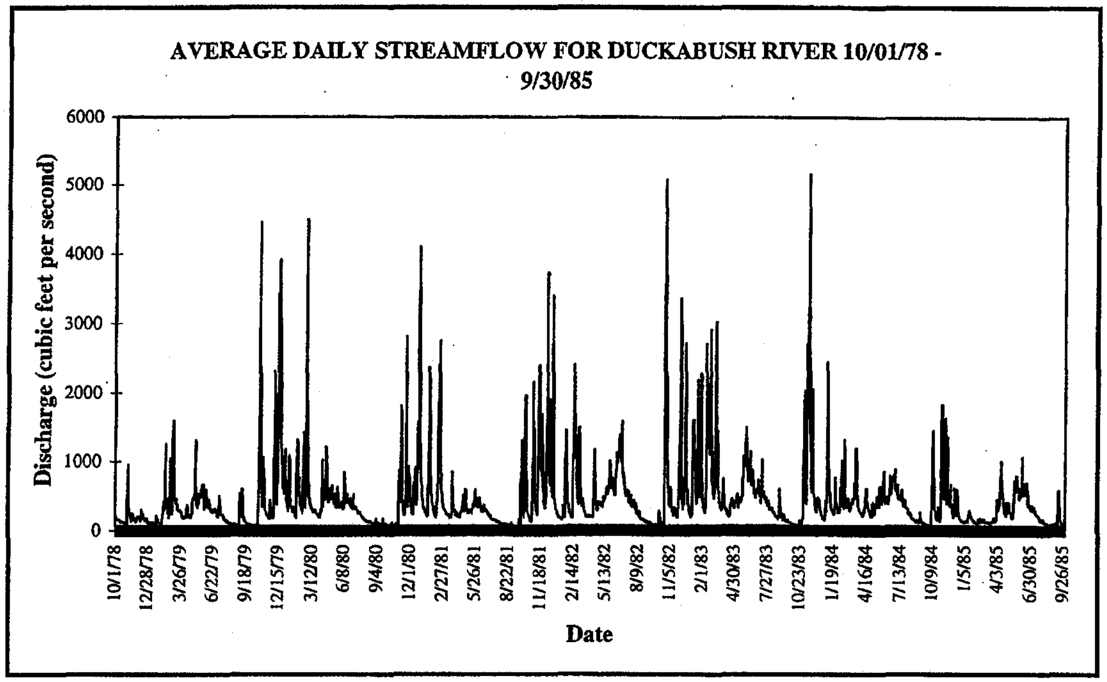
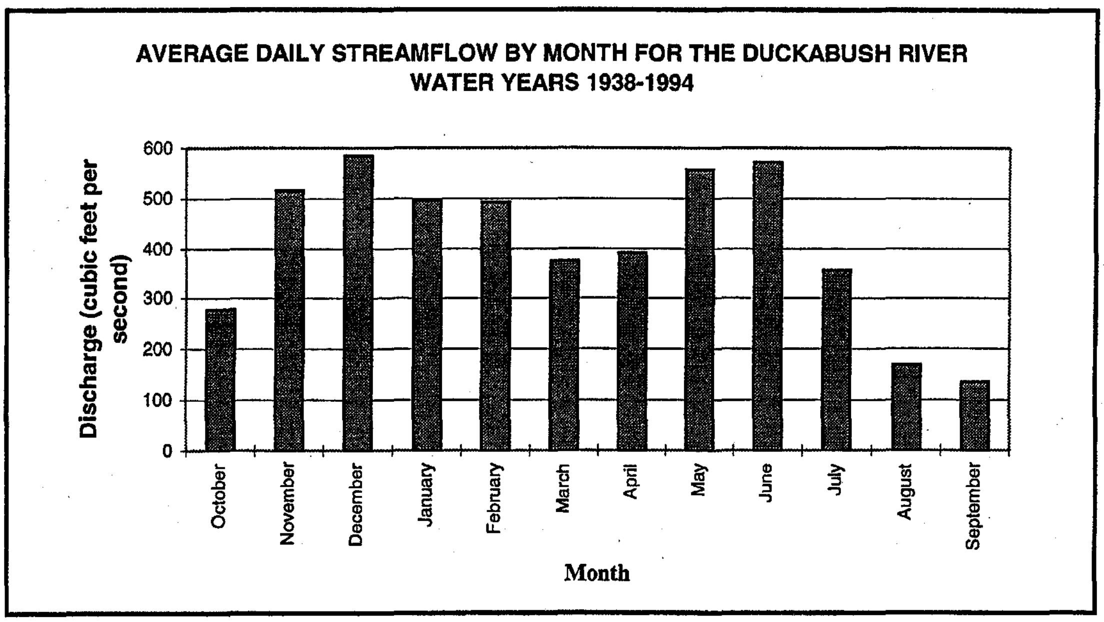
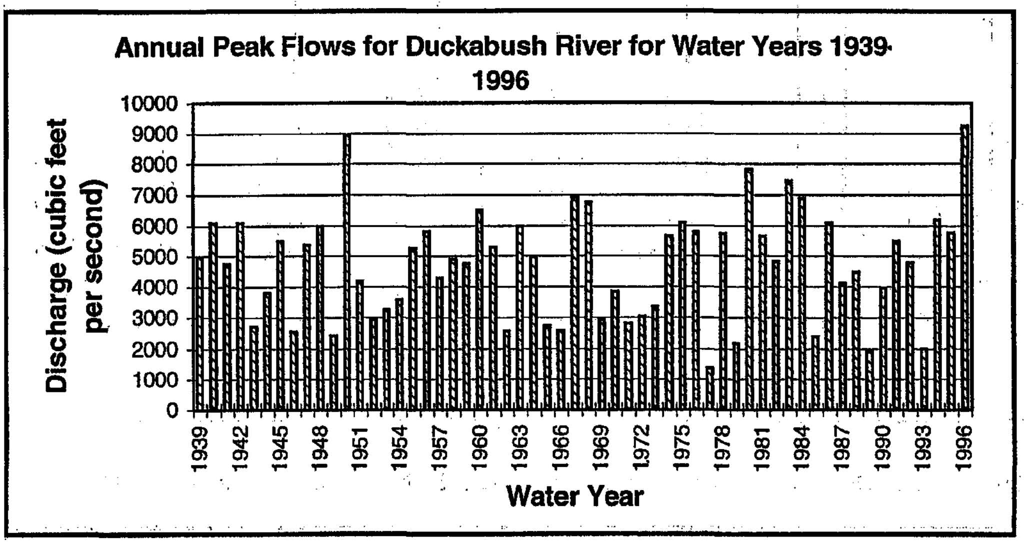


Figure 2.9D Average Daily Streamflow by Month for the Duckabush River Water Years 1938-1994



The USGS has measured peak flows at the Duckabush River gage for the period Water Years 1939 to the present. The greatest peak flow measuring 9,240 cubic feet per second (cfs) occurred in Water Year 1996. According to Log Pearson III statistics calculated for the Duckabush River gauge data (Williams et. al., 1985), this event has a recurrence interval of nearly 50 years (Figure 2.9, Table 2.9J in Appendix 2.9). The next greatest peak events occurred in Water Years 1949, 1980, 1983, 1967, and 1984 (Table 2.9I in Appendix 2.9). Table 2.9J lists the estimated discharge for the 1.01-, 1.05-, 1.11-, 1.25-, 2, 5-, 10-, 25-, 50-, and 100- year recurrence interval for USGS gauging station 12054600, based on Log Pearson III Analysis conducted by the USGS (Williams et. al., 1985).

Figure 2.9E Annual Peak Flows for Duckabush River Water Years 1939-1996



4. What are the natural and human causes of change between historic and current hydrologic conditions?

Fires

Historically, fires have had an influence on hydrologic conditions. Removal of forest vegetation in general results in increased surface erosion and mass wasting. In turn, delivery of sediment and large woody debris to channels is expected. Loss of root strength following fires also increases the likelihood of mass wasting. Removal of vegetation over a large portion of the watersheds likely increased the timing and magnitude of peak flows. Large stand-replacing fires are known to have occurred since the early 1300's with a roughly 200-year recurrence (1308, 1508, and 1701). Following fires, uplands are slow to revegetate, especially south-facing slopes. In addition, snow avalanches are more common on burned sideslopes, a process impedes establishment of vegetation (See Vegetation Module).

Floods, Timber Harvest, and Road Network

Floods have been a historic occurrence in the watershed. Forest practices can alter the magnitude and timing of streamflows by augmenting storm runoff volume due to increased soil moisture or snowmelt and increased efficiency of water conveyance by the drainage network due to surface disruption such as road construction. Stream channel characteristics and dimensions form to accommodate the bankfull discharge event (2-year) in lower gradient self-formed rivers (Wolman et. al., 1960) and apparently the 5-year event in steep mountain streams (Lisle, 1981). Because 2-year and 5-year flows are considered to be channel-forming (or channel-changing) flows, fish habitat is considered significantly affected when shear stress increases significantly or when these flows occur with increased frequency. Over bank floods are an issue in regard to downstream public resources for 25-, 50-, and 100- year events (WFPB, 1995). (See Channel and Erosion Modules).

Urban/Residential Development
Conversion of forested landscapes to urban or residential areas has altered the surface hydrology within the lower portions of the watershed. Conversion to urban and residential use has resulted in increased impervious surface area, and increased road network. General speaking, this type of land development effects local surface hydrology through decreased capacity for infiltration of water into the soil, and more rapid surface runoff (Refer to Erosion and Vegetation Modules).

5. What are the influences and relationships between hydrologic processes and other ecosystem processes (e.g., sediment delivery, fish migration)?
6. What are the influences and relationships between water quality and other ecosystem processes in the watershed (e.g., mass wasting, fish habitat, stream reach vulnerability)?

Washington State has designated all surface waters lying within NFS lands as Class AA, or extraordinary. The State has set criteria for quality of its water resources through the Clean Water Act, Chapter 173-201 WAC. Criteria is set for fecal coliform, dissolved oxygen, temperature, and pH, among others. Waters within this classification must have a pH between 6.5 and 8.5, temperatures below 16 degrees Celsius, and a DO level greater than 9.5 milligrams per liter (mg/L).

No waterbodies lying within the watershed are listed on the Washington State Department of Ecology the 1996 Section 303(d) List. Water bodies listed are those where State water quality standards have been exceeded (WDOE, 1995). However, impacts within NFS lands and other ownerships have resulted from forest practices (See Erosion, Channel, Fish and Vegetation Modules). The Duckabush watershed empties into Hood Canal (South), which is a waterbody included on the 303(d) list based on excursions of water quality standards set for dissolved oxygen and fecal coliform. The Duckabush River is delta classified as a Restricted Commercial Shellfish Area due to high fecal coliform levels.

Precipitation regime, hydrologic maturity (as related to vegetative cover), road density, drainage density, and partial peak flow data were assessed to determine potential sensitivity to change in peak flow as the result of timber harvest and roads (Table 2.9B, Table 2.9E, both in Appendix 2.9).

The watershed analysis area was stratified into precipitation zones to determine what areas of the watershed may be susceptible to rain-on-snow events. These events occur as the result of high rates of snowmelt during rainy periods when air temperature and wind speeds are high. During these events, snowmelt can dramatically increase rates of water delivery to the soil (Coffin et. al., 1992) and/or increase rates of runoff above that resulting from rain alone. Channels may be altered by bank erosion, downcutting and redistribution of sediment and large woody debris. Rain-on-snow events may also trigger slope failure in steep, marginally stable slopes due to a reduction in shear strength (resistance to downslope movement) caused by increased soil pore water pressure (Swanson et. al., 1977). Rain-on-snow events have the highest probability of occurring in the mid-elevation rain-on-snow zone followed by the next greatest probability of occurring within the adjacent snow-dominated and rain-dominated zones. These events are least likely to occur in the highland and lowland zones (WFPB, 1995).

The Duckabush River watershed lies predominantly within the rain-on-snow zone (32.7 percent) and snow-dominated (23.8 percent) zones. Distribution within other zones includes 7.6 percent highland, 8.2 percent rain-dominated, and 5.8 percent lowland (Table 3.2B in Appendix 2.9). The majority (over 50 percent) of all Duckabush subwatersheds lie within the combined rain-on-snow, rain-dominant, and snow-dominant zones. Subwatersheds with the greatest percent area within these combined zones include Murhut Cliff Creeks (95 percent), Middle Duckabush River (93 percent), and Crazy Creek (89 percent). Based on this, these watersheds are likely to be sensitive to rain-on-snow events.

Hydrologic maturity is related to the ability of the vegetative cover to store snow. The greater the canopy crown closure of the forest, the less snow is stored on the hillslope and therefore available for runoff during subsequent precipitation runoff events. Hydrologically mature represents forested stands with greater than 70 percent canopy crown closure, intermediate hydrologic maturity represents stands with 10-70 percent canopy crown closure, and hydrologically immature represents stands with less than 10 percent canopy crown closure. For this analysis, non-forested vegetative covers (agricultural, urban, open water and other) are considered to be hydrologically immature because of their ability to store deep snowpacks and generate rapid melt during periods of rain-on-snow conditions.

For the six subwatersheds assessed, hydrologic immaturity ranged from 7 to 62 percent. (Table 2.9B, Map 2.9B). Three subwatersheds with the greatest percent area in hydrologically immature condition include Headwaters Duckabush River (62 percent), Crazy Creek (35 percent), and Upper Duckabush River(28 percent). Highland areas characterized by sparse canopy cover in these three subwatersheds account for much of the area considered hydrologically immature. In comparison, logging activities in the Lower Duckabush River and portions of Murhut Cliff Creeks (specifically the Murhut drainage), define much of the hydrologically immature conditions within these subwatersheds (Refer to Vegetation Module).

Drainage density for the six subwatersheds analyzed is moderate to high, averaging 2.9 miles per square mile (Table 2.9E in Appendix 2.9, Map 2.9D). Subwatersheds with the highest overall stream densities measuring around 4 miles per square mile are Lower Duckabush River and Murhut Cliff Creek subwatersheds.. In general, Olympic National Park stream network data used to calculate stream lengths is less dense than other ownerships. Therefore, drainage densities for subwatersheds within ONP lands are likely lower than actual conditions.

Overall road density within the analysis area is low, averaging 0.6 miles per square mile. Road densities for the subwatersheds analyzed range from 0 to 2.2 miles per square mile (Table 2.9E in Appendix 2.9). Lower Duckabush River and Murhut Cliff Creeks are the only two subwatersheds that contain roads, with densities of 2.2 and 0.8 miles per square mile, respectively. Cederholm (1981) concluded that road densities greater than 2.5 miles per square mile negatively impacted salmonid habitat. This conclusion was based on studies Cederholm conducted in the Clearwater River drainage on the west side of the Olympic Peninsula.

It is assumed that the road drainage system extends the stream network by increasing the amount of water delivered to streams, and transporting it more rapidly than natural processes (Jones and Grant, 1996). Areas with both high road densities and high drainage densities are expected to be the most sensitive to peak flow increases from roads. Based on this assumption, subwatersheds likely to be most sensitive to peak flow increases from roads are Lower Duckabush River and the Murhut drainage (within the Murhut Cliff Creek watershed). Road densities within these subwatersheds reflect the concentration of urban development and timber harvest.

Partial peak analysis results for the Duckabush River gauge are depicted in the graphs below (Figures 2.9F and 2.9G, Table 2.9K in Appendix 2.9). The graphs show the total number of partial peaks for each water year for the given station. For the Duckabush gauge, partial peaks exceed a base flow of 2500 cfs. The polynomial regression , also called curvilinear regression, trend line is also shown on the graph in Figure 2.9G, and is labeled "poly". The equation for this trendline is $y = b+c_1x+c_2x^2+.... c_6x^6$.

Figure 2.9F Number of Partial Peaks for the Duckabush River for Water Years 1939-1996

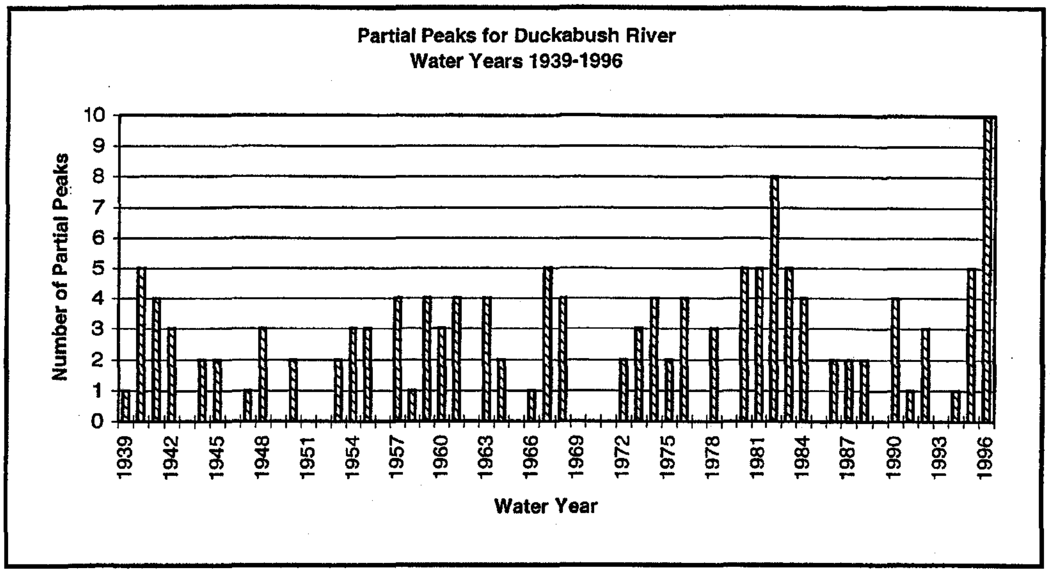
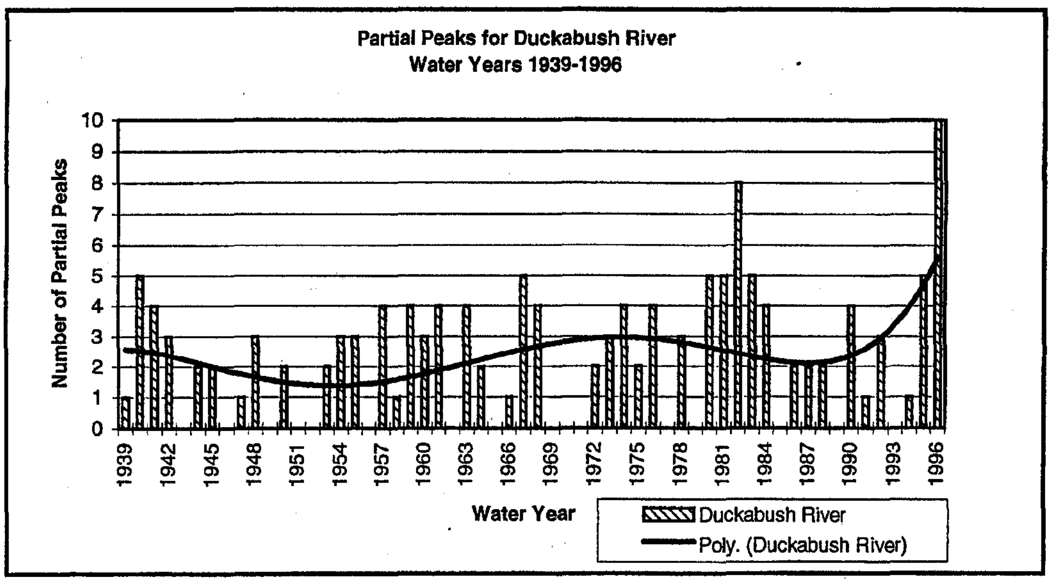


Figure 2.9G Number of Partial Peaks for Duckabush River for Water Years 1939-1996



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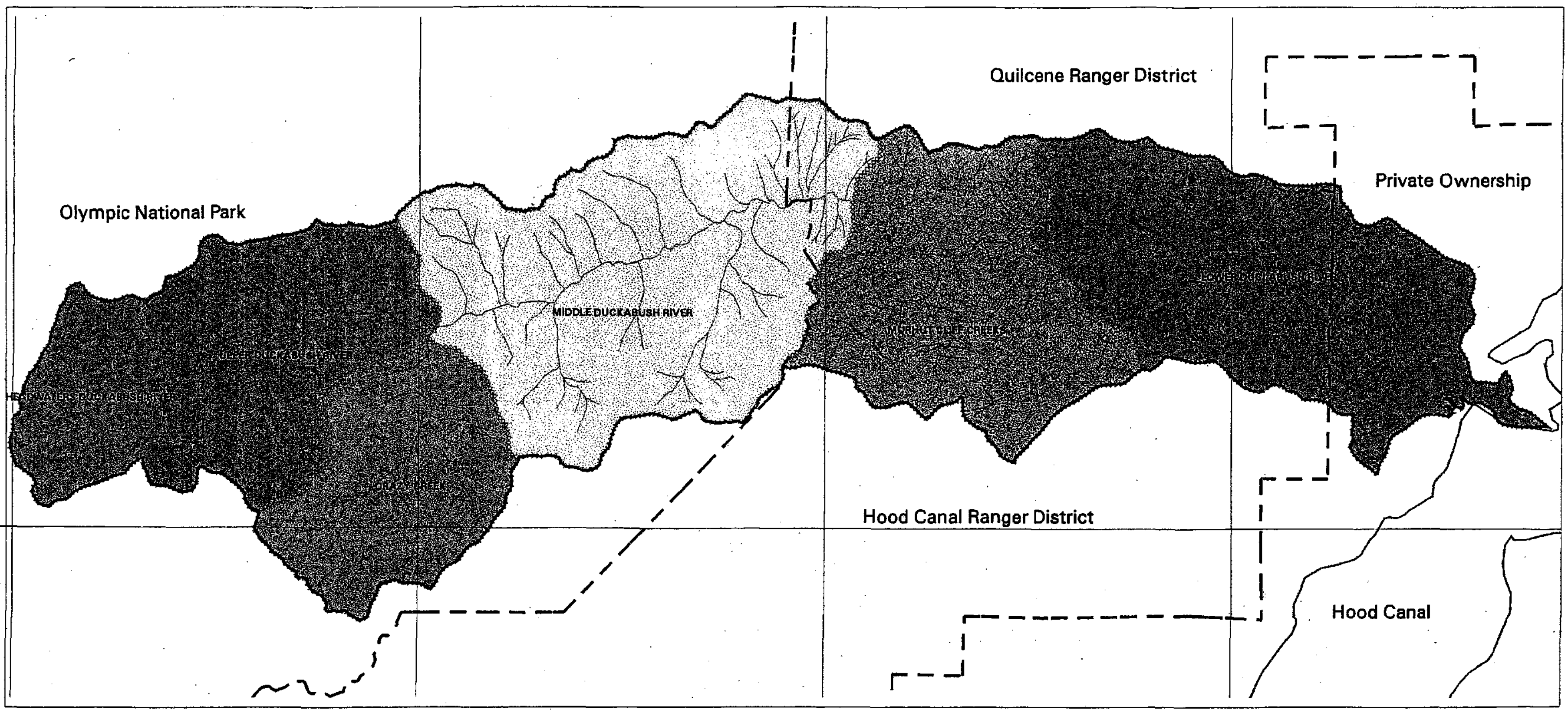


The Watershed Analysis Team cannot assure the reliability or suitability of this information for a particular purpose. Original data elements were compiled from various sources. Spatial information may not meet National Mapping Accuracy Standards. This information may be updated, corrected or otherwise modified without notification. For additional information about this data contact the Olympic National Forest.

N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

l_wasews May 18, 1998

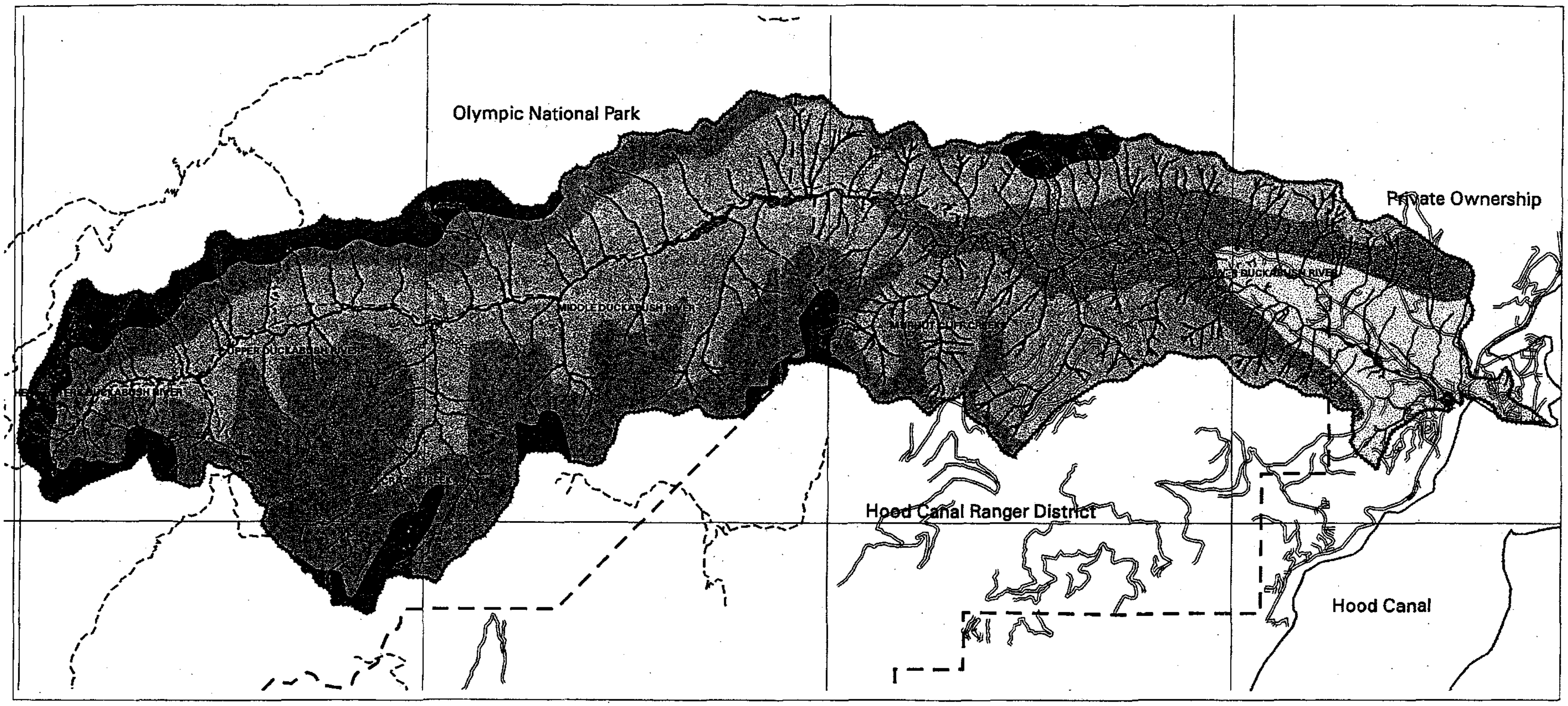
LEGEND

- Watershed Analysis Area
- Subwatersheds
- Quad Lines
- Hydronet
- Forest Boundary

Subwatersheds

Map# 2.9A

The Duckabush Watershed Analysis Team



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N

1.5 0 1.5 3 4.5

Scale is 1 inch = 1.5 Miles

LEGEND

- Watershed Analysis Area
- Subwatersheds
- Quad Lines
- Hydronet
- Forest Boundary
- Roads
- Trails
- Lakes, Ponds, & Wetlands
- Highland
- Snow Dominated
- Rain On Snow
- Rain Dominated
- Lowland

Precipitation Regimes

Map# 2.9C

The Duckabush Watershed Analysis Team

l_precip May 18, 1998

APPENDIX 2.1

TWANA PLACE NAMES

Sites of historical significance to the Twana have been documented quite extensively by Elmendorf (1960) while conducting fieldwork with two main Skokomish consultants who had knowledge that dated back to the 1750s. Place name and resource areas have also been documented by T.T. Waterman in his 1920 manuscript on Puget Sound Geography. Other sources of historic places include information from Skokomish elders that was obtained for early land claims and documentation of Indian fisheries. In this section, information specific to the Duckabush is presented chronologically for the reader's ease of reference.

The Twana community who lived in the Duckabush drainage were called the dexwyabu´s. They had a winter village near the mouth of the Duckabush River before treaty time. In 1927, Skokomish elders Dick Lewis, Robert Lewis and Joe Dan testified that the village named Dewh-ye-bose' (Duckabush) had two large houses "¼5 or 6 by 10 or 12 fathoms each, and many small houses" (Duwamish v USA: Exhibit R-2: 1927).

The first documented exploration of Hood Canal by Europeans was the voyage of British captain George Vancouver in 1792. Vancouver's report on his trip does not include any observations specific to the Duckabush area but he met with Indian people near the mouth of the Skokomish River and traded for shellfish.

In 1841 Charles Wilkes, captain of the United States Exploring Expedition, mapped the shoreline and bays of Hood Canal. He recorded the point immediately north of the Duckabush River as Quatsap Point, recognizing the Twana name for the point, kwaca´p. (Wilkes 1861:325 and chart 78; Meany 1923:237). Wilkes reported that the Twana lived in the northern part of Hood Canal and the Skokomish lived in the southern part.

Around 1920 anthropologist T.T. Waterman documented Indian place names in Puget Sound, Hood Canal and along the south shore of the Strait of Juan de Fuca. In Hood Canal Waterman recorded the following information for the Duckabush River.

> Duckabush River, DEqwi´abus, "where there is a red cliff." Myron Eells, quoted by Meany, gives this term as Do-hi-a-boos, "reddish face." The suffix -us, already mentioned, refers to a cliff or face of rock, and the human face. The word for red is qwo´tL!. (Waterman [1920]: Skokomish Site No. 93).

The information from Myron Eells account referred to the reddish face or appearance of a bluff or mountain near the Duckabush. [See below, Elmendorf's discussion of the Twana name for the Duckabush River].

> Duk-a-boos, Mason county, is a Twana name, corrupted from the original one, Do-hi-a-boos, and means "a reddish face," because the bluff or mountain near that place has a reddish face or appearance. (Eells, M. [1894] 1985:277).

In 1942, Skokomish elder Robert Lewis stated in an affidavit taken by Department of Interior attorney Edward Swindell that the Duckabush River was a traditional fishing location for the Skokomish (Twana) people.

> DUCQH-YAH-BOOSE, now known to the white people as Duckabush and located at the mouth of and on the south side of the present Duckabush River; that it meant "Wind around the Point" from the fact that it was located at [a] spot not touched by the winds prevalent at this particular place; that although the Indians had houses located at this place, it was only used during the time when the fish were running in the river; that the fish were caught with a trap. (Lewis, Robert in Swindell 1942:242?).

The different translations for the place name for Duckabush cannot be reconciled here but there is the possibility that they refer to different locations in the area around the mouth of the river.

The observation by Robert Lewis that the Duckabush was only used during fishing season may indicate that the village at the mouth of the Duckabush was disbanded before the 1850s perhaps as the result of an epidemic. Lewis was born in about 1840. Elmendorf indicates that the narrative information regarding the Duckabush River refers to the time period around the 1830s. (Elmendorf 1960).

In the 1930s and 1940s anthropologist William W. Elmendorf documented the following Twana place names in the Duckabush area during his work with Frank Allen and Henry Allen of the Skokomish Indian Reservation.

> sduk'wa'k'pu-beë, "elks." A series of large rock ledges in a tideflat on the south side of the mouth of the Duckabush River. The name has probable myth reference.

> duxwyabu´s, "place of the crooked-jawed salmon" (ya'bu´s, "crooked-jawed salmon"). Eells (1892:29) gives the mysterious etymology of "reddish face" for this place name. The Duckabush River and a winter village at its

mouth the residents were ctduxwyabu´s. The mouth of the river was also resorted to by other Twana and by Klallam visitors during the salmon season. The village headman in the early nineteenth century was a warrior named hwahw´kwseb. (Elmendorf 1960:42).xwaxwa´ceb

kwaca´p. Quatsop Point.

kwakwa´cqs, "between two points" (cf. No. 19). A camping site on a stretch of beach immediately north of Quatsop Point; the present Old Orchard Beach. (Elmendorf 1960:).

qaqaqele´at. A former small lake north of Quatsop Point, back of Old Orchard Beach; it was full of shamanistic guardian spirits (swa´daë) in the form of reptiles. When the lake was drained long ago by loggers, the swa´daë reptiles came rushing down the outlet. The loggers fled, except one who was later found dead on the spot and with contorted limbs. He was 1'idi´teb, "electrocuted" or struck by the power of the shaman spirits. (CC) (Elmendorf 1960:42). [Note: this account was provided by Charles Cush (CC), a Quilcene Twana who later lived on the Skokomish Reservation.]

Information from narratives told by Frank Allen, a Skokomish Twana, shows that Duckabush Twana were members of the secret society and traveled to Clallam Bay on the Strait of Juan de Fuca to attend ceremonies with Klallam friends and relatives. One narrative describes the Duckabush as one of the homes of a shaman power. (Elmendorf 1993:47, 202).

As noted above in place names documented by Elmendorf, a headman of the Duckabush Twana was a warrior named hwahw´kwseb. In a narrative about hwahw´kwseb that Elmendorf dates at about 1810, Frank Allen referred to a bluff on the north side of the Duckabush where the warrior headman had a lookout.

> Now hwahw´kwseb dug a hole down from the top of the bluff on the north side of Duckabush. He dug it down and came out partway down on the face of the bluff. He covered this opening over with brush so nobody could see it from the water, but he could look out. (Elmendorf 1993:126).

In the narrative the headman watched from the lookout for raiders. Eventually a party of Skagit came looking for him. hwahw´kwseb successfully defeated two separate attacks by the Skagit. According to Allen, his father Jim Allen saw the lookout hole in the bluff. (Elmendorf 1993:127-128).

Henry Allen told about the Twana first salmon ceremony and the "chief of the fish", a crooked nose fish called yabu´s. Allen described the Duckabush River as one of the best places for crook-nosed salmon. Allen's narrative is included below for his description of the first salmon ceremony, a ceremony that was followed by all Twana people.

> The Twana used to have a ceremony when the first salmon came. There is a deformed-nose fish, a crooked-nose fish, a salmon with deformed jaws. He is the chief of fish. The crooked-nose fish bring the salmon with them when they run. That crooked-nose fish is called yabu´s. Duckabush (dexwyabu´s) on the canal is supposed to be the best place for these (Elmendorf 1960:41)[no. 62].
>
> When they caught this deformed-nose fish they had a ceremony. They split him down the back and took out the backbone. Then they spread the rest of the fish out and cooked him, all of him, bones and tail and all. He was cooked by the family that caught him. The backbone they cooked separately.
>
> This first salmon was just for the children, the boys and girls of the village. They laid him down and ate him on the beach where he was cooked. When he was all eaten each child took one of the cooking spits crossways in his teeth, and dashed into the water and splashed around, and then threw the spit in the direction the chief of the salmon had come from. They thanked him and invited him to come again. There was no song with this.
>
> They laid the backbone on a log or a rock on the beach, pointing to where he had come from. Then his soul would go back to the home of the salmon [see *Tales*, nos. 25, 35, 38]. They just did this with the first crooked-jawed salmon of any kind that came. It could be done with the first yabu´s of each kind of salmon. The guts they threw away, and nothing of that fish was burnt. They ate even the skin and the head, ate him all up. Every child in the village had to eat some of the fish. This was to bring the run the next year [cf. *Tales*, nos. 37, 38]. (Elmendorf 1993:254).

Census information shows that there was a Twana community near the mouth of the Duckabush River in 1880. Some of the family members are described as employees of the sawmill (presumably the mill at Seabeck or Port Gamble); heads of family Docewaillopsh Bill was listed as a farmer and a fisherman and head of family, Old Pulsifer was listed as a fisherman. (United States, Census of the Twana: 1880).

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Appendix 2.1.2

Cultural Module

Excerpts from the Cultural Resource Survey by Western Heritage, Inc. 1983 on Portions of the Duckabush, Calawah and West Fork of the Humptulips River pertaining to logging

Indian people have lived on the Olympic Peninsula for at least 2,000 years, according to archaeological evidence, and unquestionably their arrival dates back far earlier than that. Non-Indian history spans, at most, for centuries.

It begins, at least apocryphally, in 1592 with the Greek seaman known as Juan de Fuca. He sailed under the Spanish flag in search of the Northwest Passage, which geographers of the time felt would link Europe with Asia—a confident expectation that also prompted Christopher Columbus a century earlier to send emissaries marching up a Cuban valley to greet The Emperor of Japan in the name of the Spanish throne. Regardless of the truth about de Fuca's arrival here, his name graces the strait he entered whether in fact or fancy. Ironically, though de Fuca is commemorated, no Olympic Peninsula name similarly honors the Spaniards who actually opened the door to commerce and settlement. These mariners are Juan Pérez, who in August 1774 saw Mount Olympus and named it Santa Rosalia, and Bruno Hezeta, who the following summer, rowed ashore with his men and raised the cross of possession a little way north of Moclips.

Two years after Pérez arrived, the great navigator Captain James Cook hoisted sails and departed from England on his Third Voyage of Discovery. Benjamin Franklin pleaded for safe passage to Cook, arguing that his purpose—which brought them to the Northwest Coast in 1778 -- did not conflict with the American colonies' budding revolution. Almost by chance, Cook set off trade in maritime furs, the first Northwest product exploited or exported, other than the goods Indians traded among themselves.

A brisk business erupted almost immediately. Overall, it enriched outer coast Indians who lived at points of call favored by European and American sea captains. The relative status of these groups was raised, and they gained a certain advantage in comparison with inner-coast and inland peoples who were less directly in touch with the astounding, wealthy newcomers. The maritime fur trade also initiated white settlement on the coast, albeit in abortive form.

In 1849 the peninsula's first white settler paddled over from Vancouver Island and started to trap for fur west of Port Angeles. Active settlement got underway within the next two decades. The peninsula's first townsite, Port Townsend, was platted in 1852. Within a few years, ships entering Puget Sound arrived in such numbers that the town was designated an official Unites States port of entry and Great Britain, France, Germany, Norway, Sweden, Chile, and Hawaii opened consulates and agencies. Timber prompted the boom. Symbolically, at the 1853 inaugural banquet for the state's first governor, the cook summoned guests to the festive tables by beating on a crosscut saw hung from a pole, the dinner gong typical of logging camps.

By that time, water powered mills already were sawing trees into boards at Port Townsend, Port Ludlow, Port Gamble, and on Oakland Bay near Shelton. Logging crews came mostly from Maine and Michigan. They were men experienced in the woods and intrigued with rumors—and actualities—of timber 200 feet tall and so generous in girth that felling it required standing on a springboard platform set as much as 20 feet above the ground, to eliminate having to saw through three or four feet of excess swell at the base of the tree's trunk. After "donkey" and "lokey" engines moved north from the California redwood country in 1882, logging quickly proliferated; technology took over the conquering of peninsula timberlands begun by the muscle power of oxen and mule teams.

Gold fever periodically flared and subsided in the Northwest, bringing men through Port Townsend from played-out booms en route to the shining illusion of wealth impending elsewhere. Shipping introduced the peninsula to other venturesome men, particularly sailors. Additionally, advertisements abroad, chiefly in Scandinavia, stimulated interest. Maps still left the middle of the peninsula blank, however. Men from Port Townsend started to build a trail across the peninsula in 1882, but quit after five months, having little more than barely begun. Three years later, Lieutenant Joseph O'Neil led an exploring party into the interior, but before he had crested the first range he received word of transfer to Kansas and abandoned the undertaking, leaving the name No Place to mark his stopping point.

In 1890 the Seattle newspaper Press sponsored an epic venture that at last sketched in some factual idea of the inner peninsula. This expedition was an ebullient one that started up the Elwha River west of Port Angeles by boat in January—an ignorant, utterly impossible plan—five months later emerged from the Quinault forest onto the beach near Moclips, and thence on to Aberdeen. That same year Lieutenant O'Neil again entered the unknown Olympics, disembarking from a steamer at Lilliwaup and from there brush whacking and trudging up the Skokomish and over the Quinault, then back by the same general route. He and his party climbed Mount Olympus and made a simple map of the rivers flowing east and south. They concluded: "The interior Olympics is useless for all practical purposes. It would, however, serve admirably as a national park." In 1897 President Grover Cleveland proclaimed a number of forest reserves, among them the Olympic Forest Reserve. This consisted of 1,500,000 acres, nearly two thirds of the Olympic Peninsula, and the largest of the reserves that President Cleveland established. A year later, 1898, two surveyors took a small team into the forest to map its acres and to assess their value. Theodore Rixon, a former railroad surveyor, and Arthur Dodwell emerged two years later with topographical maps of ninety-seven townships and a careful analysis of the Olympic reserve's holdings. Their findings were published by the Government Printing Office (1902) and, their study, Forest Conditions in the Olympic Forest Reserve, Washington remains a valuable, indeed, critical statement of the Olympic National Forest at the turn of the century.

By 1900 little logging had occurred in the limits of the reserve. Dodwell and Rixon noted that only 10,289 acres had been logged, adding that "it is only in the southern tier of townships that logging operations on any considerable scale have been carried on" (1901:18). The two surveyors also noted that: The reason why logging operations have not been carried on more extensively is that the rivers are too swift and subject to too many freshets, the logs being hung on the numerous bars or washed up into the bush out of the river bed. Moreover, there are no places to catch and hold the logs if they were driven down the rivers successfully. This is especially true of the rivers emptying into the ocean (Ibid 1902:18). At the time of their study, the only logging railroad that existed inside the reserve extended from Shelton and Kamilche into Township 21N, R5W and R6W. They also observed that a railroad, which extended from Clallam to the northern corner of Township 30N, R9W, would be extended to Lake Crescent (Ibid 1902:18). Perhaps the most significant features of their study of Forest Conditions in 1900 were their observations, the most valuable indicators by which to date logging activity in the early years of the Forest; and their topographical maps as useful and consistent locators still in use today.

Dodwell and Rixon's study followed, by almost ten years, the first major influx of European settlers into the river valleys of the peninsula (Righter 1978:86). The second wave of settlers arrived between 1900 and 1910, and they came to cultivate the timber claims that seemed abundant on the peninsula. Although the abundance of large reserves of fir and spruce was contested, both the topography and elevation made commercial lumbering difficult and as late as 1955, the U.S. Forest Service noted that "only a portion of the Forest is able to grow commercial timber," because of those two factors (U.S. Forest Service 1905-55:3). Early logging depended on teams of men using oxen and skid roads. Logging camps were located near tidewater rivers, and the logs were floated to the markets and/or mills. The advent of the steam engine in the 1880s changed the nature of logging. It became technologically more advanced and economically more demanding. The first steam engine to be used in logging was the donkey, patented by John Dolbeer of Eureka, California in 1882. It apparently was so named because it was unworthy of being rated in horsepower (Adams 1961:14-15).

In 1921 the proceedings of the Pacific Lumber Congress commemorated the introduction of the donkey: One logger said, "I will buy me a bid steam engine. He did and they called it a donkey. It was of the piledriver type, with two drums placed tandem, seven inch by nine inch cylinders. He equipped this monster with a Manila rope one and one-half inches in diameter, about three hundred and fifty feet long. The manpower or crew consisted of one man on the engine and one man on the rope, of course the full crew was required to pull on the end of the rope out to the log. Only a few logs were moved with this equipment, and the experiment at that time was abandoned. This type of engine, however, equipped with steel cable, came into general use to load logs onto cars. The logging engine was first used to do the light work in the camps, loading first, then yarding and hauling on skid roads. The transition period from ox team to horse team and to steam power use in Pacific Coast logging took place in the early nineties. It was at once evident that men should adopt the logging engine as more suited to meet logging requirements than the slow and inefficient teams of cattle and horses (Proceedings of the PLC 1921:29).

Over the years other engines were developed by logging engineers, but the Dolbeer donkey was the first to introduce inanimate motive power into the logging industry and, because of that, it revolutionized the industry. The Pacific Lumber Congress noted that the introduction of the donkey was "revolutionary," because it changed the nature of getting the logs out of the woods. "No one was familiar with the new way, yet one had to be developed (Ibid 1921:29). Workers had to learn new skills, roads had to be changed, and the method of selective logging had to be abandoned. In 1917, which if one reads the journals judiciously, seems to be the heyday of railroad logging in the Northwest. Washington had 1810 miles of track, though their location has not been recorded (The Timberman 1917:41-42). Washington's nearest competitor was California with 730 miles of trackage. The trackage was valued at an average of $10,000 per mile (Ibid 1917:29). Steam and donkey made logging into a business where loggers had to pay attention to cost-effective techniques, machinery operations, and competitive markets. It subordinated earlier methods of logging to the requirements of the engine. But it also made possible greater efficiency and greater quantities of timber felled.

J.J. Donovan, manager of the Bloedel-Donovan Lumber Mills in Bellingham writes in The Timberman (in November 1917): As a round guess I would say that we are probably laying twice the track now that we did years ago here in the Puget sound country in order to get our logs. That is partly due to the spar tree method whereby we must get with the track to the tree, and to the realization that by bringing the track near the tree on the whole we do better than a few years ago. Now that means, with the present scarcity of labor and the high cost of that labor, and the inefficiency of that labor, that is up to all of us to try, where possible, to use some method.by which machinery and highly-paid men will take the place of the common laborer and mere muscle. Now in our case, after struggling along with our track work in the old-fashioned way, we have just invested about $13,000 in a form of combination steam shovel and locomotive crane, and we expect hereafter to pick up a rail, ties and all, swing it around onto a car, and when the car is loaded then move off and get another one, but substituting a few men and expensive machinery for a large force of ignorant and inefficient labor. This is a step that I believe all companies doing business on a considerable scale will find advisable (Timberman 1917:51). By 1917, the presence of steam engines had become commonplace in the logging industry. Many factors contributed to this. Firstly, the technology itself had advanced to the point where it was an efficient replacement for slower horses; it could move heavier logs. and it could move them from relatively inaccessible sites. Secondly, both the activities of the Wobblies and the outbreak of war made labor at once scarce and difficult.

While the presence of the steam engine was more or less common by 1917, it was only the beginning of mechanization. Even as loggers like Donovan invested money into track and engines, loggers were being advised in the same issue of The Timberman that "steam is the motive power which is, at the present time, almost universally used on logging railways... But steam is not the only source of power that is available for mechanical haulage." (Timberman 1917:42). There were other forms of power, the journal noted. Still in the future, but in the ever close future, were gasoline and diesel powered trucks.

The history of the Spruce Production Division only bears this out. Established by the U.S. Government in 1917 to produce spruce for war-time airplane wings, the Spruce Division worked seven days a week, night and day, with soldiers and civilians cooperating to build forty-five miles of mainline and 124 miles of logging spurs (Labbe & Goe 1961:174). Four roads were considered permanent and nine were temporary. The armistice put a stop to the Spruce Division's work in 1918, and not a single log was hauled on the railroad. But history also was making the work of the Spruce Division obsolete. If airplane design changed to replace spruce wings with steel wings, logging technology also changed. While steam had revolutionized logging practices, it also presented an implicit danger: the sparks from the engine were a dangerous presence in the forest, especially in dry forest. Loggers dreaded fire and, while they were eager to put the donkey and other engines to use, they were also receptive to the technologies that replaced them. As early as 1918 the trade journals were advertising motor trucks and their particular usefulness to loggers.

The proceedings of the fiftieth anniversary of the Pacific Lumber Congress noted in 1959: The first genuine machinery show was not only a spectacular thing; it indicated, more than subjects actually discussed at the Congress, the technological revolution that was about to take over the industry. Although no less than seven logging locomotives were displayed, at least two logging trucks were shown, and so was the first tractor-with-trucks (Proceedings 1959:18). Railroad logging was a more costly venture than the earlier oxen-drawn teams it replaced. Because it depended on expensive engines, track, and skilled labor, railroad logging made the industry more aware than it had been of cost-accounting practices. In part because of that increased awareness, the logging railroad itself

was replaced by trucks and tractors. Trucks were even more mobile, but they were also cheaper - because they didn't require a well tended track.
As Kramer Adams notes in Logging Railroads in the West, "aside from labor, rails generally represented the highest cost of putting in a railroad" (Adams 1961:63). The mainline road generally was well built and could be expected to last decades. This basically was the transportation road used to get engines to the trees. The spurs that took off from the mainline were temporary. They might be used for a month or so, then taken up and moved elsewhere. Mr. Adams compares the logging spurs to an irrigation system: "The object was not to find the best route through the countryside, but to cover the entire area with a system of lines" (Adams 1961:61). Those lines originally were made of wood, but as the engines got heavier and logging more costly, metal rails proved more efficient. They were laid quickly and taken up to follow logging operations. Railroad logging, as has been noted, involved the use if inanimate motive power. That kind of logging declined with the improved reliability and superior flexibility of trucks. While companies continued to transport logs by rail, they no longer depended on the railroad engine for power. The logging railroad was not a common carrier, and its progress is difficult to document with any degree of specificity.
While the Olympic National Forest was the site of active commercial logging, it does not appear prominently in any of the trade journals. The Timberman, published in Portland, The Lumberman, published in Seattle and Tacoma, and the published proceedings of the Pacific Logging Congress in Portland cover the activities of loggers in the Pacific Northwest. They publish articles on logging methods, available machinery, and economic concerns. They feature prominent logging men who discuss their own experiences. A thorough reading of these journals suggests that the work on the peninsula was neither technologically innovative nor financially influential. Except for an occasional reference to Grays Harbor, logging on the peninsula almost never is discussed in the trade journals of the time. There was an active exchange of ideas and techniques: foreign visitors attended the annual meetings of the Pacific Logging Congress and foresters and academics met regularly with loggers to discuss matters of concern. But the activity on the peninsula did not generate either much interest or debate.
Reading the industrial record that is left, one encounters no specific names or locations of peninsula logging railroads. Furthermore, while there may indeed have been some local technological improvements on the donkey or other engines they were, according to the record, not significant enough to have been noted and adopted by other loggers. One is left to conclude that, while the forests of the peninsula continue to stir one's imagination, they do not seem to have left us a significant record, except on one very local level. Perhaps one of the reasons why the forests of the peninsula figure so prominently in our collective imagination is that we have seen them most often through the work of photographer Darius Kinsey. Still, it must be noted that Kinsey worked for the logging companies that used his photographs to secure capital and investors. In the record of their own contemporaries, however, one sees little mention of the companies on the peninsula that employed Kinsey. Thus the photographs remain as valuable artifacts that reveal logging conditions and equipment, but they in no way indicate significance in either a technological or an economic sense.
While the history of the Olympic National Forest certainly is significant and historic logging was critical to the development of the Olympic Peninsula, there is virtually no specific reference to sites within the forest units under study. Given the temporary nature of railroad logging, one is not surprised by the absence of details. But one can not manufacture a local chronology out of vanity publications, and unfortunately one is left to depend on articles whose very temporary nature renders them incomplete at best.

History of the Study Areas. The Duckabush Area. (Unit 1). In his book, This was Logging!, 1954, Ralph W. Andrews noted that: In 1912 George Webb, and English sailor who had logged the area where Fauntleroy in West Seattle is now, bought timber on Snow Creek on Olympic Peninsula and with Jim Soybey built a logging road. Later they built another road up the Duckabush River (Andrews 1954:93).

Andrews also lists the Webb Logging Co. of Brinnon, Washington along with many others that carried out logging operations on the Olympic Peninsula. However, aside from this brief mention of the Duckabush area there are no written accounts of logging practices in the study area. Conversations with Erwin Kelly (personal communication, February 13, 1983), retired logger of Brinnon, Washington; Robert Worthington, retired engineer of Quilcene, Washington; and Joe Kawamoto, dairyman, farmer, and ex-logger of Leland, Washington provided reminiscences of by-gone days on the Duckabush. Kelley recalled that: George Webb used to work with a man named Beveridge. Webb himself came over here to help buy the right-of-ways and so on, but otherwise he'd come to the camp once a month or so. His office was in Seattle and he stayed mostly there. The company logged at Snow Creek before they came here. McCoy Camp was up the

Jupiter road about 1 - 1 ½ miles. Between the Dosewallips and the Duckabush. They built that camp on sleds and could move the whole thing in only a day or two. They'd keep the camp within three or four miles of where the men were working (1983). Mr. Kelly spoke of another camp which burned about four miles upriver at the foot of the Little Hump. He stated that, prior to the railroad logging operations, early logging was done by hand, falling logs directly into the Hood Canal using peaveys and jacks. When the "easy stuff" had been logged off, good-sized companies went further up river. There was a camp at Fulton and McDonald and a log chute at McDonald Cove provided log transport to the Canal. After they got farther back, they had a chute or a donkey and they'd move the logs along then have another donkey. They used oxen, they used horses, then they drove the river. Timber clear up to Collins (on the Duckabush) went out down the river. I remember when I was a kid they had just finished up the river drives. Peterson Brothers were finishing in 1915. They logged the Jameson claim and brought the timber down the river. I remember that. When George Jameson first came here he took out the claim and he turned it over to the timber company. His claim was by the old Government fish hatchery, the federal hatchery. It's now private land. They say that a lot of people came here to prove-up for Pope and Talbot—took them off those sailing ships, you know. But that's just talk. Peterson Brothers logged around those last ranches and then drove down the river. There was a dam on private land right at the head of the first canyon—a splash dam (Ibid).

Kelly than spoke of the early settlers on the Duckabush, including a family named Brown that now lives at Discovery Bay and Charley Brinnon, an Indian who owned land at the mouth of the Duckabush. Thomas Pierce took over the Brinnon property, and the Pierce name appears on the Government Land Office map of 1872. The Worthingtons logged with oxen in former days on the Duckabush and the Suchs, George and Will, were early residents of Brinnon. "At the falls on the Duckabush, where the concrete bridge is now, I think that was the farthest upriver homestead" he said (Ibid). Kelly's conversation returned to the Webb Logging Company: Webb logged McCoy (property) the last thing he did. He got out just before the big fire of 1929. The main camp was just below Collins for two or three years; then they went up to where the trail takes off now. You can find old plates and cups there—it's about 200 feet before you get to the end of the road. The camp at Little Hump was the farthest upriver. Webb had two fires there. One burned about 1925-26. The big one went clear to the Hamma Hamma. That was 1929. It just jumped from the top of one hill to the next. I don't know how it got started but it was somewhere below the Interorrem Guard Station. The whole Mount Jupiter country was open when we came. It burned and nobody did anything about it (Ibid).

There was a boom camp at Pleasant Harbor and a "Jap" camp, according to Mr. Kelly. Japanese laborers laid all the steel and worked on the track. They stayed at independent camps, usually some distance away from the main camp. "At the old CB&M Camp there are saki bottles. They used to make it at Brinnon, up form Seal Rock Park," Kelly said (Ibid). Erwin Kelly remembered: When Webb first came here, they had a big old horse down by Jesse Allen's place. They used it to drag timbers when they unloaded them off the scow. They say that horse was one of the original ones George Webb had. Horses were used for logging between the time of the bull teams (oxen) and donkeys (engines). Webb was the only one with a railroad in the Duckabush. K. Smith had one up the Dosewallips as far as the Archer place. Webb had an engineer to put in the grades; he surveyed long before they put the railroad in. That was before the logging began; they had it surveyed and had it cruised too. We used to walk the grades to hunting before they put the line in. They surveyed it four or so years before putting the line in. The railroad must have started about 1920. I known the war was over. The crew would make the grade and put in the lines. It didn't take long to lay the tract. They'd use it and move it to the next place. They cut long trees and put ties on them and rails on that. They'd fill ballast cars with gravel and the "Japs" would come along and tamp it. The work went a lot faster than you'd think, in under the ties. One trestle was 115-120 feet (high). That's just behind Jesse Allen's. It was part of the Webb's original trestle. They say they never used a level or anything, them old pile drivers. They'd just put it in the eye (Ibid).

Asked about how the loggers took out the timber on the steep slopes beyond the tracks, Kelly replied: Skidders could go 2000 feet. Sometimes they'd put in a cold deck. Spar trees—in them days they had to raise 'em up. They used high riggers. I used to do a little rigging. My brother Barney at Mud Bay could tell you more about that. The way you used to learn to be a rigger, why you started as a whistle punk, then moved up to chokerman. The chaser

would hook the logs under the spar and when the line came undone, they liked to have the chaser go up there and save it. Some wouldn't do it, though. But I'd go up there and turn the blocks around. So that way there gets to be nothing to it. You just keep going a little farther little by little. You didn't see men much over 50 years old working on rigging, though. The choker setter, he was the second in command, and he might be more than 50 by a year or two. Before high lead days, they used ground leads (Ibid).
Kelly recalled that in the past, "They'd cut the timber and if it wasn't worth getting in a railroad, they'd just leave it. Webb left a lot of beautiful timber" (Ibid). Kelly spoke of cutting cedar and hemlock and the fact that many of the old cedars were hollow. "By the time you'd get 'em to the bay, they'd be all broken up. So they'd just leave 'em in the woods" (Ibid). According to Kelly: Webb had Climaxes and a couple of Shays (engines). They used Shays on the mainline; and Climaxes, they used them for switching stuff. Webb's skidders were Ledgerwoods. They were made by Washington Iron Works. All the equipment was good. The crew road on the "skeleton" or if it didn't have a tie between, they called it a "rattler." McCormick cut (timber) more than 100 feet long, so that spaced them way out. (The middle of the logs hung close to the track). The crew perched on top of the "skeleton" like a row of crows (Ibid).
Regarding runaway engines, Mr. Kelly commented "I heard about a runaway locomotive on the Dosewallips. They found it lying upside down in there. Finally junk men came to get it out. But I never heard of a runaway on the Duckabush. Webb had good equipment" (Ibid). William Jenner Worthington came to the Olympic Peninsula from San Francisco in 1882, and the Worthington Family have been prominent residents of the Brinnon-Quilcene area since that time. His son, Mr. Robert Worthington, a logging engineer and land surveyor, provided the following information on early logging operations on the Duckabush. My father owned a 31-1/2 foot sloop (he did not recall the name), and he traded with Indians and whites up and down the Canal. So he saw what they were doing with logging," he said (personal communication, 1983) If you're looking for the man to credit with starting logging, it's the man with just the axe, no saw. He'd chip the hell out of the trees, and they fell into the water. Next came logging jacks, turn it a little bit; roll 'em till they get into the water. In the days of hand logging they'd fall the trees right into salt water. Before there were steam tow boats they'd use the tides and hoist a sail on the log boom

It was the imagination of the early logger that made the big difference. They needed innovative men in the early days. Later on there were skid roads. First they'd put down crosspieces and that'd be the skid road. Later on they used them fore and aft and that was called a tram road. There were four wheels on a tram car. The rim was concave so it fit over the rails. Horses pulled them. It was always downgrade; horses are powerful enough to pull uphill. They used horses for the haul-back. They'd fall (the trees) onto the landing and then the horses were trained to haul the main line back into the woods. A single horse would take the main line—one inch in diameter—and that horse could pull it into the woods and a man would hook it onto a log. Horses don't put out much energy; they don't have it. Oxen were slow, easy going, and they didn't get disturbed. They'd do pretty well pulling logs. Horses didn't.

Mr. Worthington remembered a George Bridges, who was half Indian and had logged with a four-horse team and wagon. He explained that there were two men and they each had two horses, so they decided to go into the logging business. While one set for the Canal to dump the log, the other would be undercutting the tree. When the first man returned they got on the crosscut saw and cut the next tree. The process was repeated to cut an area. Mr. Worthington explained that there were no roads, but the wheels of the wagon had wide rims. He added, "I'm not saying they got rich, of course. There was Tom Dagan too, who logged. From Maine. He'd come out first and his wife later. She decided to go back and reluctantly he followed her two or three years later" (Ibid). When asked about the Duckabush, Worthington stated: They used skidders here—on the Duckabush and all through the country. Webb put in a railroad. Norman Worthington—he was four years older than I—he helped chunk out the right-of-way from Pleasant harbor when he was 16. The men running the Webb Logging Company were Mr. Webb and Mr. Beveridge. Their office was in Seattle. They always used real good equipment. They'd logged Kitsap County, then gone to Blyn and cut along Jimmy Come Lately Creek; that was known as the Snow Creek outfit. About 1920, they went to Pleasant Harbor and chewed up a bunch of timber there, and then they ended up by coming back and skinning off Mt. Jupiter. They logged on Pat McCoy's land. He had his name plastered all over that country, the Duckabush. Most of the loggers were Scandinavians. They came from over at Buckley (Ibid).

When queried about the use of splash dams on the Duckabush, Mr. Worthington replied: There weren't very many dams for driving logs on this side of the Olympics; those were mostly on the south side. By my time there were some on the Dosewallips and I think there had been on the Duckabush earlier. On the Big Quil there was a dam that gave force to the water and swept shingle bolts out to the bay. Those bolts were 52 inches long; that allowed two -

32 inch shingles plus trim per bolt. Splash dams were the fashion before the railroads went in, but they weren't very important in harvesting of timber along Hood Canal. Jack Byard was the big dam builder for this slope of the Olympics. The successful ones had his brain behind them. They all ended up by the 1920s; I guess they started around 1900. On these small streams with heavy timber, it was well to use a dam to raise the water supply. Just an extra push to the current was needed, so they'd build a dam (Ibid).

Mr. Worthington went on to say that Joe Wakamoto of Leland, Washington would remember the Webb Logging Co. because his father worked for Webb and was section foreman for the lower half of the Port Townsend and Southern Railroad. He was working for Webb on the Duckabush when the whole mountain (Mt. Jupiter) caught on fire. Worthington closed the interview, saying: When my father got enough capital, he and his brother went into the store business. His store was where the Quilcene Shell station is now. The Indians like him; he never tried to beat them. He quit the store business and came up here (to the present Worthington home in Quilcene, which was built in 1900). That was in 1908 that we moved here permanently. I was kind of lonely and I'd rather be down there where the store was and see what's going on. But my father said it was better for all of us, for the whole family. He did well in business. There's really no better recipe than buying cheap and selling dear (Ibid).

Mr. Joe Kawamoto is a dairyman, farmer, and ex-logger who resides in Leland, Washington. Mr. Kawamoto related that his father, Kaiichi, originally came from Hiroshima, Japan in 1898 and immigrated to Canada, then to the United States (personal communication, 1982). Those early immigrants worked mostly on the railroads or in the fish canneries. He and his father used to do commercial salmon fishing on the Fraser River in British Columbia. In those days, the commercial fisherman fished from rowboats. When they came to the Olympic Peninsula, they worked for the Munn family at Lake Leland, Washington. The Munns had a dairy farm and a steam milk separator, which was the only one in the area. The other dairymen would bring their milk to the Munn's farm and Joe's father would run the separator and transport the cream to Quilcene. Mr. Kawamoto recalled that he had worked at Snow Creek and on the Duckabush for the Webb Logging Company. "My father, Kaiichi, worked only on the Duckabush with Webb, not Snow Creek. My dad and I worked up the Duckabush not over two years," he said (Ibid). When asked about the Japanese laborers, he replied: There were a dozen or so Japanese laborers in Webb Company up the Duckabush. They were all single men except for one married man. His wife was the cook. There were bunkhouses for both the Japanese camp and the main camp. There were about 200 men in the main camp; maybe 5 or 6 of those in the Caucasian crew were married. They had cabins. The Japanese didn't build any of the trestles. They laid track, and took up track and moved it. Did maintenance work on the track, too. Men with Webb on the Duckabush at least, were mostly Finlanders. The camp foreman under the superintendent was a Finlander, too. They all spoke mainly Finnish. The younger people too, were Finlanders and spoke the language (Ibid). Kawamoto volunteered that Portuguese also were found among the loggers: The Almadens, who were Portuguese, worked at Snow Creek and maybe after it finished they worked at Duckabush, too. Many of those men transferred over from Snow Creek. Mr. Webb was running both camps. Before Snow Creek finished, he was in the Duckabush, too. Those workers had worked in a number of different camps. The loggers were the same way; they wouldn't stay in a camp very long. Just wanted to work some place different, I guess. (Ibid). To answer a question about pay scales in those days, Mr. Kawamoto said: Railroad workers got $3.75 to $4.00 per day. Loggers were paid a little better than railroad workers, maybe $1.00 more. You paid your board to the company. There wasn't any charge for room. They'd just load those bunkhouses, etc. onto railroad cars when moving the camp. Camp was between the Duckabush and the Hamma Hamma when I was working there. We used to cross the river, and I think there used to be another camp right after you crossed the river. The camp we stayed in was more upriver. It was one of the later camps. You crossed Fulton Creek on the highway and hiked up to the camp (Ibid). Mr. Kawamoto concluded the interview by saying that when McCormick started logging at Crocker Lake, which was the same time that Webb was logging the Duckabush, he went there because it was handier and closer to home.

Appendix 2.3A

Stream Channel Attributes

Table 2.3A. Stream Channel Attributes by Segment

Segment ID	Geol	Geomorph	Gradient Class	Confinement	Form	Response Type
1	Qa	A1	1	U	Regime	R
2	Qa	A1	1	U	PB	R
3	Qa	A3	1	U	PB	R
4	Qa	A1	1	U	Braided	R
5	Qo	G5	1	C(MC)	PB	R
6a	Qa	A1	1	MC	P/R	R
6b	Qa/Qo	A1	1	MC©	PB-P/R	R
7	Tcbb	C5	2	C(MC)	PB	R
8	Tcbb/Qo	C2	3	C	SP	R
9	Tcbb	C1	3	C	SP	R
10	Qa/Tcb	C5	2	MC©	PB	R
11	Qa	A2	1	U	Braided	R
12	Qa	A3	1	MC	P/R-PB	R
13	Qa/Tcbb	G5	2	C	PB?	R
14	Tcbb	C1	3	C	SP/C	T
15	Tcbb	C1	4	C	SP/C	T
16	Qa	A3	2	U	PB	R
17	Qo	G5	3	C	SP	T
18	Tcb	C5	3	C	SP/C	T
19	Tcb	C1	4	C	SP/C	T
20	Tcb	F1	4	C		T
21	Tcb	C1	3	C		T
22	Qo	A1	1	U	P/R (BR)	R
23	Qo	A3	1	MC	P/R (BR)	R
24	Qo	F1	2	C	PB	R
25	Qo	A1	1	U	PR	R
26	Qo	A3	2	MC	PR?	R
27	Qo	G5	1	C		R
28	Qo	G5	2	C		R
29	Tnm	S2	3	C		T
30	Tnm/Tb	S2	4	C		T
31	Tnm/Tnt	F1	3	C		T
32	Tnt/Tnm	S2	3	C		T
33	Tnm/Tnt	S2	4	C		T
34	Tnt	TS1(S2)	3(2)	MC	P/R	R
35	Tnt/Tgs	TS1(F1)	4(5)	C		T
36	Tgs	TS1	3	MC	P/R	R
37	Tgs	TS1(S2)	4	C		T
38	Tgs/Tsc	A1(TS1)	2	MC		R
39	Tsc	TS1(S5)	3	C		T
40	Tes	TS1(S5)	2	MC		R
41	Tes	A1(TS1)	3	U	Braid (PR)	R

42	Tes	A1(TS1)	3	U	Braid (PR)	R
43	Tes	S2	5	C	C	T
44	Tess	S2	4	C		T
45	Tess	S2	6	C	C	T
46	Tess	S2b	5	C	C	T
47	Tess	H3	4	C	C	T
48	Tess	H3	5	C	C	T
49	Tess	H3	6	C	C	S
50	Tess	H3	6	C	C	S
A1	Qc (Qa)	G5	4	C		T
A2	Tcbb	UIG	5	C		T
A3a	Tcbb	UIG	6	C		S
A3b	Tcbb	G5	5	C		T
A4	Qc (Qa)	G5	3	C		R
A5	Tcbb	LS1	5	C		T
A6	Tcbb	UIG	6	C		S
A7	Tcbb	C2	5	C		T
A8	Tcbb	G5	3	C		T
A9a	Tcbb	C2	6	C		S
A9b	Tcbb	UIG	6	C		S
A10	Qc	G5	4	MC		T
A11	Qc	G5	5	C		T
A12	Qc	G5	5	MC		T
A13	Qc	G5	5	C		T
A14	Qa	A4	1	U		R
A15	Qc/Tcbb	C2	5	C		T
A16	Tcbb	H2	6	C		S
A17	Qa	A4	1	U		R
A18	Qc	G5	5	C		T
A19	Qc	G5	3	C		R
A20	Tcbb	UIG	6	C		S
A21	Tcbb	UIG	5	C		T
A22	Tcbb	H2	6	C		S
A23	Tcbb	H2	6	C		S
A24	Tcbb	G5	3	MC		R
A25	Tcbb	H2	6	C		S
A26	Qc	G5	5	C		T
A27	Qc	G5	4	C		T
A28	Qc	G5	4	C		T
A29	Qc	G5	5	C		T
A30a	Tcbb	C2b	6	C		S
A30b	Tcbb	H2	6	C		S
A31	Tcbb	H2	6	C		S
A32	Tcbb	H2	6	C		S
A33	Tcbb	H2	6	C		S
A34	Qc	G5	3	MC		R
A35	Tcbb	H2	6	C		S
A36	Tcbb	G5	3	C		R
A37	Tcbb	C2b	5	C		T
A38	Tcbb	H2	6	C		S
A39	Tcbb	H2	6	C		S
A40	Tcbb	H2	6	C		S
A41	Tcbb	H2	6	C		S
A42	Tcbb	H2	6	C		S

A43	Tcbb	H2	6	C	S
A44	Tcbb	C2b	5	C	T
A45	Tcbb	C2b	6	C	S
A46	Tcbb	H2	5	C	T
A47	Tcbb	H2	6	C	S
A48a	Tcbb	C2b	6	C	S
A48b	Tcbb	UIG	6	C	S
A48c	Tcbb	H1	6	C	S
A49	Tcbb	H2	6	C	S
A50	Tcbb	H2	5	C	T
A51	Tcbb	H2	6	C	S
A52	Tcbb	H2	6	C	S
A53	Tcbb	H2	6	C	S
A54	Qc	G5	5	C	T
A55	Tcbb	H2	6	C	S
A56	Qc	G5	3	MC	R
A57	Tcbb	H2	6	C	S
A58	Qc	G5	5	C	T
A59	Tcbb	H2	6	C	S
A60a	Tcbb	C2b	6	C	S
A60b	Tcbb	UIG	6	C	S
A60c	Tcbb	H1	6	C	S
A61	Qc	G5	2	MC	R
A62	Tcbb	H2(G5)	5	C	T
A63	Tcbb	H2(G5)	5	C	T
A64a	Tcbb	UIG	6	C	S
A64b	Tcbb	H2	6	C	S
A65	Qc	G5	4	C	T
A66	Tcbb	H2(LS1)	6	C	S
A67	Tcbb	H2(LS1)	6	C	S
A68	Qc	G5	5	C	T
A69	Tcbb	H2	6	C	S
A70	Tcbb	H2	6	C	S
A71	Tcbb	H2	6	C	S
A72	Tcbb	H2	5	C	T
A73	Tcbb	H2	6	C	S
A74	Tcbb	H2	5	C	T
A75	Tcbb	H2	6	C	S
B1a	Tcb	UIG	5	C	T
B1b	Tcbb	UIG	6	C	T
B2	Tcbb	UIG	6	C	T
B3	Tcbb	G1	4	MC	T
B4	Tcb	G1	3	MC	R
B5	Tcb	G1	5	C	T
B6	Tcb	H1	6	C	S
B7	Tcb	H1	6	C	S
B8	Tcb	H1	6	C	S
B9	Tcbb	H2	6	C	S
B10	Tcbb	C2b	6	C	S
B11	Tcbb	C2b	5	C	T
B12	Tcbb	H1	6	C	S
B13	Tcbb	H2	6	C	S
C1	Tcb	C2b	6	C	S
C2	Tcb	H2	6	C	S

C3	Tcb	C2b	6	C	S
C4	Tcb	H2	6	C	S
C5	Qo	G5	4	C	T
C6	Qo	G5	5	C	T
C7	Tcb	H2	6	C	S
C8	Qo	G5	5	C	T
C9	Tcb	C2b	6	C	S
C10	Tcb	H2	6	C	S
C11	Qo	G5	4	C	T
C12	Tcb	H2	6	C	S
C13	Qo	G5	4	C	T
C14	Tcb	H2	6	C	S
C15	Tcb	H2	6	C	S
C16	Tcb	H2	6	C	S
C17	Tcb	H2	6	C	S
C18	Tcb	H2	6	C	S
C19	Tcb	H2	6	C	S
C20	Tcb	H2	6	C	S
C21	Tcb	H2	6	C	S
C22	Tcb	H2	6	C	S
C23	Tcb	C2b	6	C	S
C24	Tcb	H1	6	C	S
C25	Tcb	H1	6	C	S
C26	Tcb	H2	6	C	S
C27	Tcb	H2	6	C	S
C28	Tcb	H2	6	C	S
C29	Tcb	H2	6	C	S
C30	Tcb	H2	6	C	S
D1	Tcb	C2	6	C	S
D2	Tcb	C2	5	C	T
D3	Tcb	C2	6	C	S
D4	Tcb	C2	5	C	T
D5	Tcb	F1	5	C	T
D6	Tcb	H3	6	C	S
D7	Tcb	H3	5	C	T
D8	Tcb	H3	6	C	S
D9	Tcb	H3	6	C	S
D10	Tcb	F1	4	C	T
D11	Tcb	H2	6	C	S
D12	Tcb	H2	6	C	S
D13	Tcb	H2	6	C	S
D14	Tcb	H2	6	C	S
D15	Tcb	H2	6	C	S
D16	Tcb	C2b(H1)	6	C	S
D17	Tcb	H2	6	C	S
D18	Tcb	H2	6	C	S
D19	Tcb	H2	6	C	S
D20	Tcb	H2	6	C	S
E1	Tcb	H2	6	C	S
E2	Tcb	H2	6	C	S
E3	Tcb	H2	6	C	S
E4	Qo	H2	4	C	T
E5	Qo	H2	5	C	T
E6	Tcb	H2	6	C	S

E7	Qo	H2	5	C	T
E8	Tcb	H2	6	C	S
E9	Qo	H2	5	C	T
E10	Tcb	H2	6	C	S
E11	Qo	H2	5	C	T
E12	Tcb	H2	6	C	S
E13	Qo	H2	5	C	T
E14	Tcb	H2	6	C	S
E15	Qo	F1	5(4)	C	T
E16	Tcb	H2	6	C	S
E17	Qo	H2	5	C	T
E18	Tcb	H2	6	C	S
E19	Qo	H2	5	C	T
E20	Tbm	H2	6	C	S
E21	Qo	H2	5	C	T
E22	Tbm	H2	6	C	S
E23	Tbm	H2	6	C	S
E24	Qo	H3	5	C	T
E25	Tbm	H3	6	C	S
E26	Tcb	H3	6	C	S
E27	Tcb	H3	6	C	S
E28	Tnm	H2	6	C	S
E29	Tnm	H2	6	C	S
E30	Tb	H2	6	C	S
E31	Tb/Tnm	H2	6	C	S
E32	Tnt	H2	6	C	S
E33	Tnt/Tnm	H2	6	C	S
E34	Tnm	H2	6	C	S
E35	Tnm	H2	6	C	S
E36	Tnm	H2	6	C	S
E37	Tnm	H2	6	C	S
F1	Tnm	S2	6	C	T
F2	Tnm	G1	4	C	T
F3	Tnm	G1	5	C	T
F4	Tnm/Tbm	H3	6	C	S
F5	Tbm/Tcb	H3	6	C	S
F6	Tcb	H3	6	C	S
F7	Tbm	H1	6	C	S
F8	Tnm	H1	6	C	S
F9	Tbm	H1	6	C	S
F10	Tnm	H3	6	C	S
F11	Qo	F1	5	C	T
F12	Qo	C2b	6	C	S
F13	Qo	G1	5	C	T
F14	Qo	G1	6	C	S
F15	Qo/Tcb	G1	5	C	T
F16	Tcb	G1	5	C	T
F17	Tcb	H3	5	C	T
F18	Tcb	H3	6	C	S
F19	Tcb	H3	6	C	S
F20	Tcb	H3	6	C	S
F21	Tcb	H3	6	C	S
G1	Tsc	S5	5	C	T
G2a	Tsc	TS1(S5)	3	C	T

G2b	Tsc	TS1(S5)	3	MC	R
G2c	Tsc	TS1(S5)	3	C	T
G2d	Tsc	TS1(S5)	3	MC	R
G3	Tsc/Tb	S5	6	C	S
G4	Tnm	H3	5	C	T
G5	Tnm	H3	6	C	S
G6	Tnm	H3	6	C	S
G7	Tnm	H3	6	C	S
G8	Tsc/Tnm	H2(H3)	6	C	S
G9	Tsc/Tb	H2	6	C	S
G10	Tsc	S5	5	C	T
G11	Tsc	H3	6	C	S
G12	Tsc	H3	5	C	T
G13	Tsc	H3	6	C	S
G14	Tsc	H3	6	C	S
G15	Tsc	H2	6	C	S
G16	Tsc	H3	6	C	S
G17	Tsc	H2	5	C	T
G18	Tsc	H3	6	C	S
H1	Tnt	H2	6	C	S
H2a	Tgs	F1	6	C	S
H2b	Tnt	H2	6	C	S
H3	Tgs	H2	6	C	S
H4a	Tgs	F1	6	C	S
H4b	Tgs	H2	5	C	T
H5	Tsc	H2	6	C	S
H6	Tsc	H2	6	C	S
H7	Tsc	S5	6	C	S
H8	Tsc	TS1(S5)	5	C	T
H9	Tsc	H3	6	C	S
H10	Tsc	H3	5	C	T
H11	Tscs	H3	6	C	S
H12	Tgs	TS1	5	C	T
H13	Tgs	H2	6	C	S
H14	Tet	TS1	6	C	S
H15	Tet	H2	6	C	S
H16	Tes/Tet	TS1	5	C	T
H17	Tes/Tet	H2	6	C	S
H18	Tet	TS1	5	C	T
H19	Tet	H2	6	C	S
H20	Tes	TS1(S5)	5	C	T
H21	Tes	H3	6	C	S
H22	Tsc	H3	5	C	T
H23	Tsc	H3	6	C	S
H24	Tes	H3	6	C	S
H25	Tes	H2	6	C	S
H26	Tes	H2	6	C	S
H27	Tes	H2	6	C	S
J1	Tes	H2(H3)	6	C	S
J2	Tess	H3	6	C	S
J3	Tess	H2(H3)	6	C	S
J4	Tess	H2	6	C	S
J5	Tess	H3	6	C	S
J6	Tess	H2(H3)	6	C	S

J7	Tess	H3	5 (6)	C	T
J8	Tess	H3	6 (5)	C	S
J9	Tess	H3	6 (5)	C	S
J10	Tess	H3	6	C	S
J11	Tess	H3	6	C	S

Appendix 2.3B

Geomorphic Unit Descriptions

Alluvial Channel Types (A1, A2, A3, A4,)

Consists of four types. Alluvial channels (A1) are the most generic of the group. They represent channels displaying the basic alluvial pattern with coarse sediment stored in bar formations, meanders, floodplain and terrace features. Shifting alluvial channels (A2) include channels with the basic A1 attributes, but where observed to exhibit lateral channel shifts, changes of form, or braiding through the photo record examined. Constrained alluvial channels (A3) are those channels that are laterally constrained, typically by unconsolidated or deformable deposits. Entrenchment in alluvial or glacial deposits, landslides, fans, or toeslope deposits are the constraining elements. A4 types are tributary alluvial streams located on a larger (confluent) streams floodplain. As such, important conditions and processes affecting these channels. may be more dependent on mainstem or trunk channel conditions or processes than those of the tributary channel.

Attributes generally consistent among alluvial channel types:

- Low gradient response reaches with floodplain and/or terrace development.
- Typical form is pool-riffle with exposed gavel bars and meandering pattern.
- Sections constrained by alluvial and/or glacial terrace (I.E. segments 7-9, 12, etc.) limit the width of the valley bottom and limit the lateral freedom of the stream.
  - Streambank and or valley edge erosion is a consequence.
- In the lower sections (below segment 12) stream is entrenched within glacial valley and/or outwash terraces.
- LWD recruitment is expected to be primarily from within the main channel riparian zone, although some is delivered via debris flows in steep hillslope channels (H2 type). In- channel LWD is often in the form of jams - these often affect lateral shifting of channel position as well as pool development.
- Sediment sources include side-cutting of terrace edges, and colluvial toe slopes and debris fans. In some areas hillslope source channels deliver directly to mainstem, however, relatively wide valley bottoms and/or terraces limit connection to hillslopes. Inflow from tributaries and reworking of stream deposits are other sources.
- Near channel wetlands including meander-cutoffs, side channels, seeps and springs from terrace and toeslope deposits are potentially important habitat conditions.,

Glacial Channel Types

Two types (G1 and G5) have been defined for the watershed and are described below. All are linked directly to glacial depositional terrains. Channel bed and banks, and adjacent slopes, are composed of or originated as glacial deposits. The glacial deposits may be stratified with layers of high permeability, or layers may restrict groundwater flow. As a result groundwater interchange including springs and/or seeps as well as forested wetlands may be importnat associations with these channel types. An additional type, cirque channels, are discussed separately with the headwater and hillslope channel types.

Channels formed in glacial tributary valleys (G1)

These channels have a more or less U-shaped cross section and have varying quantites of glacial deposits at toeslope and headwater locations. These glacial deposits may greatly influence sediment production via hillslope and channel adjacent mass wasting, bank erosion, or channel head incision. Those channels flowing primarily on terrace surfaces, and those entrenched well into terrace glacial or glacial-fluvial deposits will be covered here.

- The channels discussed here have limited connection to upper hill/valley-slope (mass wasting) processes because of the buffering effect of the terrace deposits.

Undifferentiated glacial channels (G5).

Includes channels flowing on top of or incised into glacial channels. Most streams flow within mapped deposits (Carson ,1976; Tabor and Cady, 1978)

- The depth to which these channels have incised into terraces greatly influences sediment production from channel adjacent slopes. Note that the larger, more deeply incised channels are expected to produce large volumes of sediment from mass wasting of channel adjacent slopes. Many of the channels designated as Undifferentiated Inner Gorge (UIG) are incised into these deposits and are related by material type, however they are expected to exhibit more active channel adjacent slopes. Shallow -rapid and deep seated mass wasting occurs here.
- The nature of glacial deposits; outwash, till, or lacustrine, greatly influence the stability and sediment production potential of the channel adjacent slopes. Differentiating these types of deposits was beyond the scope of this analysis.
- Where tributary streams flow off of the terrace edge there may be significant incision and erosion from channel adjacent slopes. In some cases these streams may approach or overlap with inner gorge (UIG) geomorphic types.
- LWD recruitment is expected from channel adjacent slope/ terrace edge mass wasting, as well as channel adjacent riparian area. Contributions from upper hillslopes (via debris flows) is limited by terraces. Processes predicted similar to sediment supply processes.
- Sensitivity: Channel adjacent slopes in excss of 65% are expected to be quite sensitive to vegetation loss and loss of root strength. Channel incision due to increases or concentration of flow is potentially a significant condition.

Channels on Terrace Surfaces or Slightly Incised into Terrace (G3)

- These channels tend to be small, low gradient (response) channels. (larger channels tend to be incised more deeply and therefore fall into one of the above geomorphic types).
- Seeps, springs or inter- connected wetlands can be an important feature of these channels.
- Mass wasting was not noted as a common process affecting these channels. Note as above, the depth of incision into glacial deposits controls this. Some stream bank erosion occurs where banks are developed.
- LWD recruitment is expected to be from immediately adjacent areas with little if any contribution from mass wasting processes. Effectiveness as a habitat forming element is expected to be high at least in part due to the small size of the channels involved.

Channels Controlled by Bedrock Conditions

Tabor and Cady (1978) mapped the bedrock geology throughout the analysis area. For the purposes of this analysis the bedrock types are divided into two large groups: 1) the Crescent Basalt and Basalt Breccias, and 2) sedimentary rocks consisting of 12 separate mapped units. This division is similar to the two major geologic terranes identified for the Olympic Peninsula; Crescent Basalt and Breccias are part of the periferal terranes, while the sedimentary rocks are part of the Core terrane. The exception is the unit Tbm (see Map 2.4A) which is a sedimentary unit that is part of the periferal terrane.

Crescent (Basalt) Canyon Reaches (C1)

- Low to moderate gradient reaches incised deeply into basalt and/or breccia bedrock.
- Typical form is bedrock and/or boulder steps and plane-bed form.
- Though low gradient would indicate response reaches; deep, tightly confined nature may favor transport.

- In channel LWD does not seem to be a significant habitat forming process. Bedrock and boulders form the obstructions.
- Sediment production from within these reaches is limited. Hard bedrock valley walls produce large blocks through rockfall processes.

Crescent (Basalt) Fluvial Mountain Valleys, V-Shaped: Bedrock and Toe Slope Deposits. (C2)

- Confined valley segments are directly connected to hillslopes and hillslope process. Colluvial hillslope processes exert a much greater influence on this channel type than preceding type (C1).
- Typically transport reaches. Form is typically step-pool and cascade (bedrock and boulder).
- Confinement provided by stream downcutting into bedrock, or constrictions resulting from valley bottom deposition.
  - Valley bottom deposition is either in the form of toe-slope glacial, colluvial, or fan deposits. These represent deformable deposits and in some areas are chronic sediment producers.
  - Bedrock confined segments are expected to produce less sediment from banks and channel edges, but can be more directly connected to hillslope processes.
- LWD delivery is from adjacent riparian as well as via debris flow processes from first and second order channels.
- Sediment: Where associated with toe slope (unconsolidated) deposits stream side slides and erosion is likely dominant source. Sediment production from first and second order channels (debris flows) is common depending on hillslope conditions - see mass wasting module. Where channel and channel edges are predominantly bedrock, hillslope delivery from first and second order channels presumably dominates.

Very Steep Fluvial Mountain Valleys, V-Shaped: Bedrock and Toe slope deposits. (C2b)

Steep (generally 15 to 20%) version of C2 channel type. Similar to hillslope type channels (H2), but larger, not quite as steep, and having a defined valley. Believed to represent direct routing pathway of sediment and debris from headwater and hillslope sources (is this sense function is more like H2 channel type, but amount of water transmitted may limit or prevent colluvial build-up, I.E. C2b types maintain a well defined channel).

Sedimentary Bedrock controlled channels (S2, S2b, S5)

Channels in sedimentary geologic formations. See Table 2.3A for formation name, and Geologic Map of Olympic Peninsula (Tabor and Cady, 1978) for descriptions. The degree to which the differing formations (rock type assemblages) control channel function and processes is unknown. O'Conner (1995) and Peterson (1995) noted important functional distinctions related to sediment production of parent material and clast durability (among others) based on geologic formation. In a general sense, most of these channels are expected to be similar to C2 channel types with varying sediment characteristics.

Fluvial Mountain Valleys, V-Shaped with Bedrock and/or Toe Slope Deposits. (S2)

- Confined valley segments are directly connected to hillslopes and hillslope process. Colluvial hillslope processes excert much greater influence on this channel type than the preceding one.
- Typically transport reaches. Form is typically step-pool and cascade (bedrock and boulder).
- Confinement provided by stream downcutting into bedrock, or constrictions resulting from valley bottom deposition.
  - Valley bottom deposition is either in the form of toe-slope glacial, colluvial, or fan deposits. These represent deformable deposits and in some areas are chronic sediment producers.
  - Bedrock confined segments are expected to produce less sediment from banks and channel edges, but can be more directly connected to hillslope processes.

Active Slopes and Valley Bottom (Toe Slope) Deposition

This group includes channels constrained by landslides, slumps, etc; inner gorges, and channels constrained by or flowing against undifferentiated slope deposits, (for example fans). As a group these are expected to be important channels in terms of sediment production and stream bank sensitivity. For the most part these channels were lumped into the most generic type, Toe-slope deposits (TS1). In the upper watershed, above Segment 23, deposits consist of a complex of debris avalanche/ alluvial fans and glacial deposits. *Alluvial reaches above Segment 21 are somewhat unconfined but are usually partially confined (on one side) by Toe slope deposition and in places exhibit charcateristics of this geomorphic type.* Channels of this group are predicted to have a high degree of interaction with the adjacent slopes.

Constrained by Toe-slope deposits (TS1), Fan deposits (F1), and Landslides (LS1)

Constrianed alluvial (A3) channel types (Segments 23, and 26) are at least partially constrained by slope deposits and the following description is appropriate for those segments.

- Predict high degree of hillslope interaction w/channel
- Sediment production is expected to be high, many of these channels may be better characterized as source channels because of the active hillslopes and hillslope channel interaction (channel edges and toe slopes store sediment and rejuvenate storage areas where stream channels remove it) even though gradient alone would typically characterize these channels as Transport dominated.
- Expect channel complexity to be highly influenced if not controlled by slope movements and introduction of hillslope materials, constrictions and channel shifts due to active toeslopes, large blocks and boulders.
- Presence of LWD can be very important to both channel and hillslope stability. Accumulations can be well anchored by hillslope deposits which limits mobility (sediment and wood). In some channels importance of LWD as a structure forming component may by limited because of complexity supplied by hillslope materials.

Inner Gorge Channels (UIG)

Valley inner gorge as defined by Haskins et. al. (1996) is a complex mass wasting feature which develops on the lowermost slopes adjacent to stream channels. The landform generally has (side) slope gradients > 65%, and is seperated from the upslope area by a distinct break in slope. The valley inner gorge is formed primarily through mass wasting triggered by channel down cutting, lateral cutting, oversteepening and/or under cutting of the slope. Channels within these features are highly connected to hillslopes and strongly influences by hillslope processes. Hillslopes typically are quite active. Mass wasting types include deep seated (slumps and slides) and shallow (debris slide) features.

- Many attributes are expected to be similar to Toe slope (TS1) channels
- Channel adjacent slope are expected to bey very sensitve to changes in root strength and potentially the affects of high (peak) flows.
- Sediment production from channel edges and lower slopes is expected to be an important attribute of this channel type.
- LWD considerations are expected to be similar to those for Toe slope channels (TS1), especially LS1 and F1 types.

Appendix 2.4A

						Photo Year						
Sub-basin	Landslide ID	Geomorph	LS Process	Assoc land use/activity	LS Certainty	39	62	69	73	82	93	sed delivery
1	1	IG	Deep, SEF	N?, Fire/cc	P	x						Y
1	2	IG	Deep, SEF	N?, Fire/cc	P	x						Y
1	3	IG	Deep, SEF	N?, Fire/cc	P	x						Y
1	4	LO disect, gl. dep	Deep, SEF	N?, Fire/cc	Q	x						Y
1	5	IG	Deep, SEF	N?, Fire/cc	P	x						Y
1	6	IG	SR (ds)	Fire/cc	D	x						Y
1	7	IG	SR (ds)	Fire/cc	D	x						Y
1	8	IG	SR (ds)	Fire/cc	D	x						Y
1	9	IG	SR (ds)	Fire/cc	D	x						Y
1	10	IG	SR (ds)	Fire/cc	D	x						Y
1	11	IG	SR (ds)	Fire/cc	D	x						Y
1	12	IG	SR (ds)	Fire/cc	D	x						Y
1	13	IG	SR (ds)	Fire/cc	D	x						N ?
1	14	IG	SR (ds)	Fire/cc	D	x						N ?
1	15	IG	SR (ds)	Fire/cc	D	x						N ?
1	16	IG	SR (ds)	Fire/cc	D	x						N ?
1	17	IG	SR (ds)	Fire/cc	D	x						N ?
1	18	IG	SR (ds)	Fire/cc	D	x						N ?
1	19	hi disect	SR (df)	Rd, Fire/cc	D	x						Y (A29)
1	20	IG (77-78)	SR (ds)	Fire	D	x						Y
1	21	77	SR (ds)	Fire		x						Y
1	22	IG (77-78)	SR (ds)	Fire		x						Y
1	23	IG (77-78)	SR (ds)	Fire		x						Y
1	24	77	SR (ds)	Fire		x						Y
1	25	hi disect	SR (ds)	Fire		x						N
1	26	lo disect	SE gully	Rd drain		x						N
1	27	lo disect	SR	Fire		x						Y
1	28	lo disect (IG?)	SR	Rd fill		x						Y
1	29	IG (ds?)	SE	Fire/cc		x	x					Y
1	30	hillslope	SE, gully	Rd drain		x						N
1	31	Gl terrace	SE	cc (powerline)			x					N
1	32	Gl dep	SE, sidecast	Rd (powerline)			x					N
1	33	disect (Tcb)	SR (fill fail)	Rd fill			x					N
1	34	disect (Tcb)	SE, sidecast	Rd fill			x					N
1	35	disect (Tcb)	SR	Landing			x					Y
1	36	77	DS	N			x					Y
1	37	77	SR (ds)	Fire			x					Y
1	38	77	SR (ds)	Fire			x					Y

1	39	77	SR (ds)	Fire			x					Y
1	40	Gl terrace	SR	Rd fill						x		N
1	41	Gl terr edge	DS	N (cc)	Q						x	Y
1	42	77	DS (translat)	N	P	x	x		x	x	x	Y
1	43	77	DS (translat)	N/fire	Q	x	x		x	x	x	Y
1	44	77	DS (translat)	N/fire	Q	x	x		x			Y
1	45	77	DS (translat)	N/fire	P	x	x		x			Y
1	46	77	DS-SR	N/fire	D	x						Y
1	47	77	DS-SR	N/fire	D	x						Y
1	48	77	DS-SR	N/fire	D	x						Y
1	49	77	DS-SR	N/fire	D	x						Y
1	50	77	DS-SR	N/fire	D	x						Y
1	51	Fan	SR (ds-dt)	N/fire	P	x						Y
1	52	Hi disect	SR	N/fire	D	x	x		RU			Y
1	53	Hi disect	SR	N/fire	D	x						Y
1	54	Hi disect	SR	N/fire	P	x						Y
1	55	IG? (rock)	SR (ds)	N/fire	D	x						Y
1	56	IG? (rock)	SR (ds)	N/fire	P	x						Y
1	57	IG? (rock)	SR (ds)	N/fire	P	x						Y
1	58	disect (SB)	SR-DR (sef?)	N/fire	Q	x						Y
1	78	hi disect	SR	Rd fill (cc)	D		x					N
1	79	lo disect	SR	Rd fill (cc)	D		x					N
1	80	lo disect	SR	Rd fill (cc)	D		x					N
1	81	lo disect	DS (sef)	N	Q		x					N
1	127	hi disect / 78	SR	N	D			x		x	RU	N
1	136	hi disect / 78	SR	N / fire	D	?		x				N
1	137	hi disect / 78	SR	N / fire	D	?		x				N
1	138	hi disect / 78	SR	N / fire	D	?		x				N
1	139	hi disect / 78	SR	N / fire	D	?		x				N
1	140	hi disect / 78	SR	N / fire	D	?		x				N
1	141	hi disect / 78	SR	N / fire	D	?		x				N
1	142	hi disect / 78	SR	N / fire	P		x					Y/N
1	147	Lo disect	SR	Rd (fill)	D				x			N
1	148	Lo disect	SR	Rd (fill)	D				x			N
1	149	Lo disect	SR	Rd (fill)	D				x			N
1	150	Lo disect	SR	Rd (fill)	D				x			N
1	151	Alpine - BR	SR/avalanche	N	D			x				
1	152	Hi disect	SR	Rd (cut)	D		x					N
1	153	Hi disect	SR	Rd (cut)	D		x					N
1	154	Hi disect	SR	Rd (fill), scf	D			x				
1	155	Hi disect	SR	Rd (fill), scf	D		x					

1	156	Hi disect	SR	Rd (fill), scf	D		?	x				
1	157	Hi disect	SR	Landing	D		?	x				
1	158	Hi disect	SR	Rd (fill), scf	D		?	x				
1	159	Hi disect	SR	Rd (fill), scf	D			x				
1	160	Hi disect	SR	Rd (fill), scf	D		x	x				
1	161	Hi disect	SR	Rd (fill), scf	D		?	x				
1	162	Hi disect	SR	Rd (fill), scf	D		?	x				
1	163	Hi disect	SR/DT	Rd (fill), scf	D		x	x				
1	164	Hi disect	SR/DT	Rd (fill), scf	D		x	x				
1	165	Hi disect	SR/DT	Rd (fill), scf	D		x	x				
1	166	IG	SR	N	D				x			
1	167	Hi disect - 77(?)	SR	CC	P				x			
1	168	Hi disect - 77(?)	SR	CC	P				x			
1	178	hillslope disect	SR (DF)	Rd	D					x	RU	Y
1	E1	gully	SE	Rd, Fire/cc	D	x						N
1	E2	gully	SE	Rd, Fire/cc	D	x						N
2	59	IG?	SR (DS-SEF)	N/fire	P	x						Y
2	60	IG	SE	SE	P	x						Y
2	61	IG	SE	SE	P	x						Y
2	62	disect (BR)	SR (big, da)	N	D	x						Y
2	63	disect (BR)	SR (big, da)	N	Q	x						Y
2	64	disect (BR)	SR (big, da)	N	Q	x						Y
2	65	disect (BR)	SR	N/fire	D	x						N
2	66	disect (BR)	SR	N/fire	D	x						N
2	67	disect (BR)	SR	N/fire	D	x						N
2	68	disect (BR)	SR	N	D	x						N
2	69	disect/alpine	DT/avalanche	N		x						Y
2	70	disect/alpine	DT/avalanche	N	D	x						Y
2	71	disect/alpine	SR	N	D	x						N
2	99	Alpine/ gl. erosion	SR	N	D		x					Y
2	100	Hi disect	SR	N	P		x					Y
2	101	Hi disect	SR	N	P		x					Y
2	102	Hi disect	SR	N	P		x					Y
2	103	Alpine/ gl. erosion	SR/avalanche	N	D		x					Y
2	104	Alpine/ gl. erosion	SR/avalanche	N	D		x					Y
2	116	hi disect / 78	SR	N	D			x	RU		+	N
2	117	hi disect / 78	SR	N	D			x				Y
2	118	hi disect / 78	SR/avalanche	N	P			x				Y
2	119	hi disect /	SR/avalanch	N	P			x				Y

		78	e									
2	120	hi disect / 78	SR/avalanch e	N	D			x				Y
2	121	hi disect / 78	SR/avalanch e	N	D			x				Y
2	128	hi disect / 78	SR	N / fire	D			x				Y
2	129	hi disect / 78	SR	N / fire	D	?		x				Y
2	130	hi disect / 78	SR	N / fire	D	?		x				Y
2	131	hi disect / 78	SR	N / fire	D	?		x				Y
2	132	hi disect / 78	SR	N / fire	D	?		x				Y
2	133	hi disect / 78	SR	N / fire	D	?		x				Y
2	134	hi disect / 78	SR	N / fire	D	?		x				?
2	135	hi disect / 78	SR	N / fire	D	?		x				?
2	174	hillslope - BR	SR	N	D				x			N
2	175	Alpine	SR	N	D	x						Y
2	176	Alpine	SR	N	D	x						Y
2	177	Alpine	SR	N	D	x						Y
2	183	Qls (large DA)	SR	N	D					x	x	N
2	184	Alpine (BR)	SR/avalanch e	N	D					x	x	N
2b	82	IG	DS (trans)	N	Q		x					Y
2b	83	IG	SR (SB)	CC	D		x					Y
2b	84	IG	DS (trans)	N	P		x					Y
2b	85	IG	SR (SB)	CC	D		x					Y
2b	86	IG	SR (SB)	CC	P		x					Y
2b	87	IG	SR (SB)	CC	D		x					Y
2b	88	IG	SR (SB)	CC	D		x					Y
2b	89	IG	DS (trans)	N	P		x					Y
2b	90	IG	SR	Rd fill (cc)	D		x		RU			Y
2b	91	IG	SR	Rd fill (cc)	D		x		RU			Y
2b	92	IG	SR	Rd fill (cc)	D		x		-	+		Y
2b	93	Hi disect	SR	Rd fill (cc)	D		x		-			Y
2b	94	Hi disect	SR	Rd fill (cc)	D		x		+			Y
2b	95	Hi disect	SR	Rd fill (cc)	D		x		-			Y
2b	96	Hi disect	SR	Rd fill (cc)	D		x		-			Y
2b	97	Hi disect	SR	Rd	D		x					Y
2b	98	Hi disect	SR	Fire/N	P		x					Y
2b	105	Alpine/ gl. erosion	SR/avalanch e	N	P		x					Y
2b	106	Alpine/ gl. erosion	SR/avalanch e	N	P		x					Y
2b	107	Alpine/ gl.	SR/avalanch	N	P		x					Y

		erosion	e									
2b	143	Hi disect	SR	Rd (fill)	D				x			Y
2b	144	Hi disect	SR	Rd (fill)	D				x			Y
2b	145	Hi disect	SR	Rd (fill)	D				x			Y
2b	146	Hi disect	SR	landing	D				x			N (73)
2b	169	Gl valley head	SE/ gully	Rd (drain)	D				x			Y
2b	170	Gl valley head	SE/ gully	Rd (drain)	D				x			Y
2b	171	hillslope disect	SE sidecast	Rd (fill)	D				x			Y
2b	172	hillslope disect	SR	Rd (fill)	D				x			N
2b	173	hillslope disect	SR	N	D				x			N
2b	179	hillslope disect	SR	Rd (fill)	D					x		Y
2b	180	hillslope disect	SR (SB)	CC	D					x		Y
2b	181	hillslope disect	SR	Rd (fill)	D					x		Y
2b	182	hillslope disect	SR	Rd (fill)	D					x		Y
2b	185	hillslope disect	SR (DF)	Rd (fill/drain)	D						x	Y
2b	186	hillslope disect	SR (DF)	Landing	D						x	Y
2b	187	hillslope disect	SR	Rd	D					x		N
2b	188	hillslope disect	SR	Rd	D						x	Y
2b	189	Gl erosion (cirque)	SR/avalanch e	N	D	x						N/Y
2c	72	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	73	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	74	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	75	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	76	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	77	disect/alpin e	DT/avalanch e	N	D	x						Y
2c	108	Alpine/ gl. erosion	SR	N	D		x					Y
2c	109	Alpine/ gl. erosion	SR	N	D		x					Y
2c	110	Alpine/ gl. erosion	SR	N	D		x					Y
2c	111	Alpine/ gl. erosion	SR	N	D		x					Y
2c	112	Alpine/ gl.	SR	N	D		x					Y

		erosion										
2c	113	hi disect / 78	SR	N	D		x					Y
2c	114	hi disect / 78	SR	N	D		x					?
2c	115	hi disect / 78	SR	N	D		x					?
2c	122	hi disect / 78	SR/avalanche	N	D			x				Y
2c	123	hi disect / 78	SR	N	D			x				N (pot.)
2c	124	hi disect / 78	SR	N	D			x				N
2c	125	hi disect / 78	SR	N	D			x				N
2c	126	hi disect / 78	SR	N	D			x				N

2.5 WILDLIFE APPENDIX

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
AMGR	A	NORTHWESTERN SALAMANDER	AMBYSTOMA GRACILE
AMMA	A	LONG-TOED SALAMANDER	AMBYSTOMA MACRODACTYLUM
DICO	A	COPE'S GIANT SALAMANDER	DICAMPTODON COPEI
RHOL	A	OLYMPIC TORRENT SALAMANDER	RHYACOTRITON OLYMPICUS
ENES	A	ENSATINA	ENSATINA ESCHSCHOLTZII
PLVA	A	VAN DYKE'S SALAMANDER	PLETHODON VANDYKEI
PLVE	A	WESTERN RED-BACKED SALAMANDER	PLETHODON VEHICULUM
TAGR	A	ROUGH-SKINNED NEWT	TARICHA GRANULOSA
BUBO	A	WESTERN TOAD	BUFO BOREAS
PSRE	A	PACIFIC TREEFROG	PSEUDACRIS REGILLA
ASTR	A	TAILED FROG	ASCAPHUS TRUEI
RAAU	A	RED-LEGGED FROG	RANA AURORA
RACAT	A	BULL FROG	RANA CATESBEIANA
RANCA	A	CASCADE FROG	RANA CASCADAE
GAST	B	RED-THROATED LOON	GAVIA STELLATA
GAPA	B	PACIFIC LOON	GAVIA PACIFICA
GAIM	B	COMMON LOON	GAVIA IMMER
GAAD	B	YELLOW-BILLED LOON	GAVIA ADAMSII
POPO	B	PIED-BILLED GREBE	PODILYMBUS PODICEPS
POGR	B	RED-NECKED GREBE	PODICEPS GRISEGENA
POAU	B	HORNED GREBE	PODICEPS AURITUS
PONI	B	EARED GREBE	PODICEPS NIGRICOLLIS
AEOC	B	WESTERN GREBE	AECHMOPHORUS OCCIDENTALIS
DINI	B	BLACK-FOOTED ALBATROSS	DIOMEDEA NIGRIPES
DIIM	B	LAYSAN ALBATROSS	DIOMEDEA IMMUTABILIS
FUGL	B	NORTHERN FULMAR	FULMARUS GLACIALIS
PTIN	B	MOTTLED PETREL	PTERDROMA INEXPECTATA
PUCR	B	PINK-FOOTED SHEARWATER	PUFFINUS CREATOPUS
PUCA	B	FLESH-FOOTED SHEARWATER	PUFFINUS CARNEIPES
PUBU	B	BULLER'S SHEARWATER	PUFFINUS BULLERI
PUGR	B	SOOTY SHEARWATER	PUFFINUS GRISEUS
PUTE	B	SHORT-TAILED SHEARWATER	PUFFINUS TENUIROSTRIS
OCFU	B	FORK-TAILED STORM-PETREL	OCEANODROMA FURCATA
OCLE	B	LEACH'S STORM-PETREL	OCEANODROMA LEUCORHOA
PEER	B	AMERICAN WHITE PELICAN	PELECANUS ERYTHRORHYNCHOS
PEOC	B	BROWN PELICAN	P. OCCIDENTALIS CALIFORNICUS
PHAU	B	DOUBLE-CRESTED CORMORANT	PHALAROCORAX AURITUS
PHPE	B	BRANDT'S CORMORANT	PHALACROCORAX PENICILLATUS
PHPEL	B	PELAGIC CORMORANT	PHALACROCORAX PELAGICUS
BOLE	B	AMERICAN BITTERN	BOTAURUS LENTIGINOSUS
ARHE	B	GREAT BLUE HERON	ARDEA HERODIAS

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
CAAL	B	GREAT EGRET	CASMERODIUS ALBUS
BUIB	B	CATTLE EGRET	BUBULCUS IBIS
BUST	B	GREEN-BACKED HERON	BUTORIDES STRIATUS
NYNY	B	BLACK-CROWNED NIGHT-HERON	NYCTICORAX NYCTICORAX
CYCO	B	TUNDRA SWAN	CYGNUS COLUMBIANUS
CYBU	B	TRUMPETER SWAN	CYGNUS BUCCINATOR
ANAL	B	GREATER WHITE-FRONTED GOOSE	ANSER ALBIFRONS
CHCAE	B	SNOW GOOSE	CHEN CAERULESCENS
CHCA	B	EMPEROR GOOSE	CHEN CANAGICA
BRBE	B	BRANT	BRANTA BERNICLA
BRCA	B	CANADA GOOSE	BRANTA CANADENSIS
AISP	B	WOOD DUCK	AIX SPONSA
ANCR	B	GREEN-WINGED TEAL	ANAS CRECCA
ANPL	B	MALLARD	ANAS PLATYRHYNCHOS
ANAC	B	NORTHERN PINTAIL	ANAS ACUTA
ANDI	B	BLUE-WINGED TEAL	ANAS DISCORS
ANCY	B	CINNAMON TEAL	ANAS CYANOPTERA
ANCL	B	NORTHERN SHOVELER	ANAS CLYPEATA
ANST	B	GADWALL	ANAS STREPERA
ANPE	B	EURASIAN WIGEON	ANAS PENELOPE
ANAAM	B	AMERICAN WIGEON	ANAS AMERICANA
AYVA	B	CANVASBACK	AYTHYA VALISINERIA
AYAM	B	REDHEAD	AYTHYA AMERICANA
AYCO	B	RING-NECKED DUCK	AYTHYA COLLARIS
AYFU	B	TUFTED DUCK	AYTHYA FULIGULA
AYMA	B	GREATER SCAUP	AYTHYA MARILA
AYAF	B	LESSER SCAUP	AYTHYA AFFINIS
SOSP	B	KING EIDER	SOMATERIA SPECTABILIS
HIHI	B	HARLEQUIN DUCK	HISTRIONICUS HISTRIONICUS
CLHY	B	OLDSQUAW	CLANGULA HYEMALIS
MENI	B	BLACK SCOTER	MELANITTA NIGRA
MEPE	B	SURF SCOTER	MELANITTA PERSPICILLATA
MEFU	B	WHITE-WINGED SCOTER	MELANITTA FUSCA
BUCL	B	COMMON GOLDENEYE	BUCEPHALA CLANGULA
BUIS	B	BARROW'S GOLDENEYE	BUCEPHALA ISLANDICA
BUAL	B	BUFFLEHEAD	BUCEPHALA ALBEOLA
LOPCU	B	HOODED MERGANSER	LOPHODYTES CUCULLATUS
MERME	B	COMMON MERGANSER	MERGUS MERGANSER
MESE	B	RED-BREASTED MERGANSER	MERGUS SERRATOR
OXJA	B	RUDDY DUCK	OXYURA JAMAICENSIS
CAAU	B	TURKEY VULTURE	CATHARTES AURA
PAHA	B	OSPREY	PANDION HALIAETUS
ELCA	B	BLACK-SHOULDERED KITE	ELANUS CAERULEUS

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
HALE	B	BALD EAGLE	HALIAEETUS LEUCOCEPHALUS
CICY	B	NORTHERN HARRIER	CIRCUS CYANEUS
ACST	B	SHARP-SHINNED HAWK	ACCIPITER STRIATUS
ACCCO	B	COOPER'S HAWK	ACCIPITER COOPERII
ACGE	B	NORTHERN GOSHAWK	ACCIPITER GENTILIS
BUSW	B	SWAINSON'S HAWK	BUTEO SWAINSONI
BUJA	B	RED-TAILED HAWK	BUTEO JAMAICENSIS
BULA	B	ROUGH-LEGGED HAWK	BUTEO LAGOPUS
AQCH	B	GOLDEN EAGLE	AQUILA CHRYSAETOS
FASP	B	AMERICAN KESTREL	FALCO SPARVERIUS
FACO	B	MERLIN	FALCO COLUMBARIUS
FAPE	B	PEREGRINE FALCON	FALCO PEREGRINUS
FARU	B	GYRFALCON	FALCO RUSTICOLUS
FAME	B	PRAIRIE FALCON	FALCO MEXICANUS
PHCO	B	RING-NECKED PHEASANT	PHASIANUS COLCHICUS
DEOB	B	BLUE GROUSE	DENDRAGAPUS OBSCURUS
BOUM	B	RUFFED GROUSE	BONASA UMBELLUS
CACAL	B	CALIFORNIA QUAIL	CALLIPEPLA CALIFORNICA
ORPI	B	MOUNTAIN QUAIL	OREORTYX PICTUS
RALI	B	VIRGINIA RAIL	RALLUS LIMICOLA
PORCA	B	SORA	PORZANA CAROLINA
FUAM	B	AMERICAN COOT	FULICA AMERICANA
GRCA	B	SANDHILL CRANE	GRUS CANADENSIS
PLSQ	B	BLACK-BELLIED PLOVER	PLUVIALIS SQUATAROLA
PLFU	B	PACIFIC GOLDEN-PLOVER	PLUVIALIS FULVA
DO__	B	LESSER GOLDEN-PLOVER	DOMINICA SPP. (PLUVIALIS DOMINICA?)
CHAL	B	SNOWY PLOVER	CHARADRIUS ALEXANDRINUS
CHSE	B	SEMIPALMATED PLOVER	CHARADRIUS SEMIPALMATUS
CHVO	B	KILLDEER	CHARADRIUS VOCIFERUS
HABA	B	BLACK OYSTERCATCHER	HAEMATOPUS BACHMANI
HIME	B	BLACK-NECKED STILT	HIMANTOPUS MEXICANUS
TRME	B	GREATER YELLOWLEGS	TRINGA MELANOLEUCA
TRFL	B	LESSER YELLOWLEGS	TRINGA FLAVIPES
TRSO	B	SOLITARY SANDPIPER	TRINGA SOLITARIA
CASE	B	WILLET	CATOPTROPHORUS SEMIPALMATUS
HEIN	B	WANDERING TATTLER	HETEROSCELUS INCANUS
ACMA	B	SPOTTED SANDPIPER	ACTITIS MACULARIA
NUPH	B	WHIMBREL	NUMENIUS PHAEOPUS
NUAM	B	LONG-BILLED CURLEW	NUMENIUS AMERICANUS
LILA	B	BAR-TAILED GODWIT	LIMOSA LAPPONICA
LIFE	B	MARBLED GODWIT	LIMOSA FEDOA
ARIN	B	RUDDY TURNSTONE	ARENARIA INTERPRES

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
ARME	B	BLACK TURNSTONE	ARENARIA MELANOCEPHALA
APVI	B	SURFBIRD	APHRIZA VIRGATA
CACA	B	RED KNOT	CALIDRIS CANUTUS
CAALB	B	SANDERLING	CALIDRIS ALBA
CAPU	B	SEMIPALMATED SANDPIPER	CALIDRIS PUSILLA
CAMI	B	LEAST SANDPIPER	CALIDRIS MINUTILLA
CABA	B	BAIRD'S SANDPIPER	CALIDRIS BAIRDII
CAME	B	PECTORAL SANDPIPER	CALIDRIS MELANOTOS
CAAC	B	SHARP-TAILED SANDPIPER	CALIDRIS ACUMINATA
CAPT	B	ROCK SANDPIPER	CALIDRIS PTILOCNEMIS
CAALP	B	DUNLIN	CALIDRIS ALPINA
CAHI	B	STILT SANDPIPER	CALIDRIS HIMANTOPUS
TRSU	B	BUFF-BREASTED SANDPIPER	TRYNGITES SUBRUFICOLLIS
PHPU	B	RUFF	PHILOMACHUS PUGNAX
LIGR	B	SHORT-BILLED DOWITCHER	LIMNODROMUS GRISEUS
LISC	B	LONG-BILLED DOWITCHER	LIMNODROMUS SCOLOPACEUS
GAGA	B	COMMON SNIPE	GALLINAGO GALLINAGO
PHTR	B	WILSON'S PHALAROPE	PHALAROPUS TRICOLOR
PHLO	B	RED-NECKED PHALAROPE	PHALAROPUS LOBATUS
PHFU	B	RED PHALAROPE	PHALAROPUS FULICARIA
STPO	B	POMARINE JAEGER	STERCORARIUS POMARINUS
STPAR	B	PARASITIC JAEGER	STERCORARIUS PARASITICUS
STLO	B	LONG-TAILED JAEGER	STERCORARIUS LONGICAUDUS
CAMAC	B	SOUTH POLAR SKUA	CATHARACTA MACCORMICKI
LAPI	B	FRANKLIN'S GULL	LARUS PIPIXCAN
LAMI	B	LITTLE GULL	LARUS MINUTUS
LAPH	B	BONAPARTE'S GULL	LARUS PHILADELPHIA
LAHE	B	HEERMANN'S GULL	LARUS HEERMANNI
LACA	B	MEW GULL	LARUS CANUS
LAAR	B	HERRING GULL	LARUS ARGENTATUS
LATH	B	THAYER'S GULL	LARUS THAYERI
LAOC	B	WESTERN GULL	LARUS OCCIDENTALIS
LAGL	B	GLAUCOUS-WINGED GULL	LARUS GLAUCESCENS
LAHY	B	GLAUCOUS GULL	LARUS HYPERBOREUS
RIBR	B	BLACK-LEGGED KITTIWAKE	RISSA BREVIROSTRIS
XESA	B	SABINE'S GULL	XEMA SABINI
STCA	B	CASPIAN TERN	STERNA CASPIA
STHI	B	COMMON TERN	STERNA HIRUNDO
STPA	B	ARCTIC TERN	STERNA PARADISAEA
STFO	B	FORSTER'S TERN	STERNA FORSTERI
CHNI	B	BLACK TERN	CHLIDONIAS NIGER
URAA	B	COMMON MURRE	URIA AALGE
URLO	B	THICK-BILLED MURRE	URIA LOMVIA

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
CECO	B	PIGEON GUILLEMOT	CEPPHUS COLUMBA
BRMA	B	MARBLED MURRELET	BRACHYRAMPHUS MARMORATUS
SYHY	B	XANTUS' MURRELET	SYNTHLIBORAMPHUS HYPOLEUCUS
SYAN	B	ANCIENT MURRELET	SYNTHLIBORAMPHUS ANTIQUUS
PTAL	B	CASSIN'S AUKLET	PTYCHORAMPHUS ALEUTICUS
CYPS	B	PARAKEET AUKLET	CYCLORRHYNCHUS PSITTACULA
CEMO	B	RHINOCEROS AUKLET	CERORHINCA MONOCERATA
FRCI	B	TUFTED PUFFIN	FRATERCULA CIRRHATRA
FRCO	B	HORNED PUFFIN	FRATERCULA CORNICULATA
COLI	B	ROCK DOVE	COLUMBA LIVIA
COFA	B	BAND-TAILED PIGEON	COLUMBA FASCIATA
ZEMA	B	MOURNING DOVE	ZENAIDA MACROURA
TYAL	B	BARN OWL	TYTO ALBA
OTKE	B	WESTERN SCREECH-OWL	OTUS KENNICOTTII
BUVI	B	GREAT HORNED OWL	BUBO VIRGINIANUS
NYSC	B	SNOWY OWL	NYCTEA SCANDIACA
GLGN	B	NORTHERN PYGMY-OWL	GLAUCIDIUM GNOMA
ATCU	B	BURROWING OWL	ATHENE CUNICULARIA
STOCCA	B	NORTHERN SPOTTED OWL	STRIX OCCIDENTALIS CAURINA
STVA	B	BARRED OWL	STRIX VARIA
ASOT	B	LONG-EARED OWL	ASIO OTUS
ASFL	B	SHORT-EARED OWL	ASIO FLAMMEUS
AEAC	B	NORTHERN SAW-WHET OWL	AEGOLIUS ACADICUS
CHMI	B	COMMON NIGHTHAWK	CHORDEILES MINOR
CYNI	B	BLACK SWIFT	CYPSELOIDES NIGER
CHVA	B	VAUX'S SWIFT	CHAETURA VAUXI
CAAN	B	ANNA'S HUMMINGBIRD	CALYPTE ANNA
SELRU	B	RUFOUS HUMMINGBIRD	SELASPHORUS RUFUS
CEAL	B	BELTED KINGFISHER	CERYLE ALCYON
MELE	B	LEWIS' WOODPECKER	MELANERPES LEWIS
SPNU	B	RED-NAPED SAPSUCKER	SPHYRAPICUS NUCHALIS
SPRU	B	RED-BREASTED SAPSUCKER	SPHYRAPICUS RUBER
PIPU	B	DOWNY WOODPECKER	PICOIDES PUBESCENS
PIVI	B	HAIRY WOODPECKER	PICOIDES VILLOSUS
PITR	B	THREE-TOED WOODPECKER	PICOIDES TRIDACTYLUS
PIAR	B	BLACK-BACKED WOODPECKER	PICOIDES ARCTICUS
COAU	B	NORTHERN FLICKER	COLAPTES AURATUS
DRPI	B	PILEATED WOODPECKER	DRYOCOPUS PILEATUS
COBO	B	OLIVE-SIDED FLYCATCHER	CONTOPUS BOREALIS
COSO	B	WESTERN WOOD-PEWEE	CONTOPUS SORDIDULUS
EMTR	B	WILLOW FLYCATCHER	EMPIDONAX TRAILLII
EMHA	B	HAMMOND'S FLYCATCHER	EMPIDONAX HAMMONDII
EMOB	B	DUSKY FLYCATCHER	EMPIDONAX OBERHOLSERI

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
EMDI	B	PACIFIC SLOPE FLYCATCHER (WESTERN)	EMPIDONAX DIFFICILIS
SAYSA	B	SAY'S PHOEBE	SAYORNIS SAYA
TYVE	B	WESTERN KINGBIRD	TYRANNUS VERTICALIS
TYTY	B	EASTERN KINGBIRD	TYRANNUS TYRANNUS
ERAL	B	HORNED LARK	EREMOPHILA ALPESTRIS
PRSU	B	PURPLE MARTIN	PROGNE SUBIS
TABI	B	TREE SWALLOW	TACHYCINETA BICOLOR
TATH	B	VIOLET-GREEN SWALLOW	TACHYCINETA THALASSINA
STSE	B	NORTHERN ROUGH-WINGED SWALLOW	STELGIDOPTERYX SERRIPENNIS
RIRI	B	BANK SWALLOW	RIPARIA RIPARIA
HIPY	B	CLIFF SWALLOW	HIRUNDO PYRRHONOTA
PECA	B	GRAY JAY	PERISOREUS CANADENSIS
CYST	B	STELLER'S JAY	CYANOCITTA STELLERI
CYCR	B	BLUE JAY	CYANOCITTA CRISTATA
APCO	B	SCRUB JAY	APELOCOMA COERULESCENS
NUCO	B	CLARK'S NUTCRACKER	NUCIFRAGA COLUMBIANA
COBR	B	AMERICAN CROW	CORVUS BRACHYRHYNCHOS
CORCO	B	COMMON RAVEN	CORVUS CORAX
PAAT	B	BLACK-CAPPED CHICKADEE	PARUS ATRICAPILLUS
PARU	B	CHESTNUT-BACKED CHICKADEE	PARUS RUFESCENS
PSMI	B	BUSHTIT	PSALTRIPARUS MINIMUS
SICAN	B	RED-BREASTED NUTHATCH	SITTA CANADENSIS
SICAR	B	WHITE-BREASTED NUTHATCH	SITTA CAROLINENSIS
CEAM	B	BROWN CREEPER	CERTHIA AMERICANA
SAOB	B	ROCK WREN	SALPINCTES OBSOLETUS
THBE	B	BEWICK'S WREN	THRYOMANES BEWICKII
TRAE	B	HOUSE WREN	TROGLODYTES AEDON
CIPA	B	MARSH WREN	CISTOTHORUS PALUSTRIS
CIME	B	AMERICAN DIPPER	CINCLUS MEXICANUS
RESA	B	GOLDEN-CROWNED KINGLET	REGULUS SATRAPA
RECA	B	RUBY-CROWNED KINGLET	REGULUS CALENDULA
SIME	B	WESTERN BLUEBIRD	SIALIA MEXICANA
SICU	B	MOUNTAIN BLUEBIRD	SIALIA CURRUCOIDES
MYTO	B	TOWNSEND'S SOLITAIRE	MYADESTES TOWNSENDI
CAUS	B	SWAINSON'S THRUSH	CATHARUS USTULATUS
CAGU	B	HERMIT THRUSH	CATHARUS GUTTATUS
TUMI	B	AMERICAN ROBIN	TURDUS MIGRATORIUS
IXNA	B	VARIED THRUSH	IXOREUS NAEVIUS
MIPO	B	NORTHERN MOCKINGBIRD	MIMUS POLYGLOTTOS
ANSPI	B	AMERICAN PIPIT (WATER)	ANTHUS SPINOLETTA
BOGA	B	BOHEMIAN WAXWING	BOMBYCILLA GARRULUS
BOCE	B	CEDAR WAXWING	BOMBYCILLA CEDRORUM
VISO	B	SOLITARY VIREO	VIREO SOLITARIUS

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
VIHU	B	HUTTON'S VIREO	VIREO HUTTONI
VIGI	B	WARBLING VIREO	VIREO GILVUS
VIOL	B	RED-EYED VIREO	VIREO OLIVACEUS
VECE	B	ORANGE-CROWNED WARBLER	VERMIVORA CELATA
VERU	B	NASHVILLE WARBLER	VERMIVORA RUFICAPILLA
DEPET	B	YELLOW WARBLER	DENDROICA PETECHIA
DENCO	B	YELLOW-RUMPED WARBLER (AUDUBON'S)	DENDROICA CORONATA
DECO	B	YELLOW-RUMPED WARBLER (MYRTLE)	DENDROICA CORONATA
DENI	B	BLACK-THROATED GRAY WARBLER	DENDROICA NIGRESCENS
DETO	B	TOWNSEND'S WARBLER	DENDROICA TOWNSENDI
DEOC	B	HERMIT WARBLER	DENDROICA OCCIDENTALIS
DEPA	B	PALM WARBLER	DENDROICA PALMARUM
SETRU	B	AMERICAN REDSTART	SETOPHAGA RUTICILLA
OPTO	B	MACGILLIVRAY'S WARBLER	OPORORNIS TOLMIEI
GETR	B	COMMON YELLOWTHROAT	GEOTHLYPIS TRICHAS
PHME	B	BLACK-HEADED GROSBEAK	PHEUCTICUS MELANOCEPHALUS
PIER	B	RUFOUS-SIDED TOWHEE	PIPILO ERYTHROPHTHALMUS
SPAR	B	AMERICAN TREE SPARROW	SPIZELLA ARBOREA
SPPAS	B	CHIPPING SPARROW	SPIZELLA PASSERINA
POGRA	B	VESPER SPARROW	POOECETES GRAMINEUS
PASA	B	SAVANNAH SPARROW	PASSERCULUS SANDWICHENSIS
PAIL	B	FOX SPARROW	PASSERELLA ILIACA
MELME	B	SONG SPARROW	MELOSPIZA MELODIA
MELI	B	LINCOLN'S SPARROW	MELOSPIZA LINCOLNII
ZOAL	B	WHITE-THROATED SPARROW	ZONOTRICHIA ALBICOLLIS
ZOAT	B	GOLDEN-CROWNED SPARROW	ZONOTRICHIA ATRICAPILLA
ZOLE	B	WHITE-CROWNED SPARROW	ZONOTRICHIA LEUCOPHRYS
ZOQU	B	HARRIS' SPARROW	ZONOTRICHIA QUERULA
JUHY	B	DARK-EYED JUNCO	JUNCO HYEMALIS
CALA	B	LAPLAND LONGSPUR	CALCARIUS LAPPONICUS
PLNI	B	SNOW BUNTING	PLECTROPHENAX NIVALIS
AGPH	B	RED-WINGED BLACKBIRD	AGELAIUS PHOENICEUS
STUNE	B	WESTERN MEADOWLARK	STURNELLA NEGLECTA
XAXA	B	YELLOW-HEADED BLACKBIRD	XANTHOCEPHALUS XANTHOCEPHALUS
EUCY	B	BREWER'S BLACKBIRD	EUPHAGUS CYANOCEPHALUS
MOAT	B	BROWN-HEADED COWBIRD	MOLOTHRUS ATER
ICGA	B	NORTHERN ORIOLE	ICTERUS GALBULA
LEART	B	GRAY-CROWNED ROSY FINCH (WALLOWA)	LEUCOSTICTE ARCTOA TEPHROCOTIS
PIEN	B	PINE GROSBEAK	PINICOLA ENUCLEATOR
CARPU	B	PURPLE FINCH	CARPODACUS PURPUREUS
CARME	B	HOUSE FINCH	CARPODACUS MEXICANUS
CAPI	B	PINE SISKIN	CARDUELIS PINUS
LOXCU	B	RED CROSSBILL	LOXIA CURVIROSTRA

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
LOLE	B	WHITE-WINGED CROSSBILL	LOXIA LEUCOPTERA
CAFL	B	COMMON REDPOLL	CARDULIS FLAMMEA
CATR	B	AMERICAN GOLDFINCH	CARDUELIS TRISTIS
COVE	B	EVENING GROSBEAK	COCCOTHRAUSTES VESPERTINUS
PADO	B	HOUSE SPARROW	PASSER DOMESTICUS
DIVI	M	VIRGINIA OPOSSUM	DIDELPHIS VIRGINIANA
SOCI	M	MASKED SHREW	SOREX CINEREUS
SOVA	M	VAGRANT SHREW	SOREX VAGRANS
SOMO	M	DUSKY SHREW	SOREX MONTICOLUS (S. OBSCURUS?)
SOPAL	M	NORTHERN WATER SHREW	SOREX PALUSTRIS
SOBE	M	PACIFIC WATER SHREW (MARSH SHREW)	SOREX BENDIREI
SOTR	M	TROWBRIDGE'S SHREW	SOREX TROWBRIDGEI
NEGI	M	SHREW-MOLE	NEUROTRICHUS GIBBSI
SCTO	M	TOWNSEND'S MOLE	SCAPANUS TOWNSENDI
SCOR	M	COAST MOLE	SCAPANUS ORARIUS
MYLU	M	LITTLE BROWN MYOTIS	MYOTIS LUCIFUGUS
MYYU	M	YUMA MYOTIS	MYOTIS YUMANENSIS
MYKE	M	KEEN MYOTIS	MYOTIS KEENI
MYEV	M	LONG-EARED MYOTIS	MYOTIS EVOTIS
MYVO	M	LONG-LEGGED MYOTIS	MYOTIS VOLANS
MYOCA	M	CALIFORNIA MYOTIS	MYOTIS CALIFORNICUS
LANO	M	SILVER-HAIRED BAT	LASIONYCTERIS NOCTIVAGANS
EPFU	M	BIG BROWN BAT	EPTESICUS FUSCUS
LACI	M	HOARY BAT	LASIURUS CINEREUS
PLTO	M	TOWNSEND'S BIG-EARED BAT	PLECOTUS TOWNSENDI
LEAM	M	SNOWSHOE HARE	LEPUS AMERICANUS
APRU	M	MOUNTAIN BEAVER	APLODONTIA RUFA
EUAM	M	YELLOW-PINE CHIPMUNK	EUTAMIUS AMOENUS
EUTO	M	TOWNSEND'S CHIPMUNK	EUAMIAS TOWNSENDI
MAOL	M	OLYMPIC MARMOT	MARMOTA OLYMPUS
TADO	M	DOUGLAS' SQUIRREL	TAMIASCIURUS DOUGLASI
GLSA	M	NORTHERN FLYING SQUIRREL	GLAUCOMYS SABRINUS
THMA	M	NORTHERN POCKET GOPHER (MAZAMA)	THOMOMYS MAZAMA
CASCA	M	BEAVER	CASTOR CANADENSIS
PEOR	M	FOREST DEER MOUSE	PEROMYSCUS OREAS
PEMA	M	DEER MOUSE	PEROMYSCUS MANICULATUS
NECI	M	BUSHY-TAILED WOODRAT	NEOTOMA CINEREA
RANO	M	NORWAY RAT	RATTUS NORVEGICUS
CLGA	M	SOUTHERN RED-BACKED VOLE	CLETHRIONOMYS GAPPERI
PHIN	M	HEATHER VOLE	PHENACOMYS INTERMEDIUS
MIOR	M	OREGON CREEPING VOLE	MICROTUS OREGONI
MITO	M	TOWNSEND'S VOLE	MICROTUS TOWNSENDI
MILO	M	LONG-TAILED VOLE	MICROTUS LONGICAUDUS

Appendix Table 2.5 Olympic National Forest Documented and Suspected Wildlife Species

Species	C	Common Name	Scientific Name
ONZI	M	MUSKRAT	ONDATRA ZIBETHICUS
MUMU	M	HOUSE MOUSE	MUS MUSCULUS
ZATR	M	PACIFIC JUMPING MOUSE	ZAPUS TRINOTATUS
ERDO	M	PORCUPINE	ERETHIZON DORSATUM
VUVU	M	RED FOX	VULPES VULPES
URAM	M	BLACK BEAR	URSUS AMERICANUS
CALAT	M	COYOTE	CANIS LATRANS
LYRU	M	BOBCAT	LYNX RUFUS
MEMEP	M	STRIPED SKUNK	MEPHITIS MEPHITIS
PRLO	M	RACCOON	PROCYON LOTOR
MAAM	M	MARTEN	MARTES AMERICANA
MAPE	M	FISHER	MARTES PENNANTI
MUER	M	SHORTTAIL WEASEL (ERMINE)	MUSTELA ERMINEA
MUFR	M	LONG-TAILED WEASEL	MUSTELA FRENATA
MUVI	M	MINK	MUSTELA VISON
GUGU	M	WOLVERINE	GULO GULO
SPGR	M	WESTERN SPOTTED SKUNK	SPILOGALE GRACILIS
LUCA	M	RIVER OTTER	LUTRA CANADENSIS
ENLU	M	SEA OTTER	ENHYDRA LUTRIS
FECO	M	MOUNTAIN LION	FELIS CONCOLOR
CEEL	M	ROOSEVELT ELK	CERVUS ELAPHUS
ODHE	M	BLACK-TAILED DEER	ODOCOILEUS HEMIONUS
ORAM	M	MOUNTAIN GOAT	OREAMNOS AMERICANUS
ELCO	R	NORTHERN ALLIGATOR LIZARD	ELGARIA COERULEA
SCOC	R	WESTERN FENCE LIZARD	SCELOPORUS OCCIDENTALIS
CHBO	R	RUBBER BOA	CHARINA BOTTAE
THEL	R	WESTERN TERRESTRIAL GARTER SNAKE	THAMNOPHIS ELEGANS
THOR	R	NORTHWESTERN GARTER SNAKE	THAMNOPHIS ORDINOIDES
THSI	R	COMMON GARTER SNAKE	THAMNOPHIS SIRTALIS
CRDE	S	PUGET OREGONIAN	CRYPTOMASTIX DEVIA
DEHE	S	EVENING FIELD SLUG	DEROCERAS HESPERIUM
HEBU	S	KEELED JUMPING SLUG	HEMPHILLIA BURRINGTONI
HEGL	S	WARTY JUMPING SLUG	HEMPHILLIA GLANDULOSA
HEPA	S	PANTHER JUMPING SLUG	HEMPHILLIA PANTHERINA
MEHE	S	OREGON MEGOMPHIX	MEGOMPHIX HEMPHILLI
PRCO	S	BLUE-GRAY TAIL-DROPPER	PROPHYSAON COERULEUM
PRDU	S	PAPILLOSE TAIL-DROPPER	PROPHYSAON DUBIUM
VE__	S	HOKO VERTIGO	VERTIGO NEW SPECIES

SPECIES = Species code, 1st 2 letters of genus and 1st 2 letters of species names.
C = Class: A = Amphibian, B = Birds, M = Mammals, R = Reptiles, S = Molluscs (slugs and snails)

APPENDIX 2.6

Maxtrix of Pathways and Indicators

(Ranges of citeria presented here are not absolute, they may be adjusted for unique watersheds)

Pathway	Indicators	Properly Functioning
Water Quality	Temperature	50-57° F
	Sediment/Turbidity	<12% fines (<0.85mm) in gravel, turbidity low
Habitat Access	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows
Habitat Elements	Substrate	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%
	Large Woody Debris	> 80 pieces/mile >24" diameter >50ft. length; and adequate sources of woody debris recruitment in riparian areas
	Pool Frequency Channel width #pools/mile 5 ft. 184 10 ft 96 15 ft. 70 20 ft. 56 25 ft. 47 50 ft. 26 75 ft. 23 100 ft. 18	meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)
	Pool Quality	pools >1 meter deep (holding pools) with good cover and cool water, minor reduction of pool volume by fine sediment
	Off-channel Habitat	backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)
	Refugia (important remnant habitat for sensitive aquatic species)	habitat refugia exist and are adequately buffered (e.g. by intact riparian reserves); existing refugia are sufficient in size and number and connectivity to maintain viable populations or sub-populations
Channel Conditions & Dynamics	Width/Depth Ratio	<10
	Streambank Condition	>90% stable; i.e. on average less than 10% of banks are actively eroding
	Floodplain Connectivity	off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession
Flow/Hydrology	Changes in Peak/ Base Flow	watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	zero or minimum increases in drainage network density due to roads
Watershed Conditions	Road Density & Location	<2mi/mi², no valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs), $\geq$ 15% retention of LSOG in watershed
	Riparian Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition >50%

[1]APPENDIX

Table 2.7H1 Current Riparian Timber Condition and Associated Impact Call for Near-tem LWD in Lower Duckabush[2]

Stand Type	Total Riparian Acres[3]	Percent of Total Riparian Area	Total Stream Miles	Percent of Total Stream Miles	Impact Call
CYS	116.5	3.0	3.01	4.04	high
CYD	88.6	2.3	2.29	3.07	med
CMS	140.5	3.6	2.65	3.56	med
CMD	1,729.4	44.6	32.61	43.75	low
COS					
COD	469,.3	12.1	7.0	9.39	low
DYS	67.3	1.7	1.74	2.33	high
DYD	1.9	.05	.05	.07	high
DMS	5.8	.15	.11	.15	med
DMD	136.3	3.5	2.57	3.45	med
DOS					
DOD					
MYS	155.2	4.0	4.01	5.38	high
MYD	69.7	1.8	1.80	2.42	high
MMS	57.8	1.5	1.09	1.46	high
MMD	788.1	20.3	14.86	19.94	high
MOS					
MOD	49.6	1.3	.74	.99	med
non-for					
TOTAL	3,876.0	100	74.53	100	

Table Legend:

CYS= conifer, young, sparse
CYD= conifer, young, dense
CMS= conifer, mature, sparse
CMD= conifer, mature, dense
COS= conifer, old, sparse
COD= conifer, old, dense

DYS= deciduous, young, sparse
DYD= deciduous, young, dense
DMS= deciduous, young, sparse
DMD= deciduous, young, dense
DOS= deciduous, old, sparse
DOD= deciduous, old, dense

MYS= mixed, young, sparse
MYD= mixed, young, dense
MMS= mixed, mature, sparse
MMD= mixed, mature, dense
MOS= mixed, mature, sparse
MOD= mixed, mature, dense

[1] Table developed using State methods (WFPB manual) for riparian function assessment.
[2]
[3]

Table 2.7H2 Current Riparian Timber Condition and Associated Impact Call for Near-term LWD in Murhut and Cliff Creeks[1]

Stand Type	Total Riparian Acres[2]	Percent of Total Riparian Area	Total Stream Miles[3]	Percent of Total Stream Miles	Impact Call
CYS	384.2	8.9	5.99	10.6	high
CYD	259.8	6.0	4.05	7.2	med
CMS	113.7	2.6	3.05	5.4	med
CMD	628.3	14.6	16.86	29.87	low
COS	239.8	5.6	1.64	2.71	lowlow
COD	2,069.3	48.1	14.15	25.07	low
DYS	170.0	4.0	2.65	4.69	high
DYD					
DMS	8.6	.2	.23	.41	med
DMD					
DOS					
DOD					
MYS	169.3	3.9	2.64	4.68	high
MYD	41.7	1.0	.65	1.15	high
MMS	47.7	1.1	1.28	2.27	high
MMD	104.7	2.4	2.81	4.98	high
MOS	65.8	1.5	.45	.8	med
MOD					
non-for					
TOTAL	4,302.7	100	56.45	100	

Table Legend:

CYS= conifer, young, sparse
CYD= conifer, young, dense
CMS= conifer, mature, sparse
CMD= conifer, mature, dense
COS= conifer, old, sparse
COD= conifer, old, dense

DYS= deciduous, young, sparse
DYD= deciduous, young, dense
DMS= deciduous, young, sparse
DMD= deciduous, young, dense
DOS= deciduous, old, sparse
DOD= deciduous, old, dense

MYS= mixed, young, sparse
MYD= mixed, young, dense
MMS= mixed, mature, sparse
MMD= mixed, mature, dense
MOS= mixed, mature, sparse
MOD= mixed, mature, dense

Notes:

1-
2
3- Stream mile calculation counts both sides of fish-bearing waters.
4. Impact call indicates level of concern for LWD recruitment (ie., high impact call is due to poor recritment potential, medium impact call is due to fair recruitment potential and low impact call is due to good recruitment potential).

1
2
3

Table 2.7H3 Current Riparian Timber Condition and Associated Impact Call for Near-term LWD in Middle Duckabush[1] (only part of subwatershed classified)

Stand Type	Total Riparian Acres[2]	Percent of Total Riparian Area	Total Stream Miles[3]	Percent of Total Stream Miles	Impact Call[4]
CYS					
CYD					
CMS	48.8	5.12	.880	23.8	med
CMD	122.7	12.86	2.210	59.76	low
COS					
COD					
DYS					
DYD	782.4	82.02	.608	16.44	high
DMS					
DMD					
DOS					
DOD					
MYS					
MYD					
MMS					
MMD					
MOS					
MOD					
non-for					
TOTAL	953.9	100	3.698	100	

Table Legend:

CYS= conifer, young, sparse
CYD= conifer, young, dense
CMS= conifer, mature, sparse
CMD= conifer, mature, dense
COS= conifer, old, sparse
COD= conifer, old, dense

DYS= deciduous, young, sparse
DYD= deciduous, young, dense
DMS= deciduous, young, sparse
DMD= deciduous, young, dense
DOS= deciduous, old, sparse
DOD= deciduous, old, dense

MYS= mixed, young, sparse
MYD= mixed, young, dense
MMS= mixed, mature, sparse
MMD= mixed, mature, dense
MOS= mixed, mature, sparse
MOD= mixed, mature, dense

Notes:

1- Table developed using State methods (WFPB manual) for riparian function assessment.
2 Riparian acreage developed using site-potential tree height criteria for appropriate PNV, measured in feet from ordinary high water mark.
3- Stream mile calculation counts both sides of fish-bearing waters.
4. Impact call indicates level of concern for LWD recruitment (ie., high impact call is due to poor recritment potential, medium impact call is due to fair recruitment potential and low impact call is due to good recruitment potential).

1
2
3
4

Table B6: Species Ecological Classification   * Indicates taxon addressed by Survey and Manage provision.

(This table is incomplete. Only species with available information are included at this time. As additional information becomes available, more species may be added in subsequent revision of the module.)

SPECIES	Late-Succes.	Riparian	Aquatic - Lotic	Aquatic - Lentic	Seeps, Springs	Rock Outcrops	Other
BRYOPHYTES							
Antitrichia curtipendula	X	X					
**Douinia ovata*	X	X					
**Kurzia makinoana*		X					
**Scouleria marginata*			X				
Thamnobryum neckeroides							
**Tritomaria exsectiformis*			X				
FUNGI							
Clitocybe senilis	X						
Clitocybe subditopoda	X						
Cyphellostereum laeve	X						
Galerina atkinsoniana	X	X					
Galerina cerina	X						
Galerina heterocystis	X	X					
Galerina sphagnicola		X					Sphagnum bogs
Galerina vittaeformis		X					
Gomphus bonarii		X					
Gomphus clavatus		X					
Gomphus floccosus		X					
Gomphus kauffmanii	X						
**Helvella compressa*		X					
**Helvella crassitunicata*		X					
**Helvella elastica*	X	X			X		
**Helvella maculata*		X					
Neolentinus adhaerens	X						
Phaeocollybia attenuata		X					
Phaeocollybia californica		X					
Phaeocollybia carmanahensis	X	X					Old growth
Phaeocollybia fallax		X					
Phaeocollybia gregaria							Misc areas
Phaeocollybia kauffmanii		X					
Phaeocollybia olivacea		X					
Phaeocollybia oregonensis		X					
Phaeocollybia piceae							Misc areas
Phaeocollybia pseudofestiva	X						
Phaeocollybia scatesiae	X						
Phaeocollybia sipei		X					
Phaeocollybia spadicea	X						
Phlogiotis (Tremiscus) helvelloides		X			X		Calcarous soils
**Polyozellous multiplex*	X	X			X		

SPECIES	Late-Succes.	Riparian	Aquatic - Lotic	Aquatic - Lentic	Seeps, Springs	Rock Outcrops	Other
Rhodocybe nitida (Entoloma nitidum)		X					Peaty soils
Rhodocybe speciosa	X						Wood rotter
Rickenella setipes		X					
Tricholomopsis fulvescens	X						
LICHENS							
Riparian Lichens							
Cetrelia cetrarioides		X					
Collema nigrescens	X						
Leptogium burnetiae var. hirsutum	X						
Leptogium cyanescens		X					
Leptogium saturninum		X					
Leptogium teretiusculum		X					
Platismatia lacunosa		X					
Ramalina thrausta	X	X					
Usnea longissima	X	X					
Aquatic Lichens							
****Dermatocarpon luridum***			X	X	X		
****Hydrothyria venosa***			X				
****Leptogium rivale***			X				
Decaying Wood and Soil Lichens							
Cladonia bacillaris	X						
Cladonia bellidiflora	X						
Cladonia cenotea	X						
Cladonia macilenta	X						
Cladonia umbricola	X						
Icmadolphila ericitorum	X						
Xylographa abietina	X						
Xylographa vitiligo	X						
Forage Lichens							
Alectoria sarmentosa	X						
Alectoria lata	X						
Alectoria vancouverensis	X						
Bryoria capillaris	X						
Bryoria friabilis	X						
Bryoria glabra	X						
Bryoria pikei	X						
Bryoria pseudofuscescens	X						
Usnea filipendula	X						
Usnea scabrata	X						
Rock Lichens							
Leptogium gelatinosum	X						
Pilophorus acicularis						X	
Pilophorus clavatus						X	

SPECIES	Late-Succes.	Riparian	Aquatic - Lotic	Aquatic - Lentic	Seeps, Springs	Rock Outcrops	Other
Psoroma hypnorum	X						
VASCULAR PLANTS							
Allotropa virgata	X						
***Bensoniella oregana* (California)**		X					
***Bensoniella oregana* (Oregon)**		X					
Botrychium montanum		X					
Botrychium minganense		X					
Cimicifuga elata							
Coptis trifolia	X	X					
Pedicularis howellii							
MOLLUSKS							
Slugs							
Prophysaon dubium		X				X	
Land Snails							
Ancotrema voyanum	X	X					Limestone
Cryptomastix devia	X	X					
Cryptomastix hendersoni		X			X	X	
Monadenia fidelis salmonensis	X	X				X	
Monadenia rotifer	X	X				X	
Punctum (Toltecia) hannai	X	X					
Vespericola depressa		X			X		Grasslands
Vespericola euthales	X	X			X	X	
Vespericola sierranus	X	X			X	X	
Freshwater Snails							
***Fluminicola* n. species 1-3** 1. Klamath Pebblesnail 2. Tall Pebblesnail 3. Klamath Rim Pebblesnail			X		X		
***Fluminicola* n. species 4- 10** 4. Nerite Pebblesnail 5.Toothed Pebblesnail 6. Diminutive Pebblesnail 7. Topaz Pebblesnail 8. Fall Creek Pebblesnail 9. Lunate Pebblesnail 10. Keene Creek Pebblesnail			X		X		
***Fluminicola* n. sp.11** 11. Fredenburg Pebblesnail			X		X		
***Fluminicola n.* species 14 -20** 14. Potem Pebblesnail 15. Flat-top Pebblesnail 16. Shasta Pebblesnail 17. Disjunct Pebblesnail 18. Globular Pebblesnail			X		X		

SPECIES	Late-Succes.	Riparian	Aquatic - Lotic	Aquatic - Lentic	Seeps, Springs	Rock Outcrops	Other
19. Umbilicate Pebblesnail 20. Lost Creek Pebblesnail							
****Fluminicola seminalis***			X		X		
Helisoma newberryi newberryi			X	X	X		
Juga (C.) acutifilosa			X		X		
Juga (C.) occata			X		X		
****Juga* (O.) n. sp. 2** (Basalt Juga)			X		X		
****Juga* (O.) n. sp. 3** (Cinnamon Juga)			X		X		
Juga* (Oreobasis) *orickensis			X		X		
Lanx alta			X				
****Lyogyrus* n. sp. 1** (Columbia Duskysnail)					X		
****Lyogyrus* n. sp. 3** (Canary Duskysnail)					X		
Pyrgulopsis intermedia			X		X		
****Vorticifex klamathensis sintsini***					X		
****Vorticifex* n. sp. 1** (Knobby Rams-Horn)			X				
AMPHIBIANS							
Exclusive Riparian w/Restricted Distribution							
Black salamander *(Aneides flavipunctatus)* in dry areas of range	X	X				X	
Cascade torrent salamander *(R. cascadae)*		X	X		X		
Columbia torrent salamander *(R. kezeri)		X	X		X		
Cope's giant salamander *(Dicamptodon copei)*		X	X				
Olympic (Torrent) Salamander *(Rhyacotriton olympicus)*		X	X		X		
Southern torrent salamander *(R. variegatus)*		X	X		X		
***Van Dyke's salamander (Coastal, Oly. Penin.)**	X	X			X	X	
Exclusive Riparian w/ Broad Distribution							
Dunn's Salamander *(Plethodon dunni)*	X	X			X	X	
Northwestern Salamander *(Ambystoma gracile)*	X	X		X			
Pacific Giant Salamander *(Dicamptodon tenebrosus)*	X	X	X		X		
Rough-skinned Newt *(Taricha granulosa)*	X	X	X	X	X		
Tailed Frog *(Ascaphus truei)*	X	X	X		X		
Terrestrial - Supplemental Restricted							
Black salamander *(Aneides flavipunctatus)* in moist areas of range	X	X				X	
Del Norte Salamander *(Plethodon elongatus)	X	X				X	
Terrestrial - Supplemental Broad							
Clouded Salamander *(Aneides ferreus)*	X	X				X	
FISH - *Races, Species, or Groups*							
Bull Trout			X				
Coho Salmon			X				
Fall Chinook Salmon			X				

SPECIES	Late-Succes.	Riparian	Aquatic - Lotic	Aquatic - Lentic	Seeps, Springs	Rock Outcrops	Other
Resident Cutthroat Trout/Rainbow Trout			X				
Sea-Run Cutthroat Trout			X				
Spring Chinook/Summer Steelhead Trout			X				
Winter Steelhead Trout			X				
BIRDS							
Common Merganser							
**** Marbled Murrelet**							
****Northern Spotted Owl**							
White-headed Woodpecker							
BATS							
Big Brown Bat							
California myotis							
Fringed myotis							Tree roosting
Hoary bat							
Little Brown myotis							
Long-eared myotis							
Long-legged myotis							
Pallid bat						X	
Silver-haired bat	X						
Yuma myotis							
MAMMALS							
Fisher	X						
Marten	X						
Red Tree Vole** ***(Phenacomys longicaudus)							
Red Tree Vole ***(Phenacomys pomo)***							
Western Red-backed Vole							

APPENDIX 2.8 VEGETATION METHODS AND DATA

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2.8.1 Methods

Plant Association Groups

The Plant Association Group (PAG) map (MAP 2.8J) was made with a model developed by Jan Henderson, Area Ecologist for the Olympic and Mt. Baker-Snoqualmie National Forests. The PAG model is an Arc Info application for predicting Plant Association Groups on the landscape. Inputs to the model include an ecoregion map, precipitation at sea level, mean annual temperature at sea level, soil moisture, fog effect, elevation, slope, aspect and land shape. A topographic moisture variable is calculated from land shape and steepness of slope that can be modified by soil moisture data. The model was calibrated with USFS Area Ecology Program plot data and independent field checks. The model produces a pixel map of Plant Association Groups which was then grouped into Plant Association Group polygons in Arc Info for display purposes.

Results have been field checked and show a high degree of accuracy. Care should be exercised in interpreting any point on the ground. The map indicates broad patterns of vegetation across the landscape and may be misleading at the microsite scale. The model is still in a developmental phase.

The current version of Map 2.8A has some known inaccuracies:

The PAG model does not always accurately identify non-forest wetlands. Wetlands have been added from the National Wetland Inventory. Wetlands are often controlled by local soil characteristics. In most cases wetlands identified by the model should be considered equivalent to the wettest non-wetland PAG in the vicinity. Given suitable soil conditions these are areas where wetlands are highly probable however.

The Non-Forest PAGs are very narrowly defined leading to what might be perceived to be an underestimate of acreage in each of these groups. This has been largely corrected by adding a manuscripted non-forest map to the final output. The PAG model also identifies some areas as nonforest which are forested. On map 2.8A these areas are designated "nonforest" in the legend and should be considered Mountain Hemlock Zone or subalpine parkland.

Hardwoods

Hardwood stands were mapped from Washington State Gap Analysis data that proved reliable for this kind of vegetation. The hardwood data was split along PAG groupings into areas capable of supporting red alder (PAGs 901,902,1904,1905,1906,1907,1909,1910,1911) and areas too dry to support red alder (PAGs 1902,1903). It was also assumed that hardwoods usually do not grow in the Mt. Hemlock, Silver Fir, Subalpine Fir or Douglas-fir Zones except in the wetter, more maritime Silver Fir PAGs (2207,2208,2209). Hardwoods in the red alder area were assumed to be red alder, big-leaf maple and black cottonwood. Hardwoods in the dry or cold areas were assumed to be vine maple or sitka alder but these non-arboreal hardwoods could not be reliably mapped in the Duckabush Watershed by this method. The arboreal hardwood map was found to be reliable with field checks. The satellite imagery uses 30 meter pixels and does not pick up very small patches or very narrow patches as are often found along streams. The area obtained with this method is somewhat underestimated. The amount of hardwoods in an area required to produce the spectral bands which were interpreted to be hardwood appears to be about 50% but this varies with variations in reflectance of both hardwoods and whatever else is in the area of the pixel.

Fire History

Records of wildfires were accumulated from several sources. The oldest fires including 1308, 1508 and 1701 were mapped by interpolating data from USFS Area Ecology Program plots using air photos. Some of this material has already been published (Henderson and all 1989). USFS Area Ecology Program plot data was also used with air photos to delineate fires that burned later. Most later fires also have historical records which were used to help delineate them.

Historical Forest Service records were especially useful in locating the fires which burned earlier this century (FM2 East Half Historical Maps, Olympic National Forest Fire Control Atlas Prior to 1931). Fire maps for each year from 1906 to 1916 were also kept by the Olympic National Forest and are retained at the Olympic National Forest Headquarters in Olympia. While not very accurate these maps are usually sufficient to identify a large fire on an air photo.

Air photos used to map fires included 1:40,000 1989 black and white ortho photos, 1939 black and white air photos and 1:24,000 1982 color air photos. Several other sets of air photos were also used from the 1950's - 1980's.

Fires and age classes corresponding to fires were mapped at 1:40,000 on clear plastic over orthophotos. The resulting maps were scanned into LTPlus, cleaned and exported to Arc Info. where the polygons were attributed. The final age map was made by adding the managed stand layer from TRI attributed with year of origin to a fire map showing only the most recent fire age.

Some fires on state and private lands may not appear on maps in this document since state and private fire records were not consulted.

Current Vegetation

Current vegetation was evaluated with the Plant Association Group Model (PAG) which predicts potential vegetation, air photos, USFS Area Ecology Program plot data and field visits. A description of the PAG model is provided in the previous section. Age data from fire history and data from managed stands from the major land holders was coupled to site growth potential data from the PAG model and USFS Area Ecology Program plot data to define successional stages based on canopy closure and to make further inferences concerning species composition. Individual plant Association Group descriptions are given in Appendix 2.8.2. Successional stage descriptions are given in the following section.

Successional Stage and Forest Structure

Successional/structural stages were identified for each forested vegetation zone. Area Ecology plot data from each Vegetation Series were used to derive relationships between age and crown closure. Sigma Plot was used to fit polynomial curves to the age-crown closure data for each Vegetation Series.

Maps of successional stage were made in Arc Info by grouping age polygons from fire history and managed stands according to the successional stage groupings.

Forest vegetation was stratified by age related structural stages for each Series (Tables 1 and 2). Managed and unmanaged stands were considered separately since managed stands usually grow back faster than unmanaged stands. This distinction is probably only important to the three earliest successional stages. Managed stands were assumed to have started from a complete harvest clearcut. Unmanaged stands were assumed to have started from a stand replacing wildfire or windstorm. Stands which begin from other kinds or degrees of disturbance will follow somewhat different successional pathways.

Succession is a continuous process that does not lend itself to classification into discreet stages. The distinction between any two successional stages as defined here is somewhat arbitrary. For example: a stand in the later stages of the Single Storied Late Successional stage may closely resemble a stand in the early stages of the Multi-Storied Late stage.

USFS Area Ecology Program plot data was stratified by vegetation Series. Western Hemlock and Silver Fir Series plots were also stratified into moist and dry groups. Each Series was fit to an age-crown closure curve to derive the usual age at which 30% and maximum crown closure occurs. Maximum crown closure varied from about 65% for Mountain Hemlock Series to over 95% for the other groups. The Mountain Hemlock Series was the most variable. Many stands never close completely and some remain quite open at all times.

Table 1. Ages for Successional Stages in Unmanaged Stands by Series.

SUCCESSIONAL STAGE	EARLY	EARLY MID	MIDDLE MID	LATE MID	SINGLE STORIED LATE	MULTI-STORIED LATE
Sitka Spruce	0-10	11-23	24-60	61-150	151	351+
Moist Western Hemlock	0-10	11-23	24-60	61-175	176-400	401+
Dry Western Hemlock	0-15	16-40	41-100	101-200	201-425	426+
Moist Silver Fir	0-10	11-37	38-90	91-175	176-425	426+
Dry Silver Fir	0-17	18-51	52-140	141-300	301-500	501+
Mountain Hemlock	0-63	64-125	126-200	201-350	351-500	501+
Subalpine Fir	0-25	26-125	126-200	201-350	351-999	999+

Table 2. Ages for Successional Stages in Managed Stands by Series.

SUCCESSIONAL STAGE	EARLY	EARLY MID	MIDDLE MID	LATE MID	SINGLE STORIED LATE	MULTI-STORIED LATE
Sitka Spruce	0-7	8-19	20-60	61-150	none*	none*
Moist Western Hemlock	0-7	8-19	20-60	61-175	none*	none*
Dry Western Hemlock	0-11	12-29	30-100	none*	none*	none*
Moist Silver Fir	0-6	7-19	20-90	none*	none*	none*
Dry Silver Fir	0-14	15-39	40-140	none*	none*	none*
Mountain Hemlock	0-25	26-125	none*	none*	none*	none*
Subalpine Fir	none*	none*	none*	none*	none*	none*

*none indicates no managed stands exist in this age class.

Successional/Condition Stages for Unmanaged Conifer Stands.

Early Successional Stage - The Early Successional Stage is defined as young stands having 0-30% crown closure. USFS Area Ecology Program plot data for the Olympic Peninsula was stratified by vegetation Series. Western Hemlock and Silver Fir Series plots were also stratified into moist and dry groups. Each Series was fit to an age-crown closure curve to derive the usual age at which 30% crown closure occurs for that Series. Thirty percent was chosen because land with less than 30% crown closure has been shown to be a significant source of sediment to streams. This successional stage has the smallest live biomass but natural stands usually inherit a large volume of snags and/or logs from the previous stand. Stands originating from clearcuts will not have many snags or logs. This stage is heavily herb dominated when it originates from hot fires and usually shrub dominated when it originates from wind storms or harvest without subsequent burning.

Early Mid-Successional Stage - The Early Mid-Successional Stage is defined as stands having 31% to near maximum crown closure. The upper limit of the Early Mid-Successional Stage is actually defined by the lower limit of the Middle Mid-Successional Stage. Trees become the dominant lifeform during this successional stage. There is usually an abundance of snags and logs present which were inherited from the previous stand when fire or wind was the initiation event unless salvage harvest was done after the disturbance.

For the Mountain Hemlock Series the Early Mid-Successional stage was defined as beginning at the usual age for 31% crown closure and ending at 125 years when the increasing overstory and the decreasing understory curves began to flatten out. At older ages overstory and understory amounts were on the average about equal.

Middle Mid-Successional Stage - The onset of the middle mid-successional stage is defined by the depression of understory vegetation abundance as overstory crown clouser occurs. Understory vegetation decreases due to lack of light. The middle mid-successional stage ends when self thinning and growth have resulted in an even aged stand with a developing understory. The end of this stage is somewhat arbitrary. There is often little or no understory through much of this stage. The middle mid-successional stage is sometimes referred to as the stem exclusion stage but the severity of this stage is highly variable. As the overstory thins and more light reaches ground level the understory is reinitiated. The degree to which understory vegetation is excluded is determined by site potential and stand history. Not all stands pass through a stage where understory is severely limited. There is often only a slight depression in understory abundance. It should be understood that much of the area mapped in this stage (Map 2.8I) has a fairly well developed understory. Areas which have severely limited understories will usually be found in the area mapped as middle mid-successional stage. For the Mt. Hemlock Series this stage begins at 126 years and ends arbitrarily at 200 years. Snag and log legacies from the previous stand are increasingly decayed. Logs remain in abundance but snags are noticeably fewer.

Late Mid-Successional Stage - The late mid-successional stage is defined as stands beginning when understory vegetation is reinitiated by self thinning and ending when the single storied late successional stage begins. As the overstory thins and more light reaches ground level the understory is reinitiated. By the end of this stage the understory is well developed and has reached a dynamic equilibrium which will change little on the average through the stand. Tree height growth usually levels off at the end of this stage. For the Mt. Hemlock Series this stage begins at 201 years and ends at 350 years. The upper limit of this stage is really defined by the concept of the Single Storied Late Successional stage. Snag legacies from the previous stand are mostly gone. A few from especially large trees will remain but are soft and short. Log legacies are well decayed but especially large logs are still very evident.

Single Storied Late Successional Stage - The Single Storied Late Successional Stage includes older stands with well developed understories but only one main tree canopy layer which is more or less even aged. Height growth and stand basal area accumulation have leveled off. Individual trees are still growing in basal area but mortality is preventing further accumulation of live biomass. Most old-growth dependent species are able to utilize these stands. During this stage mortality of large trees increasingly provide snags, logs and large canopy holes. Douglas-fir attains its greatest volume on a stand basis during this stage in plant associations which support Douglas-fir. Table 2.8-A2 in Appendix 2.8.3 presents data showing that this stage frequently has the largest average diameters, heights and basal areas of any successional stage. This kind of vegetation has been the subject of much dispute as to whether it should be called "old-growth".

Multi-Storied Late Successional Stage - The Multi-Storied Late Successional Stage includes old stands with several canopy layers and multiple tree ages. In its ultimate state of development (climax) there is continuous distribution of ages and sizes of trees in the stand. Mortality of large trees has opened many large holes in the canopy and produced many large snags and down logs which are in all stages of decomposition. Large trees frequently have broken tops. Canopy holes support younger trees. Seral trees such as Douglas-fir may or may not be present depending on the age of the stand. Stand height may actually decrease due to top breakage of the tallest trees especially in windy environments. Stand basal area and average diameter may be level or decreasing reflecting high levels of mortality and replacement by smaller trees released from the suppressed understory (Table 2.8-A2 Appendix 2.8.3). There is little disagreement over calling this kind of vegetation "old-growth".

Other Successional Stages and Map Units

Managed stands follow the same concepts as those presented for the unmanaged stands. The only difference is that the early and early mid- successional stages are shorter due to more rapid stand establishment from planting. It might also be assumed that managed stands reach later successional stages earlier too. This may occur with additional stand treatments including thinning and fertilization but the effect is probably small. No managed stands have yet reached a late successional stage ages. New management methods may be more effective in creating old-growth characteristics in younger stands but it is not known if these stands will be comparable to natural old-growth stands.

Hardwood stands were mapped separately from satellite imagery and air photo interpretation then overlayed with the age map. Extent of hardwoods is somewhat underestimated by satellite imagery. Very small patches or very narrow riparian strips do not show up on the map. Map 2.7A shows riparian hardwoods within a 66 foot strip bordering streams. The hardwood stand successional stage is the same as a conifer stand of the same age and potential vegetation. The westernmost mile of the watershed had no satellite imagery so hardwoods could not be defined in that area.

Nonforested wetlands are not a successional stage but are shown on the successional stage map to distinguish them from forested areas. They were mapped from the National Wetland Inventory (Cowardin et al. 1979). Wetlands are shown on Maps 2.8A, C, E, and F.

Hardwood wetlands are areas shown on the National Wetland Inventory as nonforested wetlands that were overlapped by the satellite hardwood imagery. These may or may not actually be forested with hardwoods. In nearly all cases hardwoods are in the vicinity and border the wetland. In some cases these areas may represent inaccuracies in one of the layers or difference in mapping scales. In others they may represent differences in interpretation of where the edge of the non-forested wetland is.

Nonburnable terrestrial areas are also shown on Maps 2.8A, C, E, and F. These are areas of rock, ice, snow or sparse vegetation which will not normally carry a fire. They were air photo interpreted for this analysis. They represent significant natural barriers to wildfire. Most are at high elevations and represent alpine and subalpine environments. Successional status is not apparent. Often these are late successional non-forested areas.

Nonforest areas shown on Map 2.8C are areas outside of the air photo interpreted nonburnable areas that the PAG model identified as nonforested. These areas are all at high elevations but are actually forested and should be considered part of the Mountain Hemlock Series.

Wetlands and nonburnable areas are shown as fixed areas in the historical renditions of successional stages (Maps 2.8A, C, E, and F). As climates change these areas change. Some wetlands are products of river processes that also change. The intent is not to show these as static features but to indicate some were present at all times even if the exact shape or location is not known.

2.8.2 DESCRIPTIONS OF PLANT ASSOCIATION GROUPS

Forested Vegetation Series

There are 4 forested vegetation Series in the Duckabush Watershed (Map 2.8A). The area of land on which the Series is found is called the Zone. Both the Series and Zone are named for a climax dominant or codominant tree species. Vegetation in later stages of succession are identified on the Olympic National Forest to the Series (or Zone) level with the following key (Henderson et al. 1989). Each series is described in the order of the key.

The Mountain Hemlock, Silver Fir, Western Hemlock and Douglas-fir Series are present in the Duckabush Watershed.

Mountain Hemlock >= 10% cover............Mountain Hemlock Series
Silver Fir >= 10% cover..................Silver Fir Series
Sitka Spruce >= 10% cover................Sitka Spruce Series
Western Hemlock and/or
Western Redcedar >= 10% cover............Western Hemlock Series
Douglas-fir >= 10% cover.................Douglas-fir Series
Subalpine Fir >= 10% cover...............Subalpine Fir Series

Forested Plant Association Groups

One of the most important characteristics of Plant Association Groups is their predictable productivity. Table 10 lists site index for each PAG which is the height a dominant or codominant tree can be expected to grow to in 100 years. This indexes productivity on a relative basis. More detailed information of productivity at the plant association level is found in Henderson et al. (1989).

Predictable growth rates allow the calculation of tree heights at any age. The age and height at which site trees reach 95% of their maximum potential height growth is also listed in Table 10. These are the heights used for the proposed riparian buffers. Differences in the ages at which the maximum height is reached are due to differences in the shape of the height growth curves which are as much a characteristic of the site as the actual height growth potential.

Douglas-fir Series PAGs (14)

There are two plant association groups in the Douglas-fir series in the Olympic Province with a total of 3 plant associations (Table 3). The Douglas-fir Zone is mostly restricted to warm exposures on droughty soils in the northeastern part of the Olympic Mountains where precipitation is lowest. It is occasionally found elsewhere on very dry soils or around the edges of rock outcrops. Wildfire is very common in this zone. Timber productivity is very low.

Table 3. Plant Associations in each Plant Association Group in the Douglas-fir Series (14).

PAG	1402	1406
PAG NAME	Douglas-fir/Kinnikinnick-Shiny-leaf spiraea-Oregon box-myrtle	Douglas-fir/Oregongrape-Salal-Oceanspray
	PSME/ARUV-SPBEL-PAMY	PSME/BENE-GASH-HODI
ASSOCIATIONS	Kinnikinnick (CDS651)	Oceanspray-Baldhip Rose (CDS221)
		Salal (CDS255)

Douglas-fir/Kinnikinnick-Shiny-leaf spiraea-Oregon box-myrtle (PAG 1402)

The Douglas-fir/Kinnikinnick plant association is the sole representative of this PAG on the Olympic Peninsula. This PAG is found mostly in the northeastern part or associated with rock outcrops on the east side of the Olympic Peninsula. This is a minor PAG on the Olympic Peninsula. Eight plant associations have been assigned to this PAG in Region 6.

This PAG is mostly associated with low precipitation in the driest part of the Olympic rainshadow. Soils are typically shallow and coarse. It is most common on upper slopes and ridgetops, especially on south exposures. It can be found in areas of moderate precipitation as a fringe around rock outcrops. Snowpack is light and ephemeral.

Wildfire is the major agent of natural disturbance. Most of this PAG probably burned in each of the major burning events (1308,1508 and 1701). Smaller fires also play an important role.

Douglas-fir or lodgepole pine can dominate early and mid-successional stands. Small amounts of western hemlock occur. As stands age the canopy becomes quite open allowing Douglas-fir to regenerate in the openings. Canopy closure in young stands takes 80-100 years and is often never fully attained.

Timber productivity is very low. Site index base 100 for Douglas-fir is about 41.

Douglas-fir/Oregongrape-Salal-Oceanspray (PAG 1406)

The Douglas-fir/Oceanspray/Baldhip Rose and Salal plant associations represent this minor PAG on the Olympic Peninsula. This PAG is found on the east side of the Olympic Peninsula. The Oceanspray/Baldhip Rose association is more common in the northeast part. Nine plant associations have been assigned to this PAG in Region 6.

This PAG grows on shallow, stony, and well drained soils in warm areas at low to middle elevations. Snow is infrequent and ephemeral.

Wildfire is frequent. Most probably burned in each of the large events (1308, 1508, 1701) and much has burned in smaller fires as well.

Douglas-fir dominates early and mid-successional stands with some lodgepole pine. Small amounts of western hemlock and western redcedar occur in older stands. As stands age the canopy becomes open enough for Douglas-fir to regenerate. Canopy closure in young stands is highly variable but can take up to 80-100 years. Stands sometimes close much earlier creating doghair conditions that can be slow to open up.

Timber Productivity is low. Site index base 100 for Douglas-fir is about 66-86.

Dry non-forest in the Douglas-fir Zone (1471)

This is a PAG of dry nonforest communities in the Douglas-fir Zone that have not been described in published form. These communities are probably mostly bryophyte or lichen communities on rock outcrops or bare rock outcrops. Also included are communities dominated by Phlox, kinnikinnick, wild onion, selaginella, Idaho fescue, common juniper, bracken fern and yarrow. This PAG does not generally include temporarily barren areas such as erosional scarps or river bars. In some cases erosion may produce conditions for this PAG such as when bedrock is exposed on steep south facing slopes, etc.

Other non-forest in the Douglas-fir Zone (1481)

This is a PAG of other non-forest situations in the Douglas-fir Zone that is not currently being used. This PAG does not include temporarily barren areas such as erosional scarps or river bars.

Wet non-forest in the Douglas-fir Zone (1491)

This is a PAG of nonforested wetlands in the Douglas-fir Zone that have not been described in published form. It is not currently being used in the model. Communities in this PAG could include wetlands dominated by such plants as Sphagnum, sedges, rushes, bullrushes, cattalils, hardhack, swamp laurel, Labrador tea, scouring rushes, willows, devils club, stink currant, bog buckbean, spatterdock, skunkcabbage, or western crabbapple.

Kunze (1994) identified 37 freshwater wetland community types in the western Olympic lowlands. Kunze's classification is not a potential vegetation classification so it is not known how many of these are in the Douglas-fir Zone or what their successional status is.

Western Hemlock Series PAGs (19)

The Western Hemlock Series is the most common series in the Olympic Province. It includes 9 PAGs and 26 plant associations (Table 4). The Western Hemlock Zone occurs all around the Olympic Peninsula from sealevel to moderate elevations in the mountains. It is restricted to dry soils and microsites in the fog zone on the west side of the Peninsula. Precipitation comes mostly as rain. Fire is generally the most important agent of disturbance but wind is more important on the west side of the Peninsula. Wetter areas in the mountains are rarely disturbed. Timber productivity varies from low in the driest areas to high in wetter areas.

Table 4. Plant Associations in each Plant Association Group in the Western Hemlock Series (19).

Subseries	dry	dry	moist	moist	moist	moist	moist	moist	moist
PAG	1902	1903	1904	1905	1906	1907	1909	1910	1911
PAG NAME	Western Hemlock/ Pacific Rhododendron	Western Hemlock/Dry Salal	Western Hemlock/ Alaska huckleberry-Bunchberry dogwood	Western Hemlock/Vine-maple-Vanilla leaf	Western Hemlock/Mesic Salal-Oregongrape	Western Hemlock/Moist Swordfern	Western Hemlock/Alaska huckleberry-Oregon oxalis	Western Hemlock/Devils club	Western Hemlock/Skunk cabbage
	TSHE/ RHMA	TSHE/Dry GASH	TSHE/VAAL-COCA	TSHE/ACCI-ACTR	TSHE/Mesic GASH-BENE	TSHE/Moist Swordfern	TSHE/VAAL/ OXOR	TSHE/OPHO	TSHE/LYAM
ASSOCIATIONS	Rhododendron /Beargrass (CHS332)	Beargrass (CHF511)	Alaska Huckleberry/ Beargrass (CHS622)	Vannilaleaf (CHF211)	Rhododendron/ Swordfern (CHS335)	Swordfern/ Foamflower (CHF132)	Salal-Alaska Huckleberry (CHS624)	Devils Club (CHS512)	Skunkcabbage (CHM111)
	Rhododendron /Oregongrape (CHS333)	Salal/Beargrass (CHS132)			Oregongrape (CHS138)		Alaska Huckleberry (CHS621)		
	Rhododendron / Salal (CHS334)	Salal/ Oceanspray (CHS134)			Salal/Evergreen Huckleberry (CHS133)		Salal/Oregon Oxalis (CHS136)		
	Rhododendron (CHS331)	Salal (CHS131)			Swordfern/ Oregongrape (CHS139)		Swordfern/ Oregon Oxalis (CHF131)		
		Depauperate (CHF911)			Swordfern/Salal(CHS137)		Oregon Oxalis (CHF112)		
		Salal/ Oregongrape (CHS135)					Alaska Huckleberry/ Oregon Oxalis (CHS623)		

Western Hemlock/Pacific Rhododendron (PAG 1902)

The Western Hemlock/Pacific Rhododendron PAG includes the Rhododendron, Rhododendron/Salal, Rhododendron/Oregongrape and Rhododendron/Beargrass plant associations (Table 3) (Henderson et al. 1989). These plant associations are restricted to the east side of the Olympic Mountains and are most abundant in the northeastern part, especially the Quilcene District of the Olympic National Forest. The Rhododendron/Salal plant association is the most common. Rhododendron macrophyllum does not occur west of Heart of the Hills in the north or S. F. Skokomish River in the south but reappears in the Gifford Pinchot National Forest and south in the Cascade Mountains. This PAG is very common on dry, well drained flats and slopes. Fourteen plant associations have been assigned to this PAG in Region 6.

This PAG occurs at low to mid elevations in the Olympic Mountain rainshadow. Precipitation comes mostly as rain. Soils are moderately well to well drained and moderately deep but shallow in the Rhododendron-Beargrass plant association. The soils are usually gravelly to very gravelly or stony.

Disturbance is mostly from fire and commercial tree harvest. Wind disturbance is relatively uncommon and usually associated with edges created from commercial tree harvest. Most of this PAG burned in each of the fires in 1308, 1508 and 1701. Large portions of this PAG also burned in numerous post settlement fires between 1860 and 1940. This is one of the most fire prone PAGs on the Olympic Peninsula. Nutrient depletion due to repeated burning may have contributed to poor growing conditions that have resulted in persistent doghair stand conditions especially in the Rhododendron-Salal plant association. Stands in the doghair condition appear to begin a slow release after 70-90 years. Commercial harvest has removed much of the older timber.

Conifer regeneration including Douglas-fir, western hemlock, western redcedar and white pine occurs after fire. Hardwoods do not regenerate in this PAG. Regeneration is often dense and can lead to doghair conditions. Understory including salal, rhododendron and beargrass return rapidly in the absence of fire. Following fire there may be moderate amounts of salal, rhododendron and beargrass. The understory typically is severely depressed as the canopy closes but reinitiates as old-growth conditions develop.

Douglas-fir site index (base 100) ranges from 82-108.

Western Hemlock/Dry Salal (PAG 1903)

The Western Hemlock/Dry Salal PAG includes the Beargrass, Salal/Beargrass, Salal/Oceanspray, Salal, Depauperate, and Salal/Oregongrape plant associations (Table 3) (Henderson et al. 1989). These plant associations are most common on the dryer east side of the Olympic Peninsula but occur in wetter climates on dry topographic positions and soils. The Salal and Salal/Oregongrape plant associations are widespread and much more common than the others. Nine plant associations have been assigned to this PAG in Region 6.

This PAG occurs at low to mid elevations in the Olympic Mountains. Precipitation comes mostly in the form of rain. It occurs on moderately well drained to well drained soils which are often very gravelly or stony. The beargrass association occurs mostly near the upper elevation of the PAG but the Salal/Beargrass association also occurs in and around former prairies on droughty, infertile soils.

Disturbance in this PAG is mostly from fire and commercial tree harvest. Wind disturbance is relatively uncommon and usually associated with edges created from commercial tree harvest. Most of this PAG burned in each of the burning periods around 1308, 1508 and 1701. Large portions of this PAG also burned in numerous post settlement fires between 1860 and 1940. This is one of the most fire prone PAGs on the Olympic Peninsula. Commercial harvest has removed much of the older timber.

Conifer regeneration including Douglas-fir, Western Hemlock, Western Redcedar, lodgepole pine and white pine occurs after fire. Hardwoods do not regenerate in this PAG. Understory including salal and beargrass return rapidly in the absence of fire. Following fire there may be moderate amounts of salal and beargrass. The understory typically is moderately depressed as the canopy closes but reinitiates as old-growth conditions develop.

Douglas-fir site index (base 100) ranges from 86-139. The site index is more commonly over 100.

Western Hemlock/Alaska huckleberry-Bunchberry dogwood (PAG 1904)

This PAG includes only the Alaska Huckleberry/Beargrass plant association on the Olympic Peninsula (Table 3) (Henderson et al. 1989). This plant association occurs on the southeast side of the Olympic Mountains just below the Silver Fir Zone. Six plant associations have been assigned to this PAG in Region 6.

This PAG occurs in mid elevations in the Olympic Mountains. Precipitation comes mostly in the form of rain. It occurs on moderately well drained to well drained soils which are often very gravelly or stony.

Disturbance in this PAG is mostly from fire and commercial tree harvest. Wind disturbance is relatively uncommon and usually associated with edges created from commercial tree harvest. Most of this PAG burned in each of the burning periods around 1308, 1508 and 1701. Commercial harvest has removed much of the older timber.

Conifer regeneration including Douglas-fir, western hemlock, western redcedar and white pine occurs after fire. Hardwoods do not regenerate in this PAG. Understory including Alaska huckleberry and beargrass return rapidly in the absence of fire. Following fire there may be moderate amounts of Alaska huckleberry and beargrass. The understory typically is only moderately depressed as the canopy closes but reinitiates as old-growth conditions develop.

Douglas-fir site index (base 100) is about 94.

Western Hemlock/Vinemaple-Vanillaleaf (PAG 1905)

This PAG includes only the Western Hemlock/Vanillaleaf plant association on the Olympic Peninsula (Table 3) (Henderson et al. 1989). This plant association is found from the eastern reaches of the Duckabush River to Dungeness River and south to the South Fork Skokomish River at higher elevations in the Western Hemlock Zone. It is usually found in small patches. Fourteen plant associations have been assigned to this PAG in Region 6.

The Western Hemlock/Vanilla leaf plant association occurs most often on deep colluvial or glacial soils, which are subirrigated by topographic moisture. It occurs mostly on warm, moist sites at higher elevations in the Western Hemlock Zone. Precipitation comes mostly in the form of rain.

Fire and commercial tree harvest are the major agents of disturbance. Much of this area has burned in each of the major burning periods around 1308, 1508 and 1701. Wind disturbance is primarily important along edges created by harvest activity.

Douglas-fir is the primary seral tree species. Western redcedar and western hemlock are the climax dominants. Red alder and other hardwoods typically do not regenerate on these sites. The understory is herb dominated in all stages but may be severely depressed in dense second growth. Vanilla leaf, star-flowered solomonseal and Oregongrape are present in nearly all successional stages.

Timber productivity is moderate. Douglas-fir site index base 100 is about 149.

Western Hemlock/Mesic Salal-Oregongrape (PAG 1906)

There are 5 plant associations in the Olympic National Forest in this PAG including Rhododendron/Swordfern, Oregongrape, Salal/Evergreen Huckleberry, Swordfern/Oregongrape and Swordfern/Salal. The Oregongrape, Swordfern/Oregongrape and Swordfern/Salal plant associations are common and widespread on the Olympic National Forest. The Salal/Evergreen Huckleberry association is common at lower elevations mostly off the Forest. The Rhododendron/Swordfern association is a minor association in the northeast part of the Forest. Twenty-five plant associations have been assigned to this PAG in Region 6.

This PAG is most common on the east side of the Olympic Peninsula but some associations are also found on the west side. This PAG is typically found on moderately deep, well drained soils mostly on lower slopes. It is most common at the lower to mid elevations.

Fire and commercial tree harvest are the major agents of disturbance. Most of the area in this PAG has burned in each of the three major burning periods (1308, 1508 and 1701). Areas which have not been harvested date mostly to 1701 with some dating to 1508. Wind is not a major disturbance agent.

Red alder can dominate early in succession in the plant associations codominated by swordfern. Douglas-fir is the typical early seral tree species in the non-swordfern associations and can be present to dominant in the swordfern plant associations as well. Western hemlock and western redcedar codominate climax stands. Western hemlock is often important or dominant in early seral stands.

Timber productivity is moderate. Site index for Douglas-fir base 100 ranges from 95-165 but is typically in the 130-140 range.

Western Hemlock/Moist Swordfern (PAG 1907)

The Western Hemlock/Swordfern/Foamflower plant association is the only plant association in this PAG on the Olympic Peninsula. It is common and widespread at lower elevations. It is less common on the west side of the Peninsula than elsewhere. Twelve plant associations have been assigned to this PAG in Region 6.

The Swordfern/Foamflower association is typical of warm, moist sites on lower slopes and toe slopes. The soils are generally deep and well aerated but often subirrigated. Precipitation comes mostly as rain. In the wettest climates this association is replaced by the Swordfern/Oxalis association in PAG 1909.

The major agent of disturbance is fire, which has burned much of this PAG in each of the major burning periods (1308, 1508 and 1701). Fire does not always burn this PAG completely due to its location in moist sites. Some areas in this PAG have survived one or more of the major burning periods making them important refugia for old-growth dependent species since they often occur as islands in an extensive burned matrix. Wind can be an important disturbance agent on the west side of the Olympic Peninsula but is not as important as fire. Most of the old stands in this PAG have been harvested.

Red alder is the typical early successional tree species in naturally regenerated stands. Conifer stands originating from the alder pathway usually have a few large, widely spaced Douglas-fir that established along with the alder. Western hemlock and western redcedar gradually fill the remaining area as the alder dies out. Salmonberry often establishes along with red alder and can persist and delay conifer establishment for long periods even after the alder is gone. A conifer dominated pathway with Douglas-fir and western hemlock can also occur but is more typical of managed stands. Swordfern and a number of other herbs are present in all stages of succession and dominant in later stages. Dense conifer second growth stands may have severely depauperate understories. Western hemlock and western redcedar are the climax dominant trees.

This is one of the most productive PAGs. Site index for Douglas-fir base 100 is about 166.

Western Hemlock/Alaska Huckleberry-Oregon Oxalis (PAG 1909)

There are 6 plant associations in this PAG on the Olympic Peninsula including the Salal/Alaska Huckleberry, Alaska Huckleberry, Salal/Oregon Oxalis, Swordfern/Oregon Oxalis, Oregon Oxalis and Alaska Huckleberry/Oregon Oxalis. This PAG is most common on the west side of the Olympic Peninsula but the Alaska Huckleberry association extends to the southeast side of the Peninsula. Nine plant associations have been assigned to this PAG in Region 6.

This PAG is typical of lower slopes and toe slopes or flats in the climatically wetter portions of the Peninsula. These areas are usually fairly warm and usually receive little snow and much rain. The soils are usually deep and well drained. The Salal/Oxalis plant association and to a lesser extent some of the other associations can be found on mid to upper slope positions on shallower, rocky soils. Precipitation comes mostly as rain.

Wind is probably a more important disturbance agent than fire in this PAG but large fires have burned some of this PAG in the past. Much timber harvest has occurred but older age classes such as 1308 and 1508 are still common. Many stands show effects of blowdown especially in the area affected by the 1921 blow on the west side of the Peninsula.

Red alder is the typical early successional tree species in naturally regenerated stands. Salmonberry often establishes along with red alder. Conifer stands originating from the alder pathway usually have a few large, widely spaced Douglas-fir that established along with the alder. Western hemlock and western redcedar gradually fill the remaining area as the alder dies out. Salmonberry can persist and delay conifer establishment for long periods after the alder is gone. A conifer dominated pathway with Douglas-fir and western hemlock can also occur but is more typical of managed stands. Swordfern, Oregon oxalis and a number of other herbs are present in all stages of succession and dominant in later stages. Dense conifer second growth stands may have severely depauperate understories. Western hemlock and western redcedar are the climax dominant trees.

Timber productivity is moderate to high. Site index base 100 ranges from 120-188. Swordfern and oxalis tend to indicate higher sites and salal and Alaska huckleberry tend to indicate lower sites in this group.

Western Hemlock/Devils Club (PAG 1910)

The only plant association in this PAG on the Olympic Peninsula is the Devils Club plant association. This plant association occurs around the Peninsula on wet soils. Eleven plant associations have been assigned to this PAG in Region 6.

The Devils Club PAG occurs throughout the Western Hemlock Zone where soils are saturated but aerobic most of the year. Typically these sites are along flowing streams or springs. Standing water when present is very shallow (less than a few centimeters) and indicates an ecotone with wetter non-forest types. Most of this PAG exists in small patches around seeps and springs or narrow riparian strips.

Wind is the primary agent of disturbance in this PAG. Wet soils make trees susceptible to windthrow. Wildfire is also an agent of disturbance but stands in this PAG are more likely to survive wildfires than any other PAG except the Skunkcabbage PAG. The wet understory discourages ground fires but crown fires can move through smaller stands. Stands that survive large fires are important refugia for old-growth dependent species.

Red alder is the typical early successional tree in naturally regenerated stands. Salmonberry and vine maple usually establish along with red alder. Conifer regeneration may be limited to nurse logs and slightly dryer mounds such as wind throw mounds. Western hemlock and western redcedar gradually fill in as the redalder dies out. Salmonberry can persist and delay conifer establishment for long periods after the alder is gone. Swordfern and ladyfern are often prominent. Dense conifer second growth stands may have severely depauperate understories. Western hemlock and western redcedar are the climax dominant trees.

Timber productivity is moderate. Site index for Douglas-fir base 100 is in the 151-188 range but stockability is low.

Western Hemlock/Skunkcabbage (PAG 1911)

The only plant association in this PAG on the Olympic Peninsula is the Western Hemlock/Skunkcabbage plant association. This plant association occurs around the Peninsula on wet soils. Three plant associations have been assigned to this PAG in Region 6.

The Skunkcabbage PAG occurs throughout the Western Hemlock Zone where soils are saturated and anaerobic most of the year. Typically these sites are along slow flowing streams or seeps. Soils are often fine textured or organic. Shallow standing water is often present but indicates an ecotone with wetter non-forest types. Most of this PAG exists in small patches around seeps and springs or narrow riparian strips. Precipitation comes mostly as rain.

Wind is the primary agent of disturbance in this PAG. Wet soils make trees susceptible to windthrow. Wildfire is a less important agent of disturbance. Stands in this PAG are more likely to survive wildfires than any other PAG except the Devils club PAG. The wet understory discourages ground fires but crown fires can move through smaller stands. Stands that survive large fires are important refugia for old-growth dependent species.

Red alder is the typical early successional tree species in naturally regenerated stands. Salmonberry usually establishes along with red alder. Conifer regeneration may be limited to nurse logs and slightly dryer mounds such as wind throw mounds. Western hemlock and western redcedar gradually fill in as the redalder dies out. Salmonberry can persist and delay conifer establishment for long periods after the alder is gone. Western hemlock and western redcedar are the climax dominant trees.

Timber productivity is moderate. Site index for Douglas-fir base 100 is in the 130-150 range but stockability is low.

Dry non-forest in the Western Hemlock Zone (1971)

This is a PAG of dry nonforest communities in the Western Hemlock Zone that have not been described in published form. These communities are probably mostly bryophyte or lichen communities on rock outcrops or bare rock outcrops. Also included are communities dominated by Phlox, kinnikinnick, wild onion, selaginella, Idaho fescue, common juniper, bracken fern and yarrow. This PAG does not generally include temporarily barren areas such as erosional scarps or river bars. In some cases erosion may produce conditions for this PAG such as when bedrock is exposed on steep south facing slopes, etc.

Other non-forest in the Western Hemlock Zone (1981)

This is a PAG of other non-forest situations in the Western Hemlock Zone that is not currently being used. This PAG does not include temporarily barren areas such as erosional scarps or river bars.

Wet non-forest in the Western Hemlock Zone (1991)

This is a PAG of nonforested wetlands in the Western Hemlock Zone that have not been described in published form. Communities in this PAG could include wetlands dominated by such plants as Sphagnum, sedges, rushes, bullrushes, cattalils, hardhack, swamp laurel, Labrador tea, scouring rushes, willows, devils club, stink currant, bog buckbean, spatterdock, skunkcabbage, or western crabbapple.

Kunze (1994) identified 37 freshwater wetland community types in the western Olympic lowlands. Kunze's classification is not a potential vegetation classification so it is not known how many of these are in the Douglas-fir Zone or what their successional status is.

Pacific Silver Fir Series PAGs (22)

The Silver Fir Series is a common mid-montane series in the Olympic Province. Included in this series are 8 PAGs and 23 plant associations (Table 5). The Silver Fir Series is found all around the Olympic Peninsula in the middle elevations and is characterized by having a seasonal winter snowpack. This zone also receives much rainfall and fog. It comes down below 1000 feet on the wet west side and is absent from the driest part of the rainshadow. Disturbance is rare in much of this zone. Fire is important in some of the drier plant associations but absent from some of the wetter ones. Wind can be locally important especially on the west side of the Peninsula. Timber productivity ranges from low in the dry types to high in the wetter, warmer types.

Table 5. Plant Associations in each Plant Association Group in the Silver Fir Series (22).

Subseries	dry	dry	dry	dry	dry	moist	moist	moist
PAG	2201	2202	2203	2204	2205	2207	2208	2209
PAG NAME	Silver fir/Pacific Rhododendron	Silver fir/Salal-Oregongrape	Silver fir/Alaska huckleberry Dry	Silver fir/Big huckleberry-Beargrass	Silver fir/Alaska Huckleberry-White rhododendron	Silver fir/Alaska huckleberry-Wet	Silver fir/Oregon oxalis	Silver fir/Devils club
	ABAM/RHMA	ABAM/ GASH-BENE	ABAM/VAAL Dry	ABAM/ VAME-XETE	ABAM/VAAL-RHAL	ABAM/VAAL Wet	ABAM/OXOR	ABAM/OPHO
ASSOCIATIONS	Rhododendron (CFS611)	Depauperate CFF911)	Rhododendron/ Alaska Huckleberry (CFS612)	Beargrass (CFF311)	Alaska Huckleberry-White Rhododendron (CFS220)	Alaska Huckleberry/ Avalanche Lily (CFS213)	Salal/Oregon Oxalis (CFS156)	Devils Club (CFS311)
		Salal (CFS154)	Alaska Huckleberry/ Beargrass (CFS214)	Big Huckleberry/ Beargrass (CFS211)		Alaska Huckleberry/ Queenscup (CFS218)	Swordfern (CFF612)	Skunkcabbage (CFM111)
			Alaska Huckleberry/ Twinflower (CFS219)			Alaska Huckleberry/ Foamflower (CFS215)	Oregon Oxalis (CFF111)	
			Alaska Huckleberry/ Oregongrape (CFS216)				Salal/Deerfern (CFF155)	
			Alaska Huckleberry (CFS212)				Alaska Huckleberry/ Oregon Oxalis (CFS217)	

Silver fir/Pacific Rhododendron (PAG 2201)

The Rhododendron plant association is the only plant association in this PAG on the Olympic Peninsula. This plant association is restricted to the east and northeast sides of the Peninsula. Six plant associations have been assigned to this PAG in Region 6.

This PAG is found in the rainshadow of the Olympic Mountains mostly on shallow, coarse textured, well drained soils. It is usually found around 3000 feet in elevation. Snow accumulates to about 4.5 feet during the winter.

Wildfire is the major natural disturbance agent. Much of this PAG has burned in each of the major burning periods (1308, 1508,1701). Wind is a minor agent except along the edges of new clearcuts. Much of the area of this PAG has been harvested.

This PAG is ecotonal with the Western Hemlock Zone. The Rhododendron plant association was probably in the Western Hemlock Zone during the Little Ice Age. Silver fir invaded this plant association at the close of the Little Ice Age. Currently there are two successional pathways. One is dominated by western hemlock and silver fir and the other by Douglas-fir with silver fir or western hemlock. Rhododendron is usually present even in early seral stands. Later in succession rhododendron is the major dominant species.

Timber productivity is low. Douglas-fir site index base 100 is about 128. Western hemlock site index was about 118 and silver fir about 107.

Silver fir/Salal-Oregongrape (PAG 2202)

The Salal and Depauperate plant associations are the only Olympic Peninsula plant associations in this PAG. Both plant associations are found throughout the Peninsula but the Depauperate association is more common in the Duckabush watershed. Four plant associations have been assigned to this PAG in Region 6.

This PAG occurs on dry soils or microsites within the Silver Fir Zone. The Salal plant association occurs at the lower edge of the Silver Fir Zone. The Depauperate plant association occurs mostly on or near ridgetops. Precipitation comes as rain and snow. Snow pack is not as deep and is more ephemeral in this PAG than most other areas in the Silver Fir Zone.

The principal agent of natural disturbance is wildfire. Much of this PAG has burned in one or more of the three major burning periods (1308, 1508, 1701). The Salal plant association is more prone to burning.

The Salal Plant Association may have been in the Western Hemlock Zone during the Little Ice Age, which ended about 1850. Silver fir in these stands are often less than 200 years old. Early seral stands may be dominated by fireweed and pearly everlasting but salal often establishes quickly in the Salal Association. Douglas-fir, western hemlock and silver fir can all be early seral tree species. Little is known of succession in the Depauperate Plant Association. Silver fir and western hemlock are climax codominants. Western redcedar can also occur in older stands.

Timber productivity is low to moderate. Site index of the Depauperate Association is about 113 for Douglas-fir and 143 for western hemlock. Site index for the Salal Association is probably similar. Stockabillity is moderate to low.

Silver fir/Alaska Huckleberry Dry (PAG 2203)

Silver Fir/Rhododendron/Alaska Huckleberry, Alaska Huckleberry/Beargrass, Alaska Huckleberry/Twinflower, Alaska Huckleberry/Oregongrape, and Alaska Huckleberry are the plant associations in this PAG which occur on the Olympic Peninsula. Collectively these plant associations can be found throughout the Silver Fir Zone on the Olympic Peninsula. The Beargrass Plant Association is primarily found in the southeastern part of the Peninsula. The Rhododendron-Alaska Huckleberry Plant Association is found on the east side of the Peninsula. The Alaska Huckleberry Plant Association is found in most areas of the Peninsula except the northeastern rainshadow. Twelve associations have been assigned to this PAG in Region 6.

This PAG occupies moderately dry Silver Fir Zone sites. The Alaska Huckleberry Plant Association occupies moderately dry sites in moist to wet climates. The Alaska Huckleberry/Beargrass Association is more typical of dry topographic positions and the Rhododendron/Alaska Huckleberry Association is found in the rainshadow of the Olympic Mountains. All associations are on generally coarse textured, well drained soils. Snowpack accumulates to about 6 feet.

Fire is the primary agent of disturbance in this PAG but has affects some of the plant associations more than others. The Alaska Huckleberry Association has burned rarely in the last 1000 years. The Rhododendron/Alaska Huckleberry Association has burned frequently in the past and the other associations have burned rarely in the last 500 years.

Seral tree species are silver fir and western hemlock. Douglas-fir is an important seral species in all but the Alaska Huckleberry Association. Douglas-fir in the Alaska Huckleberry Association is probably relict from warmer or drier climates. Some of the associations in this PAG, especially the Alaska Huckleberry/Beargrass may have been in the Western Hemlock Zone in the Little Ice Age. Climax tree species are silver fir and western hemlock.

Timber productivity is low to moderate. Site index base 100 for Douglas-fir ranges from 94-145 for this PAG. The least productive plant association in the group is Alaska Huckleberry/Beargrass. Alaska Huckleberry and Alaska Huckleberry/Twinflower are the most productive associations.

Silver fir/Big Huckleberry-Beargrass (PAG 2204)

The plant associations in this PAG on the Olympic Peninsula are Silver fir/Beargrass and Big Huckleberry/Beargrass. These associations are found mostly on the east and southeast sides of the Peninsula. This is a minor PAG on the Olympic Peninsula. Thirteen plant associations have been assigned to this PAG in Region 6.

Soils are shallow, stony and well drained. Both associations are on dry topographic positions such as upper slopes principally on south aspects. Both associations are found in moderately dry parts of the rainshadow but not in the driest part in the northeast. Snowpack 6.5-8 feet deep.

Fire is the major agent of natural disturbance. The Beargrass Association has burned frequently in the past and the Big Huckleberry/Beargrass Association has burned once or twice in the last 500 years. Most of this PAG has not been subjected to timber harvest.

Beargrass and big huckleberry can both return rapidly after fire or clearcut. The Beargrass Association is dominated by Douglas-fir or western hemlock early in succession, by both species later and by western hemlock and silver fir in the climax stage. The Beargrass Association was probably in the Western Hemlock Zone during the Little Ice Age since most silver fir are less than 170 years old. The Big Huckleberry/Beargrass Association is dominated by silver fir and western hemlock throughout succession.

Timber productivity is low. Site index for silver fir base 100 in the Big Huckleberry/Beargrass Association is about 83. Douglas-fir site index in the Beargrass Association is 79-85.

Silver fir/Alaska Huckleberry-White Rhododendron (PAG 2205)

The Silver fir/Alaska Huckleberry/White Rhododendron Association is the only representative of this PAG on the Olympic Peninsula. This is a minor type of the east side of the Peninsula. Thirteen plant associations have been assigned to this group in Region 6.

The Alaska Huckleberry/White Rhododendron Association is found in cool dry sites mostly on shallow colluvial soils. Precipitation is moderate to low for the Peninsula and the winter snowpack accumulates to 10 feet.

Large disturbances are rare in this PAG on the Olympic Peninsula. The 1308 burning period affected many stands but the area has burned rarely since. Little timber harvest has occurred in this PAG.

Silver fir and western hemlock are seral and climax species. Alaska huckleberry and white rhododendron are present throughout succession.

Timber productivity is low. Site index base 100 ranges from about 85-98.

Silver fir/Alaska Huckleberry-Wet (PAG 2207)

The associations in this PAG on the Olympic Peninsula are the Silver fir/Alaska Huckleberry/Avalanche Lily, Alaska Huckleberry Queenscup, and Alaska Huckleberry/Foamflower associations. This is one of the most widespread PAGs in the Silver Fir Zone on the Olympic Peninsula. All three plant associations are important but none are found abundantly in the dry northeast. The Alaska Huckleberry Queenscup association has the broadest distribution around the Peninsula. The Alaska Huckleberry/Foamflower association is more abundant on the south and east sides of the Peninsula and the Alaska Huckleberry/Avalanche Lily Association is more abundant on the south side of the Peninsula. Eight plant associations have been assigned to this PAG in Region 6.

This is a PAG of cool, moist sites and high snowfall. Precipitation is moderate to high for the Peninsula. Where precipitation is lower topographic moisture is higher. Soils are moderately deep, usually coarse textured and well drained. The snowpack accumulates to 7-10 feet.

Large scale disturbance is not typical of this PAG. This PAG has burned rarely in the last 1000 years. Wind generally does not blow down large areas. Disturbance is generally on a small scale associated with normal age related disease processes and augmented by wind. Small fires occasionally burn in this PAG and the large fires of the past (1308, 1508 and 1701 have affected this PAG to a small degree. The largest influence of fire probably occurred in 1308 under different climatic conditions.

Silver fir and western hemlock are both seral and climax species. Douglas-fir established mostly after the 1308 or earlier fires under dryer conditions. Alaska huckleberry often comes back quickly after clearcuting.

Timber productivity is low to moderate. Site index base 100 ranges from 108-133 for western hemlock and silver fir.

Silver fir/Oregon Oxalis (PAG 2208)

The associations in this PAG on the Olympic Peninsula are the Silver fir/Oregon Oxalis, Swordfern, Salal/Oregon Oxalis, Salal/Deerfern and Alaska Huckleberry/ Oregon Oxalis. This is a major PAG on the west side of the Olympic Peninsula. All the plant associations except Swordfern are common or major plant associations on the west side of the Olympic Peninsula. The Swordfern Association is a minor type but extends also to the east side of the Peninsula. Seven plant associations have been assigned to this PAG in Region 6.

This is a PAG of very humid climates and moist, deep soils. Precipitation is generally moderate to high for the Peninsula and fog is common. Snowpacks in this PAG are 7-8 feet or less. They are generally less in this PAG than most of the Silver Fir Zone.

Wind is the major agent of natural disturbance in this PAG. Wind has affected many of the westernmost stands situated in the flat to rolling plain west of the mountains and on the first west and southwest slopes of the mountains. Stands situated in more interior mountain areas are rarely disturbed on a large scale. Fire has burned little of this PAG in the last 500 years. The more eastern stands of the Swordfern Association are the most vulnerable to fire.

Silver fir and western hemlock are the primary seral and climax tree species. Douglas-fir is rare or absent in old-growth stands. When present it appears to date to warmer or dryer climates. The Swordfern association may have been in the Western Hemlock Zone in the Little Ice Age.

Timber productivity is moderate to high in this PAG. Site index base 100 for Douglas-fir ranges from 133-176.

Silver fir/Devils Club (PAG 2209)

The Silver fir/Devils club Plant Association is the only association in this PAG on the Olympic Peninsula. This is a minor PAG of wet soils in the Silver Fir Zone. Five plant associations have been assigned to this PAG in Region 6.

Soils in this PAG are generally shallow but irrigated perennially from a stream or spring. They are often very organic.

Large scale disturbances are rare. Wind is the major agent of disturbance due to wet soil conditions but any sites are topographically protected from wind. Fire is a minor agent of disturbance in this PAG.

Silver fir and western hemlock with smaller amounts of western redcedar and Alaska yellowcedar are the seral and climax tree species for this PAG. Douglas-fir rarely occurs naturally in this PAG but has been grown in plantations probably on dry microsites. Devils club can come in early in succession. Devils club is browsed heavily by elk making the Devils Club Association appear less common than it might be.

Timber productivity is moderate. Site index base 100 is about 121-123 for Douglas-fir and western hemlock.

Dry non-forest in the Silver Fir Zone (2271)

This is a PAG of dry nonforest communities in the Silver Fir Zone that have not been described in published form. These communities are probably mostly bryophyte or lichen communities on rock outcrops or bare rock outcrops. Also included are communities dominated by Phlox, kinnikinnick, wild onion, selaginella, Idaho fescue, common juniper, bracken fern and yarrow. This PAG does not generally include temporarily barren areas such as erosional scarps or river bars. In some cases erosion may produce conditions for this PAG such as when bedrock is exposed on steep south facing slopes, etc.

Other non-forest in the Silver Fir Zone (2281)

This is a PAG of other non-forest situations in the Silver Fir Zone. Communities dominated by slide alder, vine maple, thimbleberrry and cowparsnip have been assigned to this group. This PAG does not include temporarily barren areas such as erosional scarps or river bars.

Wet non-forest in the Silver Fir Zone (2291)

This is a PAG of nonforested wetlands in the Silver Fir Zone that have not been described in published form. Communities in this PAG could include wetlands dominated by such plants as Sphagnum, sedges, rushes, bullrushes, cattalils, hardhack, swamp laurel, Labrador tea, scouring rushes, willows, devils club, stink currant, bog buckbean, spatterdock or skunkcabbage.

Mountain Hemlock Series PAGs (23)

The Mountain Hemlock Zone is the major forest zone of the high elevations. In the Olympic Province there are 2 Plant Association Groups (PAG) and 6 plant associations (Table 6). This is the highest zone of vegetation with a more or less continuous canopy of trees outside of the northeastern rainshadows. Precipitation comes as both rain and snow and there is considerable fog. Winter snowpacks are deep (9-15 feet). Large disturbances are rare. Snow avalanche is a locally important disturbance. Timber productivity is very low to low.

Table 6. Plant Associations in each Plant Association Group in the Mountain Hemlock Series (23).

PAG	2304	2305	2306
PAG NAME	Mountain Hemlock/Big Huckleberry-Mesic	Mountain Hemlock/Alaska huckleberry	Mountain Hemlock/Devil's Club Wet
	TSME/VAME-Mesic	TSME/VAAL	TSME/OPHO Wet
ASSOCIATIONS	Big Huckleberry/Beargrass (CMS245)	Big Huckleberry/Alaska Huckleberry (CMS244)	Devil's Club/Alaska Huckleberry (CMS450)
	White Rhododendron-Big Huckleberry (CMS312)	Alaska Huckleberry/Beargrass (CMS243)	Marsh Marigold (CMF251)
		Alaska Huckleberry (CMS241)	
		Alaska Huckleberry/Avalanche Lily (CMS242)	

Mountain Hemlock/Big Huckleberry-Mesic (PAG 2304)

The Mountain Hemlock/Big Huckleberry-Beargrass and the White Rhododendron-Big Huckleberry plant associations are the associations in this PAG on the Olympic Peninsula. Both associations are minor types on the east side of the Peninsula. The distribution in the Olympic National Park is not well known where it is probably more important. Seven plant associations have been assigned to this PAG in Region 6.

This PAG occupies shallow, coarse textured soils in upper slope positions. The Big Huckleberry/Beargrass Association is usually on south to southwest exposures. The White Rhododendron-Big Huckleberry Association is usually on a leeward side of a major ridge. Snowpack in the White Rhododendron-Big Huckleberry Association is about 11 feet and is probably less in the Big Huckleberry/Beargrass Association.

Typically wildfires have burned once or twice in the last 500 years in the Big Huckleberry/Beargrass Association but rarely in the White Rhododendron/Big Huckleberry Association. Large scale disturbance in this PAG is rare. Snow avalanche is probably a significant disturbance in some areas. There has been very little commercial tree harvest in this PAG.

Silver fir and mountain hemlock are seral and climax species. Alaska yellowcedar is often a component of older stands. Big huckleberry and beargrass are also both seral and climax species. Tree cover may take over 100 years to establish after disturbance.

Timber productivity is low or very low. Site index base 100 is below 90.

Mountain Hemlock/Alaska Huckleberry (PAG 2305)

The four plant associations in this PAG on the Olympic Peninsula are the Big Huckleberry/Alaska Huckleberry, Alaska Huckleberry/Beargrass, Alaska Huckleberry and Alaska Huckleberry/Avalanche Lily. These associations appear in the Olympic National Forest primarily on the south side of the Peninsula. Their distribution in the Olympic National Park is not known but is probably extensive outside of the rainshadow in the northeastern part. This is the major Mountain Hemlock Zone PAG on the Olympic Peninsula. Nine plant associations have been assigned to this PAG in Region 6.

The Alaska Huckleberry/Beargrass and the Big Huckleberry/Alaska Huckleberry Associations have mostly coarse textured shallow soils. The Alaska Huckleberry and Alaska Huckleberry/Avalanche Lily Associations have mostly coarse textured deep soils. This PAG is the highest closed canopy forest PAG below the subalpine types. Snow pack varies from 9-14 feet deep.

Large scale disturbance is rare in this PAG. Fire has burned rarely in the last 500 to 1000 years and possibly not at all in many areas. Snow avalanche may be a locally important disturbance. There has been very little commercial tree harvest in this PAG.

Silver fir and mountain hemlock are seral and climax species. The huckleberries and beargrass come back quickly after disturbance. Tree cover may take over 100 years to establish after disturbance.

Timber productivity is low. Site index base 100 is below 90.

Mountain Hemlock/Devil's Club Wet (PAG 2306)

The plant associations in this PAG likely to occur on the Olympic Peninsula are the Mountain Hemlock/Devil's Club/Alaska Huckleberry and the Marshmarigold associations. These minor associations have not been identified on the Olympic Peninsula but likely occur. They were described for the Mt. Baker-Snoqualmie National Forest (Henderson et al. 1992). Two plant associations have been assigned to this PAG in Region 6.

The Devil's Club/Alaska Huckleberry and the Marshmarigold Associations have poorly drained soils. There is usually surface water in the form of seeps, springs or small streams.

Large scale disturbance is rare in this PAG. Fire has burned rarely in the last 1000 years and not at all in many areas. Snow avalanche may be a locally important disturbance. There has been no commercial tree harvest in this PAG.

Silver fir and mountain hemlock are seral and climax species.

Timber productivity is low. Site index base 100 is about 42 for marshmarigold sites and up to 132 for the Devil's Club/Alaska Huckleberry site. Stockabillity in both associations is low.

Dry Non-forest in the Mountain Hemlock Zone (2371)

This is a PAG of dry nonforest communities in the Mountain Hemlock Zone that have not been described in published form. Many of these communities are bryophyte or lichen communities on rock outcrops or bare rock outcrops. Also included are communities dominated by Phlox, kinnikinnick, selaginella, common juniper, wooly sunflower and Martindale's lomatium. This PAG does not generally include temporarily barren areas such as erosional scarps or river bars. In some cases erosion may produce conditions for this PAG such as when bedrock is exposed on steep south facing slopes, etc.

Other Non-forest in the Mountain Hemlock Zone (2381)

This is a PAG of other non-forest situations in the Mountain Hemlock Zone. Communities dominated by thimbleberry, slide alder and cow parsnip have been assigned to this PAG. This PAG does not include temporarily barren areas such as erosional scarps or river bars.

Wet Non-forest in the Mountain Hemlock Zone (2391)

This is a PAG of nonforested wetlands in the Silver Fir Zone that have not been described in published form. Communities in this PAG could include wetlands dominated by such plants as Sphagnum, sedges, rushes, Labrador tea, scouring rushes, willows, devils club, stink currant, bog buckbean, or skunkcabbage.

Subalpine Fir Series PAGs (25)

The Subalpine Fir Series is important only in the northeastern rainshadow of the Olympic Peninsula. It includes one Plant Association Group with 4 plant associations on the Olympic Peninsula (Table 7). In the dry rainshadow of the Olympic Mountains this is the highest forested zone. Fire is a major agent of disturbance in this PAG. Timber productivity is low to very low.

Table 7. Plant Associations in each Plant Association Group in the Subalpine Fir Series (25).

PAG	2504
PAG NAME	Subalpine fir/White rhododendron-Beargrass
	ABLA2/RHAL-XETE
ASSOCIATIONS	Common Juniper (CES621)
	Subalpine Lupine (CEF321)
	Big Huckleberry (CES221)
	White Rhododendron (CES212)

Subalpine Fir/White Rhododendron-Beargrass (PAG 2504)

This PAG includes the Subalpine fir/Big Huckleberry, Common Juniper and Subalpine Lupine plant associations on the Olympic Peninsula. It is more common in the northeast part of the Peninsula where the Common Juniper and Subalpine Lupine associations occur. The Big Huckleberry association is found more generally on the east side of the Peninsula. Seven plant associations have been assigned to this PAG in Region 6.

This PAG occurs on shallow, stony, well drained soils on steep mid to upper slopes and ridgetops. It is most abundant in the rainshadow where the Common Juniper and Subalpine Lupine associations occur. The Big Huckleberry association occurs on dry southern exposures in areas of higher precipitation (up to 100 inches). Snowpack is typically about 4-4.5 feet.

Wildfire is the major agent of natural disturbance. This PAG has burned frequently in the past including both in the large burning events in 1308, 1508 and 1701 and in smaller fires. There has been very little commercial tree harvest.

Early successional stands can include mixes of subalpine fir, Douglas-fir and lodgepole pine. Older stands are dominated by subalpine fir with or without Douglas-fir. Complete canopy closure is not common in this PAG. The average canopy closure of older stands is 70 percent and takes about 100 years.

Timber productivity is low to very low. Site index base 100 for Douglas-fir and lodgepole pine is about 31-84.

Dry Non-forest in the Subalpine Fir Zone (2571)

This is a PAG of dry nonforest communities in the Subalpine Fir Zone that have not been described in published form. Nonforest communities associated with this zone are normally placed in the Alpine Zone (33). At this time there are no areas identified by the model in this PAG. Possible inclusions would be: bryophyte or lichen communities on rock outcrops or bare rock outcrops, communities dominated by Phlox, kinnikinnick, wild onion, selaginella, Idaho fescue, common juniper. This PAG does not generally include temporarily barren areas such as erosional scarps or river bars. In some cases erosion may produce conditions for this PAG such as when bedrock is exposed on steep south facing slopes, etc.

Other Non-forest in the Subalpine Fir Zone (2581)

This is a PAG of other non-forest situations in the Subalpine Fir Zone that is not currently being used.

Wet Non-forest in the Subalpine Fir Zone (2591)

This is a PAG of nonforested wetlands in the Subalpine Fir Zone that have not been described in published form. It is not currently being used in the model

Alpine Zone (33)

Currently both subalpine and alpine plant associations are collectively displayed as Alpine Zone in the PAG Model for the Olympic National Forest. This includes Mountain Hemlock and Subalpine Fir Parkland as well as wet and dry high elevation non-forest communities. Non-forest communities include heather, blue-leaf huckleberry, sedges, Idaho fescue, green fescue and others. Descriptions of these communities have not yet been published for the Olympic National Forest.

Table 8. Acres of plant association groups (PAG) by subwatershed.

Series	PAG Name	PAG ID	Lower Duckabush	Murhut/Cliff Cr.	Middle Duckabush	Upper Duckabush	Crazy Cr.	Headwaters	Duckabush Watershed
Douglas-fir	Oregongrape-Salal-Oceanspray	1406		2	1				3
Western Hemlock	Pacific Rhododendron	1902	2687	2239	2297	19	9		7250
	Dry Salal	1903	3710	1248	532	123	0		5614
	Vinemaple-Vanilla leaf	1905	139	232	61	6	3		441
	Mesic Salal-Oregongrape	1906	3380	556	1482	43	8		5470
	Moist Swordfern	1907	308	133	196	2			639
	Alaska Huckleberry-Oregon Oxalis	1909		4	22				26
	Devils Club	1910	19	2	21				42
	dry non-forest	1971	455	765	497	5			1721
Silver Fir	Pacific Rhododendron	2201	104	454	503	10			1072
	Salal-Oregongrape	2202	2	18	48			1	68
	Alaska Huckleberry dry	2203	53	584	1110	1136	502	141	3525
	Big Huckleberry-Beargrass	2204	90	557	1360	953	392	88	3440
	Alaska Huckleberry-White Rhododendron	2205	4	182	325				511
	Alaska Huckleberry wet	2207	2	74	106	685	298	86	1250
	Oregon Oxalis	2208		4				15	19
	Devils Club	2209				5		0	6
	dry non-forest	2271	172	878	1047	67	14	4	2181
Mountain Hemlock	Big Huckleberry-Mesic	2304	11	294	2205	1766	1757	543	6576
	Alaska Huckleberry	2305	0	39	234	1017	1247	1063	3599
	Devils Club	2306					4		4
	dry non-forest	2371	21	279	1187	363	281	114	2246
	wet non-forest	2391					19		19
	parkland	3201		101	947	1003	1137	995	4182
Alpine	alpine	3301			3	2			5
Subwatershed Total			11160	8662	14187	7204	5671	3049	49933

Table 9. Precipitation and elevation of plant association groups (PAG).

Series	PAG Name	PAG ID	Mean Precipitation	High Precip.	Low Precip.	Mean Elevation	High Elev.	Low Elev.
Douglas-fir	Oregongrape-Salal-Oceanspray	1406	111	112	110	4388	4600	4265
Western Hemlock	Pacific Rhododendron	1902	95	128	63	2368	4865	66
	Dry Salal	1903	84	132	63	1306	4449	13
	Vinemaple-Vanilla leaf	1905	96	128	82	2256	4206	1496
	Mesic Salal-Oregongrape	1906	81	130	62	2070	4308	7
	Moist Swordfern	1907	80	121	62	773	2543	7
	Alaska Huckleberry-Oregon Oxalis	1909	98	111	90	2066	3845	1348
	Devils Club	1910	77	96	62	675	1480	7
	dry non-forest	1971	100	128	75	2898	4892	561
	Wet non-forest	1991	84	84	84	1175	1175	1175
Silver Fir	Pacific Rhododendron	2201	106	127	89	3341	5177	1801
	Salal-Oregongrape	2202	103	138	91	2852	3996	1995
	Alaska Huckleberry dry	2203	119	153	91	2999	4819	1467
	Big Huckleberry-Beargrass	2204	123	154	91	3703	5358	1949
	Alaska Huckleberry-White Rhododendron	2205	110	128	93	3637	5499	1955
	Alaska Huckleberry wet	2207	125	154	92	2839	4262	1421
	Oregon Oxalis	2208	127	144	91	2686	3428	1788
	Devils Club	2209	122	136	120	721	2890	2316
	dry non-forest	2271	114	153	92	4092	5600	2270
Mountain Hemlock	Big Huckleberry-Mesic	2304	136	167	109	4440	5623	3022
	Alaska Huckleberry	2305	138	167	109	4252	5433	2671
	Devils Club	2306	133	133	133	4280	4370	4170
	dry non-forest	2371	132	165	110	4876	5738	3409
	wet non-forest	2391	133	133	132	4267	4324	4245
	parkland	3201	149	169	121	5436	6683	4557
Alpine	alpine	3301	147	165	130	6434	6624	6253

Table 10. Height potential for Olympic National Forest PAGs.

Plant Association Group (PAG)	GIS ID	PAG Name	95% Maximum Tree Ht. (ft.)	Age for 95% Maximum Tree Ht.	Range of Site Index (base 100)
Sitka Spruce Series PAGs					
	901	Salal	170		131-178
	902	Oregon Oxalis	205	214	178
Douglas-fir Series PAGs					
	1402	Kinnikinnick-Shiny-leaf Spiraea-Oregon Box-myrtle	52		41-46
	1406	Oregongrape-Salal-Oceanspray	81	161	66-86
Western Hemlock Series PAGs					
	1902	Pacific Rhododendron	115	243	82-108
	1903	Dry Salal	142	211	86-139
	1904	Alaska Huckleberry-Bunchberry Dogwood	144	487	94
	1905	Vine Maple-Vanilla Leaf	210	451	146-149
	1906	Mesic Salal-Oregongrape	173	178	95-165
	1907	Moist Swordfern	201	223	166
	1909	Alaska Huckleberry-Oregon Oxalis	167	176	120-181
	1910	Devils Club	141	248	151-188
	1911	Skunk Cabbage			130-150
Silver Fir Series PAGs					
	2201	Pacific Rhododendron	141	258	113-128
	2202	Salal-Oregongrape	162	258	113-143
	2203	Alaska Huckleberry Dry	147	239	94-145
	2204	Big Huckleberry-Beargrass	135	421	79-85
	2205	Alaska Huckleberry-White Rhododendron	123	300	85-98
	2207	Alaska Huckleberry Wet	154	159	108-133
	2208	Oregon Oxalis	158	161	133-176
	2209	Devils Club	147	197	121-123
Mountain Hemlock Series PAGs					
	2304	Big Huckleberry Mesic	102	407	below 90
	2305	Alaska Huckleberry	111	354	below 90
Subalpine Fir Series PAGs					
	2504	White Rhododendron-Beargrass	80	306	31-84
Mountain Hemlock Parkland	3201	Mountain Hemlock Parkland	49	487	below 70

2.8.4 Individual Fire Accounts

The following section gives details of each fire known to have occurred in the Duckabush Watershed larger than 10 acres. Fire information on DNR and private lands is incomplete, especially for the small fires. Wherever a name is known from a historical record it is used. Names descriptive of the location have been supplied for the others.

Fires before 1250

Trees old enough to indicate fires before 1250 are found mostly on the west and south sides of the Olympic National Forest. Several Douglas-fir, western redcedar and Alaska yellow cedar tree stumps and trees were found dating to the 926-1233 period. This encompasses most of the Medieval Optimum Period (1000-1300). These trees come from the Sol Duc, Sitkum, Quinault, Humptullips, Wynoochee and S.F. Skokomish Rivers. A few more are widly scatterred on the east side from Mildred Lakes north to the Big Quilcene Watershed.

This Medieval Optimum was a warmer, dryer period with frequent, large fires on the Olympic Peninsula. Most of the evidence of these fires would have been destroyed by the fires around 1308 at the close of the Medieval Optimum.

There is no direct evidence for this age class in the Duckabush Watershed but evidence is found both north and south of the watershed.

Fire of 1250 (F445)

Evidence for a fire around 1250 comes from Douglas-fir, western redcedar and Alaska yellow cedar trees and stumps mostly on the south side of the Olympic National Forest. Stumps and trees dating to this period come from the Queets, Quinault, Humptullips, Wynoochee, Satsop and S.F. Skokomish Rivers. One date came from Tunnel Cr. In the Big Quilcene Watershed.

This burning period came near the end of the Medieval Optimum Period (1000-1300). This period was warmer and dryer than the present and large fires were probably common on the Olympic Peninsula. The 1250 fire appears to come at the beginning of a burning period culminating with the very large fire of 1308.

There is no direct evidence for this fire in the Duckabush Watershed but evidence is found both north and south of the watershed.

Fire of 1308 (F298)

The oldest fire for which substantial evidence can be found is the fire of 1308 (Map 2.8F) which was actually several fires in several years. It burned at the end of the warm, dry Medieval Optimum Age (Henderson et al.1989). This fire burned at least half of the Olympic Peninsula. The burn pattern suggests a large fire coming out of the NE lowlands under high winds and burning across the northern and eastern sides of the Peninsula. It may have been started from multiple lightening strikes throughout the area or possibly by Native Americans. The same age class is present in much of Western Washington.

A climate in 1308 warmer than todays is shown by Douglas-fir trees dating to about 1308 growing higher in elevation than they can currently become established. The climate at the time of Douglas-fir establishment must have been warmer than the current climate which is consistent with the climate at the end of the Medieval Optimum. Most of the evidence for this fire is scattered trees and stands of Douglas-fir in the Silver Fir, Sitka Spruce and moist Western Hemlock Zones. Areas which are now Silver Fir Zone with old remnant Douglas-fir were probably in the Western Hemlock Zone at the time of the fire (Henderson et al. 1989).

Trees which date to the 1308 fire have been found mostly along the Sol Duc, Sitkum, Queets, Wynoochee, Satsop, S.F. Skokomish and Hamma Hamma Rivers. Stands of trees from 1308 age often have evidence of more recent fires indicating that these areas partially burned in subsequent fires. Thick barked, older Douglas-fir trees commonly survive ground fires. For the most part these are cool, moist valley bottoms or parts of the Silver Fir Zone where later fires did not burn hot enough to replace the entire stand. The result are several aged stands with the oldest trees dating to 1308.

It is believed that the 1308 fire burned most of the Duckabush Watershed. No direct evidence for this fire has yet been found in the Duckabush Watershed but evidence is found in the Hamma Hamma Watershed and farther south. Evidence for 1308 or older fires is also found north of the Duckabush Watershed.

Fire of 1508

The second oldest fire for which substantial evidence can be found is the fire of 1508 (Map 2.8F). This may actually have been several fires between 1448 and 1538 but one of the largest fires burned about 1508 (Henderson et al.1989). It burned during a cool, dry portion of the Little Ice Age. This fire burned much of the Olympic Peninsula. The burn pattern suggests a large fire coming out of the NE lowlands under high winds and burning across the northern side of the peninsula and down the east side. It may have been started from multiple lightening strikes throughout the area or possibly by Native Americans. The same age class is present in much of Western Washington and Oregon.

Most of the evidence for this fire consists of scattered trees and stands of Douglas-fir in stream bottoms and moist areas in the Silver Fir and Western Hemlock Zones. Areas which are now Silver Fir Zone with old remnant Douglas-fir were probably in the Western Hemlock Zone at that time.

Trees which date to the 1508 fire are found mostly on the south and west sides of the Olympic National Forest. Trees and stumps have been found in the Sol Duc, Twin Rivers, Queets, Quinault, Humptullips, Wynoochee, S. F. Skokomish, Hamma Hamma and Big Quilcene Rivers. A few more are widely scattered in northern and northeastern portions of the Olympic National Forest. Most areas mapped as 1508 age class also have evidence of more recent fires indicating that these areas partially burned in subsequent fires. The result are several aged stands with the oldest trees dating to 1508.

This fire is believed to have burned much of the Duckabush Watershed including all of the lower subwatershed, most of the Murhut Cr. Subwatershed except parts of Cliff Creek and most of the Duckabush south facing slopes of the middle and upper subwatersheds. It is possible the fire was even more extensive in the Duckabush Watershed. One tree dating to this fire was found in upper Murhut Cr. Additional trees have been found north and south of the Duckabush Watershed.

Fire of 1668

The fire of 1668 appears to have burned much of the area south of the Duckabush River to the S.F. Skokomish River and east to the Satsop River. Much of the area burned by this fire was reburned in 1701 making this fire very difficult to accurately map. This fire may have been more extensive than is currently mapped. Trees dating to this fire are found scattered throughout the mapped area but can not be differentiated from 1701 trees on air photos.

One tree dating to this fire has been documented in the Lower Duckabush Subwatershed. Additional trees have been documented south and north of the Duckabush Watershed. This fire burned at least the Lower Duckabush Subwatershed and possibly more.

Fire of 1701

The most recent large fire is the fire of 1701 (Map 2.8F). This may actually have been several fires between 1668 and 1732 but one of the largest fires burned in 1701 (Henderson et al. 1989). This suite of fires is referred to as the 1701 fire since at this time they can not be separately mapped. The 1701 fire burned over one million acres on the Olympic Peninsula during a cool, dry portion of the Little Ice Age. The burn pattern suggests a large fire coming out of the NE lowlands under high winds and burning across the northern and eastern sides of the Peninsula. It may have been started from multiple lightening strikes throughout the area or possibly by Native Americans. The same age class is present in much of Western Washington.

The fire of 1701 was smaller than the fires of 1308 or 1508 but burned over much of the same area. Since there have been no large fires since 1701 there is much evidence remaining from this fire. Most of the single-story late successional Douglas-fir forests on the Olympic Peninsula date to this burning period.

Stands that date to the 1701 fire are found nearly continuously from the S. F. Skokomish River north to the Dungeness River and west to the Sol Duc River. Scattered smaller stands of Douglas-fir dating to this period are also found on the south and west sides including the Wynoochee, Humptulips, Quinault and Queets Rivers.

Documented trees dating to this fire in the Duckabush Watershed come from upper Cliff Cr. and the mainstem Duckabush near Big Hump. Trees dating to this fire have also been found extensively north and south of the Duckabush Watershed. It is believed that this fire burned most of the Duckabush Watershed except for most of Cliff Creek and the higher portions of Crazy Creek, Upper Duckabush, and Headwaters Duckabush subwatersheds.

Fire of 1906

This fire burned in the Lower Duckabush Subwatershed on south facing toeslopes and lower slopes. Little more is known about it. The Olympic Fire Atlas prior to 1931 records it as 400 acres but as mapped it is only 299 acres. No cause for the fire or name is given. The fire occurred on 8/3/06.

Fire of 1914

This fire burned in the Lower Duckabush Subwatershed on south facing toeslopes and lower slopes. Little more is known about it. The Olympic Fire Atlas prior to 1931 records it as 200 acres but as mapped it is only 124 acres. No cause for the fire or name is given. The fire started on 7/21/14.

Duckabush Fire of 1922

This fire burned in the bottom of the Murhut/Cliff Cr. Subwatershed along the Duckabush River and in the bottom and up to the ridgeline on south facing slopes in the Lower Duckabush Subwatershed. The Olympic Fire Atlas Prior to 1931 records it as burning 2000 acres but as mapped it is 1539 acres. The cause of the fire is listed as smoking. The fire started on 7/2/22.

Big Hump Fire of 1924

This fire burned 40 acres near Big Hump on the Duckabush River. According to the Olympic Fire Atlas Prior to 1931 it started from a campfire on 7/12/24.

Upper Duckabush Fire of 1924

This fire burned mostly south facing slopes in the Middle and Upper Duckabush Subwatersheds. According to the Olympic Fire Atlas prior to 1931. It was air photo interpreted on 1939 air photos from a 1' to 4 mile pre 1931 fire map. According to the Olympic Fire Atlas Prior to 1931 the fire started on 8/11/24 from lightning in needles between 4000-5000 ft. It was a surface and crown fire.

Interrorem Fire of 1929

This fire burned from areas extending from the Duckabush/Dosewallips divide in the Lower Duckabush Subwatershed south through Fulton Cr. to Waketickeh Cr. The current map was air photo interpreted from 1939 air photos and Forest Service maps of the fire. According to the Olympic Fire Atlas prior to 1931 the fire burned 8602 acres. As mapped it includes 13362 acres. The area of uncertainty lies in private lands at the southern end of the fire which may or may not have burned in this fire but had been clearcut and burned at nearly the same time. Forest service maps do not show that portion of the fire. According to the Olympic Fire Atlas prior to 1931 the fire started on 9/6/29. The cause is listed as smoking. The Interrorem fire burned 2305 acres in the Lower Duckabush Subwatershed on both sides of the river and in the bottom.

Duckabush Fire of 1930

This fire burned 40 acres near the Duckabush Shelter according to the Olympic Fire Atlas Prior to 1931. It started in a tree from lightning on a steep north facing slope at about 3500 feet in mature timber. The fire burned on the surface, in the duff and in the crowns. It started on 7/12/30.

Cliff Cr. Fire of 1930

This fire burned 21 acres in Cliff Creek. According to the Olympic Fire Atlas prior to 1931 it started from lightning in a snag on a steep, east facing slope about 4000 feet in elevation. It was a surface, duff and crown fire in mature timber.

Crazy Cr. Fire of 1930

This fire burned 20 acres in Crazy Creek. According to the Olympic Fire Atlas prior to 1931 it started from lightning in a tree on a steep, east facing slope about 4000 feet in elevation. It was a surface and duff fire.

Murhut Cr. Ridge Fire of 1938

This fire burned 80 acres near Murhut Cr. Ridge. According to the Olympic Fire Atlas prior to 1931 it started from lightning and burned in "non-productive" forest. Seventy acres were completely killed.

Trap Pass Fire of 1971

This fire burned 37 acres in upper Murhut Cr. According to the Individual Fire Report it was started from logging line by permittee on 7/29/71. It started at about 3200 feet on a south slope in a recent clearcut.

Table 11. Fires larger than 10 acres in the Duckabush Watershed.

Fire year	Acres burned in the Duckabush Watershed	Total acres burned	Ignition	Name of fire	Location	ID #
1250	678	378352	lightning?	Prehistoric 1250 fires	widespread	F445
1308	39267	1638848	lightning?	Prehistoric 1308 fires	widespread	F297
1508	23908	1244856	lightning?	Prehistoric 1508 fires	widespread	F298
1668	6983	179901	lightning?	Prehistoric fire of 1668	widespread	F447
1701	32483	1146276	lightning?	Prehistoric 1701 fires	widespread	F299
1906	325	325	?		Lower Duckabush Subwatershed	F92
1914	169	169	campfire		Lower Duckabush Subwatershed	F111
1918	4809	5415	campfire	Duckabush	Lower and Murhut/Cliff Cr. Subwatershed	
1922	1550	1550	smoking	Duckabush	Lower and Middle Duckabush Subwatershed	F96
1924	40	40	campfire	Big Hump	Big Hump	F11166
1924	161	161	lightning	Upper Duckabush	Middle and Upper Subwatershed	F307
1929	2305	13541	smoking	Interrorem	Dosewallips R. south to Waketickeh Cr.	F95
1930	40	40	lightning	Duckabush	Duckabush	F306
1930	21	21	lightning	Cliff Cr.	Cliff Cr.	F94
1930	20	20	lightning	Crazy Cr.	Crazy Cr.	F11465
1938	80	80	lightning	Murhut Cr. Ridge	Murhut Cr. Ridge	F12746
1971	37	37	logging line	Trap Pass	Murhut Cr.	F336

Table 2.9A (Sub)watershed Names and Numbers

(Sub)watershed Name	5th Field #	6th Field #
Duckabush River	1711001824	
Lower Duckabush River		171100182401
Murhut Cliff Creeks		171100182402
Middle Duckabush River		171100182403
Crazy Creek		171100182404
Upper Duckabush River		171100182405
Headwaters Duckabush River		171100182406

Table 2.9B Precipitation Regime and Hydrologic Maturity Conditions by Subwatershed

6th Field Watershed	Precipitation Regime				Hydrologic Maturity			
Name	Zone	Acres	Sq. Miles	Percent	Condition	Acres	Sq. Miles	Percent
Lower Duckabush	Lowland	3703.8	5.8	33%	Immature	741.6	1.2	7%
River	Rain-dominated	4138.8	6.5	37%	Intermediate	2549.3	4.0	23%
	Rain-on Snow	2982.7	4.7	27%	Mature	7705	12.0	69%
	Snow-dominated	10.5	0.0	0%	Unknown	164.1	0.3	1%
	Highland	324	0.5	3%				
Murhut Cliff	Lowland	0	0.0	0%	Immature	1276.5	2.0	15%
Creeks	Rain-dominated	1111.3	1.7	13%	Intermediate	3260.2	5.1	38%
	Rain-on Snow	5514.9	8.6	64%	Mature	4124.8	6.4	48%
	Snow-dominated	1611.2	2.5	19%	Unknown	0	0.0	0%
	Highland	424.2	0.7	5%				
Middle Duckabush	Lowland	0	0.0	0%	Immature	3164.2	4.9	22%
River	Rain-dominated	0	0.0	0%	Intermediate	3015	4.7	21%
	Rain-on Snow	8027	12.5	57%	Mature	7993	12.5	56%
	Highland	969.6	1.5	7%	Unknown	14.6	0.0	0%
	Snow-dominated	5190.2	8.1	37%				
Crazy Creek	Lowland	0	0.0	0%	Immature	1987	3.1	35%
	Rain-dominated	0	0.0	0%	Intermediate	1257.7	2.0	22%
	Rain-on Snow	1033.5	1.6	18%	Mature	2427.8	3.8	43%
	Snow-dominated	4013.7	6.3	71%	Unknown	4	0.0	0%
	Highland	624.1	1.0	11%				
Upper Duckabush	Lowland	0	0.0	0%	Immature	1982.8	3.1	28%
River	Rain-dominated	0	0.0	0%	Intermediate	1503.2	2.9	21%
	Rain-on Snow	2929	4.6	41%	Mature	3705	5.8	51%
	Snow-dominated	3192.6	5.0	44%	Unknown	13.2	0.0	0%
	Highland	1082.6	1.7	15%				
Headwaters Duckabush	Lowland	0	0.0	0%	Immature	1900	3.0	62%
River	Rain-dominated	0	0.0	0%	Intermediate	410.4	0.6	13%
	Rain-on Snow	428	0.7	14%	Mature	728.3	1.1	24%
	Snow-dominated	1183.4	1.8	39%	Unknown	10.5	0.0	0%
	Highland	1437.7	2.2	47%				

Table 2.9C Description of Land Use and Cover Types for Hydrologic Maturity Determinations

Land Use and Cover Type	Description
Forested [1]	
Hydrologically mature	Maximum hydrological maturity ≥ 70 percent total crown closure AND < 75 percent of the crown cover in hardwoods or shrubs
Intermediate hydrologically mature	Intermediate hydrologic maturity 10 to 70 percent total crown closure AND < 75 percent of the crown in hardwoods or shrubs
Hydrologically immature	Minimum hydrologic maturity < 10 percent total crown closure AND/OR ≥ 75 percent of the crown in hardwoods or shrubs
Non-forested [2]	
Urban	Residential/commercial/industrial
Agriculture	Cultivated and grazing lands
Open water	Lakes, ponds, reservoirs, inundated wetlands
Other	Naturally occurring open areas (e.g. talus slopes, meadows, barrens

[1] Unmanaged or managed lands currently occupied by or capable of growing stands of trees of commercial size.
[2] Lands permanently converted from forest or incapable of growing stands of trees of commercial size.

Table 2.9D Age Thresholds for Canopy Closure by Series and Sub-Series

Series or Sub-series	Age for 10% Canopy Closure	Age for 70% Canopy Closure
Sitka Spruce	5	17
Western Hemlock (moist)	5	17
Western Hemlock (dry)	10	25
Mountain Hemlock (moist)	15	70
Mountain Hemlock (dry)	15	170
Sub-Alpine Fir	15	170
Silver Fir (moist)	5	17
Silver Fir (dry)	10	35
Douglas Fir	10	25

Table 2.9E Road and Stream Densities by (Sub)watershed

5TH & 6th FIELD WATERSHEDS	ROAD MILES (mi.)	AREA (mi^2)	ROAD DENSITY (mi/mi^2)	STREAM MILES (mi.)	AREA (mi^2)	STREAM DENSITY (mi/mi^2)
DUCABUSH RIVER						
LOWER DUCKABUSH RIVER	39	17.4	2.2	69	17.4	4.0
MURHUT CLIFF CREEKS	11	13.5	0.8	54	13.5	4.0
MIDDLE DUCKABUSH RIVER	0	22.2	0	49	22.2	2.2
CRAZY CREEK	0	8.9	0	18	8.9	2.0
UPPER DUCKABUSH RIVER	0	11.3	0	24	11.3	2.2
HEADWATERS DUCKABUSH RIVER	0	4.8	0	14	4.8	2.9
DUCKABUSH RIVER	50	78.1	0.6	228	78.1	2.9

Table 2.9F Total Monthly and Annual Precipitation (in inches) at Hoodsport Ranger District for Calendar Years 1959-1996

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1959	18.13	6.25	8.43	9.18	2.19	2.22	0.61	0.47	6.02	5.02	13.65	10.76	82.93
1960	14.79	11.75	9.9	10.14	4.62	0.48	0	2.49	0.91	8.74	13.85	9.6	87.27
1961	23.17	22.95	14.7	2.59	3.19	0.4	0.66	0.89	1.24	9.11	11.24	15.29	105.43
1962	9.34	5.42	9.39	5.13	4.08	2.46	0.54	3.27	6.34	8.29	20.43	11.84	86.53
1963	6.17	11.54	8.4	6.65	3.58	3.35	2.81	1.38	1.29	13.57	18.41	12.18	89.33
1964	23.91	4.18	6.74	1.38	1.69	3.4	2.95	1.81	2.88	2.51	16.62	14.85	82.92
1965	12.45	12.15	0.19	6.51	3.72	0.95	0.6	1.98	0.11	6.64	17.69	16.03	79.02
1966	18.45	6.75	13.08	0.99	1.31	1.36	1.36	0.41	1.86	7.1	12.54	24.6	89.81
1967	22.46	8.02	11.05	4.16	0.97	0.82	0.13	0	1.88	19.74	8.28	21.08	98.59
1968	21.86	16.15	13.94	3.27	1.75	4.15	0.41	4.91	3.1	8.74	15.11	20.44	113.83
1969	13.49	8.08	6.48	7.74	3.1	1.13	0.29	0.92	10.22	4.31	5.32	15.42	76.5
1970	17.82	5.82	7.9	8.89	1.9	0.83	0.33	0.22	4.2	7.4	13.39	25.67	94.37
1971	16.48	9.56	22.97	4.97	2.87	2.12	1.54	0.53	6.13	6.93	13.17	12.6	99.87
1972	14.48	18.77	15.43	9.69	0.44	1.19	2.96	0.61	8.4	0	10.3	26.33	108.6
1973	14.6	6.5	6.46	0	2.55	1	0	0	4.75	9.18	24.4	24.49	93.93
1974	21.86	14.91	13.46	5.95	3.22	2.17	4.3	0.5	1.2	2.48	15.39	19.5	104.94
1975	11.49	9.53	8.5	3.48	3.38	1.28	0	6.9	0	23.3	15.66	19.17	102.69
1976	13.17	15.3	9.52	3.7	3.55	0.62	1.66	1.92	1.7	4.8	2.26	5.82	64.02
1977	5	7.5	10.88	3.5	3.29	1.24	0.51	5.14	4.32	5.46	17.26	13.68	77.78
1978	13.63	7.95	4.83	6.15	7.2	1.22	0.82	2.49	10.5	0.75	8.54	4.67	68.75
1979	3.57	19.87	7.06	3.3	3.02	0.64	1.78	1.74	3.63	13.11	3.7	28.62	90.04
1980	12.92	17.04	6.23	6.11	1.16	2.2	1.56	0.38	2.86	2.79	21.86	19.04	93.55
1981	4.85	16.51	6.47	5.14	1.97	3.14	0.52	0.8	5.54	10.76	14.68	18.2	88.58
1982	13.19	18.56	5.8	7.8	0.47	1.21	0.12	0.59	1.74	11.13	11.85	20.52	92.98
1983	16.34	19.31	18.35	2.63	1.53	2.95	3.98	3.44	2.83	3.21	31.65	10.73	116.95
1984	6.98	10.74	8.85	8.14	7.68	3.11	0	0.04	2.45	7.22	22.19	9.68	87.08
1985	0.62	7.02	9.27	3.72	1.59	2.93	0.02	1.2	2.89	14.34	5.38	4.35	52.73
1986	22.71	10.17	7.76	4.23	4.27	0.73	0.66	0.01	2.2	7.65	16.75	12.71	89.85
1987	15.9	10.9	15.82	5.23	4.6	0	0.77	0.16	1.04	0.02	8.61	20.67	83.72
1988	8.72	5.22	10.02	6.18	5.92	1.64	1.03	0	4.52	3.57	22.24	3.62	72.68
1989	7	7.99	13.82	5.71	2.89	1.78	3.76	1.19	0.23	7.94	9.5	10.21	72.02
1990	23.39	14.58	6.93	2.93	2.91	4.56	0.45	1.99	0	9.05	21.72	12.42	100.93
1991	11.69	12.17	8.25	11.11	3.79	1.46	0.79	5.4	0.01	1.43	15.18	10.02	81.3
1992	24.97	10.51	1.68	8.75	0.05	2	0.42	0.67	2.96	3.85	12.55	8.75	76.56
1993	8.75	0.82	11.37	16.2	4.18	2.86	2.26	0.52	0	3.06	5.42	17.17	72.61
1994	12.1	13.91	9.88	5.75	3.61	2.14	0.47	0.49	1.78	7.63	14	28.63	100.39
1995	17.29	13.24	14.04	5.68	1.39	1.16	2.16	3.13	3.59	9.05	20.54	21.48	112.75
1996	9.94	14.08	5.98	12.7	4.12	0.42	0.97	1.07	2.89	11.12	10.84	19.54	93.67
Average	14.0	11.4	9.7	5.9	3.0	1.8	1.1	1.6	3.1	7.4	14.3	15.8	89.1

Table 2.9G USGS Gauging Station

Gauging Station #	Station Name	Location Latitude Longitude	Drainage Area (sq.mi.)	Period of Record	Greatest Peak Discharge (Water Years)
12054000	Duckabush River near Brinnon, WA	47°41'03" 123°00'37"	66.5	Dec. 1910-Dec.1911; June 1938 to present	1995 1949

Table 2.9H Average Daily Streamflow by Month for the Duckabush River Water Years 1938-1994

Month	Average Daily Discharge (cubic feet per seccond)
October	278
November	515
December	585
January	495
February	493
March	377
April	392
May	556
June	571
July	357
August	170
September	135

Table 2.9I Annual Peak Flows for USGS Gauging Station.

Water Year	Duckabush River 12054000
1939	4960
1940	6080
1941	4750
1942	6080
1943	2700
1944	3790
1945	5500
1946	2530
1947	5370
1948	5970
1949	2410
1950	8960
1951	4190
1952	2940
1953	3240
1954	3560
1955	5260
1956	5800
1957	4290
1958	4910
1959	4750
1960	6500
1961	5280
1962	2550
1963	5980
1964	4980
1965	2720
1966	2570
1967	6920
1968	6750
1969	2920
1970	3830
1971	2800
1972	3020
1973	3330
1974	5650
1975	6090
1976	5780
1977	1360
1978	5750
1979	2160
1980	7820
1981	5670
1982	4830
1983	7450

1984	6880
1985	2390
1986	6070
1987	4110
1988	4480
1989	1910
1990	3970
1991	5500
1992	4780
1993	1990
1994	6190
1995	5760
1996	9240

Table 2.9J USGS Gauging Recurrence Intervals for Estimated Discharge (based on Water Years 1939-1979)

Exceedance Probability	Recurrence Interval	Duckabush River 12054000
0.99	1.01	1587
0.95	1.05	2134
0.9	1.11	2490
0.8	1.25	2995
0.5	2	4226
0.2	5	5898
0.1	10	6991
0.04	25	8353
0.02	50	9354
0.01	100	10344

Table 2.9K Number of Partial Peak Flows for Duckabush River for Water Years 1939 -1996

Water Year	Duckabush River 12054000
1939	1
1940	5
1941	4
1942	3
1943	0
1944	2
1945	2
1946	0
1947	1
1948	3
1949	0
1950	2
1951	0
1952	0
1953	2
1954	3
1955	3
1956	0
1957	4
1958	1
1959	4
1960	3
1961	4
1962	0
1963	4
1964	2
1965	0
1966	1
1967	5
1968	4
1969	0
1970	0
1971	0
1972	2
1973	3
1974	4
1975	2
1976	4
1977	0
1978	3
1979	0
1980	5
1981	5
1982	8
1983	5
1984	4
1985	0
1986	2
1987	2
1988	2

1989	0
1990	4
1991	1
1992	3
1993	0
1994	1
1995	5
1996	10

Exhibit 2.9A Olympic National Forest Province-Wide Wetland Layer Development Methodology

Olympic National Forest Province-Wide Wetland Layer Development Methodology

Introduction

This document describes the methodology used in creating a province-wide wetland coverage from three different existing GIS coverages and various photogrammetrically interpreted coverages that resulted from the watershed analysis process. The coverage was developed in response to various forest scientists' need fro a viable base wetland coverage to be used for the watershed analysis process. The principle developers of the province-wide layer were Scot McQueen (Olympic National Forest GIS Resource Analyst), Dave Peter (Olympic National Forest Ecologist), and Robin Stoddard (Olympic National Forest Hydrologist).

Process

The wetland layers used and a brief synopsis of each follow:

- NWI Layer: photogrammetrically interpreted by the National Wetlands Inventory at a scale of 1:100,000. This layer was used as a base layer and was accepted as the least accurate coverage.

- WDNR Hydrology Layer: digitized at the 1:24,000 scale from United States Geological Survey (USGS) quads, and includes information from photogrammetric interpretations and various other internal sources by the Washington State Department of Natural Resources.

- GSC Hydrology Layer: digitized at the 1:24,000 scale from USGS 7.5 minute quads, and includes information from photogrammetric interpretations and various other internal sources by the United States Forest Service's Geometronics Service Center.

- Various Watershed Analysis developed wetland layers: digitized at the 1:24,000 scale and includes information from photogrammetric interpretations from 1:1200 aerial photos. Private landowners also contributed known wetland sites that they had digitized within their property boundaries.

Step 1: All layers were clopped to the Olympic Province boundary. The tow most accurate layers (WDNR and GSC) were then united together to make a compete province coverage. Both layers were needed as neither layer covered the entire province, in areas of layer overlap between the two, the WDNR layer was used. Unique identifiers were retained in the united coverage from both layers as a tracking mechanism.

Step 2: The united coverage was then intersected with a province-wide NWI layer. Only that area common to both input layers was preserved in this cover. This was an interim coverage used to calculate area of overlap between the NWI (more general information) and the united GSC/WDNR layers. In the areas of high overlap the NWI features were dropped and the WDNR/GSC features were retained. After some experimenting by the developers, NWI features with an area of overlap greater than 24 percent were dropped. NWI features that contained the NWI designation "Scrub/Shrub" and which overlapped WDNR/GSC features with "Marsh, Wetland, etc." designation were kept regardless of the area of overlap. After the specified features were dropped from the NWI layer, the WDNR/GSC cover was united with the remaining NWI features.

Step 3: The WDNR wetland feature coding scheme was agreed upon by the developers as the logical singe coding scheme for the final cover. Dave Peter then established a cross-walk table relating WDNR feature attributes to NWI feature attributes in areas of overlap. Once established, the cross-walk table was used to cod NWI features with the WDNR feature attribute coding scheme. This resulted in a coverage with the following items: WDNR unique number, GSC unique number, NWI unique number, a source item for tracking where the feature came from, and the WDNR wetland feature coding scheme.

Step 4: Wetland features that had been mapped during the various watershed analysis processes were then brought into the province-wide coverage and coded according to the WDNR scheme. The source item was also attributed to track the feature origination source for later reference.

Conclusion

The resulting developed coverage has provided a viable province-wide base layer that can be used as an initial examination of a particular area's wetland features. analysis at the watershed scale or finer scales may require further mapping of wetland features in that area.

Written by Scot McQueen
1996