Volume II, Chapter 12
Lewis River Subbasin—Upper North Fork

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12.0 Lewis River Subbasin—Upper North Fork

12.1 Subbasin Description

12.1.1 Topography & Geology

For the purposes of this assessment, the Upper North Fork Lewis is defined as the watershed area contributing to Merwin Dam, which is located at river mile 19.5 on the mainstem Lewis. The Lewis River has its headwaters in Skamania County and flows generally west/southwest, forming the border of Clark and Cowlitz Counties before reaching Merwin Dam. The drainage area is approximately 468,000 acres (731 mi^2) and reaches as high as 12, 270 feet on the summit of Mt. Adams.

Three reservoirs are situated on the mainstem. These are Swift Reservoir (Swift Dam Number 1, RM 47.9), Yale Lake (Yale Dam, RM 34.2), and Lake Merwin (Merwin Dam, RM 19.5). The 240-foot high Merwin Dam, completed in 1931, presents a passage barrier to all anadromous fish, blocking up to 80% of the historically available habitat.

Major tributaries to the Upper Lewis include Canyon Creek, Speelyai Creek (Lake Merwin tributaries), Siouxon Creek, Cougar Creek (Yale Lake tributaries), Swift Creek (Swift Reservoir tributary), Pine Creek, Muddy Creek, and Rush Creek (upper mainstem tributaries).

The Lewis basin has developed from volcanic, glacial, and erosional processes. Mount St. Helens and Mt. Adams have been a source of volcanic material as far back as 400,000 years ago. More recent volcanic activity, including pyroclastic flows and lahars, has given rise to the current landscape. Glaciation has shaped the valleys in upper portions of the basin as recently as 13,000 years ago. Oversteepened slopes as a result of glaciation, combined with the abundance of ash, pumice, and weathered pyroclastic material, have created a relatively high potential for surface erosion throughout the basin.

12.1.2 Climate

The climate is typified by mild, wet winters and warm, dry summers. Average annual precipitation ranges from 73 inches at Merwin Dam to over 115 inches in the upper basin (WRCC 2003). Much of the precipitation falls as snow in the higher elevations, contributing to streamflow from meltwater in dry summer months.

12.1.3 Land Use/Land Cover

The bulk of the land lies within the Gifford Pinchot National Forest. Approximately 70% of the basin is national forest or national monument land, 11% is state land, and the remainder is private, most of it in private industrial forestland ownership. Recreation uses and residential development have increased in recent years. The population of the basin is small, with only small rural communities. The year 2000 population was approximately 14,300 persons (LCFRB 2001). The majority of the basin is heavily forested, except for an area of approximately 30 square miles in the north part of the upper basin that was denuded by the 1980 eruption of Mount St. Helens. Stand replacement fires, which burned large portions of the basin between 1902 and 1952, have had lasting effects on basin hydrology, sediment transport, soil conditions, and riparian function. The largest of these was the Yacolt Burn in 1902. Subsequent fires followed in 1927 and 1929. Severe flooding in 1931 and 1934 likely was exacerbated by the effect of the fires on vegetation and soils. A breakdown of land ownership and land cover in the North Fork basin is given in Figure 12-1 and Figure 12-2. Figure 12-3 displays the pattern of landownership for the basin. Figure 12-4 displays the pattern of land cover / land-use.

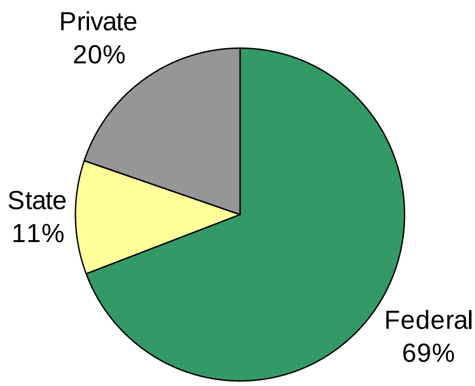


Figure 12-1. Upper North Fork Lewis River basin land ownership

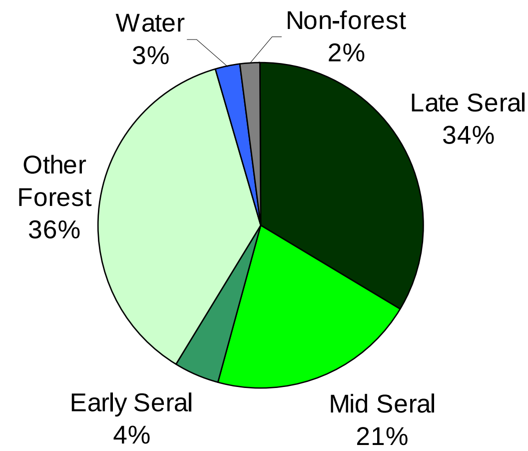


Figure 12-2. Upper North Fork Lewis River basin land cover

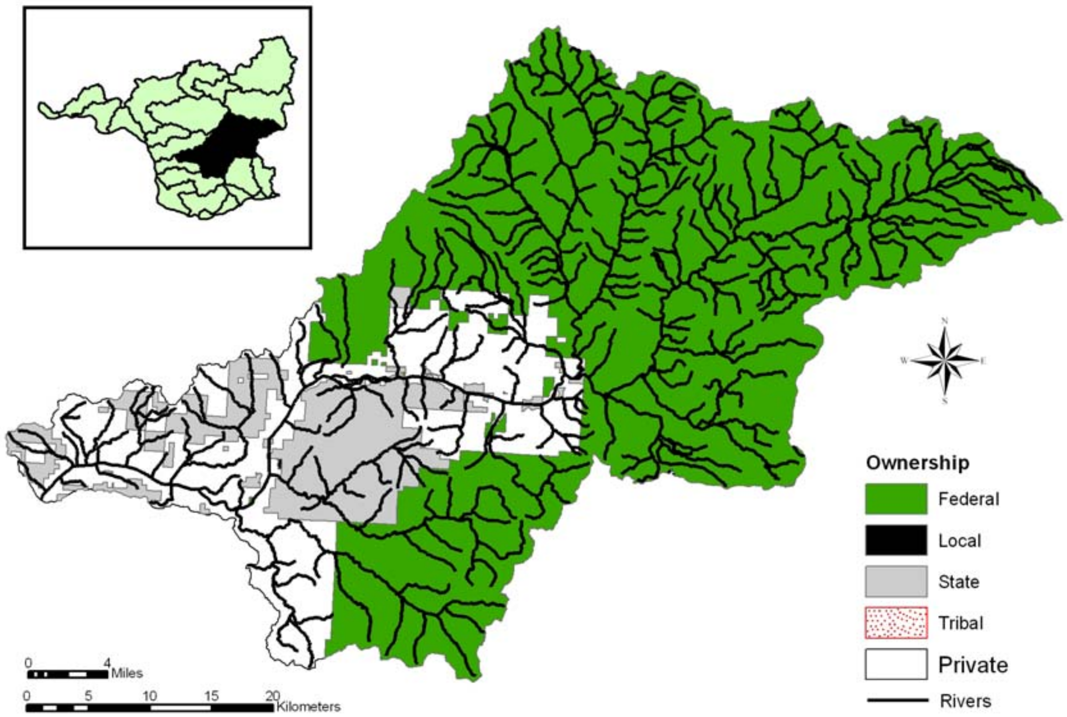


Figure 12-3. Landownership within the upper North Fork Lewis basin. Data is WDNR data that was obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

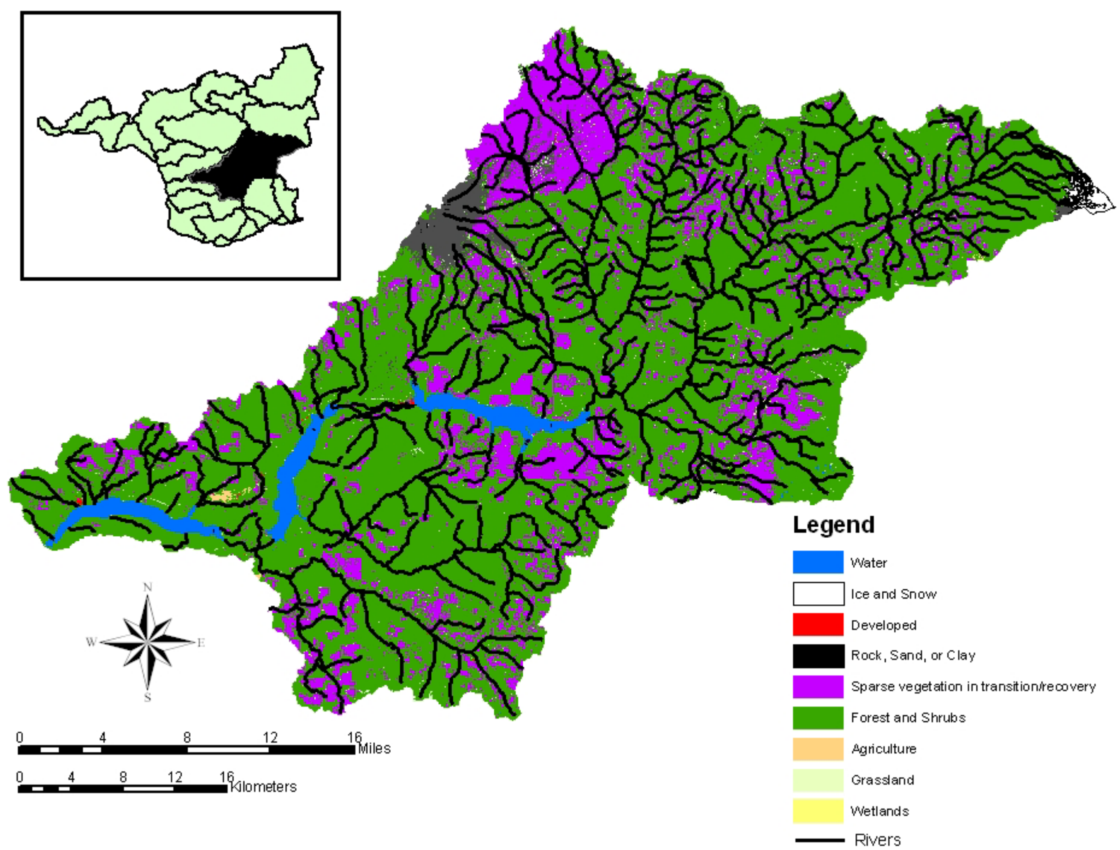
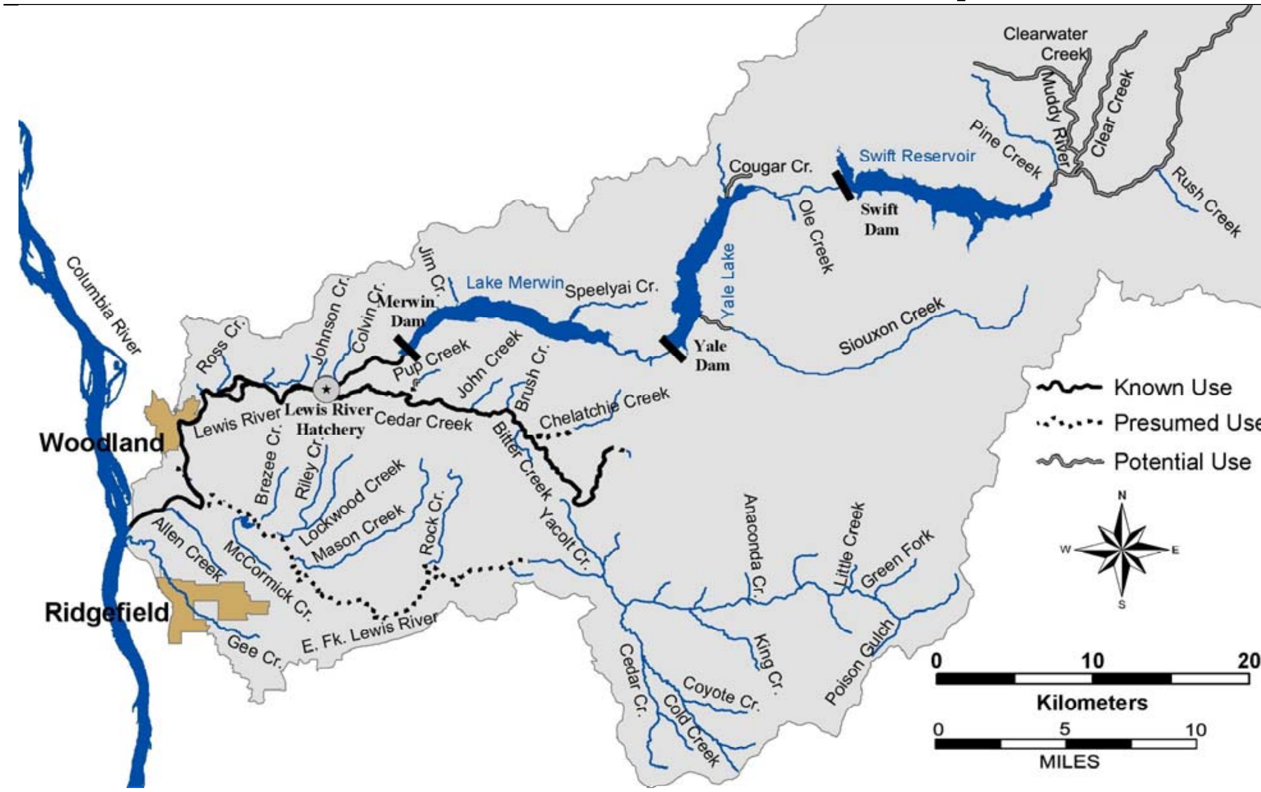


Figure 12-4. Land cover within the upper North Fork Lewis basin. Data was obtained from the USGS National Land Cover Dataset (NLCD).

12.2 Focal Fish Species

12.2.1 Spring Chinook—Lewis Subbasin

ESA: Threatened 1999 **SASSI: Depressed 2002**

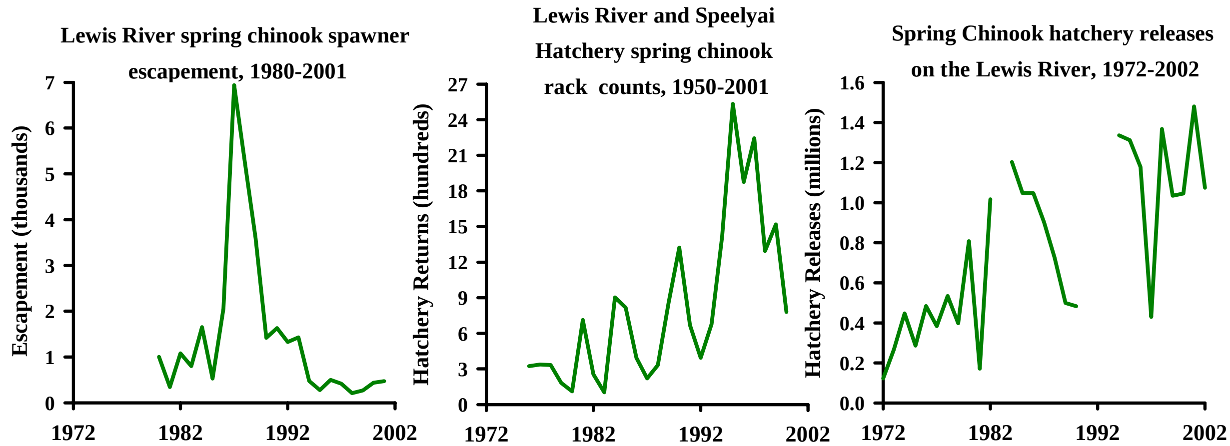


Distribution

- Historically, spring chinook were found primarily in the upper basin; construction of Merwin Dam (RM 19) in 1931 blocked access to most of the spawning areas
- Currently, natural spawning occurs on the mainstem Lewis between Merwin Dam and the Lewis River Hatchery (~4 miles), but is concentrated in the area immediately below Merwin Dam and Cedar Creek

Life History

- Spring chinook enter the Lewis River from March through June
- Spawning in the Lewis River occurs between late August and early October, with peak activity in mid-September
- Age ranges from 2-year-old jacks to 6-year-old adults, with 4- and 5-year olds usually the dominant age class (averages are 54.5% and 36.8%, respectively)
- Fry emerge between December and January on the Lewis, depending on time of egg deposition and water temperature; spring chinook fry spend one full year in fresh water, and emigrate in their second spring as age-2 smolts



Diversity

- One of four spring chinook populations in the Columbia River Evolutionarily Significant Unit (ESU)
- The Lewis spring chinook stock designated based on distinct spawning distribution and spawning timing
- Genetic analysis of the NF Lewis River Hatchery spring chinook determined they were genetically similar to, but different from, Kalama and Cowlitz hatchery spring chinook stocks and significantly different from other Columbia River spring chinook

Abundance

- Reported abundance by WDF and WDF (Smoker et al 1951) indicates that at least 3,000 spring chinook entered the upper Lewis prior to the completion of Merwin Dam in 1932
- By the 1950s, only remnant (<100) spring chinook runs existed on the Lewis
- Lewis River spawning escapements from 1980-2001 ranged from 213 to 6,939
- Native component of the stock may have been extirpated and replaced by introduced hatchery stocks; hatchery strays account for most spring chinook spawning in the Lewis River

Productivity & Persistence

- NMFS Status Assessment for the Lewis River spring chinook indicated a 0.36 risk of 90% decline in 25 years and a 0.49 risk of 90% decline in 50 years; the risk of extinction in 50 years was 0.2
- Juvenile production from natural spawning below Merwin Dam is presumed to be low
- The Current Merwin Dam mitigation goal is to 12,800 spring chinook adults annually

Hatchery

- Lewis River Salmon Hatchery is located about RM 15 (completed in 1930).
- Spring chinook eggs were collected for hatchery production beginning in 1926; spring chinook releases into the Lewis from 1972-1990 averaged 601,184
- The hatchery has reared eggs from outside sources, primarily from the Cowlitz, but a few years in the 1970s there were fish transferred from Klickitat and Carson hatcheries

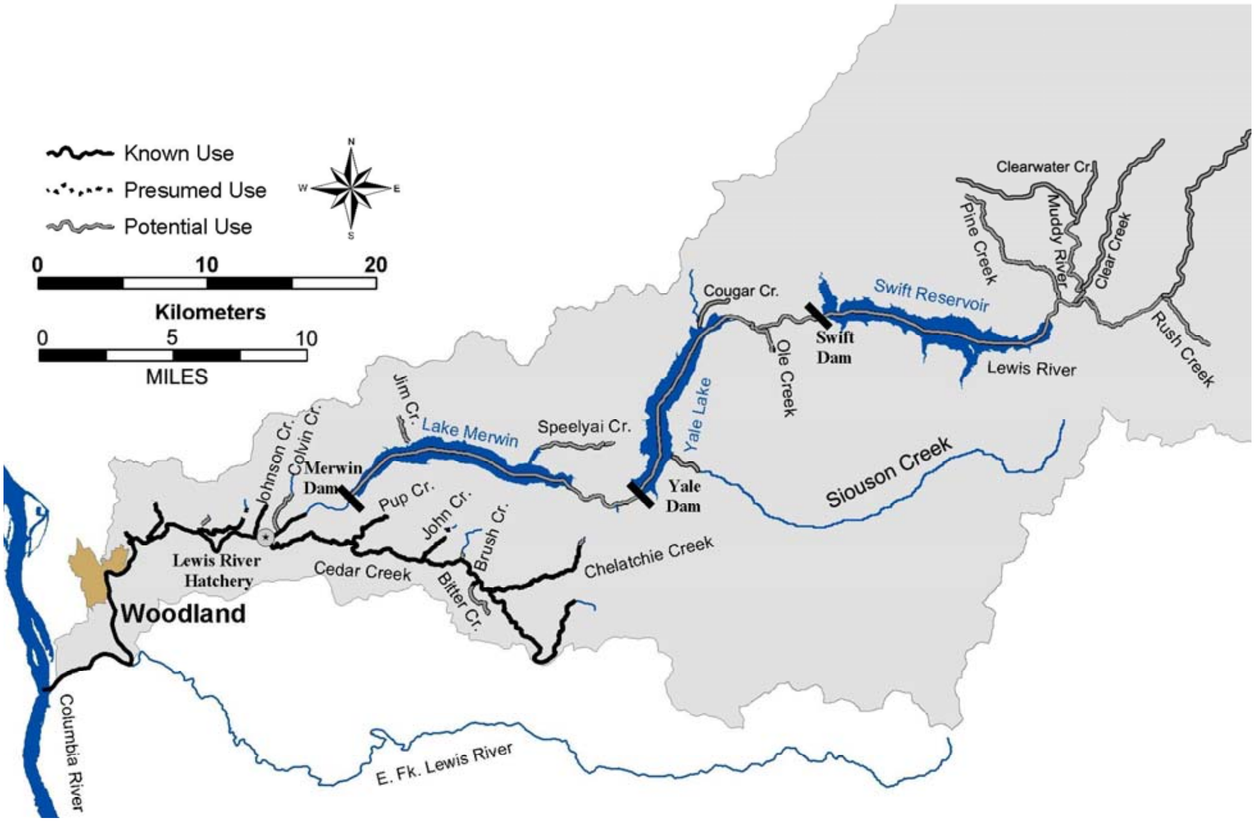
- Spring chinook broodstock return to the Lewis River Hatchery and are also trapped at Merwin Dam; a significant part of the annual return is not trapped and spawns naturally in the river

Harvest

- Spring chinook are harvested in ocean commercial and recreational fisheries from Oregon to Alaska, in addition to Columbia River commercial gill net and sport fisheries
- CWT data analysis of the 1989-1994 brood years indicates that 54% of the Lewis spring chinook were harvested and 46% escaped to spawn
- Fishery recoveries of the 1989-1994 brook Lewis River Hatchery spring chinook: Lewis sport (69%), Alaska (11%), British Columbia (10%), Washington Coast (5%), Columbia River (4%), and Oregon coast (1%)
- Mainstem Columbia River harvest of Lewis spring chinook was low after 1977 when April and May spring chinook seasons were eliminated to protect upper Columbia and Snake wild spring chinook.
- Mainstem Columbia harvest of Lewis River Hatchery spring chinook increased during 2001-2002 when selective fisheries for adipose marked hatchery fish enabled mainstem spring fishing in April and in May, 2002)
- Sport harvest in the Lewis River averaged 4,600 from 1980-1994 and reduced to 900 averaged during 1995-2002
- Tributary harvest is managed to attain the Lewis hatchery adult broodstock escapement goal

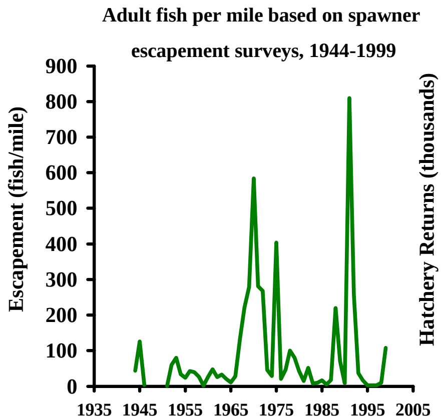
12.2.2 Coho—Lewis Subbasin (North Fork)

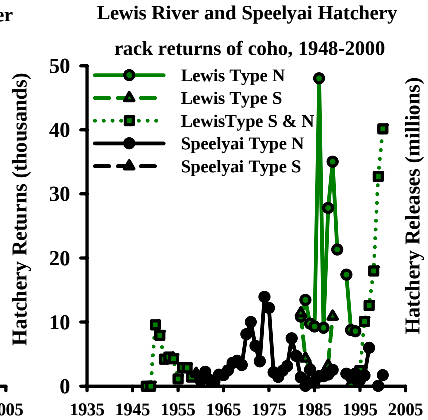
ESA: Candidate 1995	**SASSI: Unknown 2002**

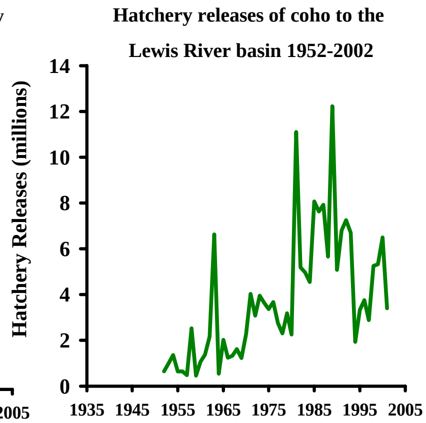


Distribution

- Managers refer to early coho as Type S due to their ocean distribution generally south of the Columbia River
- Managers refer to late coho as Type N due to their ocean distribution generally north of the Columbia River
- Coho historically spawned throughout the basin.
- Natural spawning is thought to occur in most areas accessible to coho; coho currently spawn in the North Lewis tributaries below Merwin Dam including Ross, Cedar, NF and SF Chelatchie, Johnson, and Colvin Creeks; Cedar Creek is the most utilized stream on the mainstem
- Construction of Merwin Dam was completed in 1932; coho adults were trapped and passed above Merwin Dam from 1932-1957; the transportation of coho ended after the completion of Yale Dam (1953) and just prior to completion of Swift Dam (1959)
- As part of the current hydro re-licensing process, reintroduction of coho into habitat upstream of the three dams (Merwin, Yale, and Swift) is being evaluated







Life History

- Adults enter the Columbia River from August through January (early stock primarily from mid-August through September and late stock primarily from late September through November)
- Peak spawning occurs in late October for early stock and December to early January for late stock
- Adults return as 2-year-old jacks (age 1.1) or 3-year-old adults (age 1.2)
- Fry emerge in the spring, spend one year in fresh water, and emigrate as age-1 smolts the following spring

Diversity

- Late stock coho (or Type N) were historically present in the Lewis basin with spawning occurring from late November into March
- Early stock coho (or Type S) were historically present in the Lewis basin with spawning occurring from late October to November
- Columbia River early and late stock coho produced at Washington hatcheries are genetically similar

Abundance

- Lewis River wild coho run is a fraction of its historical size
- An escapement survey in the late 1930s observed 7,919 coho in the North Fork
- In 1951, WDF estimated coho escapement to the basin was 10,000 fish in the North Fork (primarily early run)
- Escapement surveys from 1944-1999 on the North and South Fork Chelatchie, Johnson, and Cedar Creeks documented a range of 1-584 fish/mile
- Hatchery production accounts for most coho returning to the Lewis River

Productivity & Persistence

- Natural coho production is presumed to be generally low in most tributaries
- A smolt trap at lower Cedar Creek has shown recent year coho production to be fair to good in North and South forks of Chelatchie Creek (tributary of Cedar Creek) and in mainstem Cedar Creek

Hatchery

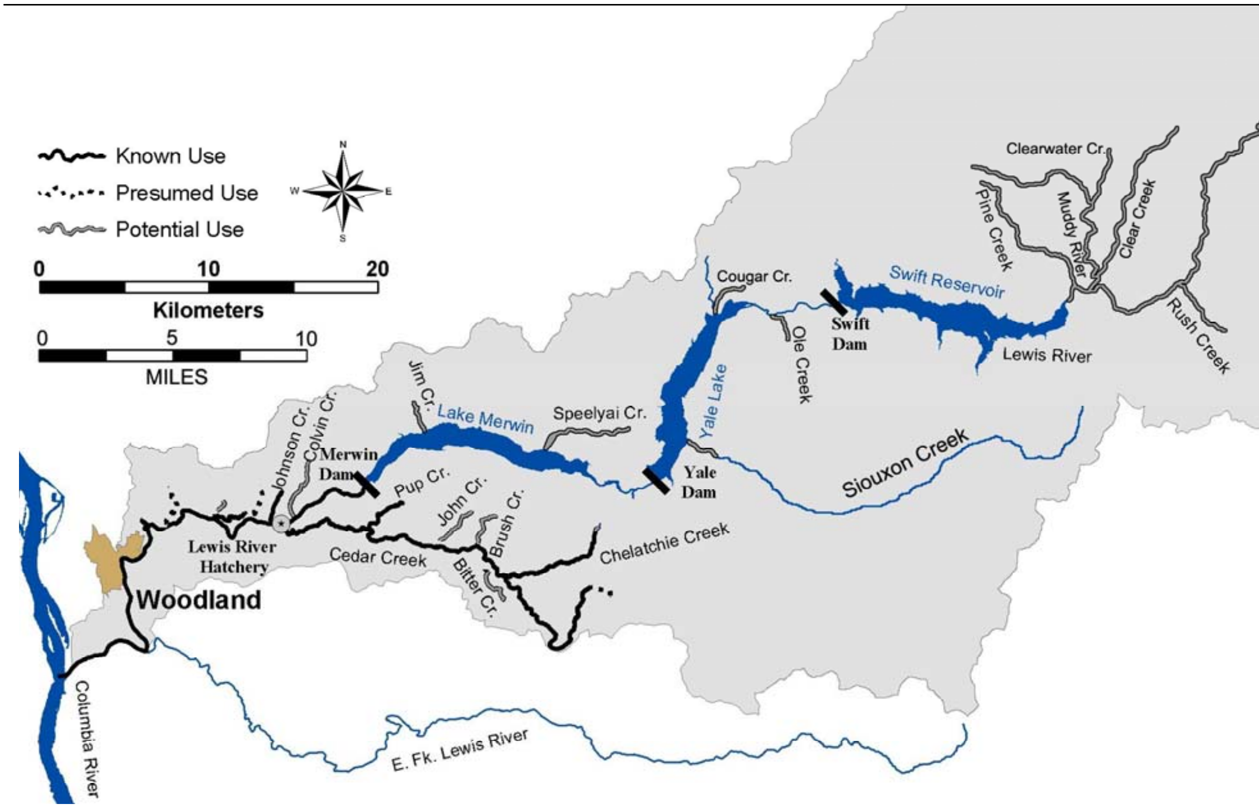
- The Lewis River Hatchery (completed in 1932) is located about RM 13; the Merwin Dam collection facility (completed in 1932) is located about RM 17; Speelyai Hatchery (completed in 1958) is located in Merwin Reservoir at Speelyai Bay; these hatcheries produce early and late stock coho and spring chinook
- Merwin Hatchery (completed in 1983) is located at RM 17 and rears steelhead, trout, and kokanee
- Coho have been planted in the Lewis basin since 1930; extensive hatchery coho releases have occurred since 1967
- The current Lewis and Speelyai hatchery programs include 880,000 early coho and 815,000 late coho smolts reared and released annually

Harvest

- Until recent years, natural produced Columbia River coho were managed like hatchery fish and subjected to similar harvest rates; ocean and Columbia River combined harvest rates ranged from 70% to over 90% from 1970-83
- Ocean fisheries were reduced in the mid 1980s to protect several Puget Sound and Washington coastal wild coho populations
- Columbia River commercial coho fisheries in November were eliminated in the 1990s to reduce harvest of late Clackamas River wild coho
- Since 1999, Columbia River hatchery coho returns have been mass marked with an adipose fin clip to enable fisheries to selectively harvest hatchery coho and release wild coho
- Natural produced lower Columbia coho are beneficiaries of harvest limits aimed at Federal ESA listed Oregon Coastal coho and Oregon State listed Clackamas and Sandy River coho
- During 1999-2002, fisheries harvest of ESA listed coho was less than 15% each year
- Hatchery coho can contribute significantly to the lower Columbia River gill net fishery; commercial harvest of early coho is constrained by fall chinook and Sandy River coho management; commercial harvest of late coho is focused in October during the peak abundance of hatchery late coho
- A substantial estuary sport fishery exists between Buoy 10 and the Astoria-Megler Bridge; majority of the catch is early hatchery coho, but late hatchery coho harvest can also be substantial
- An average of 3,500 coho (1980-98) were harvested annually in the North Lewis River sport fishery
- CWT data analysis of the 1995-97 brood early coho released from Lewis River hatchery indicates 15% were captured in a fishery and 85% were accounted for in escapement
- CWT data analysis of the 1995-97 late coho released from Lewis River Hatchery indicates 42% were captured in a fishery and 58% were accounted for in escapement
- Fishery CWT recoveries of 1995-97 brood Lewis early coho were distributed between Washington ocean (58%), Columbia River (21%), and Oregon ocean (21%) sampling areas
- Fishery CWT recoveries of 1995-97 brood Lewis late coho were distributed between Columbia River (56%), Washington coast (31%), and Oregon ocean (21%) sampling areas

12.2.3 Winter Steelhead—Lewis Subbasin (North Fork)

ESA: Threatened 1998	SASSI: Unknown 2002

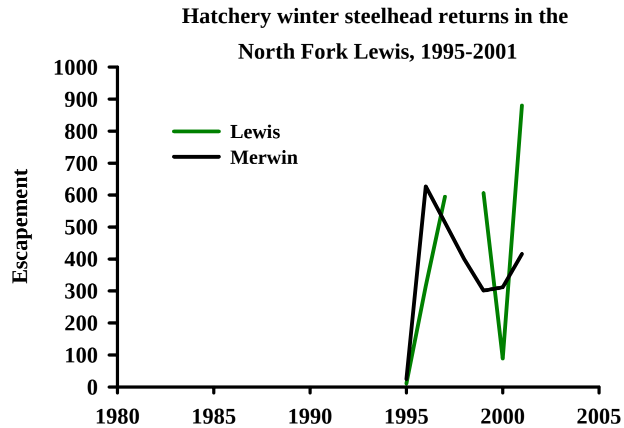


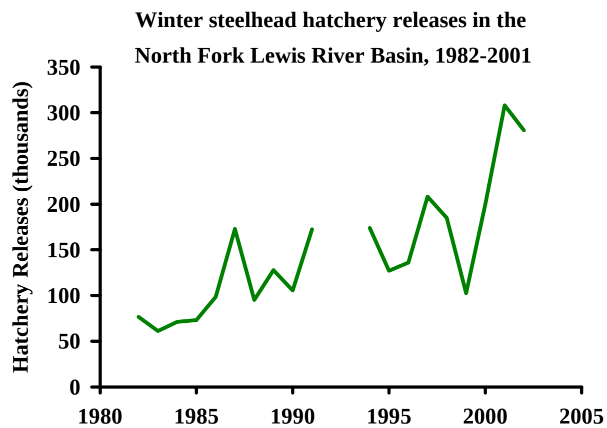
Distribution

- Spawning occurs in the NF Lewis River downstream of Merwin Dam and throughout the tributaries; natural spawning is concentrated in Cedar Creek
- Construction of Merwin Dam in 1929 blocked all upstream migration; approximately 80% of the spawning and rearing habitat are not accessible; a dam located on Cedar Creek was removed in 1946, providing access to habitat throughout this tributary

Life History

- Adult migration timing for NF Lewis winter steelhead is from December through April
- Spawning timing on the NF Lewis is generally from early March to early June
- Limited age composition data for Lewis River winter steelhead suggest that most steelhead are two-ocean fish
- Wild steelhead fry emerge from March through May; juveniles generally rear in fresh water for two years; juvenile emigration occurs from April to May, with peak migration in early May





Diversity

- Mainstem/NF Lewis winter steelhead stock designated based on distinct spawning distribution and run timing
- Concern with wild stock interbreeding with hatchery brood stock from the Elochoman River, Chambers Creek, and the Cowlitz River
- After 1980 Mt. St. Helens eruption, straying Cowlitz River steelhead likely spawned with native Lewis stocks
- Allele frequency analysis of NF Lewis winter steelhead in 1996 was unable to determine the distinctiveness of this stock compared to other lower Columbia steelhead stocks

Abundance

- Recent analysis for re-license estimate historical abundance ranging from 5,100-10,000 annually for upper Lewis above Merwin Dam
- In 1936, steelhead were reported in the Lewis River during escapement surveys
- Wild winter steelhead escapement counts for the NF Lewis River are not available
- Escapement goal for the NF Lewis River is 698 wild adult steelhead
- Hatchery origin fish comprise most of the winter steelhead run on the NF Lewis
- WDF estimated that only 6% of the returning winter steelhead in the NF are wild fish

Productivity & Persistence

- Winter steelhead natural production is expected to be low and primarily in Cedar Creek

Hatchery

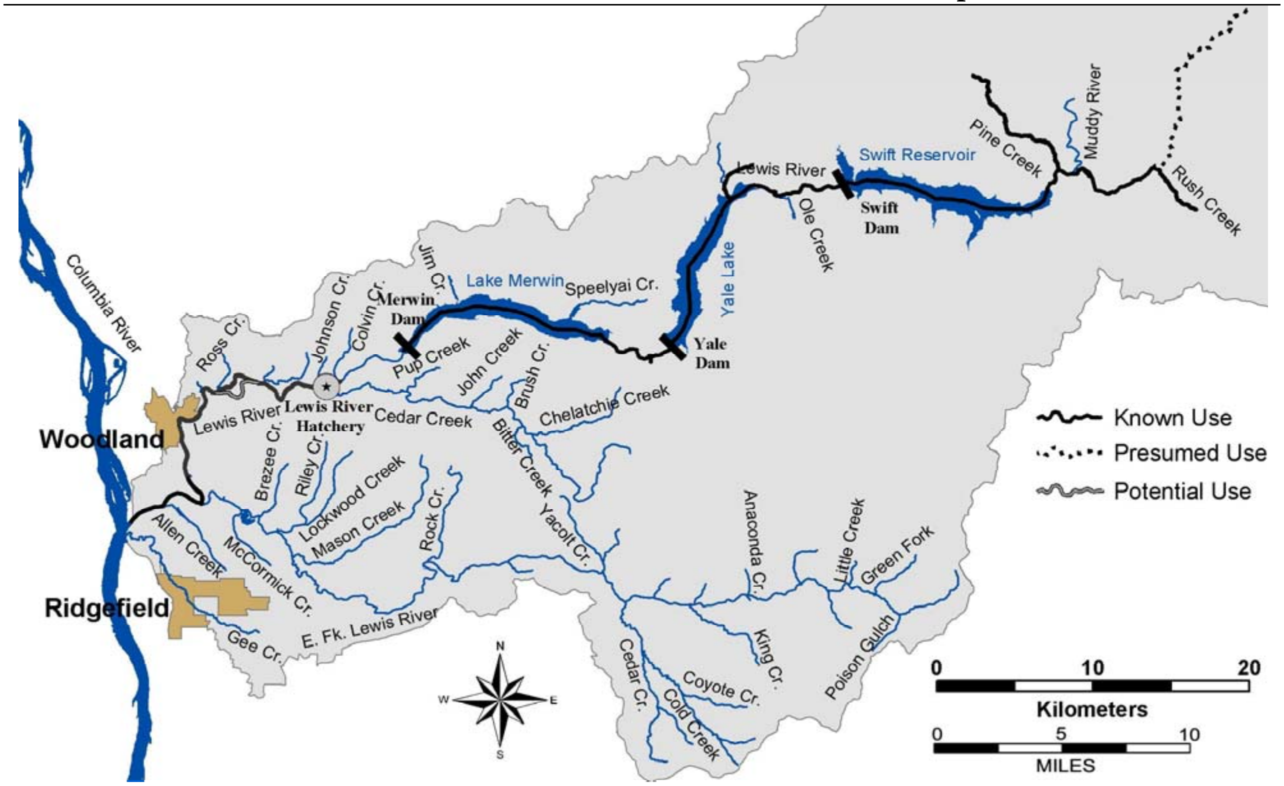
- The Lewis River Hatchery (about 4 miles downstream of Merwin Dam) and Speelyai Hatchery (Speelyai Creek in Merwin Reservoir) do not produce winter steelhead
- The Ariel (Merwin) Hatchery is located below Merwin Dam; the hatchery has been releasing winter steelhead in the Lewis basin since the early 1990s
- A net pen system has been in operation on Merwin Reservoir since 1979; annual average smolt production has been 35,000 winter steelhead; total release data are available from 1982-2001
- Hatchery fish contribute little to natural winter steelhead production in the NF Lewis River

Harvest

- No directed commercial or tribal fisheries target NF Lewis winter steelhead; incidental harvest currently occurs during the lower Columbia River spring chinook tangle net fisheries
- Treaty Indian harvest does not occur in the Lewis River basin
- Winter steelhead sport harvest (hatchery and wild) in the NF Lewis River averaged 300 fish during the 1960s and 1970s; average annual harvest in the 1980s averaged 1,577; since 1992, regulations limit harvest to hatchery fish only
- ESA limits fishery impact on wild winter steelhead

12.2.4 Bull Trout—Lewis River Subbasin

ESA: Threatened 1999	SASSI: Depressed 1998



Distribution

- The reservoir populations are isolated because there is no upstream passage at the dams

Life History

- Prior to dam construction anadromous and fluvial (rivers) forms were likely present

Diversity

- Genetic sampling in 1995 and 1996 showed that Lewis River bull trout are similar to Columbia River populations
- Swift samples were significantly different from Yale and Merwin samples, indicating that there may have been biological separation of upper and lower Lewis River stocks before construction of Swift Dam in 1958
- Stock designated based on geographic distribution

Abundance

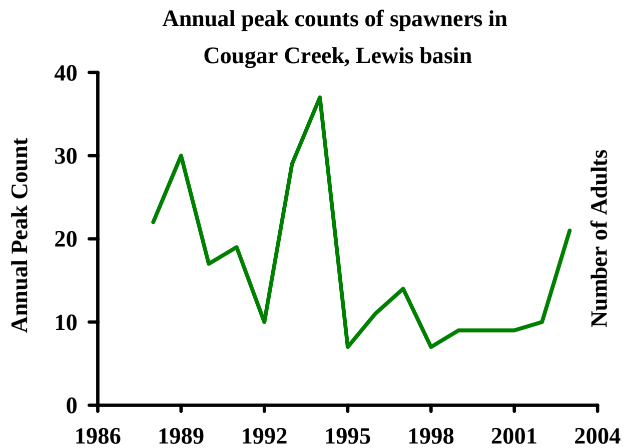
- No information on bull trout abundance in the lower NF Lewis is available

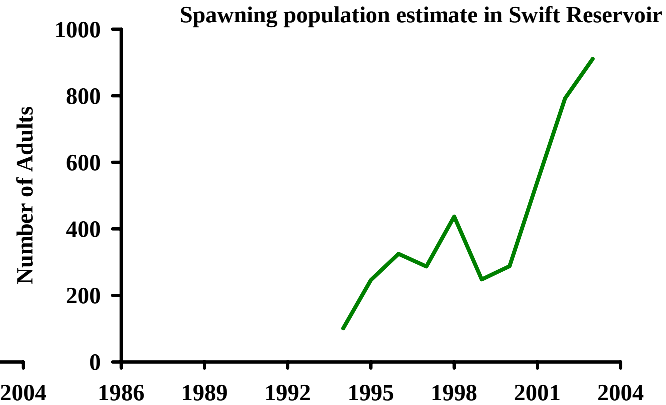
Productivity & Persistence

- WDFW (1998) considers Lewis River bull trout to be at moderate risk of extinction

Hatchery

- Three hatcheries exist in the subbasin: two below Merwin Dam, and one on the north shore of Merwin Reservoir. Bull trout are not produced in the hatcheries





Harvest

- Fishing for bull trout has been closed since 1992
- Hooking mortality from catch and release of bull trout in recreational fisheries targeting other species may occur

12.2.5 Cutthroat Trout—Lewis River Subbasin

ESA: Not Listed	SASSI: Unknown 2000

Distribution

- Anadromous forms exist in the NF Lewis and its tributaries up to Merwin Dam, which blocks passage
- Adfluvial fish have been observed in Merwin, Yale and Swift Reservoirs
- Resident fish are found in tributaries throughout the North and East Fork basins

Life History

- Anadromous, fluvial, adfluvial and resident forms are present
- Anadromous river entry is from July through December
- Anadromous spawning occurs from December through June
- Fluvial, adfluvial and resident spawn timing is from February through June

Diversity

- Distinct stock based on geographic distribution of spawning areas
- Genetic analysis has shows Lewis River cutthroat to be genetically distinct from other lower Columbia coastal cutthroat collections

Abundance

- Insufficient data exist to identify trends in survival or abundance
- No data describing run size exist
- In 1998, sea-run cutthroat creel survey results showed a catch of only 20 fish
- Fish population surveys in Yale Lake tributaries showed that cutthroat trout was the most abundant salmonid species in those streams
- Cutthroat were the only salmonid found in some small Yale Lake tributaries during sampling in 1996

Hatchery

- Prior to 1999 Merwin Hatchery annually released 25,000 sea-run smolts into the NF Lewis
- The program was discontinued in 1999 due to low creel returns and concerns over potential interaction with wild fish

Harvest

- Not harvested in ocean commercial or recreational fisheries
- Angler harvest of adipose fin clipped cutthroat occurs in the mainstem Columbia downstream of the Lewis River
- Lewis River wild cutthroat (unmarked fish) must be releases in mainstem Columbia and in Lewis River sport fisheries

12.3 Potentially Manageable Impacts

In Volume I of this Technical Foundation, we evaluated factors currently limiting Washington lower Columbia River salmon and steelhead populations based on a simple index of potentially manageable impacts. The index incorporated human-caused increases in fish mortality, changes in habitat capacity, and other natural factors of interest (e.g. predation) that might be managed to affect salmon productivity and numbers. The index was intended to inventory key factors and place them in perspective relative to each other, thereby providing general guidance for technical and policy level recovery decisions. In popular parlance, the factors for salmon declines have come to be known as the 4-H's: hydropower, habitat, harvest, and hatcheries. The index of potentially manageable mortality factors has been presented here to prioritize impacts within each subbasin.

- In general, loss of habitat quantity and quality has the highest relative impact on populations in the lower North Fork, while hydrosystem access and passage impacts are greatest for those populations that historically utilized the upper NF Lewis (i.e. winter steelhead and coho). Thus, for populations in the upper NF Lewis basin, the impact of hydrosystem access and passage minimizes the relative importance of all other potentially manageable impact factors.
- Loss of estuary habitat quantity and quality has high relative impacts on chum and moderate impacts on fall chinook and late fall chinook.
- Harvest has relatively high impacts on fall chinook and late fall chinook, while harvest impacts to spring chinook, chum, winter steelhead, and coho are relatively minor.
- Hatchery impacts are high to moderate for late fall chinook, spring chinook, winter steelhead and coho. Hatchery impacts on chum and fall chinook are relatively low.
- Impacts of predation are moderately important to coho, but are relatively minor for all populations.

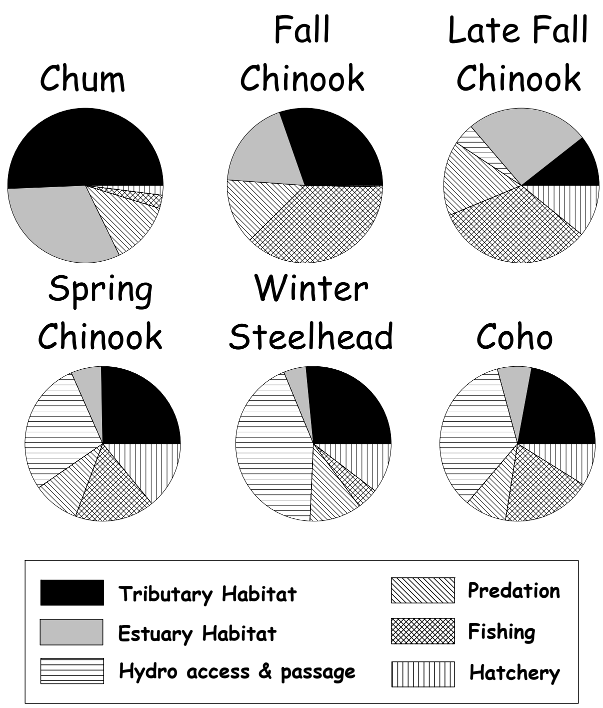


Figure 12-5. Relative index of potentially manageable mortality factors for each species in the North Fork Lewis subbasin.

12.4 Hatchery Discussion

A discussion of hatcheries in the Lewis River basin is included in Vol II, Chapter 10.4.

12.5 Fish Habitat Conditions

12.5.1 Passage Obstructions

The three dams on the mainstem are Merwin Dam (RM 20), Yale Dam (RM 35), and Swift No. 1 (RM 45). Each dam creates its own reservoir with lengths of 14.5, 10.5 and 11.5 miles, respectively. A smaller dam, Swift No. 2, diverts water from the tailrace of Swift No. 1 down a 3.5-mile canal to a power generating facility. On April 21, 2002 the Swift number 2 powerhouse was destroyed by a breach in the power canal. A rebuild of the powerhouse is underway.

All anadromous passage has been blocked by the 240-foot high Merwin Dam since shortly after its construction in 1931. This facility blocked approximately 80% of the available habitat for steelhead, approximately 50% of the spawning habitat for fall chinook, and virtually eliminated the natural run of spring chinook (WDF 1993, McIssac 1990). Over 25 miles of stream habitat was directly inundated by the reservoirs (USFS 1995a).

Bull trout populations that were historically fluvial and/or anadromous are now adfluvial populations isolated in the reservoirs, with limited access to spawning habitat. Bull Trout spawning occurs in tributaries to Swift Reservoir and Yale Lake and there is no upstream passage between reservoirs. Bull trout found in Lake Merwin are believed to have spilled over Yale Dam (Wade 2000). Passage issues for bull trout in the upper North Fork basin have been identified in the Bull Trout Recovery Plan (USFWS 2002). Upstream and downstream passage at Yale Dam and Swift Dam (Number 1 and 2) is considered necessary for Lewis River bull trout recovery (USFWS 2002).

12.5.2 Stream Flow

Average annual stream flow measured below Merwin Dam is 4,849 cfs. Flow is dominated by winter rains, though spring and summer flow in the North Fork is augmented by glacier melt. The annual hydrograph indicates peak flows from winter rain and rain-on-snow events as well as peak flows in the spring due to snowmelt (Figure 12-6). Reservoir levels and flow between reservoirs are largely controlled by releases from the dams.

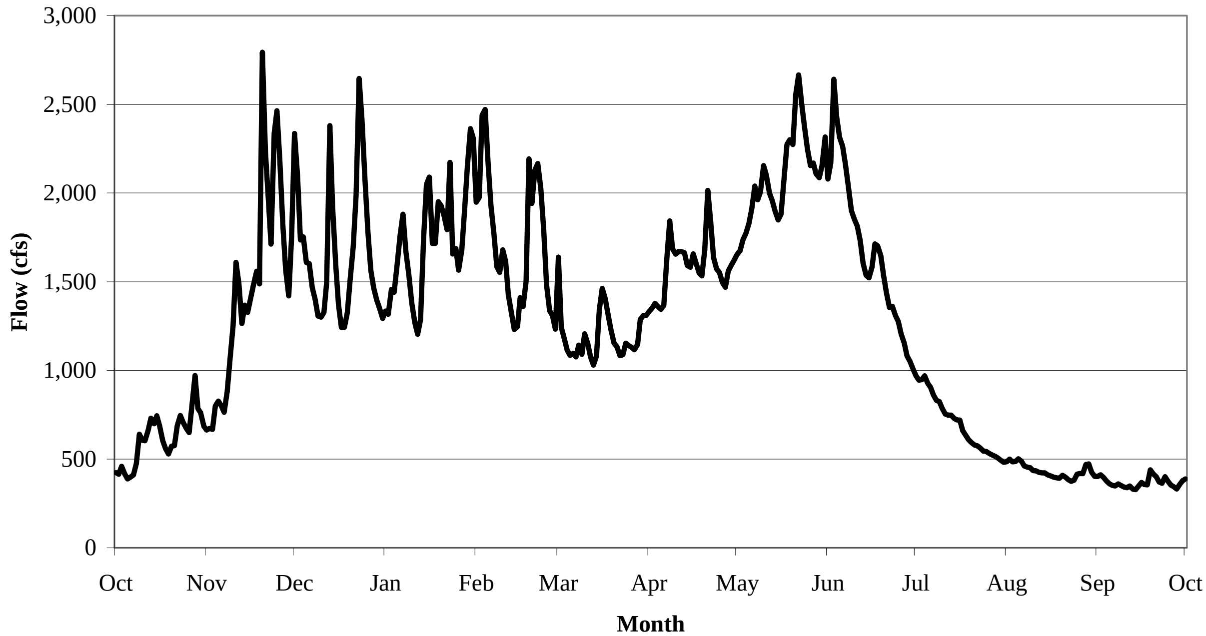


Figure 12-6. Lewis River flow above reservoirs (Lewis River above Muddy Creek) for water years 1961-1970. These data exhibit the double humped hydrograph typical of a winter rain/rain-on-snow and spring snowmelt flow regime. USGS Gage #14216000; Lewis River above Muddy River near Cougar, Wash.

The Integrated Watershed Assessment (IWA), which is presented in greater detail later in this chapter, indicates that runoff properties are "impaired" in 10 of the 77 subwatersheds (7th field) in the upper Lewis basin. Seven subwatersheds are "moderately impaired" and the remainder are "functional". Impaired subwatersheds are located primarily in the Canyon Creek drainage (Lake Merwin tributary) and other small Lake Merwin tributaries on the north side of Lake Merwin close to Merwin Dam. These areas are located mostly in private commercial timberland where forests are in young seral stages and road densities are high. Most of the basin that is within the Gifford Pinchot National Forest is in good condition with regards to runoff properties, however, peak flow analyses by the USFS in 1995 and 1996 indicated potential concerns with increases in the 2-year peak flow in lower and middle Pine Creek and middle Swift Reservoir tributaries due to vegetation conditions (USFS 1995b, USFS 1996). Many streams were also characterized as having extended stream channel networks due to roads and road ditches, which can increase peak flow potential. The channel network of lower Pine Creek has increased 48% due to the presence of roads.

The toe-width method was used to estimate low flow impacts on Upper Lewis River tributaries. The resulting values were compared to stream gauge data and spot flow measurements (Caldwell 1999). Results indicate that in Speelyai Creek, flow may be limiting for juvenile rearing June through November, and may be limiting for fall spawning species in the fall. Flows appear to be adequate for summer steelhead and coho spawning. In Canyon Creek, flows are below optimum for fall spawning, except for coho. Flows for coho spawning approach optimal conditions by mid October. In Cougar Creek, flows are also below optimum for fall spawning, except for coho. Flows for salmonid rearing are adequate.

A 1996 PacifiCorp survey in Panamaker (tributary to Cougar Creek), Ole, Rain, and Dog Creeks indicated that these experienced intermittent fall flow, potentially limiting available habitat (Wade 2000).

Total consumptive water use in the basin, estimated at approximately 672 million gallons per year (mgy) is expected to increase by 573 mgy by 2020, however, the use is minor when compared to stream base flows (LCFRB 2001).

12.5.3 Water Quality

In the upper Lewis basin, stream water temperatures have exceeded the state standard of 16°C in Pine, Siouxon, Canyon, and Quartz Creeks. This is of particular concern in Pine Creek due to the presence of bull trout that require very cold water. High temperatures on the portions of Canyon and Siouxon that lie within state and private land are attributed to lack of stream shade. It is suspected that elevated temperatures in Pine Creek are due to channel widening from timber harvest and vegetation removal as a result of the 1980 Mount St. Helens eruption (USFS 1995b, USFS 1996).

High turbidity levels have been documented in some streams. In November 1994 turbidity was measured at 94 NTUs in the Muddy River, 36 NTUs in the upper mainstem Lewis, and 18 NTUs in Pine Creek (USFS 1995b).

A lack of marine derived nutrients from anadromous salmon carcasses may be a limiting factor in the upper watershed but little information exists on this subject (Wade 2000).

12.5.4 Key Habitat

The USFS has evaluated pool frequency in the upper watershed. Upper Pine Creek, an important Bull Trout spawning stream, has both poor (</=50% desired frequency) and fair (50-99% desired frequency) pool frequency. Tributaries on the south side of Swift Reservoir received a poor pool frequency rating (USFS 1995). Many tributaries to Canyon Creek and Siouxon creek also have a poor rating, potentially impacting cutthroat trout. In the upper watershed above the Alec Creek confluence, approximately 70% of the surveyed reaches received a poor rating and 26% received a rating of fair for pool frequency (USFS 1995b).

The USFS gauges habitat fragmentation by calculating the amount of road crossings over streams per lineal mile of stream segment. Using this approach, the lower Pine Creek basin is classified as having "extreme" fragmentation (>2.26 road crossings/stream mile) and the upper Pine Creek basin has "high" fragmentation (>1.5 road crossings/stream mile). Cougar Creek was not surveyed (USFS 1995b).

12.5.5 Substrate & Sediment

Surface erosion is a particular concern in the northern portion of the upper basin due to highly erodable ash and pumice soils from past eruptions of Mount St. Helens. Mass wasting is also a concern throughout the basin and became particularly evident in the winter 1996 floods that resulted in some large landslides. Portions of the basin have a combination of high road densities, steep slopes, and highly erodable soils that make them especially vulnerable to increased sediment production and transport. These conditions, combined with heavy logging on steep slopes, have increased the potential for sediment production. According to USFS watershed analyses, over 11% of the Pine Creek basin is considered potentially unstable, over 40% of the Cougar Creek basin is considered potentially unstable, and over 27% of the upper watershed (above the Pine Creek confluence) is considered either unstable or potentially unstable (USFS 1995a, USFS 1995b, USFS 1996).

Sediment supply conditions were evaluated as part of the IWA watershed process modeling, which is presented later in this chapter. The results show that the subwatersheds with the greatest sediment supply impairments are tributary basins on the northeastern portion of Swift Reservoir and in lower Canyon Creek. Approximately half of the remaining subwatersheds are rated as moderately impaired and the remainder are rated as functional. The functional subwatersheds are clustered primarily in the upper portion of the basin. Impaired sediment supply conditions are related primarily to high road densities on naturally unstable slopes.

As part of the Interior Columbia Basin Ecosystem Management Project (ICBEMP), investigators found that an increase in road densities is associated with declines in status of bull trout. In areas where bull trout populations were strong, road densities averaged 0.45 mi/ mi^2, whereas areas where populations were depressed or absent, road densities averaged 1.36 mi/ mi^2 and 1.71 mi/ mi^2, respectively (Quigley and Arbelbide 1997). The majority of the subwatersheds contributing to bull trout streams have road densities greater than 2 miles/mi^2.

Sediment production from private forest roads is expected to decline over the next 15 years as roads are updated to meet the new forest practices standards, which include ditchline disconnect from streams and culvert upgrades. The frequency of mass wasting events should also decline due to the new regulations, which require geotechnical review and mitigation measures to minimize the impact of forest practices activities on unstable slopes.

12.5.6 Woody Debris

LWD concentrations in Pine Creek are low (<40 pieces per mile). Pine Creek also has low recruitment potential due to logging and effects of the 1980 eruption of Mount St. Helens. Surveys in the upper watershed above the Alec Creek confluence indicate that approximately 53 percent of the surveyed reaches had less than 40 pieces per mile (USFS 1995b).

12.5.7 Channel Stability

An aerial photograph analysis conducted by the USFS indicated that reaches of Pine and Swift Creeks have been adjusting to past timber harvest, roading, and the Mount St. Helens eruption. Reaches in Pine Creek increased in width by as much as 210% between 1959 and 1989 and are considered the most sensitive reaches in the area due to highly erodible mudflow deposits. High rates of bank erosion on these streams were also noticed during the analysis (USFS 1996). In 1989, the Upper Lewis mainstem, Quartz Creek, and Pin Creek were still adjusting from past sediment pulses due to 1970s flooding. Several reaches of steams on the south side of the upper mainstem suffer from bank instability and erosion (USFS 1995b).

12.5.8 Riparian Function

According to IWA watershed process modeling, which is presented in greater detail later in this chapter, 42 of the 77 subwatersheds in the upper Lewis basin are moderately impaired with regards to riparian function and the remainder are considered functional. Functional riparian areas are located primarily in the upper mainstem subwatersheds above the Muddy Creek confluence and in Siouxon Creek subwatersheds.

The Regional Ecosystem Assessment Project (REAP) report characterized riparian reserves in the upper Lewis basin as having between 50-80% late successional forest. The portion of the basin between upper Yale Lake and just above Pine Creek has only 22% of stream riparian reserves in late successional stages (USFS 1996). The upper basin (above the Alec Creek confluence) has 46% of stream riparian reserves in late successional stages (USFS 1995b).

Timber harvest has occurred on approximately 36%, 77%, and 23% of the riparian reserves in the upper, middle, and lower Pine Creek basins, respectively (USFS 1996). On Rush Creek, 13% of the riparian area in the upper basin and 23% in the lower basin has been harvested (USFS 1995a).

Riparian function is expected to improve over time on private forestlands. This is due to the requirements under the Washington State Forest Practices Rules (Washington Administrative Code Chapter 222). Riparian protection has increased dramatically today compared to past regulations and practices.

12.5.9 Floodplain Function

The Upper Lewis system consists of steep slopes with limited floodplains. Any floodplains along the mainstem would have been inundated by the reservoirs. Other floodplain areas are largely intact.

12.6 Fish/Habitat Assessments

The previous descriptions of fish habitat conditions can help identify general problems but do not provide sufficient detail to determine the magnitude of change needed to affect recovery or to prioritize specific habitat restoration activities. A systematic link between habitat conditions and salmonid population performance is needed to identify the net effect of habitat changes, specific stream sections where problems occur, and specific habitat conditions that account for the problems in each stream reach. In order to help identify the links between fish and habitat conditions, the Ecosystem Diagnosis and Treatment (EDT) model was applied to upper NF Lewis River spring chinook, coho, and winter steelhead. A thorough description of the EDT model, and its application to lower Columbia salmonid populations, can be found in Volume VI.

Three general categories of EDT output are discussed in this section: population analysis, reach analysis, and habitat factor analysis. Population analysis has the broadest scope of all model outputs. It is useful for evaluating the reasonableness of results, assessing broad trends in population performance, comparing among populations, and for comparing past, present, and desired conditions against recovery planning objectives. Reach analysis provides a greater level of detail. Reach analysis rates specific reaches according to how degradation or restoration within the reach affects overall population performance. This level of output is useful for identifying general categories of management (i.e. preservation and/or restoration), and for focusing recovery strategies in appropriate portions of a subbasin. The habitat factor analysis section provides the greatest level of detail. Reach specific habitat attributes are rated according to their relative degree of impact on population performance. This level of output is most useful for practitioners who will be developing and implementing specific recovery actions.

12.6.1 Population Analysis

Population assessments under different habitat conditions are useful for comparing fish trends and establishing recovery goals. Fish population levels under current and potential habitat conditions were inferred using the EDT model based on habitat characteristics of each stream reach and a synthesis of habitat effects on fish life cycle processes. Habitat-based assessments were completed in the upper NF Lewis basin for spring chinook, coho, and winter steelhead. There is currently no passage above the dams. Hypothetical survival through the dams and reservoirs was modeled at 100% since the primary objective of the EDT analysis is to assess the relative impact of habitat conditions in the upper basin. This should be taken into consideration when interpreting the numbers presented in the baseline EDT population analysis.

Model results indicate that adult productivity has declined for all species in the upper NF Lewis basin (Table 12-1). Current productivities are between 21% and 44% of historical levels. Adult abundance levels have also declined sharply for all species (Figure 12-7). Spring chinook have seen the greatest decline in adult abundance, with current estimates at only 15% of historical levels. Species diversity (as measured by the diversity index) has decreased from historical estimates for the upper NF Lewis (Table 12-1). Fall chinook and spring chinook diversity is currently at 35% and 30% of historical levels, respectively. Both coho and winter steelhead diversity has declined by 51% and 57%, respectively.

As with adult productivity, smolt productivity has declined for all species in the upper NF Lewis. Current productivity estimates are between 31% and 57% of the historical smolt productivity, depending on species (Table 12-1). Smolt abundance numbers are similarly low, especially for spring and fall chinook (Table 12-1). Current smolt abundance estimates for spring and fall chinook are at 20% and 30% of historical levels, respectively.

Model results indicate that restoration of PFC conditions would have important benefits in all performance parameters for all species (Table 12-1). For adult abundance, restoration of PFC conditions would increase current returns from 30% for winter steelhead to 90% for spring chinook. Similarly, smolt abundance numbers would increase for all species (Table 12-1). Spring chinook would see the greatest increase in smolt numbers with a 74% increase.

Table 12-1. Upper NF Lewis — Population productivity, abundance, and diversity (of both smolts and adults) based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

	Adult Abundance			Adult Productivity			Diversity Index			Smolt Abundance			Smolt Productivity		
Species	**P**	**PFC**	**T[1]**	**P**	**PFC**	**T[1]**	**P**	**PFC**	**T[1]**	**P**	**PFC**	**T[1]**	**P**	**PFC**	**T[1]**
Spring Chinook	1,624	3,079	10,560	4.7	8.0	15.0	0.30	0.44	0.99	66,195	114,944	335,351	176	290	424
Coho	11,526	16,208	23,332	4.7	7.7	21.8	0.48	0.59	0.97	254,912	358,878	345,473	92	150	295
Winter Steelhead	1,952	2,533	4,954	8.0	15.0	24.1	0.42	0.43	0.98	32,330	41,276	73,470	131	240	350

[1] Estimate represents historical conditions in the basin and current conditions in the mainstem and estuary.

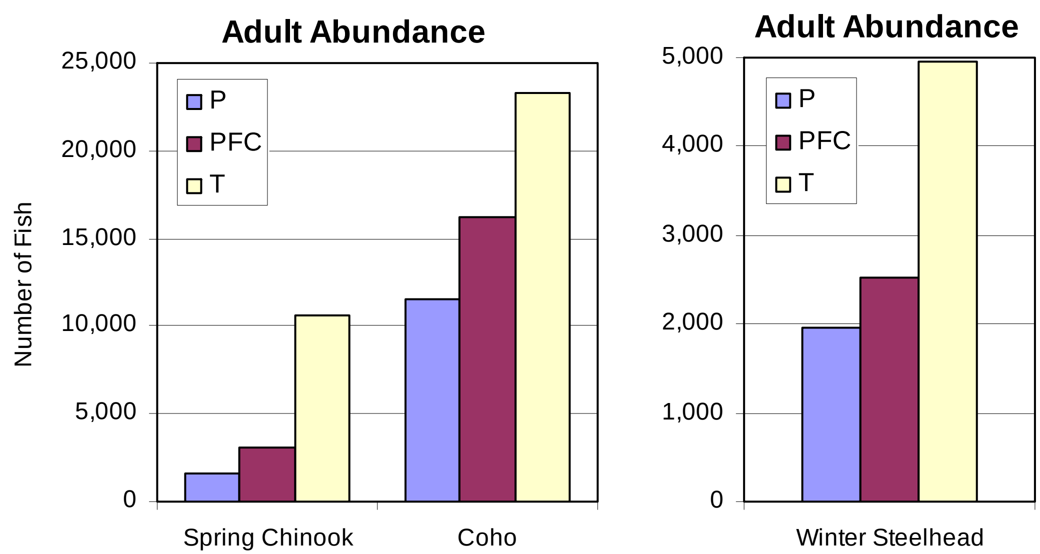


Figure 12-7. Upper NF Lewis— Adult abundance of upper NF Lewis spring chinook, coho and winter steelhead based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

12.6.2 Reach Analysis

Habitat conditions and suitability for fish are better in some portions of a subbasin than in others. The reach analysis of the EDT model uses estimates of the difference in projected population performance between current/patient and historical/template habitat conditions to identify core and degraded fish production areas. Core production areas, where habitat degradation would have a large negative impact on the population, are assigned a high value for preservation. Likewise, currently degraded areas that provide significant potential for restoration are assigned a high value for restoration. Collectively, these values are used to prioritize the reaches within a given subbasin. See Figure 12-8 for a map of EDT reaches in the upper NF Lewis Basin.

The reach analysis for the upper NF Lewis was conducted for spring chinook, coho, and winter steelhead. For all species, initial reach analyses showed strong restoration potential in reaches that are now inundated by Merwin, Yale, and Swift Reservoirs. These impoundments flooded approximately 30 stream miles of quality habitat. Due to the impracticality of any restoration measures in the flooded reaches (beside removal of the dams), these reaches were subsequently omitted and analyses run again.

Reaches with a high priority for spring chinook are located in the upper Lewis mainstem (Lewis 18-20, 22, 25 and 27) (Figure 12-9). These areas represent important chinook spawning and rearing habitat and show a combined preservation and restoration habitat recovery emphasis. Lewis 18 appears to be the reach with the highest potential for both preservation and restoration.

Important coho reaches are located in mainstem areas (Lewis 18, 19, 21 and 27) as well as in the tributaries (Diamond Creek, Clearwater Creek, Pepper Creek, and Muddy River among others) (Figure 12-10). These high priority reaches show a mix of recovery emphases. Reaches Lewis 18 and Muddy R1 appear to have the highest restoration potential of any reach modeled for coho. Similarly, reach Lewis 19 has the highest preservation emphasis of any reach modeled for coho.

For winter steelhead, the high priority reaches are similar to those for spring chinook, however, winter steelhead utilize tributary habitat to a greater extent (Figure 12-11). Important mainstem reaches include Lewis 19, 21, and 23-27. Important tributary reaches include areas in Crab Creek, Pine Creek, and Big Creek. The majority of important steelhead reaches show a preservation habitat recovery emphasis, with Lewis 18, Lewis 27, and Crab Creek showing a combined preservation and restoration recovery emphasis.

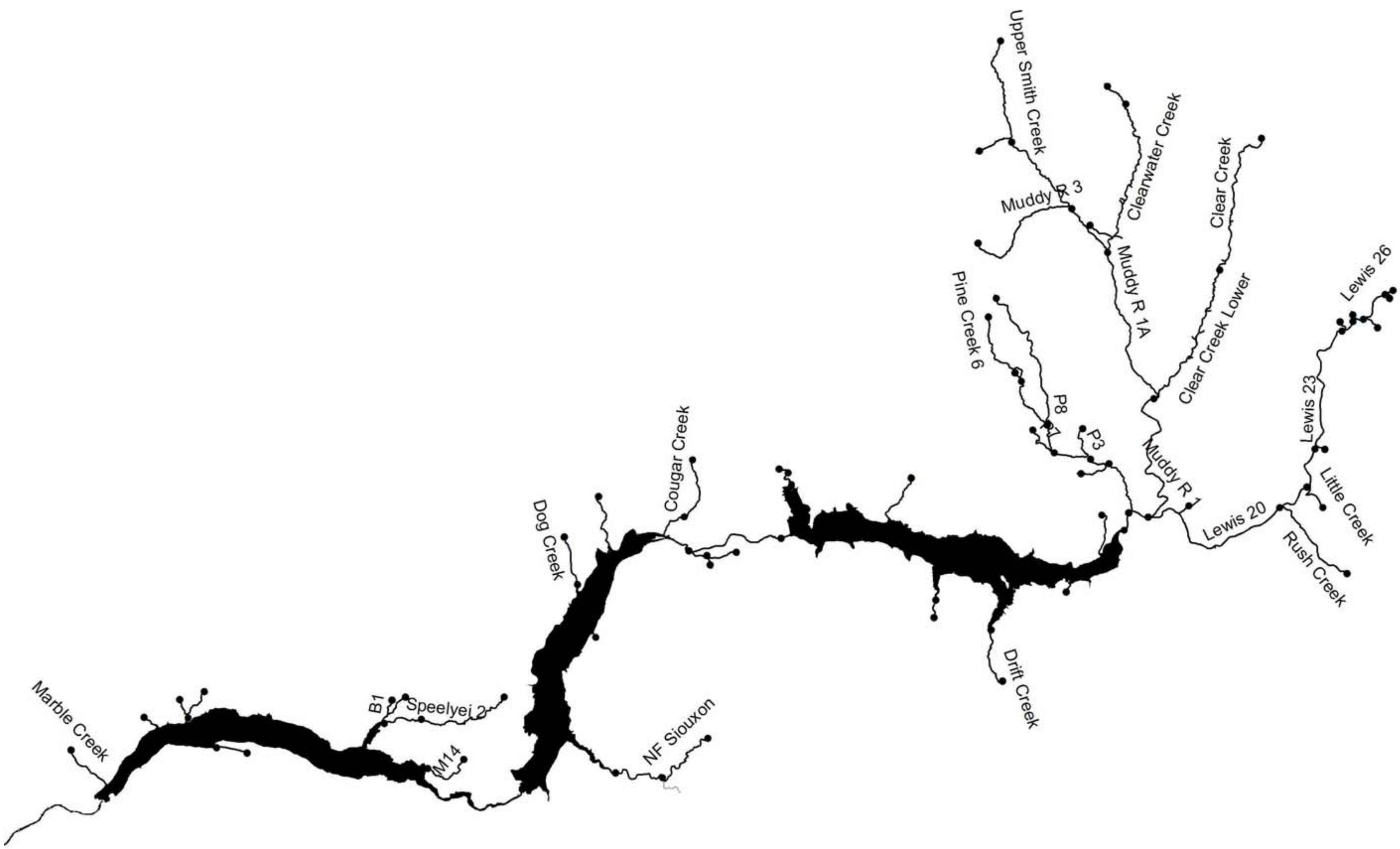


Figure 12-8. Upper North Fork Lewis Basin EDT reaches. Some reaches are not labeled for clarity.

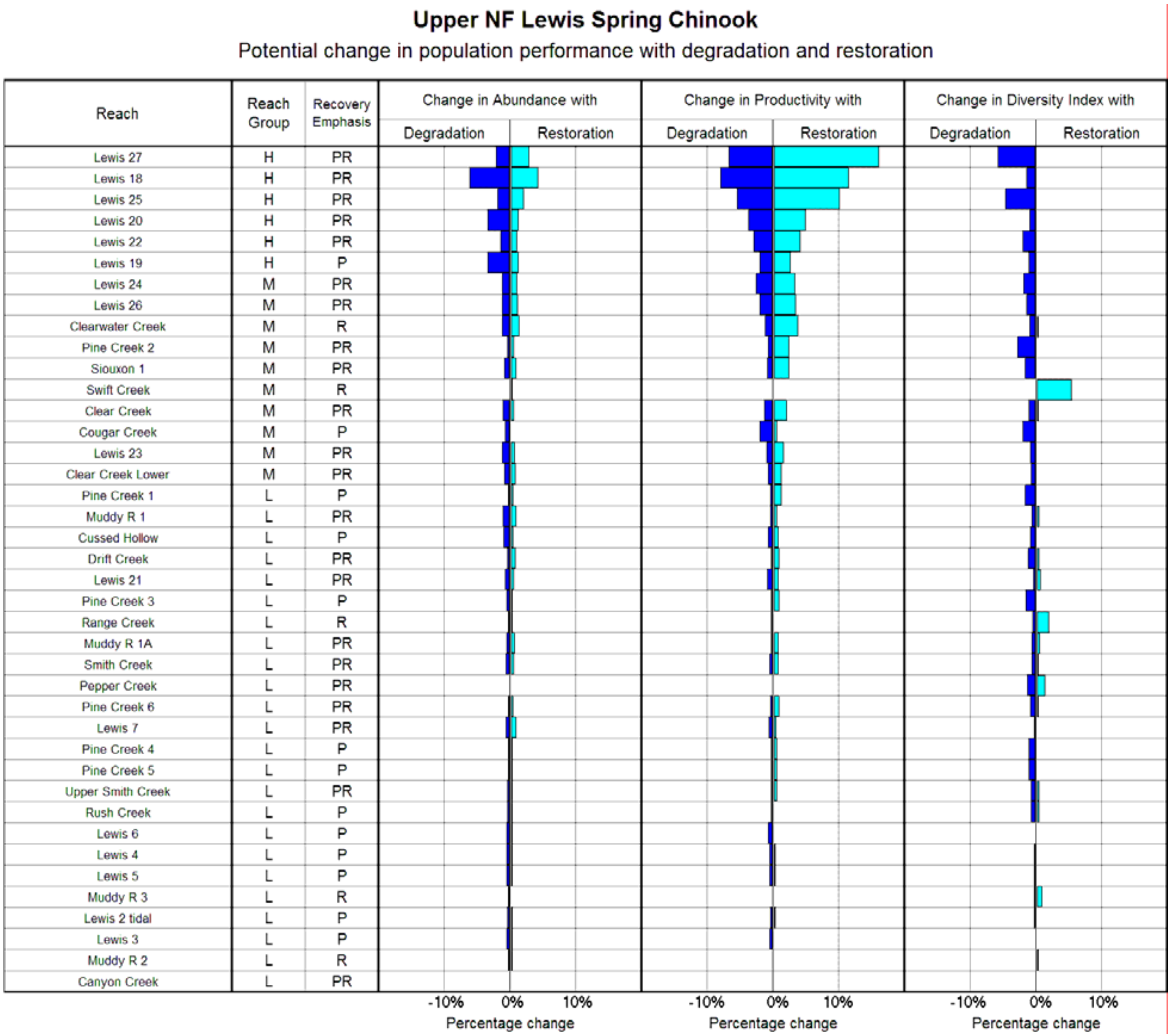


Figure 12-9. Upper NF Lewis spring chinook ladder diagram. The rungs on the ladder represent the reaches and the three ladders contain a preservation value and restoration potential based on abundance, productivity, and diversity. The units in each rung are the percent change from the current population. For each reach, a reach group designation and recovery emphasis designation is given. Percentage change values are expressed as the change per 1000 meters of stream length within the reach. See Volume VI for more information on EDT ladder diagrams.

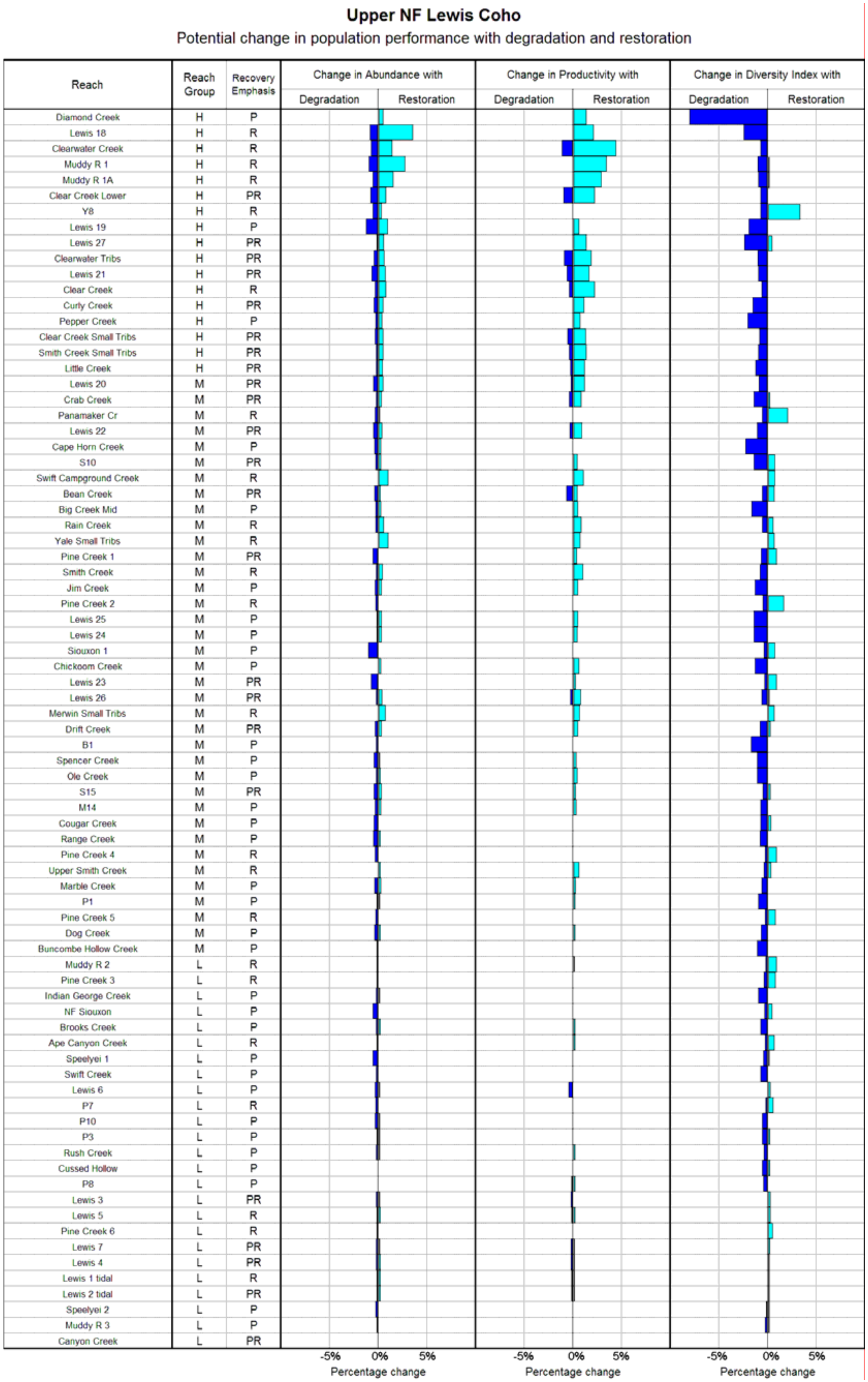


Figure 12-10. Upper NF Lewis coho ladder diagram.

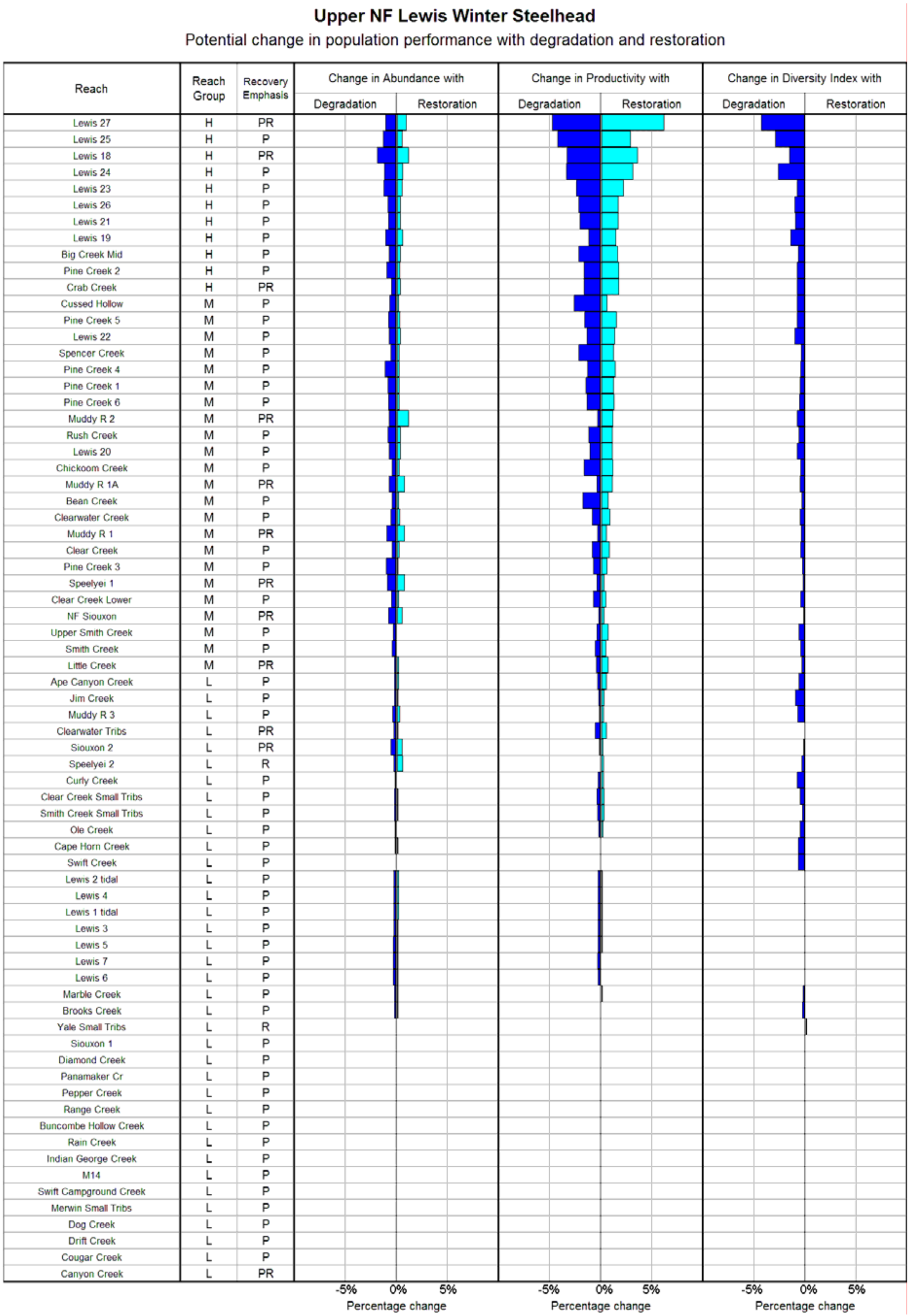


Figure 12-11. Upper Lewis winter steelhead ladder diagram.

12.6.3 Habitat Factor Analysis

The Habitat Factor Analysis of EDT identifies the most important habitat factors affecting fish in each reach. Whereas the EDT reach analysis identifies reaches where changes are likely to significantly affect the fish, the Habitat Factor Analysis identifies specific stream reach conditions that may be modified to produce an effect. Like all EDT analyses, the reach analysis compares current/patient and historical/template habitat conditions. The figures generated by habitat factor analysis display the relative impact of habitat factors in specific reaches. The reaches are ordered according to their combined restoration and preservation rank. The reach with the greatest potential benefit is listed at the top. The dots represent the relative degree to which overall population abundance would be affected if the habitat attributes were restored to historical conditions.

High priority reaches for spring chinook are located in mainstem areas. These reaches have been negatively impacted primarily by alterations to sediment and key habitat, with lesser impacts related to channel stability, habitat diversity, temperature, competition, predation, and food (Figure 12-12). High sediment impacts are related to large floods in the 1970s that delivered pulses of sediment that widened channels and contributed to instability (USFS 1995). These channels are still recovering. Predation impacts are primarily due to the potential for bull trout predation on juvenile spring chinook. Habitat diversity has been reduced due to riparian degradation and low LWD quantities compared to historical levels.

For coho, the high priority reaches appear to be most impacted by sediment, habitat diversity, key habitat, and food (Figure 12-13). Some of these impacts are related to degraded riparian, channel, and hillslope conditions due to the Mount St. Helens eruption. Other impacts are most likely associated with road construction/condition and riparian harvest, as discussed above for spring chinook.

As with spring chinook, high priority winter steelhead reaches are generally located in the mainstem areas. The greatest impacts here are sediment and habitat diversity, with lesser impacts from predation, competition, flow, and food (Figure 12-14). Once again, lingering conditions from the Mount St. Helens eruption, high road densities, and timber harvest are the primary drivers of these impacts (refer to the discussion above for spring chinook). Furthermore, these channels are still recovering from large sediment pulses from 1970s floods, which widened channels and created unstable conditions (USFS 1995). The February 1996 flood further exacerbated sediment conditions. Habitat diversity impacts are related to degraded riparian zones (harvest impacts) and low instream LWD levels.

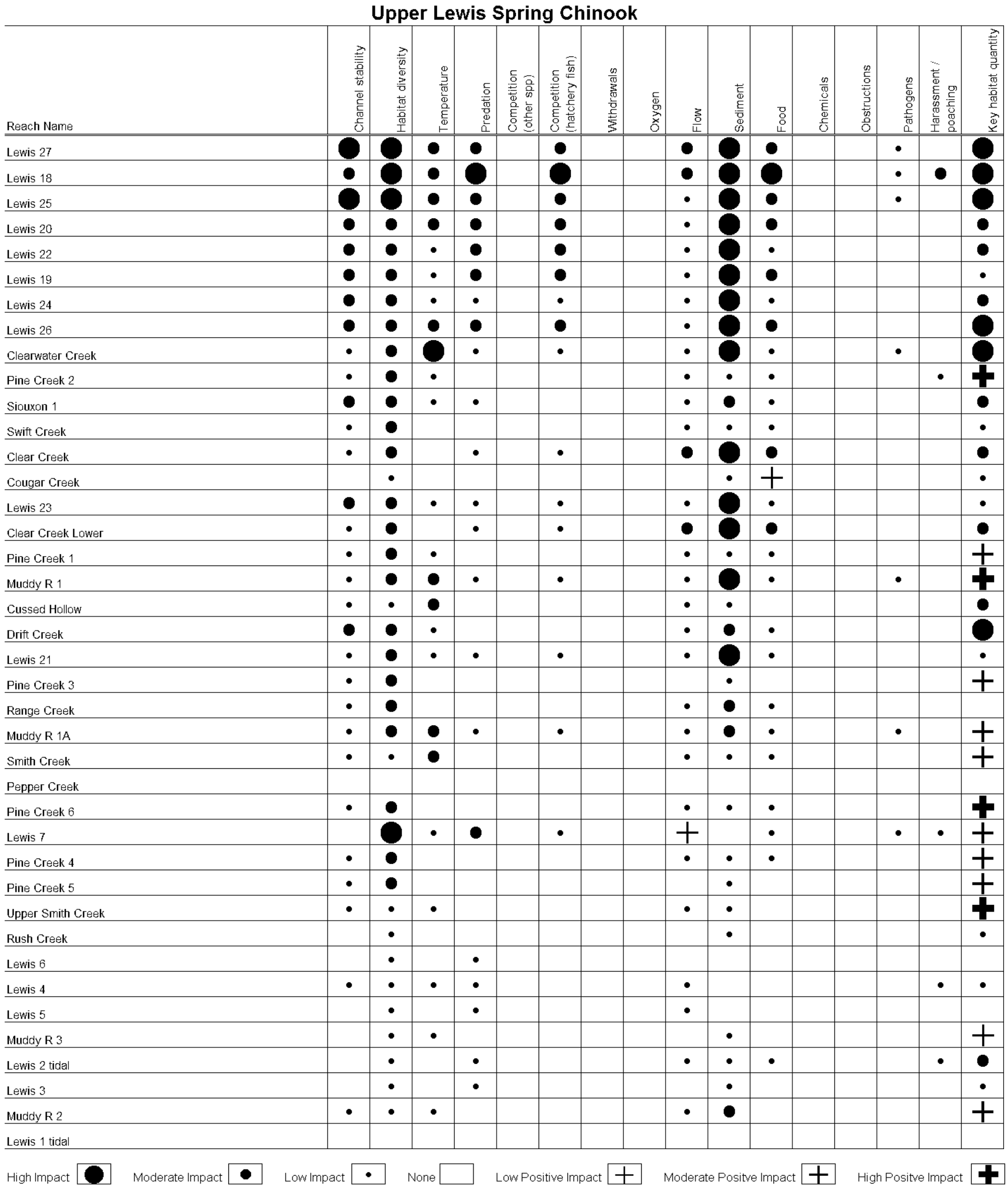


Figure 12-12. Upper NF Lewis spring chinook habitat factor analysis diagram. Diagram displays the relative impact of habitat factors in specific reaches. The reaches are ordered according to their restoration and preservation rank, which factors in their potential benefit to overall population abundance, productivity, and diversity. The reach with the greatest potential benefit is listed at the top. The dots represent the relative degree to which overall population abundance would be affected if the habitat attributes were restored to template conditions. See Volume VI for more information on habitat factor analysis diagrams.

Upper Lewis Coho

ReachName	Channel stability	Habitat diversity	Temperature	Predation	Competition (other spp)	Competition (hatchery fish)	Withdrawals	Oxygen	Flow	Sediment	Food	Chemicals	Obstructions	Pathogens	Harassment / poaching	Key habitat quantity
Diamond Creek	Moderate	High		Low		Low			Moderate	High	Low					Low
Lewis 18	Moderate	High	Low	High		High			Moderate	High	High			Moderate	Low	High
Clearwater Creek	Moderate	High	High	Low		Moderate			Moderate	High	High			Low		High
Muddy R 1	Moderate	High	High	Moderate		High			Moderate	High	High			Low	Low	High Positive
Muddy R 1A	Moderate	High	Moderate	Moderate		Moderate			Moderate	High	Moderate			Low		Moderate Positive
Clear Creek Lower	Low	High		Low		Low			Moderate	High	High			Low		High
Y8	Moderate	Moderate							Low	Moderate	Low					Low
Lewis 19	Moderate	High	Low	Moderate		Moderate			Low	High	Moderate			Low		Low
Lewis 27	Moderate	High		Low		Low			Low	High	Low			Low		High
Clearwater Tribs	Low	High		Low		Low			Moderate	High	Moderate			Low		High
Lewis 21	Moderate	High	Low	Moderate		Moderate			Low	High	Moderate			Low		Moderate
Clear Creek	Low	High		Low		Low			Moderate	High	Moderate			Low		High
Curly Creek	Moderate	High		Low		Low			Low	High	Moderate					High
Pepper Creek	Moderate	Moderate	Low	Low		Low			Low	High	Low					High
Clear Creek Small Tribs	Low	Moderate		Low		Low			Moderate	High	Moderate			Low		High
Smith Creek Small Tribs	Low	Moderate		Low		Low			Moderate	High	Moderate			Low		High
Little Creek	Low	Moderate				Low			Moderate	High	Low					Moderate
Lewis 20	Low	High	Low	Low		Moderate			Low	Moderate	Moderate					Low
Crab Creek	Low	Moderate	Low	Low		Low			Low	High	Low					Moderate
Panamaker Cr	Low	Low							Low	Low						
Lewis 22	Low	Moderate		Low		Low			Low	Moderate	Low					Low
Cape Horn Creek	Low	Moderate	Low			Low			Low	Low	Low					Moderate
S10	Moderate	Moderate							Low	Moderate	Low					Low
Bean Creek	Low	Moderate							Low	Low	Low					Moderate
Big Creek Mid	Moderate	Moderate							Low	Moderate						Moderate
Rain Creek	Moderate	Moderate	Low	Low		Low			Moderate	High	Moderate					High
Pine Creek 1																
Smith Creek	Low	High	Low	Low		Low			Low	Low	Low			Low		Moderate Positive
Jim Creek	Low	Moderate	Low	Low		Low			Low	High	Moderate					Moderate
Pine Creek 2																
Lewis 25	Moderate	Moderate		Low		Low				Moderate	Low					Moderate
Lewis 24	Low	Moderate		Low		Low			Low	Moderate	Low					Moderate
Siouxon 1																
Chickoom Creek	Moderate	Moderate	Low						Low	Moderate	Low					Moderate
Lewis 23																
Lewis 26	Low	Moderate		Low		Low			Low	High	Low					Moderate
Drift Creek	Moderate	Moderate							Low	Moderate	Low					Moderate
B1																Low
Spencer Creek	Low	Low							Low	Low						Moderate
Ole Creek	Low	Low	Low	Low		Low			Low	Moderate	Moderate					Moderate
S15	Moderate	Moderate							Low	Moderate	Low					Low
M14	Low	Moderate	Low	Low		Low			Low	High	Moderate					Moderate
Cougar Creek		Low								Low						Low
Range Creek	Moderate	Low							Low	Moderate	Low					Low
Pine Creek 4																
Upper Smith Creek	Low	Moderate	Low						Low	Low	Low					High Positive

High Impact ● Moderate Impact • Low Impact · None Low Positive Impact + Moderate Positve Impact + High Positve Impact ✚

Figure 12-13. Upper NF Lewis coho habitat factor analysis diagram. Some low priority reaches are not included for display purposes.

Upper Lewis Winter Steelhead

Reach Name	Channel stability	Habitat diversity	Temperature	Predation	Competition (other spp)	Competition (hatchery fish)	Withdrawals	Oxygen	Flow	Sediment	Food	Chemicals	Obstructions	Pathogens	Harassment / poaching	Key habitat quantity
Lewis 27	L	H	L	H		M			M	H	M			L		H
Lewis 25	L	H	L	M		M			L	H	M			L		M
Lewis 18	M	H	L	H		H			M	H	H			M	L	L
Lewis 24	M	H	L	M		M			M	H	M			L		M
Lewis 23	L	H	L	M		M			M	H	M			L		M
Lewis 26	L	M	L	M		M			L	H	L			L		M
Lewis 21	L	M	L	M		M			L	H	L			L		L
Lewis 19	L	H	L	M		M			L	H	M			L		
Big Creek Mid	L	H		L		L			M	H	L					H
Pine Creek 2	M	M	L	L		L			M	M	L				L	+H
Crab Creek		M	M	L		L			M	H	L			L		M
Cussed Hollow		M	L	L		L			M	L	L			L		M
Pine Creek 5	L	M	L	L		L			L	M	L			L	L	+H
Lewis 22	L	M	L	M		M			L	H	L			L		L
Spencer Creek																
Pine Creek 4	L	M	L	L		L			L	M	L				L	+H
Pine Creek 1	L	M	L	L		L			L	M	L				L	+H
Pine Creek 6	L	M	L	L		L			L	M	L				L	+H
Muddy R 2	M	H	M	M		M			H	H	M			M	L	+H
Rush Creek																
Lewis 20	L	M	L	M		M			L	H	M			L		L
Chickoom Creek	L	M	L	L		L			M	H	L			L		M
Muddy R 1A	M	M	M	M		M			M	H	M			M	L	+H
Bean Creek		L	L	L		L			M	H	L			L		M
Clearwater Creek	L	M	M	L		L			M	H	M			M		M
Muddy R 1	M	H	M	M		M			M	H	M			M	L	+H
Clear Creek	L	M		L		L			M	H	M			L		M
Pine Creek 3	L	M		L		L			L	M	L				L	+H
Speelyei 1	L	L		L		L			+L	L				L		M
Clear Creek Lower	L	M		L		L			M	H	M			L		L
NF Siouxon	M	H	M	L		L			M	H	L			L		M
Upper Smith Creek	M	H	M	L		L			M	H	M			L	L	
Smith Creek	M	M	M	L		L			M	M	M			M		+H
Little Creek		M		L		L			L	H	L					L
Ape Canyon Creek	L	M	L	L					L	M	L			L		M
Jim Creek	L	L	L	L		L			L	M	L					M
Muddy R 3	L	M	L	L		L			M	H	L			L	L	+H
Clearwater Tribs		L		L		L			M	H	L			L		L
Siouxon 2																
Speelyei 2																
Curly Creek		L		L					L	H	L					L
Clear Creek Small Tribs		L		L		L			L	M	L					L
Smith Creek Small Tribs																
Ole Creek		L		L					L	M	L					
Cape Horn Creek		L	L	L					L	L	L					L
Swift Creek	M	H	L	M		L			M	H	M					H
Lewis 2 tidal		M		L						M					M	M
Lewis 4		L		L						M					M	L
Lewis 1 tidal		M		L						M					M	M

High Impact (H) | Moderate Impact (M) | Low Impact (L) | None (blank) | Low Positive Impact (+L) | Moderate Positve Impact (+M) | High Positve Impact (+H)

Figure 12-14. Upper NF Lewis winter steelhead habitat factor analysis diagram.

12.7 Integrated Watershed Assessment (IWA)

For the purpose of recovery planning, the upper NF Lewis (above Merwin Dam) watershed is composed of 77 planning subwatersheds totaling 468,000 acres. The headwaters of the North Fork flow from the flanks of Mt. Adams, while several large tributaries, including Pine Creek, Smith Creek and Clearwater Creek (the latter two joining to form the Muddy River) flow from the slopes of Mt. St. Helens. The large majority of the upper NF Lewis watershed is under public ownership (80%). The subwatersheds furthest upstream are within the Gifford Pinchot National Forest (GPNF), with lower elevation areas falling under a patchwork of federal, state and private ownership. Most private holdings are in the downstream portion of the watershed. With the exception of hydro-project related facilities and a few small towns (e.g., Cougar) at lower elevations, timber production dominates the landscape, along with the increasing emphasis on non-consumptive forest uses under federal management. The lower watershed features the three reservoirs and four associated hydroelectric projects owned by PacifiCorp and Cowlitz County Public Utility District.

12.7.1 Results and Discussion

IWA results were calculated for all subwatersheds in the upper NF Lewis watershed. IWA results are calculated at the local level (i.e., within subwatershed, not considering upstream effects) and the watershed level (i.e., integrating the effects of the entire upstream drainage area as well as local effects). IWA results for each subwatershed are presented in Table 12-2. A reference map showing the location of each subwatershed in the basin is presented in Figure 12-15. Maps of the distribution of local and watershed level IWA results are displayed in Figure 12-16. Conditions for hydrology are mostly functional throughout the basin. Riparian and sediment conditions are mostly moderately impaired, with the remainder rated primarily as functional. In general, conditions deteriorate as one moves from the upper to the lower portion of the basin. The bulk of the heavily degraded subwatersheds are in the Canyon Creek/Fly Creek drainage, and in other portions of the lower watershed.

Table 12-2. Summary of IWA results for the upper NF Lewis River (above Merwin Dam)

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
10101	F	M	M	F	M	none
10102	F	F	F	F	F	none
10201	F	F	F	F	F	10101, 10102
10301	F	M	F	F	M	none
10401	F	F	F	F	F	none
10501	F	M	F	F	F	10502, 10401, 10301, 10201, 10101, 10102
10502	F	M	F	F	M	10401, 10301, 10201, 10101, 10102
10601	F	F	F	F	F	none
10701	F	F	F	F	F	none
10702	F	M	F	F	M	10703, 10701
10703	F	M	F	F	M	10701
10801	F	F	F	F	M	10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
10901	F	M	F	F	M	10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
10902	F	F	F	F	F	10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
11001	F	M	F	F	F	11002
11002	F	F	M	F	F	none
11201	F	F	F	F	F	11202
11202	F	F	M	F	F	none
11301	F	M	F	F	F	11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
11302	F	F	F	F	F	11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
11303	F	F	M	F	F	11304
11304	F	F	M	F	F	none
20101	F	F	M	F	F	none

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
20102	F	F	M	F	F	20101
20103	F	M	M	F	F	20102, 20101
20201	F	M	M	F	M	none
20202	F	M	M	F	M	20201
20203	F	F	M	F	F	none
20204	F	F	M	F	M	20203, 20202, 20201
20301	F	M	F	F	M	none
20302	F	M	F	F	M	none
20303	F	F	F	F	M	20302, 20301
20401	F	F	F	F	F	20303, 20302, 20301
20402	F	F	F	F	F	20401, 20303, 20302, 20301
20501	F	M	M	F	M	20103, 20102, 20101, 20204, 20203, 20202, 20201
20502	F	F	M	F	F	20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301
30101	F	F	M	F	F	none
30102	F	M	M	F	M	30101
30201	F	M	F	F	M	30202
30202	F	M	M	F	M	none
30301	F	I	M	F	F	30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
30302	F	M	M	F	F	30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
30401	F	M	M	F	M	30402
30402	F	M	F	F	M	none

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
30501	F	F	M	F	M	30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
30502	F	I	M	F	M	30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
30503	F	M	M	F	M	none
40101	F	M	F	F	M	40102, 40103
40102	M	M	F	M	M	none
40103	M	M	F	M	M	none
40201	F	M	M	F	M	40202, 40101, 40102, 40103
40202	F	F	F	F	M	40101, 40102, 40103
40301	F	M	M	F	M	40302, 40303, 40201, 40202, 40101, 40102, 40103
40302	F	M	F	F	M	40303
40303	F	M	F	F	M	none
40401	M	M	M	M	M	40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
40402	F	M	F	F	M	none
40501	F	M	M	F	M	40301, 40302, 40303, 40201, 40202, 40101, 40102, 40103, 40502, 40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
40502	F	M	M	M	M	40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
40503	I	M	M	M	M	40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
40504	M	F	M	M	F	none
40505	M	F	M	M	F	none
40506	F	F	F	F	F	none
60101	M	M	M	M	M	60102
60102	I	M	M	I	M	none
60103	I	M	M	I	M	none
60201	I	I	M	I	M	60203, 60204, 60205, 60202, 60103, 60101, 60102
60202	I	M	F	I	M	60103, 60101, 60102
60203	I	M	M	I	M	60204
60204	I	M	M	I	M	none
60205	M	M	F	M	M	none
60301	I	M	M	M	M	60306, 60302, 60303, 60304, 40505, 60305, 60201, 60203, 60204, 60205, 60202, 60103, 60101, 60102, 40501, 40301, 40302, 40303, 40201, 40202, 40101, 40102, 40103, 40502, 40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102

Subwatershed[a]	Local Process Conditions[b]			Watershed Level Process Conditions[c]		Upstream Subwatersheds[d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
60302	F	F	M	M	M	60303, 60304, 40505, 60305, 60201, 60203, 60204, 60205, 60202, 60103, 60101, 60102, 40501, 40301, 40302, 40303, 40201, 40202, 40101, 40102, 40103, 40502, 40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
60303	M	M	M	M	M	none
60304	M	M	M	M	M	40505, 60305, 60201, 60203, 60204, 60205, 60202, 60103, 60101, 60102, 40501, 40301, 40302, 40303, 40201, 40202, 40101, 40102, 40103, 40502, 40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
60305	I	M	M	F	M	60201, 60203, 60204, 60205, 60202, 60103, 60101, 60102, 40501, 40301, 40302, 40303, 40201, 40202, 40101, 40102, 40103, 40502, 40401, 40503, 40402, 40504, 40506, 30201, 30202, 30501, 30502, 30503, 30401, 30402, 30301, 30302, 30102, 30101, 20502, 20501, 20103, 20102, 20101, 20204, 20203, 20202, 20201, 20402, 20401, 20303, 20302, 20301, 11302, 11201, 11202, 11301, 11303, 11304, 11001, 11002, 10902, 10901, 10801, 10702, 10703, 10701, 10601, 10501, 10502, 10401, 10301, 10201, 10101, 10102
60306	I	F	M	I	F	none

Notes:

[a] LCFRB subwatershed identification code abbreviation. All codes are 14 digits starting with 170800010#####.

[b] IWA results for watershed processes at the subwatershed level (i.e., not considering upstream effects). This information is used to identify areas that are potential sources of degraded conditions for watershed processes, abbreviated as follows:

F: Functional

M: Moderately impaired

I: Impaired

[c] IWA results for watershed processes at the watershed level (i.e., considering upstream effects). These results integrate the contribution from all upstream subwatersheds to watershed processes and are used to identify the probable condition of these processes in subwatersheds where key reaches are present.

[d] Subwatersheds upstream from this subwatershed.

Figure 12-15. Map of the upper North Fork Lewis basin showing the location of the IWA subwatersheds

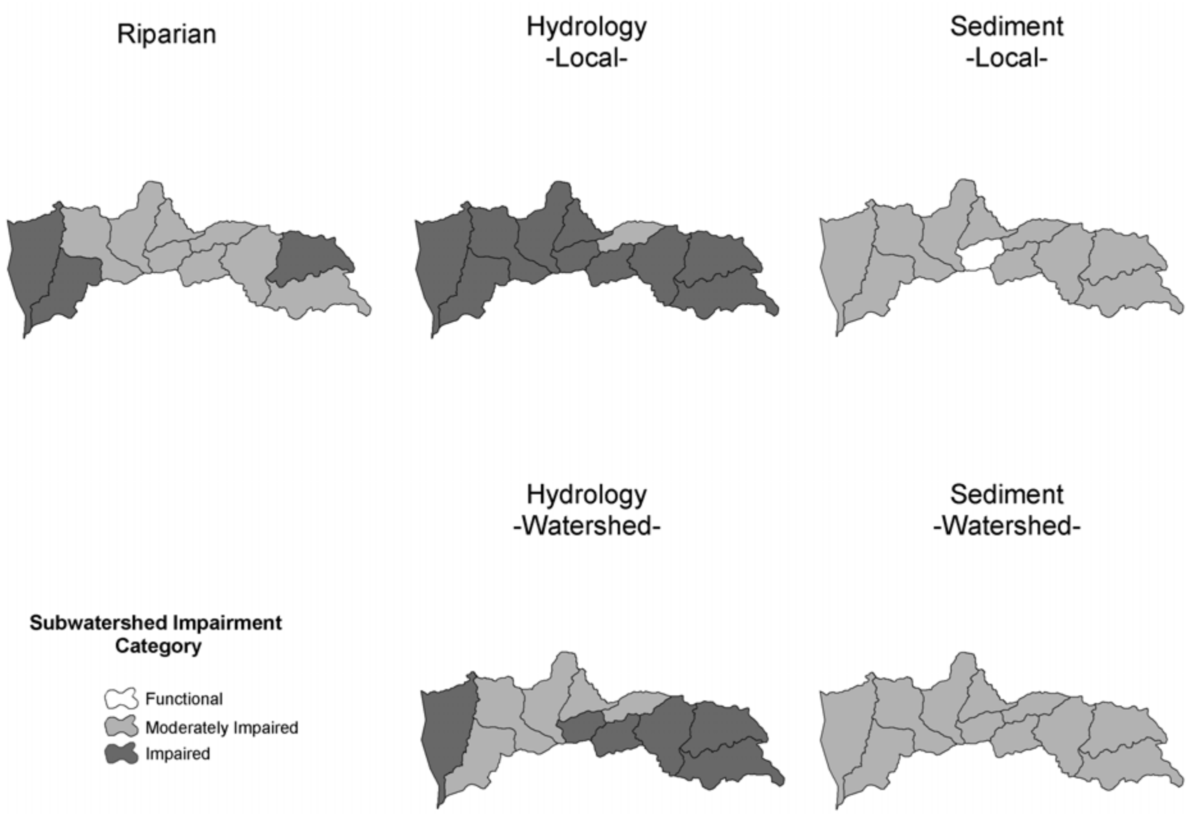


Figure 12-16. IWA subwatershed impairment ratings by category for the upper North Fork Lewis basin

12.7.1.1 Hydrology

At the local (i.e., within-watershed level) the large majority of subwatersheds in the upper NF Lewis are rated hydrologically functional. Impervious surfaces are nearly absent, as are areas zoned for urban development. Road densities are generally moderate with low densities in the uppermost subwatersheds. Streamside road densities are moderate to high with numerous subwatersheds exceeding 1 mi/stream mi. Thirty-three percent of the watershed is within the rain-on-snow elevation zone, while mature forest covers roughly 54% of the landscape.

Hydrologic conditions are also rated as functional at the watershed level throughout the majority of the watershed. It should be noted, however, that the watershed level IWA hydrologic analysis does not explicitly consider impounded areas as characteristically impaired, but focuses rather on drainage area, land cover, rain-on-snow distribution, etc. It follows that several subwatersheds containing portions of Merwin, Yale and Swift Reservoirs are certainly impaired hydrologically, even if the IWA rating suggests otherwise. The IWA is best used as a descriptor of hydrologic condition as driven by local and watershed level subwatershed process conditions at the subwatershed scale, rather than as a description of instream hydrologic conditions.

In lower portions of the watershed (below the upstream end of Swift Reservoir), public ownership rates are lower but still a relatively robust 60%. Higher levels of hydrologic impairment are in evidence in these lower elevation subwatersheds, on both private and public lands. Seven out of ten hydrologically impaired subwatersheds are located within the Canyon Creek drainage (including Fly Creek), a left-bank tributary to upper Merwin Reservoir that features substantial timber production activities on both public and private lands (60201-205, 60101-103, 60305). The drainage is largely confined with steep banks and numerous smaller tributaries entering through incised hillslopes.

The Siouxon Creek drainage, which empties into Yale Reservoir (series 401xx, 402xx, 403xx), has a high degree of public ownership and currently functional hydrologic conditions. Potentially accessible portions of the Siouxon Creek drainage are thought to have supported substantial numbers of anadromous fish and would likely do so again in the event of anadromous reintroduction into the Yale Reservoir area. In addition, the smaller Ole Creek/Rain Creek drainage (40506) has been identified as a potential site for bull trout restoration for the beleaguered Yale population. This publicly owned subwatershed (WDNR) that drains into the dewatered reach of the mainstem below Swift Dam exhibits functional conditions for all three IWA parameters.

12.7.1.2 Sediment

Moderately impaired sediment and riparian conditions are a reflection of the high levels of timber production within the watershed. Poor road management coupled with clear cutting has exacerbated sediment conditions. In the portions of the watershed flowing from Mt. St. Helens, numerous streams (such as Smith and Pine Creeks) continue to suffer from heavy sediment loads precipitated by the eruption in 1980 (20103, 20501, 20103). Riparian areas throughout these high-elevation reaches were razed by the volcanic debris flow, with the majority of sediment and debris winding up in Swift Reservoir.

The Canyon Creek drainage is largely confined with steep banks and numerous smaller tributaries entering through incised hillslopes. The area has impaired sediment conditions due to human activities, including locally high road densities up to 5 mi/sq mi and stream crossing densities in excess of 5.4 crossings/stream mile in subwatersheds 60201, 60203 and 60204. The proportion of individual Canyon Creek/Fly Creek subwatersheds in the rain-on-snow zone ranges from 15%-93%. Combined with heavily degraded sediment and riparian condition, this area is likely at greatest risk of further degradation within the watershed. However, even in the event of anadromous reintroduction, Canyon Creek would provide limited potential habitat due to impassable, natural falls just upstream of Merwin Reservoir.

Local level sediment conditions in the watershed include 45 subwatersheds with moderately impaired conditions and three with impaired conditions. Impaired and moderately impaired ratings occur throughout the Yale and Merwin portions of the watershed with only isolated pockets of functional conditions. The entire southern half of the watershed (i.e., south of the North Fork reservoirs) from Merwin Dam to the upstream end of Swift Reservoir is rated as impaired or moderately impaired, with the exception of a single subwatershed in the Siouxon drainage (40202), a tributary to Yale Lake, which is rated as functional. This portion of the watershed has experienced high levels of timber harvest, and as a consequence has a higher density of forest roads.

Functional sediment conditions are more prevalent in the upper watershed, upstream of Swift Reservoir. Contiguous concentrations of functional sediment conditions are located along nearly the entire length of Clear Creek (20303, 20401, 20402), Clearwater Creek (20203, 20204), along the mainstem North Fork above Swift (10801, 10902) and in the North Fork headwaters (10201, 10102). Rush Creek, a left bank tributary to the North Fork upstream of Swift Reservoir also has functional sediment conditions. Rush Creek is known for its moderately healthy population of Bull trout.

12.7.1.3 Riparian

Moderately impaired riparian conditions occur in 43 of the 77 subwatersheds, with none rated as impaired. The greatest concentration of functional conditions occur in the upper Lewis mainstem, Clear Creek, and Siouxon Creek drainages. Other functional conditions are scattered throughout the basin. Inadequate stream buffers are primarily related to past timber harvests and stream adjacent roadways. The 1980 Mount St. Helens eruption denuded riparian vegetation in portions of the Pine Creek (series 301xx) and Muddy River (series 201xx, 202xx, 205xx) drainages.

12.7.2 Predicted Future Trends

12.7.2.1 Hydrology

Hydrologic conditions in the watershed are generally good, particularly in areas above Swift Reservoir. The three reservoirs of course do not express functional riverine hydrology, but surrounding watershed processes are generally less impaired than areas downstream of Merwin. The overwhelming majority of lands under federal management hold promise for the protection of functional hydrologic conditions and improvement of impaired areas through continually improving forest management practices. In the event of anadromous reintroduction, key areas above Swift reservoir will form the core spawning and rearing areas within the watershed. These upper watersheds (series 20xxx and 10xxx) benefit from greater than 99% public ownership, primarily as federal forest land. While timber harvest is sure to continue, road and riparian management—coupled with other evolving aspects of the federal forest management program—are likely to produce tangible restoration and protection benefits for key areas such as Clear Creek, Clearwater Creek, Smith Creek, Muddy River, Rush Creek and the mainstem NF Lewis

River. The predicted trend for hydrologic conditions in these watersheds is stable (i.e., functional), with improvement in the landscape level factors that govern hydrologic conditions.

On the north and south sides of Swift Reservoir, many subwatersheds exhibit functional hydrologic conditions and a mixed distribution of private/public ownership. These subwatersheds (series 30xxx) are key candidates for hydrologic protection measures for lands under private ownership. Pine Creek (30101, 30102), for example, is characterized by mixed public/private ownership and is known to support bull trout. Management practices on private timberlands are also likely to improve under the Timber Fish and Wildlife Agreement. However, the likelihood of higher levels of timber harvest on these lands to offset reduced harvest on public lands suggests a trend towards increasing degradation.

Conditions in most of the Yale Reservoir tributary subwatersheds are functional (Siouxon Creek drainage) or moderaly impaired. These subwatersheds are likely to trend stable, with gradual improvement over time as with other largely publicly owned subwatersheds.

The degraded hydrologic conditions in the Canyon Creek-Fly Creek drainage are likely to persist due to a low percentage of mature vegetation, a high percentage within the rain-on-snow zone, steep slopes, and high road densities. The drainage offers limited potential anadromous habitat due to the presence of impassable natural falls at the base of the drainage.

12.7.2.2 Sediment Supply

As with hydrologic conditions, sediment conditions in the upper watershed are likely to improve over the next 20 years under federal forest management. These improvements may prove critical to the success of anadromous reintroduction efforts. The northern flank of the upper watershed (Smith Creek, Pine Creek, Clearwater Creek) will continue to process elevated natural sediment loads as a consequence of the Mt. St. Helens eruption. The long-term prognosis for these areas is quite good following natural recovery of riparian conditions.

Sediment conditions in the lower watershed are predicted to trend towards improvement on publicly owned lands as timber harvest levels decline and the impacts of improved forestry management practices are realized. In contrast, moderately impaired or impaired sediment conditions on private timberlands are likely to trend stable over the next 20 years. Improved forestry and road management practices are expected to improve sediment conditions in general, but these gains may be offset by increased timber harvest on private lands.

12.7.2.3 Riparian Condition

As a predominantly timber-driven watershed, riparian trends in the future will likely closely mimic sediment trends as described above, with progress on publicly owned lands balanced by stable conditions or slight improvements on privately held timber lands. The predicted trend in riparian conditions on public lands is towards improvement, with the trend on private land towards stability with more gradual improvement over time. Some lower-elevation subwatersheds (e.g. lower Speelyai Creek - 60303) may experience increased degradation due to development pressures.

12.8 References

Access Opportunities. 1992. ADA Evaluation and Transitional Plan for Lewis River Recreation Area. Pacific Power and Light Company, Portland, OR.

Allen, R. 1963. Lake Merwin Juvenile Fish Collector Progress Report for July 1, 1962 to June 30, 1963. Washington Department of Fisheries (WDF), Research Division.

Allen, R. 1964. Lake Merwin Juvenile Fish Collector Progress Report July 1, 1963 to June 30, 1964. Washington Department of Fisheries (WDF), Research Division.

Allen, R.L.; Rothfus, L.O. 1976. Evaluation of a Floating Salmon Smolt Collector at Merwin Dam. Washington Department of Fisheries (WDF).

Amren,J. 1997. Operations Program Lewis River Complex for January 1, 1996 to December 31, 1996. Washington Department of Fish and Wildlife WDFW), Hatcheries Program, Olympia, WA.

Anderson, D.P., R.G. Anthony, Ichisaka. 1985. Wintering Ecology of Bald Eagles on the Lewis River, Washington 1984-1985. Pacific Power and Light Co., Portland, OR.

Anderson, D.P., R.G. Anthony, Ichisaka. 1986. Wintering Ecology of Bald Eagles on the Lewis River, Washington 1985-1986. Pacific Power and Light Co., Portland, OR.

Barker, B., P. Cavanaugh, P., D. Burdick. 1996. Floodway Hazard Assessment for Home Located at 4503 NW 416th Street Near the Lewis River. Washington State Dept of Ecology (WDOE).

Bryant, F.G. 1949. A survey of the Columbia River and its tributaries with special reference to its fishery resources--Part II Washington streams from the mouth of the Columbia to and including the Klickitat River (Area I). U.S. Fish and Wildlife Service (USFWS), Special Science Report 62.

Caldwell, B. 1999. East Fork Lewis River fish habitat analysis using the Instream Flow Incremental Methodology and Toe-Width Method for WRIA 27. Publication # 99-151. Washington State Department of Ecology. Olympia, WA.

Chambers, J.S. 1957. Report on the survey of the North Fork of the Lewis River above Yale Dam. Washington Department of Fisheries (WDF).

Clearwater BioStudies, Inc. 2002. Bull trout surveys and stream temperature monitoring conducted within selected watersheds on the Gifford Pinchot National Forest, Summer 2001. Clearwater BioStudies, Inc. Canby, OR.

Crawford, B.A. 1986. Recovery of game fish populations impacted by the May 18, 1980 eruption of Mount St. Helens. Part 11. Recovery of surviving fish populations within the lakes in the Mount St. Helens National Volcanic Monument and adjacent areas. Washington Department of Game (WDG), Fishery Management Report 85-9B.

Crawford, B.A., R. Pettit, R. Claflin. Study of juvenile steelhead densities and biomass in the wind and E.F. Lewis Rivers. Washington Department of Fish and Wildlife (WDFW).

EA Engineering, Science & Technology. 1999. Initial information package for the Lewis River hydroelectric projects. Prepared for PacifiCorp and PUD of Cowlitz County, EA Engineering, Science & Technology.

Harlan, K. 1999. Washington Columbia River and tributary stream survey sampling results, 1998. Washington Department of fish and Wildlife (WDFW), Columbia River Progress Report 99-15, Vancouver, WA.

Harlan, L., R. Pettit. 2001. Forecasts for 2001 spring chinook returns to Washington Lower Columbia River tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 02-01, Vancouver, WA.

Hawkins, S. 1996. Lewis River wild stock fall Chinook tagging project, 1995. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 96-08, Battle Ground, WA.

Hawkins, S. 1996. Results of sampling the Lewis River natural spawning fall Chinook population in 1995. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 96-06, Battle Ground, WA.

Hawkins, S. 1997. Lewis River wild fall chinook tagging project. Washington Department of Fish and Wildlife (WDFW). Columbia Rive Progress Report 98-6, Vancouver, WA.

Hawkins, S. 1998. Residual hatchery smolt impact study: wild fall chinook mortality 1995-1997. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-8, Vancouver, WA.

Hawkins, S. 1998. Results of sampling the Lewis River natural spawning fall chinook population in 1997. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-7, Vancouver, WA.

Humer, J. 1989. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1988. Washington Department of Fish and Wildlife (WDFW). Columbia River Laboratory Progress Report 89-13, Battle Ground, WA.

Hutton, Robert. 1994. DRAFT East Fork Lewis River watershed action plan. Clark County Water Quality Division. pp. 56. Vancouver, WA.

Hutton, Robert. 1994. DRAFT East Fork Lewis River watershed characterization background Report. Clark County Water Quality Division, Vancouver, WA.

Hymer, J. 1990. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1989. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 90-19, Battle Ground, WA.

Hymer, J. 1992. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1991. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 92-23, Battle Ground, WA.

Hymer, J. 1993. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1992. Washington Department of Fish and Wildlife (WDFW), Columbia River Laboratory Progress Report 93-18, Battle Ground, WA.

Hymer, J. 1993. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1992. Washington Department of Fish and Wildlife (WDFW). Columbia River Laboratory Progress Report. Vol:93-18. Battle Ground, WA.

Hymer, J., B. Woodard. 1991. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1990. Washington Department of Fish and

Wildlife (WDFW), Columbia River Laboratory Progress Report 91-11, Battle Ground, WA.

Hymer, J., R. Pettit, M. Wastel, P. Hahn, K. Hatch. 1992. Stock summary reports for Columbia River anadromous salmonids, Volume III: Washington subbasins below McNary Dam. Bonneville Power Administration (BPA), Portland, OR.

Kinney, J., S. Lampo. 2002. Summary of Gifford National Forest aquatic habitat surveys on the tributaries of the Lewis River watershed between Lower Falls and Swift Reservoir, including Drift and Siouxon Creeks. Gifford Pinchot National Forest. Amboy, WA. Report. Lewis River

Lavoy, L., G. Fenton. 1983. North Fork Lewis River Steelhead Study. Washington Department of Game, Olympia, WA.

LeFleur, C. 1987. Columbia River and tributary stream survey sampling results, 1986. Washington Department of Fisheries (WDF), Progress Report 87-8, Battle Ground, WA.

LeFleur, C. 1988. Age and Stock composition of fall chinook returning to Washington Columbia River hatcheries, 1987. Washington Department of Fish and Wildlife (WDFW), Progress Report 88-15, Battle Ground, WA.

LeFleur, C. 1988. Columbia River and tributary stream survey sampling results, 1987. Washington Department of Fisheries (WDF), Progress Report 88-17, Battle Ground, WA.

Lewis County GIS. 1999. GIS Fish Distribution Maps and Analysis of Various Habitat Conditions within WRIA 27.

Loranger, Tom . 1999. Unpublished letter summarizing the results of possible water quantity impacts to salmonids within the East Fork Lewis River using instream flow incremental methodology and toe width method. Ecology Publication 99-151.

Lower Columbia Fish Recovery Board (LCFRB) 2001. Level 1 Watershed Technical Assessment for WRIAs 27 and 28, Longview, Washington. Prepared by GeoEngineers, Inc. (the prime contractor), WEST Consultants, Inc., and Hammond Collier Wade Livingstone for the LCFRB. Longview, Washington.

Lucas, B. 1985. Draft Analysis of creel check data at Lucia Falls, East Fork Lewis River. Washington Department of Wildlife (WDW).

Lucas, R.; Pointer, K. . 1987. Wild steelhead spawning escapement estimates for southwest Washington streams--1987. Washington Department of Wildlife (WDW) 87-6.

Marriott, D. et.al. 2002. Lower Columbia River and Columbia River Estuary Subbasin Summary. Northwest Power Planning Council.

McIsaac, D., H. Fiscus. 1979. Relative value of North fork Lewis River spring chinook. Washington Department of Fisheries (WDF), Memo, Vancouver, BC

McIsaac, D.O. 1990. Factors affecting the abundance of 1977-1979 brood wild fall chinook salmon (Oncorhynchus tshawytscha) in the Lewis River, Washington. University of Washington, Ph.D. Dissertation, Seattle, WA.

Montgomery Watson. 1997. Hatchery Evaluation Report, Merwin Dam Hatchery - Winter Steelhead. Bonneville Power Administration. An Independent Audit Based on Integrated Hatchery Operations Team (IHOT) Performance Measures 95-2, Bellevue, WA.

Norman, G. 1984. Memo to Don McIsaac on North Lewis River wild stock fall chinook tagging project and post-tagging recapture, 1983. State of Washington, Department of Fisheries, Battle Ground, WA.

PacifiCorp Environmental Services. 1995. Yale Hydroelectric Project Preliminary Water Quality Study. PacifiCorp Environmental Services, FERC Project 2071, Portland, OR.

Pettit, R. 1993. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1993. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 93-23. Battle Ground, WA.

Pettit, R. 1994. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1994. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 94-30.

Pettit, R. 1995. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1995. Washington Department of Fish and Wildlife (WDFW), Columbia Rive Laboratory Progress Report 95-21, Battle Ground, WA.

Pettit, R. 1996. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1996. Washington Department of Fisheries (WDF), Columbia River Laboratory Progress Report 96-19, Battle Ground, WA.

Pettit, R. 1998. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-1988. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-13, Vancouver, WA.

Pettit, R. 1998. Forecasts for 1999 spring chinook returns to Washington Lower Columbia river tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 98-11, Vancouver, WA.

Pettit, R. 2002. Escapement estimates for spring chinook in Washington tributaries below Bonneville Dam, 1980-2001. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report, 02-06. Vancouver, WA.

Pettit, R. 2002. Forecasts for 2002 spring chinook returns to Washington Lower Columbia River tributaries. Washington Department of Fish and Wildlife (WDFW), Columbia River Progress Report 02-02, Vancouver, WA.

Quinn, T.P., K. Fresh. 1984. Homing and straying in chinook salmon (Oncorhynchus tshawytscha) from Cowilitz River Hatchery, Washington. Canadian Journal of Fisheries and Aquatic Sciences 41: 1078-1082.

Roler, R. 1990. North Lewis River wild stock fall chinook tagging and post tagging recapture project, 1989. Washington Department of Fisheries (WDF), Columbia River Laboratory Report 90-09, Battle Ground, WA.

Smoker, W.A., J.M. Hurley, R.C. Meigs. 1951. Compilation of information on salmon and steelhead losses in the Columbia River basin salmon and trout in the Lewis River. Washington Department of Fisheries (WDF).

Smoker, W.A., J.M. Hurley, R.C. Meigs. 1951. Compilation of Observations on the Effect of Ariel (Merwin) Dam on the Production of Salmon and Trout in the Lewis River. Washington Department of Fisheries and Washington Department of Game.

The ICM Core Team. 1996. Integrated landscape management for fish and wildlife: an evaluation of the planning process used to develop the Lewis-Kalama River watershed plan. Washington Department of Fish and Wildlife (WDFW), Draft Report 2, Olympia, WA.

Tracy, H.B., C.E. Stockley. 1967. 1966 Report of Lower Columbia River tributary fall chinook salmon stream population study. Washington Department of Fisheries (WDF).

U.S. Forest Service (USFS), Gifford Pinchot National Forest. 2000. Lewis River Hydroelectric Projects. U.S. Forest Service (USFS), Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1995a. Middle Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1995b. Upper Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1996. Lower Lewis River Watershed analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1997. Muddy River Watershed Analysis. Gifford Pinchot National Forest.

U.S. Forest Service (USFS). 1999. East Fork Lewis River fish habitat rehabilitation project; environmental assessment. Gifford Pinchot National Forest.

Wade, G. 2000. Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory Area 27. Washington State Conservation Commission.

Wahle, R.J., R.R. Vreeland, R.H. Lander. 1973. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific salmon fisheries. National Marine Fisheries Service (NMFS), Portland, OR.

Wahle, R.J., R.R. Vreeland, R.H. Lander. 1974. Bioeconomic contribution of Columbia River hatchery coho salmon, 1965 and 1966 broods, to the Pacific Salmon Fisheries. Fishery Bulletin 72(1).

Wahle, R.J., R.R. Vreeland. 1978. Bioeconomic contribution of Columbia River hatchery fall chinook salmon, 1961 through 1964. National Marine Fisheries Service (NMFS), Fishery Bulletin 1978(1).

Washington Department of Fish and Wildlife (WDFW). 1986. Operations Report: Lewis River Complex for January 1, 1995 to December 31, 1995. Washington Department of Fish and Wildlife (WDFW), Hatcheries Program.

Washington Department of Fish and Wildlife (WDFW). 1995. Annual Report 1994 for Speelyai Salmon Hatchery. Washington Department of Fish and Wildlife (WDFW), Hatcheries Program.

Washington Department of Fish and Wildlife (WDFW). 1996. Lower Columbia River WDFW hatchery records. Washington Department of Fish and Wildlife (WDFW).

Washington Department of Fish and Wildlife (WDFW). 1997. Preliminary stock status update for steelhead in the Lower Columbia River. Washington Department of Fish and Wildlife (WDFW), Vancouver, WA.

Washington Department of Fish and Wildlife (WDFW). 1998. Integrated landscape management plan for fish and wildlife in the Lewis-Kalama River watershed, Washington: a pilot project. Olympia, Washington. Washington Department of Fish and Wildlife (WDFW).

Washington Department of Fisheries (WDF) and U.S. Fish and Wildlife Service (USFWS). 1951. Lower Columbia River Fisheries Development Program: Lewis River Area, Washington. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1951. Lower Columbia River Fisheries Development Program. Lewis River Area. Washington Department of Fisheries (WDF), Olympia, WA.

Washington Department of Fisheries (WDF). 1971. North Lewis River Surveys. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1987. Speelyai Salmon Hatchery: August 1, 1986 through December 31, 1986. Washington Department of Fisheries (WDF). Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1988. Agreement Between the Department of Wildlife, Department of Fisheries, and Pacific Power and Light Company; Regarding Construction of a Fish Hatchery Near Merwin Dam. Washington Department of Fisheries (WDF).

Washington Department of Fisheries (WDF). 1989. Annual Report for Speelyai Salmon Hatchery Fiscal Year 1988. Washington Department of Fisheries (WDF). Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1990. Lewis River Salmon Hatchery Operations Report for January 1, 1990 through July 31, 1990. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1991. Lewis River Salmon Hatchery Operations Report for July 1, 1990 through December 31, 1990. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1991. Operation of Merwin Hydroelectric Project, FERC Project No 935: Proposed Changes of Article 49 Parts II and III. Washington Department of Fisheries (WDF), Columbia River Laboratory, Battle Ground, WA.

Washington Department of Fisheries (WDF). 1992. Lewis River Salmon Hatchery Operations Report for January 1, 1991 through December 31, 1991. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1992. Speelyai Salmon Hatchery: January 1, 1991 through December 31. 1991. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1993. Annual Report 1992 for Speelyai Salmon Hatchery. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1993. Lewis River Salmon Hatchery Operations Report for January 1, 1992 through December 31, 1992. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1994. Annual Report 1993 for Speelyai Salmon Hatchery. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries (WDF). 1994. Lewis River Salmon Hatchery Operations Report for January 1, 1993 through December 31, 1993. Washington Department of Fisheries (WDF), Hatcheries Program, Olympia, WA.

Washington Department of Fisheries; Washington Game Commission. 1948. A report on the fisheries problems in connection with the proposed hydroelectric development of the Cowlitz River, Lewis County, Washington. Washington Department of Fisheries and Washington Game Commission.

Washington Department of Game (WDG). 1973. Lewis Basin Study Fish and Wildlife Appendix. Washington Department of Game (WDG). Environmental Management Division.

Washington Department of Wildlife (WDW). 1990. Columbia Basin System Planning Salmon and Steelhead Production Plan, Lewis River Basin. Washington Department of Wildlife (WDW).

Weinheimer, J. 1995. Letter to Craig Burley of WDFW Regarding Bull Trout Capture Below Yale Dam, North Fork Lewis River. Washington Department of Fish and Wildlife (WDFW). Vancouver, WA.

Wendler, H.O., E.H. LeMier, L.O. Rothfus, E.L. Preston, W.D. Ward, R.E. Birtchet. 1956. Columbia River Progress Report, January through April, 1956. Washington Department of Fisheries (WDF).

Western Regional Climate Center (WRCC). 2003. National Oceanic and Atmospheric Organization - National Climatic Data Center. URL: http://www.wrcc.dri.edu/index.html.

Westley, R.E. 1966. Limnological Study of Merwin Upper Baker and Lower Baker Reservoirs. Washington Department of Fisheries (WDF), Research Division.

Woodard, B. 1997. Columbia River Tributary sport Harvest for 1994 and 1995. Washington Department of Fish and Wildlife (WDFW), Battle Ground, WA.