Volume II, Chapter 14
Columbia Lower Tributaries Subbasin

TABLE OF CONTENTS

14.0 Columbia Lower Tributaries Subbasin

14.1 Subbasin Description

14.1.1 Topography & Geology

The Columbia Lower Tributaries subbasin contains the stream systems that drain into the Columbia River between the Lewis River and Bonneville Dam, not including the Washougal River watershed, which is considered a separate subbasin. The entire subbasin extends from Columbia River RM 87.5 to RM 142.3 and encompasses approximately 270 mi^2. The subbasin lies within Clark and Skamania Counties and can be divided into two general areas: 1) basins between the Lewis River and the Washougal River (Lake River basin), and 2) basins between the Washougal River and Bonneville Dam (Bonneville Tributaries basin). The Lake River basin lies within the highly urbanized Vancouver, Washington, metropolitan area, and therefore receives tremendous anthropogenic pressures. The Bonneville Tributaries basin consists mostly of small basins draining the steep valley walls of the Columbia River Gorge.

Surface geology in the basin is primarily sedimentary, with volcanic material in headwater areas. Much of the subbasin is underlain by alluvium from catastrophic flooding of the Columbia River during Pleistocene Ice Ages and from more recent floodplain deposits.

14.1.1.1 Lake River

Headwaters of the Lake River basin begin in the low foothills of the southwestern Washington Cascades in Clark County. Lake River drains north from 2,600-acre Vancouver Lake. Major tributaries entering Lake River are Salmon Creek, Whipple Creek, and Flume Creek. Burnt Bridge Creek flows into Vancouver Lake and its watershed is located in the heart of the city of Vancouver. Salmon Creek is the largest tributary to the Lake River basin, with a drainage area of 91 mi^2. Basin elevation ranges from near sea level at the mouth to 1,998 feet in the headwaters of the Salmon Creek basin. Most streams in the basin are low gradient, meandering systems, located within Clark County's flat alluvial plain. Vancouver Lake and Lake River itself are within the historical Columbia River floodplain and are tidally-influenced.

14.1.1.2 Bonneville Tributaries

Streams in the Bonneville Tributaries basin originate on the steep valley walls of the Columbia River Gorge and flow south through Columbia River floodplain terraces before entering the Columbia River. Most of the stream lengths are high gradient and spawning habitat is only available in the lowest reaches. The major streams (from west to east) are Gibbons, Lawton, Duncan, Woodward, Hardy, and Hamilton Creeks. Hamilton Creek has the largest channel length at over 8 miles. Anthropogenic disturbances to these systems are largely related to the transportation corridors that parallel the Columbia River.

14.1.2 Climate

The climate is typified by cool, wet winters and warm, dry summers. Temperatures are moderated by mild, moist air flowing up the Columbia from the Pacific. Precipitation levels are high due to orographic effects. Mean annual precipitation ranges from 40 inches at Vancouver to 85 inches at the Skamania Fish Hatchery in the Columbia Gorge. Average annual minimum temperature at Vancouver is 43°F (6°C) and the average annual maximum is 63°F (17°C). The minimum and maximum values at the Skamania Hatchery are 38°F (3°C) and 62°F (17°C), respectively. Winter temperatures seldom fall below freezing, with very little snowfall (WRCC 2003).

14.1.3 Land Use/Land Cover

14.1.3.1 Lake River

Land use in the Lake River basin is predominately urban and rural development, with nearly the entire Burnt Bridge Creek watershed lying within the Vancouver metropolitan area. Historical wetlands and floodplains have been converted to residential, commercial, industrial, and agricultural uses. The upper reaches of the Salmon Creek basin have been impacted by silvacultural activities and rural residential development. Major urban centers in the basin are Vancouver, Orchards, Salmon Creek, Battle Ground, and Ridgefield. The year 2000 population, estimated at 252,000 persons is expected to increase by 267,500 by year 2020 (LCFRB 2001). A breakdown of land ownership and land cover in the Lake River basin is presented in Figure 14-1 and Figure 14-2.Figure 14-3 displays the pattern of landownership for the basin. Figure 14-4 displays the pattern of land cover / land-use.

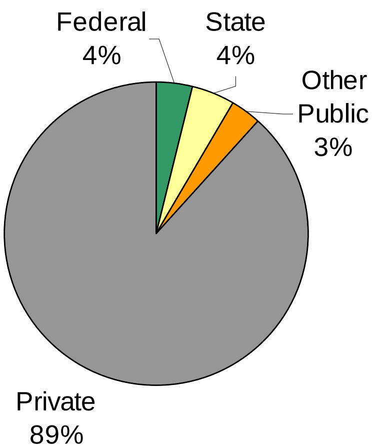


Figure 14-1. Lake River basin land ownership

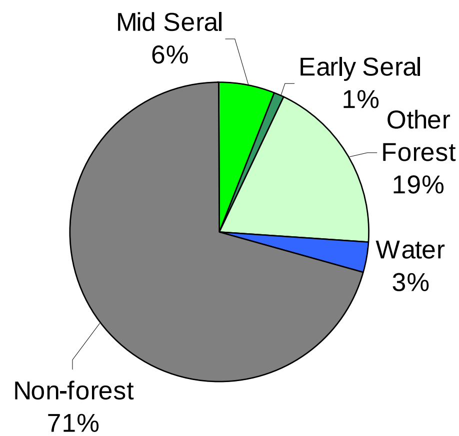


Figure 14-2. Lake River basin land cover

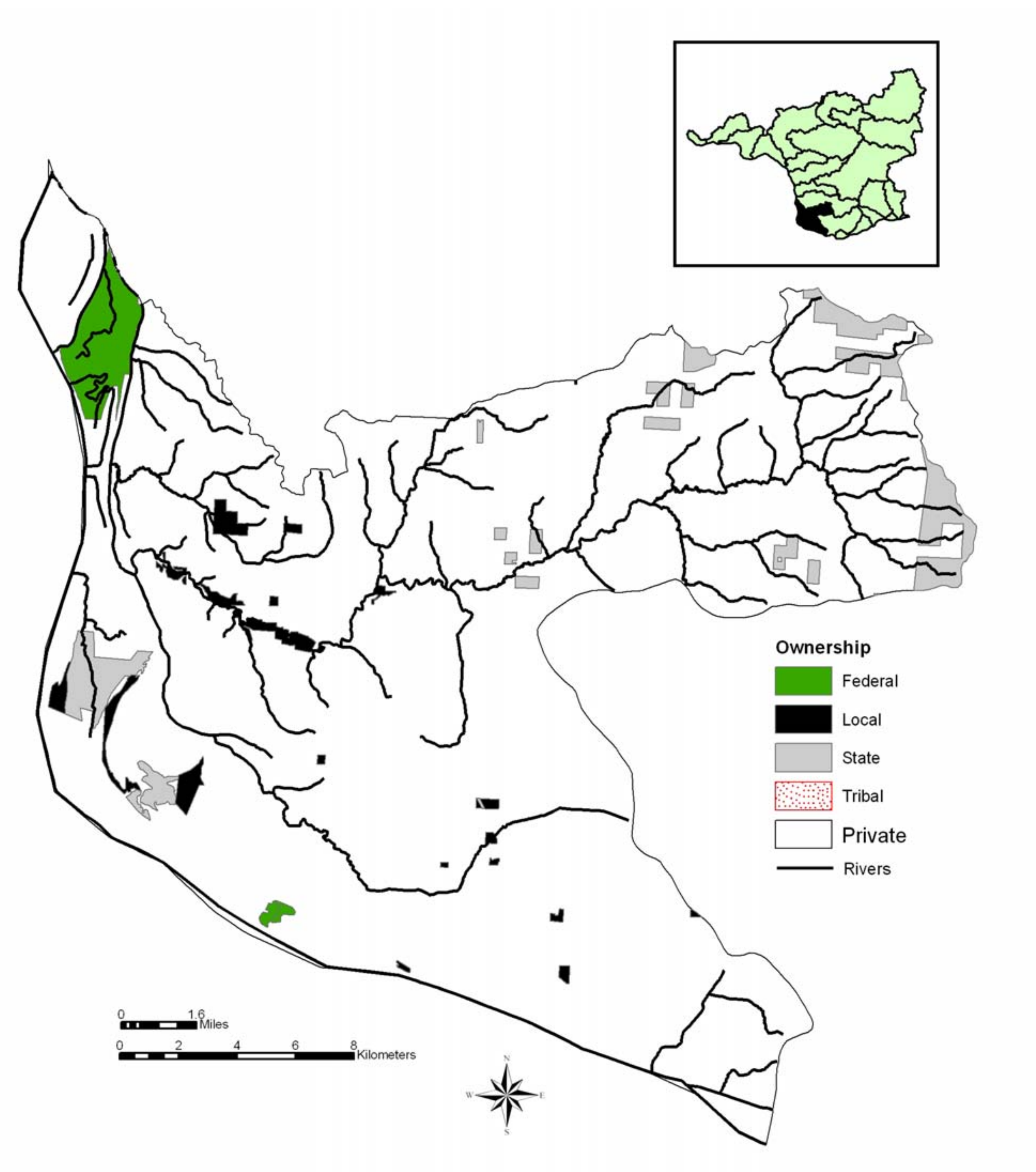


Figure 14-3. Landownership within the Lake River basin. Data is WDNR data that was obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

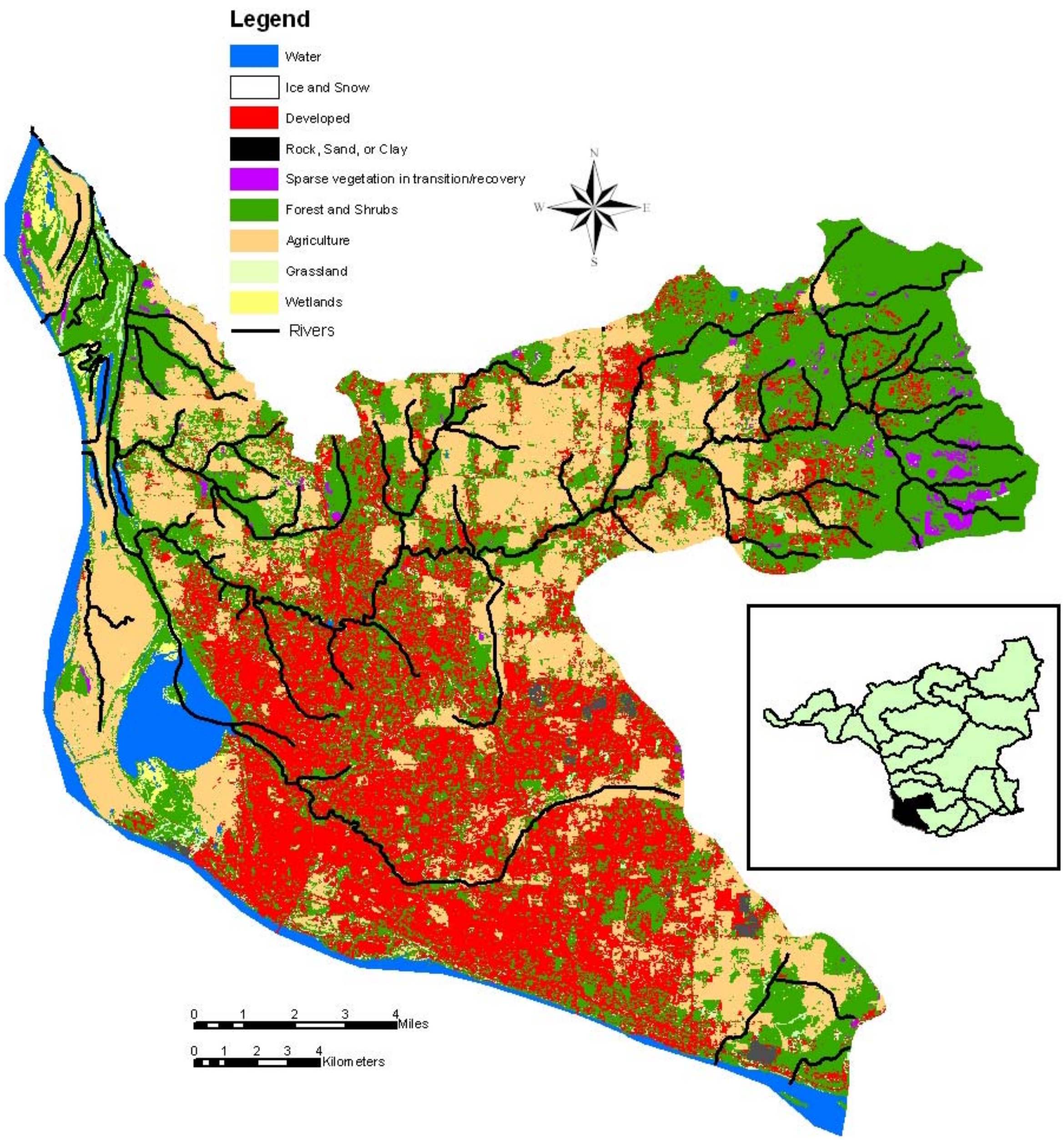


Figure 14-4. Land cover within the Lake River basin. Data was obtained from the USGS National Land Cover Dataset (NLCD).

14.1.3.2 Bonneville Tributaries

The Bonneville Tributary watersheds are mostly forested, with a higher degree of residential and agricultural development in the western portion, especially near the town of Washougal. The eastern portion of the basin lies within the Columbia River Gorge National Scenic Area, where land use and development is limited; however, rural residential and industrial uses are located along the Columbia on the lower reaches of some streams. The only population center in the eastern portion of the basin is the town of North Bonneville, situated on the Columbia River just west of Bonneville Dam. The year 2000 population is estimated at approximately 7,000 persons, and is expected to increase to 10,500 by 2020. Bonneville Tributaries land ownership and land cover are illustrated by Figure 14-5 and Figure 14-6.

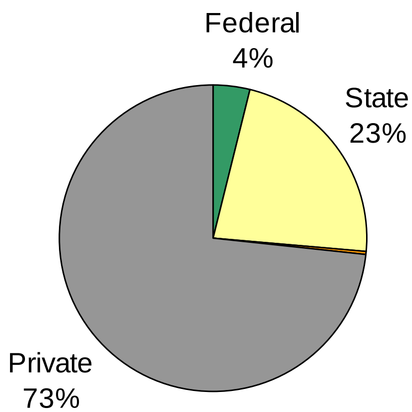


Figure 14-5. Bonneville Tributaries basin land ownership

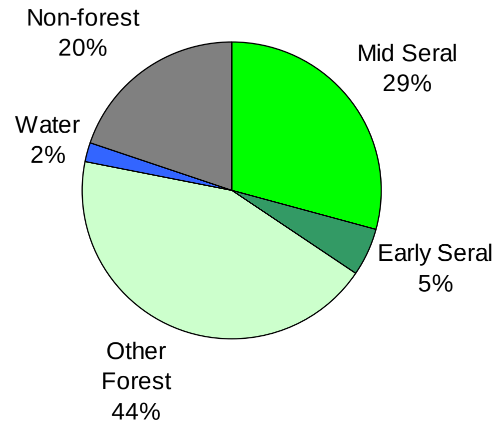


Figure 14-6. Bonneville Tributaries basin land cover

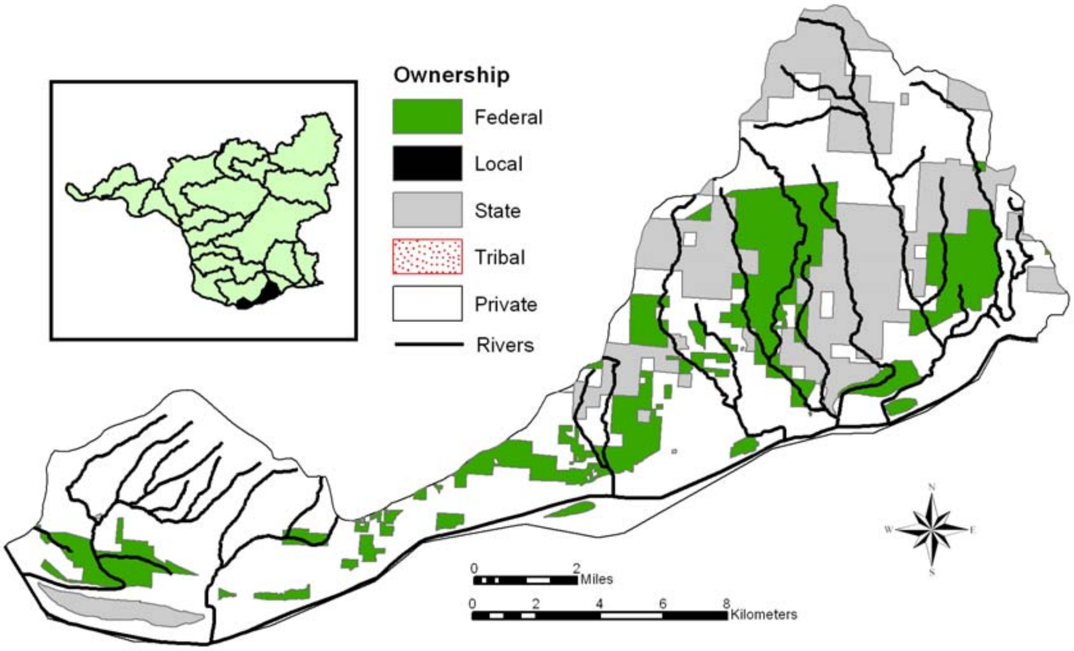


Figure 14-7. Landownership within the Bonneville tributaries basin. Data is WDNR data that was obtained from the Interior Columbia Basin Ecosystem Management Project (ICBEMP).

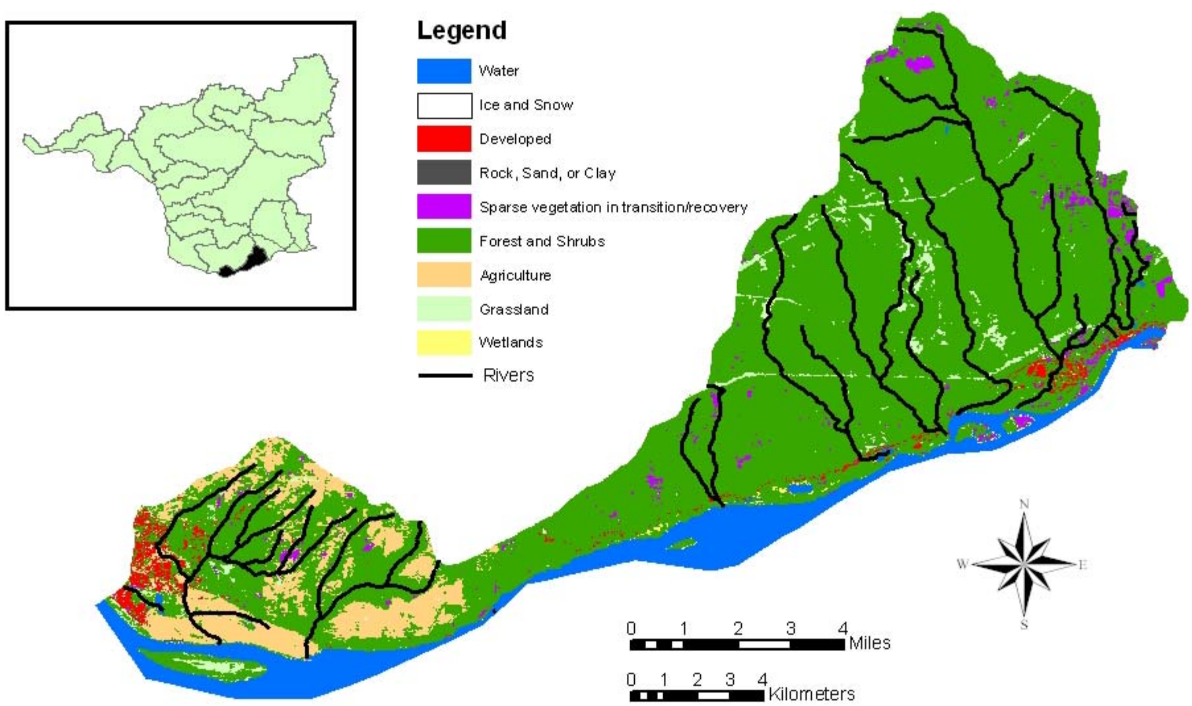
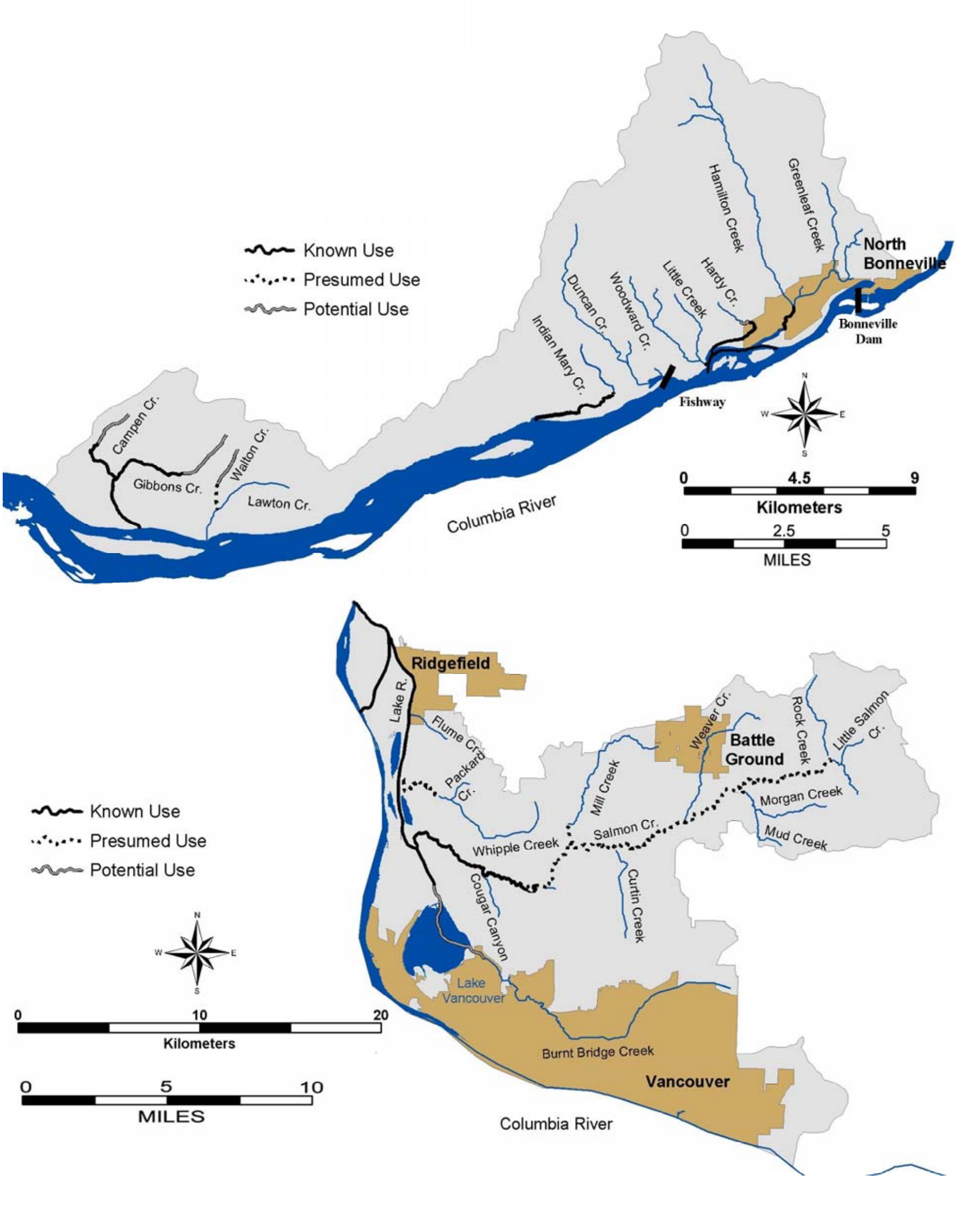


Figure 14-8. Land cover within the Bonneville tributaries basin. Data was obtained from the USGS National Land Cover Dataset (NLCD).

14.2 Focal Fish Species

14.2.1 Upriver Bright Fall Chinook—Lower Columbia Tributaries Subbasin

ESA: Threatened 1999 **SASSI: Unknown 2002**



Distribution

- Historical distribution of fall chinook in Salmon Creek was documented in 1951 as the lower 5 miles of creek
- Fall chinook have recently been observed in the mainstem Columbia River from the upper end of Pierce Island to the lower end of Ives Island, along the Washington shore in Hamilton Slough, between the mouths of Duncan and Hardy Creeks, and in the lower reaches of Hardy and Hamilton Creeks; available spawning habitat depends on the spill regime at Bonneville Dam

Life History

- Fall chinook upstream migration in the Columbia River begins in early August or September, depending on early rainfall
- Spawning in the mainstem Columbia River and Bonneville tributaries occurs from mid-October to late November
- Age ranges from 2 year-old jacks to 6 year-old adults, with dominant adult ages of 3 and 4
- Fry emerge around early April, depending on time of egg deposition and water temperature; fall chinook fry spend the spring in fresh water, and emigrate in the summer as sub-yearlings

Diversity

- Early spawning components are considered part of the tule population in the lower Columbia River Evolutionary Significant Unit (ESU)
- Bonneville upriver bright fall chinook stock spawning was discovered in 1994 in the mainstem Columbia immediately below Bonneville Dam; stock origin remains unknown; stock was designated based on distinct spawning distribution
- Allozyme analysis indicate that late bright fall chinook, spawning in the mainstem Columbia below Bonneville Dam, are genetically distinct from other Columbia River bright fall chinook stocks although they resemble Yakima bright fall chinook and upriver bright fall chinook maintained at the Little White Salmon National Fish Hatchery and Bonneville Hatchery

Abundance

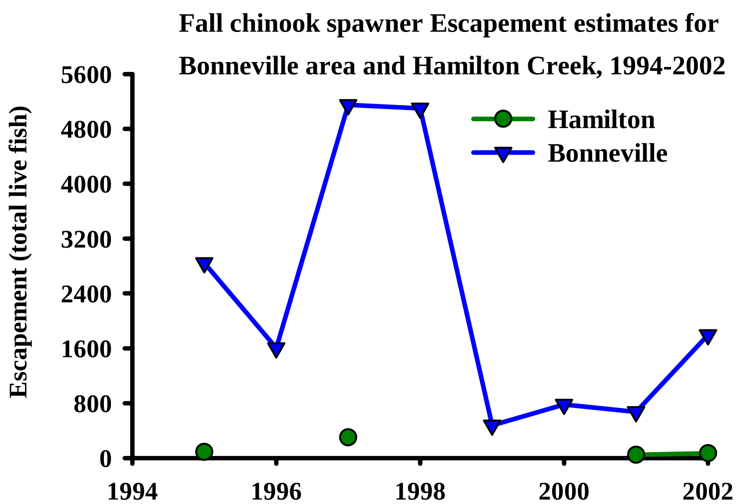
- Escapement surveys in 1936 reported 19 fall chinook spawning in Salmon Creek
- In 1951, fall chinook escapement to Salmon Creek was estimated at 100 fish
- Hamilton Creek spawning escapements from 1995-2001 ranged from 47-300 (average 144)
- Bonneville area spawning escapements from 1994-2001 ranged from 477-5,151 (average 2,143)

Productivity & Persistence

- Productivity data is limited for Bonneville area fall chinook
- Seining operations conducted by the WDFW and ODFW have shown consistent juvenile production from late spawning adults in the mainstem Columbia River below Bonneville Dam

Hatchery

- The Spring Creek National Fish Hatchery near the White Salmon River released, 50,160 fall chinook into Hamilton Creek in 1977

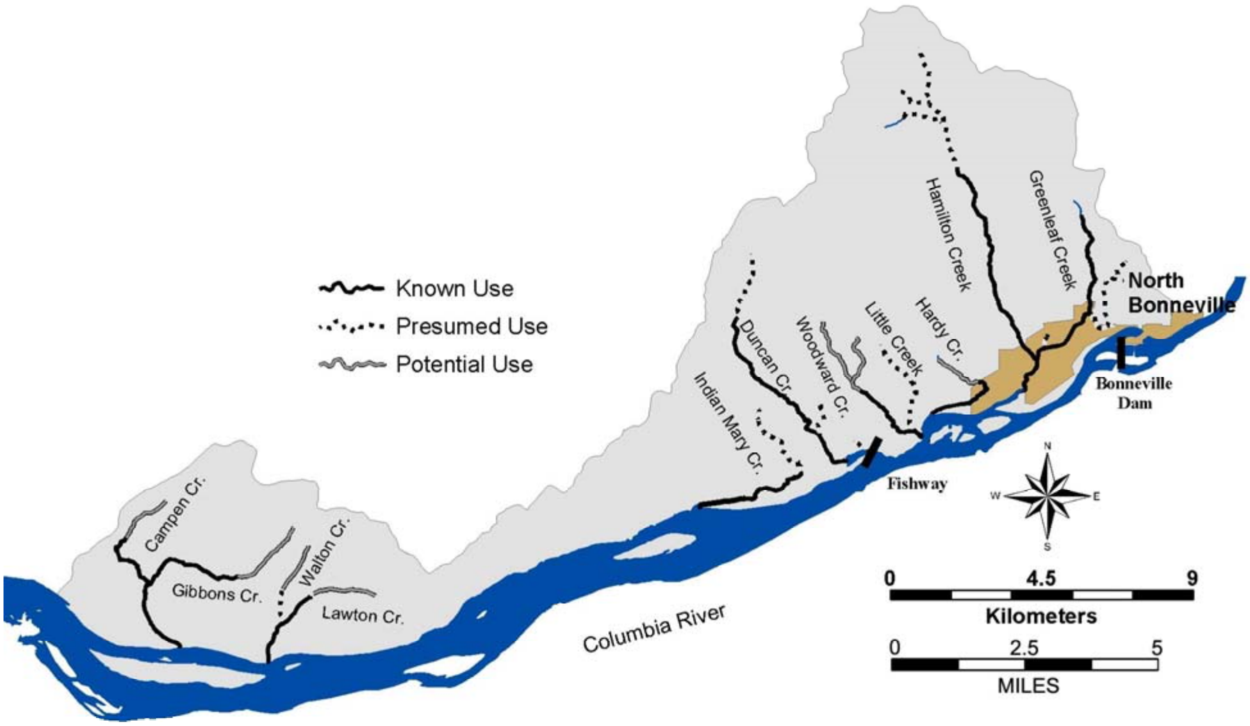


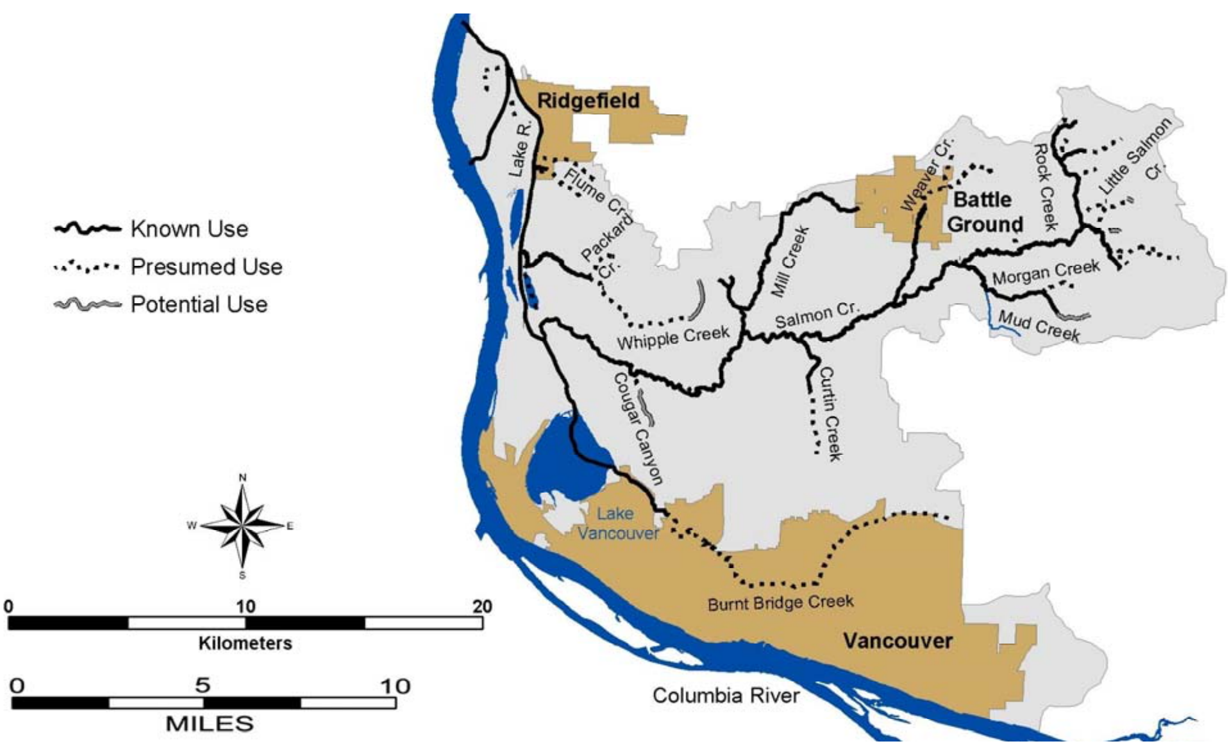
Harvest

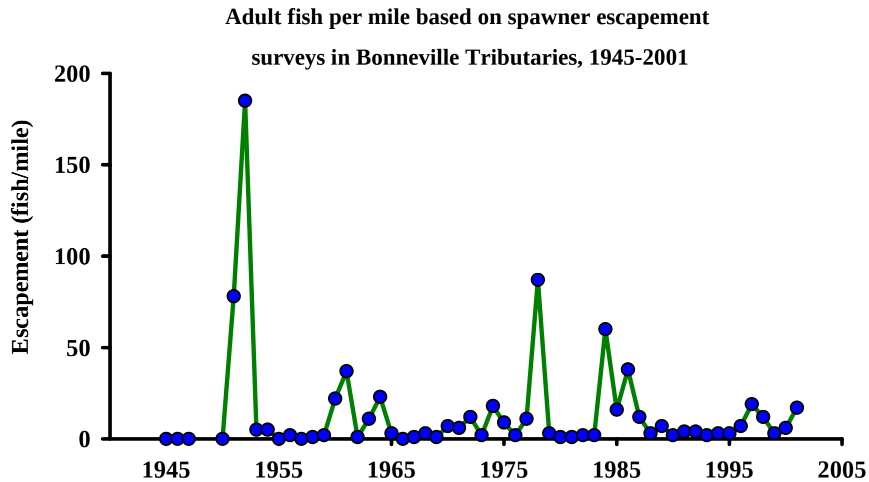
- Fall chinook are harvested in ocean commercial and recreational fisheries from Oregon to Alaska and Columbia River commercial gill net and sport fisheries
- No specific CWT data is available for these populations, however migration patterns and harvest of the bright chinook populations is likely similar to upriver bright (URB) fall chinook and the tule populations similar to lower Columbia hatchery tule chinook
- Columbia River URB chinook harvest is limited to 31.29% based on Endangered Species Act (ESA) limits on Snake River wild fall chinook; however, lower river URB chinook are harvested at a lower rate as they do not pass through the Treaty Indian fishery
- Combined ocean and Columbia River tule fall chinook harvest is currently limited to 49% as a result of ESA limits on Coweeman tule fall chinook
- A popular sport fishery has developed in the mainstem Columbia in late September and early October, targeting on the late spawning bright chinook

14.2.2 Coho—Lower Columbia Subbasin

ESA: Candidate 1995	SASSI: Bonneville Tributaries—Depressed 2002; Salmon Creek—Unknown 2002







Distribution

- Managers refer to late stock coho as Type N due to their ocean distribution generally north of the Columbia River
- Managers refer to early stock coho as Type S due to their ocean distribution generally south of the Columbia River
- Salmon Creek flows through Clark County (downstream of the Washougal River and upstream of the Lewis River) and has been largely impacted by urban development, but coho production potential exists in upper Salmon Creek and tributaries: Morgan, Rock, Mill, and Weaver Creeks
- Other creeks near the Salmon Creek watershed with coho production potential include Burnt Bridge and Whipple Creeks
- Hamilton, Hardy, Woodward, and Duncan Creeks are small Columbia River tributaries located just downstream of Bonneville Dam; Greenleaf Creek is a tributary of Hamilton Creek
- Gibbons, Lawton, and St. Cloud Creeks are located upstream of the Washougal River

Life History

- Adults enter the Columbia River from mid-September through mid-December
- Peak spawning occurs in December to early January for late stock coho
- Peak spawning occurs in late October to mid November for early 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

- Native population in the Bonneville tributaries (Duncan, Hardy, and Hamilton Creeks) were late stock coho (or type N)
- Both late and early stock (or Type S) coho are believed to be historically produced in Salmon Creek
- Other tributaries with historical coho production include: Gibbons Creek, Lawton Creek, St. Cloud Creek, Woodward Creek, and Greenleaf Creek (a tributary of Hamilton Creek)
- Columbia River early and late stock coho produced at Washington hatcheries are genetically similar

Abundance

- Wild coho runs in these Bonneville area small tributaries are believed to be a fraction of historical size
- WDFW (1951) estimated a coho escapement of 2,050 for Salmon Creek and these small tributaries between the Washougal River and Bonneville Dam combined
- Escapement surveys from 1945-2001 on Duncan, Hardy, Hamilton, and Greenleaf Creeks documented a range of 0-185 fish/mile

Productivity & Persistence

- Natural coho spawning is presumed to be very low
- Salmon Creek habitat enhancement efforts have improved recent year production potential
- Chum recovery efforts in Duncan, Hardy, and Hamilton creeks should improve coho production potential

Hatchery

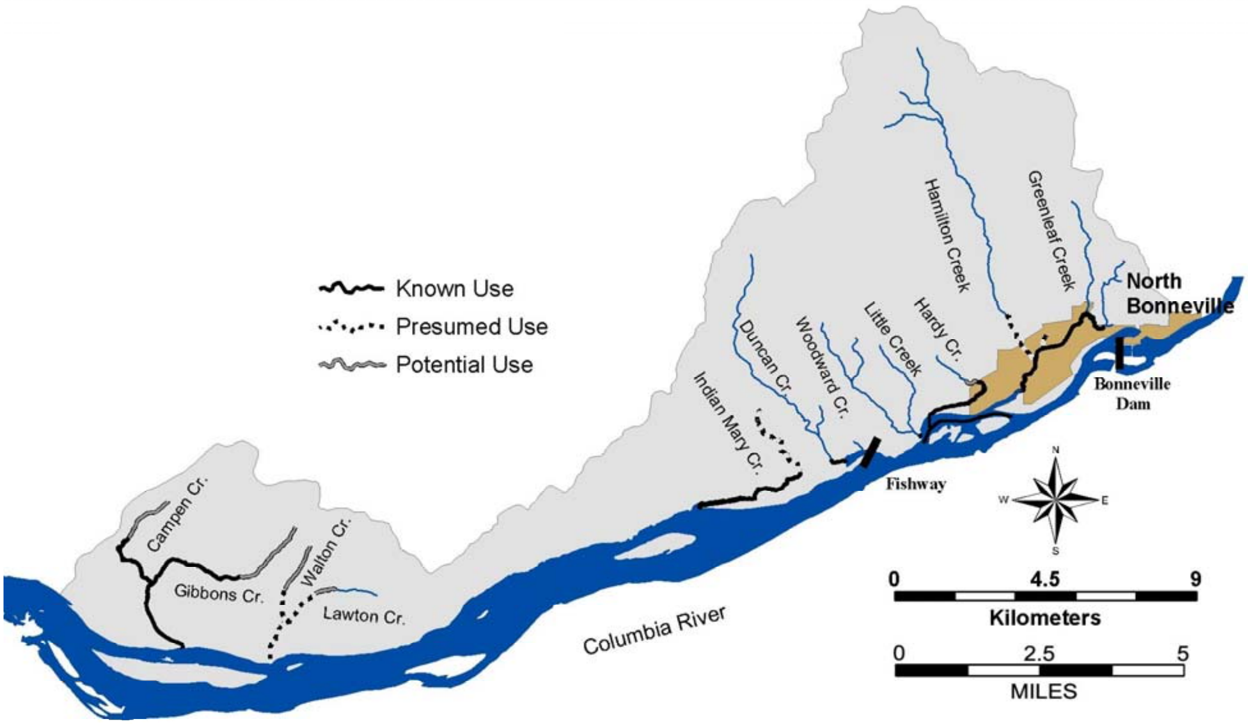
- There are no hatcheries on any of these tributaries
- Washougal Hatchery late coho were planted in Duncan and Greenleaf Creeks in 1983

Harvest

- Until recent years, natural produced 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 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
- Naturally-produced lower Columbia coho are beneficiaries of harvest limits aimed at Federal ESA listed Oregon coastal coho and Oregon listed Clackamas and Sandy coho
- During 1999-2002, harvest rates on ESA listed coho were 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 in September by fall chinook and Sandy River coho management; commercial harvest of late coho is focused in October during peak abundance of late hatchery 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
- There is no sport harvest in these tributaries
- Harvest of coho produced in these lower Columbia tributaries is assumed to be similar to Oregon's Clackamas and Sandy coho, which were harvested at less then 15% during 1999-2002
- There are no adipose fin-clipped hatchery fish released in these tributaries

14.2.3 Chum—Lower Columbia Tributaries Subbasin (Bonneville Chum)

ESA: Threatened 1999	SASSI: 2002



Distribution

- Spawning occurs in the lower 1.0 miles of Hardy Creek and Hamilton Creeks, Hamilton Slough, Duncan Creek, in mainstem Columbia River side channels with springs near the I-205 bridge, and in the mainstem Columbia at Ives and Pierce Islands.

Life History

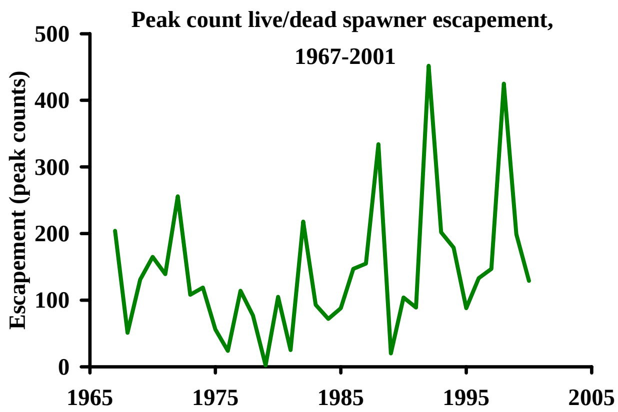
- Adults enter the lower Columbia tributaries from mid-October through November
- Peak spawning occurs in mid-December, but continues into January
- Dominant adult ages are 3 and 4
- Fry emerge in early spring; chum emigrate as age-0 smolts with little freshwater rearing time

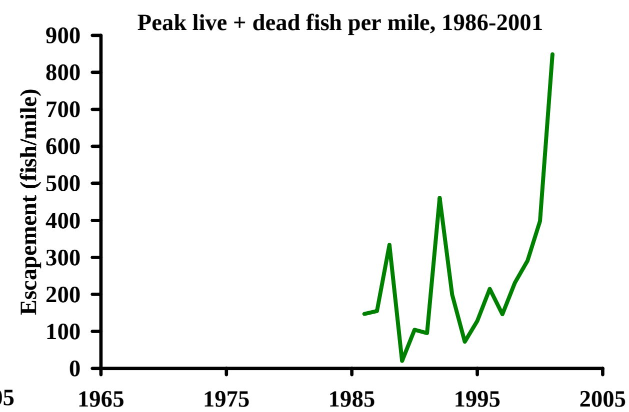
Diversity

- One of two genetically distinct populations in the Columbia River ESU
- Stock designated based on spawning distribution and genetic composition; allozyme and DNA analyses indicate that chum from Hardy Creek, Hamilton Creek, and the mainstem Columbia below Bonneville Dam are one stock (Bonneville chum) and distinct from other Washington Chum stocks

Abundance

- Adult fish/mile ranges from 20-849 for Bonneville chum from 1986-2001 as estimated from peak live/dead escapement ground spawner surveys.





Productivity & Persistence

- NMFS Status Assessment indicated a 0.0 risk of 90% decline in 25 years and a 0.01 risk of 90% decline in 50 years for Hardy Creek and a 0.4 risk of 90% decline in 25 years and a 0.86 risk of 90% decline in 50 years for Hamilton Creek; the risk of extinction was not applicable
- Hardy and Hamilton Creeks population forms one of the most productive populations remaining in the Columbia basin
- A chum habitat restoration and enhancement program is currently underway in Duncan Creek

Hatchery

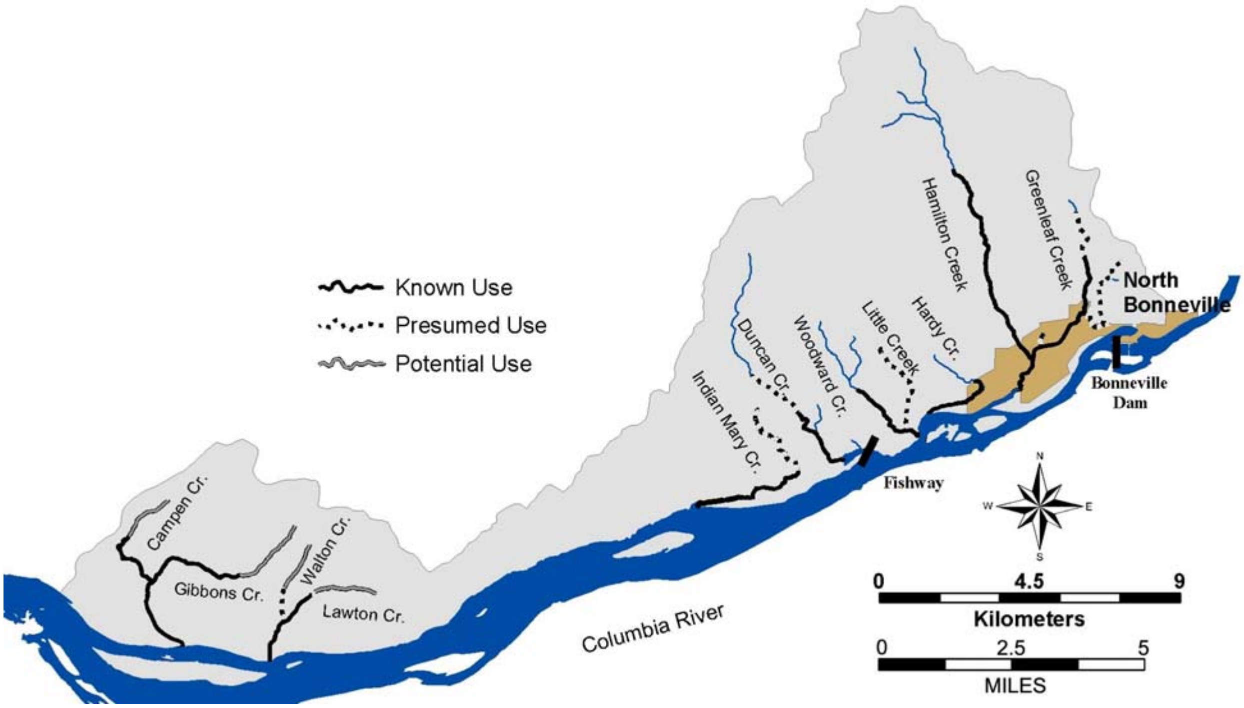
- Hatchery releases have not occurred on Hardy or Hamilton Creeks; USFWS maintains and artificial spawning channel in Hardy Creek to increase chum spawning habitat
- Washougal Hatchery is currently rearing Hardy Creek stock chum to enhance returns to Duncan Creek

Harvest

- Currently very limited chum harvest occurs in the ocean and Columbia River and is incidental to fisheries directed at other species
- Columbia River commercial fishery historically harvested chum salmon in large numbers (80,000 to 650,000 in years prior to 1943); from 1965-1992 landings averaged less than 2,000 chum, and since 1993 less then 100 chum
- In the 1990s November commercial fisheries were curtailed and retention of chum was prohibited in Columbia River sport fisheries
- The ESA limits incidental harvest of Columbia River chum to less then 5% of the annual return

14.2.4 Winter Steelhead—Lower Columbia Tributaries Subbasin (Hamilton)

ESA: Threatened 1998	SASSI: Unknown 2002



Distribution

- Winter steelhead are distributed throughout the lower reaches of Hamilton Creek (~2 mi)

Life History

- Adult migration timing for Hamilton Creek winter steelhead is from December through April
- Spawning timing on Hamilton Creek is generally from early March to early June
- Age composition data for Hamilton Creek winter steelhead are not available
- 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

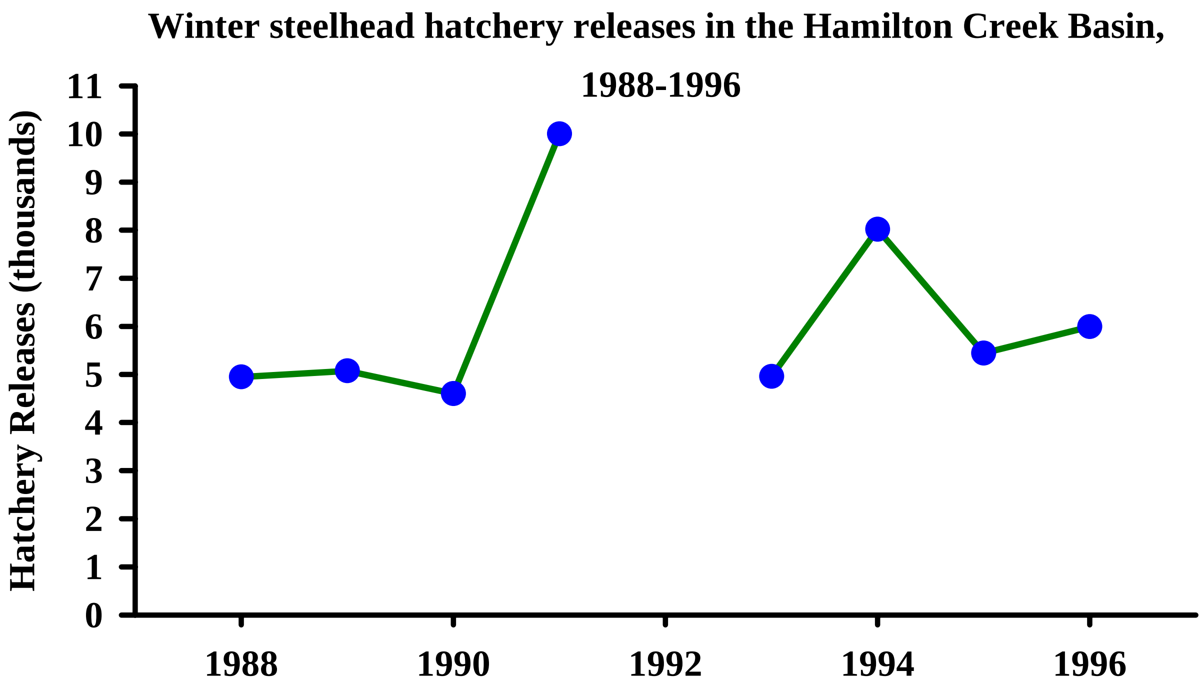
- Hamilton Creek winter steelhead stock is designated based on distinct spawning distribution
- Wild stock interbreeding with Skamania and Beaver Creek Hatchery brood stock is a potential concern

Abundance

- In 1936, steelhead were reported in Hamilton Creek during escapement surveys
- Wild winter steelhead escapement estimates for Hamilton Creek are not available

Productivity & Persistence

- Winter steelhead natural production is expected to be low



Hatchery

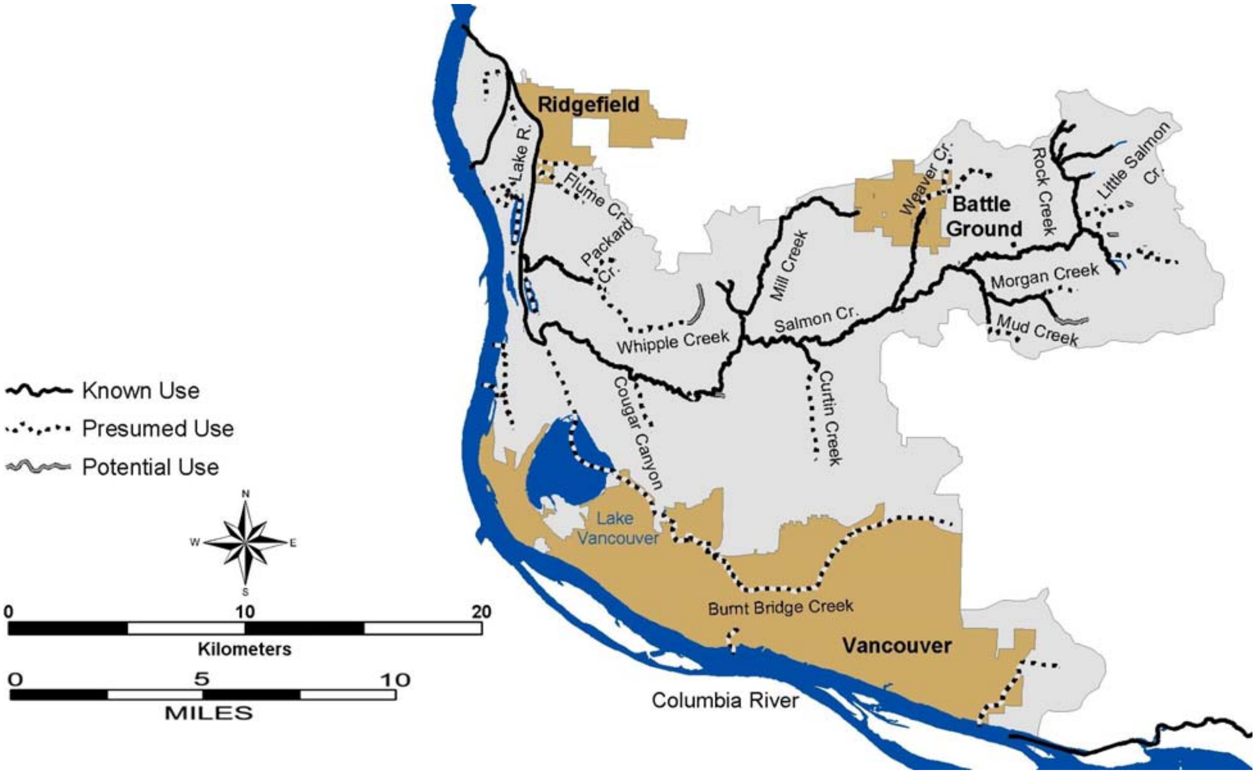
- There are no hatcheries on Hamilton Creek; hatchery winter steelhead from the Skamania (Washougal) and Beaver Creek (Elochoman) Hatcheries have been planted in the basin since 1958; release data are displayed from 1988-1991
- Hatchery fish contribute little to natural winter steelhead production in the Hamilton Creek basin

Harvest

- No directed commercial or tribal fisheries target Hamilton Creek winter steelhead; incidental mortality currently occurs during the lower Columbia River spring chinook tangle net fisheries
- Treaty Indian harvest does not occur in the Hamilton Creek basin
- Winter steelhead sport harvest (hatchery and wild) in Hamilton Creek from 1977-1986 averaged 21 fish; since 1992, regulations limit harvest to hatchery fish only
- ESA practice limits fishery impact on Hamilton Creek wild winter steelhead in the mainstem Columbia River and in Hamilton Creek

14.2.5 Winter Steelhead—Lower Columbia Tributaries Subbasin (Salmon)

ESA: Threatened 1998 **SASSI: Unknown 2002**



Distribution

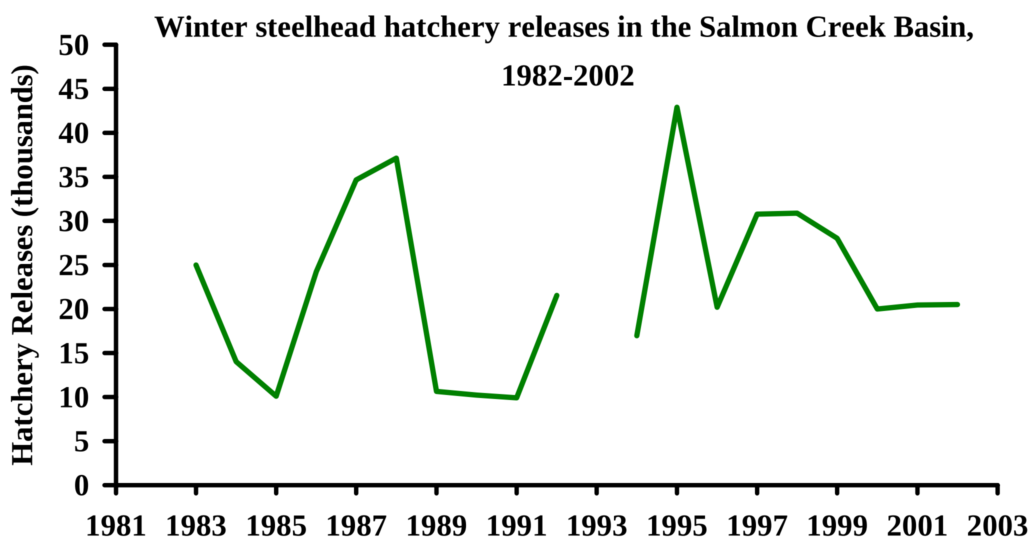
- Winter steelhead are distributed throughout Salmon Creek, the lower reaches of Gee, Whipple, and Burnt Bridge Creek, and portions of the Lake River

Life History

- Adult migration timing for Salmon Creek winter steelhead is from December through April
- Spawning timing on Salmon Creek is generally from early March to early June; limited escapement surveys suggest spawn timing may be early than most lower Columbia winter steelhead
- Age composition data for Salmon Creek winter steelhead are not available
- 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

- Salmon Creek winter steelhead stock is designated based on distinct spawning distribution
- Wild stock interbreeding with Elochoman, Chambers Creek, Cowlitz, and Skamania hatchery brood stock may have occured



Abundance

- In 1936, steelhead were reported in Salmon Creek during escapement surveys
- In 1989, wild winter steelhead spawner surveys on Salmon Creek estimated 80 adult spawners
- Salmon Creek has a winter steelhead escapement goal of 400 wild adults

Productivity & Persistence

- Winter steelhead natural production is expected to be low

Hatchery

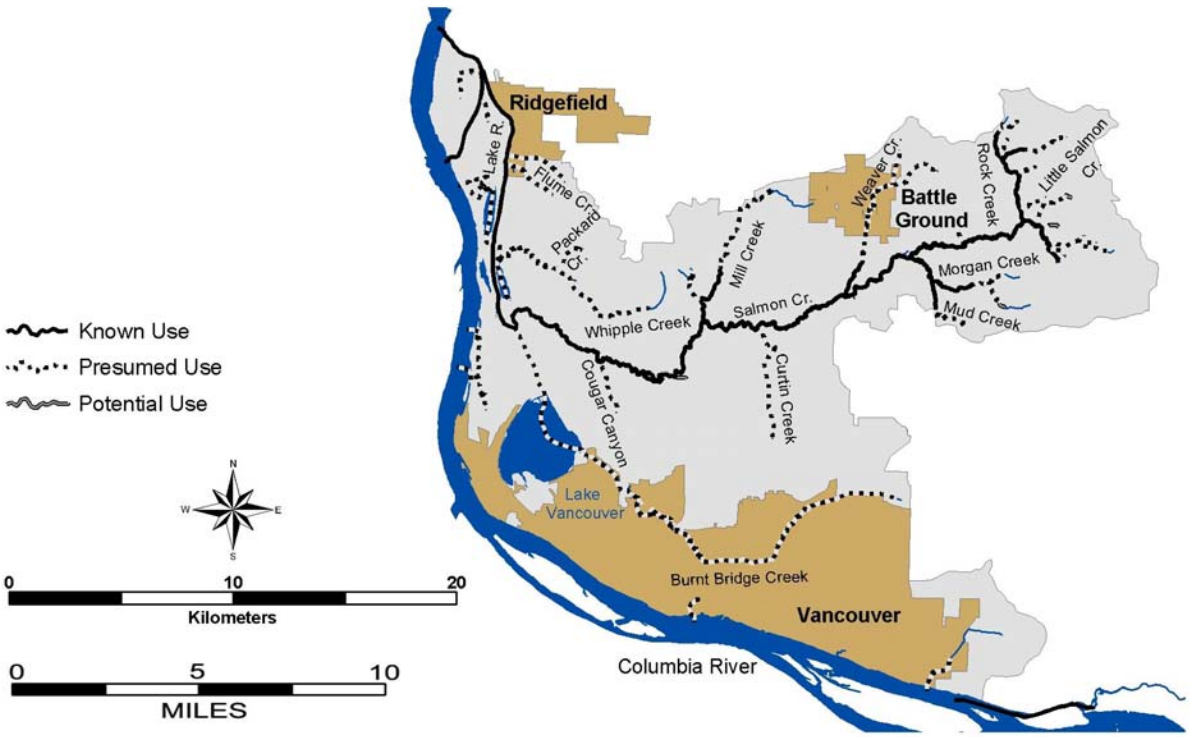
- There are no hatcheries on Salmon Creek; hatchery winter steelhead have been planted in the basin since 1957; release data are displayed from 1982-1992, and 1994-2002
- Hatchery fish contribute little to natural winter steelhead production in the Salmon Creek basin

Harvest

- No directed commercial or tribal fisheries target Salmon Creek winter steelhead; incidental harvest currently occurs during the lower Columbia River spring chinook tangle net fisheries
- Treaty Indian harvest does not occur in the Salmon Creek basin
- Winter steelhead sport harvest (hatchery and wild) in Salmon Creek from 1977-1986 averaged 89 fish; since 1992, regulations limit harvest to hatchery fish only
- ESA practice limits fishery impact on wild winter steelhead to 2 % per year

14.2.6 Cutthroat Trout—Columbia Lower Tributaries Subbasin (Salmon Creek)

ESA: Not Listed	SASSI: Unknown



Distribution

- Anadromous forms have access to the entire subbasin
- Resident forms are documented throughout the system

Life History

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

Diversity

- No genetic sampling or analysis has been conducted
- Genetic relationship to other stocks and stock complexes is unknown

Abundance

- Insufficient quantitative data are available to identify wild cutthroat abundance or survival trends

Hatchery

- Hatchery origin anadromous cutthroat were released into Salmon Creek since at least 1952
- Presently 15,000 winter steelhead smolts, and about 145,000 coho fry are released into the subbasin annually

- The hatchery cutthroat release program was discontinued in 1999

Harvest

- Not harvested in ocean commercial or recreational fisheries
- Angler harvest for adipose fin-clipped hatchery fish occurs in mainstem Columbia summer fisheries downstream of the Salmon Creek
- Wild Salmon Creek cutthroat (unmarked fish) must be released in the mainstem Columbia and Salmon Creek sport fisheries.

14.3 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.

14.3.1 Salmon Subbasin

- Loss of tributary habitat quality and quantity is an important impact for all species. Loss of estuary habitat quality and quantity is also important to chum. Harvest has a large relative impact on fall chinook and moderate impacts on coho and winter and summer steelhead. Harvest effects on chum are minimal.
- Harvest is a significant issue for coho, but not so for both chum and winter steelhead.
- Hatchery impacts are moderate for winter steelhead and coho, but are non-existent for chum.
- Predation is moderately important to all three species.
- Hydrosystem access and passage impacts appear to be relatively minor for all species.

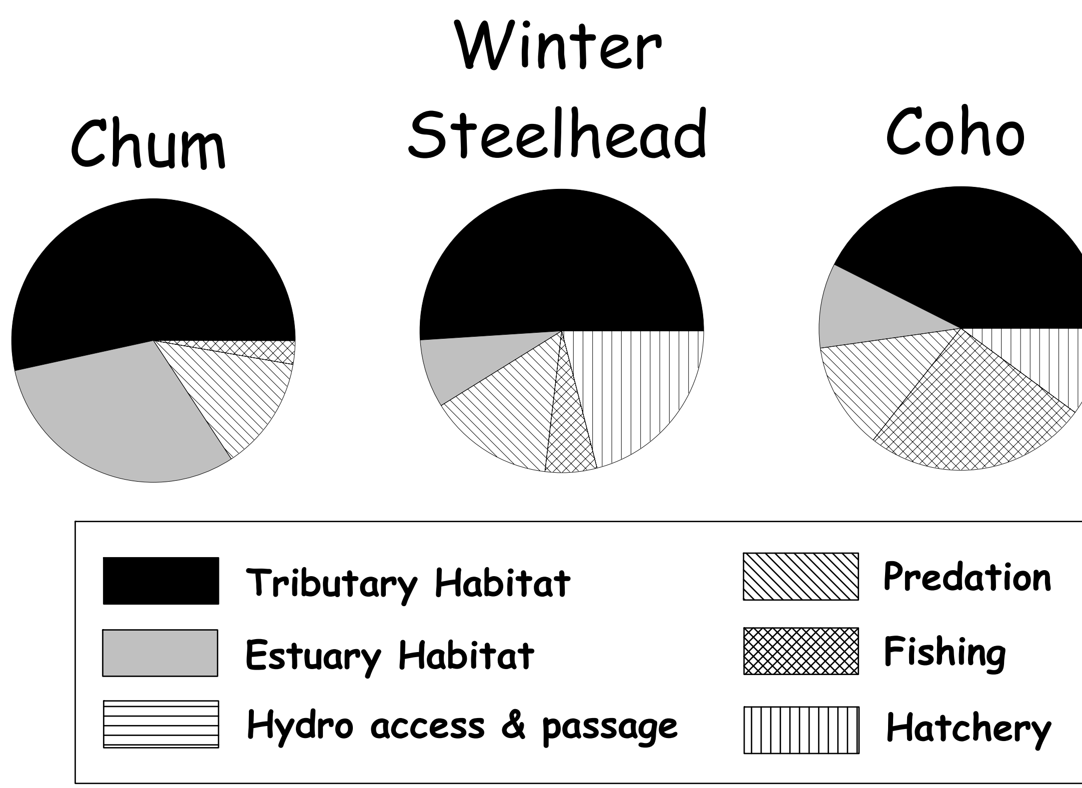


Figure 14-9. Relative index of potentially manageable mortality factors for each species in the Salmon Creek / Lake River subbasin.

14.3.2 Lower Gorge Subbasin

- Loss of tributary habitat quality and quantity is an important impact for all species. Loss of estuary habitat quality and quantity is most important to chum of the four species.
- Harvest has moderate impacts on coho and winter steelhead, but is relatively low for chum and fall chinook.
- Hatchery impacts are substantial for coho but are minimal for winter steelhead, chum, and fall chinook.
- Predation impacts are moderate for winter steelhead, but are less important for the other three species.
- Hydrosystem access and passage impacts appear to be relatively important for chum and fall chinook.

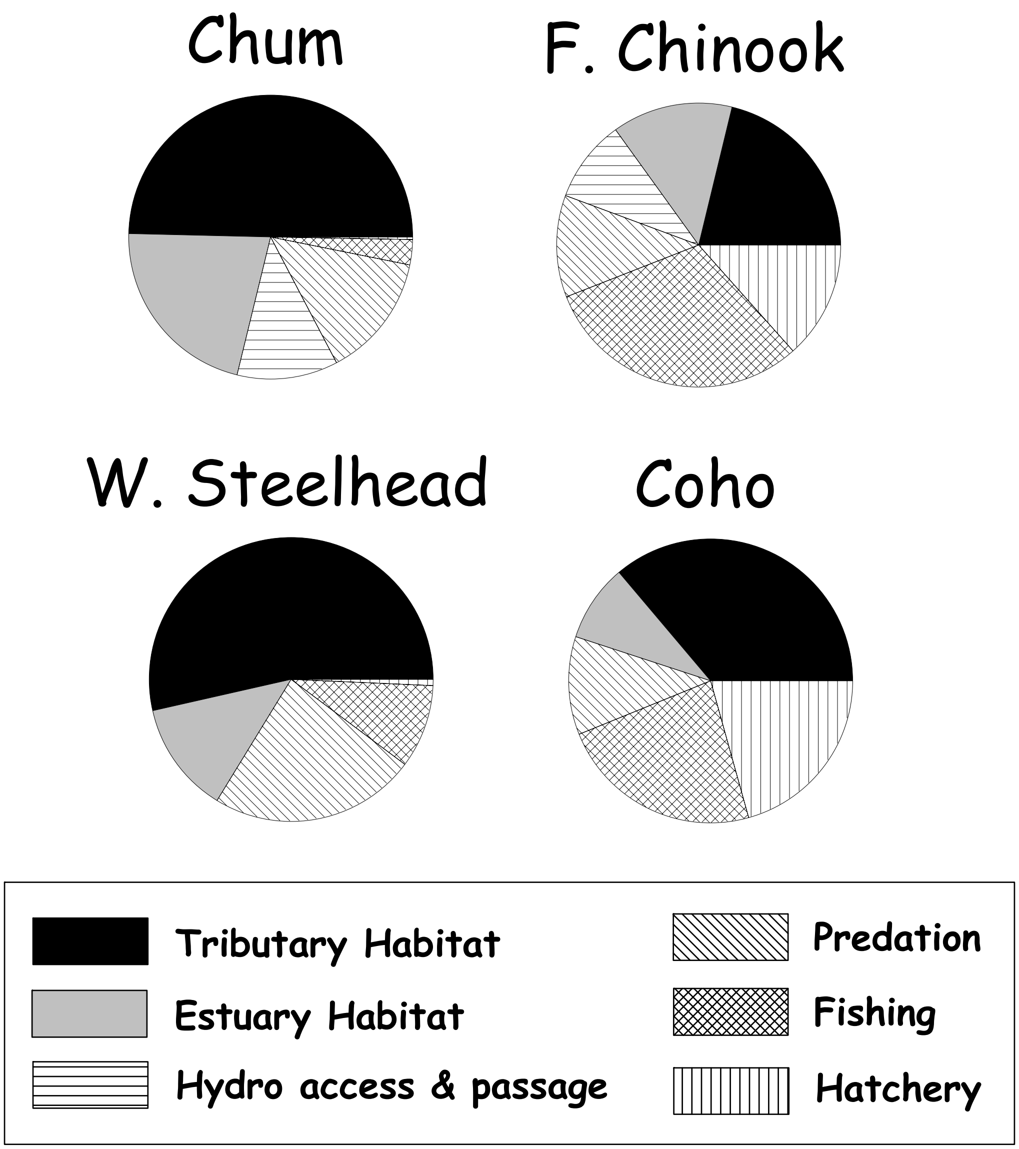


Figure 14-10. Relative index of potentially manageable mortality factors for each species in the Bonneville tributaries.

14.4 Hatchery Programs

14.4.1.1 Salmon Creek

There are no hatcheries in Salmon Creek. However, Skamania winter steelhead hatchery stock from Skamania Hatchery has been released in the basin since at least the early 1980s; current release goals are 20,000 winter steelhead smolts that are incubated at the Vancouver Hatchery (because of space limitations at Skamania), transferred to the Skamania Hatchery as fry, and acclimated in net pens in Klineline Pond, adjacent to Salmon Creek (Figure 14-11).

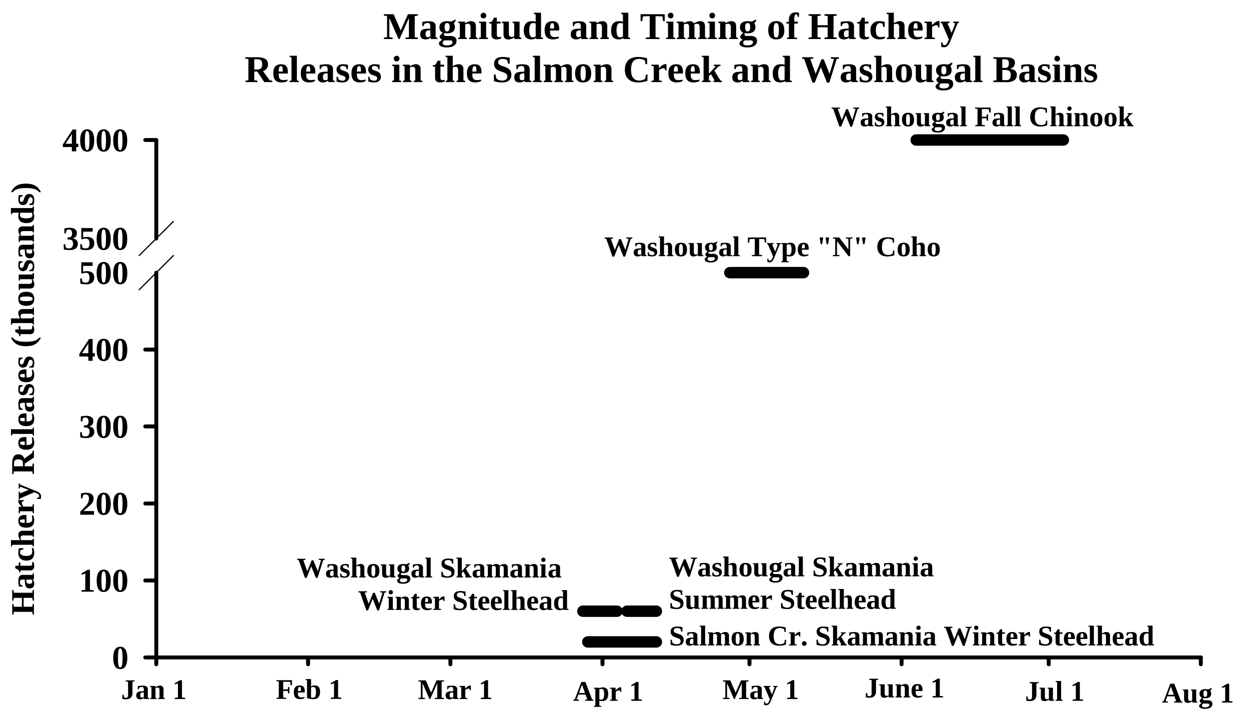


Figure 14-11. Magnitude and timing of hatchery releases in the Salmon Creek and Washougal River basins by species, based on 2003 brood production goals.

Genetics—Broodstock for the winter steelhead hatchery program at the Skamania Hatchery originated from local Washougal River winter steelhead; current broodstock collection comes from adults returning to the hatchery. Shortfalls in annual broodstock needs have been supplemented from Beaver Creek Hatchery winter steelhead stocks, which originated primarily from Chambers Creek and Cowlitz River stocks. Also, Cowlitz River stocks may have strayed to Salmon Creek after the 1980 eruption of Mt. St. Helens.

Interactions—Hatchery fish account for most adult winter steelhead returning to Salmon Creek; very few wild winter steelhead are present (Figure 14-12). Also, spawn timing of wild fish and naturally spawning hatchery fish is different, so there is likely minimal interaction between adult wild and hatchery winter steelhead. Winter steelhead natural production is low; returning hatchery adults contribute little to natural production. Hatchery winter steelhead are released as smolts and clear the river quickly, so competition for food resources with natural salmonids is probably minimal. Releases of winter steelhead into Salmon Creek are moderate in number and hatchery fish therefore are not expected to attract excessive amounts of predators toward wild fish.

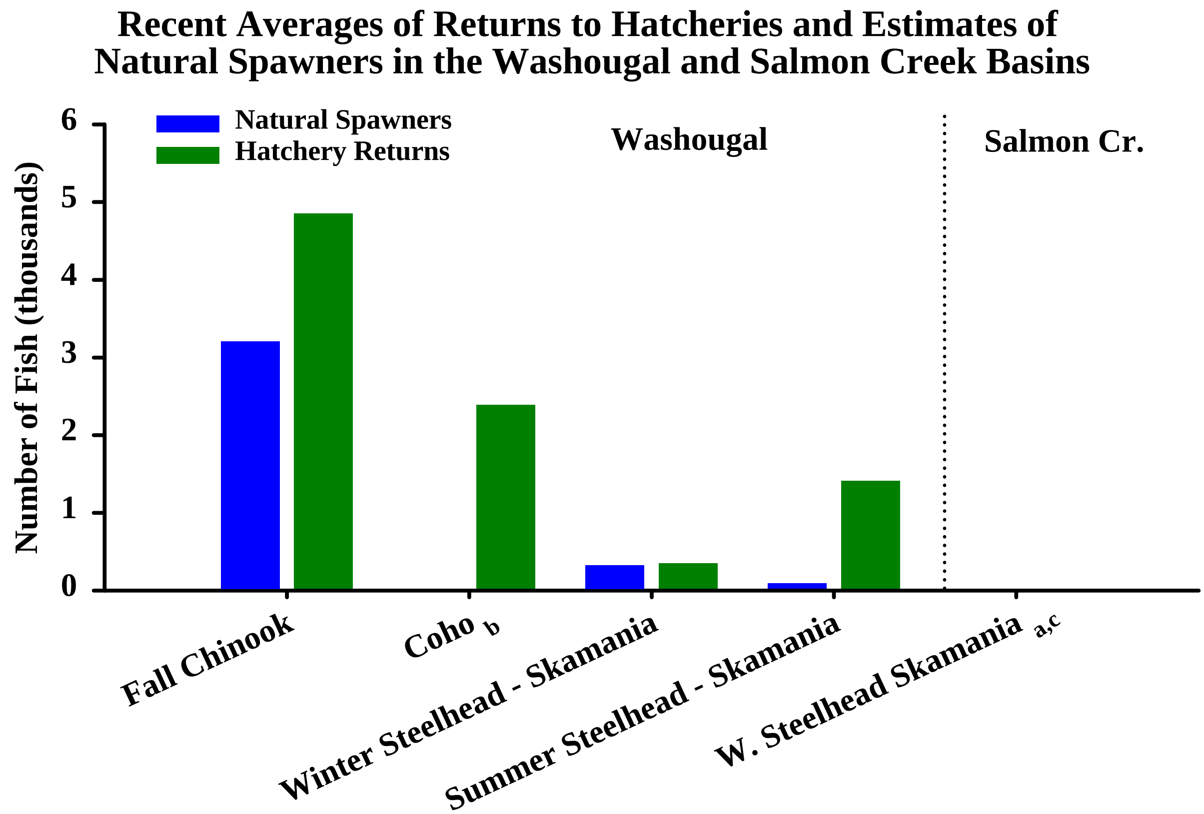


Figure 14-12. Recent average hatchery returns and estimates of natural spawning escapement in the Salmon Creek and Washougal River basins by species.

The years used to calculate averages varied by species, based on available data. The data used to calculate average hatchery returns and natural escapement for a particular species and basin were derived from the same years in all cases. All data were from the period 1992 to the present. Calculation of each average utilized a minimum of 5 years of data.

[a] There is no hatchery facility in the basin to enumerate and collect returning adult hatchery fish. All hatchery fish released in the basin are intended to provide harvest opportunity.

[b] A natural stock for this species and basin have not been identified based on populations in WDFW's 2002 SASSI report; escapement data are not available.

[c] Although a natural population of this species exists in the basin based on populations identified in WDFW's 2002 SASSI report, escapement surveys have not been conducted and the stock status is unknown.

Water Quality/Disease—Refer to the Washougal River section for information on water quality and disease control issues related to Skamania Hatchery winter steelhead program operations.

Mixed Harvest—The purpose of the winter steelhead hatchery program at the Skamania Hatchery is to provide harvest opportunity to mitigate for winter steelhead lost as a result of hydroelectric development in the lower Columbia River basin. Fisheries that may benefit from this program includes lower Columbia and Salmon Creek sport fisheries. No adults are collected for broodstock needs in Salmon Creek, so all returning adults are available for harvest. Prior to selective fishery regulations, exploitation rates of wild and hatchery winter steelhead likely were similar. Mainstem Columbia River sport fisheries became selective for hatchery steelhead in 1984 and Washington tributaries became selective during 1986–92 (except the Toutle in 1994). Current selective harvest regulations in the lower Columbia and tributary sport fisheries have targeted hatchery steelhead and limited harvest of wild winter steelhead to fewer than 10% (4% in Salmon Creek) This is a successful program supporting a popular fishery.

Passage—There are no hatcheries or facilities for adult hatchery fish collection in Salmon Creek.

Supplementation—Supplementation is not the goal of the Skamania winter steelhead hatchery releases in Salmon Creek; all hatchery winter steelhead are provided for harvest opportunities.

14.4.1.2 Bonneville Area Tributaries

There are no hatcheries in the Bonneville area tributaries. Sporadic hatchery releases of fall chinook, coho salmon, and winter steelhead have occurred over time. Hatchery winter steelhead from Skamania (Washougal) and Beaver Creek (Elochoman) stocks have been planted in Hamilton Creek beginning in 1958 and continued into the 1990s. In 1977, the Spring Creek NFH released approximately 50,000 tule fall chinook in Hamilton Creek. In 1983, the Washougal Hatchery released late-run coho in Duncan and Greenleaf creeks. More specific information regarding the hatchery programs that have released fish into the Bonneville area tributaries is available in the appropriate sections presenting information on each hatchery.

A spawning population of upriver bright fall chinook was discovered in 1994 in the mainstem Columbia River immediately downstream of Bonneville Dam. The population is considered to have originated from hatchery strays from the Bonneville Hatchery in Oregon and the Little White Salmon NFH in Washington. Allozyme analysis indicated that this population was genetically distinct from other Columbia River bright fall chinook stocks, although the population resembles Yakima bright fall chinook and upriver bright fall chinook produced at the Little White Salmon NFH and the Bonneville Hatchery. This population is not considered part of the LCR chinook salmon ESU.

A chum salmon hatchery program was recently started at the Washougal Hatchery with releases beginning in 2003. The program uses Hardy Creek chum for broodstock; the program goal is to enhance chum returns to Duncan Creek. The hatchery program occurs in conjunction with habitat restoration efforts in Duncan Creek. This program also acts as a safety-net in the event that mainstem Columbia flow operations severely limit the natural spawning of chum salmon in Hamilton and Hardy creeks and the Ives Island area below Bonneville.

14.5 Fish Habitat Conditions

14.5.1 Passage Obstructions

14.5.1.1 Lake River

Passage is naturally blocked on Salmon Creek by Salmon Falls at RM 24.1. On the lower river, a 4-foot high falls below the Hwy 99 Bridge might limit passage. The falls is the result of a headcut that followed the avulsion of the stream into gravel pits in 1996. There may be potential passage problems with the flushing channel entering Vancouver Lake due to high flow velocities. Other artificial passage barriers include several culverts, shallow flow where water courses over agricultural land, a stop gate at a private pond, headcuts, an inoperable fish passage structure on Baker Creek, a concrete flume on Burnt Bridge Creek, and railroad/road crossings on some of the Columbia River tributaries (Wade 2002).

14.5.1.2 Bonneville Tributaries

An historical wetland complex on Gibbons Creek was modified in 1966, creating fish passage problems. Fish passage restoration efforts completed in 1992 resulted in an elevated artificial channel with a fish ladder structure at the mouth. Observations in the summer of 2000 suggest that there may be some passage problems associated with the fish ladder and low flows at the mouth area. Passage problems are also associated with the structure that diverts water into the elevated channel at the head of the historical wetland complex. Bedload buildup during stormflows restricts overflow through a screened intake that feeds the wetlands, overwhelming the diversion channel and spilling fish into adjacent fields, where they become stranded (Wade 2001). Several culverts and other artificial barriers also block passage within the Gibbons Creek basin. Details are given in Wade (2001).

Culverts under State Route 14 and the railroad corridor provide various levels of passage concerns on Mary Creek, Woodward Creek, and Hardy Creek. Passage has been blocked on Greenia Creek (Hardy Creek tributary) to prevent fish access to a wetland managed as a western pond turtle refuge. On many of the streams, there are concerns with low flow problems associated with sediment buildup where the streams enter the Columbia. Flow becomes subsurface at times during the summer.

In the past, an earthen dam near the mouth of Duncan Creek restricted anadromous passage to this important chum spawning stream. Restoration of passage has been accomplished with the installation of a dam and fishway that allow for passage at critical migration periods, but retain recreational lake levels during the summer months.

14.5.2 Stream Flow

14.5.2.1 Lake River

Streamflows in the subbasin are generally a direct result of rainfall, as no substantial snow accumulations occur in these low elevation systems. The largest stream system, Salmon Creek, has a mean flow in December of nearly 450 cubic feet per second (cfs) and a mean flow in late summer of less than 25 cfs. The hydrologic regime of the Lake River basin has been highly impacted by urban and rural development, especially Burnt Bridge Creek, which exhibits the flashy flow typical of urban basins (Figure 14-13).

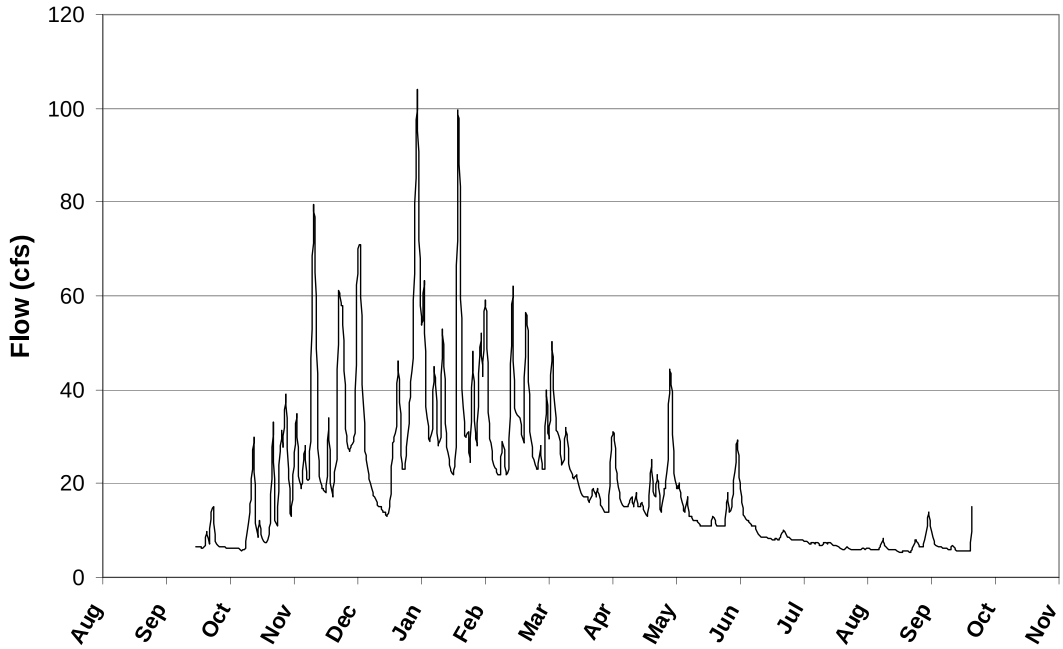


Figure 14-13. Burnt Bridge Creek for Water Year 2000. Flashy flow typical of urban basins is demonstrated by the preponderance of sharp peaks.

Many of the channels in the Lake River basin have been diked, floodplains have been filled or otherwise disconnected, and the amount of impervious land surface has increased dramatically since historical times. The area surrounding Vancouver Lake and to the west was once an extensive network of interconnected sloughs, wetlands, ponds, and tidal channels. Dikes along the Columbia and Lake River now protect developed lowlands from flooding. Vancouver Lake has had a history of water quality problems related to urban development in the basin, including eutrophication and excessive sedimentation. In order to improve water quality and recreational uses, a project in the early 1980s dredged the lake and constructed a flushing channel, which re-connected the lake to the Columbia River. Lake River and Vancouver Lake levels are influenced by tidal fluctuations and by Columbia River levels. Alterations to the flow of the Columbia from mainstem dams, disconnection of historical overflow channels, and the construction of the flushing channel have altered the flow regime of Vancouver Lake and Lake River, with subsequent impacts to water quality, nutrient levels, and sediment dynamics (Wade 2001).

Impaired runoff conditions are a concern in this highly developed basin. The Integrated Watershed Assessment (IWA), which is presented in greater detail later in this chapter, indicates that 27 of the 34 subwatersheds (7^{th} field) are “impaired” with respect to runoff conditions and the remaining 7 are “moderately impaired”. The widespread hydrologic impairment is related to the high percentage of watershed imperviousness, lack of mature forest vegetation, and alterations to the drainage network due to roads and other development. Over 87% of the Lake River basin is in non-forest or other uses and the road density is a very high 9.7 mi/mi^2. The significant increase in impervious surfaces associated with development has likely decreased infiltration, thereby increasing runoff and peak flows and decreasing base flows. Although stream gaging records on most streams in the area are too sparse or too short-term to detect anthropogenic alterations to flow regimes, there is evidence that on lower Burnt Bridge Creek, peak flows may have increased since the 1970s due to increased urbanization (EnviroData Solutions, Inc, 1998).

Watershed development and water withdrawals have likely reduced streamflows to below historical levels. Mean monthly flows in Salmon Creek fell below 12 cfs in five of the 10 years on record. Observations indicate that Mill Creek was perennial throughout its length prior to 1960; now it typically dries up by mid-July (Wade 2001). Low flow problems exist in the Salmon Creek tributaries Morgan Creek, Mud Creek, and Baker Creek. Instream flow analysis using the toe-width method revealed that, on Salmon Creek tributaries and in Whipple Creek, flows in the fall were considerably below optimum for salmonid spawning and rearing (Caldwell et al. 1999).

As part of the Phase 2 assessments for WRIA 27/28 under the Watershed Management Act, Pacific Groundwater Group completed an HSPF (Hydrologic Simulation Program – Fortran) model analysis of Salmon Creek. The analysis provided information that indicates low base flows during the summer months on Salmon Creek have been impacted by development. A summary of the results are as follows: 1) during summer months surface water diversions of 3-5 cfs may take 15-30% of stream flow when flow is 15-20 cfs, 2) reduced recharge due to impervious surfaces reduces annual base flow by 12%, 3) withdrawal of groundwater from wells (public and private) reduces base flow by an estimated 8%.

In the Salmon Creek basin, current (year 2000) levels of consumptive water use are approximately 5,000 million gallons per year (mgy) and are expected to increase by 5,475 mgy by 2020. Water use in this basin is a significant component of watershed hydrology, making up as much as 75% of late summer stream flow. Assuming full hydraulic continuity between ground and surface waters, the predicted use in 2020 may exceed late summer flows. In the Burnt Bridge Creek basin, current use already exceeds late summer stream flow volumes if one assumes full connection of ground and surface waters. Both Salmon Creek and Burnt Bridge Creek are closed to further surface water rights appropriation (LCFRB 2001).

14.5.2.2 Bonneville Tributaries

The Bonneville Tributary basins have not had substantial impacts to hydrologic regimes, as much of the area is steep and is now protected by the provisions of the Columbia River Gorge National Scenic Area legislation. There are no permanent stream gages in the basin and little information exists on flow conditions. The streams follow the same general pattern as precipitation due to a lack of storage in the form of impoundments or permanent snowpacks.

The operation of Bonneville Dam has altered flow regimes to some degree in lower Greenleaf and Hamilton Creeks due to reduced connections to overflow channels (Wade 2001). Manipulation of stream flow occurs in a couple of streams. In lower Gibbons Creek, flow exceeding 70 cfs is diverted out of the elevated, artificial channel and into a remnant channel. In Duncan Creek, flow is impounded at the dam near the mouth during the summer months to provide a recreational pond for area residents. Flows are released through the dam at other times of the year to provide adequate passage flows for fish.

Hydrologic (runoff) conditions were investigated as part of the Integrated Watershed Assessment (IWA), which is presented in greater detail later in this chapter. The IWA results indicate that watershed conditions in 3 of the 7 subwatersheds are “impaired” with respect to conditions that influence runoff; 3 are “moderately impaired”; and only 1 is rated as “functional” (upper Hamilton Creek). The greatest impairments are located in the Lawton Creek, Hardy/Woodward Creek, Duncan Creek, and Indian Mary Creek basins. Runoff impairment in the basin is related primarily to low quantities of mature forest and high road densities. Nearly 60% of the land cover in the Gibbons and Lawton Creek basins is in either non-forest (i.e. urban, agriculture) or other (i.e. cleared, scrub) cover. Over 46% of the land cover in the Duncan, Woodward, Hardy, Hamilton, and Greenleaf Creek basins is in these categories. Land cover conditions, combined with moderate-to-high road densities (>2 mi/mi^2), increase the risk of elevated peak flows and reduced base flows.

An instream flow study utilizing the toe-width method was conducted in 1998 on Gibbons, Lawton, Duncan, Woodward, Hardy, Greenleaf, and Hamilton Creeks. Spot flow measurements were taken at three different times in the fall to compare to optimal flows for salmon and steelhead. Results suggested that for all streams, the flows were well below optimum for both salmon and steelhead spawning and rearing from the first part of September to November (Caldwell et al. 1999). Summer low flow problems have also been observed at the mouths of several streams and may possibly restrict fish passage and strand juvenile fish (Wade 2001).

Current and projected future consumptive water use in the basin is believed to represent only a minor component of available water. Surface water rights appropriation has not been closed for these streams (LCFRB 2001).

14.5.3 Water Quality

14.5.3.1 Lake River

Vancouver Lake is classified as hyper-eutrophic with very high phosphorous and correspondent algal blooms. The lake was historically 20 feet deep and clear, with sturgeon. Industrial development, two nearby superfund sites, and alterations to basin runoff dynamics have had large impacts. Lake River was listed on the 1998 Washington State 303(d) list of water quality impaired water bodies for fecal coliform, temperature, and sediment bioassay. Burnt Bridge Creek is on the 303(d) list for pH, DO, temperature, and fecal coliform. Salmon Creek is on the 303(d) list for temperature, turbidity, and fecal coliform (WDOE 1998). Salmon Creek and several tributaries regularly exceed state standards for fecal coliform, turbidity, DO, and temperature. Development, septic systems, and agricultural activities contribute to these problems. Low flows and constructed ponds in the upper basin are believed to contribute to elevated temperatures. A more complete description of water quality problems in specific Salmon Creek tributaries can be found in Wade (2001).

14.5.3.2 Bonneville Tributaries

Gibbons Creek is listed on the state 303(d) list for violation of fecal coliform standards. Fecal coliform levels are believed to originate from failing septic systems and small livestock operations. The greatest proportion of the fecal coliform load comes from the Gibbons Creek tributary Campen Creek (Post 2000). Temperature monitoring in the Gibbons Creek basin in the late 1990s showed regular exceedances of the state standard (64°F [18°C]) in lower Gibbons Creek and lower Campen Creek. This likely is a result of the low riparian canopy cover levels in these reaches. Water temperatures exceeded 68°F (20°C) in lower Hardy Creek on a few summer days in 1998 and 1999. Water temperature information is generally lacking for other streams.

The USFWS conducted a benthic macroinvertebrate survey at 4 sites on Gibbons and Campen Creek using the Benthic Index of Biotic Integrity (B-IBI). This survey methodology uses the presence of particular benthic macroinvertebrate communities as an indicator of overall stream health (Kerans and Karr 1994). Results revealed poor riffle and pool habitat in Campen Creek along the golf course and fair to excellent riffle and pool habitat conditions at the other locations (Wade 2001).

Nutrient deficiencies are an assumed problem due to low anadromous salmonid escapement levels compared to historical conditions. Low returns can reduce the input of carcass derived nutrients into stream systems.

14.5.4 Key Habitat

14.5.4.1 Lake River

Pool habitat is generally lacking in most of the stream systems. Poor conditions are likely associated with a dearth of LWD, alterations to channel morphology, and changes in the flow and sediment regimes as a result of urbanization. Stormwater runoff and a lack of LWD favors glides over pools in Whipple Creek. Channelization, vegetation removal, and dredging have decreased pool habitats in Burnt Bridge Creek. Surveys conducted by the Clark County Conservation District (CCCD) in Salmon Creek revealed that only 10-15% of the stream surface area was pool habitat. Conditions in tributaries were found to be similar, with generally less than 10% of the surface area in pools (Wade 2001).

The abundance and quality of side channels has decreased significantly as a result of the extensive dike network throughout most of the basins. Side channels in the area surrounding Vancouver Lake have been further impacted by placement of dredge spoils during the dredging of the lake. Upper Burnt Bridge Creek, which was once a series of interconnected wetlands, was diked and drained, eliminating most off-channel habitats. Whipple Creek is mostly incised with few side-channels. Diking and channelization eliminated many side channels that were once present in the lower, braided reach of Salmon Creek. Mining activities have eliminated side channel development in Salmon Creek near the I-5 crossing and upper basin side channels have been reduced by various land-use activities. Side channel habitats have also been degraded / eliminated on several Salmon Creek tributaries. Details can be found in Wade (2001).

14.5.4.2 Bonneville Tributaries

State Highway 14 and the Burlington Northern Santa Fe Railroad impact channel morphologies in the lower reaches of most streams. Pool habitat was found to be lacking in 13 out of 19 surveyed reaches in Woodward, Duncan, Good Bear, Hardy, Hamilton, and Greenleaf Creeks. Eight of 11 surveyed reaches in the Gibbons Creek basin had less than 15% of the stream surface area in pools, though a few pools in the basin have considerable area and depth that may provide adequate habitat (Wade 2001).

The presence of side channel habitats is limited to only the lower portions of most of the streams. State Route 14, the railroad, and other development have isolated some of the historical side channels. There is some good side channel and off-channel habitat in lower Hamilton Creek, including the Hamilton Springs chum spawning channel. Minimal side or off-channel habitat exists in Woodward, Good Bear, Hardy, Duncan, or Greenleaf Creeks. Historically abundant side channel habitat was eliminated in Gibbons Creek as a result of modifications to wetlands in the lower reaches. The stream currently courses though an elevated artificial channel in its lower mile (Wade 2001).

14.5.5 Substrate & Sediment

14.5.5.1 Lake River

Stream surveys conducted by the CCCD in the late 1980s determined that sedimentation and compaction of spawning substrate was a major limiting factor in the basin. In Salmon Creek and tributaries, 6 of the 20 surveyed habitat units had over 75% fines.

Fine sediment is readily delivered to streams in this highly developed area due to stormwater runoff, development in riparian zones, stream-adjacent roads and trails, utility corridors, cattle impacts, and recreational activities (Wade 2001). Sediment supply conditions were evaluated as part of the IWA watershed process modeling, which is presented later in this chapter. The IWA rates 20 of the 34 subwatersheds as “moderately impaired” with respect to landscape conditions that influence sediment supply. The remaining 14 subwatersheds were rated as “functional”. The presence of functional conditions is related to the flat topography of many subwatersheds, which decreases the potential for sediment delivery to stream channels. However, based on the high natural erodability of soils and the high degree of watershed development, the potential for sediment delivery to stream channels is high. For example, the road density in the basin is a very high 9.7 mi/mi^2 and there are over 44 miles of stream-adjacent roads.

14.5.5.2 Bonneville Tributaries

USFWS surveys indicate that fine sediment is a problem throughout the Gibbons Creek basin, with all of the 11 surveyed reaches having greater than 18% fines. Only a few reaches in the upper Gibbons Creek basin had substrates suitable for salmonids. USFS surveys revealed that only the 2 upper reaches of Woodward Creek suffered from embedded substrates and that most surveyed streams consisted primarily of gravels. Local experts have expressed a concern over fine sediments in spawning areas in Hardy Creek. While Hamilton Creek does not suffer from fine sediment problems, there are concerns with the effect of bedload instability on chum production (Wade 2001). Many streams deposit large amounts of coarse sediment as they emerge from steep canyons in the Gorge. Some of this material does not reach important spawning areas due to artificial obstructions and it also creates problematic changes to channel morphology as it is routed through culverts and diversions.

Sediment supply conditions were evaluated as part of the IWA watershed process modeling, which is presented later in this chapter. The IWA rated all the subwatersheds in the basin as “moderately impaired” with respect to landscape conditions that influence sediment supply. Sediment supply impairments are related to steep slopes and moderately high road densities. Average road densities in the basin fall between 2-3 mi/mi2, considered moderate by most standards.There are a total of approximately 26 miles of stream-adjacent roads and an average of over four stream crossings per mile. These conditions may serve to increase sediment production and delivery to stream systems.

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.

14.5.6 Woody Debris

14.5.6.1 Lake River

Current levels of LWD are low in the Lake River basin. The disconnection of overflow channels and sloughs has prevented potential recruitment to stream channels. Furthermore, practices including agricultural development, diking, and road building removed riparian vegetation that could provide a source for instream large wood. Currently, only a few scattered areas have levels of natural vegetation capable of supplying wood to streams. The only stream system with any significant LWD levels is Rock Creek in the upper Salmon Creek basin (Wade 2001).

14.5.6.2 Bonneville Tributaries

USFS surveys noted low LWD levels in Woodward, Duncan, Good Bear, Hamilton, and Greenleaf Creeks, with a general increase in LWD levels in the upstream direction. All surveyed reaches had less than 0.2 pieces of LWD/meter of stream. Lower Hamilton and Greenleaf Creeks had the lowest amounts. Medium and large LWD is also lacking in the Gibbons Creek basin, with all surveyed reaches receiving a poor rating. LWD levels are also considered low in Hardy and Indian Mary Creeks (Wade 2001).

14.5.7 Channel Stability

14.5.7.1 Lake River

Streambank stabilization has occurred on most of the streams in the Lake River basin in order to protect urban and rural development. Bank hardening has protected most banks from erosion but in some cases has exacerbated erosion in adjacent areas. The avulsion of lower Salmon Creek into stream-adjacent gravel pits initiated an upstream migrating headcut. On Salmon Creek between I-5 and 182nd Avenue there is a high bank, 800-900 feet long, eroding into the creek. In agricultural areas upstream, removal of riparian vegetation has contributed to lateral channel migration. Several bank stability problem areas are located on Salmon River tributaries. These mostly involve livestock access and riparian vegetation removal. Morgan and Mill Creeks contain the most area of bank instability. Additional details can be found in Wade (2001).

14.5.7.2 Bonneville Tributaries

Information on bank stability is largely lacking. USFS surveys between 1994 and 1996 revealed generally good bank stability conditions on Hamilton and Greenleaf Creeks, except for a couple of portions of lower Hamilton Creek. Lower Woodward Creek is considered very unstable below the railroad. USFS surveys found moderately high width/depth ratios on many of the lower reaches of streams, indicating the potential for lateral bank erosion (Wade 2001).

14.5.8 Riparian Function

14.5.8.1 Lake River

Riparian conditions are poor in the Lake River basin. Residential and commercial development, agriculture, transportation corridors, placement of fill, and diking have eliminated most riparian vegetation on Lake River, Whipple Creek, Burnt Bridge Creek, and lower Salmon Creek. Upper basin reaches are impacted by agriculture, rural development, and forest practices (Wade 2001).

According to IWA watershed process modeling, which is presented in greater detail later in this chapter, 25 of the 34 subwatersheds were rated as “impaired” with respect to riparian function, 5 were rated as “moderately impaired”, and 4 were not rated. These results are consistent with an analysis of georeferenced Landsat satellite imagery data that looked at the amount of vegetation cover and stand age to determine that 74% of riparian areas were in poor condition and only 1% were in good (mid- to late-seral stage) condition (Lewis County GIS 2000).

14.5.8.2 Bonneville Tributaries

According to IWA watershed process modeling, which is presented in greater detail later in this chapter, riparian conditions are “moderately impaired” in all but 1 of the 7 subwatersheds in the basin. Only the upper Hamilton Creek subwatershed received a rating of “functional”. These results are consistent with an analysis of georeferenced Landsat satellite imagery data, which revealed that less than 10% of the riparian forests in the basin were in mid- to late-seral stages, and most of these were located in upper tributaries above the extent of anadromous habitats (Lewis County GIS 2000). Surveys by the USFS in the mid-1990s also revealed generally poor riparian conditions; only 5 of 18 surveyed reaches contained any large trees and most of the riparian areas were dominated by shrub/seedling, pole/sapling, or small tree associations. Riparian areas lack coniferous cover along lower Lawton Creek where Himalayan blackberry dominates. The Woodward Creek basin has experienced extensive logging and the riparian areas are dominated by deciduous species. Despite generally poor riparian conditions throughout the basin, surveys of canopy density in the Gibbons Creek basin showed good (>75%) cover in all but 2 reaches. These are lower Gibbons Creek (65%), where the stream flows in the artificial diversion channel, and lower Campen Creek (64%), where the stream flows through a golf course (Wade 2001).

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.

14.5.9 Floodplain Function

14.5.9.1 Lake River

Extensive urban and rural development has resulted in a substantial loss of floodplain habitats. The Vancouver Lake lowlands and Lake River were once hydraulically connected with the Columbia River and contained a network of overflow channels, sloughs, and wetlands that would have provided important salmonid rearing habitat. This area has been extensively diked, dredged, and drained over the course of human settlement in the area, primarily for agricultural and industrial purposes. Only very high flow events now flood only portions of these lowlands. One particular project that affected floodplain habitats was the dredging of Vancouver Lake in the early 1980s. This project, which was undertaken to improve lake water quality for recreational purposes, involved the placement of fill in wetlands surrounding the lake. Lake River is currently constrained by dikes and a railroad grade, and floodplain areas have been filled, drained, and leveled. Culverts and a railroad dike reduce floodplain connectivity on Whipple Creek. Burnt Bridge Creek has been highly altered through diking, draining, and rerouting into ditches and culverts. Salmon Creek suffers from extensive diking, road crossings, recreational development, bank hardening, and gravel mining operations. The stream is now incised and disconnected from its floodplain in many areas. Many Salmon Creek tributaries have been ditched and relocated as they course through areas of urban and rural development (Wade 2001).

14.5.9.2 Bonneville Tributaries

Most of the Bonneville tributaries emerge from steep canyons in the Columbia Gorge and historically contained only short sections with floodplains just upstream of their confluence with the Columbia. State Route 14, the railroad corridor, and other developments have largely eliminated floodplain connection and function (Wade 2001).

An historical wetland complex on lower Gibbons Creek was diked, drained, and diverted in the 1960s and fish passage problems were created. In an effort to restore the wetlands and fish passage, an artificial, elevated channel was constructed that provides access to spawning grounds further upstream. As a result, the stream has been disconnected from its floodplain in the lower mile, and fish access has been blocked to off-channel habitats that once existed in the Gibbons Creek and Columbia River floodplains (Wade 2001). On the Gibbons Creek tributary Campen Creek, a golf course has reduced the availability of complex floodplain habitats.

Floodplain connection has been disrupted on various other streams due to dikes, filling, gravel mining operations, channelization, and diversion. See Wade (2001) for a complete description.

14.6 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 Salmon Creek fall chinook, chum, 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. Model results are discussed in separate sections for Salmon Creek and for the Bonneville Tributaries.

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.

14.6.1 Salmon Creek / Lake River

14.6.1.1 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 Salmon Creek basin for fall chinook, chum, coho and winter steelhead.

Model results indicate a decline in adult productivity for all species in the Salmon Creek subbasin. Declines in adult productivity (from historical levels) range from 79% for fall chinook to greater than 90% for winter steelhead. Similarly, adult abundance levels have declined for all species (Figure 14-14). Current estimates of abundance are only 21% of historical levels for fall chinook, 13% of historical levels for winter steelhead, 15% of historical levels for coho, and 0% of historical levels for chum, as they are functionally extirpated from the basin. Estimated species diversity has also decreased significantly for all species in the Salmon creek basin (Table 14-1). Species diversity has declined by 57% for both fall chinook and coho, by 61% for winter steelhead, and by 100% for chum.

As with adult productivity, model results indicate that current smolt productivity is sharply reduced compared to historical levels. Current smolt productivity estimates are between 12% and 37% of historical productivity, depending on species (Table 14-1). Smolt abundance numbers are similarly low, especially for chum and coho (Table 14-1). Current smolt abundance estimates for chum and coho are at 0% and 14% of historical levels, respectively.

Model results indicate that restoration of PFC conditions would have large benefits in all performance parameters for all species (Table 14-1). For adult abundance, restoration of PFC conditions would increase current returns by 353% for fall chinook, by 251% for winter steelhead, and by 500% for coho. Adult chum returns would be approximately 1,800 fish. Similarly, smolt abundance numbers would increase for all species (Table 14-1). Coho would see an increase in smolt abundance of 538%. Chum smolts would increase in number from 0 to 484,000.

Table 14-1. Salmon Creek subbasin — 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.

Species	Adult Abundance			Adult Productivity			Diversity Index			Smolt Abundance			Smolt Productivity		
	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]	P	PFC	T[1]
Fall Chinook	91	414	444	1.6	6.6	7.7	0.43	1.00	1.00	13,341	53,922	58,100	219	746	869
Chum	0	1,789	4,482	1.0	6.5	9.5	0.00	1.00	1.00	0	483,833	802,195	406	968	1,078
Coho	772	4,621	5,266	2.2	11.0	14.3	0.43	0.99	1.00	17,887	114,139	129,864	51	260	338
Winter Steelhead	64	223	486	2.4	13.9	36.4	0.39	0.98	1.00	1,136	4,038	4,655	43	255	354

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

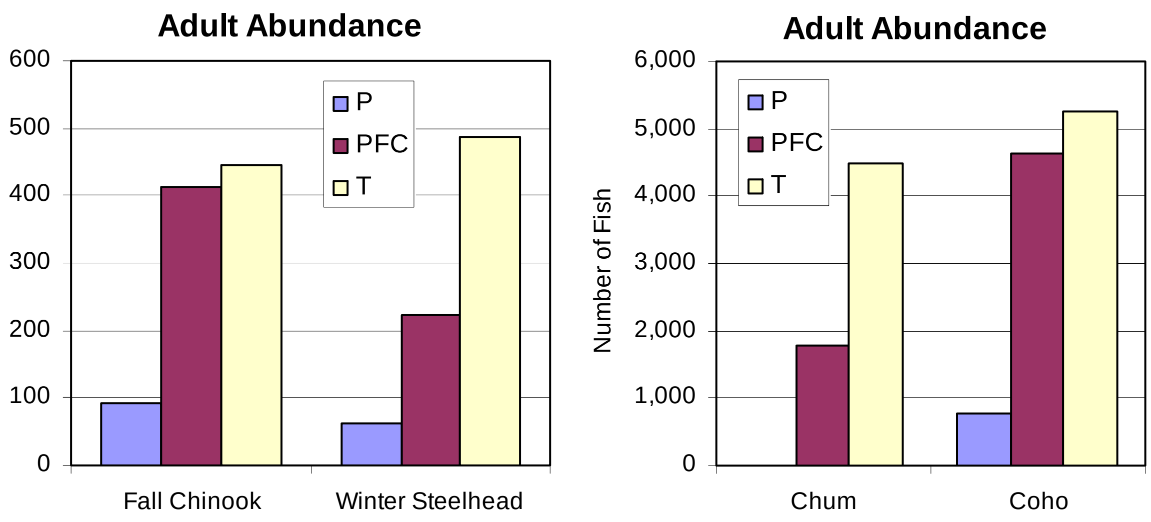


Figure 14-14. Adult abundance of Salmon Creek subbasin fall chinook, winter steelhead, chum and coho based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

14.6.1.2 Restoration an Preservation 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.

Fall chinook primarily use Salmon Creek mainstem reaches. Chum are believed to have historically had a similar distribution as fall chinook. Winter steelhead and coho are distributed throughout the mainstem and tributaries. See Figure 14-15 for a map of reaches in the Salmon Creek basin.

Reaches with a high priority ranking for winter steelhead are located in the middle and upper mainstem Salmon Creek (Figure 14-16). All high priority reaches, except reach Salmon 31, show a strong habitat restoration emphasis. Salmon 31 shows a combined habitat preservation and restoration emphasis (Figure 14-16). The reaches of Salmon 14A and 14C have the highest restoration potential of any reach modeled for winter steelhead.

Important reaches for both fall chinook (Figure 14-17) and chum (Figure 14-18) are generally located in the middle mainstem (Salmon 11-13, Salmon 14A-14C and Salmon 16). These reaches, as with the important winter steelhead reaches, all show a strong habitat restoration emphasis. For both species, the reaches of Salmon 14A and Salmon 14B have the highest restoration potential of any reach modeled within the basin.

For coho, the high priority reaches are primarily located in the middle and upper basin (Figure 14-19). Tributaries such as Suds, Lalonde, Morgan and Rock Creeks also contain high priority reaches for coho. All high priority reaches, except Salmon 31 and Lbtrib 11-1, show a habitat restoration emphasis. Salmon 31 and Lbtrib 11-1 have a combined habitat preservation and restoration emphasis. As with all other modeled species, the reaches of Salmon 14A and Salmon 14B have the highest restoration potential of any reach.

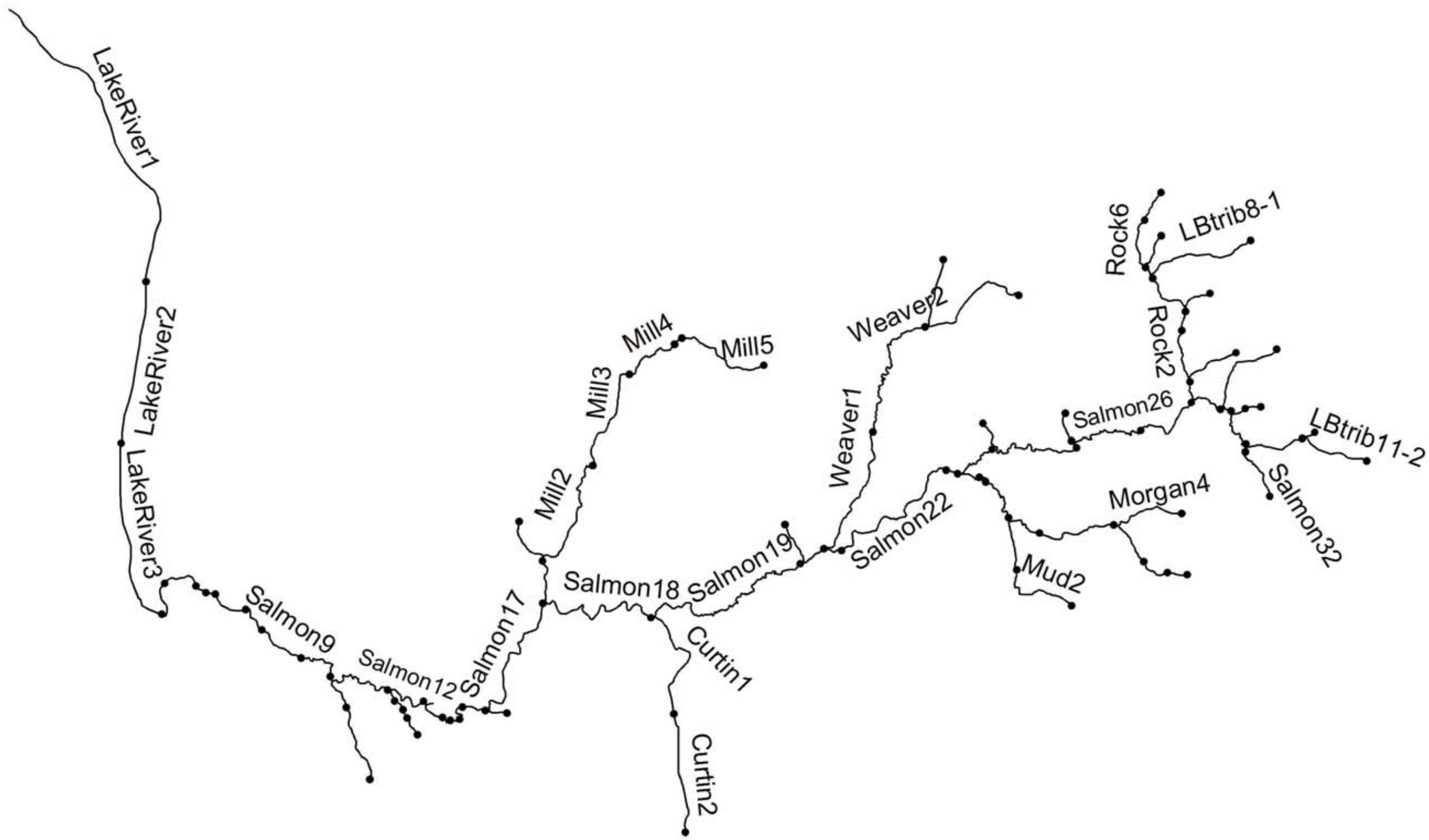


Figure 14-15. Salmon Creek basin EDT reaches. Some reaches are not labeled for clarity.

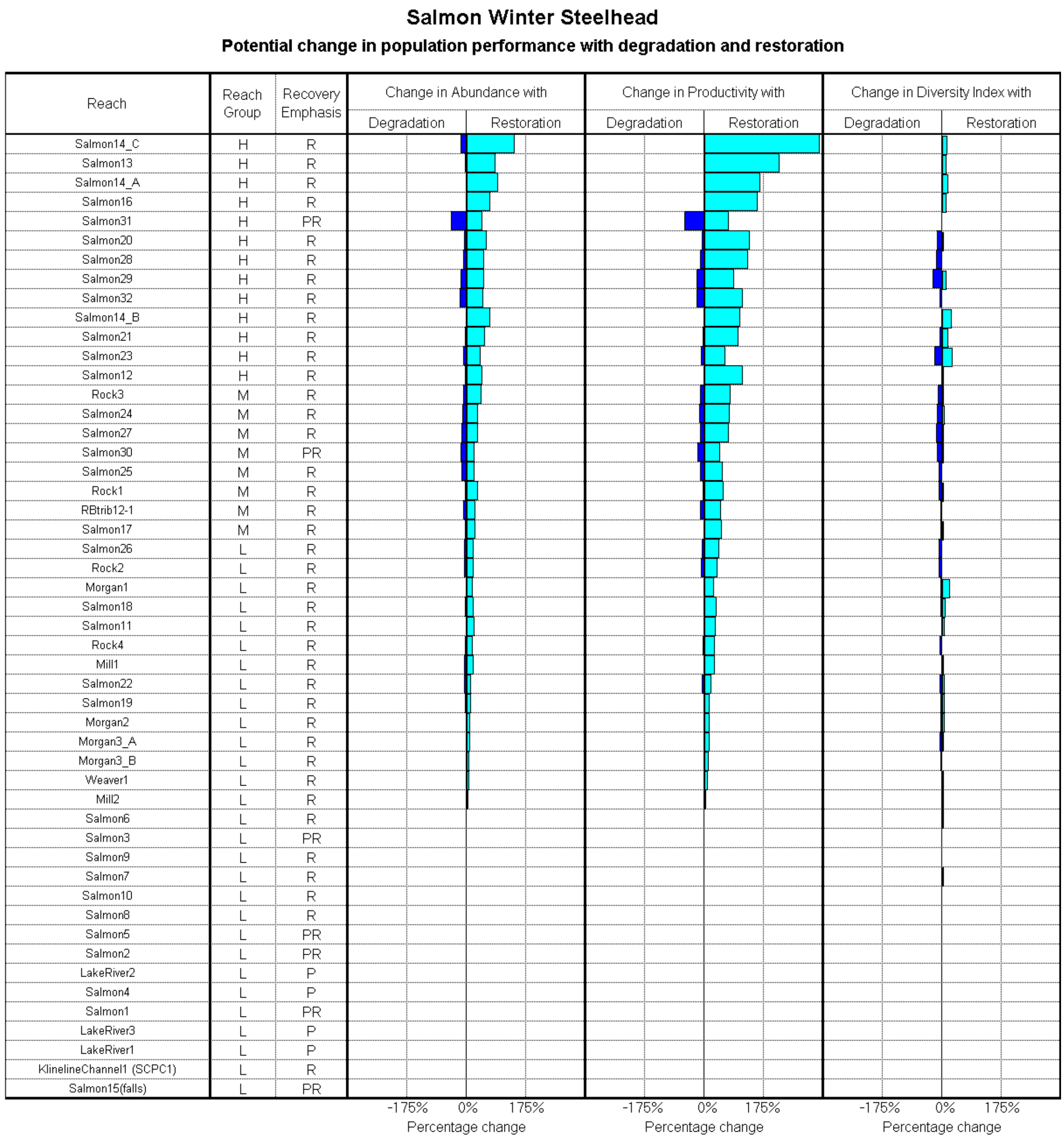


Figure 14-16. Salmon Creek winter steelhead ladder diagram. The rungs on the ladder represent the reaches and the three ladders contain a preservation value and restoration potential based on abundance, productivity, and diversity. The units in each rung are the percent change from the current population. For each reach, a reach group designation and recovery emphasis designation is given. See Volume VI for more information on EDT ladder diagrams. Percentage change values are expressed as the change per 1000 meters of stream length within the reach.

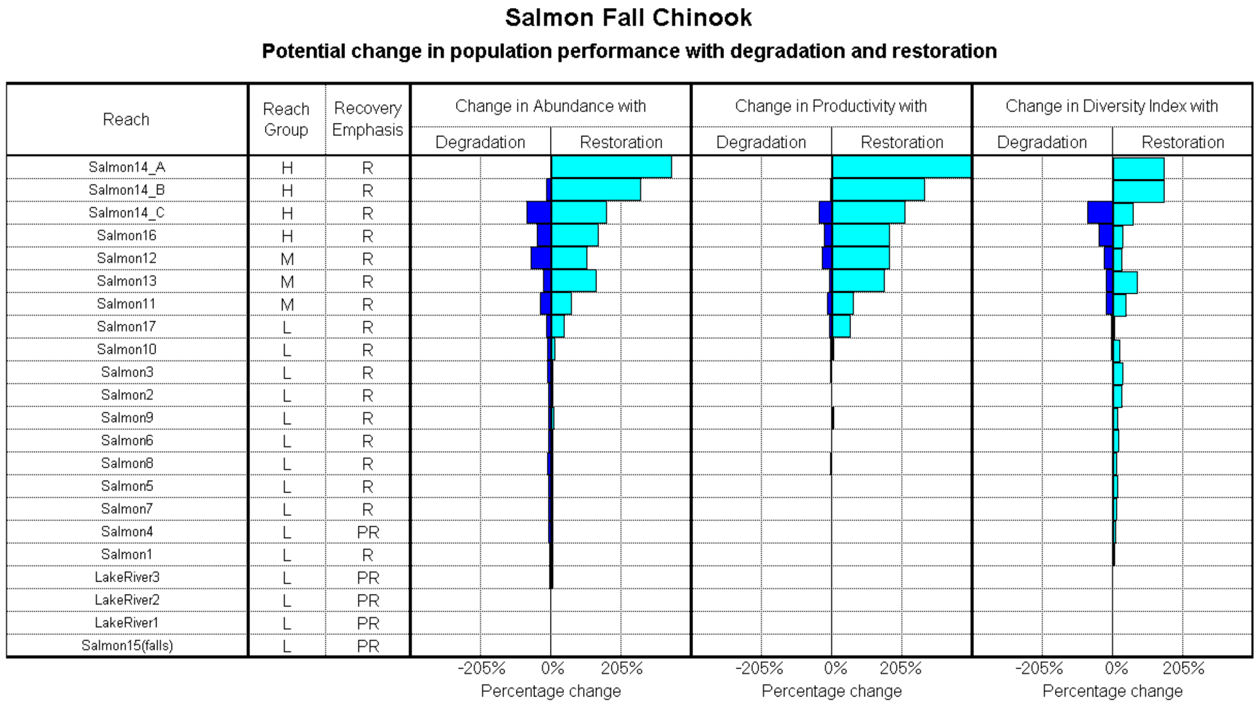


Figure 14-17. Salmon Creek fall chinook ladder diagram.

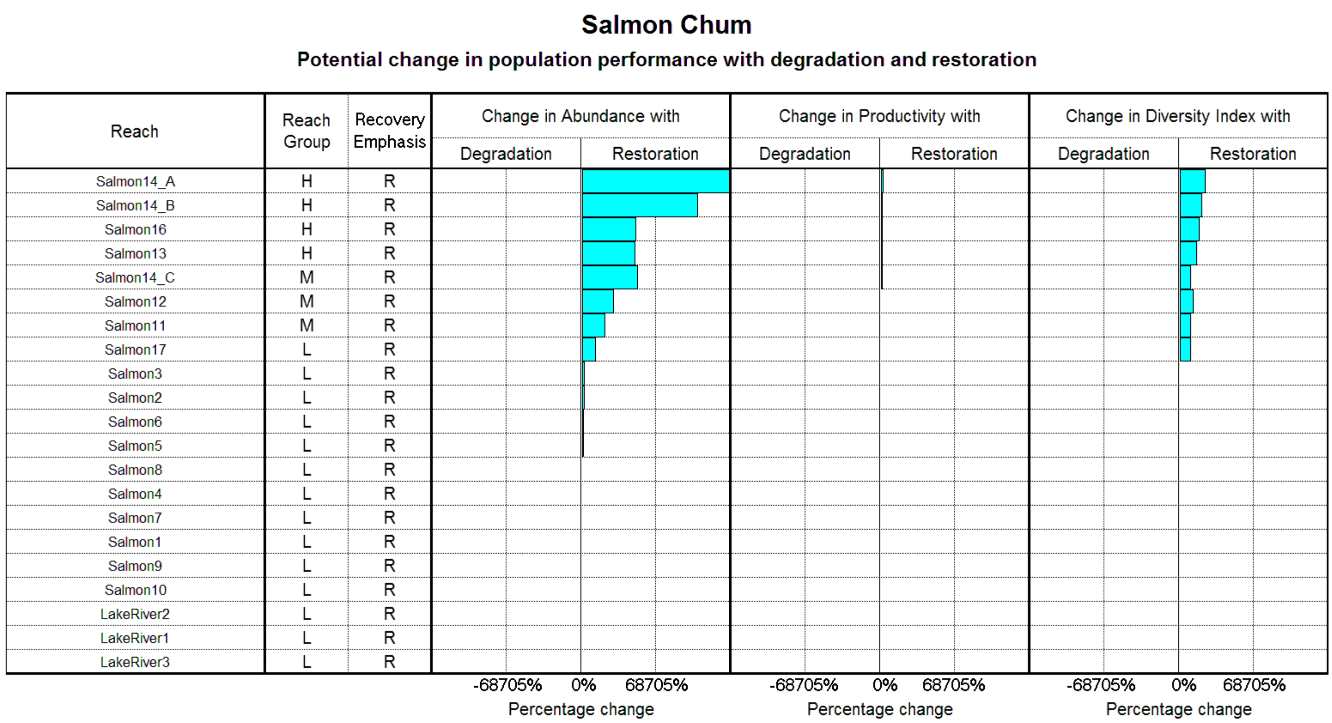


Figure 14-18. Salmon Creek chum ladder diagram.

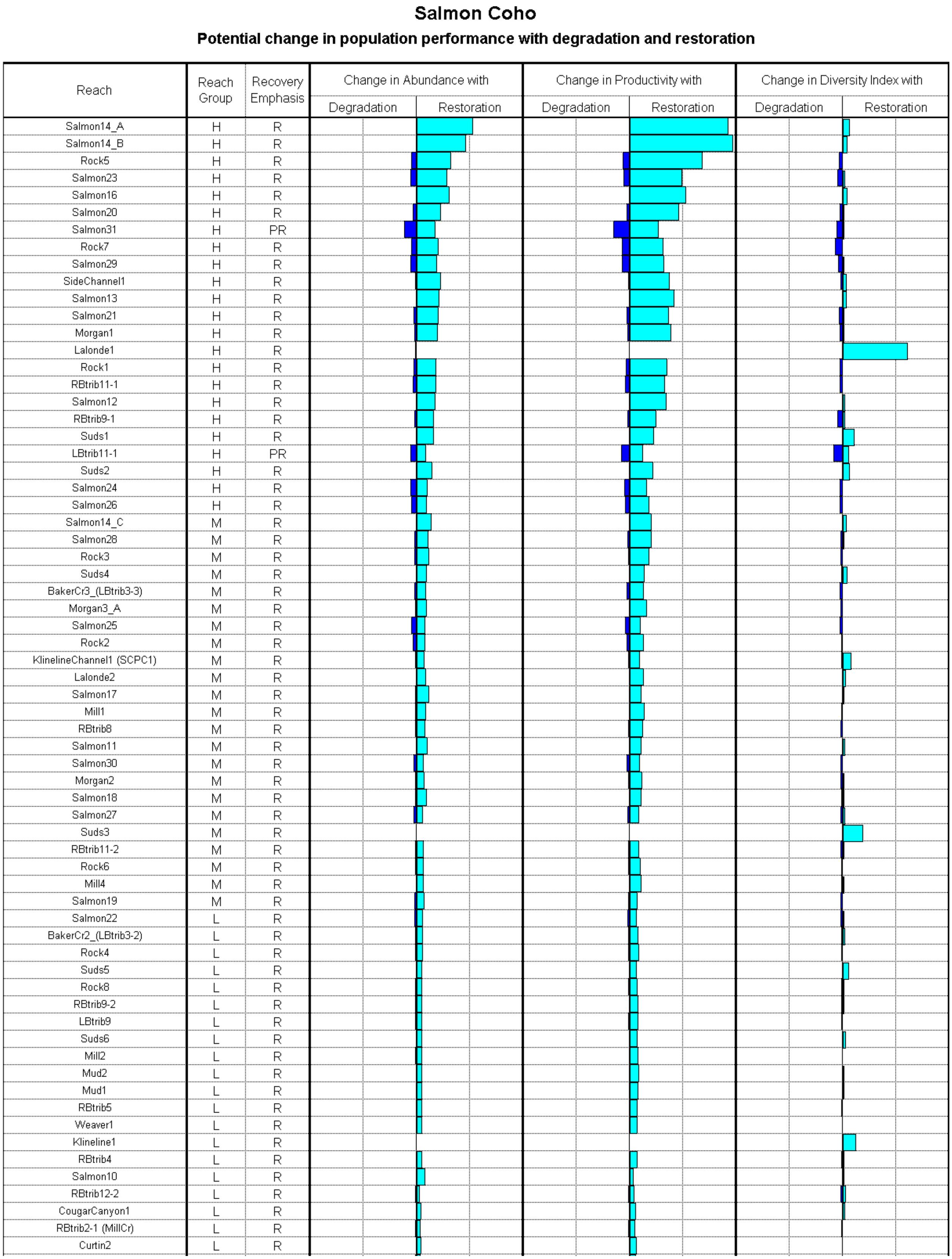


Figure 14-19. Salmon Creek coho ladder diagram. Some low priority reaches are not included for display purposes.

14.6.1.3 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.

Key reaches for winter steelhead in the Salmon Creek basin are located primarily in the middle and upper mainstem. These reaches appear to be most impacted from sediment and habitat diversity, with somewhat lesser impacts related to flow, temperature, and predation (Figure 14-20). This area has been heavily modified since historical times. Rural residential development and agriculture are the primary sources of habitat impairments.

The greatest impacts to fall chinook and chum are located in the lower and middle mainstem reaches of Salmon Creek. As with steelhead, the primary impacts to key reaches are sediment and habitat diversity (Figure 14-21 and Figure 14-22). Other impacts include channel stability, flow, and harassment. These reaches are heavily impacted by the expanding Vancouver metropolitan area. Stream channels have been straightened and confined, riparian areas have been denuded of vegetation, floodplains have been isolated from channels, and uplands have been highly developed.

Important coho reaches in the Salmon Creek basin are generally located in both the middle and upper mainstem, as well as in many of the smaller tributaries. Habitat factors affecting these reaches are varied and include sediment, habitat diversity, channel stability, key habitat and flow (Figure 14-23). Lesser impacts related to food and temperature are also affecting these reaches. The causes of these impacts are similar to those discussed above.

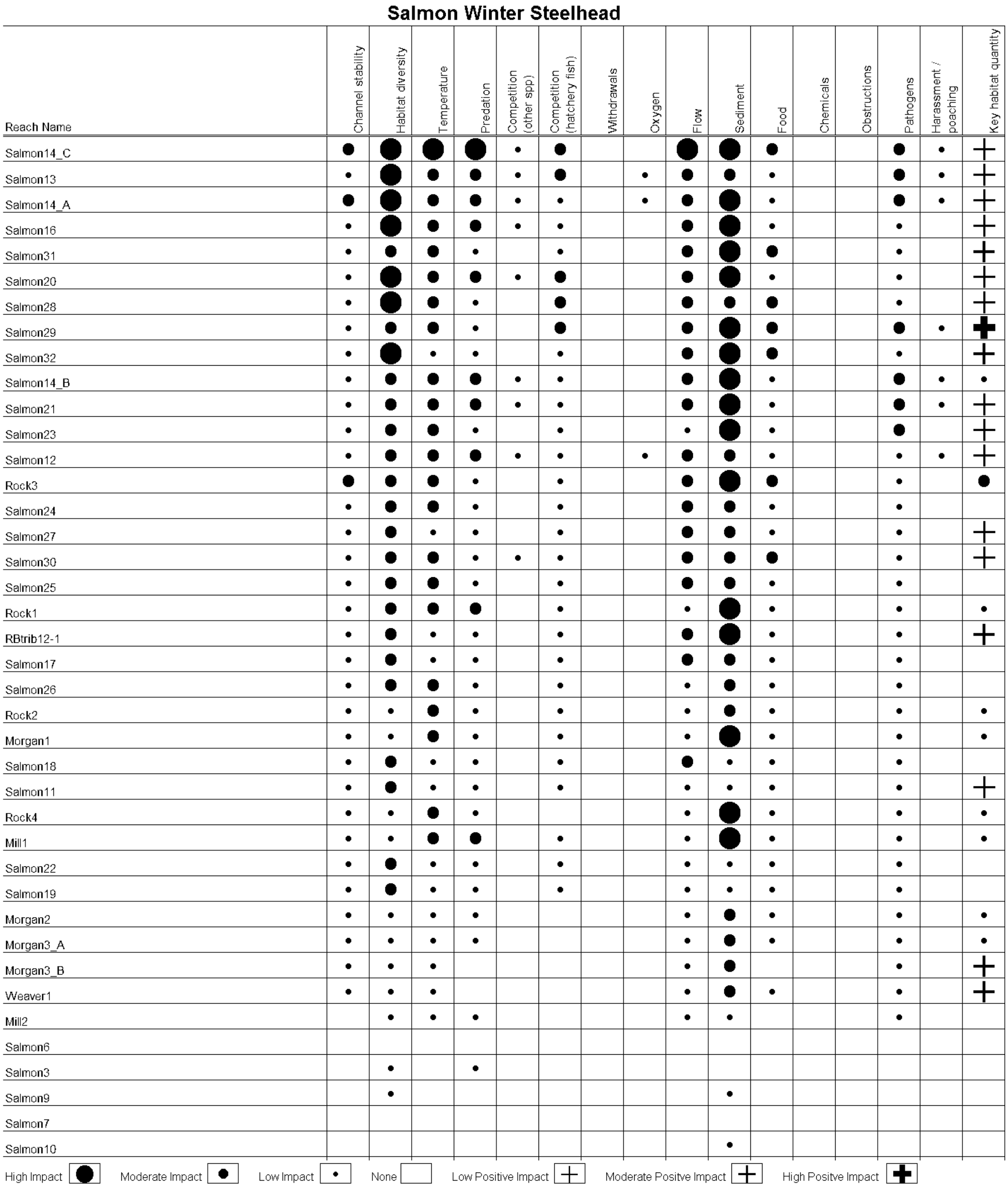


Figure 14-20. Salmon Creek winter steelhead habitat factor analysis diagram. Diagram displays the relative impact of habitat factors in specific reaches. The reaches are ordered according to their restoration and preservation rank, which factors in their potential benefit to overall population abundance, 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. Some low priority reaches are not included for display purposes.

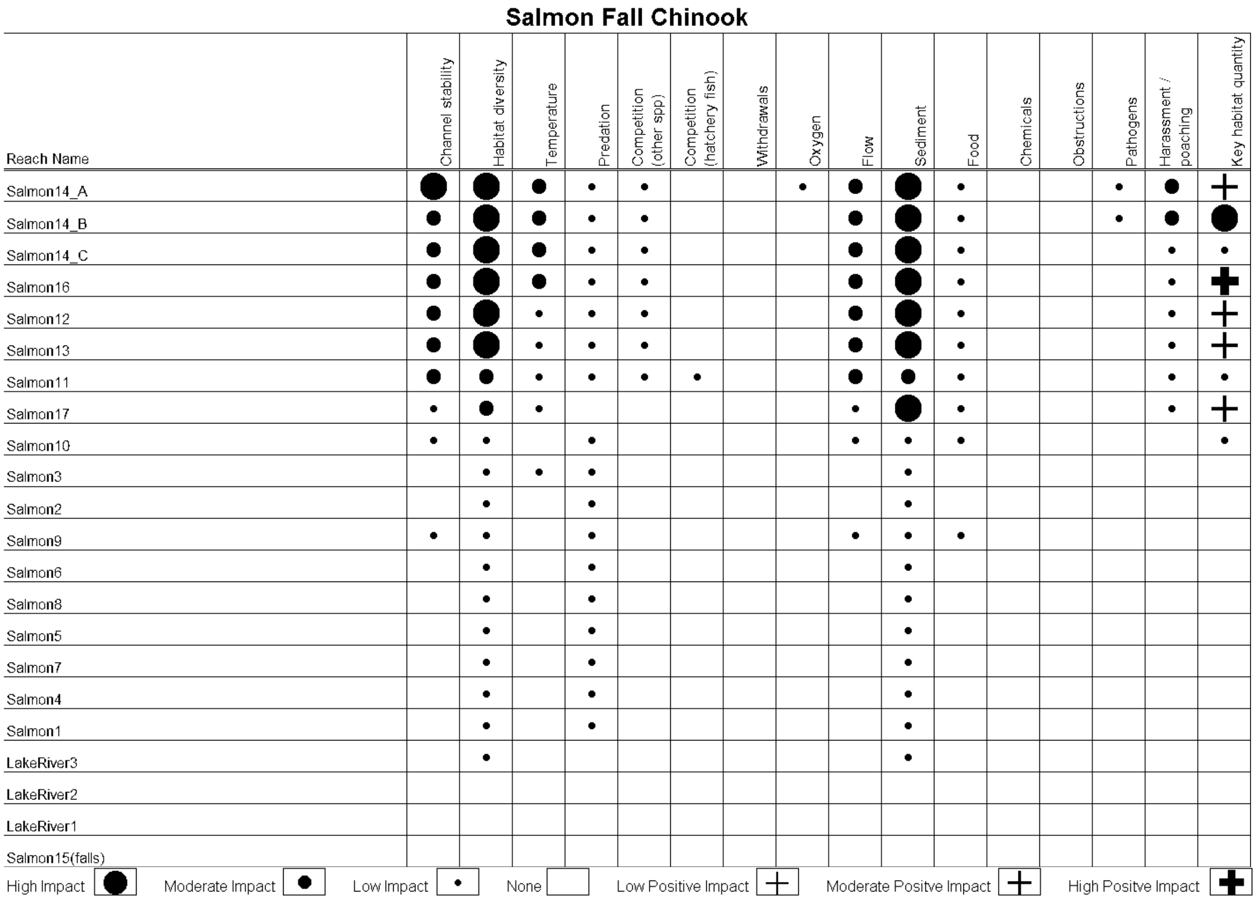


Figure 14-21. Salmon Creek fall chinook habitat factor analysis diagram.

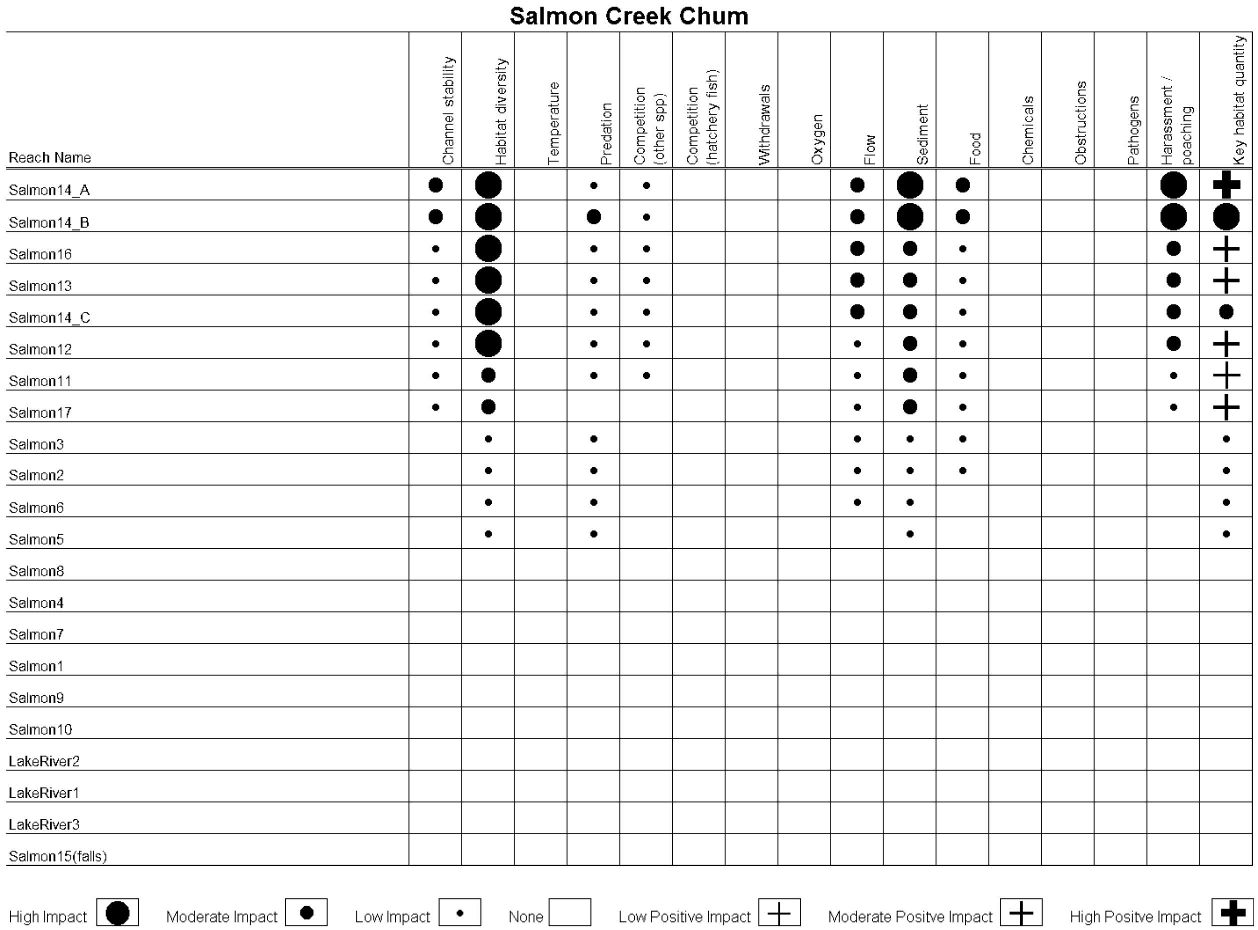


Figure 14-22. Salmon Creek chum habitat factor analysis diagram.

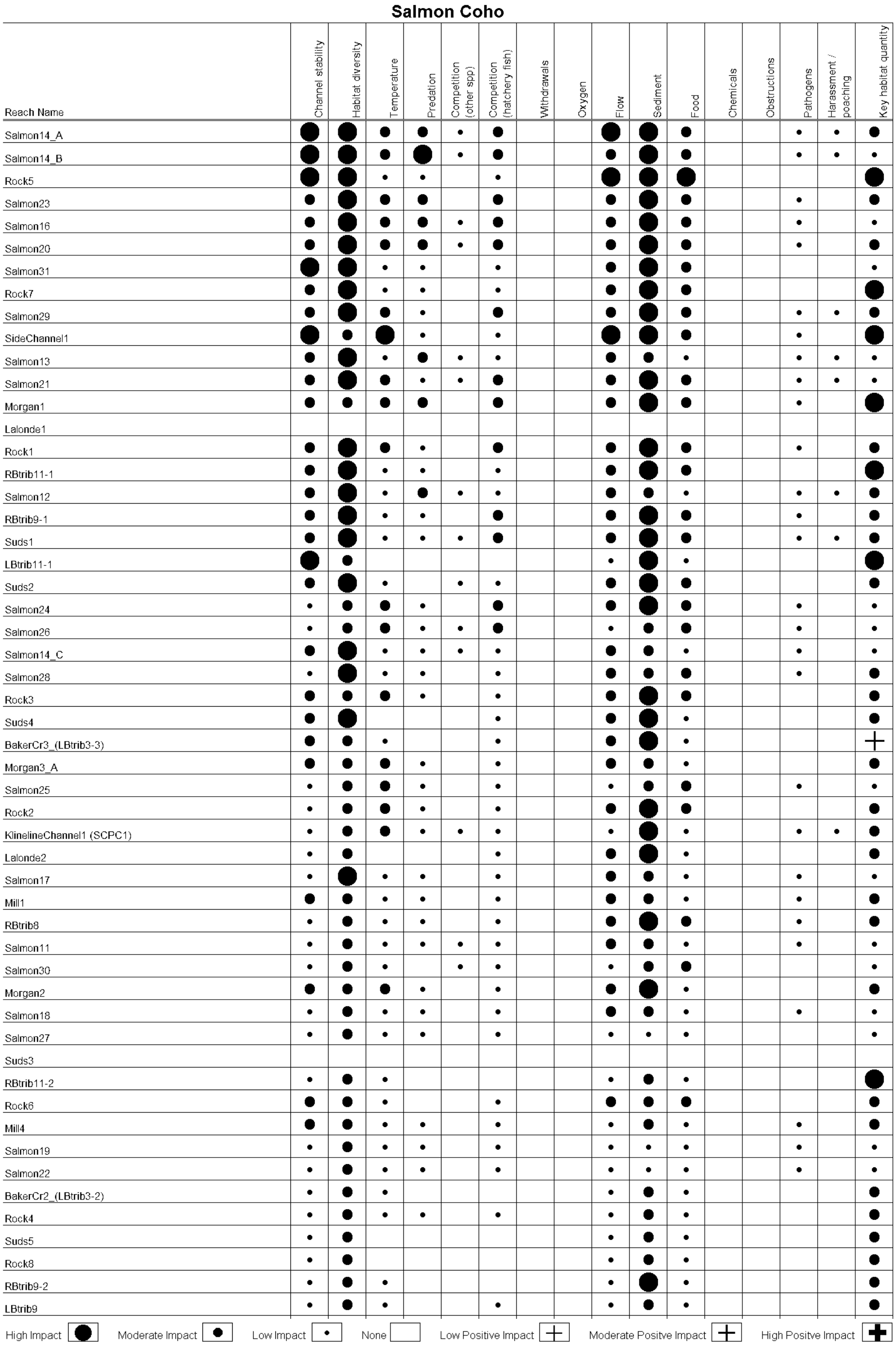


Figure 14-23. Salmon Creek coho habitat factor analysis diagram. Some low priority reaches are not included for display purposes

14.6.2 Bonneville Tributaries

14.6.2.1 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 for winter steelhead, fall chinook, chum and coho in the lower Columbia Gorge basins of Hardy, Hamilton, and Duncan Creeks. Salmon and steelhead use has also been documented in several other small lower Gorge tributaries (i.e. Gibbons and Lawton Creeks), but abundance in these streams is believed to be low. Although the EDT model was run independently for Hardy, Hamilton, and Duncan Creeks (HHD), the model outputs of these streams have been combined.

Model results indicate that adult productivity has declined for all species (Table 14-2). Both chum and winter steelhead have seen the sharpest decline in productivity, with current estimates at approximately 30% of historical levels. Adult abundance has also declined for all species in the HHD basins (Figure 14-24). Fall chinook and winter steelhead abundance has declined by 45% and 56% from historical levels, respectively. Chum and coho abundance has declined more significantly, to 14% and 20% of historical levels, respectively. Species diversity (as measured by the diversity index) has remained relatively constant for chum but has decreased by 47% for winter steelhead, by 50% for fall chinook, and by 63% for coho (Table 14-2).

Smolt productivity numbers are also lower for each species, except chum (Table 14-2). In the case of chum, this seems counter-intuitive due to the fact that chum adult abundance has declined the most out of the four species. This relatively higher smolt productivity is an artifact of the way the EDT model calculates productivity. That is, the higher productivity of chum smolts is because HHD chum now have many less trajectories (life history pathways) that are viable (those that result in return spawners); but the few trajectories that remain have higher productivities than historical trajectories (many of which were only marginally viable). Smolt abundance numbers have also declined for all species (Table 14-2). Current smolt abundance estimates range from 19% of historical levels for coho to 69% of historical levels for winter steelhead.

Model results indicate that restoration to PFC conditions would produce substantial benefits for all species (Table 14-2). Adult returns of winter steelhead and fall chinook would increase by an estimated 11% and 36%, respectively, while adult returns of chum and coho would increase by an estimated 144% and 117%, respectively. Similar results would be seen for smolt abundance (Table 14-2).

Table 14-2. Lower Gorge tributaries— 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]**
Fall Chinook	124	168	225	4.4	5.9	7.0	0.44	0.44	0.88	36,961	52,311	64,512	817	1,040	1,130
Chum	797	1,943	5,842	3.5	8.5	11.4	0.97	1.00	1.00	80,161	121,877	166,842	164	164	137
Coho	57	123	280	5.1	7.5	10.2	0.37	0.44	0.98	1,663	3,760	8,528	154	234	313
Winter Steelhead	244	270	556	15.7	19.0	45.8	0.40	0.47	0.76	2,400	2,628	3,496	188	233	344

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

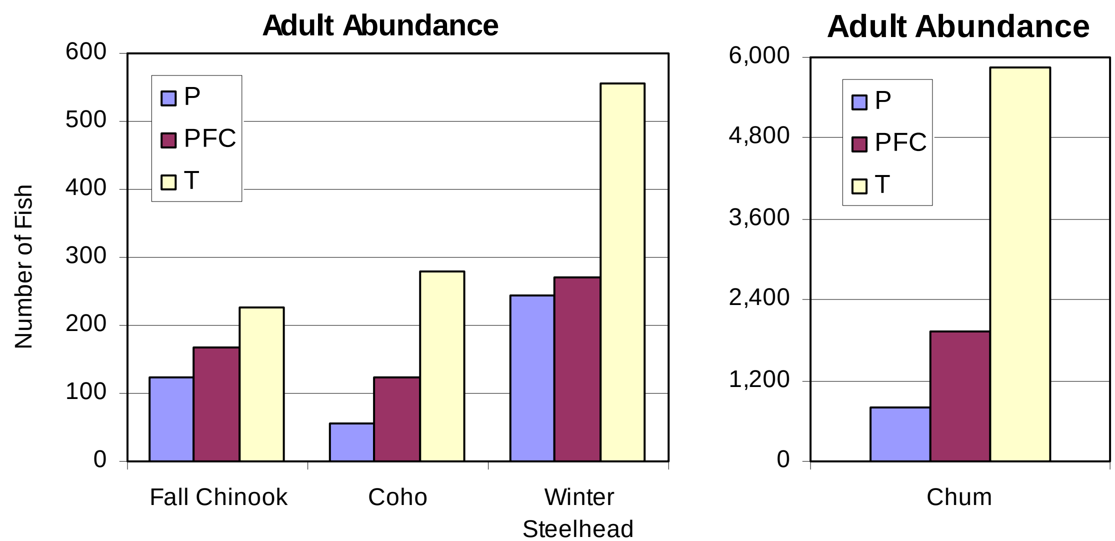


Figure 14-24. Adult abundance of Lower Gorge tributary fall chinook, coho, winter steelhead, and chum based on EDT analysis of current (P or patient), historical (T or template), and properly functioning (PFC) habitat conditions.

14.6.2.2 Restoration and Preservation 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.

The lower Gorge tributaries of Hardy, Hamilton, and Duncan Creeks were divided into numerous individual reaches. These reaches represent the low gradient, lower portions of these systems that are accessible to anadromous fish. Upstream of these reaches, gradients increase dramatically where the stream valleys carve through the steep valley walls of the Columbia Gorge. Hamilton Creek has the greatest length and capacity for fish, and also has the longest tributary, Greenleaf Creek. See Figure 14-25 for a map of stream reaches within the HHD basins.

High priority areas for winter steelhead include only one reach in upper Hamilton Creek (Hamilton 4) (Figure 14-26). This reach is important for steelhead spawning, and appears to be the least degraded. This reach has the strongest habitat preservation emphasis of any winter steelhead reach in the three basin.

Important areas for chum include the Duncan Lake outlet (reach Lake outlet), lower Hamilton (Hamilton 1A, Hamilton 2 and Hamilton Springs) and Hardy Creeks (Hardy 2) (Figure 14-27). These reaches include some of the most productive chum spawning and rearing areas in the basin. These reaches (especially Lake Outlet) show a strong habitat preservation emphasis.

As with winter steelhead, there was only one high priority reach for fall chinook, located in lower Hamilton Creek (Hamilton 1A) (Figure 14-28). This high priority reach has a combined habitat preservation and restoration emphasis.

High priority reaches for coho are located in Hamilton and Duncan Creeks (Hamilton 2 and Duncan 1) (Figure 14-29). Although these areas are considered important spawning reaches, the available habitat has been somewhat degraded. As a result, both high priority reaches show a restoration emphasis. Reach Hamilton 2 has the highest restoration potential of any coho reach modeled in the three basins.

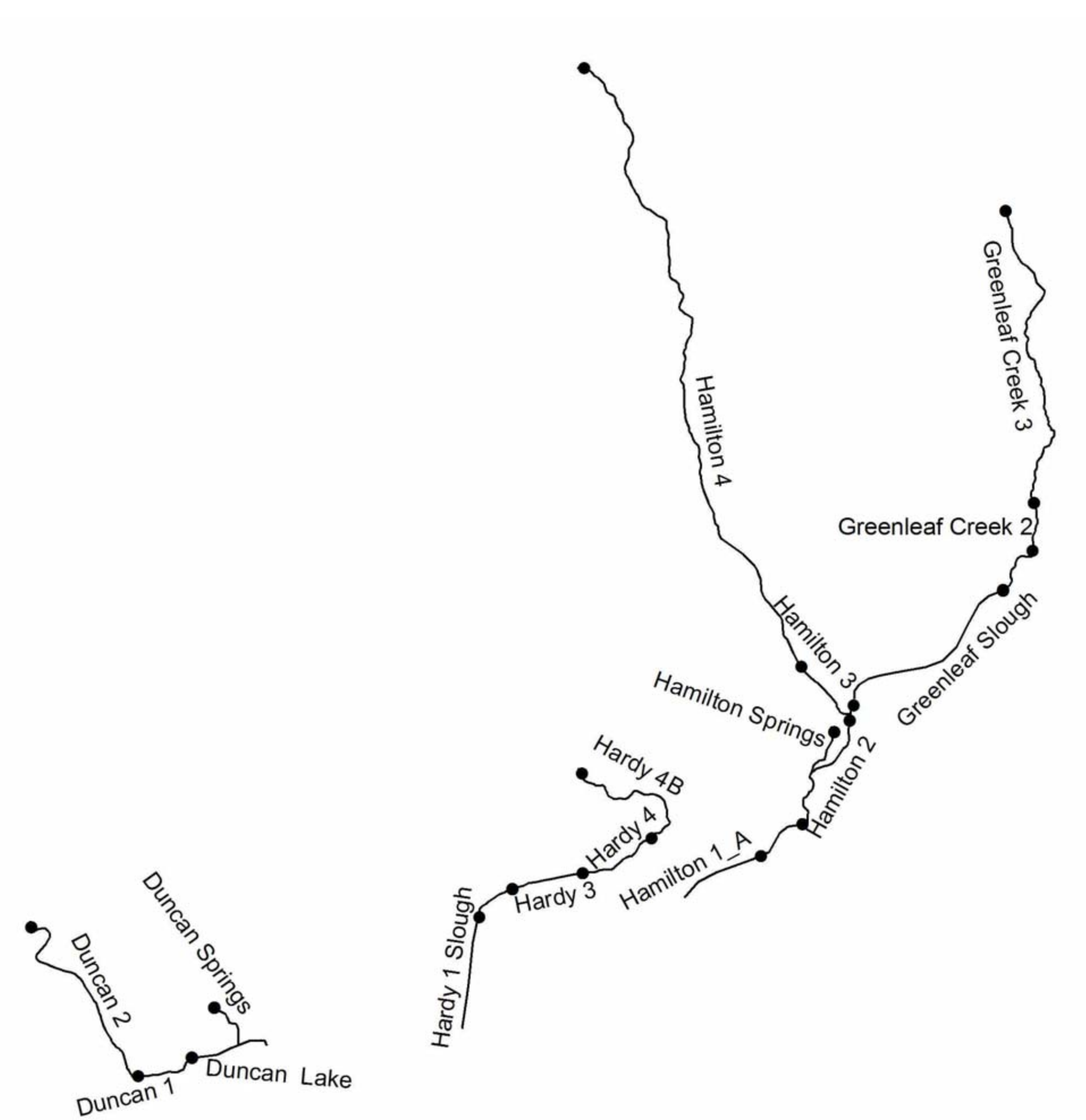


Figure 14-25. Bonneville Tributaries EDT reaches. Some reaches are not labeled for clarity.

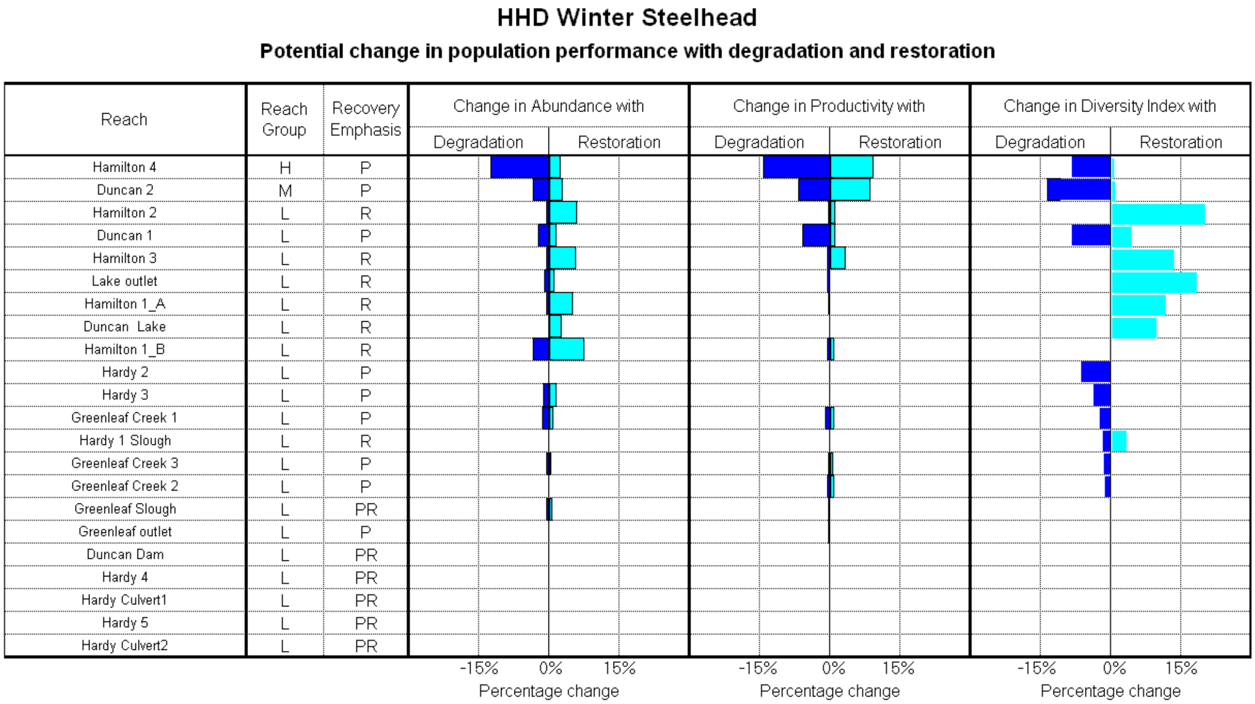


Figure 14-26. Bonneville Tributaries winter steelhead ladder diagram. The rungs on the ladder represent the reaches and the three ladders contain a preservation value and restoration potential based on abundance, productivity, and diversity. The units in each rung are the percent change from the current 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.

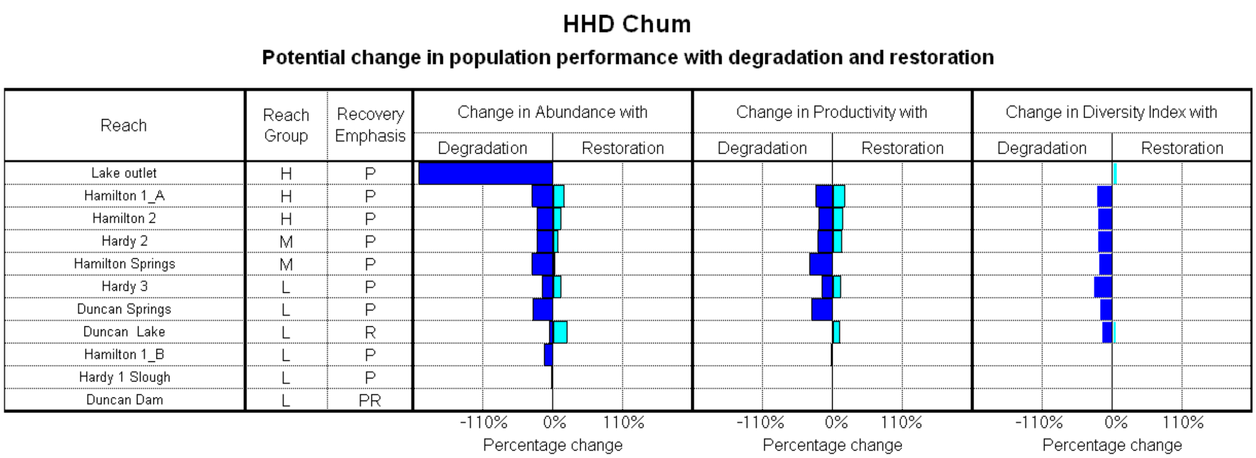


Figure 14-27. Bonneville Tributaries chum ladder diagram.

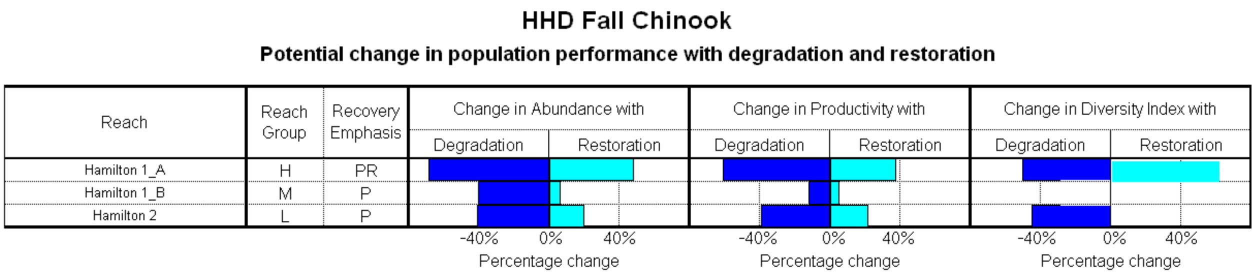


Figure 14-28. Bonneville Tributaries fall chinook ladder diagram.

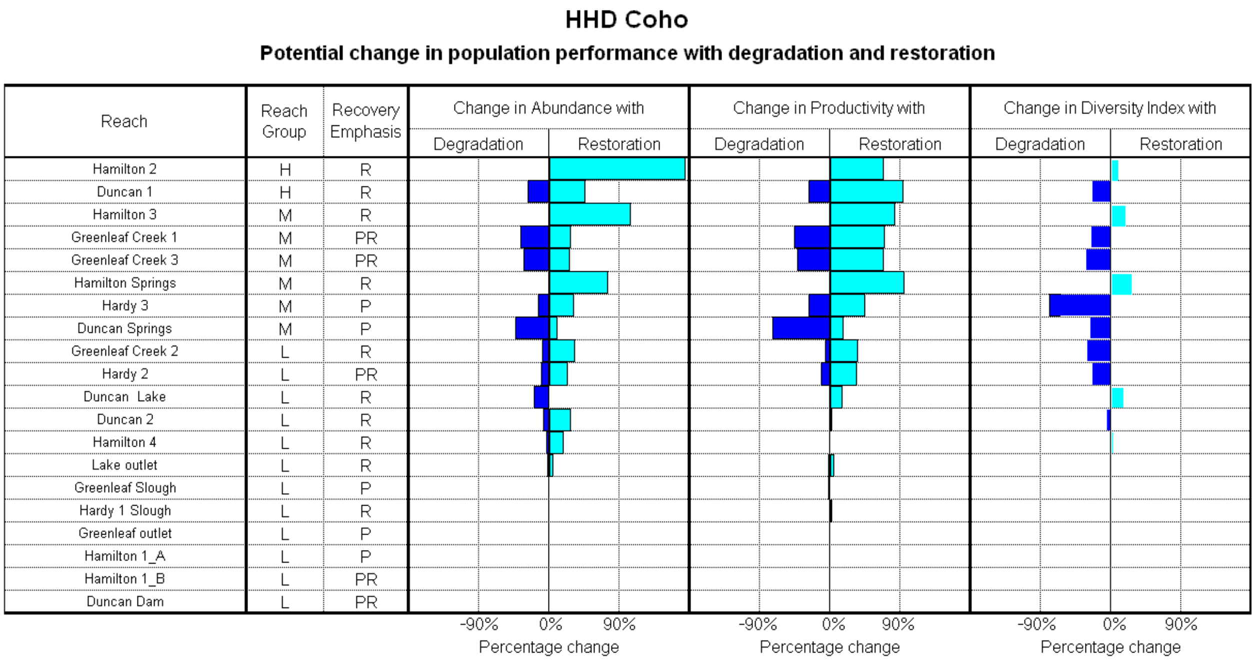


Figure 14-29. Bonneville Tributaries coho ladder diagram.

14.6.2.3 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.

In the priority areas for winter steelhead, key habitat, sediment, and temperature have the largest impacts (Figure 14-30). Key habitat has been reduced by loss of side channels and by subsurface flow conditions that reduce available summer rearing and holding habitat. Sediment, which originates primarily from upper basin sources, settles out in these low gradient reaches, impacting egg incubation and fry emergence. Flow alterations are also due to upper basin conditions, whereas temperature concerns are related to a lack of shade from riparian tree canopies.

For chum, the important reaches have suffered negative impacts from a loss of habitat diversity, loss of key habitat, increased sedimentation, and harassment (Figure 14-31). A lack of riparian function and low LWD levels contribute to habitat diversity problems. Sediment and key habitat impacts are similar to those discussed above for steelhead. There are no impacts in the Lake Outlet reach because this reach is most important for preservation.

All reaches modeled for fall chinook were in Hamilton Creek. These areas have been negatively impacted by a loss of key habitat, increased sediment, and altered temperature regimes (Figure 14-32). As with steelhead, habitat diversity and key habitat are low due to low quantities of instream LWD and channel incision/floodplain disconnection. Sediment impacts originate primarily from upstream hillslope and channel sources. Temperature alteration is due to a lack of riparian shading and increased channel widths.

Important reaches for coho are located in Hamilton, Duncan, and Greenleaf Creeks. A suite of factors has negatively impacted these areas, including impairments related to sediment, key habitat, temperature, flow, food, and habitat diversity (Figure 14-33). The causes of these impacts are similar to those discussed above for winter steelhead.

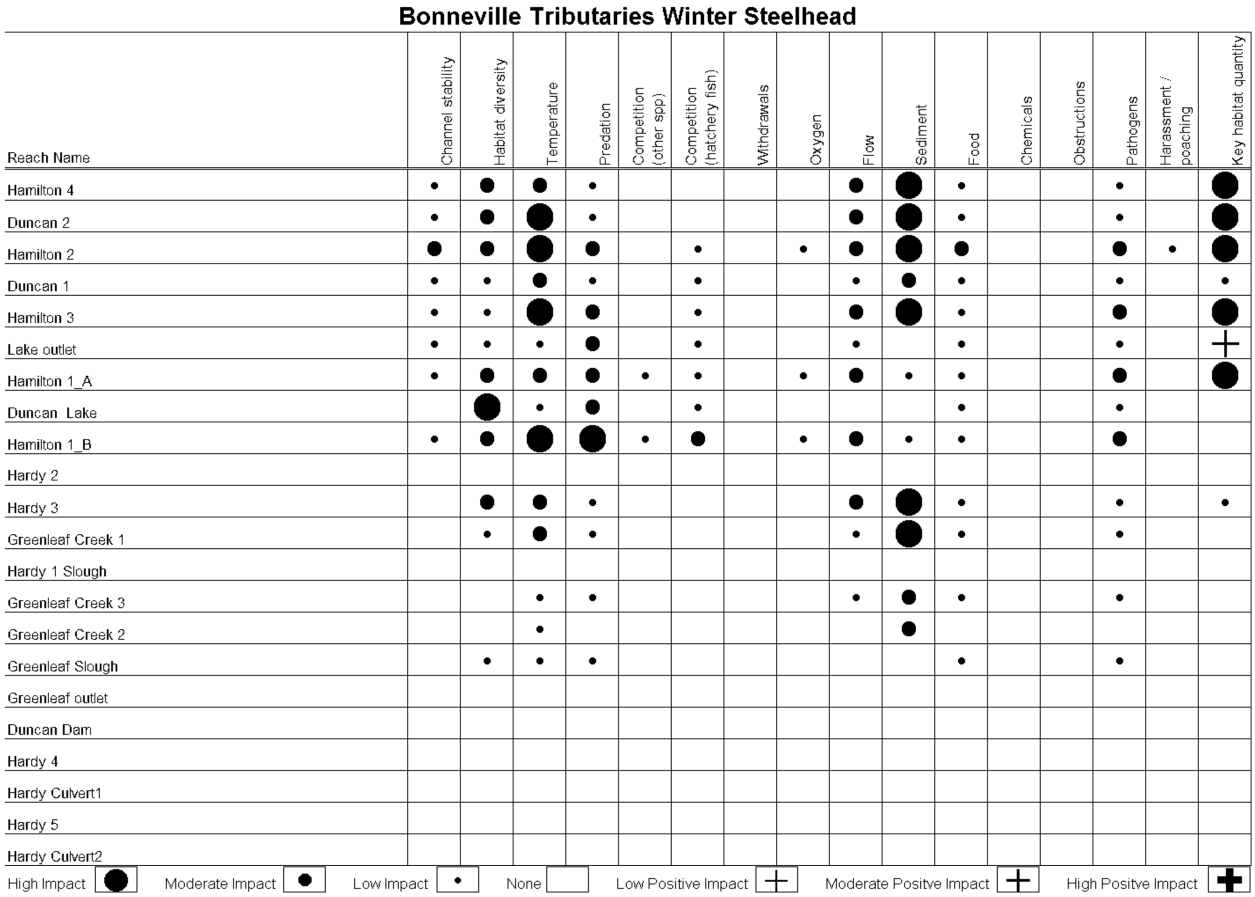


Figure 14-30. Bonneville Tributaries winter steelhead habitat factor analysis diagram. Diagram displays the relative impact of habitat factors in specific reaches. The reaches are ordered according to their restoration and preservation rank, which factors in their potential benefit to overall population 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.

Bonneville Tributaries Chum

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
Lake outlet																
Hamilton 1_A	Low	High	Low	Moderate	Low				Moderate	Moderate	Moderate				High	High
Hamilton 2	Low	High	Low						Low	Moderate	Low				High	High
Hardy 2	Low	High		Moderate	Low				Low	Moderate	Low					Moderate positive
Hamilton Springs																
Hardy 3	Low	High							Moderate	Moderate	Low					High
Duncan Springs																
Duncan Lake	Low	Moderate	Moderate positive	Moderate	Low				Low	High	Moderate			Moderate	High	High positive
Hamilton 1_B																
Hardy 1 Slough										Low						
Duncan Dam																

High Impact | Moderate Impact | Low Impact | None | Low Positive Impact | Moderate Positve Impact | High Positve Impact

Figure 14-31. Bonneville Tributaries chum habitat factor analysis.

Bonneville Tributaries Fall Chinook

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
Hamilton 1_A	Low	Moderate	High	Low	Low			Low	Low	High	Low				Low	High
Hamilton 2	Low	Low	Moderate						Low	Moderate	Low				Low	Moderate
Hamilton 1_B	Low	Low		Low	Low				Low	Low	Low					

High Impact | Moderate Impact | Low Impact | None | Low Positive Impact | Moderate Positve Impact | High Positve Impact

Figure 14-32. Bonneville Tributaries fall chinook habitat factor analysis.

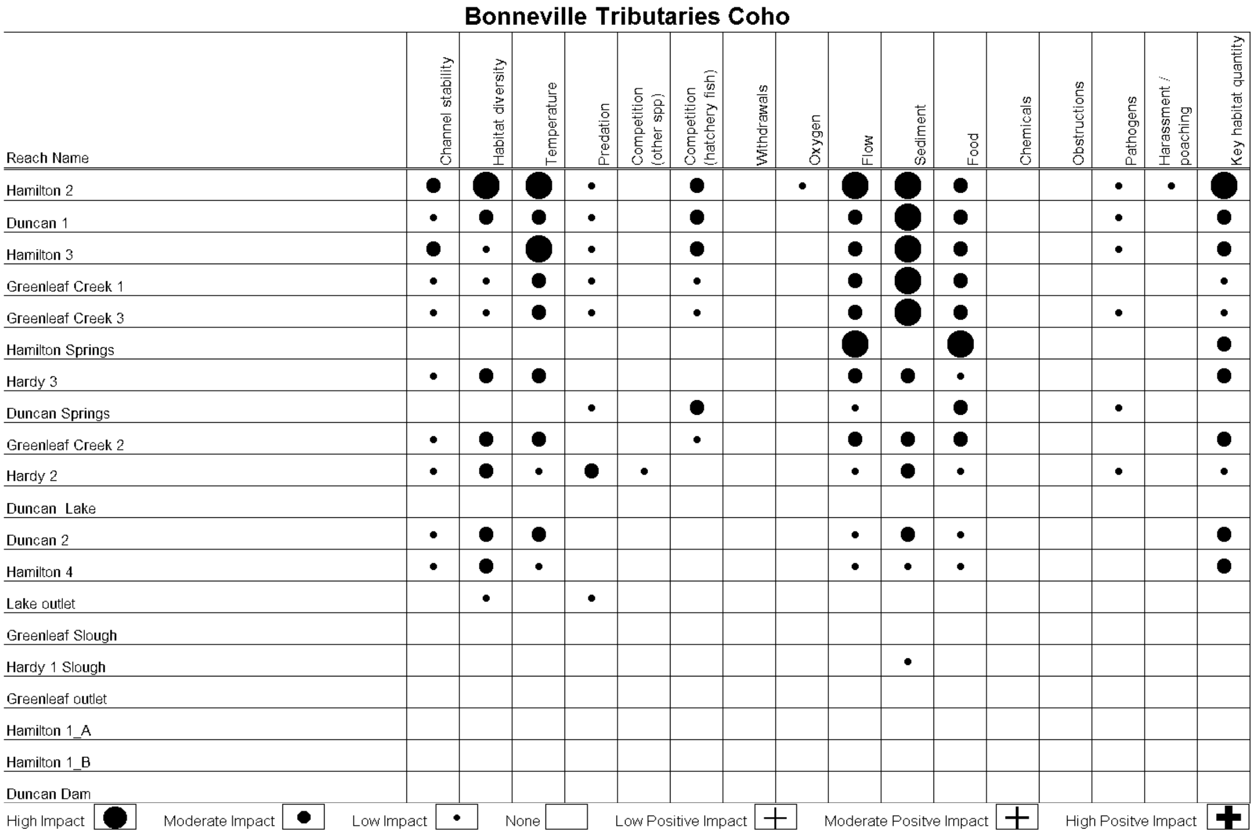


Figure 14-33. Bonneville Tributaries coho habitat factor analysis.

14.7 Integrated Watershed Assessment (IWA)

The Lower Columbia Tributaries Subbasin includes two principal recovery planning watersheds evaluated in the IWA analysis. The Salmon Creek/Lake River watershed includes Salmon Creek, Burnt Bridge Creek, and other minor tributaries to the Lake River. The Bonneville Tributaries watershed is comprised of several independent tributaries to the Columbia River, including Hamilton Creek, Hardy Creek, and Duncan Creek. The IWA analysis for the Salmon Creek/Lake River watershed is discussed below. The Bonneville Tributaries analysis is discussed in section 14.7.2.

14.7.1 Salmon Creek/Lake River

The Salmon Creek/Lake River watershed (Salmon Creek watershed hereafter) is the major drainage in a system of several smaller drainages entering the Lake River, which is a low-lying, tidally influenced system that parallels the Columbia River within and to the north of the Vancouver city limits. Other drainages entering the Lake River system include Burnt Bridge Creek, Whipple Creek, and Flume Creek. The majority of this area is within or immediately surrounding the cities of Vancouver, Battle Ground, and Camas. Much of the area is extensively developed for commercial, industrial, and residential uses. Lower Burnt Bridge Creek is fed by springs that historically provided valuable spawning habitat for chum salmon, and may have the potential to support a reintroduced run in the future.

14.7.1.1 Results and Discussion

IWA results were calculated for all subwatersheds in the Salmon Creek 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 14-3. A reference map showing the location of each subwatershed in the basin is presented in Figure 14-34. Maps of the distribution of local and watershed level IWA results are displayed in Figure 14-35.

Table 14-3. IWA results for the Salmon Creek watershed.

Subwatershed [a]	Local Process Conditions [b]			Watershed Level Process Conditions [c]		Upstream Subwatersheds [d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
90101	M	M	I	M	M	90102, 90103, 90104, 90105, 90106, 90107, 90108, 90109, 90110, 90111, 90112, 90113, 90114, 90115, 90116, 90117, 90118, 90119, 90120, 90121, 90122, 90123, 90124, 90125, 90126, 90127, 90128, 90129, 90130, 90131, 90132, 90133, 90134
90102	I	M	I	I	M	none
90103	I	F	I	M	M	90133
90104	M	M	M	M	M	90106, 90107, 90108, 90109, 90110, 90111, 90112, 90113, 90115, 90116, 90117, 90118
90105	I	F	I	I	F	none
90106	I	M	I	M	M	90107, 90108, 90109, 90110, 90111, 90112, 90113, 90116, 90117, 90118
90107	I	M	I	M	M	90108, 90109, 90111, 90112, 90113, 90118
90108	I	M	I	I	M	90109, 90112, 90113
90109	I	M	M	I	M	none
90110	M	M	I	M	M	none
90111	M	M	I	M	M	none
90112	I	M	M	I	M	none
90113	I	M	I	I	M	none
90114	M	F	I	I	F	90119, 90120, 90121, 90122, 90123, 90124, 90125, 90126, 90127, 90128, 90129, 90130
90115	I	M	I	I	M	none
90116	I	F	I	I	F	none
90117	I	F	M	I	F	none
90118	I	M	I	I	M	none
90119	I	M	I	I	M	none
90120	M	M	I	I	F	90121, 90122, 90123, 90124, 90125, 90126, 90127, 90128, 90129, 90130

Subwatershed [a]	Local Process Conditions [b]			Watershed Level Process Conditions [c]		Upstream Subwatersheds [d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
90121	I	F	I	I	F	none
90122	I	M	I	I	M	none
90123	I	F	I	I	F	90124, 90125, 90126, 90127, 90128, 90129, 90130
90124	I	F	I	I	F	90125, 90126, 90127, 90128, 90129, 90130
90125	I	F	I	I	F	90126, 90127
90126	I	M	ND	I	F	90127
90127	I	F	ND	I	F	none
90128	I	F	I	I	F	none
90129	I	F	ND	I	F	90130
90130	I	F	ND	I	F	none
90131	M	F	I	M	F	90105, 90114, 90119, 90120, 90121, 90122, 90123, 90124, 90125, 90126, 90127, 90128, 90129, 90130
90132	I	M	I	I	M	none
90133	I	M	M	I	M	none
90134	I	M	M	I	M	none

Notes:

[a] LCFRB subwatershed identification code abbreviation. All codes are 14 digits starting with 170800030#####.

[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
ND: Not evaluated due to a lack of data

[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.

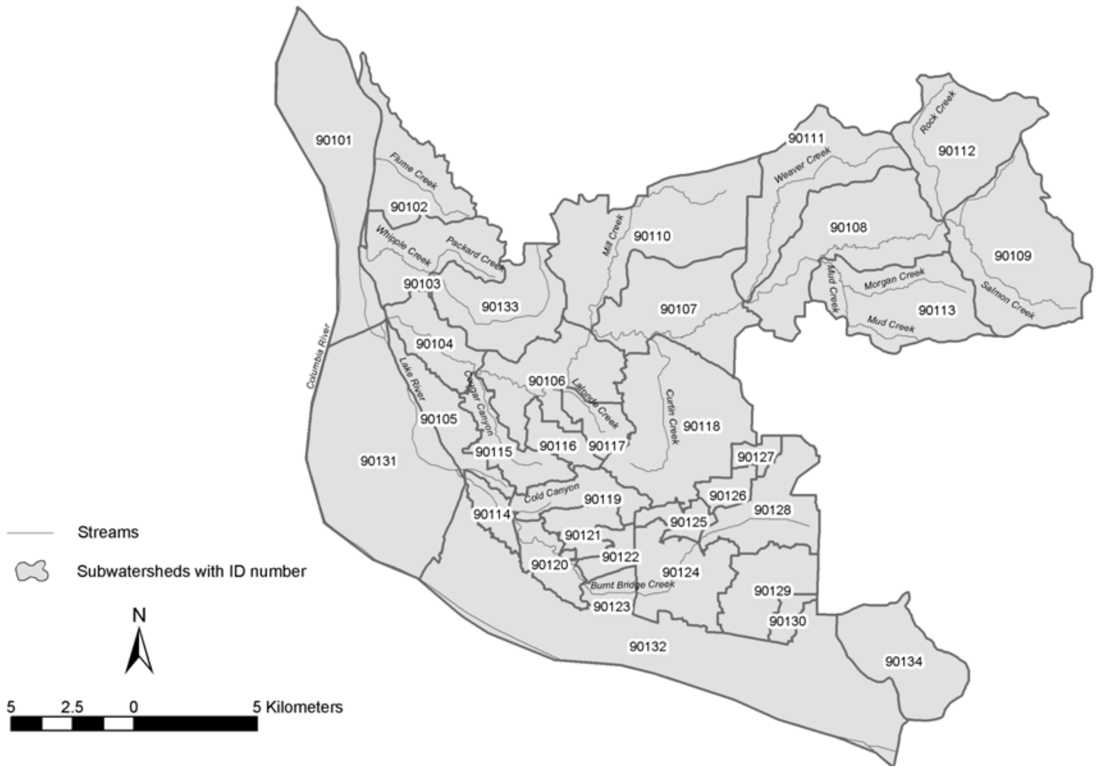


Figure 14-34. Map of the Lake River / Salmon Creek watershed showing the location of the IWA subwatersheds.

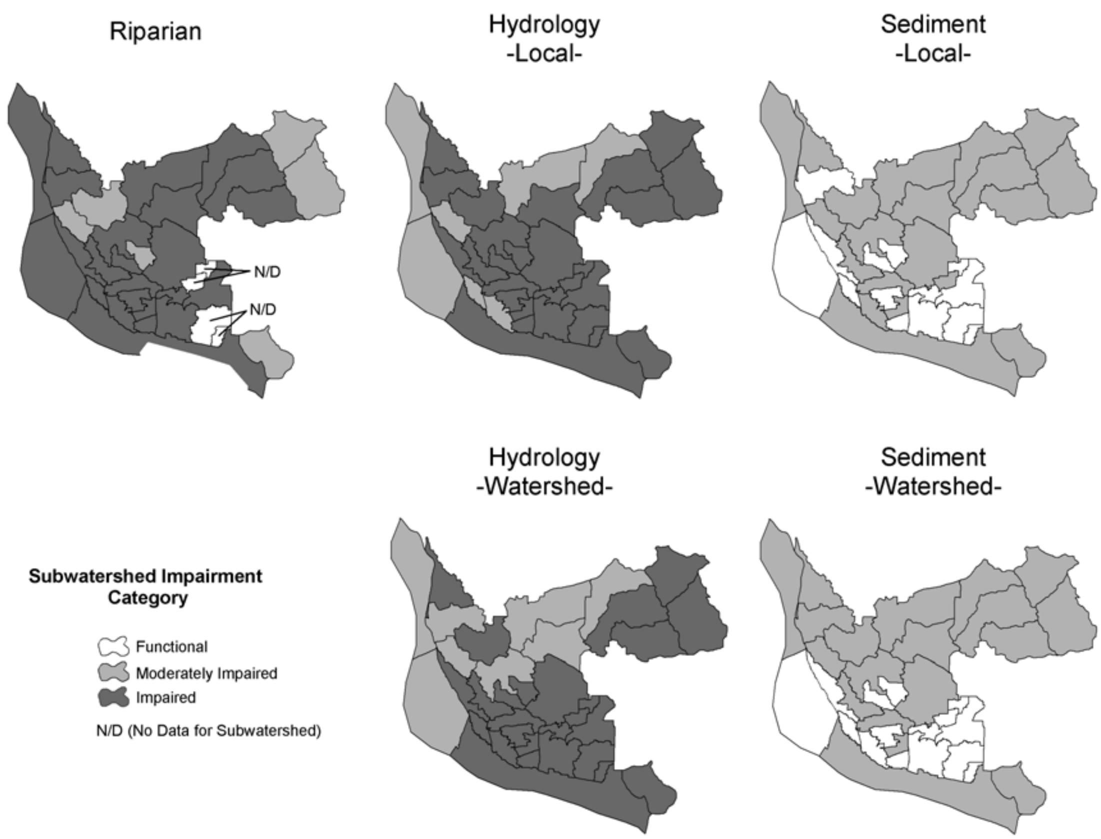


Figure 14-35. IWA subwatershed impairment ratings by category for the Lake River / Salmon Creek watershed.

Hydrology

The Salmon Creek watershed is primarily a low elevation, rain-dominated system, with the headwaters reaching an elevation of 1,998 ft. Total area of the watershed in the rain-on-snow zone is minimal. Because of the high levels of impervious surface, low levels of hydrologically mature forest cover, and high road densities found in this predominately developed area, local and watershed level hydrologic conditions are generally impaired throughout the majority of the watershed. No subwatershed was considered hydrologically functional at the local or watershed level.

Moderately impaired local and watershed level hydrology conditions are present in Mill Creek (90110), Weaver Creek (90111), and the lower mainstem of Salmon Creek (90104). Two additional subwatersheds along the Salmon Creek mainstem (90107 and 90106) are hydrologically impaired at the local level but only moderately impaired at the watershed scale, suggesting that Weaver and Mill Creeks are buffering downstream conditions to some degree. These mainstem Salmon Creek subwatersheds (90107 and 90106) are rated as moderately impaired because of currently low levels of impervious surface. The upper mainstem and headwaters of Salmon Creek (90108 and 90109) and headwater tributaries Rock Creek (90112) and Morgan Creek (90113) are all rated as hydrologically impaired at both the local and watershed level. These ratings are driven by high current levels of impervious surface, low levels of hydrologically mature forest cover (averaging 10%), and high road densities (exceeding 10 mi/sq mi). Approximately 20% of the Rock Creek and Salmon Creek headwaters subwatersheds are public lands, while an average of 15% of the lower Salmon Creek subwatersheds (90104 and 90106) are in public ownership. Other subwatersheds average less than 5% public ownership. Public lands are comprised primarily of state lands (WDNR) or county parks and open space.

Hydrologic conditions in lower Burnt Bridge Creek (90120 and 90114) are rated as moderately impaired at the local level; the rating is attributable to relatively small subwatershed area, lower impervious surface area, and some park lands. These subwatersheds are rated as impaired at the watershed level because of high levels of impervious surface in contributing upstream subwatersheds, including middle and upper Burnt Bridge Creek (90123, 90124, 90125 and 90128), as well as several contributing storm drainage basins (90126, 90127, 90190 and 90130). The Burnt Bridge Creek drainage lies entirely within the Vancouver city limits and is extensively developed.

In the Lake River mainstem, hydrologic conditions are strongly influenced by tidal fluctuations in the Columbia River. Subwatersheds 90101 and 90131 are rated moderately impaired at the local and watershed level and may be partially buffered by contributing upstream subwatersheds.

Sediment

Natural erodability rates in the Salmon Creek watershed are quite high relative to the rest of the region, with 12 of 34 exceeding a rating of 50 or greater on a scale of 0-126. One subwatershed (90116) within the Vancouver city limits has the highest natural sediment supply rating in the region (126). Sediment conditions are generally rated as moderately impaired at the local level, with the exception of some of the more heavily developed subwatersheds within the Vancouver city limits, which are rated as functional. None were rated as impaired.

The sediment results must be considered relative to the high natural erodability present. The threshold for impaired sediment conditions is a change in the erodability index under developed or disturbed conditions greater than 3 times the natural erodability index. Reaches within or downstream of subwatersheds with very high natural erodability levels that are rated moderately impaired or even functional may still be subject to considerable sediment loading, particularly in subwatersheds that are hydrologically impaired.

Sediment conditions in the Salmon Creek drainage are rated as moderately impaired throughout the majority of the system. Two small tributaries, Lalonde Creek and one unnamed stream (90117 and 90116), are rated as functional for sediment. However, given the very high natural sediment supply rates in these subwatersheds, 100 and 126, respectively, on a scale of 0-126, and the likelihood of impaired hydrologic conditions, these subwatersheds are likely to be contributing significant sediment loading to the lower mainstem of Salmon Creek.

Factors contributing to moderately impaired sediment ratings throughout the Salmon Creek drainage include high road densities and high levels of natural erodability. Because the majority of roads in the lower elevation areas of the drainage are surfaced and generally maintained, roads are considered to be less of a source of sediment supply than bank erosion from disrupted hydrologic conditions. In addition, the relatively flat topography of the Salmon Creek watershed mitigates impaired sediment conditions somewhat despite the extensive modifications of the landscape. However, the high natural erodability rates, in combination with impaired hydrologic conditions, suggest the potential for high levels of sedimentation from channel incision and bank erosion. This potential is confirmed by observed conditions (Wade 2001). High road densities in sensitive areas in headwaters contribute to moderately impaired ratings. Streamside road densities are particularly high in the Salmon Creek headwaters (90109, >0.8 miles/stream mile) and Rock Creek (90112). Unsurfaced streamside roads that are highly traveled are likely to be significant sources of sediment.

Sediment conditions in most of the Burnt Bridge Creek subwatersheds are rated as functional, despite high natural erodability. The functional ratings result from flat topography and surfaced and well maintained roads. As discussed above for Salmon Creek however, the IWA sediment analysis will underestimate the effects of increased peak flows from high levels of impervious surface on local bank erosion rates in areas with high natural erodability. Therefore, given the conditions observed in the Burnt Bridge Creek system, the functionality of sediment conditions are believed to be overestimated in this system. This is confirmed by observed conditions in the drainage (Wade 2001).

Riparian

Riparian conditions are rated moderately impaired or impaired in all 30 modeled subwatersheds. The majority of these (24 of 30) are rated as impaired, with moderately impaired ratings in the Salmon Creek headwaters (90109, 90112), Burnt Bridge Creek (90134), Whipple Creek (90133), Lalonde Creek (90117), and the lower mainstem (90104). Poor riparian conditions are related to urban, residential, and agricultural development.

Riparian conditions in Salmon Creek are moderately impaired to impaired across all subwatersheds, with the greatest impairments in the middle of the drainage. The mouth of Salmon Creek (90104), Lalonde Creek (90117), Rock Creek (90112) and Salmon Creek headwaters (90109) are moderately impaired. Lower Salmon Creek (90106) and middle Salmon Creek (90107, 90108) are rated as impaired.

Riparian conditions in the Burnt Bridge Creek drainage are rated as impaired. Riparian conditions in the independent drainages to the Columbia River are moderately impaired to impaired. Extensive development limits the potential for riparian recovery.

14.7.1.2 Predicted Future Trends

Hydrology

A portion of the Salmon Creek mainstem subwatersheds (90107, 90106) lie within the urban growth boundary of Battle Ground, and greater than 80% of these subwatersheds are zoned for development but are currently vacant. Given the likelihood for increasing development in these and other nearby subwatersheds (90104, Mill Creek 90110, and Weaver Creek 90111), the predicted trend for hydrologic conditions is to degrade further over the next 20 years.

Given the current level of and likelihood for further development, the predicted trend is for hydrologic conditions in Burnt Bridge Creek to continue to degrade.

Two hydrologically impaired subwatersheds (90134 and 90132) drain the southern portion of the watershed via steep bluffs into the mainstem Columbia River. While these subwatersheds do not support significant numbers of fish, groundwater from this area feeds springs in the mainstem Columbia that are spawning grounds for chum salmon (Wade 2001). Given the potential for development in and around Vancouver, the predicted trend in hydrologic conditions in these subwatersheds is for further degradation.

Sediment Supply

Given the potential for expanding development in the Salmon Creek drainage, the predicted trend for sediment conditions is to degrade further, particularly downstream from headwaters areas where steeper slopes are prevalent.

Given the extent of current development and the likelihood of increasing development in currently zoned areas, the predicted trend for sediment conditions in the Burnt Bridge Creek drainage is to degrade further over the next 20 years.

Riparian Condition

While development is likely to expand in all subwatersheds in the Salmon Creek drainage, existing riparian vegetation will generally be protected under existing critical areas ordinances. Given this assumption and the extent of existing development, riparian vegetation is predicted to trend stable across all impaired subwatersheds. In the moderately impaired headwaters subwatersheds, some potential for riparian recovery exists on less developed lands and publicly owned lands. However, this potential may be offset by expanding development, even under existing regulations. Given this potential, riparian conditions in the headwaters subwatersheds are predicted to trend stable, with gradual improvement in some areas.

Given the extensive development of the Burnt Bridge Creek drainage and the potential for development within existing management constraints, riparian conditions in this drainage are predicted to trend stable over the next 20 years. Similar to hydrology and sediment, given the potential for expanding development in the independent drainages to the Columbia River, riparian conditions are also predicted to trend stable.

14.7.2 *Bonneville Tributaries*

The Bonneville Tributaries watershed includes several small independent tributaries to the Columbia River to the east of the Washougal River. These streams include Hamilton, Hardy, Duncan, Lawton, and Gibbons Creeks. For the purpose of the IWA analysis, the Bonneville Tributaries watershed is comprised of seven LCFRB recovery planning subwatersheds, with the three most productive drainages for salmonids (i.e. Hamilton, Hardy, and Duncan Creeks) located in the eastern half of the watershed.

The primary drainages in the Bonneville Tributaries watershed are transitional, moving from snow-dominated highlands in the east, through the rain-on-snow zone, to rain dominated lowlands in the west. Overall drainage areas are small, ranging from 6,000 to 15,000 acres. Natural erodability rates range from low to moderate-low (7-28 on a scale of 0-126), with the higher erodability rates associated with low-lying, alluvial areas. Hydrologically mature forest coverage varies across the area, ranging from an average of 39% in Hamilton, Hardy, and Duncan Creeks, to less than 10% in the remaining western drainages. Historical fires in the region, and the presence of maintained powerline right of ways influence the extent of current forest cover. Land ownership also varies broadly, with 34% of the primary drainages in public ownership. Upper Hamilton Creek exceeds 50% public ownership, while only 11% of lands in the western three subwatersheds are publicly owned. Two of these, Gibbons Creek and Lawton Creek, have a significant proportion of area zoned for development (56% and 22%, respectively), but these subwatersheds do not support significant fish bearing streams. No zoning data were available for the remaining subwatersheds, but the lower Hamilton Creek drainage lies adjacent to modestly developed areas in North Bonneville and Fort Rains.

14.7.2.1 *Results*

IWA results were calculated for all subwatersheds in the Bonneville Tributaries 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 14-4. A reference map showing the location of each subwatershed in the basin is presented in Figure 14-36. Maps of the distribution of local and watershed level IWA results are displayed in Figure 14-37.

Table 14-4. IWA results for the Bonneville Tributaries basin

Subwatershed [a]	Local Process Conditions [b]			Watershed Level Process Conditions [c]		Upstream Subwatersheds [d]
	Hydrology	Sediment	Riparian	Hydrology	Sediment	
70101	M	M	M	M	M	70102
70102	F	M	F	F	M	none
70201	I	M	M	I	M	none
70202	I	M	M	I	M	none
70301	M	M	M	M	M	none
70401	M	M	M	M	M	none
70402	I	M	M	I	M	none

Notes:

[a] LCFRB subwatershed identification code abbreviation. All codes are 14 digits starting with 170800030#####.

[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.

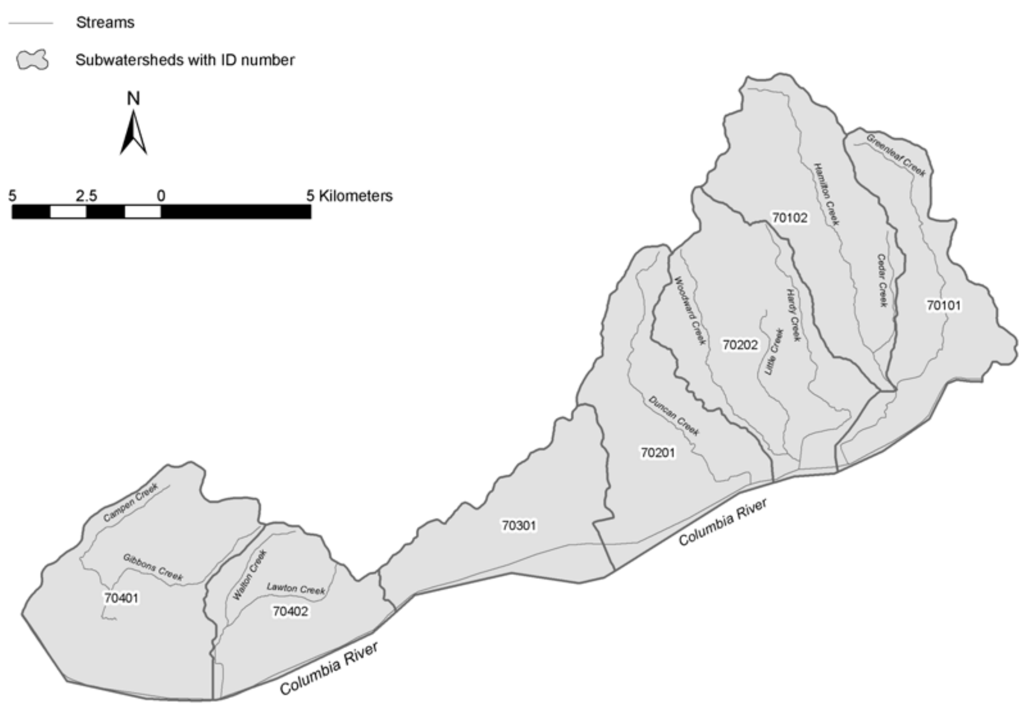


Figure 14-36. Map of the Bonneville Tributaries watershed showing the location of the IWA subwatersheds

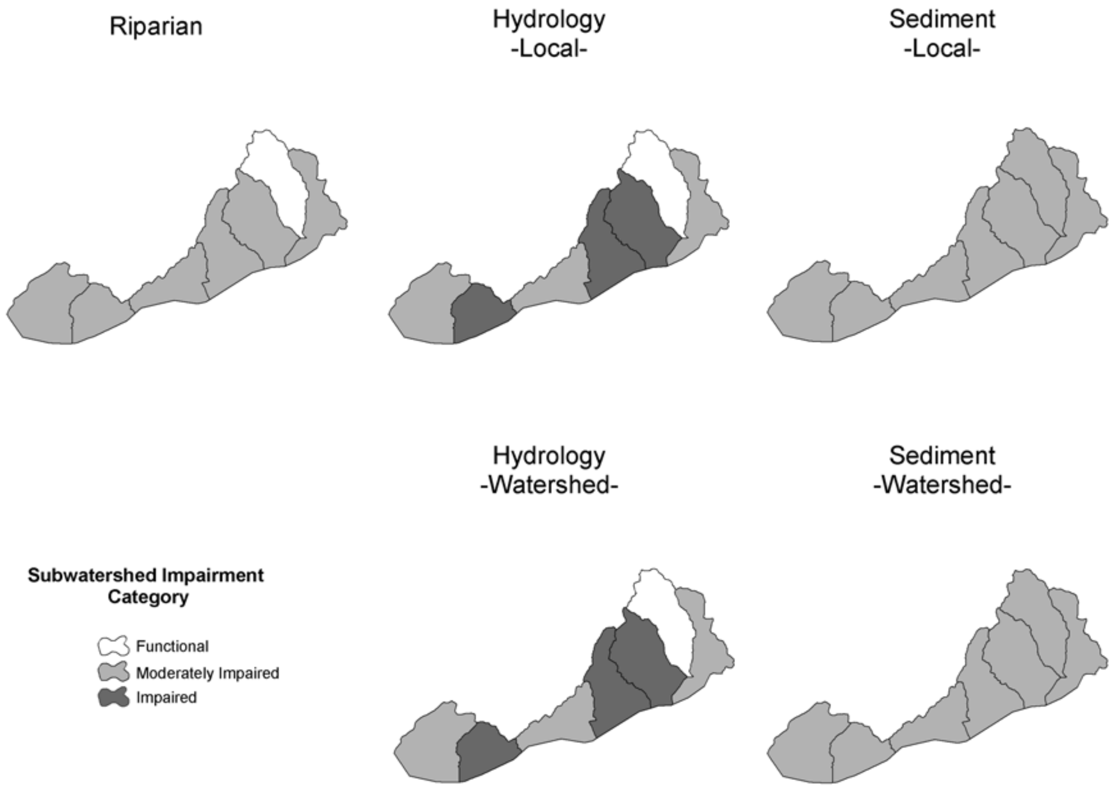


Figure 14-37. IWA subwatershed impairment ratings by category for the Bonneville Tributaries basin

Hydrology

The upper Hamilton Creek subwatershed (70102) is rated as functional for hydrology, with the remaining six subwatersheds split equally between moderately impaired and impaired ratings. Except for lower Hamilton Creek (70101), all subwatersheds in the area are terminal (i.e., having no upstream subwatersheds); thus, the watershed level results are the same as the local level results.

Functional hydrology conditions in upper Hamilton Creek are driven by relatively extensive mature forest coverage (64%) and moderate road densities (2.0 mi/sq mi). Impervious surface areas are low in this lightly developed area. Over half (53%) of upper Hamilton Creek is in public lands, administered by WDNR and Beacon Rock State Park.

Hydrologic conditions are rated moderately impaired in the lower Hamilton/Greenleaf Creek subwatershed (70101). Lower Hamilton Creek is rated as moderately impaired, based on moderate mature forest coverage levels (43%) and moderately high road densities (4.2 mi/sq mi). Roads in the lower Hamilton Creek/Greenleaf Creek subwatershed are concentrated around the Bonneville Dam facilities, which are located in the low lying areas of the watershed. Road densities in the upland areas of this subwatershed are considerably lower. Thus, the moderately impaired hydrology rating for subwatershed 70101 most likely overstates actual conditions, which may be closer to functional. In the lower Hamilton/Greenleaf Creek subwatershed, 19% is publicly owned (WDNR, state parks, and USACE). Development and land use regulations are relatively strict in the Columbia Gorge National Scenic Area.

Hydrologic conditions in Hardy and Duncan Creeks (70201, 70202) are rated impaired. Duncan Creek subwatershed (70201) has low mature forest coverage (17%) and moderately high road densities (3.4 mi/sq mi). As with lower Greenleaf Creek, a significant portion of road length in these subwatersheds are concentrated in the low-lying areas adjacent to the Columbia River. Therefore, the hydrologic conditions rating may overstate actual conditions, which may lean more towards moderately impaired. Several powerline right of ways traverse these drainages, affecting forest cover.

Hydrologic conditions in Lawton Creek subwatershed (70402) are impaired and are moderately impaired in Gibbons Creek (70401) and in 70302. Impairments here are related to young forests and high road densities (>3 miles/mi2).

Sediment

Sediment conditions in the Bonneville Tributaries watershed are rated as moderately impaired. As with hydrology, local and watershed level impairments are the same.

Erodability ratings for upper Hamilton Creek (70102) are low, whereas lower Hamilton/Greenleaf Creek (70101) is rated moderately low (7 and 26, respectively, on a scale of 0-126). The sediment supply rating for upper Hamilton Creek is borderline functional, only slightly above the threshold for a moderately impaired rating. Ratings for lower Hamilton/Greenleaf Creek are driven by high road densities on erodable geology in the low lying areas. Sediment conditions in the uplands are expected to be similar to upper Hamilton Creek, leaning towards functional. Streamside roads, which represent a significant potential source of erosion, are relatively infrequent (averaging less than 0.2 miles/mile of stream). This average is skewed by the high concentration of roads adjacent to the Columbia River and associated with Bonneville Dam facilities. Averages in the upstream areas are probably closer to 0.1 miles/stream mile.

Sediment conditions in Hardy and Duncan Creeks (70201, 70202) are rated as moderately impaired. Natural erodability ratings in this drainage are moderately low. The moderately impaired ratings are primarily driven by high road densities on erodable geology in the lowlands. Upland areas of the drainage have higher road densities relative to Hamilton Creek, exceeding 3 mi/sq mi. Streamside road densities in Duncan Creek are moderately high, approaching 0.5 miles/stream mile. Again, this average is skewed somewhat by the high density of roads adjacent to the Columbia River.

Sediment supply conditions are moderately impaired in Lawton Creek (70402), Gibbons Creek (70401), and subwatershed 70301. Road densities exceed 3 mi/mi2 in 70402 and 70401.

Riparian

Riparian conditions range from functional to moderately impaired. Upper Hamilton Creek (70102) is the only subwatershed rated as functional. Riparian conditions in lower Hamilton and Greenleaf Creek (70101) and Duncan Creek (70201) are rated as moderately impaired. These conditions track well with the hydrologically mature forest cover in these subwatersheds. Moderately impaired riparian conditions in Gibbons and Lawton Creek subwatersheds (70401, 70402) are related to residential and agricultural development.

14.7.2.2 Predicted Future Trends

Hydrology

Given the relatively high percentage of public lands in upper Hamilton Creek and upper Greenleaf Creek, combined with the land management regulations of the CRGNSA, the extent of hydrologically mature forest coverage in subwatersheds 70101 and 70102 is expected to expand over time with only limited increases in road density and development. Hydrologic conditions are therefore predicted to trend towards gradual improvement as forest cover matures.

Given the land management regulations of the CRGNSA, the extent of hydrologically mature forest cover in Hardy and Duncan Creek subwatersheds (70201, 70202) is expected to expand over time with only limited increases in road density and development. Hydrologic conditions are therefore predicted to trend towards gradual improvement as forest cover matures.

Sediment Supply

Given the extent of state park lands within both Hamilton Creek subwatersheds (70101 and 70102) and the low likelihood of expanding development or increasing forest road densities, sediment conditions are expected to trend stable in these subwatersheds.

Based on the high road densities and higher proportion of unsurfaced roads in the upper areas of the Duncan and Hardy Creek subwatersheds (70201, 70702), sediment conditions are predicted to trend stable over the next 20 years.

Riparian Condition

Given the restrictive development regulations in the CRGNSA and the emphasis on restoration of riparian zones, riparian conditions in upper and lower Hamilton Creek, Duncan Creek, and Hardy Creek subwatersheds (70101, 70102, 70201, 70202) are predicted to trend towards improvement over the next 20 years. Conditions are expected to trend stable in Gibbons and Lawton Creek subwatersheds (70401, 70402).

14.8 References

Caldwell, B., J. Shedd, and H. Beecher. 1999. Washougal River fish habitat analysis using the instream flow incremental methodology and the toe-width method for WRIAs 25, 26, 28, and 29. Washington Department of Ecology. Publication #99-153. June 1999.

EnviroData Solutions, Inc. 1998. Burnt Bridge Creek water quality data trend analysis. Prepared for the City of Vancouver Public Works Department. September 28, 1998.

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.

Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit Spirit of the Salmon The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs, and Yakama Tribes. Nez Perce, Umatilla, Warm Springs, and Yakama Tribes.

Post, R. 2000. Gibbons Creek watershed fecal coliform total maximum daily load: submittal report. Washington Department of Ecology, Publication #00-10-039. Olympia, Washington.

Vilkitis, J., C. Poly, K. Jones, S. Kocher. 1994. Population genetics of chinook salmon in the Salmon River system. Unpublished report.

Wade, G. 2001. Salmon and Steelhead Habitat Limiting Factors Water Resource Inventory Area 28. Washington State Conservation Commission, Final Report.

Washington Department of Ecology (WDOE). 1998. Final 1998 List of Threatened and Impaired Water Bodies - Section 303(d) list. WDOE Water Quality Program. Olympia, WA.

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